# Use of Dwell (Terrazole) And N-Serve As Nitrification Inhibitors with Spring Nitrogen Application For Corn Production In Southern Minnesota

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The use of nitrification inhibitors on fine textured soils of southern Minnesota has gained considerable attention over the last several years. There are several chemicals known which are capable of delaying the rate of nitrification,but there is only one currently on the market (N-Serve-Dow Chemical, U.S.A.). An experimental chemical Dwell (Terrazole - Olin Corporation) has shown nitrification inhibition characterstics and was evaluated under field condition along with N-Serve at the Southern Experiment Station at Waseca, MN in 1980. The objectives of the trial were to evaluate the use of nitrogen rates, nitrogen forms and the use of inhibitors with spring application of nitrogen fertilizer.

## Experimental Procedures

An experiment consisting of nineteen treatment, with six replication was arranged in a randomized complete block design and established at the Southern Experiment Station. A factorial arrangement consisting of a control, two nitrogen rates (75 and 150 # N/A), three nitrogen forms (urea, anhydrous ammonia and 28%), and three nitrification inhibitor treatments (none, N-Serve, and Dwell), were applied as a spring application May 8th. Urea was broadcast and the respective nitrification inhibitor treatments made as a separate spray application over the soil surface followed by immediate incorporation. The anhydrous ammonia treatments were injected at a depth of 6-8 inches utilizing 30" knife spacings. N-Serve applications were made by addition of the product directly into the anhydrous tank so that both products were applied simultaneously. Dwell applications were made simultaneously with the use of a dual-tube anhydrous shank and a separate pressurized system for the application of the Dwell. Applications of 28% N Solution were sprayed onto the plots followed by separate spray applications for the nitrification inhibitor treatments and then immediate incorporation. All nitrification inhibitors were applied at 0.5 # a.i./A. Corn (Pioneer 3732) was planted into the experimental area in 30" rows at a seeding rate of approximately 27,000 seeds/A.

Leaf samples were collected from opposite and below the ear at silking, dried, and Kjeldahl nitrogen determined. Dry matter production was determined by harvesting 15' of row from each plot at physiological maturity separating the sample into ears and stover and subsamples collected for moisture determination and Kjeldahl nitrogen analysis. Corn grain yields were determined by machine harvesting the center two rows from each plot (55') and expressing the yields at 15.5% moisture.

## General Results

A good corn production year was experienced at Waseca in 1980. Yield responses to the application of fertilizer nitrogen were obtained up through the highest rate of fertilization (150 # N/A.) Nitrogen losses large enough to reduce yields appeared to occur with the 1980 spring nitrogen application, although yield reductions were highly related to nitrogen form. At the low rates of nitrogen application both urea and 28% nitrogen solution were inferior to anhydrous ammonia. Urea was very similar to anhydrous ammonia at the higher rate of nitrogen while the use of 28% nitrogen solution was substantially lower. The use of nitrification inhibitors provided yield increases in 1980, but only with certain treatment comparisons. Within these comparisons Dwell appeared to have a slight advantage over N-Serve, but the difference between the inhibitors were not statistically significant. Substantial yield increases were obtained with Dwell at the 75 # N/A rate of application when urea was applied and with both N-Serve and Dwell at the 150 # N/A rate of application when 28% nitrogen solution was utilized. No nitrification inhibitor response was obtained in 1980 when utilized with anhydrous ammonia.

Table 1. Influence of nitrogen form nitrogen rates, and nitrification inhibitors (N-Serve and Dwell) on leaf N content, grain yield, dry matter production and nitrogen removal of corn. - Waseca 1980.

| Treatments | | | | | Dry Matter Production | | | N-Concentration | | N-Removal | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N Rate | N Form | Inhib. | Leaf N | Grain yield | Grain | Stover | Total | Grain | Stover | Grain | Stover | Total |
| #/A | | | % | Bu/A | ---------T/A-------- | | | --------%----- | | -------lbs/A---------- | | |
| Check | - | - | 1.52 | 92.6 | 2.19 | 3.32 | 5.51 | 1.16 | 0.46 | 50.5 | 30.5 | 81.0 |
| 75 | Urea | - | 1.89 | 126.5 | 2.81 | 3.82 | 6.63 | 1.36 | 0.62 | 75.9 | 46.8 | 122.7 |
| 75 | Urea | N-S | 1.86 | 130.8 | 3.18 | 3.94 | 7.12 | 1.34 | 0.59 | 84.7 | 46.8 | 131.5 |
| 75 | Urea | Dwell | 1.91 | 138.7 | 3.49 | 4.12 | 7.61 | 1.31 | 0.64 | 90.8 | 52.9 | 143.7 |
| 75 | AA | - | 2.30 | 144.2 | 3.41 | 4.31 | 7.72 | 1.37 | 0.62 | 93.4 | 53.8 | 147.2 |
| 75 | AA | N-S | 2.26 | 140.8 | 3.34 | 4.46 | 7.81 | 1.43 | 0.71 | 95.6 | 63.7 | 159.3 |
| 75 | AA | Dwell | 2.28 | 146.7 | 3.60 | 4.26 | 7.86 | 1.32 | 0.65 | 95.1 | 55.8 | 150.9 |
| 75 | 28% | - | 2.00 | 130.9 | 3.37 | 4.20 | 7.56 | 1.30 | 0.59 | 86.8 | 49.2 | 136.0 |
| 75 | 28% | N-S | 2.03 | 134.0 | 3.30 | 3.99 | 7.30 | 1.36 | 0.57 | 89.5 | 45.6 | 135.1 |
| 75 | 28% | Dwell | 1.99 | 138.0 | 3.38 | 4.08 | 7.46 | 1.29 | 0.63 | 86.9 | 51.6 | 138.5 |
| 150 | Urea | - | 2.20 | 152.7 | 3.65 | 4.63 | 8.28 | 1.37 | 0.72 | 99.9 | 66.2 | 166.1 |
| 150 | Urea | N-S | 2.15 | 151.1 | 3.50 | 4.34 | 7.85 | 1.52 | 0.78 | 106.4 | 67.0 | 173.4 |
| 150 | Urea | Dwell | 2.05 | 151.4 | 3.54 | 4.32 | 7.86 | 1.37 | 0.64 | 96.2 | 55.2 | 151.4 |
| 150 | AA | - | 2.63 | 153.5 | 3.59 | 4.68 | 8.26 | 1.60 | 0.93 | 114.4 | 87.1 | 201.5 |
| 150 | AA | N-S | 2.51 | 153.0 | 3.85 | 4.80 | 8.65 | 1.48 | 0.96 | 114.2 | 91.1 | 205.3 |
| 150 | AA | Dwell | 2.54 | 152.7 | 3.29 | 4.64 | 7.93 | 1.60 | 1.02 | 104.6 | 95.1 | 199.7 |
| 150 | 28% | - | 2.34 | 142.4 | 4.11 | 4.63 | 8.75 | 1.48 | 0.74 | 121.8 | 68.1 | 189.9 |
| 150 | 28% | N-S | 2.23 | 155.1 | 3.60 | 4.62 | 8.22 | 1.47 | 0.80 | 105.3 | 74.0 | 179.5 |
| 150 | 28% | Dwell | 2.30 | 160.8 | 4.26 | 4.79 | 9.05 | 1.44 | 0.81 | 122.2 | 77.3 | 199.5 |
| Significance | | | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| BLSD (.05) | | | 0.12 | 13.2 | 0.39 | 0.35 | 0.67 | 0.09 | 0.12 | 10.2 | 11.2 | 17.0 |
| Factorial Arrangement | | | | | | | | | | | | |
| N-Rate | | | | | | | | | | | | |
| 75 | | | 2.06 | 136.7 | 3.32 | 4.13 | 7.45 | 1.34 | 0.62 | 88.8 | 51.8 | 140.6 |
| 150 | | | 2.33 | 152.5 | 3.71 | 4.61 | 8.32 | 1.48 | 0.82 | 109.4 | 75.7 | 185.1 |
| Significance | | | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| BLSD (.05) | | | 0.05 | 4.8 | 0.14 | 0.12 | 0.24 | 0.03 | 0.04 | 3.8 | 4.2 | 6.4 |
| N-Form | | | | | | | | | | | | |
| Urea | | | 2.01 | 141.9 | 3.36 | 4.20 | 7.56 | 1.38 | 0.66 | 92.3 | 55.8 | 148.1 |
| AA | | | 2.42 | 148.5 | 3.51 | 4.52 | 8.04 | 1.47 | 0.82 | 102.9 | 74.5 | 177.4 |
| 28% | | | 2.15 | 143.5 | 3.67 | 4.38 | 8.06 | 1.39 | 0.69 | 102.1 | 61.0 | 163.1 |
| Significance | | | ** | + | ** | ** | ** | ** | ** | ** | ** | ** |
| BLSD (.05) | | | 0.05 | 5.4 | 0.17 | 0.14 | 0.28 | 0.04 | 0.05 | 4.3 | 4.6 | 7.0 |
| Inhibitor | | | | | | | | | | | | |
| None | | | 2.22 | 141.7 | 3.49 | 4.38 | 7.87 | 1.41 | 0.70 | 98.7 | 61.9 | 160.6 |
| N-Serve | | | 2.17 | 144.1 | 3.46 | 4.36 | 7.82 | 1.44 | 0.74 | 99.3 | 64.7 | 164.0 |
| Dwell | | | 2.18 | 148.0 | 3.59 | 4.37 | 7.96 | 1.39 | 0.73 | 99.3 | 64.7 | 164.0 |
| Significance | | | NS | NS | NS | NS | NS | + | NS | NS | NS | NS |
| BLSD (.05) | | | - | - | - | - | - | 0.04 | - | - | - | - |

