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NET RETURNS OF VARIABLE CORN AND SOYBEAN CROPPING SYSTEMS

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FOREWARD

This thesis is written as an manuscript to be submitted to the Journal of Production Agriculture. It is followed by appendixes containing information about soil and plant nutrients not directly referred to in the manuscript.

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## ABSTRACT

Com and soybean grown in sequence is one of the most popular cropping systems in the United States; the com-soybean rotation has enormous importance economically.

The "rotation effect" is known to increase yields of both crops, but little is known about the economic consequences of various corn-soybean rotational patterns compared with monoculture. This study was undertaken to determine the most profitable com-soybean cropping pattern for Minnesota, based on both actual and sensitivity price analyses. Rotations investigated were: corn monoculture, soybean monoculture, corn grown after two years of soybean, soybean grown after two years of com, and an annual alternation of the two crops. The field study was conducted at three locations: Lamberton, Rosemount and Waseca, MN. Lamberton and Waseca are positioned within the "com belt," whereas Rosemount is positioned beyond the northerly fringe. Actual analysis (1984-1989) indicated that com following two years of soybean was the most profitable cropping system at both com-belt locations. At Rosemount there was no clear net-return pattern. Averaged over all locations, com following two years of soybean was definitely the most profitable cropping system however. Soybean monoculture provided the lowest average return, and com monoculture had the lowest return:operating cost ratio at all locations. Projection analysis indicated that com after two years of soybean would be the most profitable com-soybean rotation in the Minnesota com belt under all expected com or soybean price combinations. Com monoculture was projected to be the least profitable pattern, and soybean monoculture the second least profitable pattern. Prices did not include government supports.

## LITERATURE REVIEW - OBJECTIVES

In the United States, the annual rotation (alternation) of corn and soybean is a very common cropping system (Sundquist et al., 1982). Both corn and soybean yield better when grown on land previously sown to the other crop than when grown continuously (Higgs et al., 1976; Slife, 1976; Peterson and Varvel, 1989a and 1989b). In long term studies conducted at Waseca and Lamberton, Crookston et al. (1990) found that compared with monoculture, either corn or soybean yielded an average of 8% better when alternated and about 16% better when kept out of monoculture for at least two years.

Early in the 20th Century, Amy (1917) reported a higher net income per acre from corn grown after legumes than grown continuously. Later, Curtiss (1926) demonstrated that a rotation of four or five years was of more value than a shorter three-year rotation which was definitely preferable to a two-year system or to continuous cropping. Recently, the beneficial effect of rotation versus continuous monoculture of corn and soybean has been estimated in the U.S. to be worth at least 300 million dollars annually (Sundquist et al., 1982). Crookston (1984) has shown that Minnesota farmers can raise their net profit on corn and soybean by as much as 50% from properly exploiting the rotation effect. Daniel and Mueller (1986) found that corn-soybean rotation increased the net profit in the corn year and in the soybean year by \$36.00 and \$20.00 per acre, respectively. In contrast, Voss and Shrader (1979) reported that continuous corn was among the most profitable systems, depending on the economic values assigned to the crops. Lazarus et al. (1980) found greater annual returns from continuous corn than from a rotational corn-soybean system.

Conflicting results about the economics of corn-soybean rotation systems justified a closer look at the rotation effect, particularly in terms of net return to the farmer. The first objective of this study was to compare the profitability of five different corn-soybean

cropping sequences over the six-year period 1984-1989 in Minnesota. The second objective was to predict the most profitable Minnesota corn-soybean cropping pattern for the foreseeable future via simulated scenarios based on expected fluctuations in commodity prices.



## MATERIALS AND METHODS

A six-year **crop** rotation study was established in 1984 at the Southwest Experiment Station at Lamberton, at the Rosemount Experiment Station, and at the Southern Experiment Station at Waseca, Minnesota. The soils at these locations are : Webster clay loam, Waukegan silt loam, and Nicollet clay loam, respectively. The corn hybrid was 'Pioneer Brand 3780' and the soybean variety was 'Hodgson 78'.

