depths were measured - 0 to 6 inch, 6 to 12 inch, 12 to 24 inch and 24 to 36 inch.

Results and Discussion

There was no significant interaction between rate of nitrogen and time of application for any of the plant responses measured.

The nitrogen rate had a significant effect on the grain and straw yield and the grain protein content corrected to 12% moisture (Table 1). The rate of 60# N/acre was adequate for yield, but the protein content increased linearly with increased rates of nitrogen. Test weight was not effected by rate of nitrogen.

When compared to the treatment of all nitrogen applied prior to planting, the split applications of fertilizer nitrogen had no effect on straw or grain yields, test weight or grain protein content (Table 2).

The amount of NO_3-N in the soil increased with the rate of applied nitrogen for all three sampling times, except the 60# rate and when measured after harvest. Sampling times - 1 being tillering stage, 2 being flag leaf and 3 being after harvest (Table 3).

Frequency of nitrogen application had no significant effect on the amount of NO_3-N measured to a depth of three feet (Table 4).

At the 60# rate of nitrogen, the addition of sulfur had no effect on any of the plant responses measured. At the 120# rate of nitrogen grain yield response was significant, but there were no other plant responses (Table 5). This response however was from a limited number of treatments and from only one years results.

Conclusion

The results of this study are from only one year. Climatic conditions have a major influence on plant response and soil interaction. 1987 grain yields were low - county average is generally 45-55 bushels per acre.

To determine if time of application and rate of nitrogen would be economically beneficial, more sites should be selected and studied.

Acknowledgement

Appreciation is extended to Tim Wagar and Fritz Breitenbach, Extension Area Agents, Rochester for their help during the growing season.

Table 1. The effect of rate of fertilizer N on spring wheat grain and straw yield, test weight of the grain and protein content of the grain.

N Applied	Straw Yield	Grain Yield	Test Weight	Grain Protein
lb./acre	lb./acre	bu./acre	lb./bu.	%
0	4358	32.2	55.8	11.5
60	5253	38.2	55.7	13.3
120	5478	35.9	55.5	14.0

Table 2. The effect of frequency of N application on spring wheat grain and straw yield, test weight of the grain and protein content of the grain.

N Application Schedule	Straw Yield	Grain Yield	Test Weight	Grain Protein
	lb./acre	bu./acre	lb./bu	%
All preplant	5219	35.7	55.5	13.6
50% preplant 50% at flag leaf	5339	37.0	56.2	13.6
50% preplant 25% at tillering 25% at flag leaf	5540	38.5	55.9	13.8

Table 3. The effect of rate of fertilizer N on total amount of NO_3-N measured to a depth of 3 feet.

N Applied	Sampling 1	Sampling 2	Sampling 3
lb./acre	----------lb. NO_3-N /acre----------		
0	72.8	29.3	46.9
60	103.1	33.2	36.5
120	140.4	57.3	51.7

Table 4. The effect of frequency of N application on the total amount of NO_3-N measured to a depth of 3 feet.

N Application Schedule	Sampling 1	2	3
	----------lb. NO_3-N/acre----------		
all preplant	134.2	55.4	50.3
50% preplant 50% at flag leaf	106.6	29.9	36.9
50% preplant 25% at tillering 25% at flag leaf	124.5	50.4	45.3

Table 5. Effect of sulfur applied with two rates of N on straw and grain yield of spring wheat, bushel weight of the grain and protein content of the grain.

Treatment N	S	Straw Yield	Grain Yield	Test Weight	Grain Protein
lb./acre		lb./acre	bu./acre	lb./bu	%
60	0	5135	36.7	56.0	13.1
60	30	5352	35.3	56.3	12.7
	Sig:	NS	NS	NS	NS
120	0	5303	34.7	57.9	14.1
120	30	5177	37.5	56.4	13.3
	Sig:	NS	*	NS	NS

* Difference between treatment means is significant at the .05 probability level.

EFFECT OF BROADCAST SULFUR ON CORN YIELD IN SOUTHEAST MINNESOTA

M.J. O'Leary and G.W. Rehm

Past research has shown that sulfur is needed on many of the sandy soils in Minnesota for optimum crop production. Questions arise concerning the possible need for S in a fertilizer program in southeast Minnesota. Many of the soils in this region are well drained with silt loam textures and low organic matter content. These soil properties increase the probability of a S response.

The objective of this study was to determine the effects of broadcast S on corn production in southeast Minnesota. Research was initiated in 1984 and results of previous years studies are reported in A Report on Field Research in Soils - Miscellaneous Publication 2, 1985 to 1987. Only results of 1987 field results are reported here.

Experimental Procedure:

Experiments were conducted in 1987 at two sites in Goodhue county. Soil classification and appropriate soil properties are listed in Table 1. There was no recent history of manure application at either site. Four rates of S (0, 10, 20, 40 lbs./acre) and four rates of N (0, 75, 150, 225 lbs./acre) were examined in a factorial arrangement replicated four times. Nitrogen and sulfur treatments along with recommended amounts of P and K were broadcast in early spring and incorporated with primary tillage. Granulated gypsum was used as the S source and urea was used as the N source. Ear leaf samples were collected at silking, dried, ground and analyzed for N and S. Plots were harvested in October for yield determination.

Results and Discussion:

Grain yields and the S and N concentration for ear leaf tissue are shown in Table 1. As would be expected, yields increased with the addition of N. Considering the relatively high yields response to N was not dramatic. A rate of 75 lbs. N/acre optimized yield at the Z87 site and 150 lbs. N/acre optimized yields at the J87 site. Sulfur had no effect on yield at the J87 site. Routine statistical analysis indicated a significant negative affect from the high rate of S on corn yield at the Z87 site. A more detailed analysis indicated that the yields from the control treatment was not significantly different from the yield of treatments that did receive S. A significant N x S interaction was measured at the J87 site, but a discernible trend is not obvious and the data does not provide an explanation for this observation.

Soil tests for S at these sites would be considered low or marginal based on the index that is used for sandy soils. Since no response was obtained, these result support previous findings which show that the soil test for S has no value in predicting a S response on non sandy soils.

Nitrogen concentration in ear leaf tissue increased with rate of applied N at each site but was not affected by S application. Sulfur concentration was affected in a similar manner. Concentration of S in ear leaf tissue at these sites was above the level generally considered to be critical (.18 - 20 % S).

Table 1. Selected soil properties and classification of the experimental sites used in 1987.

Property	Depth	Site Z87	Site J87
soil series		Timula	Seaton
pH	0-6	5.6	6.7
P, lb./acre	0-6	44	34
K, lb/acre	0-6	268	274
SO_4-S, ppm	0-6	6.5	8.0
"	6-12	6.5	5.8
"	12-24	4.5	1.8
"	24-36	5.2	2.8
"	36-48	5.0	2.5
"	48-60	4.8	3.5
Organic Matter,%	0-6	2.2	1.6
"	6-12	1.0	.4
"	12-24	.3	.1
"	24-36	.3	.2
"	36-48	.3	.2
"	48-60	.4	.3

Table 2. Effect of rate of broadcast N and S on yield and the ear leaf concentration of N and S of corn grown on silt loam soils in 1987.

Main Effects

S	site J87	site Z87	site J87	site J87	site Z87	site J87
lb./acre	-- bu/acre --		--- %S ---		----- %N -----	
0	179.7	177.5	.21	.21	3.10	2.89
10	180.8	179.1	.21	.23	2.90	2.81
20	176.6	172.2	.21	.22	3.08	2.88
40	180.6	166.7	.21	.23	2.99	2.95
sig.	ns	*	ns	ns	ns	ns
N						
lb.acre						
0	153.0	150.1	.18	.19	2.65	2.56
75	183.3	181.9	.21	.22	3.06	2.92
150	192.1	181.7	.22	.23	3.03	3.00
225	189.2	182.0	.23	.25	3.33	3.04
sig.	**	**	**	**	**	**
C.V. %	5.5	4.4	7.1	17.3	14.2	6.0

**, *, signifcant at .01 and .05 confidence level, respectively.

APPLICATION OF SULFUR IN A STARTER FERTILIZER FOR CORN PRODUCTION ON SILT LOAM SOILS

George Rehm, Andy Scobbie, Greg Cremers

Background and Justification:

Sulfur recommendations for corn production in Minnesota currently call for the use of this nutrient on sandy soils with medium to low organic matter levels. Since soil organic matter is the reservoir for sulfur in soils, many have asked if this nutrient should be added to fertilizer programs for corn where there are low organic matter soils with a silt loam texture.

Recent studies on similar soils in southeast Minnesota have shown a corn yield increase from broadcast sulfur at 2 of 8 experimental sites. Use of a starter fertilizer is a common practice in the region. Therefore, it seemed appropriate and logical to evaluate the effect of rate of sulfur applied in a starter for corn grown on these silt loam soils.

Experimental Procedure:

This study was conducted at four locations in southeast Minnesota in 1987. Soils that had an organic matter content of approximately 2% were selected. Prior to planting, soil samples were collected from 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches for purposes of site characterization. Selected soils properties are summarized in Table 1.

Sulfur was applied as 21-0-0-24 in a band to the side of and below the seed at planting at rates of 0, 6, 12, and 24 lb./acre. All plots also received 9-23-30 at a rate of 100 lb./acre as a starter fertilizer. The 9-23-30 was prepared by mixing equal quantities of 18-46-0 and 0-0-60. The N needed was supplied as 46-0-0- to provide 200 lb. N/acre. This N was broadcast and incorporated before planting.

A proven high yielding hybrid (Pioneer 3737) was planted in late April at a population of approximately 27,000 plants per acre at all sites. Weed control was achieved by using a preemergence application of a Lasso/Bladex combination.

Ear leaf samples were collected at silking, dried, ground, and analyzed for S. Grain yields were measured in mid-October and corrected to 15.5% moisture.

Results and Discussion:

Grain yields are summarized in Table 2. Although relatively high yields were recorded at all sites, use of S in a starter fertilizer had no significant effect on yield. There was some variability in yields but the low CV values indicate that there was an acceptable amount of precision in the study at each site.

Considering the soil test values for SO_4-S and organic matter and results from similar soils in 1984, 1985, and 1986, a response to S use was expected at the Goodhue (J) and Goodhue (Z) sites. These two sites had not been manured in recent years. Therefore, it appears that it is still not possible to predict with confidence silt loam sites in Minnesota where corn will respond to the use of fertilizer S.

The concentration of S in ear leaf tissue is summarized in Table 3. At each site, the rate of S applied in the starter fertilizer had no significant effect on the S concentration in the ear leaf tissue. It should be noted that S concentration values from control treatments at all sites were greater than .180 or .200 which are currently accepted "critical" levels for S in ear leaf tissue of corn. These levels of S from the control treatment indicate that, even with relatively high yields, the soils were capable of supplying adequate S for corn production. With adequate supplies of S in the root zone, dramatic increases in the S concentration of the ear leaf tissue would not be expected. The major portion of the S

supplied by the soil is probably a result of mineralization of soil organic matter.

Table 1. Selected soil properties of the experimental sites used in 1987.

Property	Depth	Site Goodhue(J)	Goodhue(Z)	Goodhue(E)	Winona
pH	0-6	6.7	5.2	7.5	6.9
P, lb./acre	0-6	39	51	23	13
K, lb/acre	0-6	275	201	256	150
SO_4-S, ppm	0-6	8.0	2.0	6.0	-
"	6-12	5.8	4.8	6.8	-
"	12-24	3.5	4.3	5.8	-
"	24-36	2.5	3.5	7.3	-
"	36-48	2.8	4.3	4.8	-
"	48-60	1.8	3.8	5.8	-
Organic Matter,%	0-6	1.6	1.3	2.3	-
"	6-12	.5	.7	1.1	-
"	12-24	.3	.3	.5	-
"	24-36	.2	.2	.2	-
"	36-48	.2	.1	.2	-
"	48-60	.1	.1	.4	-

Table 2. Effect of rate of S applied in a starter fertilizer on yield of corn grown on silt loam soils in 1987.

S Applied	Site Goodhue(J)	Goodhue(Z)	Goodhue(E)	Winona
lb./acre	bu./acre			
0	204.5	195.9	187.3	179.4
6	207.2	199.5	195.6	191.3
12	211.0	189.2	191.5	181.2
24	208.0	192.6	186.3	178.2
CV:%	3.1	3.3	4.7	4.6

Table 3. Effect of rate of S applied in a starter fertilizer on the S concentration in ear leaf tissue of corn grown on silt loam soils in 1987.

	Site			
Applied	Goodhue(J)	Goodhue(Z)	Goodhue(E)	Winona
lb./acre	%S			
0	.225	.224	.210	.233
6	.239	.229	.223	.250
12	.239	.217	.208	.243
24	.245	.228	.231	.248
CV:%	6.3	5.3	6.5	6.8

EVALUATION OF THE RELATIONSHIP BETWEEN TILLAGE AND PLACEMENT OF P AND K IN A CORN - SOYBEAN ROTATION

George Rehm, Sam Evans, Wally Nelson and Gyles Randall

Background and Justification

Until recently farmers had limited choices for placement of P and K fertilizers for corn and soybean production. They could broadcast and incorporate the P and K before planting or apply these nutrients to the side of and below the seed at planting (starter). There has, however, been a renewed interest in placement of P and K fertilizers. This interest has been stimulated by a shift to conservation tillage systems where broadcast fertilizer is not incorporated and a desire to improve the efficiency of use of P and K. This study, therefore, was designed to evaluate the impact of placement of P and K fertilizers on the yield of corn and soybeans grown in two contrasting tillage systems.

Experimental Procedure

This study was initiated at 3 branch experiment stations (Waseca, Lamberton, Morris) in the fall of 1983 and continued through the 1987 growing season. Relevant soil properties measured at the initiation of the study are listed in Table 1. Corn was the test crop in 1984, 1985, and 1987. Soybeans were grown in 1986.

Four factors (tillage system, rate of applied P_2O_5 and K_2O, placement of P_2O_5 and K_2O, and starter fertilizer use) were evaluated at the Waseca and Morris locations. Space limitations dictated that fewer treatments be used at the Lamberton location. Therefore, only one rate of P_2O_5 and K_2O was used at Lamberton. The study was conducted on both low and high fertility sites at Waseca and Lamberton. Only one site (high fertility) was used at Morris.

A suspension fertilizer, 4-12-24, was used to supply the P_2O_5 and K_2O. One rate of P_2O_5 and K_2O (44 and 87 lb. per acre respectively) approximates removal of P and K by a typical corn crop. The second rate used was 1.5 times greater than the first rate cited.

The P_2O_5 and K_2O were either broadcast on the soil surface, applied in a band on the soil surface in the middle of existing rows or knifed in to a depth of 5 to 6 inches below the soil surface in the middle of existing rows. These treatments were repeated on the initial plots each year. Treatments were applied in late October. The fall chisel tillage operation is completed after fertilizer application.

For the ridge-till system, there is no tillage operation prior to planting. The fall chisel plots are disked in the spring before planting. A 7-21-7 at 100 lb. per acre is used as a starter fertilizer at the Waseca and Lamberton locations. At Morris, a 10-34-0 applied at 117 lb./acre is used as a starter fertilizer. Every effort is made to use management practices that will contribute to the highest yield at each location. Corn yields were measured with a plot combine at all locations. Yields are corrected to 15.5% before reporting.

Table 1. Selected soil properties (0-6 in.) for the experimental sites measured at the initiation of the study.

Soil Property	Location and Fertility Level: Waseca High	Waseca Low	Lamberton High	Lamberton Low	Morris High
pH	6.6	6.1	5.8	6.0	7.5
P (B&K #1), lb./acre	48	14	33	14	39
K (1N $NH_4C_2H_3O_2$), lb./acre	433	190	305	222	259
Organic Matter, %	3.5	3.5+	3.0	3.0	3.5+
Texture	CL*	CL	CL	CL	SIL

*CL = clay loam; SIL = silt loam

Results and Discussion

Morris Trials

None of the variables used had a significant effect on corn yield at this location (Table 2). Since rate of application did not affect yield, results from the use of the lower rate are listed.

The results recorded in 1987 are consistent with those from previous years. Placement of the P_2O_5 and K_2O had no effect where soil fertility levels are high. The effect of tillage has not been consistent at this site. Because of the warm, dry planting season, tillage system should not be expected to have any effect on yield.

Table 2. Effect of tillage system, fertilizer placement, and starter fertilizer use on corn yield at Morris when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

Placement	Tillage System: Ridge-Till Starter	Ridge-Till No Starter	Ridge-Till Avg.	Fall Chisel Starter	Fall Chisel No Starter	Fall Chisel Avg.
	bu./acre					
None	155	162		172	163	
Broadcast	175	164	169	167	169	168
Surface Band	177	163	170	171	172	172
Subsurface Band	175	175	175	163	162	163
Avg.	176	167		167	168	

Lamberton Trials

Both tillage system and the placement of the P_2O_5 and K_2O and a significant effect on yield at the low fertility site at this location in 1987 (Table 3). There was no significant tillage x placement interaction.

Considering the tillage component, yields were higher where the fall chisel system was used. When averaged over all other variables, the yield difference due to tillage was approximately 3 bu./acre.

When averaged over the other variables, the broadcast treatment produced the highest grain yield. The lowest yield was produced by use of the subsurface band while the application of P_2O_5 and K_2O in a band on the surface produced yields that were intermediate. These results are somewhat inconsistent with those recorded in previous years and there is no apparent explanation for this lack of consistency.

