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PROLOGUE

This is the second technical report of the Wisconsin Integrated Cropping Systems Trial (WICST). In last year's report we discussed, in some detail, the objectives of the project, the results of the uniformity year (1989) and the first two production years (1990 and 1991). In this report we discuss the results of the third year of field trials (1992). This is the first time we have had all the phases of the three cash-grain rotations running concurrently, permitting us to begin to compare the three systems. Next year we will be able to run full systems comparisons with the forage-based systems.

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, additional faculty are setting up research plots at the Learning Centers, and a growing number of school children are coming to the sites for guided tours. In addition, results from the Learning Centers are beginning to appear in print (Appendix I). We are optimistic that 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.

Spring, 1993

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INTRODUCTION

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

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

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

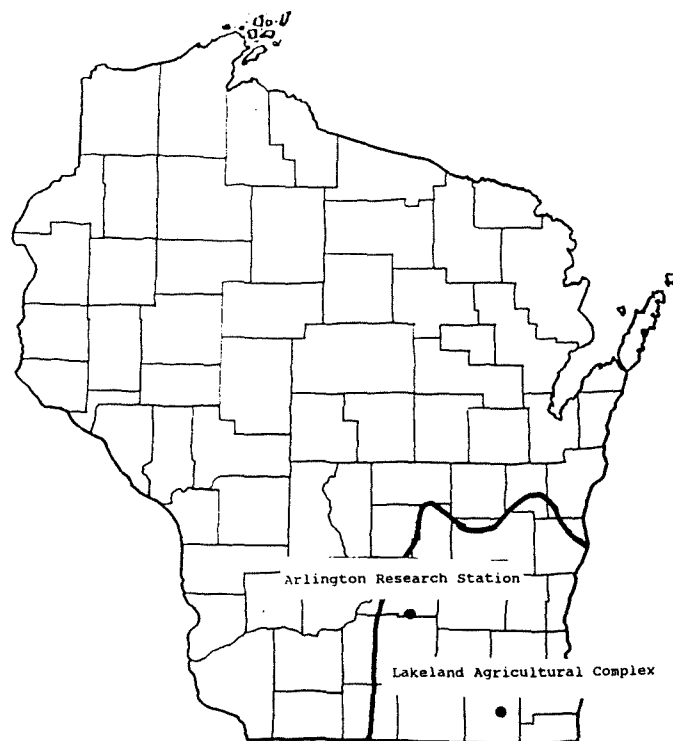
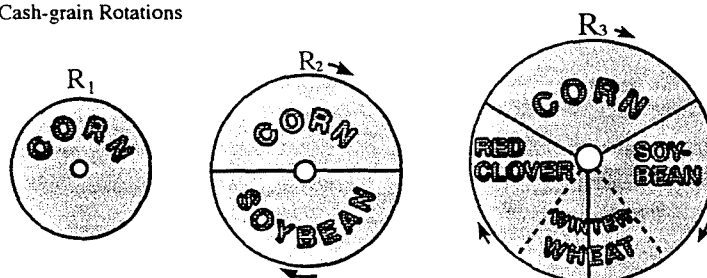
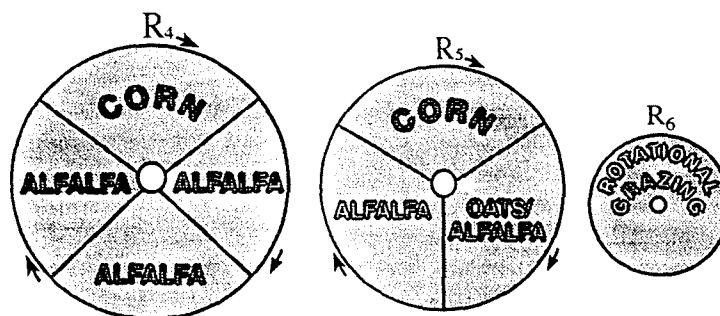


Figure 1. Outline of Major Land Resource Area 95B and Two Sites of the Wisconsin Integrated Cropping Systems Trial

Cash-grain Rotations



Forage-based Rotations



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

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

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

Rotation	Predicted yield/acre	Mean above ground productivity ¹ lb/a/yr	Mean energy input ² Mcal/a/yr	Energy output/input ³ ratio	Variable costs ⁴ \$/a/yr	Chemical inputs			Erosion ⁵ t/a/yr
						Fert N on corn lb/a	Herbicide AI/a	Insecticide AI/a	
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 corn	55 bu 160 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
R ₃ row soybean wheat corn	40 bu 60 bu/2t straw 120 bu	10,010	763	12.6	50	0	0	0	2.9
R ₄ seeding alfalfa hay I hay II corn	3t dm 5t dm 5t dm 160 bu	10,710	1188	13.7	110	10	Eptam 2.9 lb Bladex 2.0 lb Alachlor 2.5 lb	Lorsban 1.0 lb	1.9
R ₅ oats/alfalfa hay I corn	60 bu/2t dm 4t dm 120 bu	9,440	811	18.2	45	10	0	0	1.6
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. (see appendix II)

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.

I. YIELDS, WEATHER AND AGRONOMIC CALENDAR IN 1992

A. Wood*, P. Ehrhardt*, T. Mulder**, and J. Posner**

The 1992 season was quite remarkable for three reasons:

1) the open winter with periods of above freezing temperatures resulted in a large amount of alfalfa and wheat winterkill;

2) early season weed control in annual crops was difficult because of delayed development of the crop canopy. This was due to late frosts in the Spring (May 11th at both sites and June 20th at ARS) and dry May and June weather (30% of normal see Table 2); and,

3) the generally cool summer (80% of average GDD, see Figure 3) and wet, cloudy autumn weather resulted in low test weight, wet corn at harvest.

The lowest yields to date were recorded at both sites this year (Table 3). Due to the poor weather, continuous corn yields averaged 144 bu/a at ARS and 119 bu/a at LAC. The rotation effect was also less pronounced this year and the corn following beans (R_2) yielded about 5% better than continuous corn. At both sites the corn following either red clover (R_3) or alfalfa (R_5) without any additional nitrogen fertilizer, starter fertilizer or herbicide yielded around 30% less than the higher input corn in rotations 1 and 2. Soybean yields remained high and similar to previous years at LAC and again there was no significant difference between the drilled and row beans. At ARS, a missed herbicide rescue treatment on the drilled beans (R_2) resulted in poor yields¹. Even with three rotary hoeings and two cultivations, it was impossible to completely control broadleaf weeds in the row beans (R_3).

Winterkill in wheat was over 50% at both sites. Cultivation of the soybeans in 1991 left the field with ridges and furrows and the aerial seeded wheat (second week in September) winterkilled in the wetter furrows. In mid-April Marshal spring wheat was drilled (1-1.5 bu/a) into the plots. Grain yields were mediocre at both sites, and straw yields very poor. The open stands of wheat had facilitated a good catch of the frost seeded red clover (3/11 ARS and 3/14 LAC). Due to the mass of red clover beneath the wheat, the cutter bar was set high and straw yields were very low. Red clover roots plus tops produced 2.7 t DM/a at ARS and 1.8 t DM/a at LAC. This was equivalent to approximately 148 lb N/a at the former site and 93 lb/a at the latter.

¹ Although actual yields for the drilled soybeans were only 30 bu/a, on adjacent filler plots that did receive the rescue herbicide treatment yields were 48 bu/a. This later number, plus the costs of the additional herbicide were used in the economic analysis for 1992.

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

New seedings of alfalfa were completed at ARS in early April and by early May at LAC. On the sole seeded plots (R_4), ARS had another good catch and yields were excellent (3.6 t DM/a), while at LAC poor stands and heavy weed infestations resulted in poor production. In the companion seeded plots (R_5), due to the heavy weed pressure, the oats were taken as oatlage at ARS on July 31st. and then one cut of haylage was made. At LAC the oats were taken for grain, but due to the delayed planting, and cool, dry weather, were not harvested until August 26th. As a result there was no additional alfalfa harvest.

The intensively cut forage rotation (R_4) was adversely affected by winterkill at ARS. Under normal production circumstances all of these plots would have been plowed up and rotated to a non-legume crop. However, to maintain the proper rotational sequence the plots were renovated with a grass/legume mix. The first and second year hay fields were reseeded with annual ryegrass (10 lb/a) and red clover (10 lb/a). At LAC, winterkill was less of a problem and only two plots were renovated with some red clover. Rotational grazing (R_6) was initiated at LAC (see section V.) but delayed until 1993 at ARS due to the grass and legume winterkill in the paddocks. Instead, they were renovated with orchard grass (10 lb/a) and brome grass (12 lb/a) and harvested as haylage during the summer. The agronomic diary for the LAC and ARS sites for 1992 can be found in Appendices III and IV, respectively.

Table 2. Growing Season Rainfall (inches) at the Wisconsin Integrated Cropping Systems Trial.

a. Arlington Research Station¹

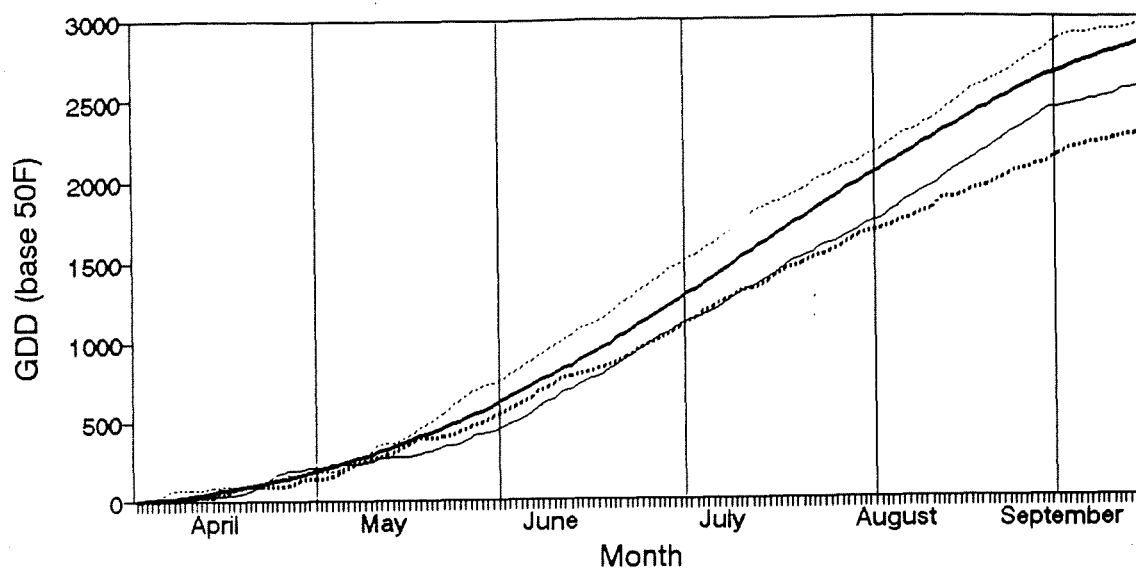
<u>Month</u>	<u>1992</u>	<u>1991</u>	<u>1990</u>	<u>30-yr avg 1959-1988</u>
April	3.96(+0.97)	4.52(+1.53)	2.49(-0.50)	2.99
May	1.22(-2.97)	1.91(-1.28)	4.25(+1.06)	3.19
June	1.19(-2.61)	2.63(-1.17)	6.32(+2.52)	3.80
July	5.80(+2.34)	3.75(+0.29)	1.57(-1.89)	3.46
August	1.91(-1.98)	1.78(-2.11)	5.36(+1.02)	3.89
September	7.46(+3.23)	4.70(+0.87)	1.22(-3.01)	4.23
Growing Season Total	21.54	19.29	21.21	21.56
Yearly Total	34.43	35.33	34.15	31.14

b. Lakeland Agricultural Complex

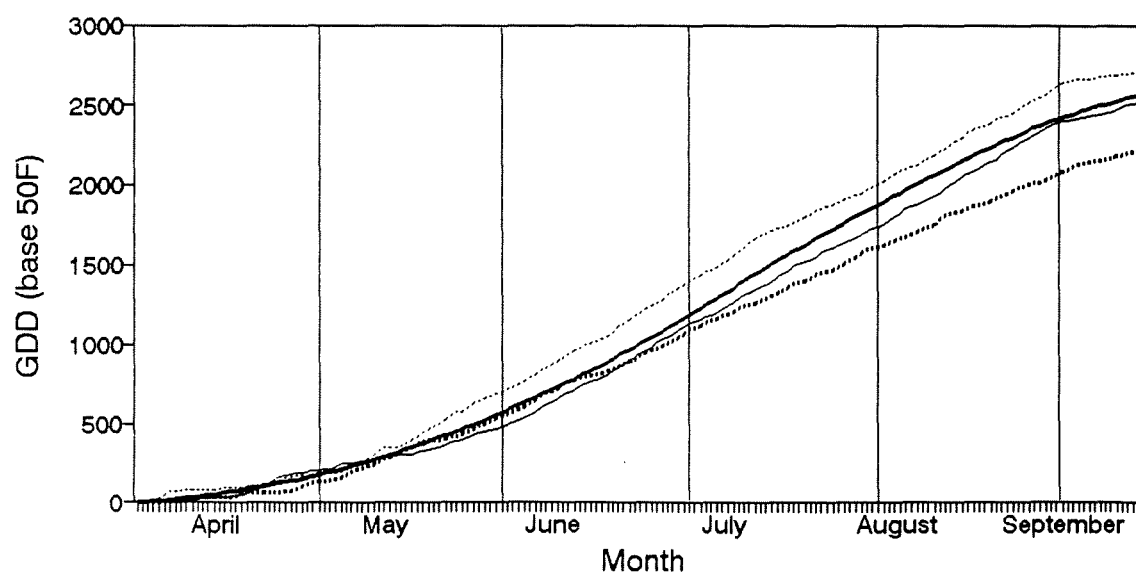
<u>Month</u>	<u>1992²</u>	<u>1991²</u>	<u>1990²</u>	<u>30-yr avg 1959-1988³</u>
April	2.21(-1.59)	4.15(+0.35)	2.47(-1.33)	3.80
May	0.50(-2.76)	2.32(-0.94)	5.53(+2.27)	3.26
June	1.35(-2.58)	1.56(-2.37)	5.26(+1.33)	3.93
July	7.18(+2.83)	2.45(-1.90)	2.51(-1.84)	4.35
August	2.60(-1.41)	2.04(-1.97)	3.93(-0.08)	4.01
September	4.43(+0.37)	4.94(+0.88)	0.96(-3.10)	4.06
Growing Season Total	18.27	17.46	20.66	23.41
Yearly Total ³	31.58	38.66	40.86	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).

Lakeland Agricultural Complex



Arlington Research Station



— 30 yr avg — 1990 1991 -.- 1992

Figure 3. Cumulative Corn Growing Degree Days for the Two WICST Sites

Table 3. Yield Results for the Wisconsin Integrated Cropping Systems Trial (1990 - 1992).

<u>Corn</u>	<u>Arlington Res. Sta.</u>			<u>Lakeland Ag. Complex</u>		
	1990	1991	1992	1990	1991	1992
	----- bu/A -----					
R ₁ - Continuous corn	166.2	160.0	144.0	165.5	121.2	119.0
R ₂ - Corn after soybean	-	185.7	150.1	-	144.7	126.2
R ₃ - Corn after red clover	-	-	99.2	-	-	73.0
R ₅ - Corn after alfalfa	-	-	112.0	-	-	101.7
LSD (P<0.05)	-	4.0	12.6	-	13.1	16.9

<u>Soybean</u>	<u>Arlington Res. Sta.</u>			<u>Lakeland Ag. Complex</u>		
	1990	1991	1992	1990	1991	1992
	----- bu/A -----					
R ₂ - Drilled soybean	56.5	58.5	30.1 ^a	58.3	52.9	46.9
R ₃ - Row soybean	52.1	49.2	38.0	51.3	54.5	51.9
LSD (P<0.05)	NS	6.1	NS	4.7	NS	NS

<u>Wheat</u>	<u>Arlington Res. Sta.</u>			<u>Lakeland Ag. Complex</u>		
	1990	1991	1992	1990	1991	1992
	----- bu/A -----					
R ₃ - Wheat	-	63.6	45.2	-	32.1	25.7

<u>Seeded alfalfa</u>	<u>Arlington Res. Sta.</u>			<u>Lakeland Ag. Complex</u>		
	1990	1991	1992	1990	1991	1992
	----- T/A dm -----					
R ₄ - Direct seeded	4.27	4.94	3.59	0	0.46	1.11
R ₅ - Oats/alfalfa	3.93 ^b	3.12 ^c	2.63 ^b	0.89 ^b	2.47 ^c	3.03 ^c
LSD (P<0.05)	NS	0.36	0.49	0.55	0.63	1.02

<u>Established forage</u>	<u>Arlington Res. Sta.</u>			<u>Lakeland Ag. Complex</u>		
	1990	1991	1992	1990	1991	1992
	----- T/A dm -----					
R ₄ - Hay I	-	5.86	3.46	-	3.88	3.65
R ₅ - Hay I	-	5.86	5.17	-	3.49	3.54
R ₄ - Hay II	-	-	3.99	-	-	3.57
R ₆ - Pasture	4.15	4.70	2.81	0	3.39	^d
LSD (P<0.05)	-	0.44	1.20	-	NS	NS

^a Should have received post herbicide treatment for grasses and broadleaves^b Oats harvested as oatlage^c Oats harvested as grain (grain and straw converted to T/A dm)^d Intensive rotational grazing

II. ROOT HEALTH STUDIES

A. FARMING SYSTEMS AND ROOT HEALTH

Walter Goldstein*

The issue of the rotation effect in corn-based rotations is of great practical and economic importance for Midwest farmers. It is also of crucial significance in the development of sustainable farming systems. Unfortunately, our understanding and acceptance of the rotation effect has generally lagged behind the phenomenon, partly because we don't understand how it works.

In a recent review, Benson (1985) pointed out that the effect of rotations on corn is not simply due to nutrients, though the exact cause of rotation effects is still unclear. Part of the phenomenon must be a negative factor reducing the performance of corn roots when grown in soil supporting a corn crop the prior growing season/seasons.

If root health is the crux of the rotation effect, then what actually determines it? Certainly, crop sequences affect the availability of disease carrying inocula (Shurtleff, 1986) and the rotation effect might be construed as simply relating to the presence or absence of such inocula.

But the literature abounds with suggestions that the cause of the rotation effect might be even more indirect. For instance, it has been shown that crop rotations with leguminous forages or oats may increase the antagonistic action of certain actinomycetes (Grossman, 1968) or fungi (Curl, 1963) that inhibit pathogens. An antagonistic role for other organisms such as micro-arthropods, giant amoebae, and nematodes, cannot at present be ruled out (Curl, et al., 1988).

Another factor that may be important is soil structure and the interaction between soil structure, root health, and disease. Crop rotations that include forage legumes and grasses have beneficial effects on soil structure (Harris, et. al, 1966) while corn alone has negative effects (Reid and Goss, 1981). Poor soil structure has a negative effect on root health because there is less pore space and oxygen for the roots (Wiklert, 1960). By stressing the roots, poor crop rotations might also increase the susceptibility of corn to root and stalk diseases or nematodes.

At the present time, crop rotation is not widely regarded as being useful for the control of root and stem rot. In fact, a recent monograph on root and stalk rots omits mention of crop rotation as a factor in the development of the major root and stem rot diseases caused by species of *Diplodia*, *Gibberella*, *Fusarium*, and *Pythium* (Shurtleff, 1986). According to the present-day "photosynthetic stress-translocation balance" concept of root and stalk rots in corn (Dodd, 1980), root rots and then stalk rots set in as tissues lose their metabolically dependant defense systems. This loss in resistance is due to increased cellular senescence caused by carbohydrate deficiency. Carbohydrate deficiency happens when the plant utilizes its carbohydrate resources to fill seed.

* Research Director, Michael Fields Agricultural Institute, East Troy, WI.

As this concept is widely prevalent, root rot is mostly regarded from the viewpoint of carbohydrate limits rather than root stresses.

On the other hand, the older literature presented a case for crop rotations being an important factor in controlling root and stem rot in corn (Curl, 1963). Studies carried out in Illinois, Ohio and Ontario indicated that preceding crops of corn and wheat were found to increase rot while oats, clover, and grass decreased it. A study of root health of corn grown in four rotations in Iowa showed roots were most healthy where corn followed alfalfa and least healthy where corn followed corn. (Staffeldt, 1953). Further more, a recent study of corn root health in corn-corn and soybean-corn rotations indicated better root health where corn followed soybeans (Nickel, et al., 1992).

To what extent is root and stalk health an important factor in the rotation effect? How important is it? The old literature probably cannot be trusted to give us a reliable estimate. We now use hybrids that grow more adventitious roots to support the plant from lodging and that have stiffer stalks that senesce later. Such hybrids should be less susceptible to yield losses due to root and stem rot. On the other hand, modern farmers grow these hybrids at very high plant populations and this increases the risk of lodging and disease because it reduces the amount of light available to each plant.

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B. NEMATODE COMMUNITIES IN THE WISCONSIN CROPPING SYSTEMS TRIAL - 1992

Ann MacGuidwin*

The Arlington and Lakeland sites of the Wisconsin Integrated Cropping Systems Trial were sampled in July and in September to determine the influence of three cropping systems on the composition of nematode communities; continuous corn (R1), soybean-corn (R2), and soybean/winter wheat-wheat/red clover-corn (R3). Soil samples collected at two depths were assayed for nematodes using an incubation procedure. Nematodes were counted by trophic level as judged by their mouthparts and esophagus.

By September there were differences in the total nematode abundance among treatments, with continuous corn supporting the most nematodes and rotation 3 the least at both 3-cm and 10-cm sampling depths at Arlington (Tables 4a and 4b). Total abundance for each treatment in September was about the same as that in July for the 3-cm samples and greater than in July for the 10-cm samples. There were no differences in total nematode abundance among treatments in September at the Lakeland Ag. Complex. At the Lakeland site, nematode population densities in September were decreased as compared to July.

The percentage of the nematode community at Arlington feeding directly on plants (i.e., plant pathogens) decreased from July to September in the 10-cm samples and stayed about the same for samples collected to a depth of 3 cm. Plant parasitic nematode genera recovered in the plots included root-lesion (Pratylenchus spp.), pin (Paratylenchus spp.), and spiral (Helicotylenchus spp.) nematodes.

Counts of bacterial-feeding and omnivorous nematodes in the 3-cm and 10-cm samples were significantly correlated ($r=0.78$, $P=0.05$; and $r=0.61$, $P=0.10$; respectively) in September 1992 at Arlington. The only statistically significant differences among treatments were for total nematodes in both the 3-cm and 10-cm samples and for bacterial-feeding, fungal-feeding, and plant-parasitic nematodes in the 3-cm samples. Continuous corn supported the fewest plant-parasitic nematodes, the most fungal-feeding nematodes, and an intermediate number of bacterial-feeding nematodes.

No treatment differences were detected at the Lakeland Ag. Complex site in September except for the percentage of plant-parasitic forms within the total population; continuous corn supported the lowest relative population of plant pathogenic nematodes as was the case at Arlington.

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It was not surprising that the composition of nematode communities was influenced by the cropping system. Changes in the abundance of pest species have long been one of the justifications of crop rotation. The significance of nematodes which perform other functional roles in the soil are not extensively documented. Our data provides at least a cursory look at how the entire nematode community responds to different sequences and intensity of corn production. The challenge now is to determine how change in the nematode community affects the health and productivity of the corn crop.

Table 4a. Numbers of nematodes classified by their food source recovered from 200 cm³ soil collected to a 3-cm depth at Arlington in September, 1992. Those nematodes which could not be positively identified are included in the total counts only.

<u>Rotation</u>	<u>Nematode Food Source</u>				<u>Plant</u>	<u>% Plant</u>	<u>Total</u>
	<u>Bacteria</u>	<u>Fungi</u>	<u>Predator</u>	<u>Omnivoires</u>			
corn	825	1709	3	267	15	1	3009
corn/ soybean	966	1385	3	207	47	2	2819
soybean/ wheat-red clover/ corn	485	1039	4	204	56	3	1889
	P=0.05	P=0.01	NS	NS	P=0.10		P=0.01

Table 4b. Numbers of nematodes classified by their food source recovered from 200 cm³ soil collected to a 10-cm depth at Arlington in September, 1992.

<u>Rotation</u>	<u>Nematode Food Source</u>				<u>Plant</u>	<u>% Plant</u>	<u>Total</u>
	<u>Bacteria</u>	<u>Fungi</u>	<u>Predator</u>	<u>Omnivoires</u>			
corn	592	808	3	98	105	7	1727
corn/ soybean	566	388	6	92	182	14	1332
soybean/ wheat-red clover/ corn	364	265	9	72	101	11	860
	NS	NS	NS	NS	NS		P=0.10

C. A SURVEY OF SOIL MACROARTHROPODS ASSOCIATED WITH CORN IN ALTERNATIVE CROPPING SYSTEMS

D. K. Young, D. B. Hogg, and G. J. Snortheim*

Background

The Wisconsin Integrated Cropping Systems Trial provides a unique laboratory for examining the ecological ramifications, both short and long term, of different approaches to farming and philosophies of land stewardship. Much of the ecological "action" will take place in and on the soil, and will be related to the health of the soil as measured in chemical, physical and biological terms. A correlate to, and presumably an indicator of, soil health is the abundance and diversity of animals utilizing the soil habitat. Numerous recent studies suggest that a thorough analysis of agroecosystems requires consideration of the insects and other arthropods.

Our operational hypothesis going into the study of arthropod diversity was that the level and frequency of soil disturbance (both chemical and physical) in the cropping systems would influence the numbers and kinds of arthropods existing in the plots. Differences in arthropods populations could contribute to, as well as result from, changes in soil characteristics. The four systems in corn during the 1992 field season provided a range of chemical inputs, from the high end (continuous corn) to essentially no inputs for a three year rotation; however, the levels of soil disturbance (see figures for tillage dates) were not as clearly delineated in the systems.

Methods

The survey was conducted at both locations (Arlington Research Station [ARS] and Lakeland Agricultural Complex [LAC]) from early June through early August. Sampling was accomplished using pitfall traps, which passively capture animals as they move on the soil surface. Although not an exhaustive species inventory strategy, we felt that this sampling method would provide a basis for treatment and site comparisons in a standard way. The "corn phase" of the cropping systems was sampled; treatments in the corn phase during the 1992 field season included, continuous corn (R1), drilled soybean-corn (R2), narrow row soybean/winter wheat/red clover-corn (R3), and rapid turnaround alfalfa (R5). [Note: The fifth corn rotation, the "green gold alfalfa," was not available in 1992, and was not included in the study.]

Four pitfall traps were placed in each plot, in each of the four replications at both sites. Trapping began in early June and terminated in early August. Like samples were pooled for comparison; thus, the contents of 16 traps (4/plot x 4 replications/site) constituted the bulk sample for each treatment. Traps were emptied weekly and to date, the first six weeks of samples have been sorted (see Table 5).

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Table 5. Pitfall Sample Collections Sorted to Date

Week #	ARS	LAC
1	04-08 June	04-11 June
2	09-16 June	12-17 June
3	16-22 June	18-24 June
4	22-29 June	24 June - 01 July
5	30 June - 06 July	02-08 July
6	07-14 July	09-15 July

[remaining dates through early August still being sorted]

Results to Date

The arthropod abundance was clearly a surprise; we were literally overwhelmed by the material that needed to be handled. As of 1 February 1993, we have separated, cleaned, and completed the first (rough) taxonomic "cut" of the trap residues for the first six weeks (approximately half of the study period) for both field sites. In this first sorting step, the material goes through an alcohol wash to remove other organic debris and soil, and the specimens are sorted into major ("first order") taxonomic groupings. As we continue to process the material, groups of particular interest and diversity, such as the beetles (Coleoptera) will be further processed taxonomically. This will enable us to make more specific taxonomic comparisons, and to better identify "functional groups" in an ecological sense.

As a first basis of comparison, however, we have completed a preliminary analysis of the data available (graphs in figures 4a-4h show results for each of the first order taxonomic groups: Diplopoda, millipedes; Chilopoda, centipedes; Opiliones, harvestmen; Aranae, spiders; Collembola, springtails; Orthoptera, crickets, grasshoppers, etc.; Coleoptera, beetles; and Formicidae, ants). A cursory look at the graphs clearly illustrates that even at this, the first and "grossest" analysis, obvious differences exist - both between treatments, and between sites. For example, the Diplopoda, functionally scavengers for the most part, were almost entirely lacking at LAC. It can also be seen that at ARS, millipede populations were much higher, at least early in the season, in the rotations (R2, R3, and R5) as compared to continuous corn (R1). The [predaceous] Chilopoda, on the other hand were more abundant at LAC than ARS, except for the continuous corn treatment (R1), for which chilopod populations were depressed at both sites. In the case of the Opiliones, the harvestmen or "daddy- long-legs", and spiders (Aranae) population responses over the first six weeks were remarkably similar at the two sites, with the ARS populations slightly more numerous.

Also of interest were the peaks and dips in population abundances at certain times of the season. Although we have not yet attempted to interpret these findings, they very well may have ecological significance. For example, Collembola populations showed a conspicuous increase around week four of the study; this is illustrated at a greater or lesser extent at both sites, and over most of the treatments. Also of interest (around sampling week two: 10-17 June) is the dip in Collembola numbers at LAC in the rotation treatments (**R2**, **R3**, and **R5**) as compared to a rise in Collembola numbers in the continuous corn treatment (**R1**).

Again, these graphic representations must be looked at with some caution: remember that they represent but the first order of taxonomic sorting and, moreover, they show only the first half of the field season. It is too early, for example, to speculate as to the general population declines in Diplopoda, Chilopoda, Araneae, and Formicidae by week six (= 8-15 July). Is this reflective of weather conditions, some sort of soil perturbation, or perhaps a function of the developmental phase of the arthropods, themselves (for example the decline of one generation and a prelude to a second)? Perhaps it represents a combination of factors, some of which will sort themselves out when the samples have been sorted out to a lower taxonomic level. Regardless, these preliminary data do appear to support our initial research hypothesis for the study: the level and frequency of soil disturbance (both chemical and physical) in the cropping systems do influence the numbers and kinds of arthropods existing in the plots. As a corollary, it does appear that arthropod abundance and diversity can be used as an ecological "indicator" of soil (= community) health.

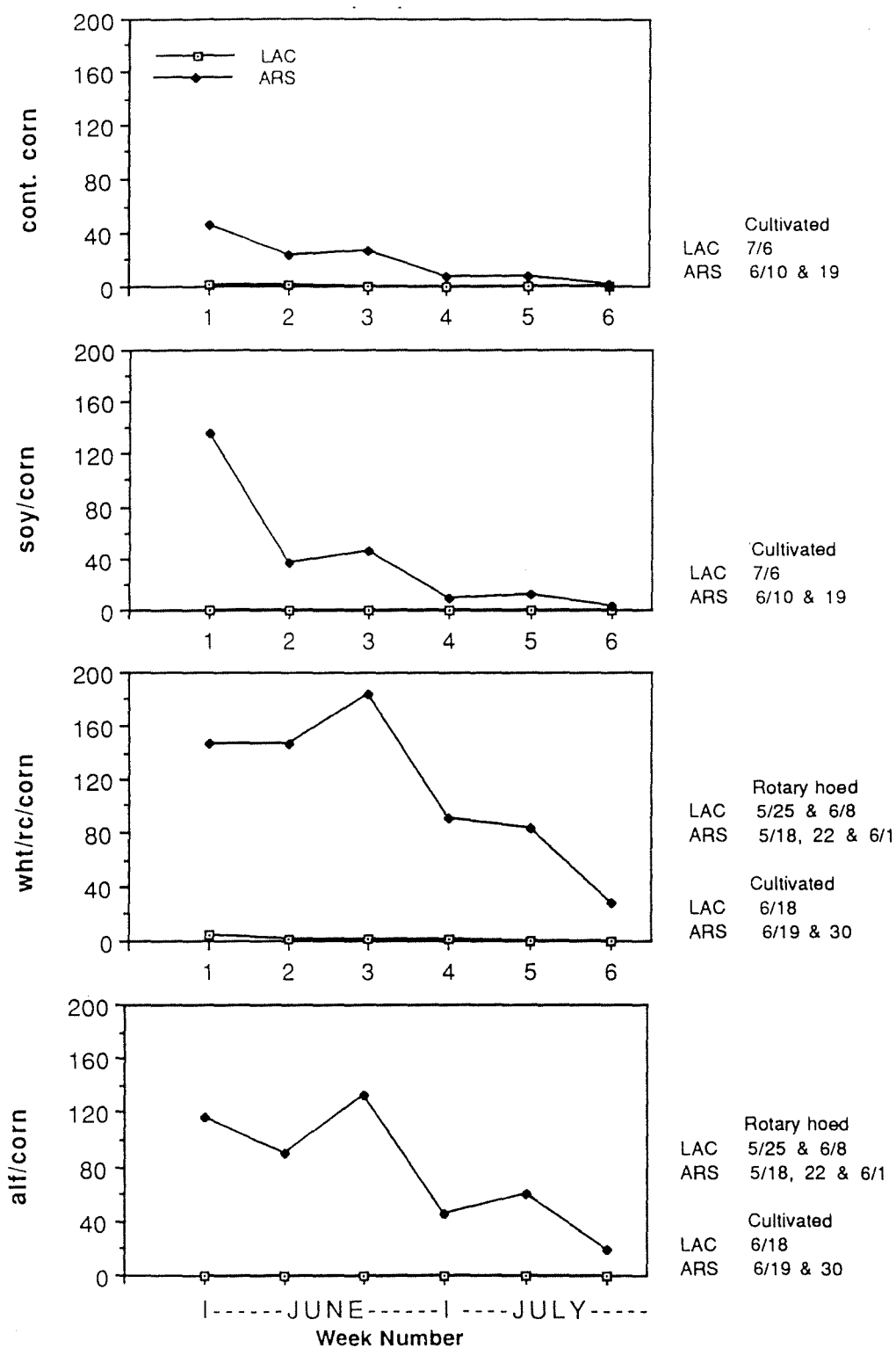


Figure 4a. Total Number of **DIPLODA** Captured by Week in Pitfall Traps
WICST 1992

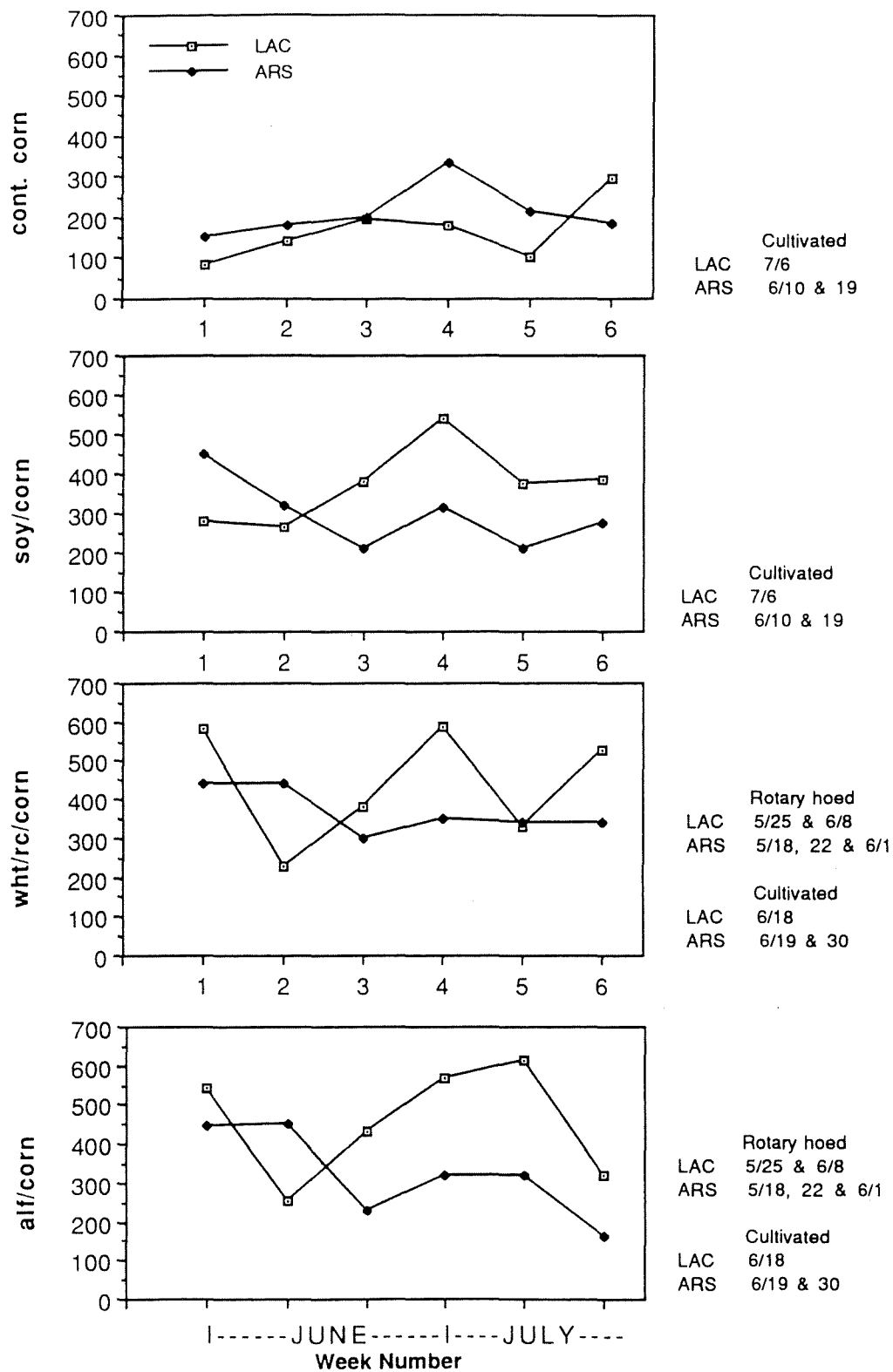


Figure 4b. Total Number of **COLLEMBOLA** Captured by Week in Pitfall Traps WICST 1992

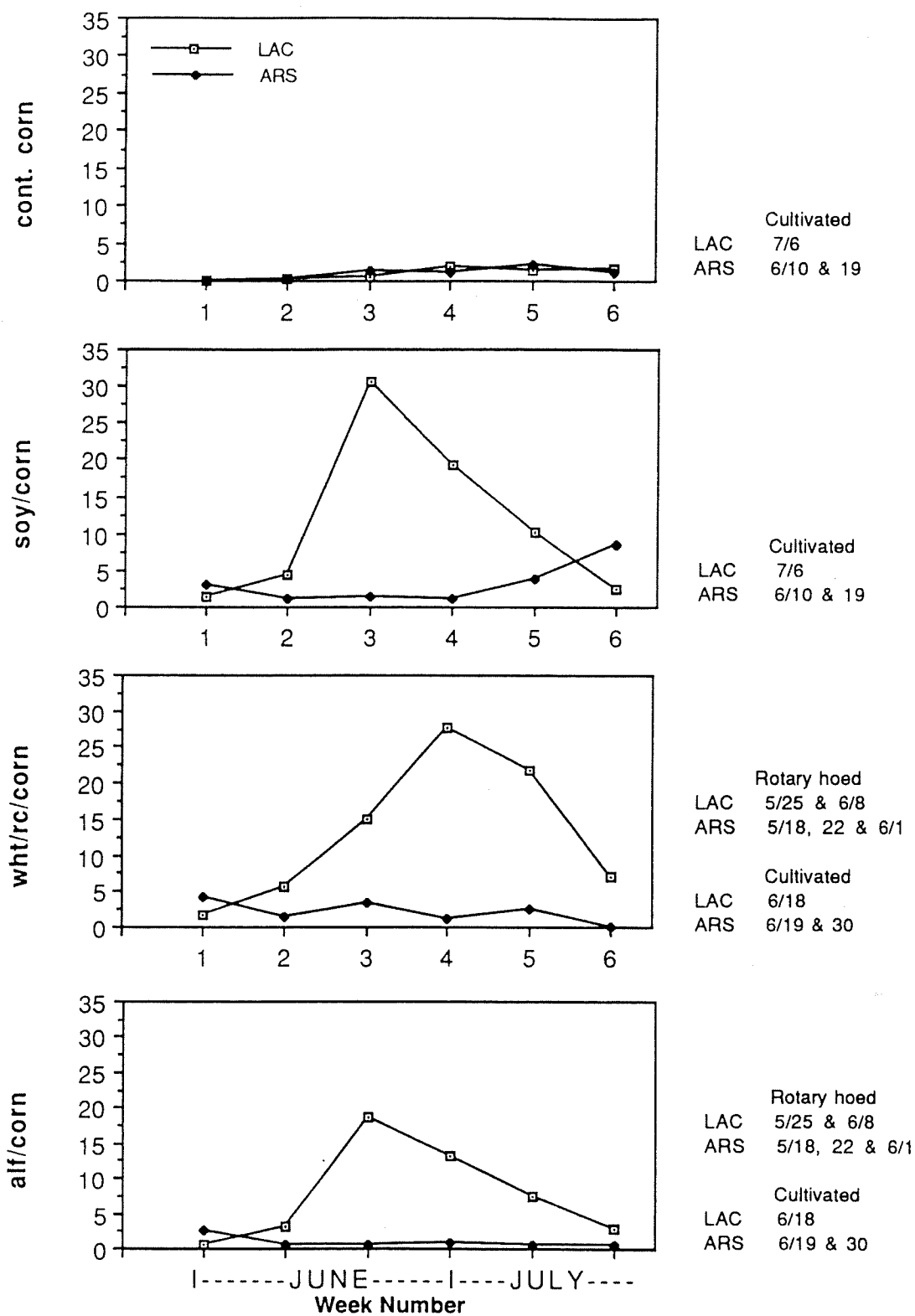


Figure 4c. Total Number of **CHILOPODA** Captured by Week in Pitfall Traps
WICST 1992