# MAXIMUM YIELD DEMONSTRATION
University of Minnesota
Southern Experiment Station
Waseca, MN
1980

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Numerous studies have been initiated over the last few years to "pull out the stops" in an effort to maximize corn and soybean yields. The purpose of our effort was to establish a "non-limiting" environment in which corn and soybean yields could be maximized in a demonstration approach without replication.

## EXPERIMENTAL PROCEDURES

The site that we selected was formerly a garden demonstration area which had a long history of high fertilization rates. The soil was a moderately well drained Nicollet clay loam with a 2-4% south-facing slope. Each crop system was planted in an area measuring 20' x 65'. Trickle irrigation using Chapin Watermatic Twin Wall 4 mil, 12" outlet tubing was installed at 45" spacings. Flow meters measured application rates. Water was applied from May 23 thru July 31. The corn was hand planted while a Tye drill was used to plant the soybeans. The corn plots were harvested and measurements taken on the center 40' of each row including the border rows. However, the data reported in Table 4 represent only the center 4 rows and, thus, eliminate the border effects. Soybean yields were taken from combine harvested areas measuring 10' x 50' from each plot. Additional experimental procedures are outlined in Table 1.

The effect of a high fertilization history is shown in Table 2. Soil test P and K levels down to 24 inches were extremely high. Soil test Zn and S were judged to be very high and high, respectively. Soil pH was slightly acid with medium to high levels of organic matter.

## RESULTS

Nutrient concentrations in the diagnostic tissues shown in Table 3 indicate sufficient amounts of all nutrients with the possible exception of Mg. The Mg levels were somewhat lower than normal probably due to the extremely high soil K levels. However, high soil K did not result in extremely high tissue K levels. Soybean leaf N levels also are somewhat lower than sometimes recommended in the literature.

Yields from this demonstration fell far below our goals of 250 and 80 bu/A for corn and soybeans, respectively (Table 4). The highest corn yield was 195.0 bu/A with one variety following corn and 192.0 bu/A with the other variety following soybeans. One variety did not stand out as being better than the other. When averaging the yields of both varieties, there was only a 5 bushel advantage for corn following soybeans (183.6 vs 178.8 bu/A).

Because of severe lodging (44 to 100%) yields were taken shortly after physiological maturity. Barren stalks ranged from 12 to 24% of the plants and accounted for a grain yield loss. Final population ranged from 37700 to 39000 and was quite close to our planted population of 40000 plants/acre.

The soybean yield following corn was 17.4 bu/A better than the continuous soybean yield (Table 4). The late season wet weather apparently resulted in increased disease pressure with the continuous soybeans. As a result they matured 9 days earlier than the soybeans in rotation. Seed size of the continuous soybeans was 146 mg/seed while the soybeans in rotation averaged 183 mg/seed.

## DISCUSSION

A number of frustrations and hazards were encountered in the 1980 season. Some of these occurrences were either directly or indirectly responsible for our failure to meet the high yield goals.

Total precipitation during June and July was the lowest since 1934. This necessitated heavy dependence on the trickle irrigation which, in general, worked quite well. However, birds in their quest for water pecked holes in the 4-mil plastic tubing. As a result we were continuously patching and/or replacing the tubing. In the future we will use either 8-mil or 12-mil tubing to resolve this problem.

Table 1. Experimental procedures used in "non-limiting" environment demonstration at Waseca in 1980.

| Parameter | Crop System: Cont. Corn | Corn after Soybeans | Soybeans after Corn | Cont. Soybeans |
|---|---|---|---|---|
| Tillage: | F. Chisel<br>Spr. f. cult.<br>(2x) | F. Chisel<br>Spr. f. cult.<br>(2x) | F. Chisel<br>Spr. f. cult.<br>(2x) | F. Chisel<br>Spr. f. cult.<br>(2x) |
| Manure: | 20,000 gal/A<br>liq. dairy<br>(ca 375#N) | 20,000 gal/A<br>liq. dairy<br>(ca 375#N) | None | None |
| Fertilizer: | 200 lb N/A<br>as urea(PPI)<br>No P or K | 200 lb N/A<br>as urea(PPI)<br>No P or K | None | None |
| Hybrid-Variety: | Cargill 921<br>Pioneer 3732 | Cargill 921<br>Pioneer 3732 | Vickery | Vickery |
| Planting date: | 4/21 | 4/21 | 5/1 | 5/1 |
| Planting rate: | 40000 ppA | 40000 ppA | 160000 ppA | 160000 ppA |
| Row width: | 15" | 15" | 6 2/3" | 6 2/3" |
| Herbicide: | Lasso + Bladex | Lasso + Bladex | Treflan + Amiben | Treflan + Amiben |
| Insecticide: | Counter(2#/A) | Counter(2#/A) | None | None |
| Rainfall: | | May | 2.54" | |
| | | June | 3.34" | |
| | | July | 0.51" | |
| | | August | 9.69" | |
| Irrigation: May | 1.23" | 0.85" | 0 | 0 |
| Jun | 1.18" | 1.14" | 0.99" | 1.31" |
| Jul | 7.82" | 9.30" | 6.51" | 3.70" |
| Harvest date: | 9/15 | 9/15 | 10/2 | 10/2 |
| Harvest method: | Hand | Hand | Combine | Combine |

High winds with 0.85 inches of rain occurred on June 27. The Cargill 921 variety lodged badly as a result but goose-necked back up before tasseling. This was our first indication that the plant population was too high.