Table 3. Effect of tillage system, fertilizer placement and starter fertilizer use on corn yield at the low fertility site at Lamberton when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	---	102		---	112	
Broadcast	135	134	135	142	141	142
Surface Band	126	132	129	140	141	141
Subsurface Band	134	126	130	134	138	136
Avg.	132	131		139	140	

Both tillage system and method of fertilizer placement had a significant effect on corn grain yield at the high fertility site in 1987 (Table 4). When averaged over the other variables used, yields were 9 bu./acre higher when the fall chisel system was used. Considering placement, highest yields were produced by the broadcast application of the P_2O_5 and K_2O. The use of the surface band produced the lowest yield while yields resulting from the use of the subsurface band were intermediate.

The results from this site in 1987 are not consistent with results recorded in previous years. Except for a response from use of starter fertilizer in 1985, fertilizer use had not previously increased yield of either corn or soybeans when soil test levels for P and K were in the high range. There is no immediate explanation for the response measured in 1987.

Table 4. Effect of tillage system, fertilizer placement, and starter fertilizer use on corn yield at the high fertility site at Lamberton when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	---	132		---	141	
Broadcast	139	139	139	150	145	148
Surface Band	132	128	130	148	134	141
Subsurface Band	139	134	137	141	147	144
Avg.	137	134		146	142	

Waseca Trials

The 1987 grain yields from the low fertility site at Waseca were significantly affected by the tillage system and the placement of the P_2O_5 and K_2O. The tillage x placement interaction was also significant (Table 5).

When averaged over other variables included in the study, average yield was 5 bu./acre higher when the ridge-till planting system was used.

The effect of placement was influenced by the tillage system used. For the ridge-till system, the band application produced the highest yield with broadcast and surface band placements producing lower yields. In the fall chisel system, the lowest yield was produced by the surface band application. The broadcast and subsurface band placement produced equal but higher yields.

These results are consistent with those recorded at this site in previous years when the use of the subsurface band in combination with a starter fertilizer has produced the highest yield.

Table 5. Effect of tillage system, fertilizer placement, and starter fertilizer on corn yield at the low fertility site at Waseca when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	126	118		121	120	
Broadcast	158	163	161	163	159	161
Surface Band	161	159	160	150	151	151
Subsurface Band	166	163	165	161	157	159
Avg.	162	162		158	156	

Grain yield at the high fertility site was not significantly affected by any of the variables used in this study (Table 6). These results are consistent with those obtained at this site in previous years.

Table 6. Effect of tillage system, fertilizer placement, and starter fertilizer on corn yield at the high fertility site at Waseca when 44 lb. P_2O_5 and 87 lb. K_2O per acre were used.

	Tillage System					
	Ridge-Till			Fall Chisel		
Placement	Starter	No Starter	Avg.	Starter	No Starter	Avg.
	bu./acre					
None	162	168		166	165	
Broadcast	169	170	170	167	168	168
Surface Band	171	170	171	161	164	163
Subsurface Band	168	163	166	167	168	168
Avg.	169	168		165	167	

EFFECT OF RATE AND PLACEMENT OF POTASSIUM ON GROWTH AND YIELD OF CORN

George Rehm, Greg Cremers, Andy Scobbie

Background and Justification:

During recent years, there has been a substantial amount of interest in fertilizer placement. This is especially true for P and K. In addition to the traditional uses of either broadcast or starter application (fertilizer applied to the side of and below the seed at planting), equipment is now available to place either liquid or dry fertilizers some precise distance from the seed. With most of this new equipment, the fertilizer is placed in a band below the soil surface.

Earlier research in Minnesota had shown that the use of subsurface bands in combination with a starter fertilizer at low soil test levels for P and/or K looked promising as a management tool for more precise placement.

Soils in southeast Minnesota typically have low to medium levels of soil test K. These soils also usually have the ability to fix or "tie up" some of the fertilizer K used for crop production. In addition, substantial amounts of K are removed from the soil system when corn silage (a common use of corn) is harvested as part of the dominant dairy enterprise in the region.

The effect of placement of fertilizer K on corn production had not been studied extensively in Minnesota. Therefore, the study described in this report was designed to measure the effect of rate and placement of fertilizer K on growth and yield of corn in southeast Minnesota.

Experimental Procedures:

This study was conducted in Olmsted County. Prior to planting, soil samples were collected from 0-6, 6-12, 12-24, 24-36, 36-48, and 48-60 inches for site characterization. Results of the analysis of these samples are summarized in Table 1.

Table 1. Relevant soil properties of the experimental site.

Soil Property	Depth(in.) 0-6	6-12	12-24	24-36	36-48	48-60
pH	6.2	-	-	-	-	-
P, lb./acre	22	-	-	-	-	-
K, lb./acre	146	153	194	206	169	136
Organic Matter, %	3.3	-	-	-	-	-

A conventional tillage system was used. The plot area was plowed in early April and treatments were applied after the first disking operation.

The fertilizer K was either broadcast and incorporated, applied as a starter at planting, or applied as a subsurface band before planting. The K was supplied as 0-0-60. When broadcast, the rates of applied K were 0, 40, 80, 160, and 320 lb./acre. The rates were reduced to 0, 15, 30, 60, 120 lb. K/acre when applied in either the starter or the subsurface band. The subsurface band was placed at a depth of 5 to 6 inches in mid-April in the middle of 30 inch rows. All plots received a preplant application of 200 lb.N/acre as 46-0-0. The preplant N and broadcast K rates were incorporated with a light disking on the day of application.

Pioneer 3737 was planted on April 28 at a population of approximately 27,000 seeds/acre. All plots received a starter fertilizer which supplied 18 lb-N and 46 lb. P_2O_5/acre. A preemergence application of

Lasso and Bladex was used for weed control. Quackgrass was controlled by a post-emergence application of atrazine and oil.

Whole plant samples (6 plants/plot) were taken approximately 30 days after emergence. Ear leaf samples were collected at early silk. These plant samples were dried, ground and analyzed for K by routine ICP procedures. Uptake of K by the young plants was computed by multiplying early plant growth by K concentration. Grain yields were measured in mid-October and corrected to 15.5% moisture.

Data collected were analyzed statistically by standard regression and analysis of variance procedures. Because of the higher rates used for the broadcast applications, data from the broadcast treatments were analyzed separately.

Results and Discussion:

Grain Yield

When applied in a starter fertilizer or as a subsurface band, grain yield was increased by the rate of K applied (Table 2). Yield increases, however, were small, but were not affected by the position of the fertilizer band. When averaged over the starter and subsurface band placement, the application of 15 lb. K/acre produced an additional 6 bu. of corn/acre with no further increases from additional K.

When the applied K was broadcast and incorporated before planting, grain yields were not affected by the rate of K used (Table 3). The data collected do not provide a complete explanation for the lack of response to broadcast K.
Based on the soil test K values for the surface 0-6 in., a response to fertilizer K would be expected. The levels of soil test K in the subsoil, however, were much higher than typically found in the region. These relatively high levels of K in the subsoil can be used to explain the small increase in yield from banded applications of fertilizer K.

Early Growth

Considering the starter fertilizer and subsurface band, average early growth increased as rate of applied K increased to 30 lb./acre with no further increases from added K. The early growth was not affected by the placement of the band (starter vs. center of row).

In contrast to yield, early growth was improved by broadcast K applications (Table 3). The weight of the young plants increased linearly as rate of broadcast K was increased. These data show that effects of K on early growth are not necessarily reflected in yield.

K Concentration in Plant Tissue

The concentration of K in young corn plants increased as the rate of applied K increased (Tables 2 and 3). The K concentration in young plants was also affected by placement (Table 2) with concentrations being higher when K was applied in a starter rather than a subsurface band between the rows. This would be expected because of a higher percentage of the root system of the young plants being closer to the fertilizer K when a starter fertilizer is used. The K concentration in young plants also increased linearly as increased rates of K were broadcast (Table 3).

When applied in either a starter fertilizer or a subsurface band, the K concentration in the ear leaf tissue increased linearly with rate of K applied (Table 2). The placement of the band had no effect on K concentration. The K concentration in the ear leaf tissue also increased linearly with rate of K that was broadcast and incorporated (Table 3).
It should be noted that K concentrations in the ear leaf tissue are much lower than currently accepted critical levels. The data gathered in this study do not provide the explanation for these low values.

Table 2. Effect of rate of K applied in either a starter or subsurface band on grain yield, early growth and the K concentration in whole plant and ear leaf tissue.

K Applied	Grain Yield	Early Growth	K Conc. Whole Plant	K Conc. Ear Leaf
lb./acre	bu./acre	gm/6 plants	%	%
Starter:				
0	188	49	1.86	1.08
15	193	61	2.33	1.13
30	191	61	3.00	1.27
60	193	61	4.35	1.55
120	194	55	4.67	1.75
Subsurface Band:				
0	188	47	1.50	.99
15	191	55	2.10	1.20
30	186	62	2.26	1.19
60	192	54	2.65	1.46
120	191	62	3.82	1.77

Table 3. Effect of rate of broadcast K on grain yield, early growth and K concentration in whole plant and ear leaf tissue.

K Applied	Grain Yield	Early Growth	K Concentration Whole Plant	K Concentration Ear Leaf
lb./acre	bu./acre	gm/6 plants	- - - - - - % - - - - - -	
0	192	52	1.86	1.20
40	195	54	2.12	1.22
80	193	58	2.41	1.41
160	195	57	3.20	1.65
320	198	63	4.23	2.10

Summary

Although soil test values for K in the surface soil were in the low to medium range, K applied in either a starter fertilizer or a subsurface band between the rows produced only small increases in grain yield with 15 lb. K/acre being adequate. Broadcast applications of fertilizer K had no impact on yield. Subsoil K values were higher than what is considered to be typical. This ample supply of K in the subsoil probably reduced the degree of response to fertilizer K.

The rate of K applied did increase the K concentration in whole plant and ear leaf tissue. The K concentration, however, was not related to yield.

EVALUATION OF THE EFFICIENCY OF BAND PLACEMENT OF P FERTILIZER FOR CORN, SOYBEAN, AND WHEAT

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INTRODUCTION: Efficient P fertilizer use is continuing to be an important area of production management for finding the least cost method of production. Little information is available in the Northern Corn Belt about which methods of application are best. Winter wheat growing areas (Kansas, Nebraska and Colorado), have found that a starter or row application of P can be many times more efficient than a broadcast application. This report is concerned with the results of the second year of a study conducted in Minnesota with the overall objective to evaluate the efficiency of band placement methods (starter, and knife) for spring wheat, corn an soybean over the northern corn belt. Under this broad objective the two following specific objectives will be addressed.

1) Determine the efficiency of band applications of P as compared to broadcast on a spring wheat - soybean rotation in northwestern Minnesota and corn-soybean rotation at two locations in southern Minnesota.

2) Determine residual effects of band and broadcast placements of fertilizer P on P uptake and crop yield.

MATERIALS AND METHODS: The second of three years of this study was conducted in 1987 at Waseca, Lamberton, and Crookston, MN. Corn and soybean were grown at Waseca and Lamberton with spring wheat and soybean grown at Crookston. Table 1 presents the soil test information for each location. The following variables were measured on corn at Waseca and Lamberton; grain yield, forage yield, forage P concentration and uptake, ear leaf P concentration at silking, and grain moisture content. Soybean variables measured at all locations were: grain yield, forage yield, forage P concentration and uptake, leaf P concentration at mid-flower, and grain moisture. At Crookston the parameters measured on the wheat were grain yield, grain protein content, bushel weight, grain moisture content, forage yield, and whole plant P concentration and uptake at anthesis. The grain moisture has been incorporated into the grain yield data. The corn, soybean, and wheat grain yields have been corrected to 15.5, 13.5 and 13.5% moistures, respectively. The wheat protein values are reported on a 13.5% moisture basis.

Table 2 lists the treatments that were established on all six sites. Four replications of a complete factorial arrangement of three methods of phosphorus placement and five phosphorus rates were established. The broadcast method was incorporated at all locations. The knife method at Waseca (corn and soybean) and Lamberton (corn and soybean), placed a preplant band of fertilizer at a 6-inch depth between the 30 inch width rows. At the Crookston (spring wheat) site the knife method placed preplant fertilizer 6 inches deep with a shank spacing of 15 inches. The knife method for Crookston soybean was two 15" width preplant bands between the 30" rows applied at a 6" depth. The starter method at Waseca (corn and soybean), Lamberton (corn and soybean), and Crookston (soybean) involved a band of fertilizer applied at planting 5 to 7 inches from the row and 2.5 to 3 inches deep. The Crookston (spring wheat) site starter treatment involved placement of fertilizer directly with the seed at Waseca and Lamberton. The phosphorus rates were 0, 10, 20, 30 and 40 lb P A^{-1}. At Crookston, the rates were 0, 5, 10, 15 and 20 lb P A^{-1}. Ammonium polyphosphate, 10-34-0, was the P source at all locations. Three extra treatments were added to the factorial to test effect of combined application methods. These were 20 + 20 lb P A^{-1} (5 + 5 lb P A^{-1} at Crookston) broadcast + knife, broadcast + row, and row + knife (Table 2). They were analyzed statistically as a method comparison with the broadcast, knife, and row treatment at the 40 lb P A^{-1} levels (10 lb P A^{-1} at Crookston).

Please refer to title page of this publication for information regarding application and use of this article.

Table 1. Soil test values for P-efficiency study, 1987.

	Crookston*		Waseca**		Lamberton**	
	Soybean	Wheat	Soybean	Corn	Soybean	Corn
pH	7.8	7.9	5.9	5.9	6.2	6.1
OM%	3.0	2.4	3.5	3.5	3.8	3.9
Salts mmho	0.2	0.4	-	-	-	-
NO_3^--N 0-24"	31	18	-	-	-	-
P lb A^{-1}	10	9	10	10	3	7
K lb A^{-1}	230	240	331	382	259	290

* $NaHCO_3$-P
** Bray-P

Table 2. Treatment description for project MN-1L.

Treatment Number	Factor: Placement	Factor: P Rate # P/A
1	Broadcast	0**
2	Broadcast	10
3	Broadcast	20
4	Broadcast	30
5	Broadcast	40
6	Knife *	0
7	Knife *	10
8	Knife *	20
9	Knife *	30
10	Knife *	40
11	Starter +	0
12	Starter +	10
13	Starter +	20
14	Starter +	30
15	Starter +	40
16	Broadcast + Knife	20 + 20***
17	Broadcast + Starter	20 + 20***
18	Knife + Starter	20 + 20***

* 15-inch width at wheat-soybean location.
\+ 5-7 inches from row in soybean and corn - applied with seed in spring wheat.
** P rates are 0, 5, 10, 15, and 20 pounds P per acre at Crookston in 1987.
*** At Crookston the P rate was 5 + 5.

Broadcast and knife applied: Crookston October 15, 1986
Lamberton October 28, 1986
Waseca November 4, 1986

Starter applied: Crookston June 1, 1987 - Soybean
Crookston April 21, 1987 - Spring Wheat
Lamberton April 23, 1987 - Corn
Lamberton May 21, 1987 - Soybean
Waseca May 5, 1987 - Corn and Soybean

Factorial Experiment: Corn - Grain yield, ear leaf P, forage yield, whole plant P, and P uptake were increased significantly by P fertilization at both Waseca and Lamberton, Tables 3 and 4. The rate response for grain yield was quadratic in nature maximizing yield at 30 lb P A^{-1} at Waseca and 40 lb P A^{-1} at Lamberton. At Waseca, there was no difference in any of the measured parameters from method of application.

At Lamberton there was a significant method response for grain yield and ear leaf P. With grain yield, broadcast application performed best, knife intermediate and finally starter performing the poorest. This is contrary to other results reported for corn. Normally if there is an advantage to method of application the starter application method is superior to broadcast. The ear leaf P contents indicate the highest concentration occurred in plants treated with the knife application method. The starter application had the lowest P concentration with the broadcast treatment intermediate. Forage yield response to the P fertilizer at Lamberton was quadratic and yield was maximized at 30 lb P A^{-1}. The P concentration data for method effects does not indicate the same result. At Waseca, forage yield response was linear with the greatest yield occurring at 40 lb P A^{-1}. At both Lamberton and Waseca, whole plant P concentration and P uptake increased linearly to P applications. Forage yield, whole plant P, and P uptake were not effected by method of application at either location.

Soybeans - The application of P fertilizer caused positive responses in grain yield, leaf P, forage yield, whole plant, and P uptake at Waseca and Lamberton, Table 3. Forage yield, Plant P and P uptake was effected at Crookston, Table 5. Lamberton forage yield, Waseca whole plant P, Waseca P uptake, and Crookston forage yield had quadratic responses while the other effects responded linearly. The maximum forage yield occurred at 40 lb P A^{-1} and 5 lb P A^{-1} at Lamberton and Crookston, respectively. The maximum whole plant P and P uptake at Waseca occurred at 40 lb P A^{-1}. The method of application significantly effected leaf P at Waseca, whole plant P at Lamberton, grain yield at Lamberton, and forage yield and P uptake at Crookston. At Waseca, the leaf P concentrations were significantly lower in the plants with the broadcast application of P than the knife or starter applications. The leaf P concentrations in starter and knife treatments were similar. The whole plant P concentrations at Lamberton were greater with broadcast application compared with knife and starter. No difference occurred between knife and starter application. The broadcast method produced the greatest grain yield (36 bu A^{-1}) at Lamberton. The starter and knife treatments performed similarly (33.4 and 34.8 bu A^{-1}, respectively). This response is similar to 1986 data. At Crookston the starter application treatment produced the greatest forage yields and P uptake. The broadcast treatments did the poorest with the forage yields and P uptake from knife applied plants intermediate.