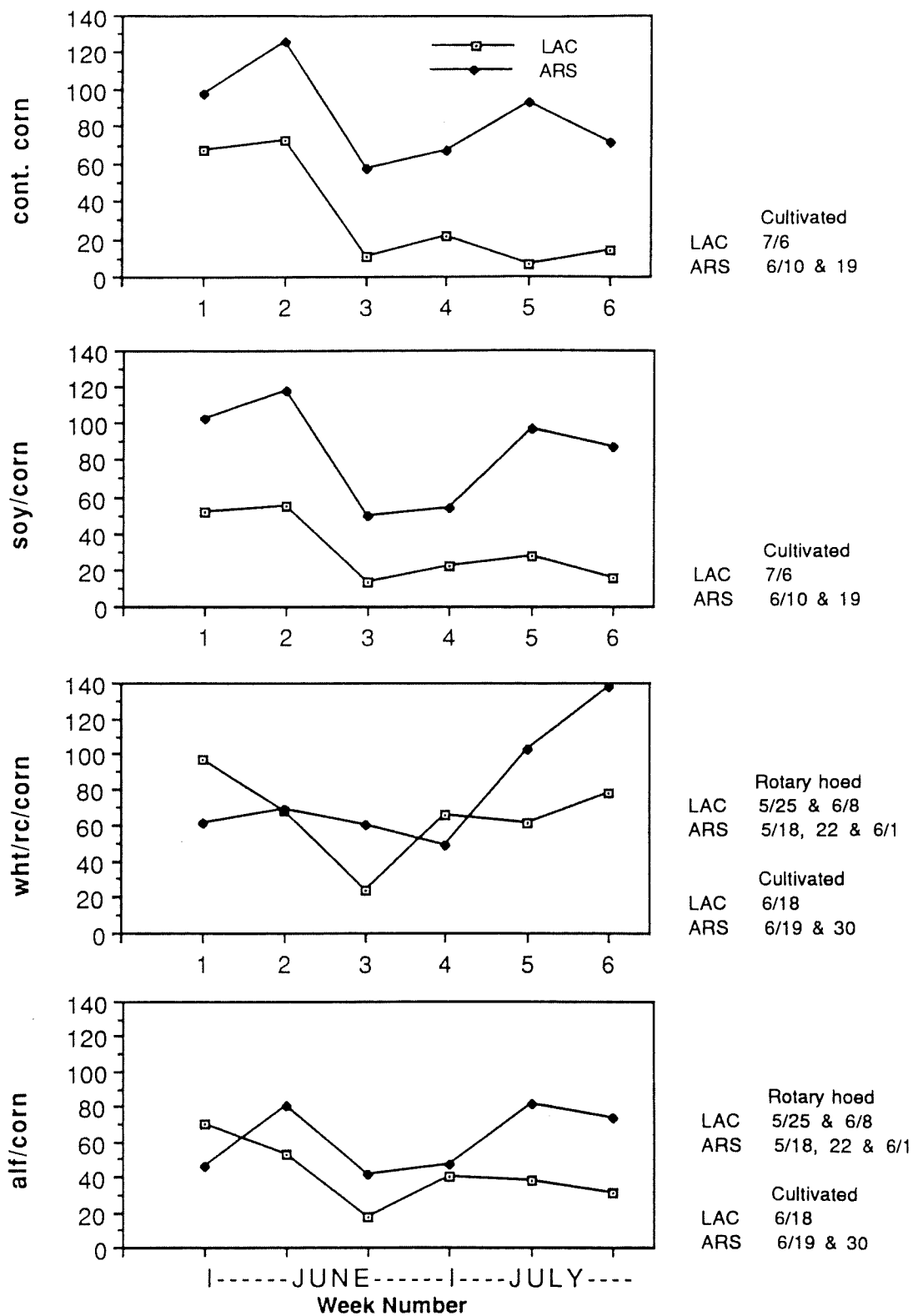


Figure 4d. Total Number of **OPILIONES** Captured by Week in Pitfall Traps
WICST 1992

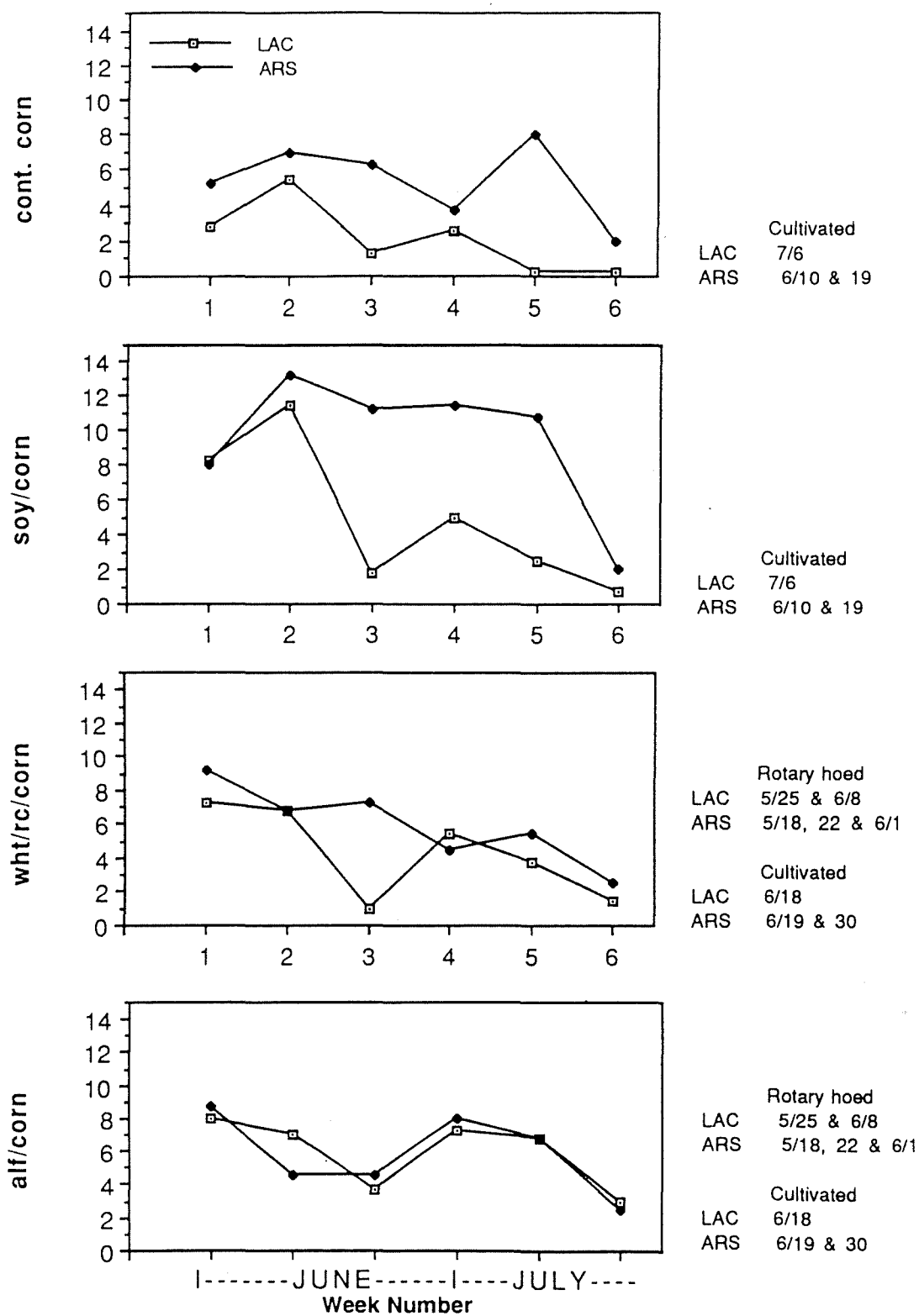


Figure 4e. Total Number of **ARANEAE** Captured by Week in Pitfall Traps WICST 1992

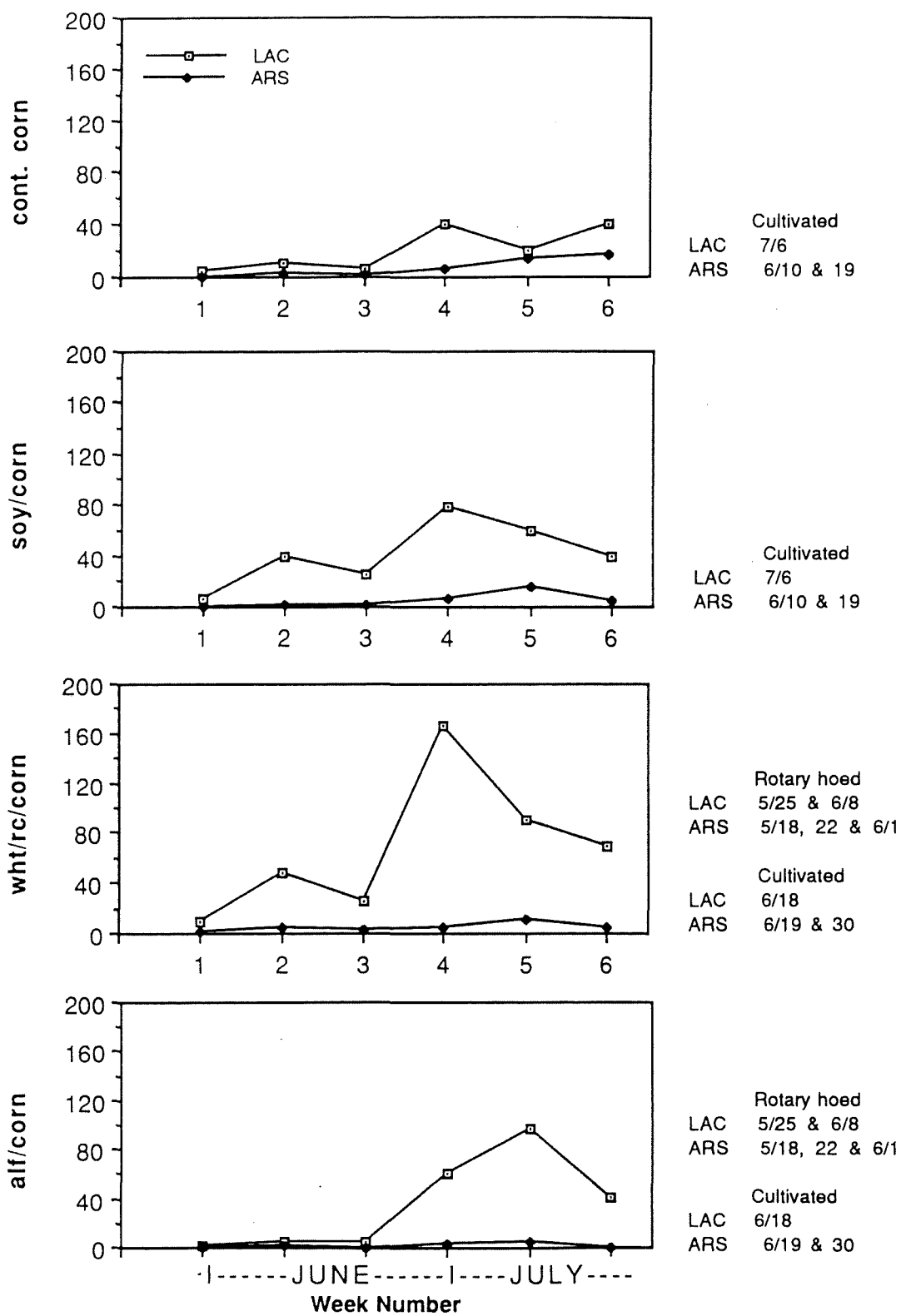


Figure 4f. Total Number of **ORTHOPTERA** Captured by Week in Pitfall Traps
WICST 1992

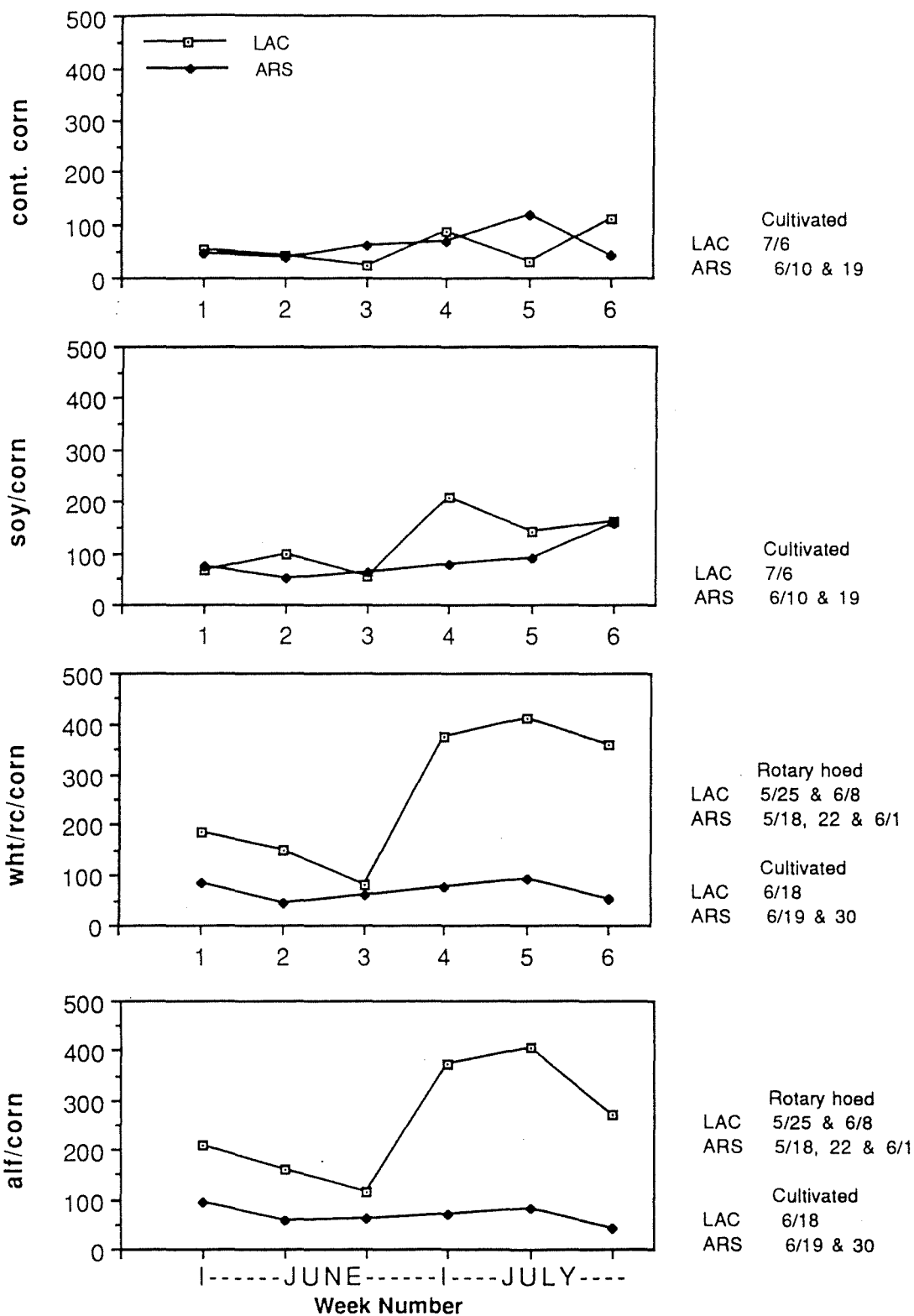


Figure 4g. Total Number of **COLEOPTERA** Captured by Week in Pitfall Traps WICST 1992

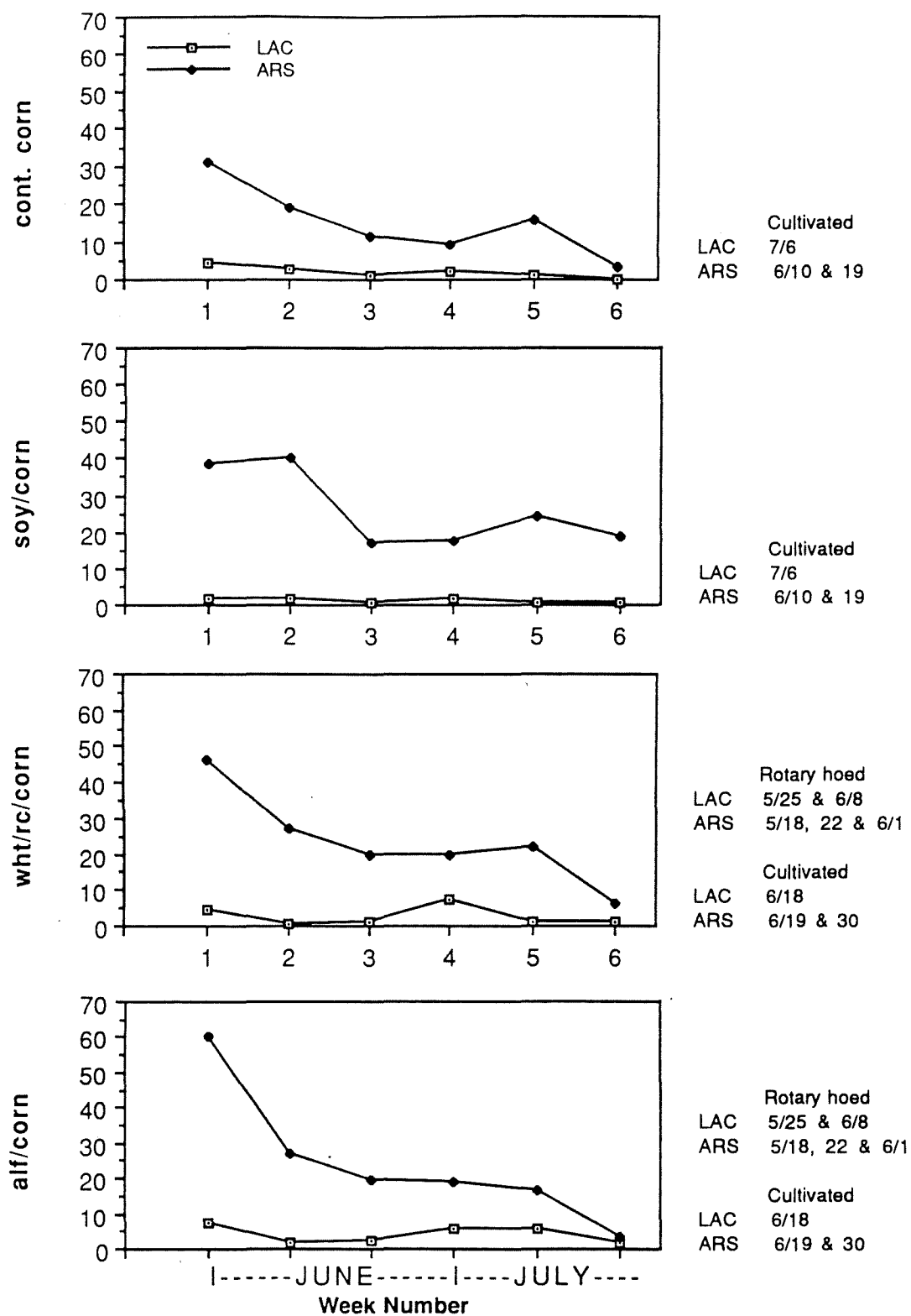


Figure 4h. Total Number of **FORMICIDAE** Captured by Week in Pitfall Traps
WICST 1992

D. PRELIMINARY CORN ROOT HEALTH STUDIES

Rick Volland* and Doug Rouse**

Abstract:

Roots were sampled from corn plants following corn (Rotation 1) and corn following red clover/wheat (Rotation 3) at the Arlington Research Station and Lakeland Agricultural Complex. These samples were analyzed for root discoloration, root density, and colonization by *Pythium*. Roots from the June 9 sampling at Lakeland did not differ in severity of root discoloration and root density. However, roots from rotation 1 had consistently more discoloration than rotation 3 at both sites for all other sample dates. The *Pythium* data was inconclusive.

Materials and Methods:

Roots were sampled from corn plants in rotation 1 and rotation 3 at both sites of the Wisconsin Integrated Cropping Systems Trial. Rotation 1 has corn planted in the same soil each year. Rotation 3 is a three year rotation (sb/w-w/rc1-c). The Lakeland (LAC) site was sampled on June 9, July 21, and August 17, 1992. The Arlington site (ARS) was sampled on June 29 and July 29, 1992. Six plants were sampled from each of the four blocks at Lakeland. These samples were analyzed for root discoloration and density. Three plants were sampled from each of the four blocks at Arlington. These samples were only analyzed for root discoloration.

Roots for all sampling dates except August 17 were selected by laying out transects along major diagonal axes, walking distances selected using a table of random numbers, and then choosing the closest plant with a representative size and inter-plant distance. On August 17, roots were selected from the northeast corner of each of the eight plots using a constant sampling pattern. On June 9, whole plants were harvested using a cylindrical earthworm sampler about 15 cm in diameter. During other sampling dates, plant tops were cut 5-10 cm above the soil line before using the same earthworm sampler. On June 9 and June 29 roots and soil were pushed from the sampling tool using a 1 cm metal bar extending from both sides of the cylindrical sampling tool. On later sampling dates, roots and soil were released from the sampling tool by repeatedly hammering the exterior of the sampling tool with a rubber mallet. Roots and soil were stored in a cold room between sampling and processing.

Roots were analyzed for discoloration after washing off the soil with very warm water. No effort was made to collect fine roots from the July 29 and August 17 samples. Discoloration was rated on a scale from 0 to 4 where 0 = no visible lesions and 4 = necrotic lesions over more than 20% of roots.

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Root density was measured after cutting all roots from the seed and from the base of the stem. The root connecting the seed to the base of the stem was not included in measurements. Root density was assessed as the number of times roots floating in water crossed the horizontal components of a 2 cm grid. Larger root systems were counted as the total of two sub-samples when the root system was too dense to be counted as a whole.

Roots from all sampling dates except August 17 were transported to the laboratory of Dr. D. Rouse at the University of Wisconsin-Madison for isolation of pathogenic fungi. A sample of washed roots from each plot was plated onto a selective medium for *Pythium* spp. This fungal genus contains several important root pathogens. After incubating the plates several days, the amount of *Pythium* on each plate was scored on a 0 to 3 scale.

Results:

Roots collected from the Walworth County site on June 9 did not differ in root density or root discoloration (Table 6). Discoloration rating values were greater in rotation 1 than in rotation 3 for the remaining sampling dates from both sites. Ninety-three of 96 root systems from the last three sampling dates fit the model where discoloration ratings for rotation 1 had the value 4 and discoloration ratings for rotation 3 had the value 3 or less. Root density at ARS site was greater for corn in rotation 1 than for rotation 3, but the reverse was true at the LAC site. It was interesting to note that more *Pythium* was present on roots from the rotation treatment compared with the continuous corn treatment. It was not determined however, if these fungi were pathogenic.

Observations:

Amount of root discoloration was consistently associated with crop rotation except for the first sampling date at the Walworth County site. This site received less than 8 cm of rain from planting until this sampling. The site then received significant rain in July including the week prior to July 21st. Yet, the soil had surface cracks on that date, and the exterior of the sampling holes appeared as dry as the compacted soil in the grass-covered access ways. Even though the corn-legume rotation has been running for only three years, it appeared to already have a beneficial effect on root discoloration compared to the continuous corn plots. Root density appeared to be more strongly associated with site than with crop rotation pattern.

Table 6. Root density, discoloration, and colonization ratings for corn plants sampled in the Wisconsin Integrated Cropping Systems Trial.

Site	Date	Root Density ¹		Root Discoloration ²		Root Colonization ³ by Pythium ^a	
		C-C-C	Sb-W/RC-C	C-C-C	Sb-W/RC-C	C-C-C	Sb-W/RC-C
LAC	June 9	64 ^b	59 ^b	2.2 ^b	2.7 ^b	nm	nm
	July 21	569 ^c	732 ^c	4.0 ^b	3.0 ^b	nm	nm
	Aug 17	nm	nm	4.0 ^d	3.0 ^d	1.3	2.1
ARS	June 29	467 ^d	262 ^d	4.0 ^d	3.0 ^d	1.4	1.8
	July 29	nm	nm	4.0 ^d	3.0 ^d	2.4	2.5

nm = not measured

¹ Root density recorded as number of times roots floating in water crossed the horizontal components of a 2 cm grid.

² Root discoloration was rated on a scale of 0 to 4 where 0 = no visible lesions and 4 = necrotic lesions over more than 20% of the roots.

³ Plates were rated on a scale of 0 = clean to 3 = severe for Pythium growth on selective media.

^a - mean of 1 plate from each of four reps

^b - mean of 24 plants

^c - mean of 6 plants

^d - mean of 12 plants

III. Corn Baseline Values of Soil Analytical Component of Soil Quality/Health: 1992 Data from Wisconsin Integrated Cropping Systems Trial

R. F. Harris, M. J. Garlynd, and A. V. Kurakov*

Introduction

Increasing attention and interest have been shown nationally and globally in developing methodology to monitor and assess soil quality (term favored by scientist)/soil health (term favored by farmers) to provide a basis for the maintenance of soil resources (Papendick and Parr, 1992). Analyzing the long term effects of various rotations in the Wisconsin Integrated Cropping Systems Trial (WICST) requires an examination of soil properties characterizing soil quality/health. The Wisconsin Soil Quality/Health project has developed a conceptual interpretive framework for studying soil quality/health (Fig. 5). This framework includes the soil and non soil (plant, animal/human, water and air) target systems, divided into categories of descriptive and analytical diagnostic properties. Defining the correlative and predictive relationships between the diagnostic properties of the soil and non soil properties, and a functional definition of soil quality/health in terms of the target systems (Harris, 1992; Garlynd et al., 1992; Harris and Bezdicek, 1992) is the goal of the project.

Our WICST study was initiated in July, 1992. The purpose of the 1992 phase of the study was to establish baseline values of the soil analytical component (chemical, physical and biological properties) of soil quality/health for WICST. Plots chosen for sampling at both sites have been in continuous corn since the establishment of the WICST in 1989. These baseline corn data are necessary to monitor changes in the soil quality/health of continuous corn and other rotations being studied over the short and long term of the cropping systems trial.

Materials and Methods

Summer soil samples were collected on July 21 at Arlington Research Station (ARS), and August 8, 1992 at Lakeland Agricultural Complex (LAC). Fall samples were taken after corn harvest, on November 18 in ARS, and December 3, 1992 at LAC.

Soil samples were collected at each site from three plots in treatment-1 (continuous corn) and treatment-10 (filler corn before high production alfalfa-corn rotation). Both treatment 1 and treatment 10 have been planted in corn since the inception of the cropping systems trial. Measurements from these plots represent the conditions that exist after at least four years of continuous corn cropping.

* Professor, Graduate Student, and Visiting Scientist, Dept. of Soil Science, Univ. of Wisconsin, Madison, respectively.

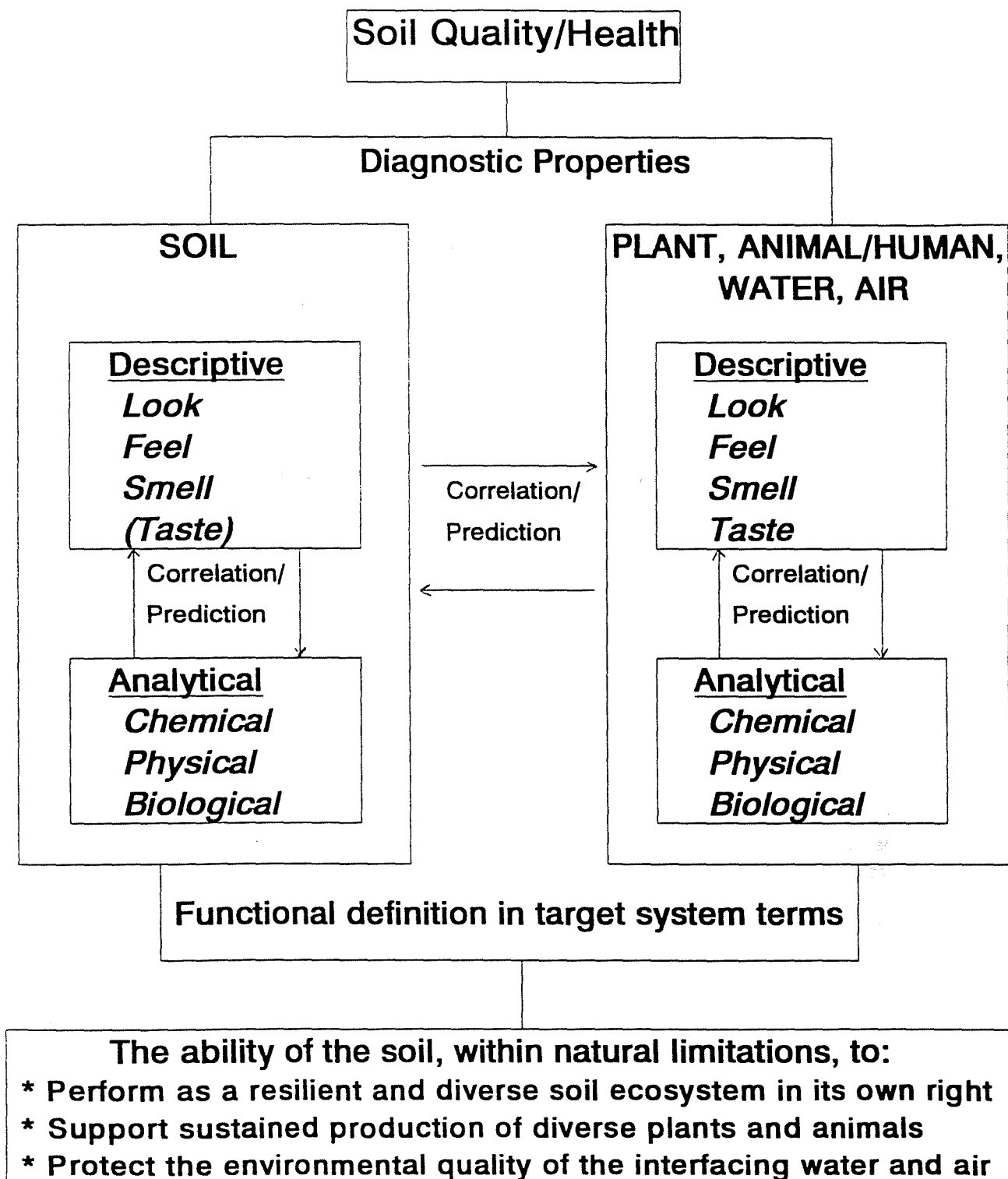


Figure 5. Soil Quality/Health Interpretive Framework

The following procedure was used to provide a randomized intensive sampling of each plot. Within each plot three stations of equal size (16m x 16m) were established and spaced evenly along the length of the plot. Each station was divided into 4x4m sq. grids. A single 3/4" core was collected from the top 15 cm of soil from each of the 16 grids. Sixteen cores from each station were combined to form a bulked sample of 48 cores to represent each plot. Three samples of 3" cores were collected for bulk density and total porosity analysis from each plot at ARS during the fall sampling time. Samples were frozen immediately after collecting and stored until sieved through a 5mm or 2mm screen. A portion of 5mm sieved soil was then air dried for chemical and physical analysis and the remaining moist soil was stored at 5°C for subsequent analysis of biological properties.

Methods of analysis of the samples were as follows. Nitrate and ammonium nitrogen were measured in a 2N KCl soil extract (Keeney and Nelson, 1982), by Technicon Auto Analyzer II (Industrial methods, 1973, 1977). Organic matter, pH, extractable phosphorous, exchangeable Ca, Mg, and K, as well as cation exchange capacity, particle size distribution, and electrical conductivity were conducted at the UW Soil and Plant Test Laboratory in Madison (Schulte et al., 1970). Bulk density and total porosity were determined using the core method (Blake and Hartge, 1986; Danielson and Sutherland, 1986). Soil aggregate stability was determined using the wet sieve method (Kemper and Rosenau, 1986). Microbial biomass was estimated by fumigation incubation method (Jenkinson and Powlson, 1976). Fifty grams of 5mm sieved soil was preincubated for 4 days followed by a 24 hour fumigation. Fumigated and unfumigated soils were then incubated for 10 days at 25°C. A K-value of 0.45 was used for conversion to microbial biomass. Labile carbon was measured by evolution of CO₂ during incubation of 50 grams of 5 mm sieved moist soil at 25°C over a period of 14 days. CO₂ was trapped by 0.5 N NaOH and measured by Technicon Autoanalyzer II (Morfaux et al., 1972). Labile nitrogen was calculated as the difference of inorganic nitrogen content (nitrate and ammonium) between the initial levels and after 14 days incubation of soil (Ross et al., 1982). Arginine ammonification of soil was measured by a slightly modified standard procedure (centrifugation of KCl-soil extract was replaced by filtration) (Alef and Kleiner, 1986). Dehydrogenase activity of soil was measured using standard method (Casida et al., 1964).

The treatments were characterized by mean values of three plots with a standard deviation reflecting the variability between plots combined with the accuracy of the analytical methods (coefficient of variation from previous laboratory analysis is in the range of 0.5-10%, except labile nitrogen analysis which was about 50%). Each field replicate/plot was represented by one laboratory replicate (three laboratory replicates were used for bulk density and total porosity). Statistical comparison of the data is presented, as executed by Minitab software (Ryan et al., 1985). A t-test was used to compare data at different sampling times within the same treatments. Comparison of data between treatments was conducted using one way analysis of variance (ANOVA).

Results and Discussion

Soil chemical, physical and biological values for continuous corn (treatment 1) and for filler corn before the introduction of alfalfa (treatment 10) for summer and fall at each WICST site, are presented in Tables 7 and 8. The chemical values for both sites fall within the range of high to optimum soil fertility level according to the recommendations of the UW Soil and Plant Test Laboratory. Statistical analysis of the data, presented in Tables 9 and 10, show that in only a few cases was there a statistically significant difference between the two sets of plots in continuous corn at either site. Only the values of pH for fall sampling at both sites were shown to have a statistically significant difference (0.1-0.2 pH) at the 90% level, and water stable aggregates ($> .25\text{mm}$) at ARS was the only occurrence of a significant difference between the sets of plots at the 95% level. Soil enzyme activity (dehydrogenase activity and arginine ammonification) and labile carbon levels tended to increase from summer to fall. Soil inorganic nitrogen and electrical conductivity level showed a statistically significant decrease in the fall compared to the summer. Lack of marked changes between values of other soil chemical properties for summer and fall may be due to collecting samples after the peak of growing period and the high fertility of these soils. The data are intended to be used as a comparative corn baseline to observe changes in soil properties resulting from different cropping rotations, or further continuous corn cropping, over the short and long term future of the cropping systems trial.

The standard deviation between plots in the same rotation closely matched the expected variation in accuracy of the methods used for analysis. Based on this data we conclude that our sampling procedure is adequate and will continue to use the same method in the future.

We intend to sample the same plots in the spring of 1993 before planting to provide a three season set of baseline corn data. This will allow for additional analysis of temporal fluctuations of soil analytical properties and statistically significant differences between plots of continuous corn treatment. Samples will also be collected from plots planted to corn in rotations 1 (corn), 2 (soybean-corn), 3 (soybean/winter wheat/wheat/red clover-corn), and 5 (3 alfalfa-corn) during spring, summer, and fall of 1993. Samples from the permanent pasture of rotation 6 will likewise be collected.

Referring back to Figure 5 it can be seen that we have focussed to date on only the analytical component of the soil system. For characterization of soil quality/health according to our interpretive framework a complete set of descriptive soil properties, as well as analytical and descriptive properties of non soil systems interfacing or supported by the soil system is needed. The Wisconsin Soil Quality/Health project is currently developing tools to be used by cooperating farmers and field superintendents familiar with the sites to collect additional information that will allow analysis of correlations between diagnostic properties of soil quality/health between and within the soil and non soil target systems.

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Table 7. Baseline data of soil analytical properties for continuous corn: WICST at Arlington site for summer and fall 1992.

Properties	Treatments and sampling times								(Units)
	TREATMENT-1 (C*-C-C-C- <u>C</u> -C-C-C-C)				TREATMENT-10 (C*-C*-C*- <u>C</u> *-A-A-A-C)				
SOIL	Summer-92		Fall-92		Summer-92		Fall-92		
Analytical									
Chemical									
pH	6.7±	0.1	6.8±	0.1	6.7±	0.1	6.9±	0.1	(-log[H ⁺])
Nitrate-Nitrogen	33.0±	6.4	13.1±	1.5	35.9±	6.9	14.6±	1.3	(mg kg ⁻¹)
Ammonium-Nitrogen	5.0±	0.4	4.2±	1.0	5.0±	0.7	3.9±	1.3	(mg kg ⁻¹)
Extractable Phosphorous	92±	2	102±	10	85±	33	81±	32	(mg kg ⁻¹)
Exchangeable Calcium	1783±	125	1833±	118	1875±	65	1917±	125	(mg kg ⁻¹)
Exchangeable Magnesium	610±	45	630±	33	660±	16	687±	39	(mg kg ⁻¹)
Exchangeable Potassium	325±	29	402±	44	323±	100	312±	117	(mg kg ⁻¹)
Cation Exchange Capacity	15±	1	15±	1	15±	1	16±	2	(meq 100g ⁻¹)
Physical									
Bulk Density	-		1.05±	.45	-		1.10±	0.10	(g cm ⁻³)
Total Porosity	-		60.3±	1.7	-		59.0±	3.0	(%)
Aggregate Stability									
(> 2.0mm)	5.7±	1.2	6.1±	2.5	5.1±	0.5	6.4±	3.8	(%)
(> .25mm)	54.1±	3.8	45.3±	7.3	42.9±	3.1	43.2±	2.2	(%)
Electrical Conductivity	15±	0	12±	1	18±	2	12±	0	(x10 ⁻⁵ mhos cm ⁻¹)
Particle Size Distribution									
(sand)	-		18±	4	-		17±	4	(%)
(silt)	-		69±	2	-		71±	2	(%)
(clay)	-		13±	2	-		12±	2	(%)
Biological									
Organic Matter	4.3±	0.6	4.4±	0.6	4.4±	0.8	4.2±	0.8	(%)
Labile Carbon	107±	13	125±	27	94±	7	136±	24	(µgC g ⁻¹ OD soil)
Labile Nitrogen	6.0±	11	0.8±	2.9	0.1±	8.3	0.9±	0.6	(µgN g ⁻¹ OD soil)
Microbial Biomass (Carbon)	255±	62	249±	45	268±	56	241±	52	
(mgC 100g ⁻¹)									
Arginine Ammonification	21.8±	2.6	22.6±	1.1	18.8±	0.3	21.7±	3.3	(µgN 10g ⁻¹ h ⁻¹)
Dehydrogenase Activity	69.8±	11.9	88.5±	9.6	69.4±	11.9	72.8±	8.4	(µgTPF 10g ⁻¹ h ⁻¹)

Key

C* = Filler corn

C = Corn

A = Alfalfa

Treatment-1 involves 3 plots: #109, #204, #306. This is Rotation-1 with corn in 1992 (C).