Each experimental area was chisel plowed each fall. Fertilizer N (urea or ammonium nitrate), P (superphosphate), and K (potash) were applied according to University of Minnesota soil test recommendations for maximum production of each crop. Herbicides: alachlor (lasso), linuron (lorox), and bentazon (basagran); and insecticides: carbofuran (furadan), terbutos (counter), and chlorpyrifos (lorsban) were applied when necessary for weed and insect control.(appendix 1).

Five different corn and/or soybean cropping sequences (Table 1) were arranged in a randomized complete block design replicated four times. Each plot consisted of eight rows 30 feet long spaced 30 inches apart. There were four replications at each location each year. Grain yield was obtained by harvesting the two center rows from each plot. Yield values were corrected for moisture (reported at 15.5%, and 13.5% moisture for corn and soybean, respectively).

Investigating the economic implications of any agricultural practice requires research on the individual components of a farm, the whole farm, commodity markets, national and international agricultural economies,etc. (Madden and Dobbs, 1988). In accessing incentives to adopt crop rotation sequences, various factors must be accounted for. Complete enterprise budgets may include all fixed and variable cost and returns associated with the farm. According to Boehlje and Eidman (1984 ) "The distinction between fixed and variable costs is important in decision -making. Only variable costs should be

considered by the manager in deciding what to produce, how to produce and ‘how much to produce in the short run. Fixed costs **will** remain at the **same** level regardless of these decisions. Thus, neither **fixed** cash nor non cash costs should be considered in decision-making”.

Our approach was to deal with the operating costs and net returns associated with production activities of a typical Minnesota farm. We assumed that **crop sequence** was the only aspect of the farm that varied. **Such** an economic approach may suffice for decision-making in the **area** of adopting more valuable **crop sequences**. Operating costs **specifically** associated with either **corn** or soybean, and incurred for the production of that **crop** were considered. According to our particular situation, adjustments were made by accurately determining the **cost** of **fertilizer**, seed, herbicide, and insecticide (table 2). Other operating costs were taken from “What to grow in 1989” (Fuller et al., 1989) (table 3). **All** operating costs were based on 1989 **prices**. Revenue per acre was calculated on the basis of the yield of corn and / or soybean multiplied by the **product price**. Operating costs were **charged** against revenues to obtain per acre net returns. Statistical analysis was via the General Linear **Procedure** of Statistical Analysis System (SAS, 1985).

A variety of possible net return **scenarios** were also calculated for a range of corn and soybean **price** combinations. **Price** combinations were based on corn and soybean **prices** for the 15-year period 1975 to 1989; costs and expenses were maintained at 1989 levels.

## RESULTS AND DISCUSSION

### Economic analysis based on 1989 dollar value

The annual grain yield of the five cropping systems are given in table 4. Enterprise budgets for the six year period 1984- 1989 were based on actual yields of corn and soybean grain for each year, and on the 1989 prices for corn and soybean of \$2.40 and \$5.85 per bushel, respectively. Operating costs were also fixed at 1989 values.

Over the six years, returns at Lamberton ranged from \$140 per acre per year for continuous soybean to \$188 per acre per year for corn grown after two successive years of soybean (Table 5). Corn following two years of soybean provided a significantly greater return than any other cropping system. Returns obtained from corn monoculture, alternated corn and soybean, and soybean grown after two years of corn were not significantly different. Soybean monoculture provided the lowest return.

Waseca results were similar to those obtained at Lamberton. Returns varied from \$91 per acre per year for soybean grown after two years of corn, to \$155 per acre per year for corn grown after two years of soybean. Corn after two years of soybean provided a significantly greater return than any other cropping system. There were no significant differences among the remaining cropping patterns.

At Rosemount, returns ranged from \$118 per acre per year for continuous soybean to \$147 per acre per year for the alternate corn-soybean system (Table 5). Continuous corn and an annual rotation of corn and soybean provided nearly equally high returns; continuous soybean provided the lowest return. Over all locations, returns ranged from \$119 per acre per year for continuous soybean to \$160 per acre per year for corn following two years of soybean (Table 5). Corn after two years of soybean returned \$33 per acre per year more than the average of all other sequences. Continuous soybean was the least profitable system and returned \$24 per acre per year less than the average of all other sequences. The difference between the most profitable system (SSCSSC) and the least

profitable system (SSSSSS) was \$46 per acre.