Wheat - Grain yield, forage yield and P uptake were increased by P fertilization at Crookston, Table 5. The grain yield was greatest at the 20 lb P A^{-1} rate and was not maximized. The forage yield response was quadratic and maximized at 15 lb P A^{-1}. P uptake response was linear and corresponded to grain yield results. No method of application response occurred to any of the measured parameters.

Summary: Of the six site locations, five had grain yield increases from P fertilization. In most instances, there was no method of application response (Crookston wheat, Waseca corn, and Waseca soybeans). At Lamberton on corn and soybean, broadcast application produced superior grain yields with the band applications (knife and starter) comparing similarily to each. This infers an advantage to dealers in Minnesota. A cheaper and easier application, broadcast, can be used, thus special adaptation of knives is not needed. The soybean data coincides with past results. Because of the soybean's later corn andnot wheatdoes data planting and pattern of P uptake, no advantage to a banded application would occur. Thecorrespond with observations in other experiments. Normally the starter placement is the optimum placement. At Lamberton the broadcast performed the best. At this time no explanation can be given.

Application Experiment: The results from the split application experiment are listed in Tables 6, 7 and 8. The statistics suggest that there were some differences among treatments. In most cases, the differences are from the response to P fertilizer and not from the mixed applications. It can be concluded that the use of mixed applications is not more advantageous than a single application of one method.

Table 3. Means and statistical analyses for Lamberton soybean and corn, 1987.

		Soybean					Corn				
Method	P Rate lb P/A	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
Broadcast	0	0.312	5615	0.199	11.21	31.1	0.182	12855	0.128	16.51	110.4
	10	0.331	5085	0.205	10.38	33.2	0.196	13285	0.136	18.07	121.8
	20	0.336	5540	0.230	12.76	36.8	0.230	13230	0.155	20.60	135.0
	30	0.403	5685	0.225	12.78	36.2	0.221	13785	0.144	19.80	128.3
	40	0.353	5780	0.228	13.31	37.9	0.239	13455	0.155	20.92	142.4
Knife	0	0.291	5745	0.188	10.70	32.1	0.180	12210	0.132	16.28	110.0
	10	0.340	5485	0.181	9.97	34.0	0.198	13455	0.127	17.06	125.0
	20	0.351	5550	0.206	11.43	33.5	0.224	13305	0.121	16.03	125.7
	30	0.378	5580	0.211	11.85	36.4	0.241	14485	0.138	20.09	127.1
	40	0.401	6005	0.220	13.22	35.3	0.253	14165	0.160	22.71	134.4
Row	0	0.285	5715	0.190	10.82	31.0	0.162	12150	0.123	15.00	113.6
	10	0.327	5285	0.182	9.60	30.6	0.185	13530	0.131	17.88	124.0
	20	0.357	5945	0.189	11.18	33.7	0.222	14200	0.145	20.61	122.2
	30	0.407	5990	0.217	12.91	31.9	0.200	13365	0.148	20.35	122.6
	40										
P Rate #/A	0	0.296	5692	0.193	10.93	31.4	0.174	12405	0.128	15.93	111.3
	10	0.332	5285	0.189	9.99	32.6	0.193	13423	0.131	17.67	123.6
	20	0.348	5678	0.208	11.79	34.7	0.225	13578	0.140	19.08	127.6
	30	0.396	5752	0.218	12.51	34.8	0.221	13878	0.134	18.64	126.9
	40	0.401	6097	0.222	13.54	36.9	0.239	13792	0.154	21.32	133.1
Method											
Broadcast		0.356	5522	0.222	12.31	36.0	0.221	13438	0.148	19.85	131.9
Knife		0.367	5656	0.204	11.62	34.8	0.229	13852	0.136	18.97	128.0
Starter		0.385	5932	0.201	11.95	33.4	0.208	13712	0.136	18.73	123.5
Method		NS	.16	.06	NS	.04	**	NS	.16	NS	.04
P Rate		**	.016	.02	**	**	**	**	**	**	**
Linear		**	.013	**	**	**	**	**	**	**	**
Quadratic		NS	.04	NS	NS	NS	.04	**	NS	NS	.07
Method x P Rate		NS	NS	NS	NS	NS	NS	.14	NS	.12	NS
C.V.		13.9	9.5	13.3	16.8	7.3	7.6	5.3	13.0	15.6	6.6

** is 0.01 significance levels.

Table 4. Means and statistical analyses for Waseca soybean and corn, 1987.

		Soybean					Corn				
Method	P Rate lb P/A	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
Broadcast	0	0.379	4727	0.195	9.27	35.8	0.159	12175	0.110	13.64	119.1
	10	0.423	5150	0.247	12.62	41.9	0.186	13480	0.109	14.90	129.2
	20	0.461	5575	0.265	14.91	43.9	0.218	14860	0.128	19.27	144.0
	30	0.465	5480	0.251	13.67	44.3	0.260	15070	0.142	21.38	147.9
	40	0.503	5849	0.316	18.52	44.7	0.249	14795	0.133	19.69	146.9
Knife	0	0.409	5040	0.205	10.42	42.6	0.168	13880	0.111	15.60	135.5
	10	0.449	5390	0.251	13.62	43.3	0.219	14535	0.121	17.63	138.0
	20	0.478	5365	0.291	15.60	43.4	0.230	15345	0.122	18.79	152.7
	30	0.482	4935	0.274	13.57	43.4	0.248	14910	0.128	19.10	156.6
	40	0.531	5465	0.286	15.57	46.4	0.253	15900	0.131	20.78	143.7
Row	0	0.388	4825	0.189	9.08	39.2	0.146	12455	0.108	13.55	121.8
	10	0.438	4770	0.272	13.02	39.0	0.190	13410	0.103	13.98	144.0
	20	0.455	5460	0.291	15.90	42.8	0.226	14370	0.109	15.70	149.2
	30	0.498	5545	0.273	15.03	45.8	0.245	15865	0.136	21.68	150.9
	40	0.535	5640	0.298	16.83	47.4	0.263	15550	0.133	20.67	146.3
P Rate #/A	0	0.392	4863	0.196	9.59	39.2	0.158	12837	0.110	14.26	125.5
	10	0.437	5103	0.257	13.09	41.4	0.199	13808	0.111	15.50	137.1
	20	0.465	5467	0.282	15.47	43.4	0.225	14858	0.120	17.92	148.6
	30	0.482	5320	0.266	14.09	44.5	0.251	15282	0.136	20.71	151.8
	40	0.523	5653	0.300	16.97	46.2	0.255	15415	0.132	20.38	145.6
Method											
Broadcast		0.463	5515	0.270	14.93	43.7	0.228	14551	0.128	18.81	142.0
Knife		0.485	5289	0.275	14.59	44.1	0.238	15173	0.126	19.08	147.7
Starter		0.482	5354	0.284	15.20	43.7	0.231	14799	0.120	18.01	147.6
Method		.06	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Rate		**	**	**	**	**	**	**	**	**	**
Linear		**	**	**	**	**	**	**	**	**	**
Quadratic		NS	NS	.02	.04	NS	**	.11	NS	NS	**
Method x P Rate		NS	NS	NS	NS	.15	NS	NS	NS	NS	NS
C.V.		6.0	10.5	13.7	16.1	6.6	11.3	9.1	12.6	17.5	9.0

** is 0.01 significance level.

Table 5. Means and statistical analyses for Crookston soybean and spring wheat, 1987.

		Soybean				Spring Wheat						
Method	P Rate lb P/A	Trifoliate P %	Plant P	Forage Yield lb/A	P Uptake %	Grain Yield Bu/A	Plant P	Forage Yield lb/A	P Uptake %	Grain Yield Bu/A	Bu. Wt. lb/Bu	Grain Protein %
Broadcast	0	0.389	0.247	4878	11.99	31.4	0.265	6034	15.85	65.2	61.9	12.1
	5	0.408	0.242	5149	12.59	33.1	0.284	6500	18.43	70.3	61.9	12.0
	10	0.385	0.220	4902	10.70	32.3	0.289	6621	18.86	69.2	62.0	12.0
	15	0.424	0.242	5337	12.89	33.3	0.247	7680	19.13	72.0	61.8	11.7
	20	0.393	0.267	5252	14.07	30.7	0.281	6762	19.26	68.8	61.9	12.2
Knife	0	0.388	0.222	5264	11.68	32.5	0.257	5213	13.45	57.7	61.9	12.4
	5	0.401	0.258	5562	14.30	32.2	0.265	6995	18.64	69.9	61.7	11.7
	10	0.400	0.232	5278	12.37	31.5	0.243	6837	16.60	63.3	61.6	12.3
	15	0.403	0.249	5587	14.12	31.5	0.279	7001	19.63	65.8	61.8	12.1
	20	0.414	0.250	5321	13.48	31.4	0.274	6805	19.07	72.0	61.5	12.0
Starter	0	0.396	0.229	4868	11.16	32.2	0.275	5505	15.00	57.3	62.0	12.3
	5	0.404	0.225	6218	14.44	32.5	0.261	6509	16.64	61.0	61.5	12.1
	10	0.401	0.234	6194	14.62	32.4	0.284	6663	18.93	69.4	62.0	12.0
	15	0.384	0.269	5814	15.61	32.0	0.300	6997	20.56	69.1	61.9	11.7
	20	0.410	0.254	5267	13.48	32.6	0.301	6666	20.10	71.4	61.8	11.8
P Rate #/A	0	0.391	0.233	5004	11.61	32.1	0.265	5584	14.77	60.1	61.9	12.3
	5	0.404	0.242	5643	13.78	32.6	0.270	6668	17.90	67.1	61.7	11.9
	10	0.396	0.229	5458	12.56	32.1	0.272	6707	18.13	67.3	61.9	12.1
	15	0.405	0.252	5558	14.08	32.3	0.275	7226	19.77	69.0	61.8	11.8
	20	0.406	0.257	5280	13.67	31.6	0.285	6744	19.48	70.8	61.7	12.0
Method												
Broadcast		0.402	0.243	5160	12.56	32.4	0.275	6891	18.92	70.1	61.9	12.0
Knife		0.404	0.247	5437	13.57	31.7	0.265	6909	18.48	67.7	61.6	12.0
Starter		0.401	0.244	5877	14.47	32.4	0.287	6709	19.06	67.7	61.8	11.9
Method		NS	NS	.02	.06	NS	NS	NS	NS	NS	NS	NS
P Rate		NS	.08	.13	.04	NS	NS	**	.02	**	NS	NS
Linear		NS	.03	NS	.03	NS	NS	**	**	NS	NS	NS
Quadratic		NS	NS	.03	NS	NS	NS	**	.18	NS	NS	NS
Method x P Rate		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.		5.9	11.5	11.8	16.2	6.8	14.8	13.8	20.5	9.9	1.1	4.6

** is 0.01 significance level.

Table 6. Means and statistical analyses for split application study for Lamberton soybean and corn, 1987.

	Soybean					Corn				
Treatment	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
B + K 20 + 20	0.380	5695	0.228	12.99	35.0	0.244	13780	0.158	21.62	134.1
B + S 20 + 20	0.384	5280	0.239	12.68	37.8	0.239	14300	0.166	23.74	134.6
K + S 20 + 20	0.421	5755	0.226	12.96	36.1	0.241	14950	0.169	25.33	133.3
B 40	0.353	5780	0.228	13.31	37.9	0.239	13455	0.155	20.92	142.4
K 40	0.401	6005	0.220	13.22	35.3	0.253	14165	0.160	22.71	134.4
S 40	0.448	6505	0.217	14.09	37.4	0.226	13755	0.148	20.35	122.6
Check	0.296	5692	0.193	10.93	31.4	0.174	12405	0.128	15.93	111.3
Treatment	**	.10	.14	.15	**	**	**	**	**	**
C.V.	11.6	9.2	14.1	16.8	5.8	7.9	6.3	11.6	14.4	5.1

** is 0.01 significance level.

Table 7. Means and statistical analyses for split application study for Waseca soybean and corn, 1987.

	Soybean					Corn				
Treatment	Trifoliate P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A	Ear Leaf P %	Forage Yield lb/A	Whole Plant P %	P Uptake lb/A	Grain Yield Bu/A
B + K 20 + 20	0.487	5625	0.322	18.04	45.0	0.251	15255	0.133	20.44	149.3
B + S 20 + 20	0.492	6095	0.304	18.37	46.9	0.250	15500	0.130	20.13	162.0
K + S 20 + 20	0.515	5460	0.257	13.97	42.2	0.258	14150	0.137	19.43	149.0
B 40	0.503	5849	0.316	18.52	44.7	0.249	14795	0.133	19.69	146.9
K 40	0.531	5465	0.286	15.57	46.4	0.253	15900	0.131	20.78	143.7
S 40	0.535	5640	0.298	16.83	47.4	0.263	15550	0.133	20.67	146.3
Check	0.392	4863	0.196	9.59	39.2	0.158	12837	0.110	14.26	125.5
Treatment	**	**	**	**	**	**	**	**	**	**
C.V.	5.0	9.4	14.8	14.6	7.8	10.3	8.7	8.5	13.5	11.1

** is 0.01 significance level.

Table 8. Means and statistical analyses for split application study for Crookston soybean and wheat, 1987.

	Soybean					Spring Wheat					
Treatment	Trifoliate P %	Plant P %	Forage Yield lb/A	P Uptake lb/A	Grain Yield Bu/A	Plant P %	Forage Yield lb/A	P Uptake lb/A	Grain Yield Bu/A	Bushel Wt. lb/Bu	Grain Protein %
B + K 5 + 5	0.471	0.242	5452	13.16	30.2	0.284	7531	21.72	67.9	61.2	11.8
B + S 5 + 5	0.398	0.270	5392	14.52	33.6	0.266	7238	19.39	70.9	62.4	11.9
K + S 5 + 5	0.418	0.252	5766	14.52	33.6	0.260	7929	20.55	75.4	61.1	11.6
B 10	0.385	0.220	4902	10.70	32.3	0.289	6621	18.86	69.2	62.0	12.0
K 10	0.400	0.232	5278	12.37	31.5	0.243	6837	16.60	63.3	61.6	12.3
S 10	0.401	0.234	6194	14.62	32.4	0.284	6663	18.93	69.4	62.0	12.0
Check	0.391	0.233	5004	11.61	32.1	0.265	5584	14.77	60.1	61.9	12.3
Treatment	NS	NS	.10	.04	NS	NS	**	.05	**	.07	NS

** is 0.01 significance level.

EFFECT OF GYPSUM AND BORON AMENDMENTS ON POTATO YIELD AND INCIDENCE OF INTERNAL TUBER QUALITY DISORDERS

C. Rosen, J. Bartz and F. Lauer

Preharvest internal tuber quality disorders such as brown center and hollow heart are of great concern to potato growers. In severe cases, these disorders make the produce unmarketable and consequently may result in considerable losses for the grower. In many cultivars such as Russet Burbank, brown center is generally considered to precede hollow heart. Susceptibility to brown center and hollow heart has been related to environmental conditions and genotype. Conditions which promote large tubers and periods of fast growth favor the development of internal disorders. In Russet Burbank, cool temperatures coupled with high soil moisture often lead to a high incidence of hollow heart. Another potato cultivar which shows a high incidence of brown center and hollow heart under certain conditions is Reddale. When grown in the Red River Valley (non-irrigated fine-textured soils), Reddale generally has very good quality. However, when grown in the irrigated sands of central Minnesota, it generally performs poorly due to a high incidence of brown center and hollow heart. One major attribute of Reddale in either environment is that it shows a high degree of resistance to Verticillium wilt, a major cause of early dieback in potato. The most popular red potato grown in central Minnesota is Norland which is susceptible to Verticillium wilt. A reduction in the incidence of brown center in Reddale would make this cultivar more useful to growers which in turn would reduce losses due to early dieback. Because calcium and boron soil levels can be low in the sandy soils of central Minnesota, the role of these nutrients in brown center and hollow heart was investigated. The purpose of this experiment was to determine the influence of gypsum and boron soil amendments on potato productivity and incidence of tuber disorders in Reddale, Russet Burbank and Krantz potatoes. Krantz was included as a cultivar resistant to internal quality disorders.