Treatment-10 involves 3 plots: #107, #205, #309. This is Rotation-4 with filler corn in 1992 (C*).

Table 8. Baseline data of soil analytical properties for continuous corn: WICST at Lakeland site for summer and fall 1992.

Properties	Treatments and sampling times								(Units)
	TREATMENT-1 (C*-C-C-C-C-C-C-C)				TREATMENT-10 (C*-C*-C*-C*-A-A-A-C)				
SOIL	Summer-92		Fall-92		Summer-92		Fall-92		
Analytical									
Chemical									
pH	6.7±	0.2	6.8±	0.2	6.8±	0.1	7.0±	0.0	(-log[H ⁺])
Nitrate-Nitrogen	17.9±	5.6	9.6±	1.3	34.0±	9.1	8.0±	0.1	(mg kg ⁻¹)
Ammonium-Nitrogen	4.8±	0.4	3.5±	1.0	6.0±	1.1	4.3±	0.7	(mg kg ⁻¹)
Extractable Phosphorous	51±	3	49±	4	42±	17	62±	45	(mg kg ⁻¹)
Exchangeable Calcium	2050±	108	2000±	204	2633±	686	2700±	668	(mg kg ⁻¹)
Exchangeable Magnesium	723±	65	720±	54	943±	227	967±	221	(mg kg ⁻¹)
Exchangeable Potassium	257±	25	230±	46	210±	24	277±	96	(mg kg ⁻¹)
Cation Exchange Capacity	17±	1	16±	2	21±	1	21±	5	(meq 100g ⁻¹)
Physical									
Aggregate Stability									
(> 2.0mm)	9.4±	3.1	13.5±	1.9	11.7±	5.3	14.1±	2.0	(%)
(> .25mm)	55.4±	8.0	55.0±	5.3	53.8±	3.1	54.7±	4.3	(%)
Electrical Conductivity	14±	1	16±	2	18±	4	14±	2	(x10 ⁻⁵ mhos cm ⁻¹)
Particle Size Distribution									
(sand)	-		21±	3	-		21±	4	(%)
(silt)	-		64±	2	-		65±	4	(%)
(clay)	-		15±	2	-		14±	1	(%)
Biological									
Organic Matter	4.2±	0.2	4.2±	0.2	5.1±	1.6	5.2±	1.6	(%)
Labile Carbon	84±	5	142±	15	90±	17	113±	14	(µgC g ⁻¹ OD soil)
Labile Nitrogen	3.6±	12	-11.3±	12.0	-8.5±	1.1	-3.1±	2.2	(µgN g ⁻¹ OD soil)
Microbial Biomass (Carbon)	293±	30	306±	34	308±	44	408±	118	(mgC 100g ⁻¹)
Arginine Ammonification	20.5±	0.8	26.3±	1.0	23.7±	5.8	23.7±	5.9	(µgN 10g ⁻¹ h ⁻¹)
Dehydrogenase Activity	62.7±	8.3	73.1±	10.8	63.1±	9.2	68.3±	8.3	(µgTPF 10g ⁻¹ h ⁻¹)

Key

C* = Filler corn

C = Corn

A = Alfalfa

Treatment-1 involves 3 plots: #101, #210, #303. This is Rotation-1 with corn in 1992 (C).

Treatment-10 involves 3 plots: #112, #214, #301. This is Rotation-4 with filler corn in 1992 (C*).

Table 9. Baseline data of soil analytical properties for continuous corn: WICST at Arlington site for summer and fall 1992.

Properties	Treatments and sampling times				(Units)
	TREATMENT-1 (C*-C-C-C-C-C-C-C)		TREATMENT-10 (C*-C*-C*-C*-A-A-A-C)		
SOIL	Summer-92	Fall-92	Summer-92	Fall-92	
Analytical					
Chemical					
pH	6.7	6.8 ^{bx}	6.7 ^{aβ}	6.9 ^{aβ, bx}	(-log[H ⁺])
Nitrate-Nitrogen	33.0 ^{ax}	13.1 ^{ax}	35.9 ^{aβ}	14.6 ^{aβ}	(mg kg ⁻¹)
Ammonium-Nitrogen	5.0	4.2	5.0 ^{ax}	3.9 ^{ax}	(mg kg ⁻¹)
Extractable Phosphorous	92	102	85	81	(mg kg ⁻¹)
Exchangeable Calcium	1783	1833	1875	1917	(mg kg ⁻¹)
Exchangeable Magnesium	610	630	660 ^{aβ}	687 ^{aβ}	(mg kg ⁻¹)
Exchangeable Potassium	325	402	323	312	(mg kg ⁻¹)
Cation Exchange Capacity	15	15	15	16	(meq 100g ⁻¹)
Physical					
Bulk Density	-	1.05	-	1.10	(g cm ⁻³)
Total Porosity	-	60.3	-	59.0	(%)
Aggregate Stability					
(> 2.0mm)	5.7	6.1	5.1	6.4	(%)
(> .25mm)	54.1 ^{bβ}	45.3	42.9 ^{bβ}	43.2	(%)
Electrical Conductivity	15 ^{ax}	12 ^{ax}	18 ^{aδ}	12 ^{aδ}	(x10 ⁻⁵ mhos cm ⁻¹)
Particle Size Distribution					
(sand)	-	18	-	17	(%)
(silt)	-	69	-	71	(%)
(clay)	-	13	-	12	(%)
Biological					
Organic Matter	4.3	4.4	4.4	4.2	(%)
Labile Carbon	107	125	94	136	(μgC g ⁻¹ OD soil)
Labile Nitrogen	6.0	0.8	0.1	0.9	(μgN g ⁻¹ OD soil)
Microbial Biomass (Carbon)	255	249	268	241	(mgC 100g ⁻¹)
Arginine Ammonification	21.8	22.6	18.8	21.7	(μgN 10g ⁻¹ h ⁻¹)
Dehydrogenase Activity	69.8 ^{aδ}	88.5 ^{aδ}	69.4	72.8	(μgTPF 10g ⁻¹ h ⁻¹)

Key

C* = Filler corn, C = Corn, A = Alfalfa

Treatment-1 involves 3 plots: #109, #204, #306. This is Rotation-1 with corn in 1992 (C).

Treatment-10 involves 3 plots: #107, #205, #309. This is Rotation-4 with filler corn in 1992 (C*).

a - statistically significant difference between two sampling times in same treatment.

b - statistically significant difference between two treatments at same sampling time.

α, β, δ - statistically significant at the 0.1, 0.5 and 0.01 levels, respectively.

Table 10. Baseline data of soil analytical properties for continuous corn: WICST at Lakeland site for summer and fall 1992.

Properties	Treatments and sampling times				(Units)
	TREATMENT-1 (C*-C-C-C-C-C-C-C)		TREATMENT-10 (C*-C*-C*-C*-A-A-A-C)		
SOIL	Summer-92	Fall-92	Summer-92	Fall-92	
Analytical					
Chemical					
pH	6.7	6.8 ^{bc}	6.8	7.0 ^{bc}	(-log[H ⁺])
Nitrate-Nitrogen	17.9 ^{bc}	9.6	34.0 ^{ac, bc}	8.0 ^{ac}	(mg kg ⁻¹)
Ammonium-Nitrogen	4.8 ^{ac}	3.5 ^{ac}	6.0	4.3	(mg kg ⁻¹)
Extractable Phosphorous	51	49	42	62	(mg kg ⁻¹)
Exchangeable Calcium	2050	2000	2633	2700	(mg kg ⁻¹)
Exchangeable Magnesium	723	720	943	967	(mg kg ⁻¹)
Exchangeable Potassium	257	230	210	277	(mg kg ⁻¹)
Cation Exchange Capacity	17	16	21	21	(meq 100g ⁻¹)
Physical					
Aggregate Stability					
(> 2.0mm)	9.4	13.5	11.7	14.1	(%)
(> .25mm)	55.4	55.0	53.8	54.7	(%)
Electrical Conductivity	14	16	18	14	(x10 ⁻⁵ mhos cm ⁻¹)
Particle Size Distribution					
(sand)	-	21	-	21	(%)
(silt)	-	64	-	65	(%)
(clay)	-	15	-	14	(%)
Biological					
Organic Matter	4.2	4.2	5.1	5.2	(%)
Labile Carbon	84 ^{ab}	142 ^{ab}	90 ^{ac}	113 ^{ac}	(µgC g ⁻¹ OD soil)
Labile Nitrogen	3.6	-11.3	-8.5 ^{ac}	-3.1 ^{ac}	(µgN g ⁻¹ OD soil)
Microbial Biomass (Carbon)	293 ^{ab}	306 ^{ab}	308 ^{ac}	408 ^{ac}	(mgC 100g ⁻¹)
Arginine Ammonification	20.5 ^{ab}	26.3 ^{ab}	23.7 ^{ac}	23.7 ^{ac}	(µgN 10g ⁻¹ h ⁻¹)
Dehydrogenase Activity	62.7	73.1	63.1	68.3	(µgTPF 10g ⁻¹ h ⁻¹)

Key

C* = Filler corn, C = Corn, A = Alfalfa

Treatment-1 involves 3 plots: #109, #204, #306. This is Rotation-1 with corn in 1992 (C).

Treatment-10 involves 3 plots: #107, #205, #309. This is Rotation-4 with filler corn in 1992 (C*).

a - statistically significant difference between two sampling times in same treatment.

b - statistically significant difference between two treatments at same sampling time.

α, β, δ - statistically significant at the 0.1, 0.5 and 0.01 levels, respectively.

IV. WEED CONTROL STUDIES

A. WEED AND WEED SEED MONITORING FOR 1992

J. Doll, T. Mulder and J. Posner*

To determine weed density and diversity, each plot is divided into thirds and 10 soil samples 0.75 in. in diameter and 6 in. deep are taken in each third in mid to late April. The 10 samples are composited into one (giving approximately 1.5 lb of soil) and stored at 35-38°F until germination studies are initiated in the greenhouse in early May. Each subsample is mixed with an equal weight of silica sand and placed in a plastic tray with small holes in the bottom. Trays are placed on a capillary mat on a greenhouse bench which is automatically watered daily.

As seeds germinate, the seedlings are identified, counted and removed. After several weeks, germination ceases and the soil/sand mixture is dried, remixed, returned to the flats and watered for another germination cycle. This process is repeated three times and all germination observations are completed by early October. The number of seedlings for the three subsamples is totaled and an average number per square foot is calculated.

Several rotations have been in place 3 years, and in addition we have the uniformity year data for the Arlington Research Station (ARS). Seed monitoring methods were described in previous reports and last year we described the sampling schedule we are using for both weed seed and weed biomass determinations. Weed biomass is determined by harvesting all weeds present in three 5 x 5-ft areas per plot, separating the weeds into broadleaves and grasses, and drying the weeds to determine dry weight per acre. We sample the corn and soybeans in all rotations that have these crops in a given year and this is done when all cultivations are completed and corn is approximately 36 inches tall. Thus far we are satisfied with the sampling procedures being used and no significant changes are planned for the near future.

We have removed the uncommon weeds from the numbers reported in the following tables. This includes weeds such as knotweed, wild buckwheat, kochia, common purslane, corn spurry, sow thistle, rough fleabane, yellow wood sorrel, purslane speedwell and broadleaf plantain. The weeds that are included in the tables include the annual grasses: giant, green and yellow foxtail; fall panicum; large crabgrass; and barnyardgrass. The annual broadleaves include pigweed species, common lambsquarters, velvetleaf, shepherd's purse, common dandelion, Eastern black nightshade, smartweed species and white cockle.

In the continuous corn rotation (R1), weed populations declined at the ARS but remained constant at the Lakeland Agricultural Complex (LAC) (Table 11). The dominance of broadleaves continues in this rotation at the ARS but grasses are increasing at the LAC. In the corn-soybean rotation (R2), weed populations are constant at both locations with little change in composition at the ARS and an increase in broadleaves at the LAC. The rotation of corn-soybean-wheat/red clover (R3, the non-herbicide system) has allowed weed populations to increase significantly at both sites and this rotation has the highest

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weed density of all the cash grain systems. Weed composition in this rotation has remained relatively constant at ARS and broadleaves again appear to be increasing at LAC.

Table 11. Evolution of weed seed populations in the WICST from the spring of 1990 to 1992.

Rota.	Tmt.	Arling. Res. Sta.				Lakeland Ag. Comp.			
		90	91	92	diff. 92-90	90	91	92	diff. 92-90
		----- seeds/ft ² -----				----- seeds/ft ² -----			
CONTIN. CORN	1	448	166	206	-242	190	68	244	+54
% broadleaf		86	84	87		87	72	50	
% grass		14	16	13		13	28	50	
SB-CN-SB	3	429	480	571	+142	193	174	116	-77
% broadleaf		75	73	78		28	22	47	
% grass		25	27	22		72	78	53	
SB/Wh-Wh/RC-CN	5	206	459	894	+688	196	328	557	+361
% broadleaf		68	80	85		42	7	84	
% grass		32	20	15		58	93	16	
O-A/A/C	11	443	855	692	+249	307	646	261	-46
% broadleaf		82	64	91		28	11	53	
% grass		18	36	9		72	89	47	
A/A/A	7	472	264	-	-	239	956	-	-
% broadleaf		82	81			47	14		
% grass		18	19			53	86		
Pasture	14	386	405	-	-	136	951	-	-
% broadleaf		88	82			50	7		
% grass		12	18			50	93		
LSD (0.05)		ns	187	175		ns	ns	201	

In the intensive alfalfa rotation (R4), weed populations have dropped at the ARS but more than tripled at the LAC (Tmt 7) with a large increase in grassy weeds at this site. The excellent stand of alfalfa established at the ARS in 1990 (forage yield of 4.3 t dm/A) resulted in a decrease in weed seeds found in 1991 while the poor stand at the LAC (no forage harvested in seeding year due in large part to weeds) resulted in a large increase in weed seeds the following year. In the short alfalfa rotation (Tmt 11), weed densities at both sites have increased greatly the year oats and alfalfa are seeded. This increase is due primarily to annual grasses. Annual grasses declined rapidly at both locations when sampled the year after full hay production (1992). Weed populations have remained constant in the pasture system (R6) at the ARS but annual grasses increased dramatically at the LAC in the establishment year (1990).

The weed biomass data show that few weeds were present in July in the continuous corn (R1) and the corn phase of the corn-soybean rotation (R2) with less than 50 lb/a of weeds escaping the management programs that included herbicides (Table 12). Broadleaf weeds were more the principal type of weed not fully controlled by these programs. When soybeans were present in the R2 rotation, weeds were more abundant at both sites, especially broadleaf weeds. The same was true for soybeans in R3 at Arlington where over 100 lb/a of weeds escaped control with the mechanical measures used. Herbicides were used at LAC to achieve adequate control in this rotation. In the corn phase of this rotation, control was much better at ARS than LAC where both grasses and broadleaves escaped the mechanical weed control practices. The corn phase of R5 had one-third fewer weeds at ARS than at LAC. Some broadleaves escaped at both sites and grass control was poorer at LAC than ARS.

Table 12. Summary of broadleaf and grass weed biomass for all rotations with corn and soybeans when corn was 36 inches tall at the Arlington Research Station (ARS) and the Lakeland Agricultural Complex (LAC) in 1992.

Rotation	Tmt.	Weed type	SITE	
			ARS	LAC
<u>90-91-92</u>			--- lb dw/a ---	
CN-CN-CN	1	bdlf	9	37
		grass	0	11
		total	19	48
CN-SB-CN	2	bdlf	22	10
		grass	5	6
		total	27	16
SB-CN-SB	3	bdlf	109	160
		grass	70	0
		total	179	160
CN-CN-SB/W	4	bdlf	111	21
		grass	26	0
		total	137	21
SB/W-W/RC-CN	5	bdlf	40	116
		grass	6	199
		total	46	315
O/A-A-CN	11	bdlf	57	108
		grass	3	78
		total	60	186

B. FINDING THE NICHE FOR MECHANICAL WEEDING IN CORN WEED CONTROL

Thomas A. Mulder and Jerry D. Doll*

INTRODUCTION

Concern about present levels of pesticide use has prompted many agriculturalists to reevaluate current practices and policies. Herbicides have been of particular concern due to detection in some surface and groundwater sources. In 1988, 60% of herbicide used in the U.S. was for corn weed control (Regnier and Jahnke, 1990). Water quality concerns and the trend to use fewer inputs has renewed interest in mechanical weeding to reduce herbicide use and weed control costs.

When herbicide use is minimized by rate reduction or banding, properly timed post-plant tillage will often be required to control weeds that emerge after loss of herbicide effectiveness or to control weeds in the area between spray bands (Dowler et al., 1974). Research completed over 20 years ago showed that weeds could be controlled by combining lower rates of herbicides and mechanical weeding (Buchholtz and Doersch, 1968). Since then, earlier corn planting dates, higher plant populations, different herbicides, and changes in mechanical weeding tools, justify reevaluating reduced systems.

Even when weeds are controlled by other methods, cultivation often improves corn yield, especially on compacted or heavier-textured soils (Meggett, 1960; Springman et al., 1989). Higher corn yields with cultivation in 19 of 20 comparisons in moldboard plowing, chisel plowing, disking, and no-tillage systems, were attributed to improved weed control, increased aeration, and improved water infiltration (Siemens and McGlamery, 1985). However, row cultivation can also lower corn yield by reducing population or by physically damaging plant shoots or roots (Buchholtz and Doersch, 1968; Buckingham, 1976).

Rotary hoeing and banded herbicide application are early season weed control practices often combined with row cultivation. Both practices attempt to control in-row weeds which is the row-cultivator's main weakness (Liebman and Jahnke, 1990). Iowa research showed no yield difference between banded and broadcast herbicide applications with identical row cultivations and the same herbicide rate in the treated area (Colvin et al., 1989). Iowa researchers also compared broadcast and banded atrazine and found 15 and 25% less herbicide in water collected from tile drainage under chisel plow and ridge-till systems, respectively, when herbicides were banded rather than broadcast (Baker et al., 1991).

Corn, a warm season crop, requires temperatures above 9 C for growth (Warrington and Kanemasu, 1983). Because many weeds are native to temperate climates and thus grow faster than corn during the cool, early growing season, weed control at this time is crucial. Delayed planting allows corn to germinate after the peak emergence time of many weeds (Regnier and Janke, 1990) and warmer temperatures accelerate corn growth. This strategy is very appropriate if using only mechanical weed controls (Granatstein, 1988; Gunsolus, 1990). However, corn yields decrease an average of 24 to 30% in Wisconsin

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(Carter, 1984; Imholte and Carter, 1987) and 18% in Ohio (Eckert, 1984) when planting is delayed from early May to early June.

The following two experiments, conducted in 1990 and 1991, were designed to compare reduced rate and no herbicide weed control strategies.

Experiment 1. Integrating Reduced Herbicide use with Mechanical Weeding in Corn

Materials and Methods

This study, conducted at the same locations as the two WICST sites, compared weed control strategies using 1) broadcast herbicide applications alone at normal or reduced rates, 2) herbicide broadcast or band applied at normal and reduced rates in combination with various mechanical weeding choices, and 3) mechanical weedings alone. At Arlington (ARS), plot size was 10 ft (four 30-in rows) by 40 ft whereas plots at the Lakeland Complex (LAC) were 15 ft (six 30-in rows) by 30 ft to match the width of available cultivators and rotary hoes. The herbicide (Bicep 6L) was applied after planting either broadcast or in 15-inch bands over the row at normal rate of 4.8 pt/A (1.6 lb a.i. A⁻¹ atrazine and 2.0 lb a.i. A⁻¹ metolachlor) or half rate of 2.4 pt/A. Rotary hoeing was done at pre-set times of 7, 14 and 21 days after planting in 1990. Because this system did not allow adjustment for varying growing conditions, in 1991 hoeing was scheduled by corn heights of 1 inch below and 2 and 5 inches above the soil surface. Row cultivations at both locations were done with Danish-tine cultivators at corn heights of 5, 10 and 20 inches (standing height of youngest horizontal leaf). Because there was significant treatment by location and year interactions, each site and year were analyzed separately.

Results

Rotary hoeing significantly reduced corn plant stand at three of the four site years. Corn plant stand was reduced significantly by the first rotary hoeing in 1990 at ARS and both years at LAC (Table 13). The second hoeing also reduced corn stand at the Arlington 1990 and Walworth County 1991 sites. The third rotary hoeing did not increase corn plant mortality in any of the trials. High stand reduction at LAC in 1990 was attributed to deep rotary hoe penetration due to loose soil with large clods resulting from preplant tillage when soil was wet. Row-cultivation did not significantly reduce plant population (data not presented).

At both sites in 1990, all herbicide treatments gave excellent pre-cultivation weed control (>90%) whether at half or normal rates of herbicide (Table 14). May temperatures averaged 2 C below the 20-yr average at Arlington in 1990, slowing corn and weed growth. Thus rotary hoeings at 7 and 14 days after planting were premature and less effective than the 21-day rotary hoeing. In 1990, a rotary hoeing at fixed times in LAC was more effective than at ARS because corn was planted later and temperatures were higher. At LAC weed control by two or more hoeings was equal to that of broadcast herbicides. At both sites in 1991, contrasts show that reducing herbicide rates decreased weed control but this decrease was eliminated by a rotary hoeing.

Table 13. Effect of rotary hoeing on corn population reduction.

Machine used	Stand reduction			
	ARS		LAC	
Rotary hoe ^a	1990	1991	1990	1991
Frequency	%			
1	.5	2.6	17.9	3.8
2	12.1	7.4	20.7	12.7
3	7.1	1.5	32.1	12.6
Contrasts^b				
0 vs 1 rotary hoeing	*	NS	**	**
1 vs 2 rotary hoeings	**	NS	NS	**
2 vs 3 rotary hoeings	NS	NS	NS	NS

^aTreatments with identical number of rotary hoeings averaged and compared to non-rotary hoed treatments.

^b** and * denote orthogonal contrasts significant at the 1 and 5% levels, respectively.

Table 14. Visual in-row weed control ratings taken before first row cultivation with conventional and reduced herbicide rates, rotary hoeing alone and combinations of herbicide and rotary hoeing.

Weeding system		In-row weed control rating ^a			
		ARS		LAC	
Rotary hoe ^b	Herbicide	1990	1991	1990	1991
Frequency		%			
0	Norm-broadcast ^c	98 a	84 ab	92 a	91 ab
0	Half-broadcast	95 a	76 bc	91 a	78 cd
1	"	97 a	86 ab	91 a	94 a
0	Norm-band	98 a	87 a	95 a	94 a
0	Half-band	97 a	70 c	95 a	80 bcd
1	"	98 a	85 ab	95 a	94 a
1	None	26 c	74 bc	75 b	69 d
2	"	29 c	83 abc	89 a	83 abc
3	"	78 b	83 abc	92 a	93 ab
0	"	0 d	0 d	0 c	0 e
Contrasts^d					
Herbicide -					
Normal- vs. half-rate		NS	**	NS	**
Half-rate herbicide -					
Alone vs. with a rotary hoeing		NS	*	NS	**
Herbicide - Normal-rate alone vs.					
half-rate with a rotary hoeing		NS	NS	NS	NS

^aMeans within a column followed by the same letter do not differ significantly at the 5% level of probability as determined by Fisher's protected LSD.

^bRotary hoeing at 7, 14 and 21 days after planting in 1990 and at corn heights of -1, 2 and 5 inches in 1991.

^cNormal herb. rate = 1.6 and 2.0 lb A⁻¹ atrazine and metolachlor, respectively.

^d** and * denote orthogonal contrasts significant at the 1 and 5% levels, respectively.

Predominant weeds at ARS were common lambsquarters (*Chenopodium album* L.) and redroot pigweed (*Amaranthus retroflexus* L.) in the non-herbicide plots and velvetleaf (*Abutilon theophrasti* Medic.) in the herbicide treated plots, while at LAC, giant foxtail (*Setaria faberi* Herrm.) predominated. Over all trials, weed control was generally 1) >90% in the integrated herbicide-mechanical treatments, 2) 80-90% in treatments with broadcast normal-rate Bicep alone or with no herbicide and three rotary hoeings, and 3) <80% with

half-rate Bicep alone or mechanical only treatments with one or two rotary hoeings (Table 15). Weed control was good (86%) with two rotary hoeings and fair (78%) with one rotary hoeing when averaging only the three trials rotary-hoed in a timely manner.

Although weed ratings were generally lower for mechanical weeding treatments, the yields were nearly equal to those of integrated systems. Results indicated no yield advantage to cultivating when using broadcast herbicide at the normal rate even though weed control improved slightly. Corn treated with a half-rate broadcast herbicide, without cultivation yielded equal to corn receiving normal-rate broadcast herbicide, but a single cultivation is recommended to control escaped weeds and to achieve a more integrated control program. Applying herbicide in 15-inch bands at normal or half-rates, followed by two cultivations produced maximum yields. If rainfall is limiting after application, a rotary hoeing may be advisable for the half-rate applications. Without herbicide, three rotary hoeings and two cultivations produced yields equal to those with normal rates of herbicide. With ideal early-season corn growing conditions and in fields with low weed pressure, two rotary hoeings may be sufficient.

Table 15. Effects of conventional and reduced herbicide rates and mechanical weeding alone and in combinations with herbicide on in-row weed control and corn yield at Arlington and Walworth County in 1990 and 1991.

Weeding system			Visual in-row weed control ^a				Corn yield			
Rotary hoeing ^b	Row-culti. ^c	Herbicide application	ARS		LAC		ARS		LAC	
			1990 ^d	1991	1990	1991	1990	1991	1990	1991
Frequency			%				bu/a			
0	0	Norm-broadcast ^e	95 a	91 bcd	95 ab	69 bcd	166 a	195 a	161 ab	131 ab
0	1	"	99 a	98 a	97 a	90 ab	164 a	184 a	166 ab	150 ab
0	0	Half-broadcast	82 bc	84 e	90 ab	49 cde	163 a	183 a	156 abc	123 b
0	1	"	97 a	97 a	93 ab	71 bcd	154 a	190 a	153 abc	133 ab
0	2	"	96 ab	97 a	97 a	83 ab	158 a	186 a	151 abc	161 a
1	2	"	96 ab	98 a	92 ab	92 a	155 a	198 a	137 c	149 ab
0	2	Norm-band	98 a	98 a	91 ab	94 a	161 a	194 a	150 abc	122 b
0	3	"	98 a	98 a	95 ab	82 abc	162 a	195 a	156 abc	144 ab
0	2	Half-band	97 a	97 a	85 abc	63 b-e	156 a	203 a	151 abc	121 b
0	3	"	97 a	98 a	92 ab	83 ab	171 a	196 a	169 ab	148 ab
1	2	"	97 a	98 a	91 ab	89 ab	160 a	200 a	146 bc	133 ab
1	2	None	34 d	88 d	73 c	71 bcd	114 b	176 a	141 bc	128 ab
1	3	"	24 de	89 cd	85 abc	64 b-e	109 b	197 a	139 bc	143 ab
2	2	"	19 e	95 ab	87 ab	83 ab	98 b	195 a	159 ab	146 ab
2	3	"	28 de	93 bc	83 bc	77 a-d	110 b	193 a	140 bc	147 ab
3	2	"	76 c	91 bcd	87 ab	87 ab	151 a	202 a	152 abc	162 a
0	0	"	0 f	0 f	0 d	0 f	80 b	134 b	138 c	50 c

^aVisual comparison to check at 90 days after planting.

^bRotary hoeing at 7, 14 and 21 days after planting in 1990 and at corn heights of -1, 2 and 5 inches in 1991.

^cCultivation at corn height of 10 in if a single cultivation, 5 and 20 in if a double cultivation without rotary hoeing, 10 and 20 in if a double cultivation following a rotary hoeing and 5, 10 and 20 in if a triple cultivation.

^dMeans within a column followed by the same letter do not differ significantly at the 5% level of probability as determined by Fisher's protected LSD.

^eNormal herbicide rate = 1.6 and 2.0 lb A⁻¹ atrazine and metolachlor, respectively.

Experiment 2. Reduced Input Corn Weed Control: The Effects of Planting Date, Early Season Weed Control, and Cultivator Selection

Materials and Methods

This study conducted at the Arlington Research Station, was a two-year, three-factorial randomized complete block design with three replications. Factors were four cultivator types (S-tine², no-till³, rolling⁴, C-shank⁵, plus a non-cultivated comparison), three planting dates (April 25, May 5 and May 15) and two methods of early season weed control (a 10-inch band of herbicide or two rotary hoeings). The early corn plantings followed the spring field cultivation while at the May 5 and May 15 planting dates, soil was also disked the day of planting. In 1991, planter malfunction resulted in low plant populations for the early planting. Plot size was 10 ft (four 30-in rows) by 40 ft.

The plots with a 10-inch herbicide band received a premix of atrazine and metolachlor formulated as Bicep 6L immediately after planting. Rotary hoeing was done at 7 and 14 days after planting in 1990 and when corn shoots were 1 inch below the soil surface and when corn was 2 inches tall in 1991 (14 and 20, 6 and 14, and 8 and 12 days after planting, respectively for the three planting dates). Cultivations were done when corn was 5 and 20 inches tall (standing height of youngest horizontal leaf). All cultivators were rear-mounted two-row units. Cultivation speeds were 4.5, 4.5, 6.0, 3.0, and 5.0, 5.5, 5.0, 6.0 MPH for the S-tine, no-till, rolling and C-shank cultivators for the first and second cultivations, respectively.

The predominant weeds both years were common lambsquarters and redroot pigweed in the non-herbicide treatments while velvetleaf was the main weed escaping the herbicide treatment. Corn and weed growth varied between years and by planting date.

Early corn growth rate was faster in 1991 than 1990 (130 and 70% of normal May growing degree days, respectively). In both years, growth rate differences were greater between April 25 and May 5 plantings than between May 5 and 10 plantings. In 1991, corn planted at these two dates reached the 5-inch height at 29 and 18 days after planting, respectively. In 1991, corn planted in April 25 and May 5 reached the 20-inch height the same calendar date, 46 and 34 days after planting, respectively, highlighting that later-planted corn grows more rapidly than early-planted corn.

In 1990, when rotary hoeing was timed by days after planting, greatest stand reduction occurred with the earliest planting, while in 1991 rotary hoeing was timed by corn height and stand reduction was more uniform over planting dates (Table 16). Row cultivation reduced corn stand an average of 1.2 and 2.5% for the first and second row cultivations, respectively. The rolling cultivator did not reduce stand at the first cultivation since it moved soil away from the corn plants. Combining data from both years, all cultivators reduced stands similarly in the second row cultivation (data not presented).

² Dakon, Tebben Mfg. Co. Inc., Clara City, MN 56222

³ Buffalo, Fleischer Mfg. Inc., Columbus, NE 68602

⁴ Bush Hog-Lilliston, Selma, AL 36702

⁵ Manufacturer unknown

Table 16. Corn stand reduction by two rotary hoeings for three planting dates in 1990 and 1991.

Planting date	Year	
	1990	1991
	--- population reduction (%) ---	
April 25	8.7	4.5
May 5	3.5	6.1
May 15	-.6	5.2
LSD (0.05)	5.4	NS

In both years, the rolling cultivator left significantly more in-row weeds after the first cultivation than the other cultivators, but all cultivators adequately controlled between-row weeds (Table 17). Early season weed control with banded herbicide reduced in-row weed density more than rotary hoeing in 1990 and 1991 (Fig. 6). Effectiveness of rotary hoeing improved in 1991 by changing the rotary hoe timing method. In both years for rotary hoeing and in 1991 with banded herbicide, weed populations were lowest when planting was delayed. This probably reflects the weed seedling mortality by the additional tillage pass for the later plantings.

Table 17. In- and between-row weed density one week after first row cultivation for four cultivators, three planting dates and two methods of early weed control in 1990 and 1991.

Cultivator	In-row weeds		Between-row weeds	
	1990	1991	1990	1991
	----- (weeds sq ft ⁻¹) -----			
S-tine	1.0	0.6	0.3	0.2
No-till	1.1	0.7	0.3	0.1
Rolling	3.0	1.0	0.2	0.0
C-shank	0.9	0.6	0.6	0.3
No cult.	3.0	1.8	5.3	3.9
LSD (0.05)	1.1	0.3	1.0	0.4

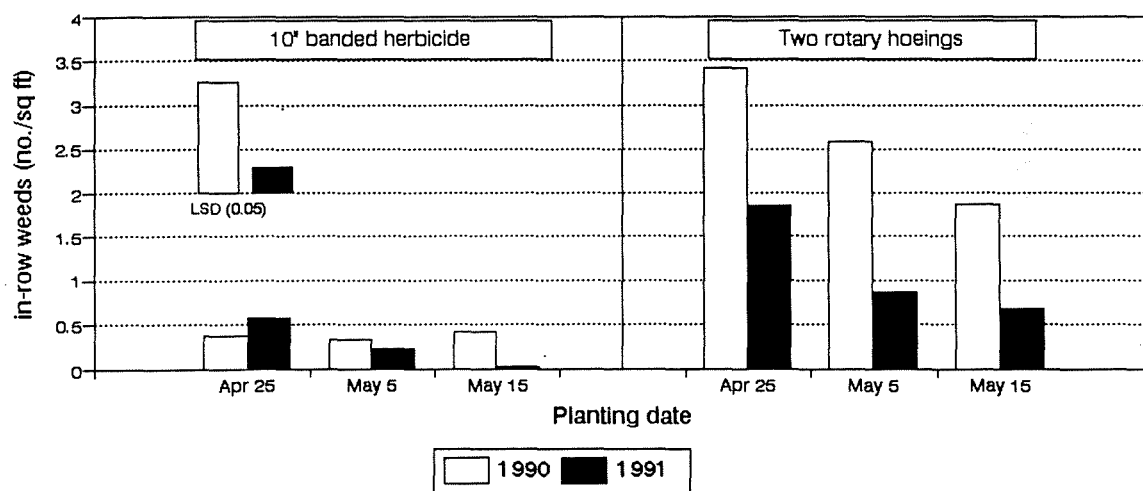


Figure 6. In-row weed density one week after the first row cultivation for three planting dates and two methods of early season weed control averaged for four cultivators.

In-row weed density decreased significantly in the non-cultivated treatments when planting was delayed from April 25 to May 5 in 1991, and when using banded herbicide versus two rotary hoeings (Table 18). Both rotary hoeing and delayed planting reduced between-row weeds in 1991 while in 1990 neither strategy was successful. Rotary hoeing at fixed times in 1990 was not effective. May 1990 was very cool and the additional tillage for the delayed plantings apparently killed fewer weeds under these conditions.

Table 18. In- and between-row weed density without cultivation at 7-inch corn height for three planting dates and two methods of early weed control in 1990 and 1991.

Planting date	In-row density		Between-row density	
	1990	1991	1990	1991
	(weeds sq ft ⁻¹)			
April 25	3.8	2.9	6.2	5.1
May 5	2.7	1.2	6.3	4.2
May 15	2.6	1.2	3.4	2.4
LSD (0.05)	NS	1.0	NS	1.5
<u>Early weeding</u>				
Banding	0.6	1.0	4.0	5.4
Rotary hoe	5.4	2.5	6.6	2.4
LSD (0.05)	2.0	0.8	NS	1.2

Visual weed ratings in 1990 show that the rolling cultivator, by not moving soil toward the corn plants at the first cultivation, controlled fewer in-row weeds than the other cultivators (Table 19). Averaged over years, the no-till gave better weed control than the rolling cultivator. Banded herbicide provided excellent (>90%) in-row weed control for all planting dates both years (Fig. 7). For all planting dates, in-row weed control with banded herbicide was more consistent and superior to that with two rotary hoeings. Weed control with two rotary hoeings improved by delaying planting from April 25 to May 5 both years and improved further by delaying planting until May 15 in 1991.

Table 19. Visual in-row weed control ratings and corn yield for four cultivator types in 1990 and 1991.

Row-cultivator	In-row weed control			Corn yield		
	1990	1991	average	1990	1991	average
	----- (%) -----			----- (bu A ⁻¹) -----		
S-tine	89 ¹	89	89	163	182 ²	172
No-till	91	91	91	157	191	174
Rolling	85	90	87	158	197	177
C-shank	92	89	90	162	185	173
LSD (0.05)	3	NS	2	NS	10	NS

¹ Ratings taken at 90 days after planting.

² Yields adjusted to compensate for low plant population of 1991 late April planting.

In 1991, corn cultivated with the rolling cultivator yielded significantly more than corn cultivated with the S-tine or C-shank cultivators, but averaged over years, yields were similar for all cultivators (Table 19). In 1990, corn planted on April 25 and May 5, treated with banded herbicide and cultivated produced highest yields (Fig. 8). Planting date did not affect yield of rotary hoed corn in 1990, while delaying planting until mid May reduced yields for the corn with banded herbicide. Because yields of corn planted in late April

1991 were severely reduced by low plant stand, we adjusted yields based on the method developed by Carter (1986) for Wisconsin. Warm weather in 1991 promoted fast, early corn growth and gave corn an advantage over weeds. Corn yields in 1991 were similar for the banded herbicide and rotary hoed treatments. Yields were highest for the April 25 and May 5 planted corn and were lowered by delaying planting until May 15. In 1991, yields of corn receiving banded herbicide were similar to yields in other corn planting date studies in Wisconsin: a slight yield decrease by delaying planting from April 25 to May 5, and a greater decrease when planting after May 10 (Carter, 1984; Imholte and Carter, 1987). In both years, for the rotary hoed corn, delaying planting from April 25 to May 5 did not decrease yield.

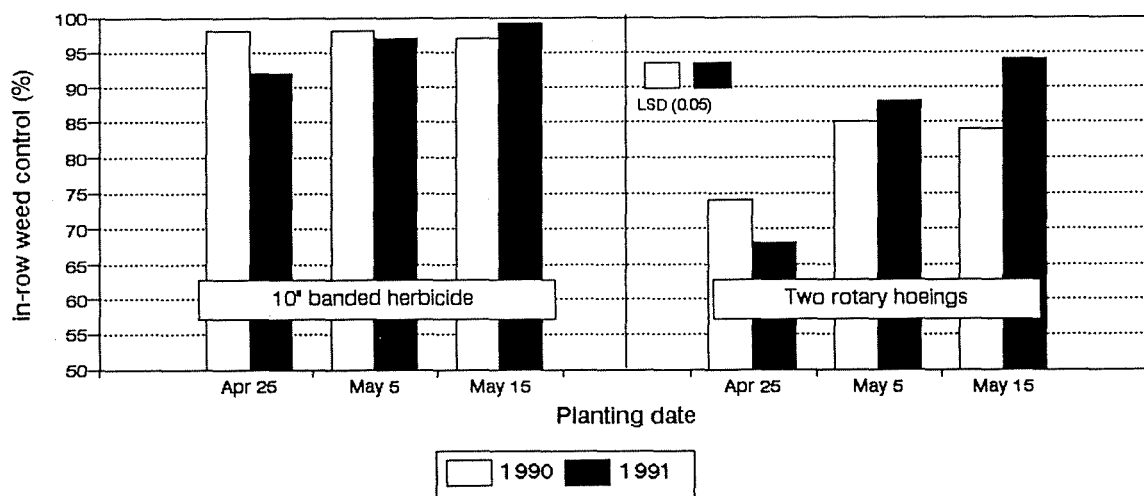


Figure 7. Visual in-row weed ratings for two years, three planting dates and two early weed control methods at 90 days after planting.