Because of the early planting this was the most mature corn in the area. As a result birds and squirrels began to attack the corn as soon as it reached the blister to early milk stages. We had to cover the corn plots with bird netting and run the netting down and under a 3-foot high wire fence which was installed completely around the plots. Between the fence and the netting most of the birds and squirrels were excluded from the plots. However, some of the ear tips on the outside rows still received considerable damage.

Heavy rains and high winds during August and early September blew off the netting and lodged much of the corn. The netting was quickly replaced. With the high population, low sunlight and lodged conditions stalk diseases entered and premature death occurred quickly.

The humid conditions in this jungle of vegetation resulted in germination of the kernels in the ear while still 6 feet off the ground. This occurred in about 1% of all ears.

Based on our observations in 1980, we will reduce our population somewhat in 1981. We feel that this should give us greater stalk strength and less chance of disease without reducing yield. It will also allow more sunlight to the plants which we think was a major limiting factor this year. In support of that argument, we averaged 270.2 bu/A corn on the outside rows and 250.6 bu/A on the second row from the outside. In this second row where plant competition occurred on each side,

greater amounts of sunlight were apparently available. This resulted in less barren plants and improved standability of the corn.

Table 2. Soil tests from "non-limiting" environment demonstration at Waseca.

| Depth | Cont. Corn | Corn after Soybeans | Soybeans after Corn | Cont. Soybeans |
|---|---|---|---|---|
| | Crop System | | | |
| inches | pH | | | |
| 0-6 | 6.6 | 6.4 | 6.1 | 6.4 |
| 6-12 | 6.4 | 6.3 | 6.0 | 6.2 |
| 12-18 | 5.9 | 5.9 | 5.6 | 5.8 |
| 18-24 | 5.9 | 5.7 | 5.4 | 5.7 |
| | OM (%) | | | |
| 0-6 | 4.5 | 5.0 | 4.4 | 4.4 |
| | Bray $P_1$ (lb/A) | | | |
| 0-6 | 317 | 262 | 255 | 235 |
| 6-12 | 285 | 260 | 200 | 195 |
| 12-18 | 101 | 148 | 95 | 112 |
| 18-24 | 42 | 60 | 28 | 30 |
| | Exch. K (lb/A) | | | |
| 0-6 | 930 | 960 | 880 | 990 |
| 6-12 | 820 | 890 | 520 | 920 |
| 12-18 | 420 | 880 | 490 | 920 |
| 18-24 | 380 | 940 | 440 | 900 |
| | Zn (ppm) | | | |
| 0-6 | 6.3 (VH) | 5.2 (VH) | 4.5 (VH) | 4.4 (VH) |
| | S (ppm) | | | |
| 0-6 | 15 (H) | 15 (H) | 13 (H) | 14 (H) |

Table 3. Nutrient concentrations in the leaf[1/] from the "non-limiting" environment demonstration at Waseca in 1980.

| Crop System | Hybrid | N | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | ppm | | | | |
| Cont. Corn | C921 | 2.84 | .34 | 2.42 | .67 | .21 | 162 | 81 | 60 | 5.3 | 13 |
| | P3732 | 2.64 | .38 | 2.92 | .56 | .24 | 212 | 53 | 21 | 5.6 | 11 |
| Corn - Sb | C921 | 2.56 | .32 | 2.67 | .56 | .15 | 170 | 50 | 36 | 4.2 | 10 |
| | P3732 | 2.64 | .38 | 2.82 | .56 | .23 | 207 | 62 | 32 | 5.8 | 10 |
| Soybeans - C | | 4.47 | .43 | 2.64 | 1.10 | .35 | 157 | 74 | 47 | 4.5 | 60 |
| Cont. Sb | | 4.29 | .38 | 2.54 | 1.22 | .36 | 146 | 56 | 43 | 3.3 | 62 |

[1/] Corn: leaf opposite and below the ear at silking.
Soybeans: uppermost, fully mature trifoliate at mid-bloom.

Table 4. Corn and soybean production in a "non-limiting" environment at Waseca in 1980.

| Crop System | Hybrid-Variety | Grain Yield | Grain Moisture | Grain Prot. | Total Dry Matter | Barren Stalks | Root + Stalk Lodging | Final Popl'n. |
|---|---|---|---|---|---|---|---|---|
| | | bu/A | % | % | T/A | % | % | x $10^{-3}$ |
| Cont. Corn | C921 | 162.5 | 32.8 | 10.0 | 9.19 | 20 | 100 | 37.7 |
| " " | P3732 | 195.0 | 33.9 | 9.1 | 11.11 | 12 | 44 | 39.0 |
| Corn - Sb | C921 | 192.0 | 36.6 | 8.8 | 10.47 | 24 | 100 | 38.8 |
| " " | P3732 | 175.2 | 32.9 | 9.6 | 9.69 | ND[1/] | 100 | 39.0 |
| Soybeans - C | Vickery | 54.8 | 13.7 | | | | | |
| Cont. Sb | Vickery | 37.4 | 13.0 | | | | | |

[1/] ND = Not Determined

## SUMMARY

Under the growing conditions and experimental conditions used in this demonstration plot in 1980, corn yields reached 195.0 and soybeans 54.8 bu/A. The high corn population which resulted in less sunlight per plant coupled with the climatic conditions were thought to be the main factors limiting yields.

# CONSERVATION TILLAGE STUDY

Waseca, 1980

G. W. Randall, J. W. Bauder and J. B. Swan

With increasing emphasis on controlling erosion and minimizing energy requirements (time, labor and fuel), tillage practices of the future will undoubtedly change markedly within the next decade. As a result these practices may be commonly referred to as "conservation tillage" systems.

## Experimental Procedures

To evaluate some of these conservation tillage practices on continuous corn an experiment was established in 1975 on a Webster clay loam at the Southern Experiment Station. Five tillage treatments (Table 1) were replicated four times. Each plot was 20' wide by 125' long. Beginning in 1979 all plots were split into two, 4-row plots -- one with 140 lb 9-23-30/A as starter fertilizer and the other without starter fertilizer. Tile lines spaced 75' apart lie perpendicular to the rows within all plots.

Ridges are built along the corn rows for the till-plant (Ridge) treatment by cultivation in June each year. After harvest the stalks are chopped and the moldboard and chisel plow operations are performed in early November. On May 5 the moldboard and chisel plow plots were field cultivated once with the chisel plots receiving a prior disking.

Corn (Pioneer 3732) was planted in 30-inch rows at a rate of 26,100 ppA on May 5. The no-tillage, fall plow and fall chisel treatments were planted with a John Deere Max-Emerge planter equipped with 2" fluted coulters. A Buffalo till planter was used for the till-plant treatments.

Broadcast P and K were applied at a rate of 20+50+150 (lb $N+P_2O_5+K_2O$/A) in November, 1979. Nitrogen (170 lb N/A as ammonium nitrate) was broadcast on May 2. Furadan (1 lb/A) was applied to all plots at planting. Chemical weed control consisted of 3½ lb Lasso and 3 lb atrazine/A applied preemergence. A postemergence treatment of atrazine and oil (2 lb + 1½ qt. oil conc./A) was applied to the no-tillage treatment on June 9 to control weeds that had escaped the preemergence application. Treatments 2, 3, 4, and 5 were cultivated on June 20. Weed control was excellent in all cultivated treatments.

Planting depth was determined by cutting off the coleoptile at the soil surface from all the plants in a 3-meter length of row in each plot 30 days after planting. The seeds were then excavated and the length of the coleoptile to the seed was measured. Early plant growth was determined by harvesting the above ground portion of 10 random plants per plot 43 days after planting. Yields were taken by combine harvesting two rows from each plot.