The fact that results from Rosemount were so different from the other two locations is worthy of some discussion. Rosemount is located north of the other two sites, and has a strikingly different soil type (appendix 2). Soils at the three locations are classified as follows: Lamberton, Webster clay loam (fine, loamy, mixed, mesic Typic Haplaquoll), Waseca, Nicollet clay loam (fine, loamy, mixed, mesic Aquic Hapludoll) ; Rosemount, Waukegan silt loam (fine, silty over sandy, skeletal, mixed, mesic Typic Hapludolls) ). Soil depth at both Lamberton and Waseca is greater than 6 feet, whereas soil depth at Rosemount is about 20 inches below. Lamberton and Waseca are located well within the “com-belt” region of Minnesota, whereas Rosemount lies beyond the northern fringe. The Lamberton and Waseca results thus represent typical com-belt soil and climatic conditions, whereas the Rosemount results better represent more marginal conditions.

Corn after two successive years of soybean was the most profitable cropping sequence at both Lamberton and Waseca. Hesterman et al. (1987) demonstrated higher gross margins for corn and soybean in rotation than for continuous corn at these same locations. Results obtained by some authors have shown that gross returns were significantly influenced by rotation in comparison with monoculture (Zetner and Campbell, 1988; Jansen et al., 1987). Our results contradict those of Lazarus et al. (1980) who concluded that monoculture of corn was more profitable than rotation.

To estimate the relative efficiency of each cropping sequence, we calculated return/operating-cost ratios (Table 6). A low value for this ratio represents a situation which could contribute to cash flow problems for some farmers. At Rosemount, for example, returns from continuous corn, alternate corn-soybean, and corn after two years of soybean were quite low. Continuous corn had the lowest return/operating cost ratio for all locations (Table 6). If credit is limited, farmers would certainly consider crops with highest net return-operating cost ratios, which give enough net return to cover operating costs incurred.

### Sensitivity analysis based upon combinations of com and soybean prices

The average returns in Table 5 were based on actual yields, prices and costs during the period 1984-1989. While these returns may be of interest from a historical standpoint, they are of limited value in projecting future returns even from these same cropping sequences in these same locations. In order to obtain some estimate of expected returns from com and soybean grown in various sequence combinations on these sites in the future, we developed several expected-return scenarios based on projected yields and prices at these sites. Yields for the scenarios were the yields from this six-year (1984-1989) study. Costs were 1989 costs. Prices were derived from average com and soybean prices in Minnesota over the 15-year period 1975- 1989 (Table 7).

From Table 7, we chose the lowest (1986) price of \$1.46 per bushel, the highest (1983) price of \$3.05 per bushel, and a somewhat medium (1989) price of \$2.40 per bushel for com. We then used the 15-year average soybean:corn ratio of 2.7 for a medium ratio. High (3.2) and low (2.2) ratios were determined by adding and subtracting the 15-year ratio standard deviation. This provided nine com-soybean price combinations which we considered to reflect prices likely to be encountered in the future.

With a low com price, com following two years of soybean provided the consistently highest projected returns at both Lamberton and Waseca regardless of the soybean:com price ratio (table 8). Continuous soybean also provided a high. return when the soybean:com price ratio was 3.2. At Rosemount there was no clear net return pattern, except that continuous com provided the lowest return under all soybean:com price ratios.

With a medium com price, com following two years of soybean again provided the consistently highest projected return at both Lamberton and Waseca. At Rosemount, there was once again no clear trend (table 8).

With a high com price, highest returns again came from the SSCSSC cropping sequence at both of the com-belt (Lamberton and Waseca) sites, regardless of the

soybean:corn price ratio (table 8). At Rosemount, there was no clear pattern.