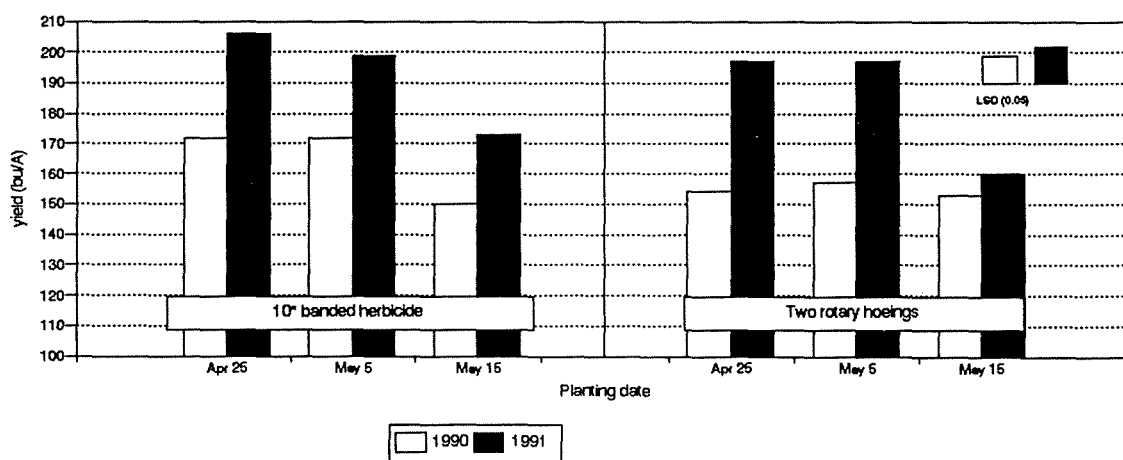


Figure 8. Corn yield for three planting dates and two early weed control methods in 1990 and 1991.

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C. The Influence of Wheel Wear, Design, Weight, Speed, and Frequency on Rotary Hoe Effectiveness

Thomas A. Mulder*

Herbicides are the primary weed control tool for corn in conventional cropping systems. Farmers who are attempting to grow crops without herbicides, use other methods, primarily mechanical, to control weeds. Many of the common midwest weeds are better adapted than corn to the cool early May temperatures that normally follow corn planting. If not controlled, these early weeds have the potential to drastically reduce corn plant growth and yield. The rotary hoe is a mechanical tool that is commonly used to destroy these early season weeds. This trial was designed to identify factors that influence rotary hoe effectiveness. Factors of interest were 1) wheel wear, 2) hoe design, 3) hoe weight, 4) speed of operation, 5) number of field passes per hoeing and 6) two rotary hoeings and two cultivations vs. three rotary hoeings and one cultivation.

This trial was designed to be part of a twilight extension demonstration highlighting weed control options. Ninety people attended this event which also included a row-cultivator with guidance system demonstration and a presentation on postemergence corn weed control options.

The trial location was the Arlington Research Station on a field of corn following corn that had been fall chisel plowed. Plots were 100 feet long and 2 rows (5 ft) wide with two replications. All hoes used were 15 ft (6 30-inch rows) and were operated at speeds of 6 and 11 MPH. A two wheel per shank John Deere⁶ hoe (Fig. 9) with very worn, worn and new wheels, on the shanks over the two left, center and right rows, respectively was used with or without 400 lb of weights added. A one wheel per shank Yetter⁷ hoe with new wheels, half set up normally (Fig. 10) and half for high residue (Fig. 11) was also used. A John Deere hoe with all worn wheels was used for the double hoeing which included a hoeing pass in each direction. The field was prepared with a field cultivator April 30 and again just prior to planting. Corn was planted at 32,100 seeds/acre on May 5. The area was rotary hoed when weeds roots were in the "white thread stage". The three hoeing dates were May 15, 21 and 30. Half of the trial area received the first two rotary hoeings and was cultivated with a danish-tine cultivator June 10 and July 6. The remaining trial area was hoed three times and was cultivated on July 6. Plant stand counts and visual weed control ratings were taken June 4 and 19 for the two and three rotary hoeing areas, respectively. Weed biomass was collected and final plant counts were taken July 20.

⁶ Deere and Company, Moline, IL 61265.

⁷ Yetter Mfg. Co., Colchester, IL 62326.

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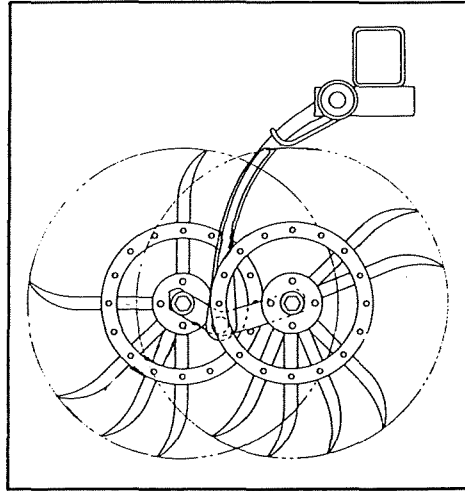


Figure 9. John Deere design with two wheels per spring tensioned shank



Figure 10. Yetter design with one wheel per spring tensioned shank

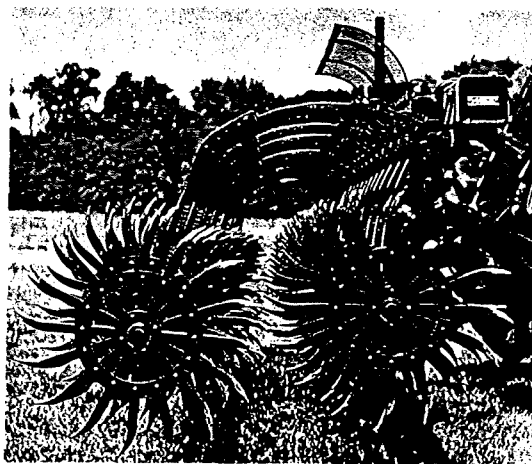


Figure 11. Yetter Min-Till design with alternating wheels moved back by shank extenders

Results

Soil condition and cooler than normal June weather were important factors that increased corn stand loss and slowed corn growth. Late April weather had been cool and wet and soil was wetter than desirable for tillage resulting in large soil clods which later became hard and dry. This poor soil condition may have slowed root establishment and the soil clods allowed deeper hoe penetration than under better conditions. Therefore corn stand reductions may have been higher than if soil conditions had been more favorable. The cool June temperatures (6% less GGD than the 30 yr average) were more conducive to weed than corn growth and many of the in-row weeds that survived the rotary hoeings were not destroyed by the row cultivations.

Corn stand was reduced an average of 12 percent by 2 rotary hoeings and the third hoeing did not significantly increase stand reduction. This, in agreement with our past research, shows that corn mortality by rotary hoeing decreases as the corn plant matures and its root system develops. Stand reduction was highest (16%) with a double pass or with new wheels and lowest (9%) with the worn or very worn wheels. Hoe weight, speed and design had no significant effect on stand reduction.

Conversely, weed control ratings increased as wheel wear decreased and if using the double pass. Average weed control ratings, collected before cultivation, were 82 percent. Ratings of 86, 82 and 75 percent for the new, worn and very worn wheels, respectively, were significantly different. Hoeing speed had no significant effect on weed control but control was increased by adding weight. Weed control by a double pass with worn wheels without added weights was similar to control with a single pass with new wheels. The single wheel per shank Yetter hoe was not significantly different from the weighted double wheel per shank John Deere hoe for weed control. Weed biomass weights also proved wheel wear to be the primary factor in rotary hoe effectiveness.

Weed control ratings less than 90 percent are unacceptable and normally decrease corn yields. In the period between last rotary hoeing and cultivation, cool weather slowed corn growth and weed control was even more unacceptable when corn reached cultivation height. The cultivations only controlled between-row weeds and in-row weeds severely decreased corn growth and yield. Corn yields were not collected.

Conclusions

Under these conditions wheel wear is the dominant factor for both weed control and corn stand loss by the rotary hoe. Treatments that gave best weed control also had highest corn stand loss. Hoe design, weight and speed had little effect on weed control or stand loss. Neither of the two combinations of rotary hoeing/cultivation satisfactorily controlled weeds. Since cool weather slowed corn growth, three rotary hoeings and two cultivations vs four rotary hoeings and one cultivation may have been more appropriate. The remaining challenge is to control early season weeds without significantly reducing corn population or stressing the young corn plants.

**V. Report on Grazing Heifers at Walworth during 1992 as a part of the
Wisconsin Integrated Cropping Systems Trial
Dan Undersander and Josh Posner***

Pastures of brome grass, Timothy and red clover were established in 1990 at both the Arlington Research Station (ARS) and the Lakeland Agricultural Complex (LAC). Winterkill was severe in pastures at Arlington and it was decided to reseed. Because of the drought and lack of growth from reseeding, no grazing trial was established at Arlington during 1992.

Fencing and water lines for pastures at both locations were built during the spring of 1992. Figure 12a and b shows paddock layout.

A grazing trial was established at the Lakeland Complex during 1992. Eight Holstein heifers were selected from the Walworth County herd with an average weight of 425 lbs. Cattle were weighed going onto pasture (May 1.) at 30-day intervals, and at the end of the season (October 14). Cattle were grazed intensively being allowed forage sufficient for either 3 or 4 days at 4% of body weight.

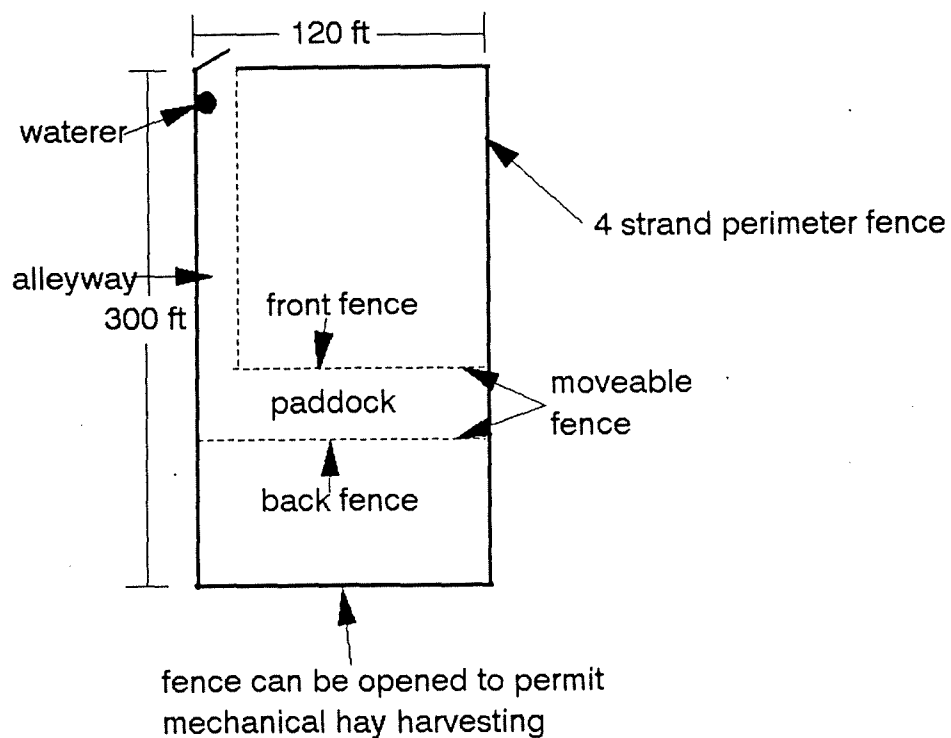
Hay was made from approximately half of pastures 1, 3, and 4 during the first week of June because it appeared that the heifers could not keep up with the spring flush of growth. Pasture 2 was judged to have less growth and no hay was made from it.

Due to low June rainfall (1.2 in), pastures 1,3, and 4 were depleted and the hay made early in the month was fed from the middle of June to the middle of July. All hay made from the pastures was fed back but no additional hay was fed to the cattle. Pasture 2 was able to keep grazing without additional feed during this time period.

Table 20 summarizes the forage available for the animals during the summer. Most of the time cattle were turned into pastures that had 1 to 1.5 tons dry matter/a forage available. This suggests that our stocking rate was low. We are considering using three heifers in 1993. The total seasonal yield for the pastures was estimated at (in order) 4.38, 4.47, 4.73 and 5.09 t/a dry matter. Total forage yield was excellent considering the shortage of moisture for a large portion of the season. Alfalfa hay plots in the same trial yielded 3.5 t dm/a on average. Figure 13 a,b,c summarizes the forage quality on the grazed plots and compares. Forage quality is compared to that of the three alfalfa harvests taken from Rotation 5 (the fourth cutting was ruined by rain and blown back onto the fields). Crude protein levels ranged from poor (13-14%) to good (19-20%), ADF was good (30-35%), and NDF was a bit high (45-55%). Data from the hay cuts (5/20; 6/30; 7/28) in rotation 5 (Tmt. 12) are superimposed on the figures as points of reference.

* Associate Professors, Dept. of Agronomy, Univ. of Wisconsin, Madison.

a. Lakeland Agricultural Complex



b. Arlington Research Station

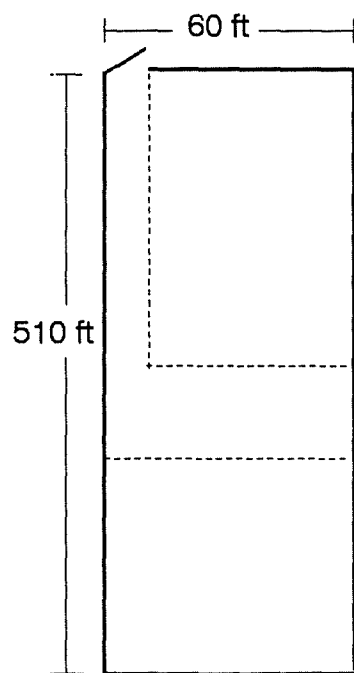


Figure 12. WICST rotational grazing pasture layout

Animal performance was excellent. Animals received no supplement beyond TM salt (and earlier harvested hay) during the entire season. Final weight averaged 804 lbs (table 21). Average daily gain of the animals was 2.27 lb/day which was slightly higher than desired but acceptable. The animal gain on the paddocks resulted in the production of 918 lb meat per acre for the season. Weight gain by 6 similar aged heifers under confined feeding management during the same period was 2.42 lb/day.

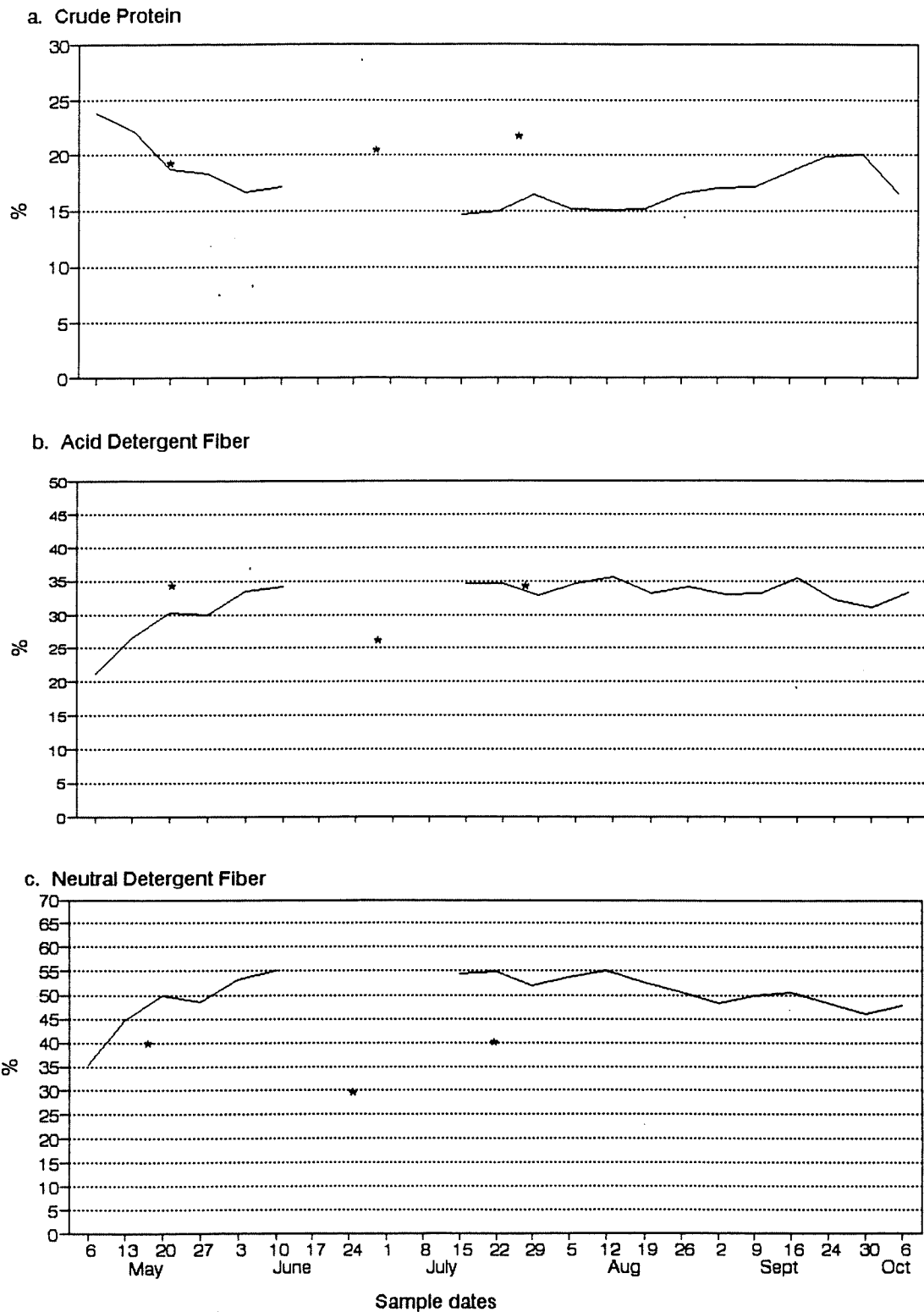
Table 20. Estimated Forage Availability on the Rotational Grazing Plots on WICST - Lakeland Agricultural Complex, 1992.

Date	Rep 1	Rep 2	Rep 3	Rep 4
	----- t DM/a -----			
06-May	0.28	0.32	0.32	0.53
13-May	1.01	0.75	0.68	0.89
20-May	1.22	0.75	1.23	1.50
27-May	1.47	1.36	1.11	1.29
03-Jun	1.37	1.08	1.25	1.35
10-Jun	1.56	1.52	0.60	0.58
18-Jun*	0.34	1.03	-	-
24-Jun*	-	0.83	-	-
01-Jul*	-	0.37	-	-
08-Jul*	-	0.93	-	-
15-Jul	0.96	0.59	0.85	0.69
22-Jul	0.99	0.65	1.46	0.95
05-Aug	1.34	0.77	1.23	1.11
29-Jul	1.67	1.17	1.56	1.63
12-Aug	1.41	1.57	1.43	1.62
19-Aug	1.36	1.15	1.51	1.28
26-Aug	1.42	0.91	1.09	1.00
02-Sep	0.97	1.42	1.00	1.53
09-Sep	1.12	1.25	1.26	1.05
17-Sep	1.04	1.29	0.98	0.84
24-Sep	0.84	0.67	0.76	0.85
30-Sep	0.85	0.81	0.77	0.71
06-Oct	0.38	0.69	0.51	0.69

* Animals on repetitions 1,3,and 4 were restricted to the alleyways and fed hay that had been harvested in early June from the same plots.

Table 21. Animal Performance on the Rotational Grazing Plots of WICST - Lakeland Agricultural Complex, 1992.

01-May - 14-Oct						
Pasture	AnimalNo.	Initial	Final	WtGain	ADG	Gain/Acre
		(lbs.)	(lbs.)	(lbs.)	(lbs./da)	(lbs.)
1	668	427.5	846	419	2.51	957.6
	674	417.5	790	373	2.23	
2	672	412.5	718	306	1.83	827.5
	665	440	818	378	2.26	
3	671	400	794	394	2.36	922.5
	667	440	808	368	2.20	
4	673	400	824	424	2.54	966.1
	664	460	834	374	2.24	
Ave.		425	804	379	2.27	918.4
StDev		21	40	37	0.22	63.5



* forage quality of harvested alfalfa (R5)

Figure 13. Rotational Grazing Pasture Production
Lakeland Agricultural Complex - 1992

VI. Fall Nitrate Monitoring Under Different Cropping Systems

T.K. Iragavarapu*, J.L. Posner**, L.G. Bundy**

Ground water pollution by agri-chemicals has been a major concern in the upper Midwest. Of all the potential ground water pollutants, nitrates (NO_3^-) are the most common in Wisconsin (WDATCP, 1989). The amount of inorganic N remaining in the soil profile following crop harvest is an important factor that reflects the "nitrate leaching" potential of a particular field situation (Magdoff, 1991). Higher amounts of NO_3^- -N may be found in the fall due to: a) poor soil structure or drought period affecting N uptake efficiency, and b) over fertilization due to overestimation of crop yield or failure to credit the N in manure or previous legume crops. Significant losses of accumulated NO_3^- could occur during late fall and early spring.

This study was aimed at measuring the amount of fall nitrates in the rooting zone as a performance criteria for environmental impact of different cropping systems common to southern Wisconsin. We developed the following nitrate monitoring hypotheses:

The annual hypotheses are:

H₁. Fall NO_3^- levels will be greater after cereals, intermediate after legumes and smaller under legume/cereal intercrops.

- a. $(\text{Corn}_{(R1)} + \text{Corn}_{(R2)} + \text{Corn}_{(R3)} + \text{Corn}_{(R4)} + \text{Corn}_{(R5)}) > (\text{Soybean}_{(R2)} + \text{Solo-seeded alfalfa}_{(R4)} + \text{Alfalfa hay I}_{(R4)} + \text{Alfalfa hay II}_{(R4)} + \text{Alfalfa hay II}_{(R5)})$
- b. $(\text{Soybean}_{(R2)} + \text{Solo-seeded alfalfa}_{(R4)} + \text{Alfalfa hay I}_{(R4)} + \text{Alfalfa hay II}_{(R4)} + \text{Alfalfa hay II}_{(R5)}) > (\text{Sb/W}_{(R3)} + \text{W/RC}_{(R3)} + \text{O/A}_{(R5)})$.

Fall NO_3^- levels should be greater under fertilized cereal phases of rotation compared to those of unfertilized legume phases. Intercropping should have lesser NO_3^- -N since no fertilizer N is added and the small grain should utilize some residual N.

H₂. Among corn phases, fall NO_3^- levels will be greater where total N credits (additions + credits) are greater.

- a. $\text{Corn}_{(R4)} > \text{Corn}_{(R5)}$
- b. $\text{Corn}_{(R1)} = \text{Corn}_{(R2)}$
- c. $\text{Corn}_{(R1)} = \text{Corn}_{(R2)} > \text{Corn}_{(R3)}$

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This hypothesis is based on the estimated total available N. Rotations 4 and 5 should have more fall $\text{NO}_3\text{-N}$ due to both legume and manure credits compared to the corn in cash grain rotations (R_1 , R_2 , and R_3).

H_3 . Among legume phases, fall NO_3^- will be greater after annual legumes, intermediate after seeding year legumes, and smaller under established hay plots.

a. $\text{Soybean}_{(R2)} > \text{Solo-seeded alfalfa}_{(R4)}$

b. $\text{Solo-seeded alfalfa}_{(R4)} > (\text{hay } I_{(R4)} + \text{hay } II_{(R4)} + \text{hay } I_{(R5)}) / 3$

Fall $\text{NO}_3\text{-N}$ should be greater under annual legume plots and smaller under seeding year and established alfalfa plots due to the scavenging ability of alfalfa.

H_4 . Among legume/cereal intercrops, there will be no difference in fall NO_3^- levels.

$$\text{Sb}/\text{W}_{(R3)} = \text{W}/\text{RC}_{(R3)} = \text{O}/\text{A}_{(R5)}$$

H_5 . Fall NO_3^- levels will be lower after a phase with a longer vigorous life cycle than one with a shorter life cycle due to small grains (wheat or oats) utilizing N.

$$\text{Sb}/\text{W}_{(R3)} < \text{Sb}_{(R2)} \text{ and } \text{O}/\text{A}_{(R5)} < \text{A}_{(R4)}$$

The system-wide hypotheses include:

H_6 . Fall $\text{NO}_3\text{-N}$ levels will be greater in cash grain systems than forage systems.

$$(R_1 + R_2 + R_3) / 3 > (R_4 + R_5 + R_6) / 3$$

Addition of N in the form of inorganic-N in the cash grain systems results in greater fall nitrate levels.

H_7 . Fall $\text{NO}_3\text{-N}$ levels will be greater in high-input systems than lower input systems.

$$(R_1 + R_4) / 2 > (R_2 + R_5) / 2 > (R_3 + R_6) / 2$$

High-input and output systems will have greater N losses compared to the low-input systems.

Methods

Nitrate samples were taken in 30-cm increments to a depth of 90 cm with a 3.8 cm diameter probe. Sampling took place in the fall, after the soil temperature dropped to 10°C , after the crop harvest, and in the next spring prior to planting (before the soil warms above 10°C). Five cores were taken per plot and bulked. Soil samples were also taken on adjacent idle land as a non-agricultural or "background" level check.

Results and Discussion

Fall nitrate levels

Fall $\text{NO}_3\text{-N}$ levels in the check plots were not included in the analysis of variance (ANOVA) procedure in all the three years.

1990: Fall $\text{NO}_3\text{-N}$ levels were not statistically different among the treatments at ARS. Although the corn yields at ARS and LAC were the same in 1990, corn plots at LAC had very high (222 kg/ha) amounts of fall $\text{NO}_3\text{-N}$ (Table 22). Corn plots had significantly greater amounts of fall $\text{NO}_3\text{-N}$ compared to other treatments at LAC.

The difference in the amounts of fall NO_3^- under the corn plots between the two sites could be due to greater amounts of inorganic N added at LAC and the short season (90-day) corn hybrid (Pioneer 3790) at LAC probably did not utilize all the N in 1990.

Although not included in the analysis, the amount of fall nitrates in the check plots at LAC were arithmetically similar to new seeding alfalfa plots. Drilled soybeans had twice as much nitrates compared to the check plots.

Combined analysis over the two locations in 1990 indicated that the location and treatment effects were not statistically different. However, the location x treatment interaction was significant. This is due to greater differences in the fall $\text{NO}_3\text{-N}$ among the treatments at LAC compared to ARS in 1990.

1991: At ARS, continuous corn plots had significantly greater amounts of $\text{NO}_3\text{-N}$ compared to all other treatments. Drilled soybeans had significantly greater amounts of fall NO_3^- compared to row beans plus wheat. Row beans, wheat/red clover, and hay year alfalfa were all on par.

At LAC, both the continuous corn and rotated corn plots had significantly greater amounts of fall $\text{NO}_3\text{-N}$ compared to all other non-fertilized treatments (Table 22). Drilled soybeans had significantly greater amounts of fall NO_3^- compared to row beans. Fall $\text{NO}_3\text{-N}$ levels under row soybeans and wheat/red clover were similar to the check plots. The seeding and first year alfalfa plots had more fall $\text{NO}_3\text{-N}$ due to heavy manure application coupled with poor hay yields.

Combined analysis in 1991 indicated that fall NO_3^- levels at the two locations were significantly different. In 1991, LAC had greater amounts of fall $\text{NO}_3\text{-N}$ compared to ARS (Table 22) under all the treatments, in large part due to poorer crop yields. However, heavy rainfall in September and October (290 mm) probably leached some NO_3^- below 1 m before sampling at ARS. Due to poor drainage conditions this excess rainfall in September and October (283 mm) at LAC may not have affected the profile $\text{NO}_3\text{-N}$ content as much. Furthermore, the very low LSD at ARS suggests that the profile was heavily leached in all the treatments prior to sampling.

The low measured soil $\text{NO}_3\text{-N}$ levels at ARS in 1991 therefore, are probably due to the leaching prior to sampling and not the better synchrony between N availability and uptake of the crop rotations at this site. The interaction between treatments and locations was also significant primarily due to the magnitude of the difference between the sites, not because the treatment rankings were different. Whereas, NO_3^- levels were 100 kg ha^{-1} greater under corn at LAC compared to ARS, they were only 30-35 kg ha^{-1} higher under soybeans, wheat and alfalfa plots.

Table 22. Fall nitrates in the 90 cm of the soil profile in 1990, 1991 and 1992 in the Wisconsin Integrated Cropping Systems Trial.

Crop	1990		1991		1992	
	ARS	LAC	ARS	LAC	ARS	LAC
----- kg/ha -----						
<u>Corn:</u>						
R ₁ . Corn	98	222	54	148	109	96
R ₂ . Corn after soybeans	--	--	46	140	118	87
R ₃ . Corn after red clover	--	--	--	--	75	70
R ₅ . Corn after alfalfa	--	--	--	--	113	87
<u>Soybean:</u>						
R ₂ . Narrow-row soybeans	87	62	47	85	83	96
R ₃ . Wide-row soybeans	84	55	28	38	74	71
<u>Wheat:</u>						
R ₃ . Wheat/red clover	--	--	29	55	54	50
<u>Alfalfa:</u>						
R ₄ . New seeding alfalfa	52	38	36	75	68	46
R ₄ . Alfalfa Hay I	--	--	30	80	55	61
R ₄ . Alfalfa Hay II	--	--	--	--	67	71
LSD (0.05)	NS	29	6	42	29	NS
Check	36	38	26	35	28	29

Combined Analysis over Locations

	1990	1991	1992
Location	NS	*	NS
Rep (Loc)	NS	NS	NS
Treatments	NS	NS	*
Loc x Treatment	*	*	NS

ARS=Arlington Research Station; LAC=Lakeland Agricultural Complex

NS = not significant

* = significant at 0.05 probability level

1992: Corn plots with added N (fertilizer or manure) had significantly greater amounts of fall NO₃-N compared to unfertilized corn in R₃ at ARS. The drilled soybeans had greater fall NO₃ compared to row beans plus wheat plots, although the difference was not statistically significant. The wheat/red clover and alfalfa plots had approximately double the fall nitrate levels of the check plots.

The treatments were not statistically different at LAC. Although the corn yields in 1992 were modest, fall NO_3^- levels were lower compared to the previous years. Also, the corn following red clover (R_3) had significantly lower yield, but the fall NO_3^- -N levels were equivalent among the four corn plots. Similar to ARS, the NO_3^- -N levels under wheat/red clover, seeding year alfalfa and first year hay plots were double those of the check plots.

Combined analysis in 1992 indicated that the treatments were significantly different; whereas, location and the location x treatment interaction were not significant. This non-significant interaction is due to the fact that the treatments behaved in a similar way at both the locations in this year.

Of particular interest in 1992 was a comparison of the four corn phases. Although corn following red clover in R_3 had significantly lower crop yield at both the sites, fall NO_3^- -N levels were not significantly different from the other three corn plots at LAC and only slightly lower at ARS. This suggests that cool summer temperatures in 1992 affected the N availability during the peak growing season (July-August), depressing corn yield. Mineralization from the residual organic N may have occurred late in the season after active N uptake by the crop had ceased. This explains how N may have limited corn yields during the season, yet large residual amounts of nitrates were found in the late fall.

Combined analysis (Table 23) was also done over the years (1991 & 1992) and locations on seven treatments to test our annual hypotheses (H_1 - H_6). Single degree of freedom comparisons were made for the available two years data. Corn plots had significantly greater amounts of fall NO_3^- compared to the legume plots (H_1 a). Fall NO_3^- levels were also greater under the legume plots compared to the intercrops (sb/w and w/rc) (H_1 b). Also, continuous corn (R_1) and rotated corn (R_2), which had equivalent "N-credits", also had similar amounts of fall NO_3^- -N. Due to the scavenging ability of alfalfa, fall NO_3^- -N levels were lower under solo-seeded alfalfa and established alfalfa compared to drilled soybeans (H_3 a and b). Among the intercropped phases (row beans/wheat and wheat/red clover), fall NO_3^- levels were similar (H_4). Drilled soybeans had significantly greater amounts of fall NO_3^- compared to row beans (H_5), indicating fall sown winter wheat may have utilized some residual N.

As the F-tests indicated, location x year interaction was significant. Heavy post-season rainfall in 1991 leached most of the nitrates by the sampling time at ARS, while these heavy rains did not affect the profile NO_3^- -N content at LAC due to the poor drainage conditions. However, in 1992, fall NO_3^- levels at ARS were greater than at LAC (Table 22) in all the treatments except drilled soybeans, which contributed to a significant year x location interaction. Non-significant interactions for year x treatment and location x treatment indicate that the treatments were consistent across the years and locations. However, higher order interaction (year x treatment x location) was significant, suggesting fall NO_3^- levels were greatly influenced by the type of the year and location.

In order to test the system-wide hypotheses, fall NO_3^- levels under R_1 and R_2 were compared in the fall of 1991 (Fig 14 a and b). The three cash grain rotations (R_1 , R_2 , and R_3) were compared by the end of 1992 (Fig 14 C and D). In order to calculate the fall NO_3^- levels in each rotation, the mean fall NO_3^- -N was taken from the soybean and corn phases in the soybean-corn rotation (R_2), and three phases in R_3 (sb/w, w/rc, c) in the fall of 1992.

Table 23. Fall nitrate levels in the top 90 cm depth at ARS and LAC in 1991 and 1992.

Crop	1991		1992		Mean
	ARS	LAC	ARS	LAC	
	----- kg ha ⁻¹ -----				
R ₁ Continuous corn	54	148	109	96	102
R ₂ Rotated corn	46	140	118	87	98
R ₂ Drilled beans	47	85	83	96	78
R ₃ Row beans	28	38	74	71	53
R ₃ Wheat/red clover	29	55	54	50	47
R ₄ New seeding alfalfa	36	75	68	46	56
R ₄ Alfalfa hay I	30	80	55	61	57
LSD (0.05)	6	44	31	36	--
Natural Check	26	35	28	29	30

	F-test
Years	*
Locations	**
Years x Locations	**
Reps (Loc x Year)	NS
Treatments	**
Years x Treatments	NS
Location x Treatments	NS
Year x Loc x Treatment	**

Contrasts:

H ₁ a. corn vs legumes	**
H ₁ b. legumes vs intercrops	**
H ₂ b. cont corn vs rotated corn	NS
H ₃ a. soybean vs solo-seeded alfalfa	**
H ₃ b. Soybean vs hay	**
H ₄ Sb/w vs w/rc	NS
H ₅ Sb vs sb/w	**

ARS = Arlington Research Station;

LAC = Lakeland Agricultural Complex;

NS = not significant

* = significant at 0.05 p level

** = significant at both 0.01 and 0.05 p level

As hypothesized (H_7), the system-wide analysis indicates that the high-input continuous corn (R_1) system has more fall NO_3^- compared to the medium-input soybean-corn rotation (R_2) at both sites in 1991 and 1992 (Figs 14 a-d). The low-input soybean-wheat/red clover-corn rotation (R_3) had the least amounts of fall NO_3^- compared to the other two systems in 1992 (Figs 14 c and d). However, the systems were not statistically significant in both the years.

Conclusions

Averaged over two years, profile NO_3^- ranking among the treatments was in the following order: continuous corn > rotated corn > drilled soybeans > hay I > seeding year alfalfa > row soybeans > wheat/red clover. Fall NO_3^- levels following legumes were significantly lower compared to that of corn. Fall nitrate levels were also lower under longer growth phases than shorter growth phases.

One year (1992) data suggests that irrespective of the source of N, fall NO_3^- levels were similar under corn in all three rotations.

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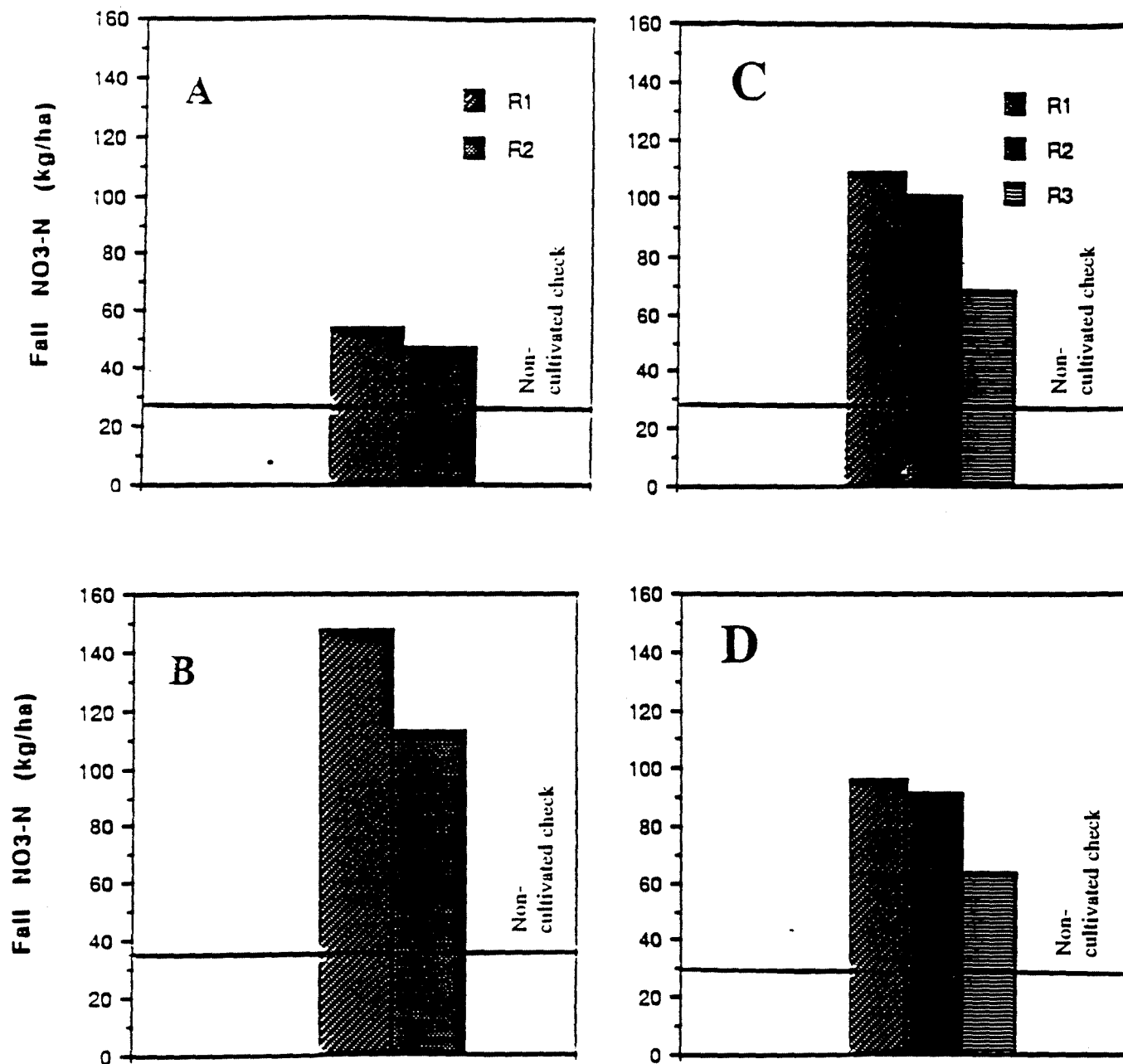


Figure 14. Comparison of Average Fall Nitrates in Continuous Corn (R_1) and Soybean-corn (R_2) Systems in 1991 at ARS (A) and LAC (B); and Comparison of Average Fall Nitrates in 1992 in Continuous Corn (R_1), Soybean-corn (R_2), and Soybean-wheat/Red clover (R_3) at ARS (C) and LAC (D).