## Results

Significant differences in final population, grain moisture, N removal in the grain and grain yield were found among the tillage treatments (Table 1). Grain protein was not affected.

Grain yield of the moldboard plow treatment (MP) was significantly higher than any of the other treatments (Table 1). Differences among the other systems were not significant, but the chisel plow (CP), till plant (ridge) (TP-R) and till plant (flat) (TP-F) yielded 10 to 15 bushels/A more than the no tillage (NT) system. This was the first year in six years of the study that the MP treatment had excelled to this degree over the other tillage systems. A probable cause could have been the extremely dry and hot conditions during late June and July. Rainfall for the June plus July period was the lowest since 1934. Shortly after cultivation all treatments except the MP showed drought signs. Leaves were rolled and the plants became stunted compared to the MP plants (Table 5). Even though substantial rain fell in August, the stunted plants from the CP, TP-R, TP-F and NT treatments never did equal the MP plants. Perhaps the higher residue/mulch levels of the CP, TP-R, TP-F and NT systems resulted in shallower root growth early in the season. Roots in the MP plots may have been growing deeper. As the hot, dry conditions prevailed, plants from the MP system may have been in a better position to acquire subsoil moisture to meet the high ET demands of the crop. In addition, the cultivation operation on June 20 may have pruned some of the shallow roots and caused

greater evaporation losses. This operation would then have been more critical to the tillage systems with higher surface residue accumulation. Visual stress notes taken on July 18 showed plant stress to increase in the order MP < CP < TP-R < TP-F < NT.

Table 1. Influence of tillage methods and starter fertilizer on continuous corn production at Waseca in 1980.

| Treatment | | | Grain | | | |
|---|---|---|---|---|---|---|
| Tillage | Starter[2] fertilizer | Final popl'n x $10^{-3}$ | Moist. | Protein | N Removal | Yield |
| | | | --------%-------- | | lb/A | bu/A |
| No tillage[1] | S | | 26.3 | 9.50 | 94.2 | 131.6 |
| No tillage | NS | | 26.7 | 9.06 | 87.8 | 128.2 |
| Fall plow, f.cult.[1] | S | | 23.8 | 9.00 | 108.6 | 159.6 |
| Fall plow, f.cult. | NS | | 24.0 | 9.06 | 115.8 | 168.5 |
| Fall chisel, d., f.cult.[1] | S | | 25.6 | 9.12 | 100.1 | 146.6 |
| Fall chisel, d., f.cult. | NS | | 26.5 | 8.81 | 88.1 | 133.0 |
| Till plant (Ridge) | S | | 24.7 | 9.62 | 102.7 | 142.8 |
| Till plant (Ridge) | NS | | 25.7 | 9.50 | 99.8 | 139.8 |
| Till plant (Flat) | S | | 26.0 | 8.75 | 94.1 | 143.2 |
| Till plant (Flat) | NS | | 26.2 | 8.38 | 92.4 | 145.5 |
| Individual Factors | | | | | | |
| Tillage | | | | | | |
| No tillage | | 22.8 | 26.5 | 9.31 | 91.0 | 129.9 |
| Fall plow | | 24.1 | 23.9 | 9.06 | 112.2 | 164.0 |
| Fall chisel | | 24.1 | 26.0 | 8.94 | 94.1 | 139.8 |
| Till plant (Ridge) | | 24.2 | 25.2 | 9.56 | 101.2 | 141.4 |
| Till plant (Flat) | | 21.7 | 26.1 | 8.56 | 93.3 | 144.3 |
| Significance:[3] | | ** | ** | NS | ** | ** |
| BLSD(.05) : | | 1.2 | .8 | -- | 7.5 | 15.8 |
| Starter fertilizer | | | | | | |
| Starter | | | 25.3 | 9.19 | 99.9 | 144.8 |
| No starter | | | 25.8 | 8.94 | 96.8 | 143.0 |
| Significance: | | | * | NS | + | NS |
| Till x SF IA | | | | | | |
| Significance: | | | NS | NS | * | NS |
| BLSD(.05) : | | | -- | -- | 8.9 | -- |
| CV(%) : | | 3.4 | 2.7 | 6.6 | 5.5 | 5.4 |

[1] Planted with J.D. Max-Emerge planter with fluted coulters.

[2] S = starter fertilizer used; NS = no starter fertilizer.

[3] **, *, + are significant at the 99, 95 and 90% levels, respectively; NS = not significant at the 90% level.

Starter fertilizer did not improve grain yield when averaging over all treatments (Table 1). However, the 13.6 bu/A increase with starter on the CP treatment was an economical response even though the tillage x starter fertilizer interaction was not significant (P=.10 level). An F value of 2.27 was obtained when a value of 2.36 was needed to be significant.

Final population for the MP, CP and TP-F systems were equal and were significantly higher than the population of the TP-F or NT systems (Table 1).

Grain moisture, an indication of maturity, was significantly lower with the MP treatment (Table 1). The TP-R treatment was intermediate and showed significantly less moisture than the CP, TP-F and NT treatments. Slightly less moisture was associated with the addition of starter fertilizer.

Nitrogen removal in the grain (product of grain N times yield) was closely related to yield because grain protein (N) levels were not affected by the tillage or starter fertilizer treatments (Table 1). Highest N removal occurred with the MP system, intermediate removal with the TP-R system and lowest removal with the CP, TP-F and NT systems. Slightly higher removal was associated with the starter fertilizer. The tillage x starter fertilizer interaction shows significantly more N removal with the CP system when starter fertilizer is used.

Surface residue measured just prior to secondary tillage on the CP system and planting of the TP-R system showed 2.8 and 4.4 T residue/A, respectively (Table 2). Eight days after planting these residue levels were reduced to 1.9 T/A by secondary tillage of the CP system and to 2.5 T/A by till planting on the ridges. Significantly higher residue amounts were found on the TP-F and NT systems after planting. Because of the large corn yields in 1979, some residue was found on the surface of the MP treatment in 1980.

Table 2. Influence of tillage methods for continuous corn on surface residue and seedling depth at Waseca in 1980.

| Treatment | Surface Residue: Before Planting | Surface Residue: After Planting | Planting Depth: Average | Planting Depth: S | Planting Depth: Range |
|---|---|---|---|---|---|
| | -------T DM/A-------- | | ----------mm---------- | | |
| No tillage | | 4.39 | 56.7 | 7.3 | 36-70 |
| Fall plow | | 0.64 | 64.4 | 5.4 | 53-78 |
| Fall chisel | 2.81 | 1.88 | 58.3 | 8.0 | 37-72 |
| Till plant (Ridge) | 4.43 | 2.54 | 47.0 | 6.7 | 25-70 |
| Till plant (Flat) | | 3.85 | 49.6 | 10.2 | 30-69 |
| Significance: | * | ** | ** | | |
| BLSD(.05) : | | .68 | 8.1 | | |
| CV(%) : | 15. | 18. | 9.4 | | |

Planting depth generally averaged significantly deeper when the John Deere planter was used (NT, MP and CP systems) as compared to the Buffalo till-planter (Table 2). Greatest average depth was found with the MP system. The variability in the seeding depth as measured by standard deviation (S) and shown by the range in depths indicates least variability with the MP system and greatest with the TP-F system. Seed placement ranged between 2.1" and 3.1" for the MP system and between 1.2" and 2.7" for the TP-F system. Although the range was greater for the TP-R system (1.0" to 2.7") the standard deviation ranked second to the MP system. Careful adjustment of the till-planter must be practiced, otherwise stand losses will be encountered with shallow seed placement. The shallow and variable seed placement with the TP-F system probably was responsible for the reduced final plant population in 1980.