In order to better visualize the projected performance of the five sequences, the results of each com price and soybean:corn price ratio combination were portrayed by rank (Table 9). The superiority of the SSC pattern at the Lamberton and Waseca locations is clear. It can also be seen that continuous com achieved the number 5 ranking more than any other sequence at these two locations. With only two exceptions, whenever continuous com was not ranked 5th, continuous soybean filled the number 5 rank. In the two exceptional situations, the 5th ranked sequence was CCS. Thus it is clear that monoculture of either crop, but especially of com, is likely to result in lowest returns for farmers in the Minnesota com belt unless future prices fluctuate considerably from the 1975- 1989 pattern.

At Rosemount, there was no clear ranking trend. CSCSCS was projected to be more profitable four times, SSSSSS three times, and CCCCCC two times. The CCSCCS and SSCSSC sequences were never projected to be most profitable.

## CONCLUSION

This study was conducted under the condition of crop selection being limited to corn and soybean, with resulting cropping systems being some sequential combinations of these two crops. We conclude that choice of corn soybean cropping sequence can be of considerable economic importance for Minnesota farmers. The sequence of soybean-soybean-corn (S S C) clearly was (and is projected to be) the most profitable sequence across all locations, but especially at the two corn-belt locations. However, not all farmers in the state can adopt such a system, other factors, particularly government prices will influence crop selection.

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Table 1. Cropping sequences maintained at Lamberton, Rosemount, and Waseca during the six year period 1984 to 1989. (C=corn; S=soybean).

<u>Treatment</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>
	----- crop -----					
1	c	c	c	c	c	c
2	s	s	S	S	S	S
3	c	s	c	s	c	s
4	c	c	s	c	c	s
5	S	S	c	s	S	C

Table 2. 1989 prices of inputs used in the analysis

<u>Seed</u>		
corn	21.00	\$ acre-l
soybean	9.00	"
<u>Fertilizer</u>		
N	0.12	\$ pound <sup>-1</sup>
P	0.22	"
K	0.14	"
<u>Herbicide</u>		
Lasso	4.80	"
Lorox	12.10	"
Basagran	13.20	"
<u>Crop. oil</u>	7	\$ pint <sup>-1</sup>
<u>Insecticide</u>		
Furudan	8.70	\$ ounce <sup>-1</sup>
Counter	8.70	"
Lorsban	8.70	"

Table 3.    Estimated operating costs for corn and soybean grown at three locations in Minnesota. From Fuller et al., 1989.

	<u>Lamberton</u>		<u>Rosemount</u>		<u>W a s e c a</u>	
	Com	Soybean	Com	Soybean	Com	Soybean
	----- \$ acre <sup>-1</sup> -----					
Fuel	7.59	5.04	7.59	5.07	7.59	5.06
Repairs & Maintenace	19.79	14.98	19.79	15.00	19.59	14.97
Other cash expenses <sup>†</sup>	28.75	-	37.50	-	38.75	-
Interest on cash exp.	7.56	4.66	8.71	4.60	8.67	4.38
Crop Insurance	6.04	6.65	8.06	7.18	8.14	7.18
<b>Total</b>	<b>69.73</b>	31.33	81.65	31.89	82.94	3 1.59

<sup>†</sup> harvest, drying, purchased irrigation, custom operations, technical services.

Table 4. Average grain yield of cropping sequences maintained at Lamberton, Rosemount, and Waseca during the six year period 1984 to 1989. (C=corn, S=soybean).