VII. Phosphorus and Potassium Nutrient Budgets in Different Cropping Systems

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During the past 30 years, high-input systems have resulted in a build-up of soil fertility on many conventional farms. On the other hand, most scientists feel that low- or zero-input systems will simply mine the soil and ultimately reach an equilibrium at an uneconomically low yield level. As a result, it was decided to monitor soil fertility on the cropping systems trial. In this study, soil fertility status of the cropping systems was monitored at the beginning and after three years of cropping.

Objectives: To examine the effect of contrasting cropping systems on changes in soil test values of P and K.

The hypotheses are:

H₁) High-input systems will result in a build-up of available P and exchangeable K.

H₂) Low-input systems will result in a draw-down of soil P and K.

H₃) Forage systems with dependence on P and K from manure sources will result in cyclical changes in soil test P and K (R₄, R₅, and R₆).

Phosphorus and potassium management in soils can affect the profitability of crop production. Reducing the production costs while maintaining the crop yields are primary concern of crop producers (Voss, 1993). Judicial management may reduce the production costs by reducing or eliminating fertilizer P and K additions on fields that do not require additional amounts of these nutrients.

In the past two decades, farmers have applied phosphorus and potassium fertilizers in excess of crop removal expecting greater yields and profits. As a result, the available P and K have increased in many soils (Thomas, 1989). In testimony of these P and K fertilization practices, soil test results from the University of Wisconsin Soil Testing Laboratory (Table 24) show that the state average available P increased from 34 ppm in 1968-73 to 48 ppm (41% increase) during 1986-90. Similarly, the average soil test K value increased from 88 ppm during 1968-73 to 133 ppm (51 % increase) during 1986-90. These soil test values are far above the optimum soil test P (20 ppm) and K (105 ppm) requirement for a high-demanding crop like alfalfa (Schulte and Kelling, 1991).

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Table 24. Changes in state average soil test values with time.

Soil test	Summary Period				
	1968-73 [†]	1974-77 [†]	1978-81 [†]	1982-85 [†]	1986-90 [‡]
No. of samples	513,473	477,047	670,488	513,473	414,000
P (ppm)	34	37	40	44	48
K (ppm)	88	98	106	124	133

[†] Source: Schulte (1986)

[‡] Source: Combs and Bullington (1992)

Several researchers have reported the effect of long-term fertilization in a corn-soybean rotation on soil test P and K values. (Randall and Evans, 1992; Mallarino et al., 1991; Webb et al., 1992). In a 11-yr soybean-corn rotation study near Nashua, Iowa, with a soil testing 28 ppm P and 170 ppm K initially, the annual addition of either 22 or 45 kg ha⁻¹ yr⁻¹ of fertilizer P increased the soil test P by an average of 1.0 or 3.6 ppm/yr, respectively. The annual addition of 134 kg ha⁻¹ of K increased the soil test K by an average of 10 ppm/yr, while 67 kg ha⁻¹ of K did not change the soil test K. In an unfertilized treatment, the drop in the soil test values was only 1 and 8 ppm/yr for P and K, respectively. Except in two years of this 11-yr study, the corn and soybean yields in the unfertilized treatment were almost equal to the fertilized treatments. At Waseca, Minnesota, over a six-year period, the average drop in soil test P was 2.7 ppm/yr on an unfertilized soil testing 45 ppm initially (Randall and Evans, 1992).

Looking at the check plots of a 35-year fertility trial at Purdue, Barber, (1989) reported that a net removal of 13 kg ha⁻¹ of P resulted in a soil test drop of 1 ppm on high P (46 ppm) soils, while it took exportations of 50 kg ha⁻¹ of P to reduce the soil test P by 1 ppm on low P (15.5 ppm) soils.

Materials and Methods

a. Soil sampling density: Reed and Rigney (1947) indicated that 30 borings in a visually uniform field of two hectares would permit P and K determination within 10% of the true field average. Since the plots at ARS and LAC are 0.3 ha in size, five cores were bulked per plot. A 3.8 mm diameter probe was used to collect the soil samples.

b. Depth of sampling: Numerous authors have measured the importance of deeper roots (> 15 cm) in the nutrition of annual (Jankus, 1959; Taylor and Klepper, 1973), and perennial crops (Ogus and Fox, 1970; Peterson et al., 1983). As a result, it was decided to sample at several depths, i.e., 0-15, 15-30, 30-60, and 60-90 cm for available P and exchangeable K. Although not affecting the budget *per se*, the cycling of nutrients from deeper depths to the soil surface in plant residue (phyto cycling) is another reason to sample more than just the plow layer.

c. Frequency: Sampling for soil available P and exchangeable K took place at the beginning of each rotation and again at the end of the three growing seasons in each of the first five rotations. For example, by the fall of 1992, one cycle was completed in the soybean/wheat-wheat/red clover-corn (R_3) and oats/alfalfa-alfalfa-corn (R_5) rotation. Continuous corn (R_1) had completed three years, and in R_2 , two soybean phases and one corn phase were completed. In R_4 , the plots were sampled after three growing seasons of alfalfa. Rotation 6 was not sampled due to rotational grazing.

Chemical analysis: Soil available P and exchangeable K are 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).

Statistical analysis: Data were subject to analysis of variance using the statistical analysis system (SAS Institute, 1985).

Results and Discussion

Initial fertility: The initial fertility status of the two sites in 1990 was high (Table 25). The initial soil test values for P and K are well above the state average values in Table 24, and are typical of well managed fields. This is attributed to the rich silt loam loess that was deposited after glaciation, the high organic matter content of these prairie soils, and past fertilizer and manure applications. The initial soil available P and exchangeable K values were above the optimum soil test levels for Wisconsin (Schulte and Kelling, 1991). Therefore, no fertilizer additions of P and K were warranted at either of the sites. However, the forage rotations (R_4 , R_5 , and R_6) were manured at an average rate of 22.5 metric tons $\text{ha}^{-1} \text{yr}^{-1}$. The manure rates were based on the fact that typical dairy farms have approximately 20 metric tons $\text{ha}^{-1} \text{yr}^{-1}$ to spread on each tillable hectare. This assumes a 50-cow herd in confinement with replacements on 81 tillable hectares.

Table 25. Initial fertility status (0-15cm) at the two sites in 1990

Site	Soil type	Sub-soil group ¹	pH	Organic matter	Phosphorus (P)	Potassium (K)
				%	-----ppm-----	
ARS	Plano sil	B	6.8	4.5	89	237
LAC	Griswold sil	B	6.5	4.8	62	187
Optimum level ²					13	90

¹ Sub-soil group B has medium P and K nutrient supplying power, and a buffering capacity of 4 and 4.2 of P and K, respectively.

² Soils lower than this threshold soil test level will respond profitably to the added nutrients in 60% or more of the cases - (Schulte and Kelling, 1991)
 ARS= Arlington Research Station
 LAC= Lakeland Agricultural Complex

Soil testing: Soil samples were taken at the end of the third cropping season (1992) to determine the change in the soil available P and exchangeable K. The sampling depth and density are the same as described previously. A greater change in available P and exchangeable K was noticed at the higher testing ARS site compared to LAC.

In general, the variation among the treatment means was greater at ARS compared to LAC due to higher soil test values for P and K at this site. The draw-down (drop) was greater at ARS compared to LAC due to greater yields at ARS and probably some conversion from available to unavailable forms of P and K.

The initial soil test P and K values were statistically similar under the five rotations in 1990. At the end of the three cropping seasons, however, the soil test P differed statistically among the treatments in the 0-15 cm depth at ARS (Table 26). Rotation 5 had significantly greater soil test P values (103 ppm) compared to R₃ (69 ppm) and R₂ (79 ppm). This was probably due to no fertilizer or manure additions in R₃, and only starter fertilizer P additions in R₂. On the other hand, 34 metric tons ha⁻¹ of dairy manure was added twice (addition of 123 kg ha⁻¹ of P) to R₅ rotation. Soil test P did not differ statistically at any of the four depths at LAC. The soil test K was statistically similar at all four depths at both ARS and LAC.

Table 26. Comparison of soil test results (0-15 cm) between 1990 and 1992 at ARS and LAC

Rotation	<u>Arlington Research Station</u>			<u>Lakeland Agric. Complex</u>		
	Soil test (mg/kg)			Soil test (mg/kg)		
	1992	1990	Difference	1992	1990	Difference
----- phosphorus -----						
1. <u>C-C-C</u>	93	105	-12	58	66	-8
2. <u>Sb-C-Sb</u>	79	98	-19	52	59	-7
3. <u>Sb/W-W/RC-C</u>	69	105	-36	46	64	-18
4. <u>A-A-A-C</u>	94	115	-21	57	76	-19
5. <u>O/A-A-C</u>	103	110	-7	41	53	-12
LSD (0.05)	15	NS	--	NS	NS	
----- potassium -----						
1. <u>C-C-C</u>	219	257	-38	205	196	-9
2. <u>Sb-C-Sb</u>	239	199	+40	186	178	+8
3. <u>Sb/W-W/RC-C</u>	189	236	-47	173	195	-22
4. <u>A-A-A-C</u>	175	277	-102	186	216	-30
5. <u>O/A-A-C</u>	181	211	-30	161	163	-2
LSD(0.05)	NS	NS	--	NS	NS	

C=corn; Sb=soybean; W/rc=wheat/red clover; A=alfalfa; O/A=oats/alfalfa.
NS=not significant

Conclusions

The drop in soil test values for both P and K are somewhat faster in soybean-corn rotations than the values reported by Randall and Evans (1992), and Mallarino et al. (1991). The decrease in soil test values for P and K is probably faster in this study since the soils at the two sites are at an excessively high range for both P (58-108 ppm) and K (188-255 ppm). This faster rate of decrease is expected to continue until the soil test P and K reach optimum level (Mallarino et al., 1991). At this stage, there will be an equilibrium between removal of P and K by plants and conversion of unavailable forms of P and K to available forms.

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VIII. Study of Water Movement Through Soil using a Bromide Tracer

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Crop rotation study

Introduction: The preliminary leaching frame study conducted in the summer of 1990 on bare soil indicated that preferential flow is the dominant mechanism of downward movement of water and solutes. However, in this preliminary study the conditions were artificial i.e., plants were not growing, water was added very rapidly, and the soil profile was above field capacity throughout the season. It was decided in summer of 1991 to verify the findings of the 1990 leaching frame study under natural field conditions. The objective of this study was to determine the time for a surface-applied chemical to reach the groundwater in the presence of crops under field conditions.

Materials and Methods

Treatments: The five rotations that were compared are:

1) R_1 - Continuous corn, 2) R_2 - Soybean-corn, 3) R_3 - Soybean-wheat/red clover-corn, 4) R_4 - Alfalfa-alfalfa-alfalfa-corn, and 5) R_5 - Oats/alfalfa-alfalfa-corn. Bromide salt was surface-applied to the first phase of each of these five rotations, e.g., the soybean plots in R_2 (sb-c-sb), and the companion seeded alfalfa plots in R_3 (o/a-a-c). Corn was the previous year's crop for all the treatments. Pasture plots in R_6 were not included in this study since Br⁻ could affect the grazing animals' health.

Well installation: In early spring 1991, one monitoring well was installed in each of the five rotations (R_1, T_1), (R_2, T_3), (R_3, T_6), (R_4, T_6), and (R_5, T_{12}). Although not part of the Br⁻ study, wells were also installed in the pasture plots (R_6, T_{14}). Two check wells (4.0 m and 8.5 m deep) adjacent to the plots were also installed to monitor depth to ground water during the growing season. One check well was installed deeper than the other to determine the ground water pressure distribution. Wells were constructed using 38 mm i.d. PVC pipes. These PVC pipes have a 1.5 m screen at the bottom in the water. Wells were 4.0 m deep in the northern end of the field and 3.0 m deep in the south due to the proximity of the water table in the southern end of the field. Wells were kept covered 46 cm below the soil surface during the growing season to facilitate field operations and were brought to the soil surface during the remainder of the year. While buried, the top of the capped wells are covered with aluminum cans sitting on a metal plate surrounding the tube for protection while uncovering the wells.

Bromide application: On May 22, 1991, a one-time application of potassium bromide (KBr) salt was surface-applied uniformly to a 5m x 5m subplot surrounding the monitoring well at the rate of 300 kg ha⁻¹ (197 kg ha⁻¹ of Br⁻).

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Soil sampling: Soil sampling took place initially to determine background Br⁻ content in the soil and initial moisture content. Subsequent sampling took place on August 13, 1991 and again after the crops were harvested on November 16, 1991 to determine Br⁻ distribution under different crops. Soil samples were also collected the following spring (April 29, 1992) to determine over-winter changes in Br⁻ distribution in the soil profile. Eight cores were taken from each plot. Four cores were drawn to a depth of 100 cm in six increments (0-10,10-20,20-40,40-60,60-80, and 80-100cm), and the other four to a depth of 20 cm in 10 cm increments. Due to dry soil conditions in August, soil samples were collected only to 80 cm depth. All 32 samples were analyzed separately.

Ground water sampling: Wells were drained three times using a bail (0.6 cm i.d. x 61 cm ht) and allowed to recover to ensure that the water sampled was representative of surrounding water. Initial water samples were collected to determine background Br⁻ concentrations. Ground water samples were analyzed for Br⁻ at the UW-Plant and Soil Analysis Laboratory. Water samples were collected twice a year (spring and fall) during 1991 and 1992. Water samples were also analyzed for triazines and nitrates at the State Hygiene Laboratory.

Analytical methods:

Soil analysis: Bromide was determined using an Orion Model 94-35 electrode and a Model 90-01 single junction electrode (Onken et al., 1975).

Water analysis: Br⁻ concentrations in the water samples were quantified using high pressure liquid chromatography (HPLC) consisting of a Dionex QIC analyzer and a Spectra Physics 4270 Integrator.

Water samples for triazines were analyzed using Immuno Assay method in the spring of 1991, fall 1991, and spring of 1992. However, in the fall of 1992, water samples were analyzed using the Gas Chromatography method (Pittman, 1992) to detect various atrazine metabolites.

Results and Discussion

A monthly water balance for 1990, 1991, and 1992 were simulated using GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) developed by Leonard et al. (1987). These simulated values were compared to 25-yr average values. The values in Tables 27 and 28 indicate that at both sites, growing season ET values were approximately 10% greater than the 25-yr averages for the growing season (May-September) in 1990. However, in 1991 and 1992, the season was not as favorable for crop growth, and ET values averaged 10% below the long-term mean. These data would suggest that corn yields were lower in the latter two years (which they were) and that more residual nitrates would be available in the soil in the fall.

The 25-yr average values in Tables 27 and 28 also indicate that growing season percolation losses were generally low at both the sites. The model predicted leaching events during the growing season in May of 1990 and July of 1990 and 1992 at ARS. At LAC, May was wet in both 1990 and 1991, and leaching was predicted. Leaching during

Table 27. Measured rainfall and GLEAMS simulated ET and percolation under corn at Arlington Research Station in 1990, 1991 and 1992 compared to 25-yr (1965-1989) averages.

	growing season								
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	----- mm -----								
<u>Rainfall</u>									
25-yr average	114	96	79	96	89	103	114	64	53
1990	158	52	120	70	127	128	46	61	22
1991	148	132	53	74	83	67	112	92	114
1992	195	92	34	43	141	39	170	70	38
<u>Evapotranspiration</u>									
25-yr average	26	58	65	77	120	146	89	42	25
1990	44	56	83	81	134	157	104	46	30
1991	41	72	58	72	124	131	49	50	27
1992	37	66	59	50	118	152	95	51	27
<u>Percolation</u>									
25-yr average	0.4	11	7	12	5	0.2	10	2	4
1990	11	0	28	0	29	0	0	0	0
1991	0	0	0	0	0	0	0	0	24
1992	37	27	0.5	0	16	0	0	0	0

Values for December, Januray, and February months are not given due to frozen soil conditions

Table 28. Measured rainfall and GLEAMS simulated ET and percolation under corn at Lakeland Agricultural Complex in 1990, 1991 and 1992 compared to 25-yr (1965-1989) averages.

	growing season								
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	----- mm -----								
<u>Rainfall</u>									
25-yr average	135	176	83	102	106	110	97	74	63
1990	161	77	153	61	121	71	92	80	84
1991	100	126	80	50	35	103	53	152	98
1992	143	20	49	23	69	159	87	73	69
<u>Evapotranspiration</u>									
25-yr average	27	63	70	80	123	156	94	43	25
1990	50	61	89	84	143	157	96	38	31
1991	41	61	83	67	97	147	63	52	28
1992	48	41	54	40	99	153	106	52	28
<u>Percolation</u>									
25-yr average	2	53	14	16	13	3	6	5	7
1990	27	24	55	3	1	0	0	0	0
1991	0	0	11	0	0	0	0	0	14
1992	11	0	0	0	0	8	0	0	0

Values for December, January, and February months are not given due to frozen soil conditions

these periods could result in the downward movement of surface-applied chemicals and nitrates.

Post-season percolation losses were predicted to be small at ARS and greater at LAC. At both sites, heavy rains in the fall resulted in some estimated percolation in November, 1991. The model also predicted percolation in early spring of 1990 at LAC before the trial was initiated and during the same period at ARS in 1992.

Groundwater Analysis

Considerable fluctuation in the water table elevation was observed during 1991 and 1992 (Fig 15). The water table dropped from 0.5 m below the soil surface in May to 2.6 m below the soil surface in August, 1991 due to the dry weather coupled with high crop water demand. By December, the water table had risen to 1 m due to heavy post-season rainfall.

Bromide distribution in the soil (August, 1991)

A cumulative total of 170 mm of rainfall was recorded by the August sampling date after Br⁻ application. Similar to the leaching frame study in 1990, detectable amounts of Br⁻ were found to 80 cm in all the treatments in August.

Corn: Bromide remained concentrated in the top 20 cm of the soil profile (Fig 16a). The mean Br⁻ concentrations were 30, 8, 3, 3, and 3 mg kg⁻¹ at 5, 15, 30, 50, and 70 cm depths, respectively, with the CV for Br⁻ concentration of 83, 158, 157, 144, and 147 % at the five depths. Sporadic heavy rainfall in July and August at this location might have moved Br⁻ through the soil cracks. The high CV at all depths could be due to the channelization of Br⁻ in the soil profile.

Drilled soybeans: Similar to the other treatments, highest concentrations of Br⁻ remained in the top 30 cm of the profile under drilled soybeans (Fig 16b). The mean Br⁻ concentrations were 30, 32, 14, 12, and 15 mg kg⁻¹ at 5, 15, 30, 50, and 70 cm depths, respectively. The CV of Br⁻ concentration ranged from 89 to 156% on this sampling date.

Row soybeans: Bromide concentrations were low under wide-row soybeans compared to narrow-row soybeans (Fig 16c). The mean Br⁻ concentrations were 17, 15, 17, 12, and 9 mg kg⁻¹ at 5, 15, 30, 50, and 70 cm depths, respectively. The CV of Br⁻ concentration ranged from 97 to 130% at various depths.

Alfalfa: Similar to corn plots, Br⁻ was distributed over the entire profile, with the highest concentrations remaining in the top 30 cm of the profile (Fig 16d). The mean Br⁻ concentrations were 22, 20, 9, 7, and 7 mg kg⁻¹ at 5, 15, 30, 50, and 70 cm depth, respectively. The CVs for Br⁻ concentration ranged from 99 to 134%.

Oats/alfalfa: Oats/alfalfa had the highest concentrations of Br⁻ compared to the other four treatments over the entire profile on this sampling date. The mean Br⁻ concentrations were 42, 31, 26, 24, and 56 mg kg⁻¹ at 5, 15, 30, 50, and 70 cm depths, respectively. The CV of Br⁻ concentration ranged from 86 to 222%.

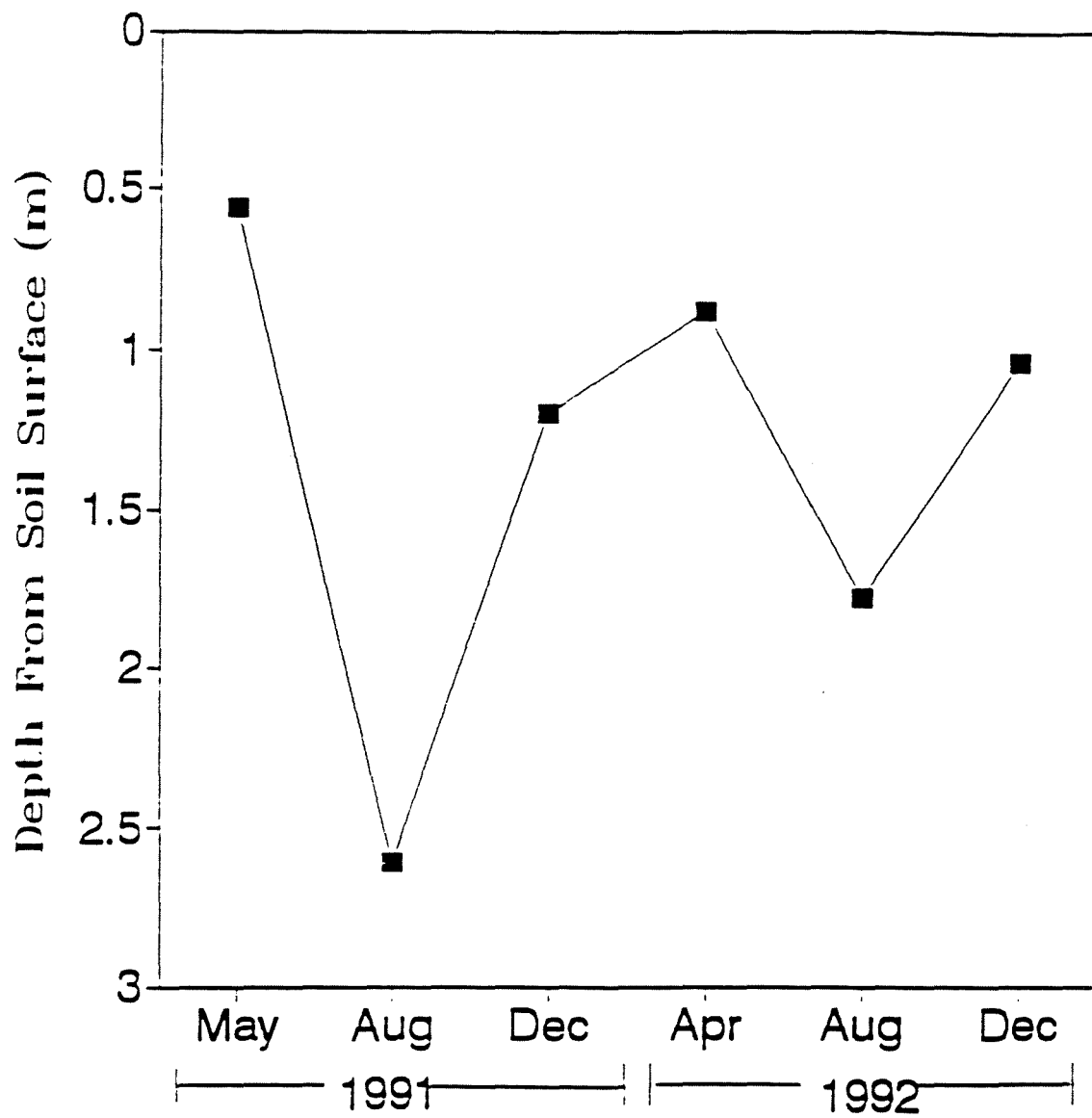


Figure 15. Water Table Elevation in the Check Wells at the Lakeland Agricultural Complex During 1991-1992.

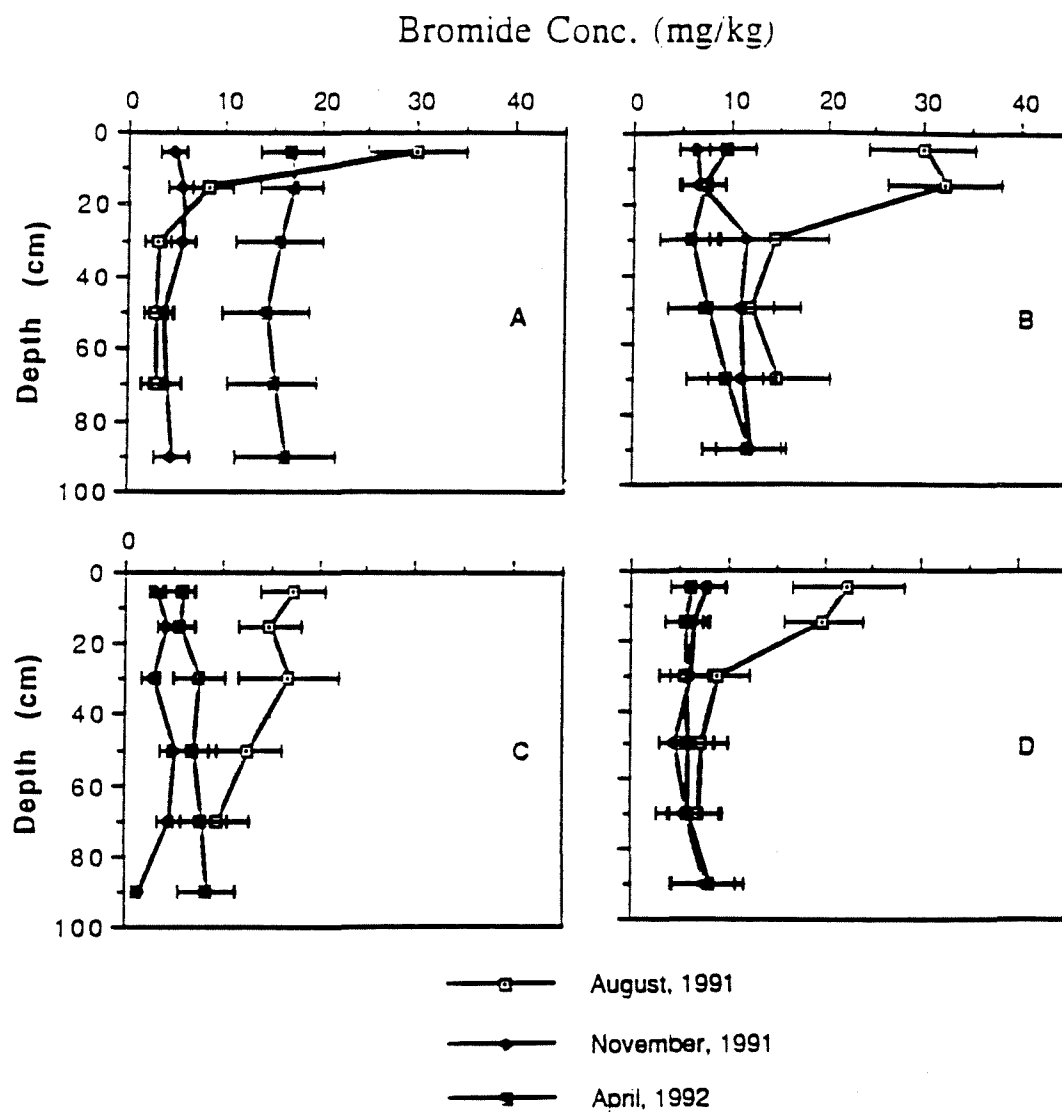


Figure 16. Bromide Distribution in the Soil Profile at Three Sampling Dates Under Different Crops: corn (A), drilled soybeans (B), row soybeans (C), and solo-seeded alfalfa (D). Horizontal lines indicate SE around the mean.

After Br⁻ application, there was no disturbance of the surface soil in corn, drilled soybeans and alfalfa plots. However, the row beans were rotary hoed and cultivated twice resulting in slightly smaller CVs compared to other treatments.

Bromide distribution in November, 1991

By November, Br⁻ concentration decreased markedly (Fig 16a-d) in the top 20 cm compared to the August sampling date under all the crops. Between the two sampling dates 303 mm of rainfall was received. In general, the CV of Br⁻ concentration was higher on this sampling date compared to August in all the treatments. These high CVs could be due to channelization of Br⁻ by November. Most of the Br⁻ had leached between August and November sampling dates under all crops. Heavy late-season rainfall in September and October might have leached Br⁻ deeper from the surface layers.

Bromide distribution in April, 1992

Little change in the Br⁻ content in the profile was noticed between Nov 17-April 29 (Fig 16a-d) in all the treatments except corn. This indicates that Br⁻ got distributed in the soil matrix and the moving water bypassed the soil matrix. Variations (CVs) similar to November sampling were noticed on this sampling date also.

Most of the Br⁻ leaching occurred between August and November sampling dates due to the heavy post-season rain received in September and October (284 mm). Little change in Br⁻ content between late fall (1991) and early spring of 1992 in the profile also indicates that the water moving through the profile did not leach Br⁻ and bypassed the bulk of the soil matrix.

Comparison with GLEAMS simulations

Field observations were compared with the GLEAMS simulations. The GLEAMS simulations were compared to Br⁻ leaching under corn since corn had the greatest percolation losses in a 12-year simulation study and also represents the worst case scenario. Daily precipitation, mean daily temperature, maximum and minimum temperature data for 1991 at LAC site were used for simulations. Simulations were run using rooting depths of 30, 45, and 60 cm to estimate how far Br⁻ would move by piston-type flow. According to GLEAMS simulations, Br⁻ should move only to 45 cm by September 22, and 60 cm by November 5, 1991 in the corn profile. However, Br⁻ was found to a depth of 80 cm under all the crops by the August sampling date. This disagreement between GLEAMS simulations and field observations provides another indication that Br⁻ did not move by piston-type flow as used in the GLEAMS model. The GLEAMS predicted percolation losses below 90 cm depth by November. Heavy post-season rains in September and October in 1991 brought the soil profile (1 m) to field capacity, and percolation losses could occur by piston-type flow. This indicates that Br⁻ could have moved beyond 1 m depth even by piston-type flow due to heavy post-season rainfall in 1991.

Ground water analysis

Background Br⁻ concentrations taken in May, 1991 were zero in all but one of the 16 wells tested. By December, however, Br⁻ was detected in all wells. Bromide concentration under solo-seeded alfalfa was 29.9 mg/L, and was significantly greater than the other four treatments (Fig 17). Earthworms were most abundant in this treatment (520 m⁻²). Bromide might have moved through these earthworm channels and ultimately to the ground water. Another possible explanation could be that Br⁻ moved preferentially through the root channels of the previous corn crop. The treatments did not differ in the Br⁻ concentrations on the April, 1992 sampling date. However, Br⁻ concentrations on this date were significantly lower in a paired T-test compared to those of December, 1991. In April, 1992, the five treatments did not differ statistically in the Br⁻ concentration. Bromide concentration decreased over time (Fig 17) in all the treatments due to dilution in the ground water.

When analyzed by Immuno Assay Method, atrazine levels in the groundwater were below the Enforcement Standard of 3.5 parts per billion in all the monitoring wells (Table 29). However, when the water samples were analyzed by the Gas Chromatography method for various atrazine metabolites, 12 out of 20 wells exceeded the Enforcement Standard (3.5 ppb). Nitrate + nitrite concentrations were above the safe limit (45 ppm) in six wells in May 91, and in three wells in December, 91, and April, 1992. Only one well exceeded the safe limit in December 1992 (Table 29).

Conclusions

By August, 1991 after only 170 mm of accumulated rainfall, bromide moved to a depth of 80 cm under all rotations.

The speed with which Br⁻ moved deep in the profile and ultimately to the ground water indicates that macropore flow is the dominant mechanism even under natural field conditions.

Surface-applied chemicals could reach ground water within one growing season irrespective of the cropping system under these field conditions.

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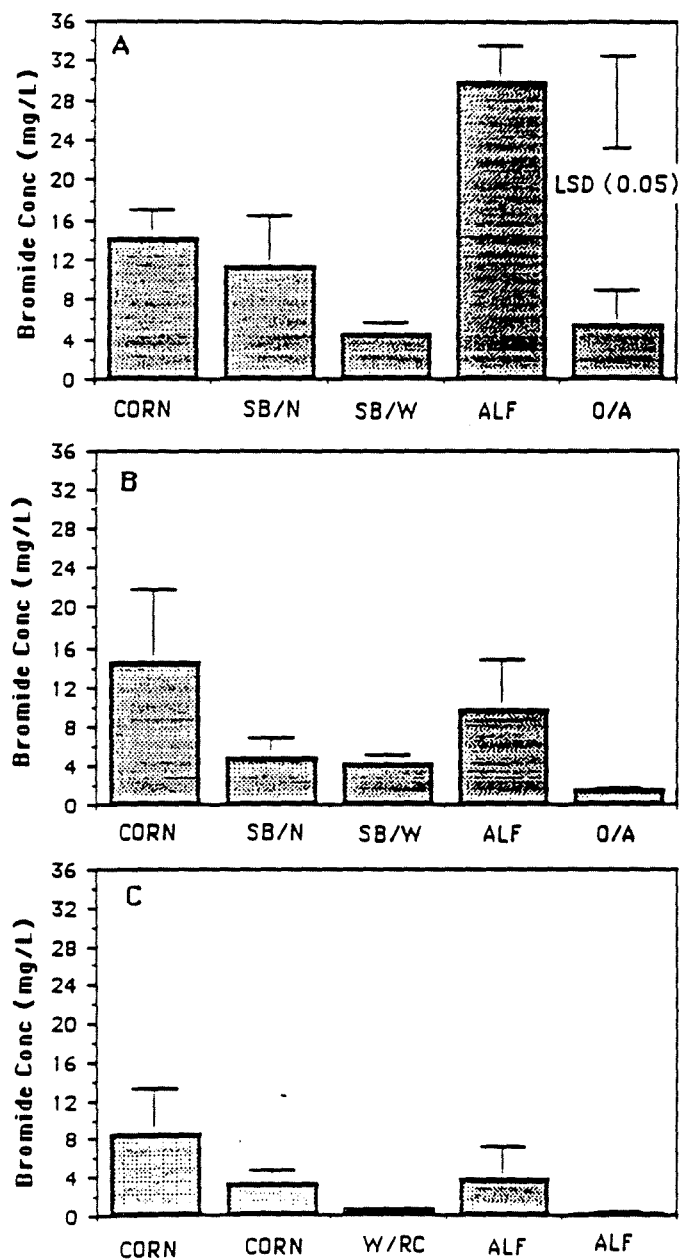


Figure 17. Bromide Concentration in the Monitoring Wells Under Different Crops at Three Sampling Dates: December 1991 (A), April, 1992 (B), and December, 1992 (C). Vertical lines indicate one-half SE around the mean.

Table 29. Atrazine and Nitrate concentrations in the monitoring wells at Lakeland Agricultural Complex in 1991 and 1992

Field Treat- ID	ment#	Well #	Triazine Concentration				Nitrite + Nitrate Concentrations			
			5/20/91 [†]	12/10/91 [†]	4/23/92 [†]	12/9/92 [‡]	5/20/91	12/10/91	4/23/92	12/9/92
			ppb				ppm			
101	1	EC361	0.4	1.3	0.7	10.3	80.8	41.5	40.2	39.7
210	1	EC371	0.1	0.4	0.2	3.6	52.8	48.5	46.1	44.2
303	1	EC373	0.1	1.9	0.6	1.7	34.9	21.3	38.5	36.4
<u>Mean</u>							<u>56.2</u>	<u>37.1</u>	<u>41.6</u>	<u>40.3</u>
108	2	EC365	0.2	0.5	0.3	7.9	70.8	60.5	55.9	47.8
203	2	EC367	0.3	0.4	0.2	7.6	11.4	14.0	26.0	20.0
304	2	EC374	0.1	0.4	0.2	4.7	12.8	20.1	28.1	20.1
<u>Mean</u>							<u>31.7</u>	<u>31.5</u>	<u>36.7</u>	<u>29.3</u>
111	6	EC366	0.3	0.3	0.3	11.3	60.8	43.8	9.1	18.4
208	6	EC369	0.2	0.5	0.4	11.7	37.3	28.6	14.9	38.4
306	6	EC376	0.1	0.3	0.2	4.7	28.8	42.3	9.4	23.8
<u>Mean</u>							<u>42.3</u>	<u>38.2</u>	<u>11.3</u>	<u>26.9</u>
102	8	EC362	0.2	0.3	0.1	0.5	38.7	15.1	12.5	4.84
209	8	EC370	0.4	0.5	0.3	4.5	48.8	6.8	14.9	14.4
305	8	EC375	0.1	0.2	0.2	1.8	34.8	10.3	8.5	5.73
<u>Mean</u>							<u>40.8</u>	<u>10.7</u>	<u>12.0</u>	<u>8.3</u>
105	12	EC364	0.1	0.2	0.1	1.2	16.5	15.4	21.8	10.8
207	12	EC368	0.2	0.3	0.3	5.2	69.6	49.7	3.9	38.7
309	12	EC377	0.1	0.2	0.1	2.7	11.9	7.3	56.1	8.34
<u>Mean</u>							<u>32.7</u>	<u>24.1</u>	<u>27.3</u>	<u>19.3</u>
104	14	EC363	0.1	0.3	0.2	5.4	24.7	21.3	2.8	21.4
213	14	EC372	--	0.2	0.1	1.3	--	2.2	29.6	2.84
314	14	EC378	--	0.2	0.2	5.5	--	63.2	--	30.0
<u>Mean</u>							<u>24.7</u>	<u>28.9</u>	<u>16.2</u>	<u>18.1</u>
1S [†]	-	EC379	--	0.1	0.1	0.2	--	31.1	2.8	2.07
1D [‡]	-	EC380	--	0.2	<DL	0.3	--	6.9	29.6	10.6

[†] Check well #1 13 feet deep| Located in the northern end of

[‡] Check well #2 28 feet deep| the field

DL = detection limit

Treatment codes in 1991:

1 = continuous corn (C-C-C)

2 = narrow-row soybean phase of soybean-corn-soybean (Sb-C) rotation

6 = Wide-row soybean phase of soybean-wheat/red clover-corn (Sb-W/rc-C) rotation

8 = Seeding year alfalfa phase in alfalfa-alfalfa-alfalfa-corn (A-A-A-C) rotation

12= Companion seeded alfalfa phase in oats/alfalfa-alfalfa-corn (O/A-A-C) rotation

14= Continuous pasture.

[†] Immuno Assay Method

[‡] Gas Chromatography method

IX. Cover Crop Research of the Wisconsin Integrated Cropping Systems Trial

J. Stute, J. Posner and E. Mallory

Midwestern cash grain production systems, typified by corn (*Zea mays* L.) grown in monoculture or in rotation with soybean (*Glycine max* L. merr), do not have the significant internal sources of N that livestock systems have (manure, legume forage stands), and hence require large amounts of N fertilizer (Heichel, 1987). In Wisconsin, corn is grown on 3.7 million acres, approximately 40% of the tillable acreage, and consumes 80% of the N fertilizer used in the state (WDATCP, 1990; WDATCP 1989). Objections to the heavy use of N fertilizer include both the tremendous amount of fossile energy used in its production (Keeney, 1982; Pimentel *et al.*, 1973), and the potential for negative environmental impact (Keeney, 1982).

The use of legume cover crops offers the potential for reducing the amount of N fertilizer used in corn cash grain production. To be successful, the cover crop must be integrated into systems without disrupting the rotation, and produce sufficient N to have a positive effect on the following corn crop. Most previous work on cover crop productivity in the upper Midwest has focused on spring seeding methods (Sheaffer *et al.* 1988; Groya and Sheaffer, 1985; Stickler and Johnson, 1959a, 1959b; Fribourg and Johnson, 1955), ignoring several other potential establishment timing opportunities. Research measuring the effect that legumes have on subsequent crops has focused on N contributions from older forage stands or annual forages. For these reasons, the full potential of the practice of cover cropping in cash grain systems is unknown. Since 1989, several satellite trials have been evaluating the practice of cover cropping, with the intent of reducing the amount of N fertilizer used in corn production.