Materials and Methods

This experiment was conducted at the Sand Plains Research Farm in Becker, MN. The soil, a Hubbard Loamy Sand had the following soil chemical properties prior to planting (0-6"): pH, 6.3; P, 109 lb/A; K, 239 lb/A; Ca, 1105 lb/A; S, 5 ppm; B, 0.2 ppm. The previous crop was sweet corn. Prior to planting, 0-0-22 at the rate of 250 lbs/A was broadcast and incorporated. Four nutritional treatments were evaluated: 1) control, 2) 1.0 lb/A B as solubor applied at hilling, 3) 500 lb/A Ca as gypsum preplant broadcast and incorporated, and 4) 1.0 lb/A B at hilling and 500 lb/A Ca preplant. Gypsum was applied by hand and incorporated one week prior to planting. Solubor treatments were applied by hand and then incorporated during hilling. Reddale, Russet Burbank, and Krantz certified seed were planted by hand on April 13 at a spacing of 3' between rows and 1' within the row. A 3 X 4 factorial treatment arrangement was used with 4 replications in a randomized complete block design. After planting, all cultivars received 1000 lbs/A of 8-10-30 as a band application. Nitrogen, as ammonium nitrate, was sidedressed at emergence (70 lb N/A) and at hilling (70 lb N/A). The most recently matured leaves from each cultivar were sampled on July 8. Samples were dried, ground, and then analyzed for Ca and B using ICP procedures. Two days prior to harvest, soil samples from the top 12 inches in the middle of the hill were collected air dried and analyzed for Ca, S, and B. All cultivars were harvested on September 22. Subsamples of 20 tubers per size category for each cultivar were collected for quality evaluation.

Results

Gypsum and boron soil amendments increased soil test levels of Ca, S, and B (Table 1). Boron levels in the treated plots were still in a range considered low for most crops. Soil Ca increased slightly with gypsum application; however, the check plot had Ca levels considered adequate for crop growth. Soil S increased from a level in the low range in the check plot to a relatively high level in the gypsum treated plots.

At the rates applied, gypsum and/or B amendments had no effect on potato yield (Table 2). Reddale died back early due to an apparent preferential infestation of European corn borer. Despite this early dieback, Reddale yield was greater than either Russet Burbank or Krantz. The yield of Reddale was made up largely of jumbo size potatoes which is an undesirable size for fresh market potato production.

Tissue levels of B and Ca varied with cultivar (Table 3). Krantz had the highest concentrations of B and Ca, Russet Burbank the lowest and Reddale was intermediate. Gypsum applications did not significantly increase leaf tissue Ca levels. Boron applications increased tissue B in all three cultivars.

Because of significant interactions between cultivar and soil amendments, the effect of B and/or gypsum on tuber quality was analyzed separately for each cultivar. Neither of the amendments alone or in combination reduced the incidence of brown center or hollow heart in jumbo Reddale potatoes (Table 4). In the smaller A size potatoes, gypsum and gypsum plus boron significantly reduced the incidence of internal quality disorders compared to the check plot. Boron alone tended to lower incidence of brown center and hollow heart, but the effect was not significant. In the B size category, brown center and hollow heart were virtually nonexistent. There was no effect of gypsum or B amendments on Russet Burbank tuber quality (Table 5). The internal disorders of Russet Burbank were somewhat different than those of Reddale. The hollow heart in Russet Burbank was located more near the end of the tuber as a horizontal cavity. In contrast, The hollow heart in Reddale was more in the center of the tuber, more widespread and usually was much darker. These differences may imply that the internal disorder of Reddale is not the same as the internal disorder of Russet Burbank. Krantz did not show any sign of hollow heart or brown center in treated or untreated plots (Table 6). If tuber quality disorders have been a problem in a particular area, Krantz would be a good cultivar to grow.

Further studies are planned with Reddale to determine whether higher rates of boron and cultural manipulation to reduce tuber size can be used to lower the incidence of internal tuber quality disorders.

Table 1. Effect of gypsum and boron amendments on soil test B, Ca and S (0-12") at harvest. (Averaged over cultivar).

Treatment	Element		
	Calcium	Boron	Sulfur
	lb/A	-------- ppm	---------
Check	1148	0.28	4.7
Boron	1182	0.41	5.3
Gypsum	1285	0.28	31.2
Boron + Gypsum	1363	0.44	60.4
Significance	**	**	**
BLSD (0.05)	115	0.07	12.1

Table 2. Effect of gypsum and boron on yield of Reddale, Russet Burbank and Krantz.

Treatment	Tuber Size Distribution				
	< 3 oz.	3-7 oz.	7-12 oz.	> 12 oz.	total
Reddale	cwt/A				
Check	8.7	87.7	321.5	230.5	648.4
Boron	10.1	91.1	311.4	231.6	644.2
Gypsum	7.7	79.7	331.0	207.0	625.4
Boron + Gypsum	6.2	77.5	289.8	269.5	643.0
Russet Burbank					
Check	13.1	350.1	200.3	19.1	582.6
Boron	11.8	286.9	272.1	23.8	594.6
Gypsum	15.0	300.9	265.3	41.4	622.6
Boron + Gypsum	14.1	268.3	287.4	29.8	599.6
Krantz					
Check	12.7	116.7	452.9	55.7	638.0
Boron	11.4	109.1	417.7	62.8	601.0
Gypsum	9.9	94.9	389.5	53.5	547.8
Boron + Gypsum	9.5	110.7	409.2	63.7	593.1
Statistics					
Cultivar					
Reddale	8.2	84.0	313.4	234.6	640.2
Russet Burbank	13.5	301.5	256.3	28.6	599.9
Krantz	10.9	107.8	417.3	58.9	595.0
Significance	**	**	**	**	**
BLSD (0.05)	2.2	27.2	31.6	24.5	30.5
Nutrition					
Check	11.5	184.8	324.9	101.8	623.0
Boron	11.1	182.4	333.7	106.1	613.3
Gypsum	10.9	158.5	328.6	100.6	598.6
Boron + Gypsum	9.9	152.1	328.8	121.1	611.9
Significance	NS	NS	NS	NS	NS
BLSD (0.05)	--	--	--	--	--
Cultivar x Nutrition					
Significance	NS	NS	NS	NS	NS

NS = not significant, * = significant at 5%, ** significant at 1%

Table 3. Effects of gypsum and boron soil amendments on leaf tissue concentrations of boron and calcium.

	Cultivar					
	Reddale		Russet Burbank		Krantz	
	Element					
Treatment	Calcium	Boron	Calcium	Boron	Calcium	Boron
	---%---	-ppm-	---%---	-ppm-	---%---	-ppm-
Check	1.01	31.7	0.91	23.3	1.35	41.2
Boron	1.19	42.3	0.85	27.0	1.38	47.9
Gypsum	1.05	34.2	0.91	23.7	1.32	41.4
Boron + Gypsum	1.10	39.1	0.86	27.4	1.35	45.5

Statistics	Calcium	Boron
	---%---	-ppm-
Cultivar		
Reddale	1.09	36.8
Russet Burbank	0.88	25.3
Krantz	1.35	44.0
Significance	**	**
BLSD (0.05)	0.06	1.3
Nutrition		
Check	1.09	32.1
Boron	1.14	39.1
Gypsum	1.09	33.1
Boron + Gypsum	1.10	37.3
Significance	NS	**
BLSD	--	1.6
Cultivar x Nutrition		
Significance	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%

Table 4. Effect of gypsum and boron soil amendments on incidence of brown center and/or hollow heart - Reddale.

Treatment	Tuber Size Distribution		
	B	A	Jumbo
	---------- % incidence ----------		
Check	0.0	12.5	65.0
Boron	0.0	6.8	58.5
Gypsum	0.0	2.5	65.0
Boron + Gypsum	1.0	1.3	42.5
Significance	NS	*	NS
BLSD (0.05)	--	9.5	--

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 5. Effect of gypsum and boron soil amendments on incidence of brown center and/or hollow heart - Russet Burbank.

Treatment	Tuber Size Distribution	
	7-12 oz.	> 12 oz.
	---------- % incidence ----------	
Check	6.0	19.0
Boron	12.1	12.0
Gypsum	9.0	7.0
Boron + Gypsum	11.0	10.8
Significance	NS	NS
BLSD (0.05)	--	--

NS = not significant, * = significant at 5%, ** = significant at 1%

Table 6. Effect of gypsum and boron soil amendments on incidence of brown center and/or hollow heart - Krantz.

Treatment	Tuber Size Distribution	
	7-12 oz.	> 12 oz.
	---------- % incidence ----------	
Check	0	0
Boron	0	0
Gypsum	0	0
Boron + Gypsum	0	0
Significance	NS	NS
BLSD	--	--

NS = not significant, * = significant at 5%, ** significant at 1%.

MONITORING SPRING NITROGEN STATUS OF STRAWBERRIES

C. Rosen, J. Luby, E. Hoover

The influence of various nitrogen fertilizer rates and application times on strawberry ('Honeoye') yield and leaf/petiole nitrogen status was examined. The experiment was located at the Sand Plains Research Station (Hubbard loamy sand) in Becker, MN. A matted row system was used with 3 ft. between row centers. Yield data and tissue samples were taken during the spring of the third fruiting season. The treatments were as follows:

Treatment Number	Renovation 1986	Fall 1986	Spring 1987
	---------- lb N/A	----------	
1	50	0	0
2	50	0	25
3	50	0	50
4	50	50	0
5	50	50	25
6	50	50	50

Nitrogen, as ammonium nitrate, was topdressed and irrigated in after each application. Recently matured leaves (leaflets and petioles) were collected during initial flowering (5/13/87), fruit maturation (5/28/87), initial harvest (6/11/87), and final harvest (6/24/87). Samples were dried and ground to pass through a 30 mesh screen. Total Kjeldahl N was determined following digestion in H_2SO_4. Petiole samples from recently matured leaves were also collected at the same dates indicated above. The samples were placed in a plastic bag and kept in a cooler for subsequent nitrate analysis. Sap from 6 petioles was expressed into a small plastic container using needle nose pliers. EM Quant (EM Science Cherry Hill, NJ) nitrate strips were dipped into the sap mixture. After two minutes, color was subjectively evaluated using a chart which related color to ppm nitrate.

RESULTS

Strawberry maturity was initially delayed by spring applications of N (Table 1). Total yields were not significantly affected by N treatments. However, except for treatment 5, supplemental nitrogen (either in fall and/or spring) after renovation tended to increase yields. Spring nitrogen did not increase the amount of rotten berries (data not presented). It should be noted that this was a relatively dry spring. Except for treatment 5, berry size increased with spring N treatments (Table 2). The reason for anomalous behavior of treatment 5 is not presently known. Nitrogen treatment did not affect % soluble solids in ripe berries (data not presented). Concentrations of total N in strawberry leaves decreased as the season progressed and was related to nitrogen treatment (Table 3). Petiole nitrates also decreased as the season progressed (Table 4). E M Quant nitrate strips were easy to use and appeared to a sensitive indicator of strawberry plant N status.

Table 1. Influence of nitrogen fertilizer treatments on marketable strawberry yield.

	Nitrogen Treatment			Harvest Date					
	Ren.	Fall	Spring	6/8	6/11	6/15	6/18	6/24	Total
	------ lb N/A		-----	----------		1000 lb/A		----------	
1.	50	0	0	2.1	2.8	3.6	3.4	4.6	16.5
2.	50	0	25	1.9	2.1	4.1	4.1	5.6	17.8
3.	50	0	50	0.9	2.2	4.4	4.7	7.3	19.6
4.	50	50	0	2.4	2.9	4.6	4.3	5.5	19.7
5.	50	50	25	1.4	2.3	3.9	2.6	5.4	15.7
6.	50	50	50	1.5	2.6	4.2	4.1	6.0	18.4
			Pr > F	0.09	0.08	0.50	0.17	0.34	0.24
			LSD (0.10)	0.8	0.5	-	-	-	-

Table 2. Influence of nitrogen fertilizer treatments on berry size.

	Nitrogen Treatment			Harvest Date					
	Ren.	Fall	Spring	6/8	6/11	6/15	6/18	6/24	Weighted Avg.
	------ lb N/A -----			---------- g/berry ----------					
1.	50	0	0	15.1	13.8	10.0	6.9	6.7	9.9
2.	50	0	25	14.7	14.9	11.5	8.1	6.9	10.2
3.	50	0	50	15.0	16.0	12.1	8.4	7.7	10.1
4.	50	50	0	15.9	13.4	10.3	7.6	6.3	9.9
5.	50	50	25	14.5	14.1	9.7	6.5	7.1	9.5
6.	50	50	50	15.5	15.4	10.7	8.6	7.9	10.5
			Pr > F	0.59	0.01	0.03	0.01	0.09	0.08
			LSD (0.10)	-	1.1	1.3	1.0	0.9	0.5

Table 3. Influence of nitrogen fertilizer on total N in strawberry leaves.

	Nitrogen Treatment			Sampling Date			
	Ren.	Fall	Spring	May 13	May 28	June 11	June 24
	------- lb N/A -----			---------- % N ----------			
1.	50	0	0	2.60	1.78	1.65	1.44
2.	50	0	25	3.10	2.32	1.97	1.56
3.	50	0	50	3.08	2.45	2.14	1.67
4.	50	50	0	2.53	2.07	1.81	1.50
5.	50	50	25	3.08	2.40	1.93	1.55
6.	50	50	50	3.02	2.51	2.08	1.69
			Pr > F	0.01	0.01	0.01	0.01
			LSD (0.05)	0.31	0.28	0.22	0.10

Table 4. Influence of nitrogen fertilizer on nitrate in strawberry petioles.

	Nitrogen Treatment			Sampling Date			
	Ren.	Fall	Spring	May 13	May 28	June 11	June 24
	------- lb N/A -----			---------- ppm NO_3 ----------			
1.	50	0	0	320	10	137	20
2.	50	0	25	1000+	800	635	452
3.	50	0	50	1000+	900	900	700
4.	50	50	0	700	400	270	174
5.	50	50	25	1000+	850	825	656
6.	50	50	50	1000+	850	950	850
			Pr > F	0.01	0.01	0.01	0.01
			LSD (0.05)	170	280	242	358

PRELIMINARY EVALUATION OF CARBOSAN SEQUESTERED COPPER AND MANGANESE AS MICRONUTRIENT SOURCES FOR RADISH PRODUCTION ON ORGANIC SOILS

C.J. Rosen and H.J. Buchite

Soil or foliar application of micronutrients for vegetable crop production on organic soils is a cultural practice frequently used by growers. Organic soils tend to be inherently low in certain micronutrients and can form organic complexes that may reduce micronutrient availability to plants. The primary micronutrients involved are copper and manganese. Radish is a crop commonly grown on organic soils and also has a relatively high demand for copper and manganese. Low levels of these nutrients in radish leaves are frequently observed when the crop is grown on organic soils with a pH of 5.8 or greater. Polysaccharide compounds of varying chain lengths are commonly used in the animal industry to sequester micronutrients thereby increasing availability of the sequestered nutrient. Little research has been conducted to evaluate these compounds as sources of micronutrients for improving agronomic or horticultural crop production. The objective of the following experiments was to compare the effects of polysaccharide sequestered (Carbosan) copper and manganese with sulfate sources and commercially available chelate sources of these micronutrients on radish production. The primary reason for selecting radish is because of its high demand for these nutrients, relatively fast growth cycle and significant economic value in Minnesota.

Experimental Procedures:

Three experiments, one in the greenhouse and two in the field were conducted to evaluate the various copper and manganese treatments on radish growth and nutrition.

Experiment I - Greenhouse Experiment. A Rifle Muck Organic soil (0-6") from the experimental field in Andover, MN was collected and thoroughly mixed in the greenhouse. The mixed soil had the following chemical properties: pH (water) 6.0; P (Bray 1), 200+ lb/A; K (NH_4OAc) 370 lb/A; Mn (DTPA) 8.9 ppm; Cu (DTPA) 1.0 ppm. Nitrogen as ammonium nitrate was incorporated at the rate of 0.03 gram/1.0 lb soil (approximately 40 lb N/A). Three sources of copper and manganese were evaluated: 1) Carbosan Cu chelate (10.0% Cu) and Mn chelate (10.8% Mn) manufactured by Quali Tech, Inc. 2) Frit copper chelate (EDTA and Citric acid - 5% Cu) manufactured by Frit Industries Inc. and THIS Mn chelate (5% Mn) manufactured by Stoller Chemical Co. Inc. 3) Mn sulfate (32% Mn) and Cu sulfate (25% Cu).

Four radish seeds (cv. 'Fuego') were planted in plastic pots containing 2.5 lbs of the organic soil (60 % moisture). There were 21 treatments which included:

1) check, unsprayed
2) water sprayed
3) water + Tween 80 (0.05 ml/L)
4) Cu Carbosan - foliar 0.3 lb Cu/A
5) Cu Chelate - foliar 0.3 lb Cu/A
6) Cu Sulfate - foliar 0.3 lb Cu/A
7) Mn Carbosan - foliar 0.3 lb Mn/A
8) Mn Chelate - foliar 0.3 lb Mn/A
9) Mn Sulfate - foliar 0.3 lb Mn/A
10) Cu + Mn Carbosan - foliar 0.3 lb Cu/A + 0.3 lb Mn/A
11) Cu + Mn Chelate - foliar 0.3 lb Cu/A + 0.3 lb Mn/A
12) Cu + Mn Sulfate - foliar 0.3 lb Cu/A + 0.3 lb Mn/A
13) Cu Carbosan - soil 6.0 lb Cu/A
14) Cu Chelate - soil 6.0 lb Cu/A
15) Cu Sulfate - soil 6.0 lb Cu/A

16) Mn Carbosan - soil 12.0 lb Mn/A
17) Mn Chelate - soil 12.0 lb Mn/A
18) Mn Sulfate - soil 12.0 lb Mn/A
19) Cu + Mn Carbosan - soil 6.0 lb Cu/A + 12.0 lb Mn/A
20) Cu + Mn Chelate - soil 6.0 lb Cu/A + 12.0 lb Mn/A
21) Cu + Mn Sulfate - soil 6.0 lb Cu/A + 12.0 lb Mn/A

Soil treatments were mixed in thoroughly prior to planting. All foliar treatments were applied with Tween 80, a surfactant, at the rate of 0.05 ml/L. Foliar fertilizer treatments at the rates indicated above were applied at 12, 18 and 21 days after emergence with a hand held sprayer calibrated to deliver the required amount. A randomized complete block design was used with 4 replications. Pots were watered as required. Plants were harvested 23 days after emergence. Fresh and dry weight of roots and leaves were recorded. Roots less than 1/4 inch in diameter were considered as nonmarketable. Burn damage due to foliar spray was qualitatively scored. Soils samples were collected from the soil applied treatments and extracted with DTPA for subsequent Cu and Mn determination.