Lamberton						
Treatment	Year					
	1984	1985	1986	1987	1988	1989
	----- grain yield(bu. acre <sup>-1</sup> ) -----					
1. C C C C C C C	133	160	136	140	54	137
		38		44	35	38
3. C S C S C S	142	42	83	48	71	37
4. C C S C C S	127	170	35	149	70	39
5. S S C S S C	40	40	183	51	31	146
Rosemount						
Treatment	Year					
	1984	1985	1986	1987	1988	1989
	----- grain yield(bu. acre <sup>-1</sup> ) -----					
1. C C C C C C C	147	89	169	163	22	125
2. S S S S S S S	39	27	42	42		
3. C S C S C S	156	29	181	44	118	34
4. C C S C C S	127	96	40	169	70	40
5. S S C S S C	34	26	184	45	24	11
Waseca						
Treatment	Year					
	1984	1985	1986	1987	1988	1989
	----- grain yield(bu. acre <sup>-1</sup> ) -----					
1. C C C C C C C	95	133	137	145	85	144
2. S S S S S S S	30	25	39	41	27	39
3. C S C S C S	81	30	132	48	63	40
4. C C S C C S	89	122	44	129	25	37
5. S S C S S C	32	27	133	46		194
All locations combined						
Treatment	Year					
	1984	1985	1986	1987	1988	1989
	----- grain yield(bu. acre <sup>-1</sup> ) -----					
1. C C C C C C C	125	127	147	149		135
				42	74	36
3. C S C S C S	137	30	183	47	68	37
4. C C S C C S	114	129	40	149	27	38
5. S S C S S C	35	31	167	47		153

Table 5.           Average returns based on history of cropping systems (1984-1989)

Treatments	location			locations
	Lamberton	Wascea	Rosemount	combined
	-----	return (\$ acre-1 year <sup>-1</sup> )		-----
CCCCCC	156 b	108 b	145 a	136 b
ssssss	140c	99 b	118 c	114 d
cscscs	159 b	95 b	147 a	134 bc
ccsccs	156 b	91 b	123 bc	123 c
sscssc	188 a	155 a	138 ab	160 a
C.V.(%)	6.5	18.0	8.4	10.4

\* Within each column means with the same letter are not significantly different at the 0.05 probability level according to Duncan's Multiple Range Test.

Table 6. Return:operating cost ratios of the **five** cropping systems.

Treatments	Lamberton	Rosemount	Waseca
	----- - ratio* -----		
1 - c c c c c c	- - - -	0.57	0.88
2 - s s s s s s	<del>1.86</del>	1.03	1.50
3 - c s c s c s	1.37	0.63	1.20
4 - c c s c c s	1.28	0.61	0.89
5 - s s c s s c	1.82	1.29	1.29

\* ratio =  $\frac{\text{return (\$/acre/year)}}{\text{operating cost (\$/acre/year)}}$

Table 7. Average annual prices paid to Minnesota farmers.

Year	Price of		Soybean: Corn price ratio
	Corn	Soybean	
	--- \$ bushel <sup>-1</sup> ---		
1975	2.50	5.02	2.01
1976	2.03	7.22	3.55
1977	1.90	5.90	3.11
1978	2.08	6.52	3.13
1979	2.26	6.00	2.65
1980	2.85	7.23	2.54
1981	2.33	5.77	2.48
1982	2.63	5.81	2.21
1983	3.05	7.64	2.50
1984	2.47	5.60	2.27
1985	2.05	4.98	2.43
1986	1.46	4.72	3.29
1987	1.55	5.70	3.68
1988	2.35	5.50	2.34
1989	2.40	5.80	2.42
Mean			2.70
Std. Dev.			0.50
Low			2.01
High			3.68

**Source:** *Minnesota agricultural statistics*  
(prices do not include government support).



Table 8. Sensitivity analysis: returns above operating costs (\$/acre/year) for selected com prices and soybean:corn (S:C) ratios at Lamberton, Rosemount, and Waseca.

Com price = \$1.46/bu (low)

Treatments	<u>Lamberton</u>			<u>Rosemount</u>			<u>Waseca</u>		
	<u>S:C ratio</u>			<u>S:C ratio</u>			<u>S:C ratio</u>		
	2.2	2.7	3.2	2.2	2.7	3.2	2.2	2.7	3.2
----- \$ acre <sup>-1</sup> year <sup>-1</sup> -----									
1. c c c c c c	37 b*	37d	37d	24bc	24b	24 d	• 8 c	• 8 c	• 8 c
2. S S S S S S	41 b	69 b	97 a	30 ab	55 a	75 a	12 b	36 b	61 a
3. C S C S C S	45 b	50c	76 c	36 a	49a	62b	- 4 bc	10 c	25 b
4. C C S C C S	43 b	60bc	61 c	16 c	26b	36 c	• 8 c	3 c	13bc
5. s s c s s c	65 a	85 a	105 a	36 a	51 a	67 b	39 a	58 a	78 a
C.V.(%)	14	11	9	24	18	14	100	70	55