A. Evaluation of Several Cover Crop Options for Wisconsin

The objective of this study was to screen a broad range of legume species for dry matter (DM) production in the seeding year, when seeded in several different establishment windows. Based on the finding of Fribourg and Johnson (1955), that a good correlation between herbage DM yield and total N yield exists, cover crop performance was evaluated solely on herbage DM yield. This allowed for the screening of a large number of species in several establishment windows.

Materials and Methods

Field studies were conducted in 1989 and 1990 at the University of Wisconsin Experimental Station near Arlington Wisconsin on a Plano silt loam soil. This trial consisted of five separate experiments.

- | | |
|---------------|---|
| Experiment 1: | Solo seeded in the spring (set-aside) |
| Experiment 2: | Companion seeded with oat (for grain) |
| Experiment 3: | Interseeded in corn at last cultivation |
| Experiment 4: | Sequentially seeded after canning pea harvest |
| Experiment 5: | Sequentially seeded after oat (grain) harvest |

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Each experiment represented a different establishment window in which nine forage legumes were screened. Treatments consisted of individual legume cover crops (Table 30).

The forage legumes were seeded at a rate of 50 viable seeds /ft² in 6 inch rows, using a precision plot seeder. All legume seed was treated with the appropriate *Rhizobium* species inoculum prior to planting. The primary crop in each establishment window was grown following University of Wisconsin Extension (UWEX) recommendations, using field scale equipment. Primary tillage for all experiments consisted of chisel plowing. Secondary tillage consisted of field cultivation and/or cultmulching in both years.

A completely randomized design with each treatment replicated three times was used in each experiment. Individual plots measured 6 feet wide and 10 feet long in 1989. Plot length was increased to 13 feet in 1990. Data were subjected to analysis of variance procedures using the Statistical Analysis System (SAS) computer programs. Analysis was done by year and combined over years. Differences among treatment means were compared using a protected Least Significant Difference Test (LSD) at the 0.05 level of significance.

Table 30. Cover crop species and varieties evaluated.

Species	Life Variety	cycle
Medium Red Clover (<i>Trifolium pratense</i> L.)	Arlington	Perennial
Mammoth Red Clover	common	Biennial
Alsike Clover (<i>Trifolium hybridum</i> L.)	common	Perennial
Ladino Clover (<i>Trifolium repens</i> L.)	common	Perennial
Nondormant Alfalfa (<i>Medicago sativa</i> L.)	Nitro	Perennial
Dormant Alfalfa	Wrangler	Perennial
Hairy Vetch (<i>Vicia villosa</i> Roth)	common	Annual
Biennial Sweetclover		
[<i>Melilotus officinalis</i> (L.) Lam]	Madrid	Biennial
Biennial Sweetclover	Yellow	Biennial
	Blossom	

Results and Discussion

Cover crop herbage DM yields, measured in the fall of the seeding year, are reported in Table 31. These values should be used as relative indicators of cover crop performance, not total DM production, because root DM yield was not measured. Related studies conducted at the same location (Stute and Posner, unpublished data) have shown that roughly 50% of the total seeding year DM production is contained in the herbage for biennial and perennial species (Table 30). On the other hand, hairy vetch herbage DM yield represents the majority of biomass production of this annual species. This should be considered when evaluating the yield data.

In general, good stands of all species were obtained in both years of this study. The resulting DM yields within each establishment window are the result of the adaptability of each species to that establishment window.

Table 31. Above ground cover crop dry matter yield at Arlington, 1989 and 1990 Experiments.

	<u>Experiment 1</u>			<u>Experiment 2</u>			<u>Experiment 3</u>			<u>Experiment 4</u>			<u>Experiment 5</u>		
	Solo Seeded in Spring (set aside)			Companion Seeded with Oat			Interseeded into Corn (last cult.)			Sequentially Seeded after Pea			Sequentially Seeded after Oat		
Legume	1989	1990	Mean	1989	1990	Mean	1989	1990	Mean	1989	1990	Mean	1989	1990	Mean
	ton/acre														
Medium Red Clover	0.82	1.91	1.37	0.41	0.51	0.46	0.00	0.36	0.18	0.67	0.82	0.74	0.64	0.70	0.67
Mammoth Red Colver	0.42	0.87	0.64	0.16	0.61	0.39	0.00	0.04	0.02	0.40	0.64	0.52	0.17	0.33	0.25
Alsike Clover	0.25	0.56	0.40	0.08	0.34	0.21	0.00	0.31	0.16	0.08	0.61	0.35	0.77	0.31	0.51
Ladino Clover	0.13	1.20	0.66	0.52	1.04	0.78	0.00	0.00	0.00	0.10	0.64	0.37	0.22	0.27	0.25
Nondormant Alfalfa	0.17	0.05	0.11	0.04	0.12	0.08	0.00	0.03	0.02	0.69	0.58	0.64	0.64	0.44	0.54
Dormant Alfalfa	0.17	0.56	0.37	0.07	0.07	0.07	0.00	0.00	0.00	0.70	0.55	0.63	0.51	0.22	0.73
Hairy Vetch	2.69	4.34	3.51	1.72	0.99	1.36	0.08	0.89	0.49	2.24	2.77	2.50	1.84	2.10	1.97
Biennial Sweetclover															
cv. Yellow Blossom	0.57	1.03	0.80	0.37	0.39	0.38	0.00	0.00	0.00	0.69	0.58	0.64	0.65	0.45	0.55
cv. Madrid	1.01	0.94	0.98	0.22	0.32	0.27	0.00	0.00	0.00	0.77	0.76	0.77	0.63	0.45	0.54
LSD(0.05)	0.40	1.09		0.38	0.64		NS	0.36		0.34	0.42		0.38	0.30	
Mean	0.69	1.27	0.98	0.40	0.49	0.44	0.01	0.18	0.09	0.70	0.88	0.79	0.68	0.59	0.64

Results of this study indicate that several establishment windows may be used to advantage for the production of cover crop biomass. In general, these results show that maximum dry matter yields are obtained in situations which offer the longest possible growing season, with the least amount of competition from other species. Averaged over cover crop species, highest herbage DM yields were obtained in the solo seeded establishment window, followed by the sequentially seeded establishments, after pea and oat respectively. Because these three establishment windows are free from crop competition, the length of the growing season is the major factor governing DM production. As a result, DM production declines as planting dates become progressively later in the season. Intercropping, as is the case with companion seeding with oat or interseeding into corn, produces competition between the cover crop and the primary crop, limiting DM yield. Because components of competition, such as light interception by the primary crop, were not measured in this study, it is not clear whether competition or the length of the growing season, is the major factor limiting DM production.

Solo seeding in the spring allows for the longest growing season. However, this study indicates that weed pressure, when herbicide is not used, is the major factor limiting dry matter production. Legumes which can tolerate clipping, such as medium red clover, or which are effective competitors, such as hairy vetch, produce good yields in this establishment window. Clipping (ASCS requirement for set-aside acreage) for weed control can greatly reduce sweetclover DM yields. Sweetclover would, however, be a viable option if clipping were not required (ie. outside of program) and weed pressure was light. The prevalence of the potato leafhopper in this region makes alfalfa a poor choice for this or any other establishment window. Although treatment for the insect would maximize alfalfa dry matter yields, the cost would offset the dollar value of the N accumulated, at current prices.

Companion seeding with a small grain allows for a long growing season, but offers a competitive environment for the cover crop. This study indicated that red and ladino clovers are best suited to this establishment window. Although hairy vetch produced high yields of dry matter in both years of the study, the potential for lodging and subsequent loss of grain yield makes using this species unwise. Low clipping, to maximize straw yield or to harvest lodged grain reduces sweetclover yields. Sweetclover would be a viable option, if clipping height at oat harvest was increased. In this situation, the grower would sacrifice some straw yield to maximize sweetclover yield.

Sequential seeding, following pea or small grain harvest, offers the potential for utilizing land which would normally sit idle until the following spring. This study indicated that weed pressure, volunteer oats and dry soil conditions after harvest were major constraints to cover crop growth. Hairy vetch proved to be a viable option however, while the other legumes were not competitive enough to produce substantial dry matter yields. In moderation, volunteer oats may actually increase the N input to the system. Competition for soil N between the oat and hairy vetch would force the legume to fix more N to meet its requirements, while the grass species would act as a nitrogen sponge, conserving the available mineral N.

Interseeding into corn at last cultivation is a potential method for integrating green manures into continuous corn production. Results from this study show that at recommended corn populations (27-32,000) this establishment window is not viable.

B. Legume Cover Crops as a Nitrogen Source for Corn in an Oat-Corn Rotation.

The objectives of this study were: 1) To identify the most productive cover crop species and planting method to be used with oat; 2) To measure the effect of cover crops on grain yield of the following corn crop; 3) To compare corn yields following a cover crop with those using fertilizer as the N source.

Materials and Methods

This satellite experiment evaluated the use of legume cover crops as a N source for corn in the context of a two-year oat/cover crop - corn rotation at the Arlington Research Station. In the oat phase of the rotation, oats were grown in combination with several cover crop options or followed by fallow. In the corn phase of the rotation, corn was grown following the cover crops with no additional N or following the oat/fallow treatment with several rates of added N. Corn was also grown continuously with the same rates of N as were applied to the rotated corn. The experimental design was a randomized complete block (RCB) with three replications. Individual plots measured 15 by 30 feet. Crop varieties and seeding rates are listed in Table 32.

Table 32. Crop variety and seeding rate.

Crop	Hybrid/ variety	Seeding rate (lb/acre)
<u>Cover Crops</u>		
Nondormant Alfalfa	Nitro	15
Dormant Alfalfa	Wrangler	15
Medium Red Clover	Arlington	10
Biennial Sweetclover	Yellow Blossom	10
Hairy Vetch	common	30
<u>Grain Crops</u>		
Oat	Centennial	75
Corn	Dekalb DK547	27700*

* Kernels/acre.

Phase 1

The legume cover crops were both companion seeded with oats and seeded after oat harvest (sequentially seeded). The legumes were inoculated with the appropriate *Rhizobium* spp. and seeded using a corrugated roller seeder. The sequentially seeded cover crop treatments were sown following a light disking. Weeds were controlled in the "fallow" plots by clipping. Cover crop biomass yields were measured following a killing frost. Herbage samples were taken by harvesting two random half meter square areas, one inch above the soil surface and were separated into legume and weed fractions. Root and

crown samples were taken by undercutting the cover crops to a depth of 10 inches, and removing the roots from a half meter square area. Biomass samples were dried at 140°F for 3 days, weighed, ground to pass through a 1mm screen and analyzed for N content using a Leco N determinator.

Phase 2

Corn was planted following spring tillage. Chisel plowing served both to kill the cover crop, and incorporate most of the residue. Weed control consisted of a standard PPI herbicide and cultivation. Rootworm insecticide was applied to the continuous corn treatments. Nitrogen fertilizer (as ammonium nitrate) was broadcasted at planting to the N fertilizer treatments at rates of 0, 40, 80, 120, 160, and 200 lb. N per acre. Phosphorus and potassium were not applied, due to excessively high soil test levels for these nutrients. Corn grain was harvested from two 30 foot rows using a plot combine, and yields were corrected to 15% moisture.

Results and Discussion

Phase 1

Seeding year N yields (tops and roots) are presented in Table 33. In general, two cover crop options: companion seeded red clover and sequentially seeded hairy vetch produced the highest seeding year N yields (Figure 18). On average, these two species produced a total of 120 lb N per acre by the fall of the seeding year. In addition, both are capable of producing a substantial amount of regrowth in the spring of the second year. Nitrogen yields of the other cover crops were limited by several factors. Stands of the companion seeded dormant and nondormant alfalfa were weakened by potato leafhopper (*Empoasca fabae* Harris) feeding. Yields of companion seeded sweetclover and hairy vetch were reduced by the removal of large amounts of herbage with the harvest of the oat crop, and slow subsequent regrowth. This phenomenon has been previously reported (Stickler and Johnson, 1959). While the companion seeded hairy vetch did not have a significant negative effect on oat yields (data not shown), its climbing growth habit made harvest difficult.

With the exception of the sweetclover and hairy vetch treatments, N yields of the sequentially seeded cover crops were generally the same or less than those of the companion seeded treatments, due primarily to the short growing period from oat harvest to a killing frost. The effect of seeding method was significant in all years, but no clear pattern was evident. Mean yields for the sequentially seeded treatments were higher than those of the companion seeded treatments in 1990 and 1991. Higher yields of the hairy vetch and sweetclover treatments in those years is primarily responsible for the effect.

Phase 2

Grain yields of corn following the cover crops without additional fertilizer N are presented in Table 34. In the combined analysis of variance, the effect of year was not significant. This was reflected by the similar experimental means for individual years. In all years, corn yields following a cover crop were significantly higher than those following the no cover crop (fallow)/0 N treatment.

Table 33. Total (tops and roots) nitrogen yields of cover crops in the seeding year.

Cover Crop	1989	1990	1991	1992
-----lb N/acre-----				
<u>Companion Seeded</u>				
Nondormant Alfalfa	55	77	36	55
Dormant Alfalfa	59	66	7	61
Red Clover	150	132	89	141
Sweetclover	98	62	2	26
Hairy Vetch	144	48	25	97
<u>Sequentially Seeded</u>				
Nondormant Alfalfa	49	78	52	8
Dormant Alfalfa	55	60	33	19
Red Clover	71	73	27	31
Sweetclover	72	82	89	24
Hairy Vetch	141	150	97	45
LSD (0.05)	48	22	28	29
<u>Mean-Companion Seeded</u>	101	77	32	76
<u>Mean-Sequentially Seeded</u>	78	89	60	25

Roots harvested to a depth of 10 inches.

Mean oat yields (bu./acre): 1989,64; 1990,111; 1991,63; 1992, 102.

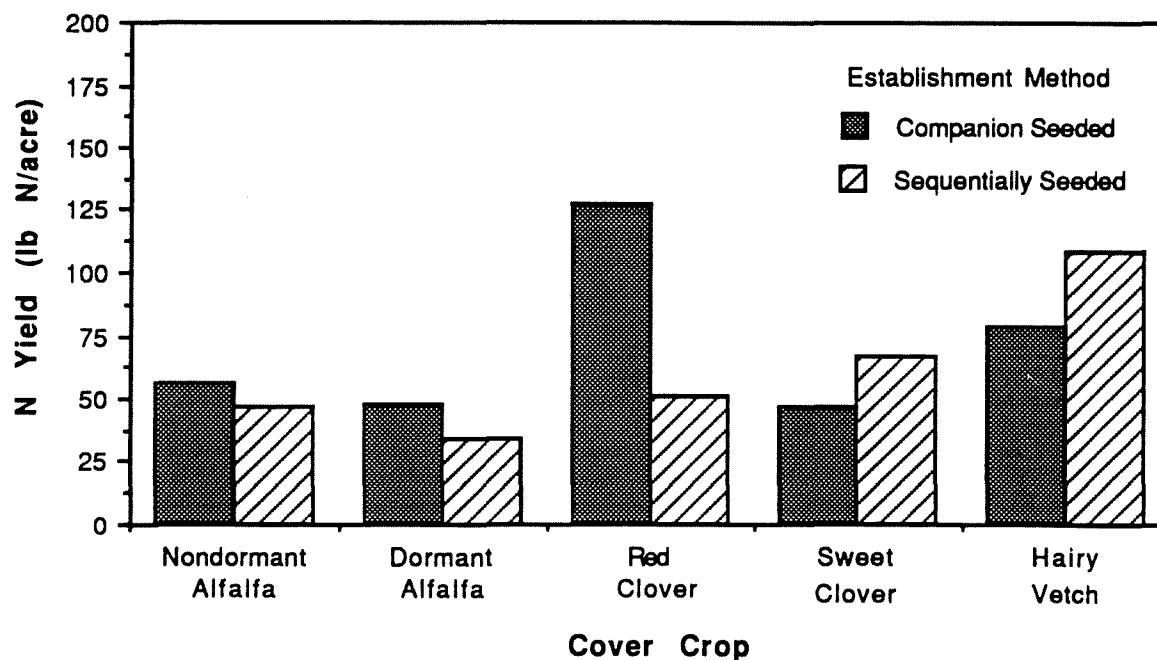


Figure 18. Mean cover crop N yields (tops and roots) at Arlington, 1989 to 1992.

Table 34. Corn grain yield following oats and a cover crop with no added N fertilizer.

Previous Cover Crop	1990	1991	1992
<u>Companion Seeded</u>	----- bu/acret -----		
Nondormant Alfalfa	162	165	167
Dormant Alfalfa	153	145	145
Red Clover	172	172	170
Sweetclover	161	156	151
Hairy Vetch	170	161	168
<u>Sequentially Seeded</u>			
Nondormant Alfalfa	181	170	175
Dormant Alfalfa	164	161	151
Medium Red Clover	157	156	156
Sweetclover	164	165	153
Hairy Vetch	162	188	178
No Cover	137	143	141
LSD (0.05)	19	19	NS
Cover Crop Mean	165	164	161
Contrasts:			
Cover vs. No Cover	**	**	*
Companion vs. Sequent. Seeded	NS	*	NS

*,** Significant at the 0.05 and 0.01 level of probability. NS Not significant. †Corn yield a 15% moisture.

This experiment was conducted on a plano silt loam soil with an average organic matter (SOM) content of 3.5 percent. Results of "top foot" $\text{NO}_3\text{-N}$ soil sampling, done at the six leaf stage of corn growth indicated that a response to additional N fertilizer was unlikely (Magdoff, 1991) for corn following any of the cover crops. This would indicate that in many instances, the soil was providing sufficient N to mask any treatment effect. For this reason, future cover crop work should be conducted on "poorer" soils, where the nutrient supplying capacity of SOM is much lower.

Grain yields of the fertilizer treatments were analyzed for response to incremental additions of fertilizer using regression. The best fit equations from this analysis were used to estimate the fertilizer replacement values (FRV) reported in Table 35. Fertilizer replacement value is defined as the amount of N fertilizer required to produce a corn yield for corn not following a cover crop which is equivalent to that produced following a cover crop. Fertilizer replacement values were estimated by rearranging the best fit equation and solving for N rate in terms of cover crop yield. The estimated FRVs for this experiment range from 0 to 162 lb N/ acre. Although these values indicate a large potential savings in fertilizer N, they may underestimate the actual value of the cover crop, due to a lack of fit of the regression equation and little yield response beyond 80 lb. N/ acre in the rotation corn. For this reason, the FRV should be used as a rough guide only.

While potentially underestimating the actual value of the cover crop, the FRVs do demonstrate the yield advantage for growing crops in rotation. The positive rotation effect can be seen by comparing the FRVs of corn grown in rotation with those of continuous corn (Table 35). In many cases, the yields following a cover crop were well above those obtained with the apparent optimum N rates in the continuous corn. In these situations, FRVs could not be estimated using the best fit equations. Where FRVs were estimatable in the continuous corn, they were around 100 lb./ acre (Table 35).

Table 35. Estimated fertilizer replacement values of cover crops for corn grown in rotation and corn grown continuously.

Previous Cover Crop	Corn in Rotation			Continuous corn	
	1990	1991	1992	1991	1992
	----- lb N/acre -----				
<u>Companion Seeded</u>					
Nondormant Alfalfa	66	56	90	*	*
Dormant Alfalfa	31	-	12	69	88
Red Clover	102	85	103	*	*
Sweetclover	57	21	27	114	102
Hairy Vetch	96	36	*	*	*
<u>Sequentially Seeded</u>					
Nondormant Alfalfa	133	79	162	*	*
Dormant Alfalfa	71	40	29	*	104
Red Clover	52	26	42	*	116
Sweetclover	69	58	36	*	111
Hairy Vetch	65	*	*	*	*
Mean	74	48	74	*	*

-FRV estimate below the zero fertilizer control.

*FRV estimate above prediction level with the fertilizer rates used (0-200 lb N/acre).

Summary

Using legume cover crops as green manures appears to be means for reducing the N fertilizer used in corn production. Medium red clover, companion seeded with oats and hairy vetch seeded after oat harvest are two promising cover crop options. On average, these two cover crops produced a total (tops and roots) of 120 lb N/ acre by the fall of the seeding year and both have potential for substantial regrowth in the spring. Corn grain yields following these cover crops averaged 174 bu/ acre, equivalent on average to yields produced with 65 to 103 lb N/ acre when corn was grown in rotation with oats. These yields were higher than those produced with 200 lb N/ acre in continuous corn. In addition to providing N, cover crops apparently increase corn yields by enhancing the positive rotation effect.

C. Corn Fertilizer Rates Following a Green Manure Plowdown

Introduction

Results from the oat-corn rotation study (study II) indicate that the two best treatments, companion seeded red clover and sequentially seeded hairy vetch, can contribute significant amounts of nitrogen to the following corn crop, thereby decreasing fertilizer needs. However, to attain optimum yields, it is possible that supplemental fertilizer nitrogen may be needed to "top up" the legume nitrogen. The objective of this study is to generate and compare nitrogen fertilizer response curves for continuous corn and corn in rotation following red clover and hairy vetch, and to use these curves to direct nitrogen management decisions.

Materials and Methods

The trial, located at the Lakeland Agricultural Complex, uses a split plot arrangement of treatments within a randomized complete block design to compare three different rotations (main plots) at six different nitrogen fertilizer rates (subplots). The treatments are listed in Table 36 and are replicated four times.

During phase 1, red clover was seeded simultaneously with the oats whereas, hairy vetch was planted following oat harvest with a no-till drill. Both of the legumes were inoculated with the appropriate *Rhizobium* spp. at seeding. Cover crop biomass and nitrogen yields were sampled and measured according to the methods outlined in study II, phase 1. Phase 2 materials and methods follow those described in study II, phase 2, except that corn grain was harvested from two rows 20 feet in length.

Table 36. Corn fertilizer rates following a green manure plowdown.

Rotation	<u>Treatments</u>			
	<u>Phase 1</u>		<u>Phase 2</u>	
	<u>Mainplot</u>	<u>Subplot</u>	<u>Mainplot</u>	<u>Subplot</u>
I	Corn	0 N 40 N 80 N 120 N 160 N 200 N	Corn	0 N 40 N 80 N 120 N 160 N 200 N
II	Oats/ Companion seeded Red Clover	*	Corn	0 N 40 N 80 N 120 N 160 N 200 N
III	Oats/ Sequentially seeded Hairy Vetch	*	Corn	0 N 40 N 80 N 120 N 160 N 200 N

* No subplots for these treatments in Phase 1.

Results and Discussion

Green manure biomass and nitrogen yields from 1991 and 1992 do not reflect the potential observed in the Arlington rotation study (Table 37). Dry weather during both seasons and an especially cool August in 1992 affected the late planted hairy vetch more than the companion seeded red clover which benefitted from a longer growing period. Nitrogen production from the two seasons averaged 98 lbs/a for red clover and 25 lbs/a for hairy vetch.

Table 37. Total (tops and roots) nitrogen yields of cover crop treatments in the seeding year.

Cover Crop Treatment	1991	1992
	----- lb N/acre -----	
Companion seeded Red Clover	101.40	95.35
Sequentially seeded Hairy Vetch	28.50	22.32

Roots harvested to a depth of 10 inches.

One year of corn response data (Table 38) shows that corn following both of the green manures reached their greatest yields with 120 lbs/a of supplemental fertilizer, in contrast to the 160 lbs/a N needed to obtain the maximum yield for continuous corn. Even at this higher rate of nitrogen, the continuous corn yielded lower than the lowest rotation corn yield. Dry weather, herbicide failure and corn rootworm damage, as observed by increased lodging in the continuous corn plots, contributed to this substantial yield difference, in addition to other "rotation effects".

Table 38. Effect of previous crop and nitrogen rate on corn yields at Elkhorn, Wisconsin, 1992.

N rate	Previous Crop		
	Red Clover	Hairy Vetch	Corn
lb/acre	----- bu/acre @ 15% moisture -----		
0	101	114	36
40	108	124	45
80	122	124	58
120	148	144	72
160	126	142	90
200	136	140	83
Mean	123	131	64
Orthogonal Polynomial Contrasts			
N rate linear	*	*	*
N rate quadratic	NS	NS	NS
N rate cubic	NS	NS	NS

NS not significant

*, ** significant at the 0.05 and 0.01 level of probability.

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X. Economic Analysis of the Wisconsin Integrated Cropping Systems Trial 1990, 1991, and 1992

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Introduction

The strength of the Wisconsin Integrated Cropping Systems Trials (WICST) in terms of reliability of the analyses and its relevance for educational programs has been enhanced because of the following three characteristics:

- a) The input, production, and economic analyses are based on data from systems of agricultural production, not on comparisons among individual crops.
- b) The systems to be studied and methods of economic analysis were selected through consultation and agreement among farm operators, county Extension faculty, and university research scientists.
- c) The plots are large enough to be treated using conventional farm equipment for the region, yet meet the highest standards for experimental design. In addition, the demonstrations are conducted at two locations, each in important farming areas of the state.

The economic analysis addresses the profitability of a system of production, i.e. the combined profitability of all crops in a rotation. It focuses decisions on the entire rotation rather than less meaningful comparisons between the most profitable crop in one system versus the most profitable crop in another. The analysis presented here is based on input and production data for each crop enterprise in each system each year, with the information presented in a crop budget format. During the 12 or more years of the trials, additional information about the crops and use of some of the crops by livestock in each system will be acquired.

While short term data can produce an estimate of the average profitability of each system, the additional years in the WICST will generate information on the long-term average and the year to year variability in the profitability. The trial is also unique in permitting evaluation of the costs and returns during the years of the transition from continuous corn to the existing cropping system. The long term nature of the trial permits measuring and evaluating environmental costs and effects associated with the various systems.

Finally, the large size of each plot permits use of the same full-size farm machinery used on farms in the neighborhood, increasing the credibility of the farm applicability of the practices. The researchers have the flexibility to treat each plot as a separate field.

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The economic analysis presented below illustrates the basic methodology to be used in analyzing the six cropping systems from the WICST. The analysis is divided into four parts. The first two parts contain a general description of the methodology used to generate the enterprise and systems budgets included in the analysis. The third part describes the results from the trials. The fourth part describes the "focus group" approach to determine what various user groups would like to see in current and future economic analyses and how this information has been incorporated into this analysis.

Budget Reporting Description

The budgets discussed below (details contained in Appendices V.A & B) are based on traditional enterprise budgeting techniques. They contain enterprise-based information on enterprise sales (gross returns), direct (variable) input costs, and gross margins (returns to labor, management and capital). The examples presented in the appendix are based on data from both the Arlington Research Station and Lakeland Agricultural Complex sites for the 1992 continuous corn Rotation 1 (R1); the 1992 corn and soybean crops for Rotation 2 (R2); and the 1992 corn, soybean, and wheat crops from Rotation 3 (R3).

As discussed in more detail below, the measure that seemed most important to our farmer advisors was gross margins (gross returns minus variable costs), which is the return to the farm's fixed resources for the entire crop rotation. In the case of the continuous corn rotation R1, the system consists of a single enterprise -- corn. Thus, the enterprise and system budgets are identical.

However, cropping systems' budgets for multi-year rotations can only be calculated when all crops (phases) in the rotation are produced in the same year. Given that data exist only for three years, 1990, 1991, and 1992, this is the first year that the cash crop systems (R1, R2, and R3) can be evaluated.⁸

Enterprise and System Returns

The budget methodology used can be illustrated by the 1992 continuous corn budget (Appendix V.A). The average yield on the four plots (replicates) at Arlington equalled 144.05 bushels per acre. Given a harvest time price of \$1.85 (market price of \$1.97 minus 12 cents dock for low test weight) per bushel, this enterprise generated a total income of \$266.50 per acre.

⁸ The initial evaluation of the three livestock oriented cropping systems (R4, R5, and R6) will be completed following the 1993 crop year. With data from each additional year more information about the average profitability and the variability of each system will be acquired.

The direct (variable) costs of \$166.93 per acre include the actual costs of purchased seed, fertilizer, and pesticides; custom operations hired; leased equipment; and grain drying. In addition the estimated fuel and repair costs of field machine operations from tillage following the harvest of the previous crop through the harvest of the current crop are also included.⁹

What remains after the variable costs are paid is called the gross margin and represents the returns to labor, management, and capital. This equalled \$99.56 for continuous corn in 1992 grown at Arlington.

The budgets can be used to develop a whole farm projection. For example, assuming that a farmer grew 500 acres of continuous corn in 1992, the whole-farm gross margin to the fixed resources would equal a little under \$50,000 for the year (\$99.56/acre x 500 acres). If the family drew \$25,000 from the farm, then \$25,000 would be left for the capital-related cash obligations of land rent, taxes, machinery replacement, and debt service. If the farmer rented 300 acres at \$100 per acre and paid \$40 per acre property taxes on 200 acres that was owned, then the farm business would be \$13,000 short of meeting those two cash requirements; not to mention machinery replacement or debt service. This illustrates the concept that the ability to meet capital-related cash obligations depends on a number of factors including, but not limited to, the gross margin of the corn enterprise.

Having only \$25,000 available to meet the capital-related cash obligations contrasts with the 1990 and 1991 evaluations where \$72,000 and \$54,000, respectively, was available. Over the three-year (1990-92) period an average of \$50,333 was available.

1990-1992 Rotation Economics

Table 39 contains a summary of crop yields and mean gross margins for the cash grain rotations. The supporting 1992 data are in Appendices V.A & B. Yields are reported on an individual crop basis. However, the mean gross margin is calculated as an average across all crops grown in that rotation in a given year. For example, the average corn, soybean, and wheat yields for rotation R3 at the Arlington Research Station (Columbia County) site in 1992 were 99.2, 38, and 45.2 bushels/acre, respectively. The mean gross margin for rotation R3 equalled \$92.69 \$/acre ($\$158.36 + \$52.16 + \$67.55$ divided by 3). This was nearly equal to the 1992 gross margin for continuous corn of \$92.36 per acre. Similarly, the 1992 gross margin for the corn-soybean rotation (R3) at the Lakeland Agricultural Complex (Walworth County) of \$90.81 per acre exceeded the continuous corn gross margin of \$62.47 per acre.

Figures 19 and 20 re-summarize the data in histogram form.
The following observations can be made:

⁹ These estimated costs are based on the actual field operations used, in this case, on the Arlington Research Station site in Columbia County. The costs for fuel and repairs are for the operations in the Minnesota Farm Machinery Economic Cost Estimates for 1992 that most closely resemble the actual operations.

Table 39. Crop Yields (bu/a) and Gross Margins (\$/a) for R1, R2, and R3 Cropping Systems at the Arlington Research Station and Lakeland Agricultural Complex, 1990, 1991, and 1992.

Arlington Research Station (ARS):

	1990	1991	1992	Avg. (91-92)*
Continuous Corn (R1)				
Corn Yield	165.8	160.0	144.1	152.0
Mean Gross Margin	\$258.48	\$233.47	\$92.36	\$162.92
Corn-Soybean (R2)				
Corn Yield		184.7	150.4	167.5
Soybean Yield	56.7	60.4	48.5	54.4
Mean Gross Margin		\$275.20	\$143.75	\$209.48
Soybean/Wheat-Wheat-Corn (R3)				
Corn Yield			99.2	
Soybean Yield	52.4	59.2	38.0	
Wheat Yield		63.6	45.2	
Mean Gross Margin			\$91.17	

Lakeland Agricultural Complex (LAC):

	1990	1991	1992	Avg. (91-92)
Continuous Corn(R1)				
Corn Yield	163.6	121.2	119.1	120.1
Mean Gross Margin	210.7	157.1	62.5	109.8
Corn-Soybean (R2)				
Corn Yield		144.7	126.3	135.5
Soybean Yield	52.8	58.7	46.9	52.8
Mean Gross Margin		\$220.47	\$137.45	\$178.96
Soybean/Wheat-Wheat-Corn (R3)				
Corn Yield			73.0	
Soybean Yield	54.3	51.6	51.9	
Wheat Yield		32.1	25.7	
Mean Gross Margin			\$91.74	

Source: Economic analysis of WICST data

- * The purpose of the average is to compare the rotations (continuous corn & corn-soybean) in the two years (1991-1992) in which all crops in the rotation were grown.

Arlington Research Station (Figure 19)

- * R2 had slightly higher corn yields in 1991 and 1992
- * R2 had slightly higher soybean yields all three years
- * Average rotation direct costs were highest for R1, and lowest for R3
- * R2 had higher average rotation gross margins in 1991 and 1992

Lakeland Agricultural Complex (Figure 20)

- * R2 had slightly higher corn yields in 1991 and 1992
- * R2 and R3 had similar soybean yields all three years
- * R2 and R3 had lower average rotation direct costs than R1 from 1991-92
- * R2 had higher average rotation gross margins in 1991 and 1992

The data for the first three years of the trials can tell only a portion of the story about how these systems will compare over time. These systems will be compared over a number of years in order to examine the impacts of weather, cultural factors, and prices on system profitability. But the above discussion does illustrate the concepts of gross margins and systems' analysis. We would note, however, that any measurable contribution of the cropping systems to environmental contamination and environmental costs is important and will need to be factored into the economic analysis.

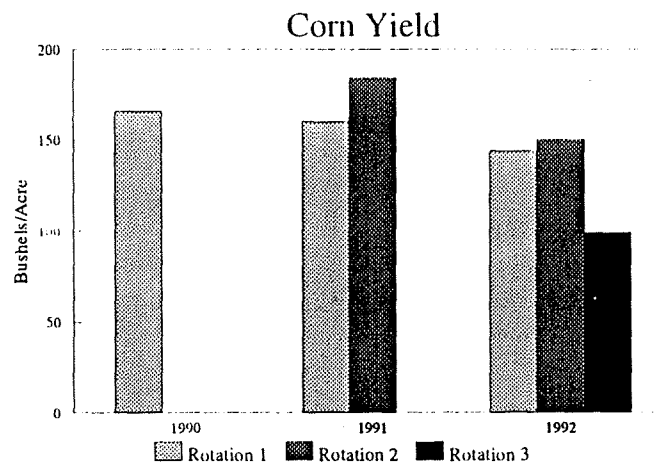
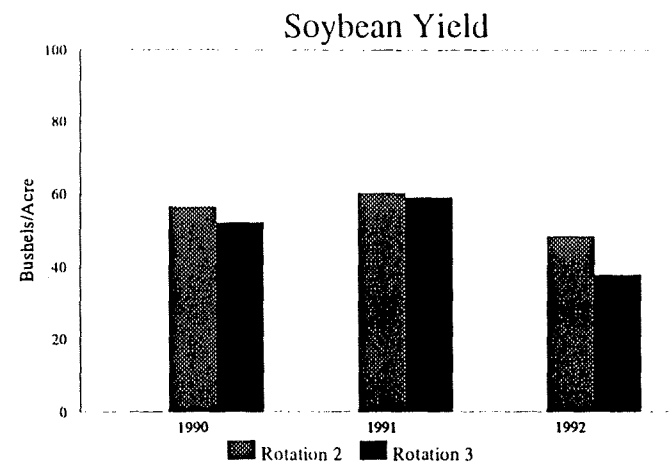
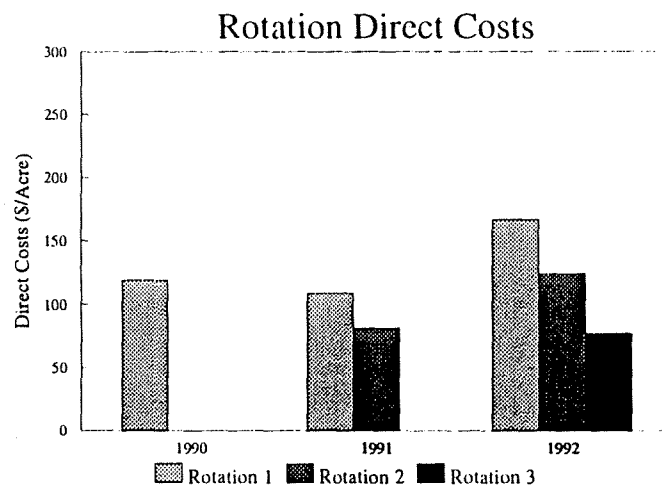
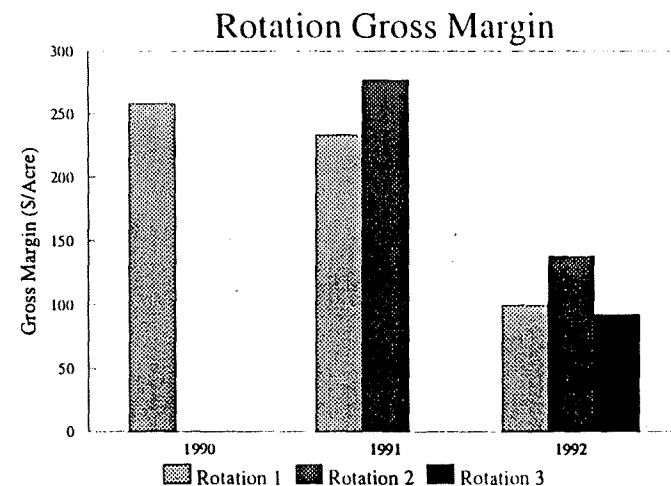
Future Directions

A more complete economic analysis and the inclusion of environmental costs are near-term objectives of this project. As the study progresses to a point where all crops/phases are being completed in the same year, we will be able to include all six systems in the comparative analysis as we have done with the first three rotations. With that data, we will be better able to address questions involving the transition from continuous corn to various alternative crop rotations. In addition, we will begin to incorporate variability of returns into the comparative analysis that currently is limited to a comparison of averages.

Another important objective of the Wisconsin Integrated Cropping Systems Trial is the dissemination of project results to a range of audiences -- farmers, environmentalists, policy-makers, urban consumers, students, etc. An important aspect of teaching is how the information is packaged and presented. In other words, we must deliver the information in a form that is readily understandable and useable. We are continuing the process of updating the analysis based on feedback we receive from "focus-group" sessions, held to address a variety of such questions.

Most of the suggestions concerning the analysis from the first two focus group meetings with farmers have been included in this analysis. Examples include using harvest prices to calculate total crop value, using gross margins as the key profit indicator, and examining the rotations from a system's perspective. Other issues, including pricing the crops in the livestock rotations, valuing cattle manure that is used in rotations 4-6, determining the process for assigning environmental costs, and valuing and assigning labor costs remain elusive and will continue to be addressed as we conduct these sessions with academic and environmental groups.