Experiment II - Field Experiment. The experimental site was located at Andover, MN on a Rifle Muck soil. Soil chemical properties are the same as those listed above. The field was planted in radish the previous year and radish was the previous crop in the current season. Fertilizer was broadcast and incorporated prior to planting the first radish crop at the rate of 55 lb N/A, 150 lb K_2O/A and 25 lb S/A. The second radish crop was planted June 22 in 6 row beds with 10" between rows and 2 feet between beds at a population of 426,000 seeds/A. Only foliar fertilizer treatments were applied in the field experiment (treatments 1-12). Because copper treatments severely burned foliage in the greenhouse experiment, half the rate (0.15 lb Cu/A) was used in the field experiment. Manganese rates were the same as in the greenhouse experiment. Treatments were applied 7, 16,and 19 days after emergence with a backpack CO_2 sprayer at 20 psi with 100 gal water/A. Each plot consisted of a bed 20 ft in length. A randomized complete block design with four replications was used. Two 4 ft rows from the center of each bed were harvested 24 days after emergence (July 9). Fresh weight of roots and leaves was recorded. Nonmarketable plants (roots less than 1/4 inch in diameter) were discarded before weighing. Subsamples of roots and leaves were weighed, rinsed twice in deionized water, dried, reweighed and ground for subsequent nutrient determinations. For each plot, the most recently matured leaf from 10 plants was evaluated for color using Pantone color paper as a reference. Burn damage due spray applications was subjectively evaluated for each treatment.

Experiment III - Field Experiment. A third study was conducted at the same site 11 days after the harvest of experiment II. Fertilizer was applied at planting at the rate of 55 lb N/A, 150 lb K_2O/A and 25 lb S/A. Foliar treatments were the same as in experiment II except that only foliar applications of Carbosan and conventional chelates were evaluated and the rate of copper application was dropped to 0.1 lb Cu/A. Treatments were applied 7, 12, 16, 19, and 21 days after emergence. On August 14, 23 days after emergence, radishes were harvested following the same procedures as in experiment II.

Results and Discussion

Experiment I. Fresh and dry weight yields of radish roots and leaves were significantly lower with foliar applications of all copper sources (Table 1). Lower yields generally corresponded to increased foliar damage due to copper sprays and poor root development. Damage to leaves and negative effects on yields tended to be ameliorated when manganese was applied with the copper. Soil-applied copper and manganese and foliar-applied manganese did not affect yields or % usable roots. Soil applications of copper and manganese increased DTPA extractable levels of these nutrients (Table 2). Manganese sulfate was not as effective as the chelated sources in increasing extractable manganese. All sources of copper appear to be equal in supplying copper. Extractions were made less than 4 weeks after application. Longer term studies are needed to determine whether differences in fixation occur over time.

Experiment II. Radish yields were not significantly affected by any of the copper or manganese treatments (Table 3). Despite the fact that half the rate of copper was used compared to that of experiment I, spray damage was still evident. The amelioration of spray damage with manganese observed in Experiment I was not evident in experiment II. Leaf color was examined because of the importance of having green leaves for the green top market. There were no differences in leaf color due to treatment. Foliar applications of copper increased concentrations and content of copper in both leaves and roots (Tables 4 and 5). Copper apparently was translocated from the leaves to the roots. In contrast, leaf manganese concentrations increased with manganese applications but, there did not appear to be significant translocation to the roots. The sulfate source of manganese was not as effective as the chelate sources in increasing leaf manganese levels.

Experiment III. Although there was no significant effect of copper or manganese on radish yields (Table 6), there was a trend for yields to be greater when manganese was applied. As in Experiment II, spray damage was evident from copper sprays. Leaf color was not affected by either copper or manganese treatments. Foliar applications of copper and manganese increased concentrations and content of these nutrients in both leaves and roots (Tables 7 and 8). Unlike experiment II, both copper and manganese were translocated to the roots. The main reason for this difference is probably due to the additional sprays - 5 in experiment III and only three in experiment II.

The results of these experiments suggest that the Carbosan micronutrient sources were as effective as the commercial chelate sources in increasing tissue levels of copper and manganese. In order to avoid foliar spray damage, rates of copper application should not exceed 0.1 lb Cu/A per application. It is probable that either source could be used to supply copper and manganese if a deficiency exists.

Nutrient Composition and Uptake Experiments II and III. Average nutrient concentrations in radish leaves and roots from Expts. II and III are presented in Table 9. Manganese and copper values are taken from the check plots only. From these values and percent moisture determinations, nutrient uptake by the radish crop was calculated (Tables 10 and 11). Of all the nutrients, potassium uptake was greatest followed by nitrogen. Most of the potassium accumulated in the roots while nitrogen accumulated in the leaves. As expected, higher yields resulted in greater nutrient uptake. Although nutrient uptake appears to be relatively low for a single crop, these values should be multiplied by the number of crops (3-5) grown during the season to obtain total nutrient removal.

Table 1. Effects of Cu and Mn soil and foliar applications on radish yields and leaf damage. Greenhouse study. Expt. I.

Treatment	Yield Roots	Yield Leaves	Yield Roots	Yield Leaves	Useable Roots	Spray Damage[1]
	- - g fw - -		- - g dw - -		--%--	
1. Control	32.0	19.8	1.93	1.88	87.5	1.0
2. Water spray	33.5	21.1	1.97	1.94	87.5	1.0
3. Water + Tween 80	32.1	21.0	1.91	1.94	95.0	1.0
4. Cu - Carbosan, foliar	19.9	18.9	1.25	1.82	62.5	2.1
5. Cu - Chelate, foliar	15.0	16.3	0.92	1.61	50.0	3.0
6. Cu - Sulfate, foliar	16.4	21.5	1.00	2.10	75.0	3.0
7. Mn - Carbosan, foliar	35.8	21.1	2.10	2.00	95.0	1.1
8. Mn - Chelate, foliar	30.4	22.4	1.73	2.04	87.5	1.0
9. MN - Sulfate, foliar	35.8	21.3	2.07	2.00	87.5	1.0
10. Cu + Mn - Carbosan, foliar	20.1	19.2	1.22	1.88	75.0	1.2
11. Cu + Mn - Chelate, foliar	25.1	18.3	1.52	1.87	75.0	1.2
12. Cu + Mn - Sulfate, foliar	26.2	21.8	1.55	2.10	82.5	2.3
13. Cu - Carbosan, soil	25.6	19.8	1.59	1.81	70.0	1.0
14. Cu - Chelate, soil	31.6	20.8	1.85	1.87	87.5	1.0
15. Cu - Sulfate, soil	36.2	20.2	2.14	1.89	95.0	1.2
16. Mn - Carbosan, soil	32.2	21.1	1.98	1.97	87.5	1.0
17. Mn - Chelate, soil	30.9	19.9	1.87	1.91	100.0	1.0
18. Mn - Sulfate, soil	33.2	19.1	2.05	1.81	87.5	1.0
19. Cu + Mn - Carbosan, soil	31.4	18.6	1.94	1.71	95.0	1.0
20. Cu + Mn - Chelate, soil	35.0	22.1	2.10	2.01	87.5	1.0
21. Cu + Mn - Sulfate, soil	29.0	19.8	1.81	1.88	87.5	1.0
Significance	**	**	**	**	*	**
BLSD (0.05)	10.4	3.5	0.63	0.26	47.5	0.3

[1]Spray damage score: 1 = no damage 2 = slight damage 3 = severe damage

Table 2. DTPA extractable copper and manganese soil levels after radish harvest. Greenhouse study - Expt. I.

Treatments	Mn	Cu
	--------ppm--------	
1. Control	20.1	2.3
3. Water + Tween 80	20.7	2.4
13. Cu Carbosan	19.4	47.7
14. Cu Chelate	20.4	33.0
15. Cu Sulfate	21.2	34.0
16. Mn Carbosan	49.0	2.5
17. Mn Chelate	63.5	2.5
18. Mn Sulfate	38.3	2.6
19. Cu + Mn Carbosan	57.9	45.0
20. Cu + Mn Chelate	49.5	25.2
21. Cu + Mn Sulfate	37.5	66.4
Significance	**	**
BLSD (0.05)	16.0	26.0

Table 3. Effect of Cu and Mn foliar applications on radish yield, leaf color and burn damage. Expt. II.

Treatment	Roots	Leaves	Total	Spray Damage[1]	Leaf Color[2]
	---------1000lb/A---------				
1. Control	7.06	3.65	10.71	1.4	6.4
2. Water	7.12	3.71	10.83	1.0	6.5
3. Water tween	6.68	3.54	10.22	1.0	6.9
4. Cu Carbosan	6.26	3.58	9.83	2.8	6.3
5. Cu Chelate	6.52	3.78	10.30	2.8	6.5
6. Cu Sulfate	5.55	3.17	8.72	2.9	6.7
7. Mn Carbosan	5.73	3.02	8.75	1.0	6.8
8. Mn Chelate	6.39	3.31	9.70	1.3	6.6
9. Mn Sulfate	6.24	3.50	9.74	1.0	6.3
10. Cu + Mn Carbosan	5.73	3.08	8.81	2.8	6.8
11. Cu + Mn Chelate	6.27	3.27	9.54	2.1	6.3
12. Cu + Mn Sulfate	5.88	3.48	9.37	3.0	6.9
Significance	NS	NS	NS	**	NS
BLSD (0.05)	-	-	-	0.5	-

[1] Spray damage score: 1 = no damage 2 = slight damage 3 = severe damage
[2] Leaf color score: 1 = yellow 9 - dark green

Table 4. Effect of (Cu and Mn) foliar applications on Cu and Mn concentrations in radish roots and leaves. Expt. II.

Treatment	Cu		Mn	
	Roots	Leaves	Roots	Leaves
	----------ppm----------			
1. Control	1.3	3	6.1	23
2. Water	1.3	3	6.3	27
3. Water + Tween 80	1.3	3	6.1	24
4. Cu Carbosan	2.7	34	5.9	25
5. Cu Chelate	2.5	34	5.7	24
6. Cu Sulfate	3.1	44	6.3	25
7. Mn Carbosan	1.2	5	6.6	208
8. Mn Chelate	1.1	3	6.5	214
9. Mn Sulfate	1.2	3	6.3	36
10. Cu + Mn Carbosan	2.7	36	6.9	215
11. Cu + Mn Chelate	2.6	30	6.9	209
12. Cu + Mn Sulfate	2.9	47	6.0	35
Significance	**	**	(0.07)	**
BLSD (0.05)	0.4	8	1.0	27

Table 5. Effect of Cu and Mn foliar application on content of Cu and Mn in radish roots and leaves. Expt. II.

Treatment	Cu		Mn	
	Roots	Leaves	Roots	Leaves
	----------oz/A----------			
1. Control	0.007	0.010	0.033	0.079
2. Water	0.007	0.011	0.034	0.097
3. Water + Tween 80	0.007	0.010	0.032	0.078
4. Cu Carbosan	0.013	0.109	0.028	0.079
5. Cu Chelate	0.013	0.120	0.029	0.082
6. Cu Sulfate	0.014	0.133	0.027	0.076
7. Mn Carbosan	0.006	0.014	0.030	0.594
8. Mn Chelate	0.005	0.008	0.032	0.650
9. Mn Sulfate	0.006	0.010	0.031	0.118
10. Cu + Mn Carbosan	0.012	0.109	0.031	0.649
11. Cu + Mn Chelate	0.013	0.088	0.035	0.607
12. Cu + Mn Sulfate	0.013	0.159	0.029	0.118
Significance	**	**	NS	**
BLSD (0.05)	0.003	0.035	-	0.119

Table 6. Effect of Cu and Mn foliar application on radish yields, leaf color and spray damage. Expt. III.

Treatment	Roots	Leaves	Total	Spray Damage[1]	Leaf Color[2]
	-------1000 lb fw/A-------				
1. Control	6.64	5.10	11.74	1.0	4.5
2. Water + Tween	7.21	5.24	12.45	1.0	4.8
3. Cu Carbosan	6.59	4.99	11.58	1.7	3.8
4. Cu Chelate	6.03	4.49	10.52	1.7	4.9
5. Mn Carbosan	8.08	5.88	13.96	1.0	4.5
6. Mn Chelate	7.75	5.51	13.26	1.0	4.1
7. Cu + Mn Carbosan	7.95	5.48	13.43	2.0	3.8
8. Cu + Mn Chelate	7.48	5.92	13.41	2.0	4.3
Significance	NW	NS	NS	**	NS
BLSD (0.05)	-	-	-	0.7	-

Spray Damage Score: 1 = no damage, 2 = slight damage, 3 = severe damage
Leaf Color Score: 1 = yellow, 9 = green

Table 7. Effect of Cu and Mn foliar applications on Cu and Mn concentrations in radish roots and leaves. Expt. III.

Treatment	Cu		Mn	
	Roots	Leaves	Roots	Leaves
	ppm			
1. Control	2.2	4	7.6	32
2. Control + Tween	2.3	4	8.3	35
3. Cu Carbosan	3.0	40	8.7	33
4. Cu Chelate	3.0	78	7.0	32
5. Mn Carbosan	1.3	4	10.3	308
6. Mn Chelate	1.3	4	11.3	332
7. Cu + Mn Carbosan	2.3	37	11.0	313
8. Cu - Mn Chelate	2.6	44	10.3	275
Significance	NS	**	*	**
BLSD (0.05)	-	9	2.8	60

Table 8. Effect of Cu and Mn foliar application of on content of Cu and Mn in radish roots and leaves. Expt. III.

Treatment	Cu		Mn	
	Roots	Leaves	Roots	Leaves
	oz/A			
1. Control	0.009	0.014	0.031	0.120
2. Control + Tween	0.010	0.015	0.037	0.138
3. Cu Carbosan	0.012	0.149	0.033	0.119
4. Cu Chelate	0.013	0.251	0.029	0.102
5. Mn Carbosan	0.007	0.017	0.057	1.211
6. Mn Chelate	0.006	0.017	0.058	1.370
7. Cu + Mn Carbosan	0.012	0.137	0.061	1.169
8. Cu + Mn Chelate	0.014	0.189	0.053	1.175
Significance	-	**	*	**
BLSD	NS	0.056	0.019	0.33

Table 9. Nutrient concentrations in radish roots and leaves at harvest. Expt. II and III.

Plant Part	Experiment	Nutrient									
		N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		----------%----------					--------ppm--------				
Leaves	II	4.98	0.39	4.36	3.71	0.38	188	25	33	3.0	24
Roots		2.55	0.36	6.43	0.52	0.19	39	6	29	1.3	22
Leaves	III	5.17	0.37	4.87	3.36	0.31	256	33	36	3.8	24
Roots		3.04	0.43	6.97	0.52	0.20	44	8	30	2.2	26

Table 10. Total nutrient removal by a radish crop - 63 cwt/A - Expt II.

Plant Part	Nutrient									
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------lb/A----------					----------oz/A----------				
Leaves	9.9	0.8	8.7	7.4	0.8	0.6	0.08	0.10	0.010	0.08
Roots	7.8	1.1	19.5	1.6	0.6	0.2	0.03	0.14	0.007	0.12
Total	17.7	1.9	28.2	9.0	1.4	0.8	0.11	0.24	0.017	0.20

Table 11. Total nutrient removal by a radish crop - 73 cwt/A - Expt III.

Plant Part	Nutrient									
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	----------lb/A----------					----------oz/A----------				
Leaves	12.4	0.09	11.7	8.0	0.8	1.0	0.13	0.14	0.014	0.10
Roots	9.0	1.27	20.5	1.5	0.6	0.2	0.03	0.14	0.010	0.12
Total	21.4	2.17	32.2	9.5	1.4	1.2	0.16	0.28	0.024	0.22

CORN - TILAGE RESIDUE MANAGEMENT, LANCASTER, 1987

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The driftless soils area has the greatest county average estimated soil losses from cropland in Minnesota, ranging from 4.0 to 6.6 t/ac/yr in the six counties involved. Typical soils of the region such as Fayette-Dubuque, Seaton, and associated soils, are highly erodible, form dense crusts if unprotected from raindrop impact, and consequently, have low final infiltration rates and high runoff from the intense storm events common to the region. New and improved tillage practices are increasingly being relied upon to meet environmental goals under more intense cropping systems. These systems modify the soil and water losses as well as the kind and concentration of materials in the runoff. A more complete understanding of these tillage systems will allow a more accurate prediction of their effect on the environment and will permit them to be more effectively incorporated into the overall farming systems of the region.