Soil temperature at the 4-inch depth measured by thermocouples placed directly beneath the seed was affected by the surface residues in the five-week period following planting (Table 3). Average temperatures were warmest with the FP treatment (65.6°) and coolest with the NT treatment (60.5°). The TP-R treatment (63.5°) was slightly warmer than the CP system (63.3°) and the TP-F system (60.9°).

Table 3. Soil temperature (4" average) after planting as influenced by tillage practices at Waseca in 1980.

| Treatment | Period: 5/12 -17 | 5/19 -24 | 5/26 -31 | 6/2 -7 | 6/9 -14 | 6/16 -19 |
|---|---|---|---|---|---|---|
| | ----------°F---------- | | | | | |
| No tillage | 49.4 | 57.2 | 64.1 | 63.0 | 64.0 | 65.3 |
| Fall plow | 53.5 | 64.2 | 69.6 | 66.5 | 69.3 | 70.4 |
| Fall chisel | 51.4 | 61.0 | 67.4 | 64.7 | 67.0 | 68.1 |
| Till plant (Ridge) | 51.6 | 60.9 | 67.5 | 65.1 | 67.2 | 68.7 |
| Till plant (Flat) | 49.9 | 57.8 | 64.7 | 63.2 | 64.5 | 65.5 |

The rate of seedling emergence was determined by counting the number of plants that had spiked thru in 50-feet of row/plot each day from the 17th to the 28th day following planting (emergence was much slower in 1980 than 1979). Emergence, as a percent of final stand, shown in Table 4 indicates the most rapid germination and growth with the TP-R and FP treatments. The CP treatment was somewhat slower. Slowest emergence occurred with the NT system. The TP-F system was somewhat faster than the NT system but lagged behind the others.

Table 4. Influence of tillage methods on the emergence progress of continuous corn at Waseca in 1980.

| Treatment | Days Post Planting | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 28 |
| | % emerged | | | | | | | | | |
| No tillage | 0 | 0 | 3 | 16 | 41 | 70 | 87 | 96 | 98 | 100 |
| Fall plow | 18 | 59 | 84 | 93 | 97 | 98 | 98 | 98 | 99 | 100 |
| Fall chisel | 0 | 10 | 36 | 68 | 89 | 95 | 98 | 98 | 99 | 100 |
| Till plant (Ridge) | 20 | 63 | 89 | 95 | 98 | 100 | 100 | 100 | 100 | 100 |
| Till plant (Flat) | 0 | 3 | 22 | 39 | 67 | 82 | 92 | 96 | 97 | 100 |

Table 5. Influence of tillage methods and starter fertilizer for continuous corn on small whole plant growth, plant height, tassel and silking date at Waseca in 1980.

| Treatment | | Early plant growth | Plant[1/] height | Tassel date | Silking date |
|---|---|---|---|---|---|
| Tillage | Starter fertilizer | g/10 plants | inches | | |
| No tillage | S | 41.0 | 47.1 | 7/22 | 7/26 |
| No tillage | NS | 29.0 | 43.6 | | |
| Fall plow | S | 75.5 | 58.0 | 7/18 | 7/22 |
| Fall plow | NS | 57.2 | 58.4 | | |
| Fall chisel | S | 61.2 | 51.4 | 7/18 | 7/23 |
| Fall chisel | NS | 45.2 | 51.7 | | |
| Till plant (Ridge) | S | 68.5 | 52.9 | 7/18 | 7/22 |
| Till plant (Ridge) | NS | 62.2 | 52.3 | | |
| Till plant (Flat) | S | 40.2 | 47.9 | 7/20 | 7/24 |
| Till plant (Flat) | NS | 32.5 | 45.4 | | |
| Individual Factors | | | | | |
| Tillage | | | | | |
| No tillage | | 35.0 | 43.4 | | |
| Fall plow | | 66.4 | 58.2 | | |
| Fall chisel | | 53.2 | 51.6 | | |
| Till plant (Ridge) | | 65.4 | 52.6 | | |
| Till plant (Flat) | | 36.4 | 46.7 | | |
| Significance: | | ** | ** | | |
| BLSD(.05) : | | 9.8 | 1.8 | | |
| Starter fertilizer | | | | | |
| Starter | | 57.3 | 51.5 | | |
| No starter | | 45.2 | 50.3 | | |
| Significance: | | ** | ** | | |
| Till x SF IA | | | | | |
| Significance: | | NS | * | | |
| BLSD(.05) : | | | 1.8 | | |
| CV(%) : | | 19. | 2.2 | | |

1/ Taken on July 2.

Early plant growth (EPG) measurements shown in Table 5 indicate substantial differences among the tillage treatments. Plant growth by mid-June showed significantly larger plants with the MP and TP-R systems, intermediate growth (80% of the MP and TP-R) with the CP system and smallest plants (55% of the MP and TP-R) with the TP-F and NT systems. Starter fertilizer significantly improved

early growth with all tillage systems. The correlation between EPG and grain yield was not significant with starter fertilizer (+.255$^{NS}$) and no starter treatments (+.248$^{NS}$).

Because of the stress symptoms and apparent stunting, plant height of 10 plants/plot were taken on July 2 and are shown in Table 5. Plants grown on MP tillage were significantly taller than all others. Intermediate height was shown with the CP and TP-R systems. Plants were somewhat taller with the TP-F system as compared to NT. A height response to starter fertilizer was also shown.

Tasseling and silking dates were 2 to 4 days later with the TP-F and NT treatments (Table 5). The effect of the dry conditions can be seen by the silking dates which were 4 to 5 days later than the tassel date.

The small whole plants taken for early plant growth (EPG) measurements were chemically analyzed (Table 6). Nutrient analyses indicated significant effects (P=.10) of the tillage treatments on small plant P, K, Ca, Mg, Fe and B. Highest P levels were obtained with the TP-R system. Significantly higher K and B concentrations were found with the MP system. The TP-F system had significantly less plant K. Plant Fe was higher for all systems which received some tillage, indicating that soil had probably splashed onto the plants and contamination resulted. The addition of starter fertilizer reduced plant Ca, Mg, Mn, Zn, Cu and B, but the reason is not known. A tillage x starter fertilizer interaction was evident with only Mg and Cu (P=.05). All plant concentrations appeared to be sufficient for optimum yields.

Table 6. Influence of tillage methods and starter fertilizer for continuous corn on small whole plant nutrient concentrations at Waseca in 1980.