Corn price = \$2.40/bu (medium)

Treatments	<u>Lamberton</u>			<u>Rosemount</u>			<u>Waseca</u>		
	<u>S:C ratio</u>			<u>S:C ratio</u>			<u>S:C ratio</u>		
	2.2	2.7	3.2	2.2	2.7	3.2	2.2	2.7	3.2
----- \$ acre <sup>-1</sup> year <sup>-1</sup> -----									
1. c c c c c c	156 b*	156 b	156 d	145 a	145 ab	145 b	1108 a	108 b	108 c
2. s s s s s s	121 c	167b	213b	101 c	141 ab	189a	81 b	1120 b	162 b
3. c s c s c s	148b	173' b	198b	138 a	160a	181 a	8 4 b	108 b	131 bc
4. c c s c c s	1 4 9 b	164 b	179 c	116bc	132b	148b	8 4 b	100 b	117 c
5. s s c s s c	173a	203 a	238a	127ab	152a	178 a	1.41 a	173 a	206 a
C.V.(%)	7	6	6	9	8	7	18	18	19

Com price = \$3.05/bu (high)

Treatments	<u>Lamberton</u>			<u>Rosemount</u>			<u>Waseca</u>		
	<u>S:C ratio</u>			<u>S:C ratio</u>			<u>S:C ratio</u>		
	2.2	2.7	3.2	2.2	2.7	3.2	2.2	2.7	3.2
----- \$ acre <sup>-1</sup> year <sup>-1</sup> -----									
1. c c c c c c	239 ab*	239 b	239 c	229 a	229 ab	229 b	1188 a	1188b	188 b
2. S S S S S S	176 c	239' b	294 b	149d	201 c	253 a	129 b	180 b	231 b
3. C S C S C S	219b	251 b	284b	209 ab	236a	264a	1147 b	1175 b	205 b
4. C C S C C S	2 2 3 b	2 4 1 b	260 c	185 c	206 b	2 2 6 b	1145 b	168 b	189 b
5. s s c s s c	247a	289 a	330a	191 bc	223 abc	256 a	211 a	253 a	294 a
C.V.(%)	6	6	5	7	7	6	14	14	15

\* within each column means with the same letter are not significantly different at the 0.05 probability level according to Duncan's multiple range test.

Table 9. Ranking of returns for five cropping systems at Lamberton, Waseca, and Rosemount for different combinations of com prices, and corn:soybean price ratios.

Lamberton		Com Price								
		Low (\$1.46/bu)			Med(\$2.40/bu)			High (\$3.05/bu)		
		Soybean:corn ratio			Soybean:corn ratio			Soybean:corn ratio		
		2.2	2.7	3.2	2.2	2.7	3.2	2.2	2.7	3.2
Treatment		ranking*								
1 • c c c c c c c		5	5	5	2	5	5	2	5	5
2 • s s s s s s s		4	3	2	5	3	2	5	4	2
3 • c s c s c s c		2		3	4	2	3	4	2	3
4 • c c s c c c s		3	4	4	3	4	4	3	3	4
5 • s s c s s c c		1	1	1	1	1	1	1	1	1
Rosemount		Com Price								
		Low (\$1.46/bu)			Med(\$2.40/bu)			High (\$3.05/bu)		
		Soybean:corn ratio			Soybean:corn ratio			Soybean:corn ratio		
		2.2	2.7	3.2	2.2	2.7	3.2	2.2	2.7	3.2
Treatment		ranking*								
2 • s s s s s s s		3	3	3	4	4	5	5	5	2
1 • c c c c c c c		1	5	5	3	1	4	4	1	1
4 • c c s c c c s		5	4	4	3	5	4	4	4	5
5 • s s c s s c c		2	2	2	2	2	3	3	3	3
Waseca		Com Price								
		Low (\$1.46/bu)			Med(\$2.40/bu)			High (\$3.05/bu)		
		Soybean:corn ratio			Soybean:corn ratio			Soybean:corn ratio		
		2.2	2.7	3.2	2.2	2.7	3.2	2.2	2.7	3.2
Treatment		ranking*								
1 • c c c c c c c		5	5	5	5	4	5	2	2	5
2 • s s s s s s s		2	2	2	3	2	2	5	3	3
3 • c s c s c s c		3	3	3		3	3	4	4	3
4 • c c s c c c s		4	4	4	4	5	4	3	5	4
5 • s s c s s c c		1	1	1	1	1	1	1	1	1