Arlington Research Station



Rotation 1 => Continuous Corn

Rotation 2 => Corn-Soybean

Rotation 3 => Corn-Soybean-Wheat

Figure 19. Yield and Economic Comparisons of the WICST Cash Grain Rotations - 1990-1992 (ARS)

Lakeland Agricultural Complex

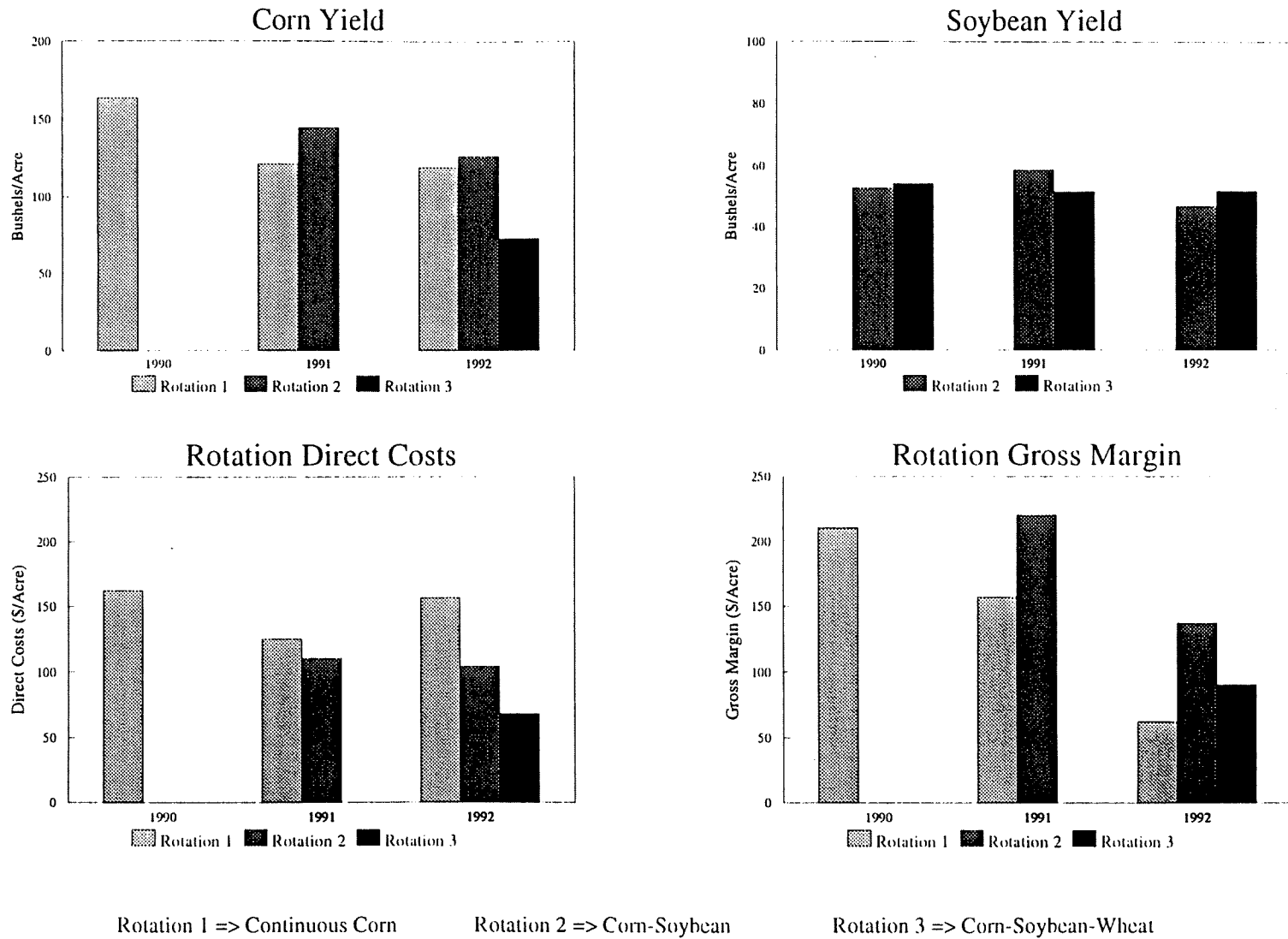


Figure 20. Yield and Economic Comparisons of the WICST Cash Grain Rotations - 1990-1992 (LAC)

XI. COMMENTS ON EXPERIMENTAL DESIGN

J. L. Posner and M. D. Casler*

Brandt's dictum (as quoted in Cady, 1991) simply stated is that long-term rotation experiments must provide for all components of each crop rotation to be grown each year, and that the treatments be randomized. Accepting the producers desire that the work be conducted on large plots and the general concern from researchers about sampling procedures led the decision to conduct a homogeneity trial. The objectives during this uniformity year were three fold:

1. to block the trial based on corn yield variability.
2. to test the effectiveness of the blocking plan for removing variation in baseline variables other than corn yield.
3. to identify an adequate sampling procedure for baseline variables.

1. Blocking the trial:

At each site an approximately 25 ha area was set aside for the trial. Corn was planted to the entire field in 1989. Yields were measured with a weigh wagon during every third pass with the 6-row combine in pre-marked 25.8 m lengths. Yields from the harvest strips were considered also representative of the bulked strips on either side, resulting in a unit yield plot of 25.8 m by 13.8 m. At the Arlington Research Station (ARS) 625 plots were harvested; at the Lakeland Agricultural Complex (LAC), 665 plots. Fortunately 1989 had a typical growing season, and mean corn yields were 8000 kg/ha at the former site and 9550 kg/ha at the latter.

Harvest units were aggregated into "plots" with sizes ranging from 0.0038 ha (1 unit) to 0.301 ha (8 units in a 1 x 8, 2 x 4, 4 x 2, or 8 x 1 configuration). Aggregated plots were, for each size and shape, then grouped into 12-plot blocks of various shapes. One-way analysis of variance was computed on the plot mean corn yields for each plot size, plot shape, and block shape combination. The error variance (plots within blocks) was used to estimate the ($P=0.05$) LSD considering a future trial with $r = 3$ to 6 replicates. While plot shape did not affect the magnitude of calculated LSD values, block lay-out did.

Doubling the number of replicates reduced the LSD by 30% (Table 40). While increased repetitions would markedly increase costs, the farmer-inspired focus on transition period meant that good precision would be necessary from the inception of the trial. Doubling the plot size, which would be cheaper than doubling the number of replicates, also was effective and reduced LSD by 14 to 32%. As expected, the largest reductions in LSD, due to increasing plot size were for the smallest plots. Considering the desire to conduct the trial using farm-scale machinery, it was decided that plots needed to be long, and with adequate alleyways for maneuvering (15-20 m wide). As a result, it was determined that the project could afford a maximum of four replicates and the randomized complete block design was chosen. The available land area with four replicates would allow a plot size of 0.30 ha at each location, which was expected to be as efficient as a plot size of 0.19 ha with five replicates or 0.13 ha with six replicates. Results from the

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uniformity year predicted that LSD values for corn would be between 200 - 300 kg. During the first three production years of the experiment corn LSD at the two locations has ranged from 100 to 400 kg.

Table 40. The effect of plot area (ha) and number of replicates (r) on LSD(P=0.05) using corn yield during the uniformity year, 1989.

a. Arlington Research Station (ARS)

Plot Size (hectares)	LSD (P=0.05) kilogram			
	r=3	r=4	r=5	r=6
0.038	447.1	386.1	345.5	315.0
0.075	345.5	299.7	266.7	243.8
0.113	312.4	269.3	241.3	221.0
0.151	279.4	243.9	218.5	198.1
0.226	266.7	231.1	205.8	188.0
0.301	241.3	210.8	188.0	170.2

b. Lakeland Agricultural Complex (LAC)

Plot Size (hectares)	LSD (P=0.05) kilogram			
	r=3	r=4	r=5	r=6
0.038	561.4	487.7	434.4	396.3
0.075	383.6	330.2	297.2	271.8
0.113	337.8	292.2	261.6	238.8
0.151	----	----	----	----
0.226	271.8	233.7	210.8	190.5
0.301	----	----	----	----

2. Effectiveness of the blocking plan on other variables:

At ARS, in addition to the yield study, a 55 m by 27 m soil sampling grid was established. At each grid point, in the spring of 1989, ten soil samples (0-15cm depth) were taken in a 5m radius for both soil fertility and weed seed measurements. These sampling points were then classified according to block and plot number in the newly established field map. The soil variables were subjected to analysis of variance using the RCB model and the new randomization plan. Analysis of variance revealed large and significant ($P < 0.01$) differences among block means for several variables, four of which are shown in Table 41 row 3. Although blocking was conducted exclusively according to patterns of variation in uniformity-year corn yield, a large portion of the variation for these variables was removed by blocking. Furthermore, the lack of significant treatment effects (rows 4, 5, and 6) indicates that the randomization of treatments to plots was effective in eliminating potential bias to individual treatments. Future treatment comparisons for these variables will not therefore be confounded by variation in initial levels.

Table 41. Block means and P-values for block and treatment effects for 1989 uniformity-year data superimposed upon the long-term experimental design of the WICST.

Statistic	Variable			
	Weed seeds ¹		Soil ¹	
	Grass	Broadleaf	P	K
	-- 10 ³ seeds/m ² --		----- PPM -----	
Block means				
1. High	2.11	9.37	120	288
2. Low	0.46	3.20	79	225
	P (>F)			
3. Blocks	< 0.01	< 0.01	< 0.01	< 0.01
Treatment effects	(df)			
4. Enterprise Type	1	0.13	0.59	0.12
5. Strategy/Enterprise	4	0.30	0.64	0.40
6. Phases/Strategy	8	0.67	0.31	0.18

¹ 0-15cm soil sampling depth

3. Sampling protocol:

The soil variables were also analyzed according to a nested sampling model, with blocks, plots within blocks and samples within plots as the three sources of variation. Variance components for the experimental (plots within blocks) and sampling (samples with plots) error were estimated. In developing an optimal sampling scheme, it was considered desirable to have the power of hypothesized tests on treatment means to be at least 0.8. Power is the probability that two means which are truly different will be declared different following the hypothesis test. Number of samples per plot (n) required to detect a hypothesized treatment mean difference (d) with power = $1 - \beta = 0.8$ and significance level $\alpha = 0.05$ was computed as:

$$[N = 2 (t_{\alpha/2, 46} + t_{\beta, 46})^2 \text{MSe} / 4d^2]$$

The ratio of sampling error to experimental error (S_s^2/S_e^2 ; Table 42, row 1) was always substantially greater than unity. The magnitude of the sampling error suggested that large numbers of samples per plot would be required to have an impact on reducing standard errors of the treatment means. The mean values for weed seed and soil P and K levels are presented in row 2. Considering that the area had been in an alfalfa-corn rotation for a number of years and had heavy applications of manure, it was felt that grass and broadleaf numbers were average to somewhat high for typical forage rotations (pers. communication. J. Doll). An initial hypothesis was that the continuous corn with herbicide and one cultivation (R_1) would ultimately be the treatment with the lowest weed seed load, and that the three phase, low-input rotation (R_3) with two years of row crops would have the highest weed seed load. Due to the ease of killing grass weeds in corn with herbicides it was estimated that the numbers would drop dramatically in continuous corn (R_1) while they would increase when relying only on mechanical weed control in rotation 3. It was therefore estimated that there would be a maximum range of 5,000 grass weed seeds/m²

between the best and worst rotations. Broadleaves were more prevalent at the site and also are more difficult to control. It was estimated that the maximum range of broadleaf weed seed would grow to 11,000 seeds/m² between rotations 1 and 3. It would require a minimum of 20 grass seed determinations per plot and 41 broadleaf seed determinations per plot to detect treatment differences as small as 20% of these ranges (with $\alpha = 0.05$, $\beta = 0.20$, and $r = 4$).

Table 42. Means and sampling statistics for four variables measured during the uniformity year, 1989.

Statistic	Variable			
	Weed seeds ¹		Soil ¹	
	Grass	Broadleaf	P	K
	-- 10 ³ seeds/m ² --		----- PPM -----	
1. Variance ratio ² S_e^2/S^2	10.1	5.6	12.1	3.3
2. Mean in 1989	1.5	6.8	103	265
3. Predicted maximum range ³	5.0	11.0	90	220
4. Treatment difference(d) to be detected ⁴	1.0	2.2	18	44
5. Number of samples/plot required ⁵	20	41	16	25

¹ 0-15cm soil sampling depth

² Ratio of variance components for sampling error(s) and experimental error(e)

³ Range expected among treatment means after 12-16 years of rotation

⁴ Desired detection level (20% of maximum range) for differences among treatment means, $P = 0.05$

⁵ Minimum number of samples per plot required to detect "d" with power = 0.80 and $P = 0.05$

A similar analysis was done with surface soil phosphorous and potassium levels. Due to the use of starter fertilizer in the continuous corn plots (R₁), it was estimated that the high levels of P and K would be maintained. On the other hand, in the low-input rotation (R₃), nutrient removal would not be replaced by either fertilizer or manure. Assuming average yields, it was estimated that within 15 years P and K levels would drop to soil equilibrium levels of 10 ppm and 45 ppm respectively (Schulte, pers. communication). Yields would also drop since optimum soil test levels are considered to be 20ppm for available phosphorous and 100 ppm for exchangeable potassium (Kelling *et al.*, 1991). These calculations permitted establishing a maximum range and setting a desired minimum detectable difference value. It would require a minimum of 16 samples/plot to detect a treatment mean difference as low as 20% of the range for phosphorous, and 25 samples/plot for potassium. Frequent and heavy additions of k-rich manure may explain the greater heterogeneity for this element.

In the case of the weed seed measurements, it was decided to sample the soil in each plot 30 times and to identify all the weed seed that germinated during three irrigation cycles. Results from the spring of 1992 (Table 43) indicate that, as was expected, weed seed numbers are dropping under continuous corn and increasing in the mechanically

weeded plots (R_3). The difference in both broadleaf and grass weed seed numbers between these two rotations is already significant. As a result, our plan for the future is to focus on corn as the "test" phase in each rotation. Every third year we will sample all plots coming out of corn.

On the other hand, it would be prohibitively expensive to analyze chemical fertility on anything greater than 10 soil samples per plot. Therefore, it was decided to simply monitor the treatments by bulking 5 cores per plot and make one single annual analysis during the early years of the trial. As expected, the continuous corn rotation has approximately maintained P and K levels while the three phase rotation is showing a drawdown of these nutrients (Table 43). Not surprisingly, the difference in soil test P and K values between rotations is not yet significant. Due to the expense of sampling, the plan is to wait until the 6th year of the trial (1995), and then intensively sample (5 cores/sample; 10 samples/plot) one phase in each rotation.

Table 43. Comparison of Rotation One and Rotation Three in Weed Seed Bank and Soil Fertility Evolution between 1989 and 1992.

Rotation	Weed Seed Bank ^{1/} (0-15cm)				Soil Fertility ^{2/} (0-15cm)			
	Grass		Broadleaf		Available P		Exchangable K	
	1989	1992	1989	1992	1989	1992	1989	1992
	----- ppm -----		-----		----- seeds/m ² -----		-----	
R_1 C-C-C	1958	288	7378	1928	105	93	257	219
R_3 Sb-W/rc-C	1608	1442	6430	8177	105	69	236	189
LSD(P=0.05)	NS	668	NS	1905	NS	NS	NS	NS

^{1/}Soil sample made up of 30 coring, 15cm deep and 0.92 cm diameter. Total number of emerged plants after three wetting cycles in the greenhouse

^{2/}Composite of 5 cores (0.92cm dia)

Source: J. Doll et. al, 1993
T. Iragavarapu, 1993

Using a Staggered Start:

Due to the farmer's interest in the results from the early years of the experiment, it was decided that a staggered start for the trial should be employed (Figure 21). This meant beginning each rotation with the legume phase and growing "filler" corn in the plots not yet phased into the experiment. This approach, rather than the simultaneous initiation of all the phases was selected because it was felt that more realistic production and costs estimates could be made, especially in the low-input systems that rely heavily on legume nitrogen.

Superimposed on Figure 21 are shaded ovals and rectangles that highlight two complementary approaches to the statistical analysis of the experiment. The ovals enclose

the combination of plots that would be used in the "transition analysis" of the trial data. For example, in 1996 we will have 7 years of data on rotation one, six completed rotations from R_2 , and five completed rotations from the three-phase R_3 . The degrees of freedom for this analysis are keyed out in Table 44a. In this analysis linear contrasts that emphasize the trends that appear within rotations will be tested. The effect of cycles, for each rotation, will be partitioned into polynomial contrasts to test and estimate the transition response of each rotation.

ROTATION	Year							
	1989	1990	1991	1992	1993	1994	1995	1996
R_1	F	C	C	C	C	C	C	C
R_2	F	Sb	C	Sb	C	Sb	C	Sb
	F	F	Sb	C	Sb	C	Sb	C
R_3	F	Sb W/RC	C	Sb W/RC	C	Sb	C	Sb
	F	F	Sb W/RC	C	Sb W/RC	C	Sb W/RC	C
	F	F	F	Sb W/RC	C	Sb W/RC	C	Sb W/RC
R_4	F	A	A	A	C	A	A	A
	F	F	A	A	A	C	A	A
	F	F	F	A	A	A	C	A
	F	F	F	F	A	A	A	C
R_5	F	O/A	A	C	O/A	A	C	O/A
	F	F	O/A	A	C	O/A	A	C
	F	F	F	O/A	A	C	O/A	A
R_6	F	P	P	P	P	P	P	P

F = filler corn Sb = soybean
 P = pasture A = alfalfa
 C = corn W = wheat
 O = oats RC = red clover

■ = unit of analysis for transition comparisons
 □ = unit of analysis for whole farm comparisons

Figure 21. "Staggered Start for WICST"

The rectangles on the other hand, represent a whole-farm analysis approach to the same data. Here we analyze output, income, or environmental impact variables on a farm-wide basis assuming that an entire farm is in one of the six rotations. The emphasis in this analysis (see Table 44b) will be the effect of years, rotations, and the rotation x year interaction. This analysis, for example, will focus attention on the risk involved in the alternative systems. It will address the long term year-to-year stability of each rotation and allow comparisons among rotations, for both long-term mean performance and stability.

Table 44. Analysis of variance, sources of variation, and degrees of freedom for two complementary analyses.

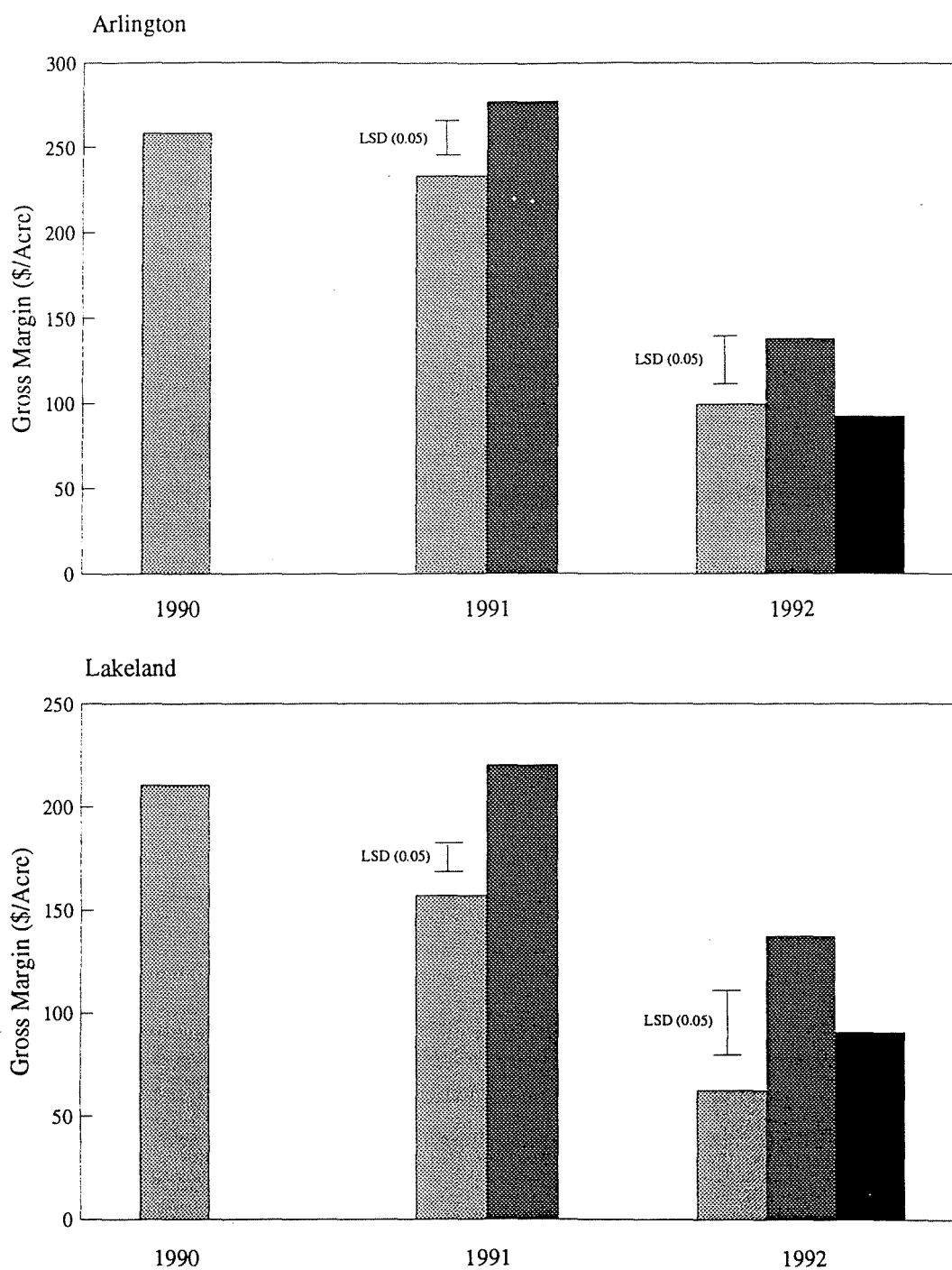
<u>A. Transition Analysis</u>		<u>B. Whole-farm Analysis</u>	
Source of variation	df	Source of variation	df
Blocks	3	Blocks	3
Enterprise	1	Enterprise	1
<u>Cash grain rotations</u>		<u>Cash grain</u>	
Rotations-linear	1	Years-linear (Y_L)	1
Rotations-nonlinear	1	Years-quadratic (Y_Q)	1
Phases / R_1		Years-cubic (Y_C)	1
Linear	1	Rotations (R)	2
Quadratic	1	R x Y_L	2
Cubic	1	R x Y_Q	2
Residual	3	R x Y_C	2
Phases / R_2 †	5	Residual	6
Phases / R_3 †	4		
<u>Forage-livestock rotations</u>		<u>Forage-livestock</u>	
Rotations-linear	1	Years-linear (Y_L)	1
Rotations-nonlinear	1	Years-quadratic (Y_Q)	1
Phases / R_1		Years-cubic (Y_C)	1
Linear	1	Rotations (R)	2
Quadratic	1	R x Y_L	2
Cubic	1	R x Y_Q	2
Residual	3	R x Y_C	2
Phases / R_2 †	5	Residual	6
Phases / R_3 †	4		
Pooled error	99	Pooled error	99

† Degrees of freedom will be partitioned in a manner similar to that for R_1 .

The data from the first 3 years of the trial have been analyzed using the whole-farm model. Gross annual rotation margins are shown for the cash-grain rotations from Arlington (Figure 22a) and Lakeland (Figure 22b). Gross margins are gross returns minus variable costs and represent the returns to the farm's unpaid fixed resources (labor, management, capital, and land). While it is clear that the corn-soybean rotation was the most profitable in 1991 and 1992, it is interesting to note that the three phase rotation with soybeans-wheat-corn, was statistically equivalent to continuous corn in 1992 at both locations. At the end of 1993, and every year thereafter, all the plots will be in their proper rotation position, and whole-farm analysis will be conducted.

References

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Source: Gumz, et al. 1993.

Figure 22. Rotation Gross Margins by Year, Arlington Research Station and Lakeland Agricultural Complex (Gross Margins per Acre).

XII. BASELINE SURVEY OF WICST OUTSIDE AUDITORS

B. Bacaltchuk and Richard Powers*

1. INTRODUCTION:

The challenge of the information age is not figuring out how to produce, store, or transmit information. The challenge is figuring out what is really worth knowing or informing about and then getting people to actually use that information. The mandate of this component of the Wisconsin Integrated Cropping System Trial (WICST) is to evaluate, over time, what members of the public know, understand, perceive and learn from the project, and how it is relevant to their specific roles in the rural community.

A strategy to evaluate the project's effectiveness in achieving its educational goals was initiated by the creation of an "Outside Auditors Group." Two clusters of individuals were chosen purposely to be functional representatives from communities near the project sites. They were selected from a list of 158 names and addresses submitted by extension agents of Walworth, Dane, and Columbia counties. The final sample which constitutes the case study has 132 respondents.

Several steps will be taken to keep this group informed about project activities. This same group will be interviewed several times to measure respondents' knowledge about the project and attitude changes on relevant issues. The effort reported here is the first or "benchmark" survey.

2. SURVEY METHODOLOGY:

A questionnaire was pre-tested on ten previously chosen community members. After minor revisions, the "purposive sample" was interviewed, face to face, with a 36-question survey probing the respondents' understanding, perception and knowledge of technology, policy, economic and value issues related to farming in Wisconsin.

Benami Bacaltchuk, a Brazilian agronomist studying for a Ph.D. in Mass Communication, conducted all the interviews, which averaged about 76 minutes each. The survey required 46 working days, between July and October of 1992, and 6,619 miles of travel (average of 144 miles per day).

3. PRELIMINARY RESULTS:

a) Sample characteristics: Table 45 shows the interviewed group by their main occupation. They came from 31 different towns, mainly in Columbia and Walworth counties; 83% of the respondents are men and the average age was about 46 years old; considering the entire sample, 58% reported four years college, and 17% had gone further.

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This was a group of rural leaders and on average the respondents are associated with five organizations of various types; 55% belonged to at least one professional organization, 50% to an economic (commodity) organization, 48% to religious group, 32% to a social organization (clubs), 18% to an environmental group, 16% to a political organization, and 60% to a community organization.

Table 45. Respondents Main Occupation

Occupation	Columbia County	Walworth County	Percent of total
FARMER	25	23	36.4
POLICY MAKER	5	6	8.3
CONSUMER	5	4	6.8
AGRIBUSINESS REPRESENTATIVE	10	10	15.1
EDUCATOR	8	6	10.6
GOVERNMENT AGENCY	9	7	12.1
ENVIRONMENTALIST	5	4	6.8
RESEARCHER	5	-	3.8
TOTAL	72	60	100.0

b) Knowledge base: The group was quite knowledgeable about production agriculture. Recognition was 71% or better for all the key topics listed in Table 46. The lowest response of recognition was for "lock and load", a new packaging approach for dealing with pesticides and "rotational grazing". For this group, there's not a great deal of room for improvement of awareness in the general knowledge areas the survey asked about.

Table 46. Respondents' Recognition of Agri-Related Topics

Topic	Recognition Percentage
1. Maximum yield varieties	96
2. Variety diversification	93
3. Genetics to breed pest resistant crops	95
4. Biotechnology	95
5. Anhydrous ammonia in corn	96
6. Nitrogen credit from manure	95
7. Natural pesticides	95
8. Insect scouting	86
9. Use of herbicide	99
10. Pre-emergence herbicides	94
11. Post-emergence herbicides	94
12. Rotating herbicides	89
13. Rotary hoe	95
14. Corn cultivator	99
15. Lock and Load	71
16. Linking subsidies to soil conservation	96
17. Crop rotation with sod crops	97
18. Conservation tillage	97
19. Contour strips	98
20. Contour tillage	98
21. Using cover crops	97
22. No-till planting	98
23. Use of hormones to increase milk production	98
24. Embryo transfer	97
25. Total mixed rations	90
26. Rotational grazing	71

c) Concept of sustainable agriculture: About 80% of the sample were able to articulate their understanding about this concept. When asked in an open-ended question requesting them to define sustainability, 30% of the sample associated it with the permanence on the land, 34% to using less inputs, and 17% to environmental protection.

The question why farmers would want sustainable agriculture had 39% reporting it as for economical reasons, 18% for the benefit of future generations, 13% as for environmental protection, and 10% reported it is because of farmers' personal values.

Outstanding in their ideas about why farmers don't adopt sustainable practices was fear of lower yields and (to a lesser extent) fear of lower profits. Most popular of their suggestions on sustainable practice adoption was to try it on a small scale on part of the farm (42% picking this as first choice). Next was the idea of talking to other farmers who used the practice successfully (30% first choice), and 11% gave first choice to attendance at field days demonstrating the new system. All three of these popular choices are part of the WICST program and other sustainable efforts. There was low preference for extension agents (6%), university specialists (4.5%), consultants (3%) and government agencies (not checked as first choice by any respondent). This suggests that the project should focus on farmer networks.

Their agreement to statements about sustainable agriculture indicate a rational understanding: they did not consider sustainable practices to be exotic or not ready for use, they did not think the focus was exclusively on chemical reduction, and they were divided nearly equally on whether expert advice was needed for applying sustainable agriculture techniques.

d. Support of current farm policy: Open-ended questions about current farm policies and rules were coded into statements of approval, neutral, and disapproval (Table 47).

Table 47. Support for Current Farm Policy

Policy	Approval	Neutral	Disapproval
	%	%	%
Soil conservation Compliance	38	24	26
Wetland Preservation Policy	25	15	43
Set-Aside Acres Program	23	17	51
Atrazine Management Area	51	15	11
Removal of all Farm-Programs	25	22	48

e) Perception: We asked respondents to express the first thing coming to their mind in response to certain statements. All were open-ended questions to avoid providing set responses, and we coded the replies into categories. Responses to the statements were as follows:

- To the statement "*farming as a way of life*" 61% of the responses related to family values, the remaining respondents attributed it to independence (7%), cynicism and economics (11%), and others (9%); only the agribusiness segment of the sample had divided opinion between family values and economics (41% each).

- "*Farming as high-technology*" had 47% of responses related to need for knowledge; researchers used terms implying it is a economic factor (60%) while government agency employees regarded it in terms of survival (42%).

- "*Farming as a business*" had 51% who merely confirmed this, with agribusiness, policy makers, environmentalists and researchers also mentioning more specific economic factors.

- For "*farming as stewardship*", 31% of the comments mentioned the farmers' responsibility, 21% related it to environmental protection, 17% attributed it to values, and 16% to concern for the future generations. The rest of the respondents attributed it to choice, societal responsibility, or a new trend and some were unaware of any meaning. Policy makers also see it as concern with future generations, while educators and environmentalists often see it as environment protection concern.

- The statement "*farms getting fewer but larger*" had 33% considering it as lamentable, while 27% expressed approval (among these were, educators, agribusinesses, government agency personnel). It was mentioned by 17% of the respondents as a consequence of socio-economic factors and 16% of the respondents mentioned economic factors. Farmers, educators, and policy makers noted specific consequences of the trend toward getting larger.

- The statement "*getting government out of farming*" had 33% of respondents expressing approval (38% farmers, 22% policy makers, 23% educators, 38% government agency employees, 33% environmentalists, 40% researchers), 24% do not believe it will ever happen (notably 33% for agribusiness representatives), and 20% expressed mixed-feelings (40% among the financial people). Only 14% of the respondents disapproved of it. The remaining respondents mentioned mixed feelings or conditionalities.

- Finally, the statement "*low input farming*" had 21% of the respondents expressing approval (24% farmers, 25% educators and government agency employees, and 22% environmentalists), 13% disapproved of it, 17% established some technical concepts for it (60% researchers and 30% financial), and 8% established some conditionalities. While 15% said it is an economic necessity, 14% were not able to give their perceptions.

When asked to choose the best from a list of criteria for judging the success of agriculture in Wisconsin, 32% emphasized "*crop and livestock product yield*", 24% conferred the highest score for "*number of non-farmers that a farm family feeds*", 19% focused on the "*net farm income*" and 15% rated the "*harmony of agriculture and the environment*" as first. The "*quality of soil conservation*" was prized by 9% while only 4% put "*increased energy efficiency*" in first place.

We asked what respondents considered as problems in farming in Wisconsin. About half of the respondents regarded *soil erosion, surface water contamination, ground water pollution, pesticide residues, government policies, input prices, equipment prices, and labor* as large problems. Two-thirds considered *price of products sold from farm and profit* as large problems. *Market location to sell farm products and credit* got classified by less than one-third of the respondents as large problems.

When asked if "*modern agriculture causes environmental damages*", 39% of farmers agreed and 35% of them disagreed, while 36% of the policy makers and 67% of the agribusiness respondents (especially the money lenders) disagreed. Agreement was registered by consumers and environmentalists (67%), agribusiness representatives (57%),

government agency employees (56%), and educators (50%). Contrasting this statement we asked respondents to state their levels of agreement or disagreement to the statement "*farming's impact in the environment has been grossly exaggerated.*" Almost three-fourths of the total group agreed or strongly agreed. Only environmentalists (90%) and agribusiness personnel (40%) either disagreed or strongly disagreed. Government agency employees and agribusiness representatives were about equally divided between agreement and disagreement.

f) Project impact: The question about familiarity with institutions involved in the project indicated that two-thirds of the respondents have some level of familiarity with *CALS*, *DNR*, and *SCS*, but only one-third are familiar with the acronym *LISA*, less than one-fifth have familiarity with *Michael Fields Agricultural Institute* and less than half the respondents have some familiarity with the label *WICST*.

Only 44% of the respondents could name some of the *WICST* goals; 36% of those who did indicated that the main aim of the project is to study *cropping systems*, 22% identified the project goals as *educational*, 19% indicate it as being *alternative agriculture*, 14% see *WICST* as studying *environmental impact* and less than 9% see it as *farm economics*. 58% of the respondents had never taken part in *WICST* activities or ever talked to others about *WICST*.

Only 40% of the respondents could *name one specific project* being done by the *WICST*, with the only significant recall being for *rotational grazing*. The respondents residing close to the Walworth Agricultural Complex could name 23 different specific activities while the respondents residing close to Arlington Research Station could name only 12. This suggests some areas of concentration for communications programs with this group, especially in terms of knowledge of specific goals and awareness of specific projects. Different occupational segments had different perceptions of the agencies and functions.

g) Information Channels: The above findings suggest areas the *WICST* program might choose to emphasize. Further analysis should reveal more information about what groups hold which opinions. This can sharpen the project's focus to match audience needs with project information. The following graph (Figure 23) indicates use of information channels by members of this group, which the project can use in choosing ways to disseminate information or to establish programs to enhance credibility of various sources.

4. The Future

There are three future activities for this component of the project. The first is to complete the statistical analyses of the descriptive data presented above. Some of these analyses will suggest why differences occur; others will give us ideas for targeting certain information efforts and program emphases.

The second future thrust concerns a "co-orientational" view of this group. Co-orientation is a communications research concept that deals with how one group perceives other groups' perceptions or attitudes about ideas or objects. For example, what do the farmers believe the environmentalists think about the phrase "*Farming damages the environment?*" And how does that compare with the true position of the

environmentalists, and how far apart are the farmers and environmentalists in their reaction to this statement? The goal is to draw a perceptual map of how the participants involved in the Outside Auditors Group view one another in respect to issues and practices central to WICST's interest. Future interviews will indicate how this perceptual map changes as the project progresses.

Our third task is to assure that the educational focus of the project brings more accuracy and harmony to the rural community (which presently seems a bit divided on some of the issues). The co-orientation procedure provides a way to quantify such things and observe changes over time. The findings at this stage will also inform the project of perceptual differences and inaccuracies of perceptions among the various factions within the outside auditors group. Like knowledge of information gaps, knowledge of intragroup perceptual gaps will help adjust the project's focus to rectify them.

INFORMATION SOURCE

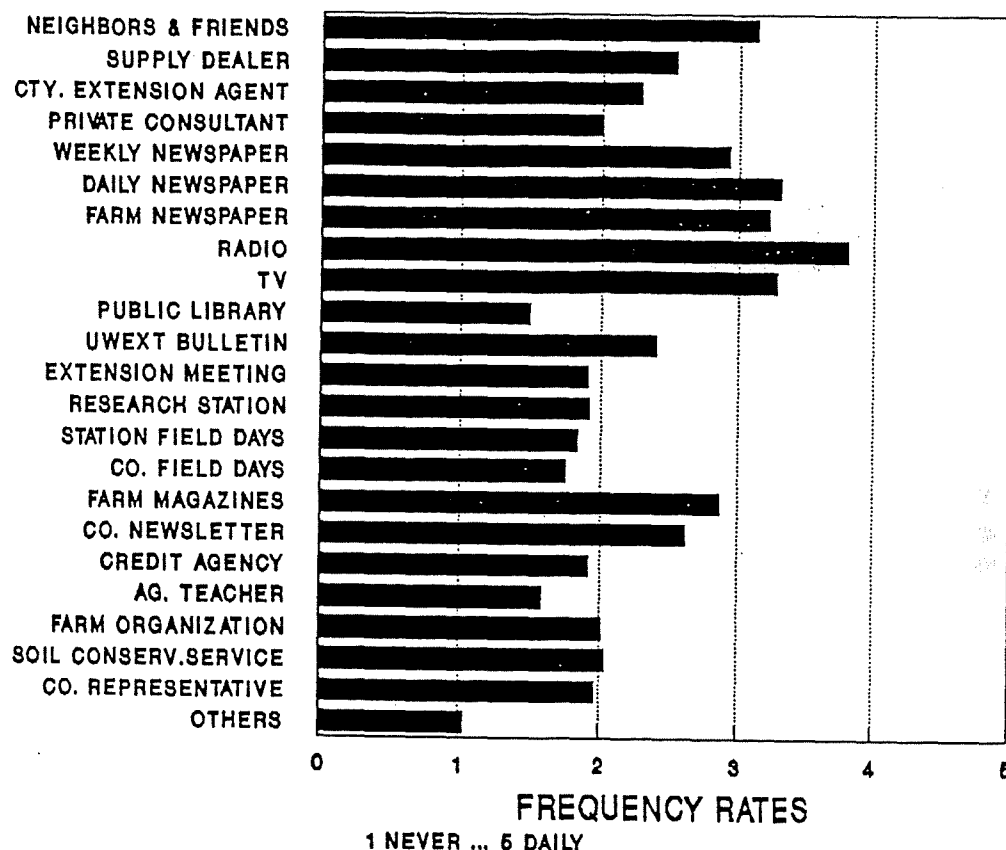


Figure 23. Survey Results of Sources of Information and Frequency of their Use

XII. OUTREACH ACTIVITIES

A. Lakeland Agricultural Complex: Annual Educational Outreach Report - 1992

Lee Cunningham* and John Hall**

Within the confines of this report it is very tempting to simply identify the groups and the number of people that have come in contact with the WICST outside classroom in 1992. Those numbers do help to identify the wide range of people that are showing increased interest in the methods utilized to grow the food we eat so we will once again include them (Table 48). However, those numbers do not show the impact the WICST project is having on the people involved. To document some of this impact 30 people have been contacted, by this agent, that were introduced to the Walworth County WICST site over the last three years. They were asked if they had changed their own personal views about the methods they were using to produce crops in the last three years. Twenty-one answered "yes!" When asked if their involvement in the WICST project had influenced them to think about personal change, all twenty-one answered "yes!" For this project to have influenced these people to at least think about change is very reassuring that we are truly developing a forum that fosters thought, discussion, and even change.

The following is a brief description of the groups and/or activities that took place at the Walworth County WICST site in 1992:

As an integral part of the annual pesticide certification training for private pesticide applicators, the WICST project is highlighted as a forum that offers alternatives to total dependence on chemical control of crop pests.

Individuals from the Walworth County Land Conservation Committee, the Federal ASCS staff, and the Soil Conservation Service have taken an active role in attending and supporting the activities at the site.

Walworth County Board members also continue to take an active role by attending the events held at the site as well as within the county government structure.

A newsletter co-authored by Lee Cunningham, University Extension Agent, Greg Blum ASCS Director, Greg Igl, SCS Director, and Lou Olsen, Land Conservation Director, goes to over 1300 active farmers in the county each month.

Twenty-one Elementary Teachers have been involved in discussions about the benefits the WICST project has to offer them in the classroom as well as site visits. As a result of the Sustainable Agriculture teaching unit many students have benefitted both from the classroom activities as well as on-site field trips where hands-on activities have been carried out.

* Walworth County UW-Extension Agri/Business Agent.

** Michael Fields Agricultural Institute Agronomist.

Individual producer contacts has been very rewarding for both the farmers, as well as the Extension Agent. Meaningful discussions can take place in the middle of the WICST project. Being in the field adds to the exchange of ideas.

The annual WICST fall field day was well attended. Emphasis was once again put on the participants having the freedom to pick and choose what topics they wanted to spend the most time at. This format has added to the opportunity for more in-depth exchanges to take place between field day presenters and participants.

Extension Agents from other counties have also taken advantage of the opportunity to share ideas and expertise as they have toured the WICST site on various occasions.

Other contacts have also been made directly by the Michael Fields Agricultural Institute. The following is a sample of these additional outreach activities:

Michael Fields Agricultural Institute (MFAI) made extensive use of the WICST Project as part of it's on-going educational programs in 1992. These events included workshops, field days, conferences, meetings, and site visits. Audiences attending these events included farmers and agricultural specialists interested in sustainable systems; consumers and marketers concerned with food safety, health and nutrition; teachers and students studying ecological systems; and many individuals interested in the environmental implications of farming systems. The WICST Project received enthusiastic support from all of these audiences.