| Treatment | | Nutrient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Starter fertilizer | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
| | | % | | | | ppm | | | | |
| No tillage | S | .41 | 4.59 | .35 | .23 | 177 | 40 | 32 | 7.7 | 5.6 |
| No tillage | NS | .40 | 4.65 | .40 | .27 | 161 | 44 | 37 | 9.8 | 6.4 |
| Fall plow | S | .41 | 5.53 | .41 | .26 | 427 | 44 | 40 | 7.0 | 6.6 |
| Fall plow | NS | .40 | 5.02 | .50 | .30 | 368 | 59 | 43 | 10.0 | 7.6 |
| Fall chisel | S | .38 | 4.59 | .42 | .28 | 361 | 54 | 36 | 8.7 | 6.4 |
| Fall chisel | NS | .39 | 4.94 | .43 | .26 | 312 | 53 | 36 | 9.2 | 6.8 |
| Till plant (Ridge) | S | .44 | 4.90 | .38 | .27 | 323 | 43 | 37 | 7.6 | 6.4 |
| Till plant (Ridge) | NS | .42 | 4.57 | .49 | .38 | 318 | 48 | 46 | 10.5 | 6.8 |
| Till plant (Flat) | S | .39 | 4.04 | .43 | .30 | 364 | 46 | 36 | 9.6 | 6.1 |
| Till plant (Flat) | NS | .40 | 4.23 | .50 | .36 | 299 | 47 | 43 | 11.2 | 6.5 |
| Individual Factors | | | | | | | | | | |
| Tillage | | | | | | | | | | |
| No tillage | | .40 | 4.62 | .38 | .25 | 169 | 42 | 35 | 8.7 | 6.0 |
| Fall plow | | .40 | 5.28 | .45 | .28 | 398 | 51 | 42 | 8.5 | 7.1 |
| Fall chisel | | .39 | 4.77 | .42 | .27 | 336 | 54 | 36 | 9.0 | 6.6 |
| Till plant (Ridge) | | .43 | 4.74 | .44 | .32 | 320 | 45 | 41 | 9.0 | 6.6 |
| Till plant (Flat) | | .39 | 4.14 | .47 | .33 | 331 | 46 | 39 | 10.4 | 6.3 |
| Significance: | | + | ** | + | + | ** | NS | NS | NS | ** |
| BLSD(.05) : | | | .38 | | | 56 | | | | .4 |
| Starter fertilizer | | | | | | | | | | |
| Starter | | .40 | 4.73 | .40 | .26 | 330 | 45 | 36 | 8.1 | 6.2 |
| No starter | | .40 | 4.68 | .46 | .31 | 292 | 50 | 41 | 10.1 | 6.8 |
| Significance: | | NS | NS | ** | ** | + | ** | ** | ** | ** |
| Till x SF IA | | | | | | | | | | |
| Significance: | | NS | NS | + | * | NS | + | + | * | NS |
| BLSD(.05) : | | | | | .06 | | | | 1.4 | |
| CV(%) : | | 7.9 | 7.9 | 7.7 | 12. | 21. | 11. | 8.6 | 8.9 | 6.7 |

Nutrient uptake by the small plants was calculated by multiplying the nutrient concentrations (Table 6) by the EPG found in Table 5. The differences in uptake values among the tillage treatments are closely associated with the respective EPG values (Table 7).

Uptake of all elements was significantly affected by the tillage treatments. Generally, uptake was greatest with MP and TP-R systems, intermediate with the CP system and least with the TP-F and NT systems. Starter fertilizer resulted in significantly higher uptake of P, K, Fe, Zn and B.

Table 7. Influence of tillage methods and starter fertilizer for continuous corn on small whole plant nutrient uptake at Waseca in 1980.

| Treatment | | Nutrient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Starter fertilizer | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
| | | -----g/10 plants------ | | | | ---------mg/10 plants--------- | | | | |
| No tillage | S | .17 | 1.88 | .14 | .09 | 7.2 | 1.64 | 1.32 | .317 | .229 |
| No tillage | NS | .12 | 1.35 | .12 | .08 | 4.6 | 1.29 | 1.08 | .285 | .188 |
| Fall plow | S | .30 | 4.16 | .31 | .19 | 31.7 | 3.24 | 3.07 | .530 | .497 |
| Fall plow | NS | .22 | 2.86 | .28 | .18 | 20.3 | 3.46 | 2.41 | .573 | .432 |
| Fall chisel | S | .24 | 2.81 | .26 | .17 | 21.8 | 3.28 | 2.23 | .529 | .396 |
| Fall chisel | NS | .18 | 2.24 | .19 | .12 | 14.0 | 2.39 | 1.64 | .412 | .312 |
| Till plant (Ridge) | S | .30 | 3.35 | .26 | .18 | 21.7 | 2.92 | 2.51 | .521 | .438 |
| Till plant (Ridge) | NS | .26 | 2.90 | .30 | .23 | 19.6 | 2.93 | 2.85 | .641 | .422 |
| Till plant (Flat) | S | .16 | 1.65 | .17 | .12 | 14.7 | 1.72 | 1.45 | .366 | .243 |
| Till plant (Flat) | NS | .13 | 1.38 | .16 | .12 | 9.8 | 1.48 | 1.40 | .354 | .209 |
| Individual Factors | | | | | | | | | | |
| Tillage | | | | | | | | | | |
| No tillage | | .14 | 1.62 | .13 | .09 | 5.9 | 1.46 | 1.20 | .301 | .208 |
| Fall plow | | .26 | 3.51 | .30 | .18 | 26.0 | 3.35 | 2.74 | .552 | .464 |
| Fall chisel | | .21 | 2.52 | .22 | .14 | 17.9 | 2.83 | 1.94 | .470 | .354 |
| Till plant (Ridge) | | .28 | 3.12 | .28 | .21 | 20.6 | 2.93 | 2.68 | .581 | .430 |
| Till plant (Flat) | | .14 | 1.52 | .17 | .12 | 12.2 | 1.60 | 1.42 | .360 | .226 |
| Significance: | | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| BLSD(.05) : | | .04 | .52 | .04 | .05 | 3.1 | .78 | .57 | .105 | .072 |
| Starter fertilizer | | | | | | | | | | |
| Starter | | .23 | 2.77 | .23 | .15 | 19.4 | 2.56 | 2.12 | .453 | .360 |
| No starter | | .18 | 2.15 | .21 | .14 | 13.7 | 2.31 | 1.88 | .453 | .312 |
| Significance: | | ** | ** | NS | NS | ** | NS | + | NS | * |
| Till x SF IA | | | | | | | | | | |
| Significance: | | NS | NS | NS | NS | * | NS | NS | NS | NS |
| BLSD(.05) : | | | | | | 4.0 | | | | |
| CV(%) : | | 20. | 21. | 24. | 24. | 15. | 26. | 20. | 24. | 20. |

Leaf samples were taken from the leaf opposite and below the ear at silking. With the exception of Mg and B, nutrient concentrations were not affected significantly (P=.05) by the tillage systems (Table 8). Significantly lower Mg and B concentrations were found with the MP system. Although a definite trend toward lower leaf K in the TP systems was evident, concentrations were not statistically different (P=.10). Starter fertilizer did not affect leaf nutrient concentrations with the exception of lower K and Cu with the row-applied fertilizer.

Table 8. Influence of tillage methods and starter fertilizer for continuous corn on the nutrient concentration in the earleaf at Waseca in 1980.