\* ranking of 1 = the most profitable sequence; 5 = the least profitable sequence.

Appendix 1: Rates of inputs applied on plots at Lamberton, Rosemount, and Waseca  
from 1984 to 1989

	Fertilizer (# per acre)			Herbicides (#peracre)				Insecticides (oz.per 100 ft )		
	N*	P	K	lasso	lorox	basagran	oil	furadan	counter	losban
LAMBERTON										
1984	125	100	100	2.5	2.5	-	-			
1985	125	100	100	2.5	1.5	-	-			
1986	125	-	-	2.5	1.5	-	-			
1987	125	-	-	3.0	1.5	-	-		1.0	
1988	125	100	100	2.5	1.5	-	-	1.0		1.0
1989	130	-	-	3.0	1.5	-				1.0
ROSEMOUNT										
1984	-	-	-	-	-	-	-			
1985	160	-	-	2.5	-	1.0	-		1.0	
1986	160	-	-	2.5	-	1.0	-		1.0	
1987	180	-	-	2.5	-	1.0	2.0		1.0	
1988	170	-	-	-	-	-	2.0		1.0	
1989	160	-	-	2.5	-	1.0	2.0			1.0
WASECA										
1984	163	-	-	3.5	1.5	-	2.0	1.0		
1985	175	-	-	-	-	-	2.0	1.0		
1986	175	-	-	3.0	1.5	-	2.0	1.0		
1987	175	-	-	3.5	1.5	1.0	2.0		1.0	
1988	163	-	-	3.5	1.5	-	2.0		1.0	1.0
1989	163	-	-	3.5	1.5	1.0	2.0			1.0

\* Nitrogen was applied only on plots planted to corn.

## Appendix 2: Soil characteristics

Lamberton: Webster: fine loamy, mixed, Typic Hapluquoll

- slope 0-3%
- poorly drained soil on glacial moraines
- surface layer black granular or blocky, friable clay loam or loam 14 to 16 inches thick
- subsurface layer very dark gray to olive gray, friable clay loam 19 to 21 inches thick, certain few mottles
- underlying material strongly mottled, gray calcareous loam, substrats with many lime concretions, 32 to 37 inches thick
- available water capacity: 15.6 inches to 5 feet
- high organic mater: 6-7%
- moderately permeable

Waseca: Nicollet: fine loamv. mixed, Aauic Hanludoll

- slope: 0-2%
- moderately well drained soil on the uplands
- surface layer black to very dark grayish brown clay loam 8 to 16 inches thick
- subsurface dark grayish brown clay loam 2 5 to 35 inches thick
- underlying material olive gray calcareous loam or clay loam
- available water capacity: 9.5 inches to 5 feet
- high organic mater: 6%
- moderately permeable

Rosemount: Waukegan: fine silt loam, mesic, Typic Hapludoll

- slope: 2-6%
- well drained soil
- surface layer black silt loam about 14 inches thick
- subsurface layer dark grayish brown silt loam about 3 inches thick
- underlying material dark brown sand about 4 inches thick
- available capacity: 10.7 inches to 40 inches
- organic mater: 2-6%
- moderately permeable in upper mantles and rapid in underlying soil and bedrock

Appendix 3.1 **Soil** levels of extractable phosphorus and exchangeable potassium  
as affected by **crop** history.