Experimental Procedures

The experimental site is located on the Lancaster Experimental Farm. Four tillage treatments are replicated four times (Table 1), the first replicate is located on Palsgrove silt loam; the other three replicates are located on Rozetta silt loam. Each treatment is split into normal and mulched subtreatments. On the no-till (slot plant) plots an additional subtreatment (bare) is established by removing all residue prior to planting; this residue is then placed on the adjacent no-till mulched plot. Corn residue additions are made after tillage but before planting to obtain approximately 60 to 80 percent surface cover. Plots are approximately 90 to 100 feet in width and 80 feet in length. Row width was 36 inches in 1987. Pioneer 3747 was planted April 30, 1987 at 30,000 plants/acre. The conventional (Moldboard) treatment was plowed about April 23 and secondary tillage with a disk was done April 29 on the conventional and chisel treatments. The Ro-till unit replaced the paraplow treatment. No-till plots were planted with a 4-row John Deere 7000 Max-Emerge planter equipped with fluted coulters on one side and "trash whip" units on the other side which removed residue from an 8 to 9 inch area over the row. Fluted, coulters were used on all four rows on the conventional, chisel, and Ro-till treatments.

Nitrogen (250 lb N/acre as urea) was applied in April prior to planting. Starter fertilizer at planting was 200 lb/acre of 6-24-24. The insecticide was Furadan at 10 lb/acre. Pre-emergence herbicide was applied on April 30 (1.5 lb/A of Aatrex 4L and 1 qt/A of Dual 8E). Banvel was applied postemergence at 1 pint/A.

Percent cover was determined from slides taken May 13. Planting depth, rate of emergence, and silking date measurements were made on deisgnated portions of each plot. Hourly spring soil temperatures, leaf number, soil moisture, bulk density, and percent cover were measured on chisel, no-till, and Ro-till treatments in Rep 3 for mulch added, bare, and normal treatments. Soil temperature was measured at depths of 1, 5, 10, 15 and 50 cm. Yields for individual plots were determined by hand harvesting 60 foot of row (two subsamples each consisting of paired 15 ft. lengths of row) in October.

Ten plot frames (45 3/4 x 45 3/4 inches) were emplaced May 1 after planting before the surface was weathered by rainfall. Infiltration measurements were made on Ro-till mulch, no-till bare and mulch, and conventional normal and mulch treatments during the period May 11 to 14. Paired tensiometer measurements were made at three depths within the plot frame during the infiltration event.

Results - Corn yields

Precipitation amounts and distribution were very favorable at Lancaster in 1987 and corn yields ranged from 164 to 177 bu/A (tables 1 and 2). Corn yields of individual tillage, residue, and in-row residue management treatments were not significantly different at the 5 or 10 percent level of significance. Average corn yields of the four replicates were also not significantly different, ranging only from 168 bu/A in rep. one to 171 bu/A in rep. three (table 3). As in 1981 and 1982 soil depth was not related to

corn grain yield; however, yield increased with depth in each of the four intervening years. Thus the effect of rooting depth and available water holding capacity in the root zone on yields depends greatly on climatic conditions in the individual year as well as on the crop grown.

Seedbed Conditions and Corn Growth

For the 12 treatments, the average planting depth and average standard deviation of planting depth were statistically different at the 0.01 and 0.025 level of significance, respectively. The planting depths of the coulter and trash whip no-till treatments were not significnalty different. The standard deviations of planting depth were significantly less at the 10% level for the trash-whip treatment compared to the coulter treatment. The standard deviations of planting depth increased with in row cover according to the relationship:

Eq 1: Standard Deviation = 5.9 mm + 0.05 (% cover) ; $R^2 = 0.78$

On the chisel, Ro-till and conventional mulch treatments the heavy mulch and loose seedbed frequently prevented the coulter from cutting through the residue and planting depths were 4 to 12 mm deeper on normal than on mulch treatments. In some cases, the residue was pushed into the loose soil by the coulter making it difficult for the disc opener on the planter unit to penetrate the residue. For no-till, average planting depth for coulter and trash whip units differed by less than 1 mm for bare and normal residue treatments. However, for the no-till mulch treatment average planting depth for the trash whip units was approximately 7 mm deeper than the coulter. The trash whip units were adjusted for no-till conditions and consequently ran excessively deep in the looser soil conditions on the moldboard and chisel treatments.

In-row residue cover was reduced about 20 to 30 percent by the trash whip attachment (TW) compared to the in-row cover resulting from the coulter unit (C) (table 1). The regression equation

Eq 2: % cover TW = -4.2 + 0.61 (% cover C)

explained 80% of the variation in % cover of the TW treatments for the combined 1984, 1985, 1986,and 1987 data. The effect of increasing in-row residue cover (by mulch additions) was to increase the number of day required to reach 75% emergence (table 4) and to delay the date of silking (table 1):

Eq 3: Days to 75% Emergence = 15.7 + 0.058 (% in-row cover); $R^2 = 0.67$

Percent in-row cover was less closely related to grain moisture in 1986 and 1987 than in 1985:

For 1985 Eq 4: % Grain Moisture = 20.5 + 1.97 x 10^{-2} (% in-row cover); $R^2 = 0.87$
For 1986 Eq 5: % Grain Moisture = 19.1 + 0.69 x 10^{-2} (% in-row cover); $R^2 = 0.47$
For 1987 Eq 6: % Grain Moisture = 17.1 + 1.24 x 10^{-2} (% in-row cover); $R^2 = 0.49$

Percent in-row cover was closely related to air growing degree days to 6-leaf in 1984, 1985, 1986 and 1987 (measured on rep 3):

For 1987 Eq 7: Air GDD (planting to 6 leaf) = 278 + 0.52 (% in-row cover); $R^2 = 0.79$
For 1986 Eq 8: Air GDD (planting to 6 leaf) = 296 + 0.54 (% in-row cover); $R^2 = 0.84$
For 1985 Eq 9: Air GDD (planting to 6 leaf) = 273 + 0.47 (% in-row cover); $R^2 = 0.91$
For 1984 Eq 10: Air GDD (planting to 6 leaf) = 285 + 0.53 (% in-row cover); $R^2 = 0.96$

On the no-tillage treatment, grain yields and populations were not significnatly different between trash whip and coulter treatments. Grain moisture was significantly increased (0.1% level of significance) by surface residue cover as was the case for when all treatments were analyzed together (Eq. 6).

The effect of in-row residue cover and tillage on soil temperature and corn growth was evaluated at Lancaster in 1983, 1984, 1985, 1986, and 1987. Hourly soil temperatures were recorded for 1, 5, 10, 15, 50, and 100 cm depths under the row on chisel normal and mulch, no-till bare and mulch, and paraplow normal and mulch treatments in 1984, 1985, and 1986. In 1987 the Ro-till treatment replaced the paraplow treatment. Soil temperatures were measured using 4-couples in parallel for 15 cm and shallower depths.

Leaf stage measurements were taken periodically. Eq. 7 was developed using station air temperatures and leaf stage observations; the results in 1987 agree with previous station air temperatures and leaf stage observations (Eq. 8, 9 & 10).

Increasing the absorption of solar radiation by painting the soil surface black increased soil temperature and early corn growth. Adjacent strips 15 feet long and 1 foot wide (centered over the row) were painted on May 11 or 73.6 air GDD (^{o}C) after planting. Black paint reduced the air GDD to 6-leaf by 3 and 6 GDD on the no-till bare and chisel normal treatments and by 10 GDD on the no-till mulch and chisel mulch treatments. A leaf number represents slightly over 30 GDD so the increase in leaf number ranged from 0.1 to 0.3 leaf number. In 1986 increases up to 0.5 leaf number were measured on the black painted treatments.

Large differences in "final" (50 to 60 minute average) infiltration rates were measured between treatments (tables 5 and 6). Final infiltration rates from conventional tillage mulch treatments equalled or exceeded the comparable normal conventional tillage treatment. Large differences in infiltration and matric potential were measured on both the no-till bare and mulch cover treatments. On the conventional mulch treatments, positive matric potential measured at the 8 and 18 cm depths indicate the presence of a flow restricting layer below the plow layer (table 7). The Ro-till treatment with mulch had final infiltrations rates equal to or greater than the no-till treatment and to the conventional normal treatment but less than the conventional mulch treatment.

Final infiltration rates for 1981-1987 are given in table 6. The ratio of (bare/mulch) infiltration rates for conventional tillage was 0.24 which was below the 6 year average of 0.52. The ratio of no-till mulch to conventional bare was 1.06 which is close to the long term average of 1.16.

The results again illustrate the requirement for rapid infiltration of 1) a porous surface layer with high saturated conducitivity, 2) a protective mulch cover, 3) absence of flow restricitng layers within the depth of infiltration. Residue cover by itself is not sufficient to produce a high infiltration rate when significant restirction to flow occurs within the infiltrating profile.

Summary

Five and eight year yield results with continuous corn at Lancaster show nearly equal yields from conventional tillage, ridge till, and chisel treatments (table 8). In both 1986 and 1987 no-till (slot plant) was the highest yielding treatment. Thus farmers in the driftless soil area can choose between a variety of tillage options which have yields comparable to conventional tillage, but which are superior in soil and water conservation and offer savings in time, labor, and fuel compared to the conventional moldboard plow tillage method.

Table 1. Effect of tillage and mulch treatments on percent cover, planting depth, emergence, silking date, population and grain yield - 1987 Lancaster, WI.

Treatments Tillage	Residue	In Row Residue Mtg.	Percent Cover In-Row	Percent Cover Entire Area	Planting Depth Ave mm	Planting Depth S.D. mm	Days Post Plant To 75% Emergence	Date 50% Plants Silked July	Ave. Pop. At Harvest Plants/Ac	Ave. Grain Yield Bu/Ac	Ave. Grain Moisture %
No Till	Normal (N)	C	59	67	32.5	8.99	17.5	12.5	30,000	177.3	17.6
		TW	38	58	33	5.08	17.0		29,280	170.3	17.3
	Bare (0)	C	15	12	36	5.80	16.0	12.0	28,660	164.7	16.9
		TW			36	5.94	15.2		28,200	165.2	16.7
	Mulch (2X)	C	85	91	30.5	6.80	20.3	15.3	28,200	170.7	17.7
		TW	53	72	37.0	3.91	19.8		29,160	173.4	17.8
Bush Hog	Normal (N)	C	14	40	34.5	6.15	16.5	12.8	29,220	172.2	16.9
	Mulch (1X)	C	41	71	27.5	8.44	21.0	14.8	28,680	165.0	18.2
Chisel	Normal (N)	C	18	23	27	7.00	17.0	12.0	28,680	168.4	17.5
	Mulch (1X)	C	81	86	23	11.23	19.5	13.5	29,220	164.7	18.4
Conv.	Normal (N)	C	2	3	36	6.18	16.0	12.0	28,070	168.2	17.5
	Mulch (1X)	C	72	75	24	8.06	20.8	13.3	28,130	164.2	18.3
	Significance Level				0.01	0.025			NS	NS	0.01

Table 2. 1987 Weather Summary Lancaster, WI Experiment Station.

Month	Precipitation inches Total	Precipitation inches Departure	Growing Degree Days 1987	Growing Degree Days Depart.	Air Temperature Avg. Max	Air Temperature Avg. Min	Air Temperature Avg.	Air Temperature Depart.
	----- inches -----		---------- 'F					----------
April	2.83	-0.33	--	--	62.2	39.0	51.0	+3.5
May	3.78	+0.33	385	+85	72.6	48.7	60.9	+3.1
June	4.15	-0.40	602	+87	81.8	58.9	70.3	+3.2
July	6.71	+2.42	729	+69	85.3	63.3	74.4	+3.0
August	6.78	+2.16	561	-34	77.8	59.3	68.2	-0.7
Sept.	2.34	-1.12	360	+ 8	71.3	50.5	61.1	+0.2
Total:	26.59	+3.07	2637	+215				

Table 3. Average Yields and Depth to Clay Residuum by Replicate and Monthly precipitation for 1981 through 1987, Lancaster, WI.

Year	Replicate Number 1	2	3	4	Monthly Precipitation May	June	July	August
	---------- Bu/Ac ----------				---------- inches ----------			
1981	146.8	146.7	142.1	147.1	0.85	4.28	2.91	11.35
1982	150.0	143.4	142.8	147.3	5.46	3.45	5.29	4.06
1983	72.8	85.2	96.4	111.2	5.18	3.28	3.34*	3.12*
1984	107.3	110.4	118.0	120.1	3.92	7.77	2.57**	1.37**
1985	118.5	121.1	129.6	130.6	4.95	1.32***	2.11***	3.34
1986	159.5	162.4	168.6	164.8	3.90	5.47	1.85	3.65
1987	168.3	167.7	170.9	168.0	3.78	4.15	6.71	6.78
Avg. Depth to Clay Residuum inches	29	41	46	62				

1981 - Subplots with population < 17,000 omitted.
1982 - Missing values estimated for 8 plots out of a total or 48 plots.
1983 - Subplots with population < 18,000 omitted Rep. II, III, IV.
*1983 - 1.13 inches precipitation from July 3 to Aug. 25 (53 days).
**1984 - 1.52 inches precipitation from July 18 t Aug. 31 (45 days.
***1985 - 1.59 inches precipiation from May 28 to July 25 (57 days).
Largest rain was 0.36 inches.

Table 4. Influence of tillage method and residue management on rate of emergence - 1987 Lancaster, WI.

Treatment Tillage	Residue	Coulter or trash whip unit	Percent Emergence Days Post Plant 12	14	16	19	21	24
No-Till	Normal	C	0	0	30	83	98	99
		TW	0	0	52	93	100	100
	Bare	C	6	32	78	83	97	10
		TW	8	45	95	99	100	100
	Mulch	C	0	0	0	9	91	95
		TW	0	0	5	36	94	99
Bush Hog Ro-Till	Normal	C	12	27	70	88	98	100
	Mulch	C	0	0	23	45	76	95
Chisel	Normal	C	5	39	68	80	93	100
	Mulch	C	0	0	26	59	88	96
Conventional	Normal	C	20	42	77	85	92	95
	Mulch	C	1	5	19	45	78	94
Air Growing Degree Days from planting (including plant date April 30)		'F	148.5	169.5	192.5	245.0	278.5	302
		'C	82.5	94.2	106.9	136.1	154.7	167.8

All treatments reached 100% emerged by Day 28.

Table 5. 1987 Lancaster, WI Infiltration Rate Measurement.

Tillage	Residue	Rep.	Application rate	Water applied before runoff	Infiltration rate X min. after runoff commences - in/hr. 2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5
			in/hr	inches	- - - - - - - - - - - - - inches/hour - - - - - - - - - - - - -											
No Till	Bare	E	5.44	0.18	2.55	1.12	0.64	0.64	0.64	0.40	0.88	0.64	0.28	0.28	0.64	0.40
		W	5.60	0.28	2.24	1.28	1.28	1.76	1.76	1.76	2.00	2.00	2.00	1.52	2.00	2.00
	Mulch	E	5.36	0.25	3.68	2.00	1.28	1.52	1.28	1.04	1.28	1.52	1.52	1.76	1.28	1.52
		W	5.36	0.31	3.44	2.48	2.12	1.88	1.76	1.28	1.04	1.28	1.64	1.40	1.04	1.04
Conv.	Normal	E	5.76	0.96	4.32	3.36	2.40	1.68	1.92	1.44	1.20	1.80	1.80	1.20	1.20	1.20
		W	4.88	0.85	3.56	2.48	1.88	1.52	1.28	1.52	1.76	1.28	1.16	1.28	1.04	1.16
	Mulch	E	5.44	4.90	5.38	5.38	5.32	5.32	5.08	5.32	5.08	4.96	4.84	4.96	5.08	4.96
		W	5.44	3.62	5.32	5.08	4.96	5.20	4.83	4.96	4.71	4.71	4.60	4.60	--	--
Bush Hog	Mulch	E	5.28	0.97	2.88	2.16	1.68	1.92	2.16	1.92	1.92	2.40	2.28	2.28	1.80	1.80
Ro-Till		W	5.28	0.59	3.36	2.88	2.88	3.12	2.76	3.00	2.88	2.64	2.40	2.04	2.52	2.64

Table 6. Infiltration rate 55 minutes after runoff begins (paired observations).

Tillage	Treatment Residue	1981	1982	1983	1984	1985	1986	1987	Avg.
		inches/hour							
No Till	Bare	--	--	--	1.68	1.00	1.24	1.26	
	Mulch	1.46	1.10	3.53*	0.60	3.02	2.10	1.22	1.58+
Conventional	Bare	0.97	1.52	0.54	1.70	1.40**	1.83	1.15	1.30
	Mulch	2.72	2.34	1.49	2.90	2.14**	2.25	4.81	2.66
		Ratio							
Conv. Bare/Conv. Mulch		0.36	0.65	0.36	0.58	0.65	0.81	0.24	0.52
No Till Mulch/Conv. Bare		1.51	0.72	6.53	0.35	2.16	1.15	1.06	1.16+

* Soil disturbed prior to planting by anhydrous ammonia injection.

** 1 observation only.

\+ omit 1983

Table 7. Relationship of infiltration rates (Avg. 40 to 60 min. after runoff starts) to matric potential in 1987.