| Treatment | | Nutrient | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Starter fertilizer | N | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
| | | % | | | | | ppm | | | | |
| No tillage | S | 2.5 | .26 | 1.93 | .61 | .38 | 154 | 40 | 25 | 5.0 | 12.2 |
| No tillage | NS | 2.5 | .24 | 2.02 | .57 | .40 | 132 | 39 | 24 | 6.3 | 10.6 |
| Fall plow | S | 2.6 | .24 | 1.98 | .53 | .32 | 137 | 44 | 24 | 5.0 | 7.9 |
| Fall plow | NS | 2.6 | .25 | 2.15 | .54 | .30 | 150 | 42 | 28 | 5.4 | 8.6 |
| Fall chisel | S | 2.6 | .25 | 1.91 | .59 | .41 | 144 | 46 | 25 | 5.1 | 10.2 |
| Fall chisel | NS | 2.4 | .24 | 1.98 | .59 | .40 | 146 | 44 | 25 | 5.3 | 10.4 |
| Till plant (Ridge) | S | 2.5 | .24 | 1.77 | .59 | .46 | 152 | 39 | 25 | 4.5 | 9.8 |
| Till plant (Ridge) | NS | 2.4 | .24 | 1.77 | .61 | .45 | 148 | 41 | 26 | 4.7 | 9.6 |
| Till plant (Flat) | S | 2.6 | .24 | 1.75 | .61 | .43 | 135 | 44 | 25 | 5.1 | 10.6 |
| Till plant (Flat) | NS | 2.5 | .23 | 1.84 | .60 | .42 | 128 | 42 | 24 | 5.2 | 9.6 |
| Individual Factors | | | | | | | | | | | |
| Tillage | | | | | | | | | | | |
| No tillage | | 2.5 | .25 | 1.98 | .59 | .39 | 143 | 39 | 24 | 5.7 | 11.4 |
| Fall plow | | 2.6 | .25 | 2.06 | .54 | .31 | 144 | 42 | 26 | 5.2 | 8.3 |
| Fall chisel | | 2.5 | .25 | 1.94 | .59 | .40 | 145 | 45 | 25 | 5.2 | 10.3 |
| Till plant (Ridge) | | 2.4 | .24 | 1.77 | .60 | .46 | 150 | 40 | 25 | 4.6 | 9.7 |
| Till plant (Flat) | | 2.5 | .23 | 1.80 | .60 | .42 | 131 | 43 | 24 | 5.2 | 10.2 |
| Significance: | | NS | NS | NS | NS | * | NS | NS | NS | NS | ** |
| BLSD(.05) : | | | | | | .09 | | | | | 1.4 |
| Starter fertilizer | | | | | | | | | | | |
| Starter | | 2.5 | .25 | 1.87 | .58 | .40 | 144 | 43 | 25 | 5.0 | 10.2 |
| No starter | | 2.5 | .24 | 1.95 | .58 | .39 | 141 | 42 | 25 | 5.4 | 9.8 |
| Significance: | | NS | NS | * | NS | NS | NS | NS | NS | * | NS |
| Till x SF IA | | | | | | | | | | | |
| Significance: | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| CV(%) : | | 6.7 | 6.2 | 5.8 | 8.6 | 8.9 | 8.8 | 11. | 8.8 | 9.5 | 12. |


## SUMMARY

A field experiment was established in 1975 to evaluate five tillage systems (no tillage, moldboard plow, chisel plow, till-plant (ridge) and till-plant (flat)) on continuous corn on a Webster clay loam. Beginning in 1979 all plots were split to evaluate the effect of starter fertilizer with these tillage treatments. Grain yields with the moldboard plow were significantly higher than with any of the other systems. This was probably due to greater root penetration into the subsoil to supply the plants with water during the hot, dry June and July. Lowest yields were obtained with no tillage. Starter fertilizer did not improve yields when averaged over all treatments. Even though the interaction between tillage and starter fertilizer was not significant a 13 bu increase was obtained when the chisel plow system received starter fertilizer.

## SIX-YEAR YIELD SUMMARY

Grain yields have been obtained from the five tillage systems where starter fertilizer was used from 1975-1980 (Table 9). The 6-year average yield shows a 4.5 bu/A yield advantage for the moldboard plow over the till-plant (ridge) system. Most of this difference could be attributed to the 17 bushel advantage in 1980 for moldboard plowing. The chisel plow and till-plant (flat) systems showed intermediate yields while lowest yields were obtained with no tillage. Weed control has been excellent in all treatments except no tillage. In the last two years, however, postemergence herbicides have also provided good weed control with no tillage.

Two-year data indicate some advantage for the use of starter fertilizer with the chisel plow, till-plant (ridge) and no tillage systems. No reason can be given for the obvious difference in response to starter fertilizer between the no tillage and till-plant (flat) systems when both treatments represent the most severely reduced tillage systems.

Table 9. Influence of tillage methods and starter fertilizer on continuous corn yields at Waseca.

| Treatment | | Grain | |
|---|---|---|---|
| Tillage | Starter fertilizer | 1979-80 Avg. Yield | 1975-80 Avg. Yield |
| | | bu/A | |
| No tillage | S | 144.2 | 126.7 |
| No tillage | NS | 138.9 | |
| Fall plow | S | 165.4 | 147.2 |
| Fall plow | NS | 170.4 | |
| Fall chisel | S | 157.8 | 137.3 |
| Fall chisel | NS | 147.8 | |
| Till plant (Ridge) | S | 154.0 | 142.7 |
| Till plant (Ridge | NS | 148.6 | |
| Till plant (Flat) | S | 149.8 | 140.0 |
| Till plant (Flat) | NS | 152.2 | |

# SOYBEAN TILLAGE-HERBICIDE STUDY

Waseca, 1980

G. W. Randall, E. L. Carter and G. E. Ham

Concern for soil erosion has increased interest in tillage methods that leave residue on the soil surface. In addition, tillage methods which require lesser amounts of energy yet result in an acceptable seed bed are being considered. In south central Minnesota soybeans are generally grown in a corn-soybean sequence; hence, large amounts of corn residue are present. The objective of the study is to determine the effect of various tillage-herbicide systems (residue management) on soil parameters, weed control, nitrogen fixation and soybean production.

## EXPERIMENTAL PROCEDURES

To evaluate various tillage-herbicide systems on soybean production following corn, an experiment consisting of 8 tillage-herbicide treatments was established in the fall of 1979 on a Webster-Nicollet clay loam soil complex at the Southern Experiment Station. Primary tillage treatments included no tillage, fall moldboard plow, fall chisel plow, combined fall and spring disking and a double spring disking. The latter three treatments were split to also evaluate methods of herbicide application with minimum tillage. A preplant incorporate herbicide (Treflan) was compared to a preemergence herbicide (Lasso). All plots were 125' long and 20' wide (8-30" rows).

In the fall of 1979, fertilizer was broadcast at a rate of 0+120+200 ($N+P_2O_5+K_2O$/A) before any tillage was started. Row-placed fertilizer at planting was not used.

The no tillage, moldboard and chisel plow treatments were stalk chopped on November 14 and were immediately followed by the fall moldboard, chisel and disk tillage operations. Corn stalks on the spring disk treatments were allowed to stand throughout the winter. Secondary tillage was conducted on May 14. All chisel and disk treatments were disked with Treflan being applied at 1 qt/A to the PPI treatments. The fall plow and chisel treatments were field cultivated the same day.

Soybeans (Corsoy) were planted in 7 of the 8 rows at 8.4 beans/foot on May 15. A non-nodulating isoline was planted in the remaining row to determine the effect of the tillage treatments on dinitrogen fixation and yield only. A John Deere Max-Emerge planter with 2" fluted coulters was used on all plots. On May 16 the preemergence herbicide treatment (Lasso, 3 qt/A) was applied. Amiben at a rate of 5 qt/A was superimposed over all plots on the same date. All plots were cultivated once on July 7. In addition, one-half of all plots were handweeded to evaluate the sole effect of tillage on soybean yield without confounding with weed pressure. A tillage-herbicide x weed interaction could then be investigated.

Thermocouples and soil moisture blocks (gypsum) were installed at the 4-inch depth on April 22 to determine soil temperature and moisture prior to planting. They were removed for planting and then reinstalled directly below a soybean row on May 16. Plant emergence rates were measured in four 10-foot sections from May 25 thru June 11. Final population was taken at that time. Surface residue amounts were determined by removing, weighing, washing and drying corn residue from 27 $ft^2$/plot on May 27. Early plant growth was determined on July 3 by harvesting and drying the above ground portion of 16 randomly selected plants from the center 4 rows of each plot. Nutrient composition of these samples was determined by ICP analysis. Uppermost, mature trifoliate samples were taken on July 30 for chemical analysis. Volunteer corn population counts were taken on June 30 by counting the total number of single plants or clumps (if a large number of plants emerged from a single ear) in the plot area which was not handweeded. Seed yields were determined by harvesting the center 4 rows with a modified JD 3300 combine and the non-nodulating row with an ALAMCO plot combine on October 6.