	<u>LAMBERTON</u>				
Crop to be planted	C	S	S	C	S
No.of years of C out of previous 5	5	3	2	1	0
No.of years of S out of previous 5	0	2	3	4	5
Soil P(lb.acre-1)	50	51	54	57	57
Soil K (lb.acre- 1)	263	277	330	310	330
	<u>ROSEMOUNT</u>				
Crop to be planted	C	S	S	C	S
No.of years of C out of previous 5	5	3	2	1	0
No.of years of S out of previous 5	0	2	3	4	5
Soil P(lb.acre-1)	68	60	81	70	83
Soil K(lb.acre-1)	257	268	276	279	316
	<u>WASECA</u>				
Crop to be planted	C	S	S	C	S
No.of years of C out of previous 5	5	3	2	1	0
No.of years of S out of previous 5	0	2	3	4	5
Soil P(lb.acre-1)	69	88	76	79	88
Soil K(lb.acre-1)	388	397	406	409	411
	<u>ALL LOCATIONS COMBINED</u>				
Crop to be planted	C	S	S	C	S
No.of years of C out of previous 5	5	4	3	1	0
No.of years of S out of previous 5	0	2	3	4	5
Soil P(lb.acre-1)	62	66	70	69	76
Soil K(lb.acre- 1)	303	314	337	322	352

Important points

1. Com **monoculture** reduced **soil** P and **K** levels as **compared** to soybean monoculture.
2. **There** was a trend of increasing **soil** P and **K** with decreasing frequency of years of com **during** the last 5 years.

Appendix 3.2: Com (C) and soybean (S) leaf concentration of P and K at flowering  
(com=silking, soybean=R3) in 1989.

	<u>Lamberton</u>		<u>Rosemount</u>		<u>Waseca</u>	
	P	K	P	K	P	K
	.....g.kg-1.....					
Continuous C	3.0	17.8	3.5	12.9	2.9	17.0
C after year of S	2.9	18.0	3.5	12.9	2.8	17.0
Continuous S	4.5	18.9	6.5	21.8	6.0	21.9
S after year of C	4.6	19.9	6.7	21.8	5.7	21.9
S after year of C	4.5	18.5	7.0	23.0	6.1	22.7

Important point

Com and soybean leaf concentration of P and K was not affected by the rotation history.

Appendix 3.3: Leaf concentration of Ca, Mg, Fe, Mn, Zn, Cu, and B in com (silking stage) and soybean (R3 stage) plants in 1989.

LAMBERTON

	Ca	Mg	Fe	Mn	Zn	CU	B
	g.g-1	g.g-1	mg.g-1	mg.g-1	mg.g-1	mg.g-1	mg.g-1
Continuous C	5.6	4.7	124.5	55.0	21.5	9.5	6.3
C after 2 years of S	5.2	4.5	133.0	55.0	24.0	10.3	6.6
Continuous S	8.4	4.4	92.3	41.5	32.5	7.0	37.0
S after 1 year of C	8.3	4.2	90.5	44.5	32.5	7.0	36.0
S after 2 years of C	8.5	4.4	93.0	41.5	32.0	7.0	37.5

ROSEMOUNT

Continuous C	6.7	8.1	154.0	54.0	22.0	11.0	6.0
C after 2 years of S	6.8	8.3	162.0	57.0	23.0	10.5	5.5
Continuous S	10.2	5.3	98.3	59.0	42.0	5.6	40.0
S after 1 year of C	9.2	5.1	95.8	57.0	43.3	7.5	39.0
S after 2 years of C	9.3	5.1	95.0	54.0	45.5	10.0	38.5

WASECA

Continuous C	4.9	4.1	150.0	27.0	25.0	8.0	5.0
C after 2 years of S	5.0	4.4	128.5	25.5	22.5	8.8	5.5
Continuous S	10.3	4.9	101.0	44.0	41.5	8.0	47.5
S after 1 year of C	10.3	4.7	101.5	47.0	42.5	9.3	46.5
S after 2 years of C	10.0	4.5	96.5	46.3	41.5	9.5	47.5

Important points

1. Com and soybean concentration of Ca, Mg, Fe, Mn, Zn, Cu., and B was not affected by the rotation history.
2. Ca and B concentration was greater in soybean leaves than in com leaves.
3. Fe concentration was higher in com leaves than in soybean leaves.