Treatment				cm soil depth					
				7.5	17.5	40	7.5	17.5	40
Tillage	Residue	Rep.	in./hr	cm H_2O					
No-Till	Bare	E	0.40	-168	-173	--	-50	-110	-19
		W	1.88	-4	-55	+12	-1	-1	+11
	Mulch	E	1.52	-16	-14	+31	-27	-25	-11
		W	1.28	-30	-5	-32	-2	-7	-15
Conven.	Normal	E	1.35	+9	+14	-30	--	+7	-64
		W	1.16	+8	-8	+28	+8	+8	--
	Mulch	E	4.96	+7	+12	+5	+8	+11	+6
		W	4.60*	-4	-3	+11	+2	-10	+19

*40 to 50 min only

Table 8. 1979-1987 Continuous corn tillage yield results, Lancaster, WI.

Tillage Treatment with normal residue	1979	1980	1981	1982	1983	1984	1985	1986	1987	79-83	79-87
	bu/A										
Ridge plant	162	157	157	147	100	---	---	---	---	145	---
No-Till (slot plant)	163	146	151	141	85	108	120	165	177	137	140
Chisel	160	150	167	154	95	115	125	159	168	145	144
Conventional	169	159	168	151	89	121	133	164	168	147	145
Paraplow*	---	---	---	---	---	106	125	162	---	---	---
Ro-Till	---	---	---	---	---	---	---	---	172	---	---

*Fall 1983 and Fall 1984

TILLAGE EFFECTS ON CORN PRODUCTION IN NORTH EASTERN MINNESOTA

J.F. Moncrief, J.J. Kuznia, and D.D. Breitbach

Plots have been established in Pine and Isanti counties to evaluate four different tillage systems at each site. Tillage ranges from moldboard plowing to a "strict no till" approach. Corn follows corn at the Pine county site and soybeans at the Isanti county site.

The Pine County data are shown in table 1 to 8. At this site corn followed corn on a well drained Cushing loam soil. The Chisel, Moldboard, and spring disc treatments had similar yields. The no till system resulted in a yield reduction of about an 18 bushel per acre. It does not appear to be the result of stand reduction. It is possible that there was competion for soil moisture by weeds (nutsedge).

PINE COUNTY

Table 1. Cultural practices at Pine County, MN. 1987.

Tillage

No Till
Disc-Plots were disced on May 4, 1987.
Chisel-Plot were chisled on May 4, 1987.
Moldboard-Plots were plowed on May 4, 1987
All plots except No Till had Rotary tillage with a Lilly Roterra on May 4 1987 to incorporated the hebicide applied prior to planting.

Preceding Crop

Corn

1987 Crop

Land O Lakes 1093
Single cross hybrid
(95 day)

Planting and Harvest Date

Planter used was a John Deere Maximerge with 2 inch fluted coulters and 36 inch rows.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 4, 1987	26,700 plants/ac	October 6, 1987

Fertilizer

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	--- lbs/ac --			Date Applied
Corn	46-0-0	250 lbs/ac	115	0	0	May 2, 1987
	10-15-35[1]	280 lbs/ac	28	42	98	May 4, 1987

1. Planter applied 2" beside and 2" below seed.

Soil

The soil at this site is a Cushing (Glossic Eutroboralfs, fine-loamy, mixed) loam.

Herbicide Control

3 qt/ac (3.375 lbs/ac) Bicep was applied with a Lily roterra.

Soil Test

Table 2. Initial soil test on proposed tillage plots on soil test on April 7, 1987.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
	Sig. of	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Nutrient	Tillage	lb/ac							
NH_4-N	(.050)	5.0	1.2	5.1	0.6	4.3	0.7	3.6	0.4
NO_3-N	(.975)	35.9	5.8	32.5	11.9	32.8	15.3	33.4	10.6
NH_4+NO_3	(.954)	40.9	5.8	37.5	11.4	37.0	15.5	37.1	10.3
P	(.193)	124.0	60.1	107.0	55.8	60.6	44.5	83.9	45.9
K	(.711)	471.0	115.9	411.4	41.8	463.6	72.3	421.5	78.7

Table 3. The effect of tillage on soil cover by corn residue on May 28, 1987, n=24.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
		mean	stdev	mean	stdev	mean	stdev	mean	stdev
Location	Tillage	%							
In Row	(.000)	56.0	23.1	41.5	15.2	26.0	10.1	1.33	2.54
Between Row	(.000)	77.5	18.9	58.6	15.9	34.8	10.7	3.66	7.07

Table 4. The effect of tillage on corn growth stages, n=40.

	Tillage							
	No Till		Disc		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Date	%							
5/24[1]	1.69	.966	1.88	.782	2.00	.751	2.34	.878
6/17[2]	5.28	.818	5.45	.977	6.10	.702	6.34	.733

1. Significance of tillage was .007.
2. Significance of tillage was .000.

Table 5. The effect of tillage on corn stand, n=16.

	Tillage							
	No Till		Disc		Chisel		Moldboard	
	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Date	plants/ac x1000							
5/24[1]	23.2	3.3	22.1	2.8	26.5	2.5	27.2	3.7
6/17[2]	23.4	3.3	22.0	4.4	25.6	1.8	27.3	2.9

1. Significance of tillage was .000.
2. Significance of tillage was .000.

Table 6. The effect of tillage on the presence of weed species and density on May 28, 1987, n=32.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
	Sig. of	mean	stdv	mean	stdv	mean	stdv	mean	stdv
Weed	Tillage	plants/ac x1000							
Pigweed	(.059)	0.6	1.6	1.3	1.9	5.5	6.0	5.0	10.0
Foxtail	(.059)	0.0	0.0	0.7	2.0	3.8	7.2	8.0	9.6
Crabgrasss	(.187)	5.9	11.1	8.5	14.3	0.0	0.0	0.0	0.0
Nutsedge	(.552)	72.9	116.2	24.7	45.0	63.9	83.7	39.7	41.8
Ragweed	(.288)	1.2	2.2	2.9	3.7	6.9	7.1	11.1	19.4
Lambsquarter	(.099)	0.0	0.0	2.4	6.8	7.7	9.7	3.8	5.2
Smartweed	(.409)	0.0	0.0	2.4	6.8	0.0	0.0	0.0	0.0
Vol Corn	(.330)	0.0	0.0	5.5	9.9	4.2	8.6	0.9	2.3
Quackgrass	(.026)	0.0	0.0	0.9	1.3	0.0	0.0	0.0	0.0

1. Due to unequal variances, a natural log transformation was used for analysis of variance.

Table 7. The effect of tillage on the presence of weed species and density on June 17,1987, n=32.

		Tillage							
		No Till		Disc		Chisel		Moldboard	
Weed	Sig. of Tillage	mean	stdv	mean	stdv	mean	stdv	mean	stdv
		plants/ac x1000							
Crabgs	(.400)	1.8	3.9	0.0	0.0	12.1	34.2	0.0	0.0
Nutseg	(.320)	117.1	163.7	37.9	64.3	35.8	42.4	47.2	79.5
Ragwed	(.287)	0.3	0.8	1.2	3.4	4.9	10.0	0.3	0.7
Lambqr	(.343)	0.0	0.0	0.0	0.0	2.8	6.7	2.7	3.8
Smrtwd	(.025)	0.0	0.0	0.0	0.0	2.0	3.8	0.3	0.8
Volcrn	(.011)	0.1	0.3	15.9	15.9	11.8	13.8	5.2	9.4
Quacgr	(.373)	2.8	5.9	2.1	3.3	5.8	9.8	3.9	7.3

1. Due to unequal variances, a natural log transformation was used before analysis of variance.

Table 8. The effect of tillage on yields and grain moisture at harvest, October 6, 1987, n=4.

	Tillage							
	No Till		Disc		Chisel		Moldboard	
Sig. of Tillage	mean	stdev	mean	stdev	mean	stdev	mean	stdev
	bu/ac							
(.026)	141	6.6	158	5.8	166	7.0	155	14.1
	% moisture							
(.000)	26.7	.78	25.7	.39	25.5	.38	24.2	.73

Isanti County data is presented in tables 9 to 11. At this site corn followed soybeans on an Alstad fine sandy loam soil that is somewhat poorly drained. The performance of the tillage systems evaluated at this site were similar to the Pine county site. All were similar except the no till treatment. The yield reduction associated with this system was 11 bushels per acre. At this site differences in plant populations account for the yield reduction associated with the no till system. The planter used at both sites was equipped with 2" fluted coulters to cut through crop residue. It may be that the planter did not have the weight to penetrate dry soil under no till conditions at this site which resulted in the stand loss. The point is, if stand differences are accounted for in the statistical analysis there is no effect of tillage on yields.

ISANTI COUNTY

Table 9. Cultural practices at Isanti County, MN. 1987.

Tillage

No Till

Disc-Plots were disced on May 5, 1987

Chisel-Plots were chiseled then disced on May 5, 1987

Moldboard-Plots were plowed then disced on May 5, 1987

Preceding Crop

1986-Soybeans

1987 Crop

Corn-Pioneer 3790

Planting and Harvest Date

Planter was a John Deere 7000 equipped with ripple conservation coulters.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 6, 1987	27,200 plants/ac	October 6, 1987

Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Actual Mg	Date Applied
			------- lbs/ac -------					
Corn	12-14-26-4-3	277 lbs/ac	33	38	73	11	9	May 6, 1987
	82-0-0	146 lbs/ac	120	0	0	0	0	June 5, 1987

Soil Test

Organic Matter	pH	Bray 1 Phosphorus	Potassium	Sulfur	Zinc
		---------- lbs/ac ----------		--- ppm ---	
Medium	7.0	115	238	15	1.1

Soil

The soil at this site is a Alstad (Aquic Eutroboralfs, fine-loamy, mixed) fine sandy loam, 0 to 2 percent slope. Soil is somewhat poorly drained.

Weed Control

2 qt/ac (2 lbs/ac) Lasso + 1 qt/ac (1 lb/ac) Bladex + 1 qt/ac (1 lb/ac) Atrazine.

Table 10. The effect of tillage on plant populations on August 1, n=6.

Sig. of Tillage	No Till mean	No Till st dev	Disc mean	Disc st dev	Chisel mean	Chisel st dev	Moldboard mean	Moldboard st dev
	---------- plants/ac x 1000 ----------							
(.014)	22.3	4.27	26.6	1.05	26.3	.55	26.6	.76

Table 11. The effect of tillage on corn yields and moisture harvested on October 6, 1987, n=6.

Sig. of Tillage	No Till mean	No Till st dev	Disc mean	Disc st dev	Chisel mean	Chisel st dev	Moldboard mean	Moldboard st dev
	---------- bu/ac ----------							
(.344)[1]	157	9.1	166	7.6	168	6.1	168	6.2
	---------- % moisture ----------							
(.006)	23.1	.77	22.3	.76	21.7	.79	22.0	.47

1. Plant population was used as a covariate in this analyis of varience. If population effects are accounted for there is no difference in yield due to tillage.

INVESTIGATIONS OF TILLAGE AND CORN HYBRID ON A PACHIC UDIC HAPLOBOROLL SOIL IN WESTERN MINNESOTA

J.F. Moncrief, S.D. Evans, and A.E. Olness

This study was initiated in the fall of 1983 to evaluate the interactions of tillage system, hybrid and nitrogen response of corn grown continuously. This paper focuses on the influence of tillage on corn hybrid performance. Four tillage systems were used to evaluate two single cross hybrids (Pioneer 3906 and DeKalb-Pfizer XL8). Tillage treatments are fall moldboard and chisel plowing (with the exception of 1986), ridge till, and no till. Ridge tilled corn was the only treatment that received cultivation. This site has been in continuous corn since 1982. The planter used was equipped with disc row cleaners which were only used in the ridge till treatment. All other treatments had "in row" tillage by a 2" fluted coulter. Nitrogen was spring applied as anhydrous ammonia. Nitrogen rates were pooled beyond the level of corn response to evaluate tillage and hybrid interactions. Phosphorus and potassium was applied with the planter.

The results of the analysis of variance is shown in table 1. There are significant main effects of year, tillage, and hybrid as well as several interactions. The Pioneer 3906 hybrid had grain yields an average of 20 bushels per acre higher than the DeKalb XL8 (table 2). There was a significant interaction between hybrid and year. In the last two years of the study the difference was greatest (table 2). There was also a significant tillage by hybrid interaction (table 3). The greatest difference between the two hybrids occurred with ridge tillage (29 bu/acre) followed by the no till, chisel, and moldboard treatments respectively. Tillage systems that eliminate primary tillage had larger differences between

Table 1. The effect of tillage, corn hybrid, and year on the significance of an F test for yield from analysis of variance.

Source of variation	Sig. of F
Year	<.000
Rep	.416
Till	.030
Till x Year	.042
Hybrid	<.000
Hybrid x Year	.003
Hybrid x Till	.015
Hybrid x Rep	.681
Till x Hybrid x Year	.265
Year x Hybrid x Rep	.340
Till x Year x Rep	.254
Hybrid x Till x Rep	.058

Table 2. The effect of hybrid and year on grain yields.

	Year				
	1984	1985	1986	1987	Avg.
	---------Bu/acre---------				
P 3906	130	89	130	150	125
DK XL8	119	74	100	128	105
Diff.	11	15	30	22	20

Table 3. The effect of tillage and hybrid on grain yields from 1984 to 1987.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	---------Bu/acre--------				
P 3906	120	127	133	118	125
DK XL8	109	111	104	96	105
Diff.	11	16	29	22	20

Table 4. The effect of tillage and hybrid on grain yields in 1984.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	---------Bu/acre--------				
P 3906	135	128	137	116	129
DK XL8	126	120	125	106	119
Diff.	9	8	12	10	10

Table 5. The effect of tillage and hybrid on grain yields in 1985.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	---------Bu/acre--------				
P 3906	88	96	87	84	89
DK XL8	72	82	69	70	73
Diff.	16	14	18	14	16

Table 6. The effect of tillage and hybrid on grain yields in 1986.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	---------Bu/acre--------				
P 3906	102	139	149	129	130
DK XL8	92	114	107	85	100
Diff.	10	25	42	44	30

Table 7. The effect of tillage and hybrid on grain yields in 1987.

	Tillage				
	Mld	Chsl	Rdg	NT	Avg.
	---------Bu/acre--------				
P 3906	157	145	156	141	150
DK XL8	142	128	117	123	128
Diff.	15	17	39	18	22

Table 8. The effect of tillage and year on grain yields.

	Year				
	1984	1985	1986	1987	Avg.
Tillage	---------Bu/acre--------				
Mldbrd	130	80	97[1]	149	114
Chisel	124	89	127[1]	137	119
Ridge	131	78	128	137	119
No Till	111	78	107	132	107

1. Due to wet fall conditions in 1985, primary tillage was done in the spring of 1986.

hybrids. Although the tillage x hybrid x year interaction was not statistically significant (.265), the biggest difference between hybrids grown with ridge tillage seemed to occur the last two years of the study (tables 4-7).

The growing season rainfall was highest in 1986 and lowest in 1987. Plant moisture stress data show that the DK XL8 hybrid consistently had higher levels of stress (not measured in 1986). In 1987 there was a significant tillage by hybrid interaction. There was a larger difference in stress between the two hybrids when grown with ridge till and no till systems. One plausible explanation may be that the DK XL8 hybrid is more sensitive to root pruning that is associated with the ridge till system. In 1987 there was very little rainfall following the ridging operation. This hybrid may have been more sensitive to the reduced soil temperatures and increased resistance to root penetration under no till conditions, which could have resulted in shallow rooting making it more sensitive to the dry season. At this point this is speculation until the total body of supporting data is interpreted.

Corn yields were low in 1985 due to an early frost. The four year averages show the ridge till and chisel plowing systems to result in the highest grain yield (table 8). Moldboard plowing was done in the spring of 1986 due to wet soil conditions in the fall of 1985, which resulted in a very low yield (table 6). The four year average yield was 5 bushels per acre less when moldboard plowing than corn grown with the ridge till or chisel plowing system. No till grown corn resulted in grain yields 12 bushels per acre less than the chisel or ridge till corn.

THE EFFECT OF TILLAGE ON SMALL GRAIN AND SOYBEAN PRODUCTION IN NORTHWESTERN MINNESOTA-1987

J.F. Moncrief, J.J. Kuznia, and D.D. Breitbach

Plots were established in the fall of 1985 to evaluate the effect of tillage on small grain and soybean production in northwestern Minnesota. The rotation at each site is wheat-soybeans-barley. In the wheat year the plots are split with winter and spring wheat. In 1987 soybeans were grown at the Becker County site and Winter and Spring wheat at the Douglas County site. The tillage systems being evaluated are fall moldboard or chisel plowing followed by secondary tillage in the spring and no tillage.

The Becker County data is presented in tables 1 to 6. The soil covered by wheat residue after planting was 75%, 26%, and 10% for the no till, chisel, and moldboard plow systems respectively (table 2). Plots were split with drill applied (with the seed) fertilizer (diammonium phosphate-DAP). The University of Minnesota does not recommend applying DAP with the soybean seed at the rates we used in this study. This is the dominant source of dry phosphate in Minnesota and was used to illustrate the effect of tillage on seed injury with this source of fertilizer.

The major weeds at this site are mustard and field bindweed. The weed density at harvest is shown in table 3. Tillage and starter fertilizer had an effect on the presence of weeds at harvest. There were much more weeds in the no till plots. There was also an increase in weeds when starter was used. This was due to the stand loss associated with the no till treatment and further reduction when starter was applied. This could have been due to more shallow planting, failure to close the seed furrow, or less soil mixing.