Five workshops or Field Days sponsored by MFAI included reports and/or discussions of WICST Project issues, objectives and progress. These were:

1. Toward a Sustainable Agriculture Workshop, co-sponsored by the Wisconsin Rural Development Center for high school FFA students and teachers from East Troy and Oconomowoc.
2. The annual MFAI Urban-Rural Workshop addressing common issues for farmers and consumers.
3. The Krusenbaum Farm Field Day co-sponsored by MFAI and UW-Madison and focussing on issues of beginning farmers and conversion to organic systems.
4. The annual MFAI Research Reporting Day attended by farmers, research and extension specialists and other interested individuals.
5. The Sustainable Farmers Education Network Farm Management Workshop.

MFAI staff also coordinated many visits to the Walworth County WICST Site for various groups and individuals interested in the project. For example: about 90 students, teachers and parents from the Cambria-Friesland Junior High School Science Classes visited the trials as part of a field trip to enhance a unit on ecology. A group of farm managers and agronomists from Russia, Moldova, Ukraine, Lithuania, and Hungary visited and were very enthusiastic about the implications this type of research could have on the major changes occurring in agriculture in their countries.

Christine Jurzykowski, director of the Fossil Rim Wildlife Center in Glen Rose, Texas visited the trial site to discuss the effects of farming systems on wildlife habitat.

Presentations of results and progress from WICST were given by MFAI staff at numerous meetings and field days during the year. Some examples include: The Monroe, WI FFA Chapter Field Day, the Rock County Farm Sustainable Agriculture Demonstration Project Field Day, Sustainable Agriculture Conference held in Kursk, Russia.

Table 48. 1992 LAKELAND AG COMPLEX/WICST CONTACTS

	<u>No. of participants</u>
Farmers through Pesticide Certification Classes	72
Committee Members of Land Conservation, ASCS, and Soil Conservation Service	14
County Board Members	26
Farmers through "Your Partners in Farm Business" Newsletter	1300
Elementary School Teachers	21
Elementary Students	391
Out of State Elementary Students	51
High School Students	542
College Students	16
FFA Alumni	17
Individual Farmer Contacts	128
WICST Fall Field Day	189
Rodale Institute Participants	67
Vocational School Instructors	2
High School Ag Teachers	6
International Ag Professionals	18
Out of State Farm Bureau Group	68
County Ag Extension Agents	12
Tri-County Marketing Group	15
Seed Dealers	26
Outside Auditors	60
TOTAL 1992 CONTACTS	3041

B. Columbia County Committee: Annual Educational Outreach Report - 1992
 Raymond Saxby*, Paul Ehrhardt**, and Lee Gross***

The WICST has continued to gain in popularity as data becomes available. The audience has become much more diversified, (Table 49) both locally and from the scientific community.

In early June a Mechanical Weed Control Field Day created a lot of interest. This was a field day prompted by the weed control options being tested on the trial field. A large percentage of those present were area farmers. Several crop consultants were also in attendance. Their presence will have a multiplier effect in getting more non-chemical weed control on farms out of the immediate area of Columbia and Dane counties.

The activity that drew the largest group for the second straight year was the "Ducks and Butter" twilight meeting. This program meets one of our primary objectives of informing the general public about research that is being conducted with an emphasis on farming practices that protect the environment. The audience was a good mix of farmers, urban members of the Audubon Society and youth. The highlight of this program was an activity involving the youth. Children between the ages of four to eight were given insect sweep nets and they then went into the field and collected insects. They were then assisted in identifying the insects they collected and determined which were "good" insects and which were "bad" insects for the crop. They also determined that there were different insects in different crops. The youth also had their own program in a soil pit, looking at earthworm holes, roots, and different kinds of rocks and their properties.

Another group that visited the trial that can have a great deal of impact statewide were the High School Agriculture Education Teachers and Vocational-Technical and Adult Education Farm Trainers. This group emphasized the rotational grazing system that is being studied.

One of the farmers that is participating in the On-Farm Demonstration phase of the project, hosted the Columbia County Annual Forage Council Field Day. Thirty seven farmers and agri-business men discussed and viewed a field where we are attempting to no-till corn into an annual alfalfa stand. This demonstration is a two year rotation of corn and annual alfalfa. We hope to determine if we can get adequate yield from the annual alfalfa and it turn fix enough nitrogen to grow the next years corn crop. Is this system economical and will it provide adequate yield to feed the dairy herd? This field is determined "highly eroded land" and therefore no-till practices to establish both crops were implemented.

There have also been several foreign educators and students that have been very interested in the research design and the variables we are trying to measure. Traditionally, research programs have not focused on the environmental impact of agricultural systems nor attempted full rotation economic analysis. They are very interested in the "sustainable agriculture-environmental soundness" aspect of this study.

* Columbia County Agricultural Agent.

** Farm Superintendent, Arlington UW-Research Station.

*** Dane County Agricultural Agent.

Table 49. Educational Activity Listing For Columbia County

	<u>No. of Participants</u>
- Mechanical Weed Control Field Day	90
- International Farm Trainees	45
- Bolivian Graduate Students	9
- Farming The Prairie For Ducks and Butter (2nd annual)	165
- High School Agriculture Educators and VTAE Farm Trainers	40
- Visitors from Finland and Austria	5
- International High School Students	90
- Norwegian Agriculture Students	2
- Illinois Farm Bureau Young Farmers	50
- UW Librarians	15
- Columbia County Forage Council Field Day	37
- Visiting McClay Fellow	1
- Individual Contacts Off Site	22
Total Contacts	<u>571</u>

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APPENDIX II.**Energy Use and Output/input Ratios on the Wisconsin Integrated Cropping Systems Trial
Josh Posner, Tom Mulder*, and Hany Tageldine****

Interest in the consumption of non-renewable energy in agriculture is an issue that waxes and wanes in importance. The sudden price rise of oil in the early 1970's spawned a number of studies on the use of energy in agriculture (Pimentel, 1973; Heichel, 1973). Energy however, remained relatively cheap, and high energy based technologies continued to be developed. More recently, in 1990, farmers were concerned with the effect of the impending conflict in the Middle East on natural gas prices for drying corn during the wet fall. That winter, during Operation Desert Storm fertilizer dealers were not quoting prices for anhydrous ammonia for delivery in the spring. When prices didn't rise, interest again waned, but most recently the President's proposed BTU tax has farmers and researchers again thinking about energy use in agriculture.

Predicted energy use in the six rotations of Wisconsin Integrated Cropping Systems Trial was estimated by using published tables on the energy required to produce agricultural inputs (Pimentel, 1980; Stout, 1984) and the Minnesota Farm Machinery Economic Cost Estimates (1992) for fuel use estimates. Some of the key conversions to energy consumption are summarized in Table II.1.

In order to build predicted energy use and output/input ratios, three theoretical issues were addressed by the team:

1. Only the fuel cost in spreading manure is counted as an input in rotations 4 and 5. The energy content of the manure or the equivalent energy value of the nutrients in the manure were not considered as external inputs to the cropping system on a dairy farm.

2. We assumed that in an average year in the upper Midwest, farmers using full season corn hybrids would have to dry their corn to 15.5 % from an average harvest moisture of 23%.

3. The energetic value of the cropping system output was calculated on a total energy basis, not metabolic energy for either cows or humans. In this way the numbers were standardized, regardless of end use of the agricultural product.

Estimated energy use and the output/input ratios for the past three years are presented in Table II.2. As might be expected, the energy input in corn in rotations 1 and 2 is higher than the systems where no herbicides or nitrogen fertilizer is purchased (rotations 3 and 5). However, the yields are also higher so the output/input ratios in 1993 are nearly equivalent in all 4 corn systems. The large annual variation in energy inputs is due to the energy needed to dry the corn.

For example, in 1993 the energy used in this one post-harvest activity represented just over 50% of the total energy used to produce, harvest and store the crop.

With soybeans, there is little difference in energy use by production system. However, compared to corn, growing a legume like soybeans without a nitrogen fertilizer requirement and energy for drying results in a much lower energy requirements and higher output/input ratios.

* Project Coordinator and project manager, Agronomy Department, UW-Madison

** former graduate student, currently Agronomy Department, Cairo University, Egypt.

In the hay-based rotations, energy inputs during the seeding year are relatively high and hay output is modest. In fact, at LAC, poor seeding year harvests resulted in very low output/input ratios. During the haying years however, the only major energy input is for harvesting (approximately 4 gals/a/harvest) and output/input ratios are excellent. Overall, the output/input ratios during these first three years appear to be fairly variable. It will be necessary to wait until several cycles of the rotations have been completed before meaningful average numbers can be reported.

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

INPUTS

	<u>Kcal/lb</u>		<u>Kcal/lb a.i.</u>
Seed		Pesticides	
Corn	11275	Herbicides	
Soybean	3447	Atrazine, Extrazine	23186
Wheat	1365	Bladex	24376
Oats	1867	Lasso, Confidence	32710
Red Clover	17093	Treflan	35170
Alfalfa	28009	Roundup, Ranger	51759
Timothy	9480	Basagran, Eptam	45414
Orchard Grass	9839	Lexone, Assure (same as Treflan)*	35170
(P 32 CRC Pimentel)		Poast, Poast Plus, Classic, Pinnacle,	
		Harmony (same as Roundup)*	51759
Fert		2,4-D	30505
82-0-0	4473	Banvel	34550
28-0-0	1849	Crop oil (same as diesel fuel)*	43145
6-24-24	903	Insecticides	
4-10-10	476	Granules (Counter)	33773
0-34-0	464	Wettable Powder (Lorsban, Malathion)	27941
0-0-60	436	(P 47 CRC Pimentel)	
(P 24 CRC Pimentel)			

Drying 756 Kcal (3000 BTU) to remove 1 lb H₂O
 lb H₂O/bu - Table 6.8 Grain Drying, Handling and Storage Handbook (Midwest Plan, 1987)

Fuel 43145 Kcal/gal (P 15 CRC Pimentel)

Fuel requirements for specific field operations

chisel plowing - 10'	.91 gal/A
corn planting - 6 row 30"	.75 gal/A
rotary hoeing - 15'	.20 gal/A
Row-cultivation - 15'	.15 gal/A
Manure spreading - 225 bu	1.52 gal/A
Forage harvesting (haylage)	3.72 gal/A
Corn Harvesting - 6 row 30"	1.97 gal/A

(Minnesota Farm Machinery Economic Cost Estimates for 1992)

OUTPUTS**

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

* No available data - estimated energy values.

** Kcal/g (fat - 9.45, prot - 5.65, carbo - 4.1) -Table 7.1 Nutr Req for Dairy Cattle (1989)

Table II.2. Energy Use (Mcal/A) and Output/Input Ratios During the First Three Years of the WICST.

		<u>Arlington Res. Station</u>			<u>Lakeland Ag. Complex</u>		
		<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>
Corn							
R ₁	Mcal/A	2808	2173	3138	1873	1343	2800
	O/I	5.6	7.0	4.4	8.4	8.6	4.0
R ₂	Mcal/A	-	1971	3085	-	1532	3127
	O/I	-	9.0	4.6	-	9.0	3.8
R ₃	Mcal/A	-	-	2551	-	-	1755
	O/I	-	-	3.7	-	-	4.0
R ₆	Mcal/A	-	-	2692	-	-	2181
	O/I	-	-	4.0	-	-	4.5

Soybeans

R ₂	Mcal/A	481	548	635*	573	494	470
	O/I	15.5	14.1	10	13.4	14.1	13.1
R ₃	Mcal/A	448	420	494	494	465	508
	O/I	14.3	14.4	9.5	12.8	14.4	12.6

* Used corrected treatment yield and inputs - see section I.

Seeding Year of Forage Rotations

R ₄	Mcal/A	1838	2014	1728	1334	1420	1604
	O/I	8.9	9.4	8.0	0	1.25	2.7
R ₆	Mcal/A	1246	987	1065	926	977	883
	O/I	12.0	11.8	9.3	3.8	8.7	11.9
R ₆	Mcal/A	1573	-	-	1106	-	-
	O/I	10.1	-	-	0	-	-

Established Forage Years

R ₄ HayI	Mcal/A	-	730	481	-	630	642
	O/I	-	30.9	27.6	-	23.7	21.9
R ₄ HayII	Mcal/A	-	-	816	-	-	708
	O/I	-	-	18.8	-	-	19.4
R ₆ HayI	Mcal/A	-	695	481	-	865	642
	O/I	-	32.5	41.3	-	15.6	21.0
R ₆	Mcal/A	-	547	810	-	321	**
	O/I	-	32.9	13.3	-	40.5	**

** Rotational Grazing

Appendix III.A. Lakeland Agricultural Complex WICST Input/Output Data - 1992
Corn treatments

Crop-92 Prev Crop Rotation Treatment Plot #'s	Cont. Corn Corn R1 1 101,210,303,401	Corn Soybean R2 2 108,203,304,409	Corn Wheat/RC R3 5 107,205,307,406	Filler Corn Filler Corn R4 10 112,214,301,403	Corn Alfalfa R5 11 106,211,312,413
Primary Tillage	Chisel Plow 5/2/92 ^{1/}	No-till	Chisel Plow 5/5/92	Chisel Plow 5/2/92 ^{1/}	Chisel Plow 5/5/92 ^{1/}
Secondary Tillage	Tilloll 5/6/92	None	Tilloll 5/6/92	Tilloll 5/6/92	Tilloll 5/6/92
Planting Date	5/8/92	5/8/92	5/8/92	5/8/92	5/8/92
Variety	Pioneer 3758	Pioneer 3758	Pioneer 3758	Pioneer 3758	Pioneer 3758
Planting Rate	32,000	32,000	32,000	32,000	32,000
Fertilizer Starter	10.2 gal(109 lb)/A of 4-10-10	10 gal (107 lb)/A of 4-10-10	None	None	None
Nitrogen	167 lb/A of 82-0-0 7/6/92	40 gal (426 lb)/A of 28-0-0 7/6/92	45 lb/A N as Red Clover	30 gal (320 lb)/A of 28-0-0	None
Manure	None	None	None	None	15 Ton/A 4/14/92 ^{1/}
Pesticides	Lasso 2 qt/A Extraz. II DF 2.5 lb/A pre 5/18/92 Counter 15G 9 lb/A planter applied	Lasso 1.3 qt/A Bladex 1.7 qt/A pre 5/18/92	None	Lasso 1.3/qt A Bladex 1.7 qt/A pre 5/18/92 Counter 15G 9 lb/A planter applied	None
Rotary Hoe	None	None	#1 5/25/92 #2 6/8/92	None	#1 5/25/92 #2 6/8/92
Cult.	S-tine 7/6/92	No-till 7/6/92	No-till 6/18/92	S-tine 7/10/92	No-till 6/18/92
Fall Practices	Chisel Plow 12/19/92	Chisel Plow 12/19/92	Chisel Plow 12/19/92	20 T/A manure 12/18/92 Chisel Plow 12/19/92	15 T/A manure 12/18/92 Chisel Plow 12/19/92
Harvest ^{2/}	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92
Yield	119 bu/A	126 bu/A	73 bu/A	109 bu/A	102 bu/A
Crop-93	Corn	NR Soybean	WR Soybean	D.S. Alfalfa	Oats/Alfalfa

^{1/} Wet weather prevented fall chisel plowing and manure application in 1991.

^{2/} rep #1 harvested 11/19

Appendix III.B. Lakeland Agricultural Complex WICST Input/Output Data - 1992
Soybean and Wheat treatments

Crop-92	Narrow Row Soybean	Wide Row Soybean	Wheat/ Red Clover
Prev. Crop	Corn	Filler Corn	Soybean
Rotation	R2	R3	R3
Treatment	3	4	6
Plot #'s	113,206,311,410	109,204,308,404	111,208,306,407
Primary	Chisel Plow 5/4/92 ^{1/}	Chisel Plow 5/4/92 ^{1/}	None
Secondary Tillage	Tilloll 5/6/92	Tilloll 5/6/92	None
Planting Date	5/11/92	5/11/92 SB 9/27/92 Wh	9/12/91 W Wheat 3/14/92 Rd Clov 4/2/92 S Wheat
Variety	Pioneer 9272	Pioneer 9272 SB Caldwell wheat	Caldwell Wheat Arlington RC Marshall wheat
Planting Rate	75 lb/A	61 lb/A SB 180 lb/A Wh	180 lb/A 12 lb/A 100 lb/A ^{2/}
Fertilizer	None	None	None
Pesticides	Poast Plus 1.5 pt/A Classic .25 oz/A Harmony .08 oz/A 28% N - 1 gal/A post 6/22/92	Poast Plus 1.5 pt/A ^{3/} post 6/22/92	None
Rotary Hoe	None	5/25, 6/5	None
Cult.	None	S-tine 7/6/92	None
Harvest	10/13/92	10/13/92	8/13/92 wheat
Fall Practices	None	aerial seeding wheat 9/27/92	None
Yield	47 bu/A	52 bu/A	26 bu/A ^{4/} 1.8 T DM/A red clover
Crop-93	Corn	Wheat/ Red Clover	Corn

^{1/} (T3 & T4) Wet weather prevented fall chisel plowing in 1991

^{2/} Spring wheat was not planted where stand of winter wheat was good

^{3/} Herbicide applied since a delayed rotary hoeing allowed weed escapes

^{4/} Wheat was short - no straw harvested

Appendix III.C. Lakeland Agricultural Complex WICST Input/Output Data - 1992**Forage treatments**

Crop-92	D. Seeded Alfalfa	Estab. Alfalfa I	Estab. Alfalfa II	Oats/ Alfalfa	Estab. Alfalfa I	Pasture
Prev. Crop	Corn	D.S. Alf.	Alfalfa I	Corn	Oats/Alf.	Pasture
Rotation	R4	R4	R4	R5	R5	R6
Treatment	9	8	7	13	12	14
Plot #'s	110,212,302,414	102,209,305,402	103,202,310,411	114,201,313,405	105,207,309,412	104,213,314,408
Primary Tillage	Chisel Plow 4/14/92 ^{1/}			Chisel Plow 4/14/92 ^{1/}		
Secondary Tillage	Tilloll (2X) 5/2/92	^{2/}	^{2/}	Tilloll (2X) 5/2/92		
Planting Date	5/4/92	4/26/91	5/30/90	5/2/92	4/26/91	5/30/90
Variety	Magnum III	Magnum III	Magnum III	Horicon-oats Magnum III-alf.	Magnum III	Timothy-Toro Brome-Badger RC-Marathon
Planting Rate	16 lb/A			64 lb/A oats 16 lb/A alfalfa		
Fertilizer Manure	20 ton/A 4/10/92 ^{1/}	None	None	15 ton/A 4/14/92 ^{1/}	None	10 ton/A 4/14/92 ^{1/}
Pesticides	Eptam 2 qt/A ppi	None	None	None	None	None
Harvest	7/1/92 haylage ^{3/} 7/28/92 haylage	5/28/92 haylage 6/30/92 haylage 7/28/92 haylage 9/22/92 ^{2/}	5/26/92 haylage 6/30/92 haylage 7/28/92 haylage 9/22/92 ^{2/}	8/26/92 oats 9/20/92 straw	5/26/92 haylage 6/30/92 haylage 7/28/92 haylage 9/22/92 ^{2/}	Int. Rot. Grazing 4/30 - 10/14/92 baled hay ^{4/}
Fall Practices			20 T/A manure 12/22/92		15 T/A manure 12/22/92	
Yield	1.1 T DM/A	3.7 T DM/A	3.6 T DM/A	48.5 bu/A oats 2.4 T DM/A straw	3.5 T DM/A	918 lb/A animal wt. gain
Crop-93	Alfalfa I	Alfalfa II	Corn	Alfalfa I	Corn	Int. Rot. Grazing

^{1/} Wet weather prevented fall chisel plowing and manure application in 1991.^{2/} No-till reseeded with 15 lb/A Arlington Red Clover on 4/29/92 due to winterkill.^{3/} (T9) Uneven germination and slow growth of direct seeded alfalfa delayed initial harvest.^{4/} (T7, T8 & T12) Wet weather after 4th cutting - spoiled forage chopped back onto field.^{5/} In reps I, III & IV spring growth of forage was more than the heifers could eat, excess was baled (average of .5 T DM/plot) and fed to the heifers.

Appendix IV.A. Arlington Research Station WICST Input/Output Data - 1992
Corn treatments

Crop-92 Prev Crop Rotation Treatment Plot #'s	Cont. Corn Corn R1 1 109,204,306,412	Corn Soybean R2 2 108,206,310,408	Corn Wheat/RC R3 5 106,202,307,411	Filler Corn Filler Corn R4 10 107,205,309,404	Corn Alfalfa R5 11 110,208,304,413
Primary Tillage	Chisel Plow Fall 1991	No-till	Chisel Plow Fall 1991	Chisel Plow Fall 1991	Chisel Plow Fall 1991
Secondary Tillage	Disk 5/5/92 Soil Finisher 5/5/92	None	Disk 5/5/92 Soil Finisher 5/11/92	Disk 5/5/92 Soil Finisher 5/5/92	Disk 5/5/92 Soil Finisher 5/11/92
Planting Date	5/5/92	5/5/92	5/12/92	5/5/92	5/12/92
Variety	DeKalb 547	DeKalb 547	DeKalb 547	DeKalb 547	DeKalb 547
Planting Rate	32,100	32,100	32,100	32,100	32,100
Fertilizer Starter	100 lb/A of 6-24-24	100 lb/A of 6-24-24	None	None	None
Nitrogen	165 lb/A of 82-0-0 5/4/92	146 lb/A of 82-0-0 5/4/92	125 lb/A N as Red Clover	177 lb/A of 82-0-0 5/4/92	None
Manure	None	None	None	None	15 Ton/A Fall 1991
Pesticides	Lasso 2 qt/A Extraz. II DF 2.5 lb/A 5/12/92 premerge Counter 15G 9 lb/A planter applied	Lasso 1.3 qt/A Bladex 1.7 qt/A 5/8/92 premerge	None accent (plot #307 and west 1/4 #106)	Lasso 2 qt/A Extraz. II DF 2.5 lb/A 5/7/92 premerge Counter 15G 9 lb/A planter applied	None
Rotary Hoe	None	None	#1 5/18/92 #2 5/22/92 #3 6/1/92	None	#1 5/18/92 #2 5/22/92 #3 6/1/92
Cult.	S-tine 6/10/92 6/19/92	S-tine 6/10/92 6/19/92	S-tine 6/19/92 6/30/92	S-tine 6/10/92 6/19/92	S-tine 6/19/92 6/30/92
Fall Practices	Chisel Plow 11/30/92	Chisel Plow 11/30/92	Chisel Plow 11/30/92	20 T/A manure 11/30/92 Chisel Plow 11/30/92	15 T/A manure 11/30/92 Chisel Plow 11/30/92
Harvest	11/18/92	11/18/92	11/18/92	11/18/92	11/18/92
Yield Bu. Wt.	144 bu/A 46 lb/bu	150 bu/A 45 lb/bu	99 bu/A 42 lb/bu	132 bu/A 46 lb/bu	112 bu/A 42 lb/bu
Crop-93	Corn	NR Soybean	WR Soybean	D.S. Alfalfa	Oats/Alfalfa

Appendix IV.B. Arlington Research Station WICST Input/Output Data - 1992
Soybean and Wheat Treatments

Crop-92	NR Soybean	WR Soybean\Wheat	Wheat/Red Clover
Prev. Crop	Corn	Filler Corn	Soybean
Rotation	R2	R3	R3
Treatment	3	4	6
Plot #'s	101,214,303,401	104,201,301,402	102,212,313,407
Primary	Chisel Plow Fall 1991	Chisel Plow Fall 1991	None
Secondary Tillage	Digger 5/9/92 Soil Finisher 5/10/92	Digger 5/9/92 Soil Finisher 5/10/92	None
Planting Date	5/14/92	5/14/92 SB 9/18/92 Wh	9/12/91 Wheat 3/11/92 Rd Clov 4/29/92 Spr. Wheat
Variety	Pioneer 9272 Ozzy 6/15/92 ^{1/}	Pioneer 9272 Caldwell wheat	Arlington RC Marshall Spr. Wheat
Planting Rate	90 lb/A	60 lb/A SB 180 lb/A wheat	12 lb Rd Clover 115 lb Marshall Wheat
Fertilizer	None	None	None
Pesticides	Treflan 1.5 pt/A Lexone DF .5 lb/A 5/12/92 ppi ^{2/}	None	None
Rotary Hoe	None	#1 5/20/92 #2 5/28/92 #3 6/3/92	None
Cult.	None	S-tine 6/17, 6/30/92	
Harvest	10/26/92	10/26/92	8/20/92 wheat 8/24/92 straw
Fall Practices	None	aerial seeding wheat 9/18/92	None
Yield	30 bu/A ^{2/}	38 bu/A	45 bu/A wheat 0.33 Ton/A straw 2.7 T DM/A red clover
Crop-93	Corn	Wheat/ Red Clover	Corn

^{1/} Planted skips in plot # 101

^{2/} Should have received post herbicide treatment for grasses and broadleaves

Appendix IV.C. Arlington Research Station WICST Input/Output Data - 1992**Forage Treatments**

Crop-92	D. Seeded Alfalfa	Estab. Alfalfa I	Estab. Alfalfa II	Oats/ Alfalfa	Estab. Alfalfa I	Pasture
Prev. Crop	Filler Corn	D.S. Alf.	Alfalfa I	Filler Corn	Oats/Alf.	Pasture
Rotation	R4	R4	R4	R5	R5	R6
Treatment	9	8	7	13	12	14
Plot #'s	105,203,308,406	113,210,311,414	111,209,305,409	114,211,312,403	103,213,314,410	112,207,302,405
Primary Tillage	Chisel Plow Fall 1991			Chisel Plow Fall 1991		Harrow 4/7/92
Secondary Tillage	Disk Soil Finisher 4/7/92	^{1/}	^{1/}	Disk Soil Finisher 4/7/92	^{2/}	Brillion Seeder
Planting Date	4/7/92	4/8/91 4/28/92 A.R.G. 7/31/92 Alfalfa	4/23/90 4/28/92 A.R.G. 5/5/92 Rd Clov	4/7/92	4/8/91	4/23/90 4/30/92 7/31/92
Variety	Magnum III	Magnum III Annual Rye Grass Olds 98 Alfalfa	Magnum III Annual Rye Grass Arlington Rd Clov	Horicon-oats Magnum III-alf.	Magnum III	Timothy-Toro Brome-Badger RC-Marathon
Planting Rate	15 lb/A	10 lb/A A.R.G. 12 lb/A Olds 98	10 lb/A A.R.G. 10 lb/A Rd Clov	15 lb/A alfalfa 64 lb/A oats		6 lb/A Orch Gr 12 lb/A Brome 6 lb/A Timothy Pltd 4/30/92 4.5 lb/A Orch Gr Pltd 7/31/92
Fertilizer		None	None		None	
Manure	20 ton/A Fall 1991			15 ton/A Fall 1991		
Pesticides	Eptam 2 qt/A	None	1 pt/A Banvel 1 pt/A 2,4-D 1 pt/A Round-up 9/30/92	None	None	None
Harvest	6/26/92 haylage 7/31/92 haylage 9/4/92 haylage	6/4/92 haylage 7/22/92 haylage 8/24/92 haylage	6/4/92 haylage 7/22/92 haylage 8/24/92 haylage	6/22/92 Oatlage 7/31/92 haylage	6/4/92 haylage 7/22/92 haylage 8/24/92 haylage	6/10/92 Haylage 7/28/92 Haylage
Fall Practices			20 T/A manure 11/30/92 Chisel Plow 11/30/92		15 T/A manure 11/30/92 Chisel Plow 11/30/92	10 ton/A 10/4/92
Yield	3.6 T DM\A	3.5 T DM\A	4.0 T DM\A	1.4 T DM\A Oatlg 1.2 T DM\A Haylg	5.2 T DM\A	2.8 T DM\A
Crop-93	Alfalfa I	Alfalfa II	Corn	Alfalfa I	Corn	Pasture

^{1/} Reseeding due to winterkill with no-till drill^{2/} Plots 103 and 213 disked by mistake on 4/7/92 and no-till interseeded with 10 lb/A Arlington Red Clover.

Appendix V.A. WICST Economics - Corn (R1 and R2) - Arlington

Rotation: 1 (Continuous Corn)				
Crop: Corn		Site:	Arlington	
Year: 1992		Plots:	Average across 4 plots	

I.	Gross Returns (\$/Acre) :			Dollars
	Product	Yield	Unit	Price per acre
	Corn @15.5%	144.05	Bu	1.85 266.50
	Total			\$266.50

II.	Direct Costs (\$/Acre) :		Price or	Dollars
	Input	Amount	Unit	Factor per acre
	Seed (DK547)	0.40	Bag	67.99 27.28
	Anhydrous	153.75	Lb	0.11 16.14
	Starter	100.00	Lb	0.08 8.40
	Lasso	2.00	Qt	5.88 11.75
	Atrazine 4L	0.68	Qt	2.64 1.78
	Counter	9.00	Lb	1.52 13.68
	Bladex 4L	1.33	Qt	5.19 6.90
	Drying 2¢/pt (from 32.2%	144.05	Bu	0.34 48.40
	Fuel	9.00	Gal.	0.70 6.30
	Repairs	1.00	\$	16.85 16.85
	Interest	157.48	\$	0.060 9.45
	Total			\$166.93

III.	Gross Margin (\$/Acre) :			\$99.56

Rotation: 2 (Corn-Soybeans)				
Crop: Corn		Site:	Arlington	
Year:1992		Plots:	Average across 4 plots	

I.	Gross Returns (\$/Acre) :			Dollars
	Product	Yield	Unit	Price per acre
	Corn @15.5%	150.35	Bu	1.83 275.14
	Total			\$275.14

II.	Direct Costs (\$/Acre) :			Dollars
	Input	Amount	Unit	Price or Factor per acre
	Seed (DK 547)	0.40	Bag	67.99 27.28
	Anhydrous	146.00	Lb	0.11 15.33
	Starter	100.00	Lb	0.09 8.56
	Lasso	1.30	Qt	5.86 7.61
	Bladex	1.70	Qt	5.19 8.82
	Drying 2¢/pt (from 33.2%	150.35	Bu	0.37 53.46
	Fuel	7.13	Gal.	0.70 4.99
	Repairs	1.00	\$	15.77 15.77
	Interest	141.84	\$	0.060 8.51
	Total			\$150.33

III.	Gross Margin (\$/Acre) :			\$124.81

Appendix V.A. WICST Economics - Soybeans (R2 and R3) - Arlington

Rotation: 2 (Corn-Soybeans)

Crop: Soybeans (NR)

Year: 1992

Site: Arlington

Plots: Average across 4 plots

I. Gross Returns (\$/Acre) :					Dollars
Product	Yield	Unit	Price		per acre
Soybeans @13%	48.50	Bu	5.14		249.29
Total					\$249.29

II. Direct Costs (\$/Acre) :					Dollars
Input	Amount	Unit	Price or Factor		per acre
Seed (P9272)	90.00	Lb	0.30		26.73
Lexone	0.50	Lb	22.73		11.37
Treflan	1.50	Pt	3.49		5.24
Poast	1.50	Pt	14.07		21.11
Basagran	1.00	Qt	14.22		14.22
Crop Oil	1.00	Qt	0.83		0.83
Fuel	3.14	Gal.	0.70		2.19
Repairs	1.00	\$	10.51		10.51
Interest	92.19	\$	0.060		5.53
Total					\$98.49

III. Gross Margin (\$/Acre) :	\$150.80
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Rotation: 3 (Corn/Soybeans/Wheat)

Crop: Soybeans (WRow) /Wheat

Year: 1992

Site: Arlington

Plots: Average across 4 plots

I. Gross Returns (\$/Acre) :					Dollars
Product	Yield	Unit	Price		per acre
Soybeans @13%	38.00	Bu	5.14		195.32
Total					\$195.32

II. Direct Costs (\$/Acre) :					Dollars
Input	Amount	Unit	Price or Factor		per acre
Seed Pioneer 9272	60.00	Lb	0.30		17.82
Fuel	6.65	Gal.	0.70		4.66
Repairs	1.00	\$	12.39		12.39
Interest	34.87	\$	0.060		2.09
Total					\$36.96

III. Gross Margin (\$/Acre) :	\$158.36
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Appendix V.A. WICST Economics - Wheat/Clover (R3) and Corn (R3) - Arlington

Rotation:3 (Corn/Soybeans/Wheat)

Crop: Wheat/Clover

Year:1992

Site: Arlington

Plots: Average across 4 plots

I.	Gross Returns (\$/Acre) :			Dollars
	Product	Yield	Unit	Price per acre
	Wheat @13%	45.23	Bu	2.75 124.37
	Straw	0.34	T	50.00 16.75
	Total			\$141.12

II.	Direct Costs (\$/Acre) :			Dollars
	Input	Amount	Unit	Price or Factor per acre
	Wheat Seed (Caldwell)	3	Bu	7.50 22.50
	Wheat Seed (Marshall)	115	Lb	0.20 23.00
	RedClover	12	Lb	1.15 13.80
	Cus Aerial	1	Pass	10.50 10.50
	Fuel	3.79	Gal.	0.70 2.65
	Repairs	1.00	\$	11.47 11.47
	Interest	83.92	\$	0.060 5.04
	Total			\$88.96

III.	Gross Margin (\$/Acre) :			\$52.16

Rotation:3 (Corn/Soybeans/Wheat)

Crop: Corn

Year:1992

Site: Arlington

Plots: Average across 4 plots

I.	Gross Returns (\$/Acre) :			Dollars
	Product	Yield	Unit	Price per acre
	Corn @15.5%	99.15	Bu	1.77 175.50
	Total			\$175.50

II.	Direct Costs (\$/Acre) :			Dollars
	Input	Amount	Unit	Price or Factor per acre
	Seed (DK-547)	0.40	bag	67.99 27.28
	Accent (1/4 of plot)	0.08	oz	11.82 0.98
	Drying 2¢/pt (from 42%)	99.15	Bu	0.53 52.74
	Fuel	7.73	Gal.	0.70 5.41
	Repairs	1.00	\$	15.06 15.06
	Interest	101.46	\$	0.060 6.09
	Total			\$107.55

III.	Gross Margin (\$/Acre) :			\$67.55

Appendix V.B. WICST Economics - Corn (R1 and R2) - Walworth Co.

Rotation: 1 (Continuous Corn)				
Crop: Corn		Site:	Walworth Co	
Year: 1992		Plots:	Average across 4 plots	

I.	Gross Returns (\$/Acre) :			Dollars
	Product	Yield	Unit	Price per acre
	Corn @15.5%	119.05	Bu	1.84 219.05
	Total			\$219.05

II.	Direct Costs (\$/Acre) :			Dollars
	Input	Amount	Unit	Price or Factor per acre
	Seed (Pioneer 3578)	0.40	Bag	73.11 29.24
	Anhydrous	167.00	Lb	0.10 16.53
	Starter (4-10-10)	10.20	Gal	0.62 6.30
	Counter	9.00	Lb	1.53 13.77
	Confidence (Lasso)	2.50	Qt	5.18 12.94
	Extrazine	2.00	Lb	3.81 7.62
	Drying 2¢/pt (from 32.5	119.05	Bu	0.34 40.71
	Fuel	7.07	Gal.	0.67 4.74
	Repairs	1.00	\$	15.86 15.86
	Interest	147.72	\$	0.060 8.86
	Total			\$156.58

III.	Gross Margin (\$/Acre) :			\$62.47

Rotation: 2 (Corn-Soybeans)				
Crop: Corn		Site:	Walworth Co	
Year:1992		Plots:	Average across 4 plots	

I.	Gross Returns (\$/Acre) :			Dollars
	Product	Yield	Unit	Price per acre
	Corn @15.5%	126.25	Bu	1.84 232.30
	Total			\$232.30

II.	Direct Costs (\$/Acre) :			Dollars
	Input	Amount	Unit	Price or Factor per acre
	Seed (Pioneer 3578)	0.40	Bag	73.11 29.34
	28% Nitrogen	40.00	Lb	0.62 24.80
	Starter (4-10-10)	10.00	Lb	0.59 5.90
	Lasso	1.30	Qt	5.62 7.31
	Bladex 90DF	1.70	Qt	4.64 7.89
	Drying 2¢/pt (from 35.5	126.25	Bu	0.42 52.90
	Fuel	4.07	Gal.	0.67 2.73
	Repairs	1.00	\$	13.10 13.10
	Interest	143.95	\$	0.060 8.64
	Total			\$152.59

III.	Gross Margin (\$/Acre) :			\$79.71

Appendix V.B. WICST Economics - Soybeans (R2 and R3) - Walworth Co.

Rotation: 2 (Corn-Soybeans)				
Crop: Soybeans (NR)			Site:	Walworth Co
Year:1992			Plots:	Average across 4 plots

I. Gross Returns (\$/Acre) :				Dollars
Product	Yield	Unit	Price	per acre
Soybeans @13%	46.90	Bu	5.35	250.92
Total				\$250.92

II. Direct Costs (\$/Acre) :			Price or	Dollars
Input	Amount	Unit	Factor	per acre
Seed (P9272)	75.00	Lb	0.26	19.19
Poast Plus	1.50	Pt	5.88	8.82
Harmony	0.08	Oz	36.66	3.06
Classic	0.25	Oz	16.42	4.11
28% Nitrogen	1.00	Gal	0.62	0.62
Fuel	4.31	Gal.	0.67	2.88
Repairs	1.00	\$	13.90	13.90
Interest	52.57	\$	0.060	3.15
Total				\$55.72

III. Gross Margin (\$/Acre) :				\$195.19

Rotation:3 (Soybeans/Wheat)				
Crop: Soybeans/WRow			Site:	Walworth Co
Year:1992			Plots:	Average across 4 plots

I. Gross Returns (\$/Acre) :				Dollars
Product	Yield	Unit	Price	per acre
Soybeans @13%	51.90	Bu	5.35	277.67
Total				\$277.67

II. Direct Costs (\$/Acre) :			Price or	Dollars
Input	Amount	Unit	Factor	per acre
Seed Pioneer 9272	60.80	Lb	0.26	15.55
Poast Plus	1.50	Pt	5.88	8.82
Fuel	6.76	Gal.	0.67	4.53
Repairs	1.00	\$	15.93	15.93
Interest	44.83	\$	0.060	2.69
Total				\$47.52

III. Gross Margin (\$/Acre) :				\$230.14

Appendix V.B. WICST Economics - Wheat/Clover (R3) and Corn (R3) - Walworth Co.

Rotation: 3 (Soybeans/Wheat)

Crop: Wheat/Clover

Year: 1992

Site: Walworth Co

Plots: Average across 4 plots

I. Gross Returns (\$/Acre) :				Dollars
Product	Yield	Unit	Price	per acre
Wheat @13%	25.70	Bu	2.64	67.85
Straw	0.00	T	0.00	0.00
Total				\$67.85

II. Direct Costs (\$/Acre) :			Price or	Dollars
Input	Amount	Unit	Factor	per acre
Wheat Seed (Cardinal)	180.00	Lb	0.10	17.82
RedClover (Arlington)	18.90	Lb	1.18	22.30
Cus Aerial	1.00	Pass	9.00	9.00
Wheat Seed (Marshall)	102.00	Lb	0.14 (1plo	3.57
Fuel	3.20	Gal.	0.67	2.14
Repairs	1.00	\$	12.08	12.08
Interest	64.22	\$	0.060	3.85
Total				\$68.07

III. Gross Margin (\$/Acre) :	(\$2.92)
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Rotation: 3 (SB/Wheat/Corn)

Crop: Corn

Year: 1992

Site: Walworth Co

Plots: Average across 4 plots

I. Gross Returns (\$/Acre) :				Dollars
Product	Yield	Unit	Price	per acre
Corn @15.5%	72.98	Bu	1.84	134.27
Total				\$134.27

II. Direct Costs (\$/Acre) :			Price or	Dollars
Input	Amount	Unit	Factor	per acre
Seed (Pioneer 3578)	0.40	Bag	73.11	29.34
Drying 2¢/pt (from 38.5	72.98	Bu	0.46	33.72
Fuel	7.90	Gal.	0.67	5.29
Repairs	1.00	\$	15.59	15.59
Interest	83.94	\$	0.060	5.04
Total				\$88.97

III. Gross Margin (\$/Acre) :	\$45.30
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