Grain yields and moisture are shown in table 4 and 5 respectively. Yields are similar for the chisel and moldboard plow treatments and there is no response to drill applied fertilizer. No till yields reflect the reduced stands that allowed better competition by broadleaf weeds.

BECKER COUNTY

Table 1. Cultural practices at Becker County, MN. 1987.

Tillage	Preceding Crops	1987 Crop
No Till	1985-Barley	Soybeans-McCalls
Chisel-Fall	1986-Winter and Spring wheat	
Moldboard-Fall		

Planting and Harvest Dates

Planter was a Haybuster No Till Disc Drill.

	Planting		
Crop	Date	Rate	Harvested
Soybeans	June 2, 1987	225,000 plants/ac	October 1, 1987

Fertilizer

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---lbs/ac----			Date Applied
Soybeans	18-46-0[1]	110 lbs/ac	20	51	0	June 2, 1987

1. Drill applied with the seed.

Soil

Hamerly clay loam (Aeric Calciaquolls, fine-loamy, frigid)-Winger silty clay loam (Typic Calciaquolls, fine-silty, frigid) complex, 2 percent slope. Soil is somewhat poorly drained to moderately well drained soil.

Weed Control

1 qt/ac ($^3/_4$ lb/ac) Roundup was applied on May 18, 1987.
$1^1/_2$pt/ac ($^3/_4$ lb/ac) Basagran + $^1/_2$ pt/ac (.125 lb/ac) Blazer was applied on June 18, 1987.
$^3/_4$ pt/ac (.375 lb/ac) Basagran was applied on July 20.
1 pt/ac (.125 lb/ac) Fusilade 2000 was applied on August 1, 1987.

Table 2. The effect of tillage on soil cover by wheat residue on June 2, 1987, n=12.

		Tillage					
		No Till		Chisel		Moldboard	
	Sig. of Tillage	mean	st dev	mean	st dev	mean	st dev
		%					
Between	(0.0)	69.0	10.3	23.3	12.9	7.7	5.2
In Row	(0.0)	81.3	9.2	31.0	18.4	11.3	9.6

Table 3. The effect of tillage and starter on the presence of weed cover on October 1, 1987[1], n=3.

	Tillage (.000)						
	No Till		Chisel		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Fertilizer[2]							
Starter	4.33	0.57	0.67	0.57	0.33	0.57	1.78
No Starter	3.00	0.00	0.33	0.57	0.00	0.00	1.11
average	3.67	0.81	0.50	0.54	0.17	0.40	

1. The visual rating used is as follows; 1=None, 2=Slight, 3=Moderate, 4=Severe and 5=Very Severe.
2. The significance of tillage was .008; tillage x fertilizer interaction was .006.

Table 4. The effect of tillage and starter on soybean yields October 1, 1987, n=3.

	Tillage(.002)						
	No Till		Chisel		Moldboard		
	mean	stdev	mean	stdev	mean	stdev	Avg
Fertilizer[1]	bu/ac						
Starter	31.2	0.60	42.8	1.33	42.6	1.35	38.8
No Starter	36.9	2.01	41.9	2.18	42.7	0.57	40.5
average	34.1	3.43	42.3	1.69	42.7	0.93	

1. The significance of tillage was .073; tillage x fertilizer interaction was .061.

Table 5. The effect of tillage and starter on the moisture of soybeans at harvest, October 1, 1987, n=3.

	Tillage (.249)					
Sig. of Fert.[1]	No Till		Chisel		Moldboard	
	mean	stdev	mean	stdev	mean	stdev
Fertilizer(.722)	%					
Starter	8.6	0.12	8.5	0.20	8.4	0.48
No Starter	8.9	0.65	8.3	0.15	8.5	0.38
average	8.7	0.44	8.4	0.17	8.4	0.39

1. The significance of tillage x fertilizer interaction was .603.

The crops grown at the Douglas County site are winter and spring wheat. Tillage treatments are moldboard, chisel, and no till. Spring soil test values are shown in table 6. There was more mineral nitrogen in the top two feet of the winter wheat plots due the fall applied fertilizer with the drill (table 6). There were higher levels of mineral nitrogen in the no till winter wheat treatment than the plots that were chisel or moldboard plowed. This may be due to the slower rate of nitrification of the fall applied ammonium due to cooler soil temperatures that would have prevented losses. The soil P at this site is very variable. There were no discernable tillage trends. The soil K was affected by tillage and was higher under no till conditions in the winter wheat plots. A similar trend occurred in the spring wheat plots although not statistically significant. This has been observed at other sites and reflects the slower soil fixation of K when it is mixed with a smaller volume of soil.

The soil cover by crop residue is shown in table 8. Cover was about 10, 40, and 75% for the moldboard, chisel, and no till systems respectively and similar in and between the row. The stands were quite variable (table 9). Tillage effects on stand were not statistically significant. Early growth was affected by tillage but differences were small and would not be expected to affect grain yields (table 10).

Although tillage effects on the density and presence of various weed species were statistically significant in some cases, the levels were low and not expected to affect yields (tables 11, 12, and 13).

The main effect of tillage on winter wheat grain yields was not statistically significant (table 14). There was a tillage by variety interaction, however. The two varieties used at this site responded differently to chisel plowing. The authors don't have an explanation at this time. Tillage did not effect spring wheat yields. There was a winter wheat varietal effect on test weight (table 16) but not tillage. Tillage did effect spring wheat test weight. No till grain test weights were two lbs/bushel lower than the chisel and moldboard grain. Protein was not affected by tillage for either winter or spring wheat although there was a difference between varieties and winter and spring wheat.

DOUGLAS COUNTY

Table 6. Cultural practices at Douglas County, MN. 1987

Tillage

No Till
Chisel Plow-Plots were chiseled on September 11, 1986.
Moldboard Plow-Plots were plowed on August 29, 1986.
The chisel and moldboard plow treatments were followed by a spring field cultivation before seeding the spring wheat.

Preceding Crop

1985-Soybeans, 1986-Barley

1987 Crop

Spring Wheat-Pioneer 2369
Winter Wheat-Bighorn and Roughrider

Planting and Harvest Date

Planter was a Haybuster 107 drill, with 7" row spacing that had double disk openers and twin angled packing wheels.

Crop	Planting Date	Harvested
Winter Wheat	September 29, 1986	July 24, 1987
Spring Wheat	April 21, 1987	July 24, 1987

Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			--- lbs/ac ---			
Winter Wheat	18-46-0[1]	100 lbs/ac	18	46	0	September 29, 1986
	46-0-0[2]	217 lbs/ac	100	0	0	May 29, 1987
Spring Wheat	18-46-0[1]	100 lbs/ac	18	46	0	April 21, 1987
	46-0-0[2]	217 lbs/ac	100	0	0	May 29, 1987

1. Drill applied with seed.
2. Urea was broadcast.

Soil

Complex of: Barnes (Udic Haploborolls, fine-loamy, mixed)-Langhei (Typic Udorthents, fine-loamy, mixed (calcareous) ,frigid) loams, 2 to 6 percent slopes, well-drained eroded. The Langhei occurs on eroded knobs and Barnes on uniform slopes and valleys.

Weed Control

No Till Plots:

1 qt/ac ($^3/_4$ lb/ac) Roundup + surfactant on September 5, 1987.

Winter Wheat:

1.5 pt./ac Bromoxynil(Buctril) + 1 pt/ac MCPA(ester) on May 28, 1987.

Spring Wheat:

1 pt/ac 2,4-D on June 1, 1987.

Soil Test

Table 7. Soil test results from Douglas County on April 9, 1987.

			WINTER WHEAT							SPRING WHEAT					
			Tillage							Tillage					
		Sig. of	No Till		Chisel		Moldboard		Sig. of	No Till		Chisel		Moldboard	
	Depth	Tillage	mean	stdev	mean	stdev	mean	stdev	Tillage	mean	stdev	mean	stdev	mean	stdev
Nutrient	Inches	WtWheat	lbs/ac						SpWheat	lbs/ac					
NO_3	0-6	(.162)	36.8	4.7	29.5	7.9	32.3	6.0	(.801)	20.7	3.5	24.0	6.9	21.1	10.5
	6-24	(.320)	41.4	4.7	33.2	6.1	34.2	12.9	(.965)	31.3	10.3	31.8	14.0	33.2	21.4
	0-24	(.150)	78.2	8.6	62.7	9.0	66.5	17.5	(.929)	52.0	13.4	55.8	20.2	54.3	14.4
NH_4	0-6	(.000)	7.9	0.6	5.8	0.5	6.1	0.8	(.181)	12.2	9.3	6.0	1.0	7.8	2.2
	6-24	(.070)	20.9	1.7	19.5	3.0	17.5	1.5	(.662)	20.4	4.4	18.5	4.4	18.8	4.1
	0-24	(.010)	28.8	2.1	25.3	2.9	23.6	2.1	(.223)	32.6	12.6	24.5	5.0	26.6	6.0
NO_3+NH_4	0-6	(.053)	44.7	4.7	35.3	8.2	38.4	5.8	(.765)	32.8	12.5	30.1	3.7	28.9	8.7
	6-24	(.189)	62.3	5.0	52.7	7.8	51.6	13.4	(.963)	51.7	14.3	50.3	16.9	52.0	25.0
	0-24	(.050)	107.0	8.7	88.0	8.9	90.0	17.8	(.899)	84.5	25.4	80.4	22.8	80.9	19.4
P	0-6	(.246)	20.4	18.1	10.8	11.9	8.2	10.3	(.569)	18.4	19.4	28.5	36.1	39.2	40.3
K	0-6	(.065)	350	67.8	278	36.7	273	53.8	(.347)	347	51.4	309	68.6	316	51.5

Table 8. The effect of tillage on barley residue on June 4, 1987.

			Tillage					
			No Till		Chisel		Moldboard	
			mean	st dev	mean	st dev	mean	st dev
Crop	Variety	Location	%					
Winter Wheat	Bighorn	In Row	65.0	21.6	38.0	20.9	7.7	6.7
(n=12)		Between Row	74.3	14.4	36.3	14.3	13.0	7.8
	Roughrider	In Row	71.7	16.4	41.7	19.7	10.0	6.7
		Between Row	78.7	13.3	41.7	26.8	7.3	6.9
Spring Wheat	Pioneer	In Row	70.2	14.9	45.8	22.1	10.8	15.7
(n=24)		Between Row	73.5	13.4	41.3	17.1	15.8	14.8

Table 9. The effect of tillage on plant population on June 4, 1987.

Crop-Variety	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		------ plants/ac x 1000 ------					
Winter Wheat	(.704)	n=12					
Bighorn		153	44.7	128	62.8	137	58.5
Roughrider		153	62.2	195	31.4	150	68.9
Spring Wheat		n=24					
Pioneer	(.491)	124	65.3	116	63.2	148	64.3

1. The significance of variety was .175, and the variety x tillage interaction was .328.

Table 10. The effect of tillage on crop growth stages on June 4, 1987.

Crop-Variety	Sig. of Tillage[1]	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		---- Zadoks growth stage ----					
Winter Wheat	(.000)	n=60					
Bighorn		55.4	5.79	57.7	2.99	58.9	1.99
Roughrider		56.0	4.35	59.2	2.12	59.1	2.09
Spring Wheat		n=60 --- Haun growth stage ---					
Pioneer	(.000)	3.71	0.32	3.69	0.39	3.97	0.44

1. The significance of variety was .073, and the variety x tillage interaction was .510.

Table 11. The effect of tillage on weed species present in spring wheat (Pioneer 2369) and their density on June 4, 1987, n=18.

Weed	Sig. of Tillage	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		---------- % of coverage ----------					
Foxtail	(.155)	1.18	1.30	7.41	10.5	1.22	1.65
Mustard	(.867)	0.37	0.22	0.43	0.36	0.43	0.17
Lambsquarter	(.682)	0.33	0.26	0.55	0.74	0.40	0.15
Buckwheat	(.878)	0.33	0.26	0.30	0.22	0.37	0.21
Ragweed	--	0.00	0.00	0.08	0.20	0.08	0.20
Quackgrass	--	0.00	0.00	0.00	0.00	0.33	0.41
Cockle	--	0.17	0.26	0.00	0.00	0.10	0.20
Wormweed	(.811)	0.25	0.27	0.17	0.26	0.17	0.26
Smartweed	(.879)	0.33	0.23	0.33	0.26	0.41	0.30
Pigweed	--	0.00	0.00	0.10	0.20	0.00	0.00
Pennycress	(.456)	0.28	0.25	0.80	1.57	0.20	0.21
Dandelion	--	0.25	0.27	0.00	0.00	0.00	0.00

Table 12. The effect of tillage on weed species present on Bighorn winter wheat and their density on June 4, 1987. Weed species which were significantly affected by tillage are in bold type, n=18.

Weed	Sig. of Tillage	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		-------- % of coverage --------					
Foxtail	(.693)	0.87	0.60	0.77	0.67	0.53	0.40
Mustard	**(.065)**	0.53	0.15	0.20	0.10	0.40	0.10
Lambsquartr	(.207)	0.20	0.00	0.43	0.31	0.50	0.00
Buckwheat	**(.088)**	0.20	0.10	0.36	0.23	0.70	0.30
Ragweed	--	0.00	0.00	0.20	0.26	0.00	0.00
Quackgrass	--	0.03	0.06	0.00	0.00	0.00	0.00
Cockle	(.129)	0.03	0.06	0.30	0.26	0.33	0.29
Wormweed	--	0.20	0.26	0.20	0.26	0.00	0.00
Smartweed	(.444)	0.27	0.15	0.13	0.15	0.20	0.26
Pigweed	**(0)**	0.17	0.29	0.17	0.29	0.17	0.29
Pennycress	(.921)	0.37	0.23	0.30	0.10	0.30	0.36
Dandelion	--	0.33	0.29	0.00	0.00	0.00	0.00

Table 13. The effect of tillage on weed species present on Roughrider winter wheat and their density on June 4, 1987. Weed species which were significantly affected by tillage are in bold type, n=18.

Weed	Sig. of Tillage	No Till mean	No Till stdv	Chisel mean	Chisel stdv	Moldboard mean	Moldboard stdv
		-------- % of coverage --------					
Foxtail	(.132)	0.50	0.10	0.33	0.06	0.37	0.15
Mustard	--	0.00	0.00	0.20	0.26	0.07	0.06
Lambsquartr	(.224)	0.23	0.23	0.33	0.21	0.50	0.10
Buckwheat	(.311)	0.07	0.16	0.37	0.23	0.23	0.25
Ragweed	--	0.00	0.00	0.33	0.29	0.33	0.29
Quackgrass	--	0.00	0.00	0.00	0.00	0.33	0.29
Cockle	--	0.03	0.06	0.17	0.29	0.00	0.00
Wormweed	--	0.40	0.17	0.17	0.29	0.00	0.00
Smartweed	**(.016)**	0.50	0.00	0.03	0.06	0.27	0.21
Pigweed	--	0.00	0.00	0.00	0.00	0.20	0.35
Pennycress	--	0.17	0.06	0.20	0.20	0.00	0.00
Dandelion	--	0.17	0.29	0.00	0.00	0.00	0.00

Table 14. The effect of tillage on wheat yields on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	bu/ac						
Winter Wheat[1]	n=12						
Bighorn	36.9	9.1	44.4	4.5	38.0	5.0	39.8
Roughrider	38.0	5.5	29.0	4.2	37.7	4.3	34.9
Spring Wheat[2]	n=8						
Pioneer	34.4	4.1	32.5	9.3	38.9	8.2	35.3

1. The significance of tillage was .832 and variety was .005, the significance of tillage x variety interaction was .000.
2. The significance of tillage was .149.

Table 15. The effect of tillage on harvest moisture on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	%						
Winter Wheat[1]	n=12						
Bighorn	9.6	2.4	12.0	0.5	11.5	1.4	11.0
Roughrider	15.0	10.0	10.8	3.1	11.1	0.8	12.3
Spring Wheat[2]	n=8						
Pioneer	15.5	3.2	13.6	1.3	13.1	1.4	13.9

1. The significance of tillage was .839 and variety was .421, the significance of tillage x variety interaction was .188.
2. The significance of tillage was .048.

Table 16. The effect of tillage on test weights on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	lb/bu						
Winter Wheat[1]	n=12						
Bighorn	55.8	0.68	55.9	0.92	56.9	1.20	56.2
Roughrider	58.2	0.26	58.2	0.82	58.3	0.87	58.2
Spring Wheat[2]	n=8						
Pioneer	58.6	2.16	60.1	1.48	59.8	1.53	59.5

1. The significance of tillage was .121 and variety was .000, the significance of tillage x variety interaction was .303.
2. The significance of tillage was .048.

Table 17. The effect of tillage on protein on July 24, 1987.

	Tillage						
	No Till		Chisel		Moldboard		
	mean	stdv	mean	stdv	mean	stdv	Avg
	%						
Winter Wheat[1]	n=12						
Bighorn	12.7	0.20	12.4	0.37	12.2	0.70	12.4
Roughrider	14.5	0.52	13.9	1.18	14.5	0.90	14.3
Spring Wheat[2]	n=8						
Pioneer	14.9	1.27	15.3	0.92	15.6	1.01	15.3

1. The significance of tillage was .302 and variety was .000, the significance of tillage x variety interaction was .353.
2. The significance of tillage was .259.