## RESULTS

Significant differences in small soybean plant K, Ca, Mg, Fe and Ca concentrations were found among the tillage treatments (Table 1). Moldboard plowing resulted in higher K and Fe levels and lower Ca and Mg levels than most of the reduced tillage treatments. Iron differences may have resulted largely from soil splash as influenced by the surface residue, however. No tillage and the fall plus spring disk treatment showed the lowest K concentrations.

Table 1. Influence of primary tillage-herbicide combinations for soybeans following corn on the nutrient concentration of small whole soybean plants in 1980.

| Treatment | | Nutrient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Herbicide[1] | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
| | | % | | | | ppm | | | | |
| No tillage[2] | Pre | .28 | 1.96 | 1.90 | .68 | 196 | 49 | 30 | 7.5 | 34 |
| Fall plow[2] | Pre | .29 | 2.33 | 1.77 | .60 | 265 | 53 | 30 | 7.0 | 34 |
| Fall chisel[2] | Pre | .29 | 2.22 | 1.89 | .64 | 235 | 51 | 30 | 7.4 | 35 |
| Fall chisel[2] | PPI | .28 | 2.07 | 1.88 | .66 | 250 | 49 | 30 | 8.2 | 35 |
| Spr. disk (2x) | Pre | .28 | 2.15 | 1.76 | .70 | 220 | 43 | 27 | 6.3 | 32 |
| Spr. disk (2x) | PPI | .29 | 2.16 | 1.80 | .71 | 213 | 44 | 29 | 6.9 | 34 |
| Fall & Spr. disk | Pre | .28 | 2.05 | 1.90 | .67 | 223 | 47 | 31 | 7.4 | 35 |
| Fall & Spr. disk | PPI | .28 | 2.00 | 1.91 | .70 | 213 | 47 | 31 | 7.6 | 36 |
| Significance:[3] | | NS | ** | ** | ** | ** | + | NS | ** | NS |
| BLSD(.05) : | | | .14 | .09 | .06 | 31 | | | .7 | |
| CV(%) : | | 5.5 | 5.6 | 4.1 | 6.7 | 11. | 11. | 9.3 | 7.8 | 6.6 |

[1] Pre = Lasso (3½ lb/A), PPI = Treflan (1 lb/A).

[2] These treatments were stalk chopped.

[3] **, *, + are significant at the 99, 95, and 90% levels, respectively. NS = not significant at the 90% level.

Dry matter per acre (product of DM/plant times plants/A) was affected significantly by the tillage treatments (Table 2). Dry matter accumulation five weeks after emergence was significantly higher with moldboard plow tillage than with most reduced tillage treatments. This was probably due to more rapid emergence as shown in Table 5. Even though no tillage resulted in the least DM accumulation, DM was not significantly less than with any of the reduced tillage treatments.

These dry matter differences coupled with the associated nutrient concentration resulted in large tillage treatment differences in uptake of most nutrients (Table 2). Moldboard plow tillage showed the highest uptake levels and significantly higher levels of K, Fe, and Mn than all other treatments. In general, nutrient uptake ranked in order of increasing degree of tillage (plow > chisel = disk > no tillage).

Table 2. Influence of primary tillage-herbicide combinations for soybeans following corn on small plant dry matter accumulation and nutrient uptake in 1980.

| Treatment | | | Nutrient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Herb. | DM | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
| | | lb/A | | | | | | | | | |
| No tillage | Pre | 481 | 1.34 | 9.5 | 9.1 | 3.3 | .093 | .023 | .014 | .0036 | .016 |
| Fall plow | Pre | 718 | 2.09 | 16.8 | 12.7 | 4.3 | .192 | .038 | .021 | .0050 | .024 |
| Fall chisel | Pre | 610 | 1.74 | 13.6 | 11.6 | 3.9 | .140 | .031 | .018 | .0044 | .021 |
| Fall chisel | PPI | 561 | 1.59 | 11.7 | 10.6 | 3.7 | .141 | .028 | .017 | .0046 | .019 |
| Spr. disk (2x) | Pre | 558 | 1.57 | 12.0 | 9.9 | 3.9 | .122 | .024 | .015 | .0035 | .018 |
| Spr. disk (2x) | PPI | 562 | 1.67 | 12.1 | 10.2 | 4.0 | .118 | .024 | .016 | .0038 | .019 |
| Fall & Spr. disk | Pre | 619 | 1.73 | 12.8 | 11.7 | 4.1 | .134 | .029 | .019 | .0045 | .021 |
| Fall & Spr. disk | PPI | 588 | 1.66 | 11.8 | 11.2 | 4.1 | .124 | .027 | .018 | .0045 | .021 |
| Significance: | | * | * | ** | + | NS | ** | ** | * | + | * |
| BLSD(.05) : | | 143 | .38 | 2.8 | | | .029 | .006 | .005 | | .005 |
| CV(%) : | | 18. | 17. | 19. | 19. | 21. | 19. | 19. | 21. | 21. | 19. |

At the mid-to late bloom stage (four weeks after the whole plants were sampled), leaf K was highest for the moldboard plow treatment, intermediate with chisel plowing and lowest with the disk and no tillage treatments (Table 3). Opposite effects were noticed on leaf Ca and Mg. Leaf Mn was also highest with the plow treatment.

Soil temperatures at the 4-inch depth in the two week period before planting ranged from about 53°F with the no tillage and fall chisel treatments to over 56°F with moldboard plowing (Table 4). Temperatures were intermediate with the disk treatments. In the week immediately following planting soil temperatures averaged about 5°F warmer with the plow treatment and about 1°F warmer with the chisel and disk treatments as compared to no tillage. During the six-week period following planting soil temperatures with the chisel and disk treatments averaged about 1°F and the plow about 3°F warmer than no tillage. These temperature differences were governed largely by the surface residue accumulations shown in Table 6.

Table 3. Influence of primary tillage-herbicide combinations for soybeans following corn on the leaf nutrient concentration of soybeans in 1980.

| Treatment | | Nutrient[1/] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Herb. | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
| | | % | | | | ppm | | | | |
| No tillage | Pre | .30 | 1.53 | 1.47 | .50 | 106 | 51.8 | 35.1 | 8.8 | 58 |
| Fall plow | Pre | .31 | 1.88 | 1.37 | .41 | 110 | 55.7 | 34.0 | 8.6 | 57 |
| Fall chisel | Pre | .30 | 1.67 | 1.42 | .46 | 105 | 48.8 | 37.0 | 8.8 | 58 |
| Fall chisel | PPI | .31 | 1.68 | 1.37 | .46 | 107 | 50.0 | 35.5 | 9.3 | 57 |
| Spr. disk (2x) | Pre | .30 | 1.54 | 1.45 | .49 | 105 | 46.8 | 34.2 | 8.7 | 57 |
| Spr. disk (2x) | PPI | .31 | 1.54 | 1.44 | .50 | 104 | 45.8 | 35.2 | 8.9 | 58 |
| Fall & Spr. disk | Pre | .30 | 1.58 | 1.48 | .49 | 105 | 46.3 | 35.9 | 8.7 | 58 |
| Fall & Spr. disk | PPI | .30 | 1.56 | 1.48 | .48 | 107 | 51.0 | 37.0 | 8.9 | 60 |
| Significance: | | NS | ** | ** | ** | NS | ** | NS | NS | NS |
| BLSD(.05) : | | | .11 | .06 | .04 | | 4.5 | | | |
| CV(%) : | | 4.5 | 6.2 | 3.6 | 6.6 | 5.0 | 7.6 | 5.7 | 7.0 | 6.3 |

1/ Uppermost, mature, trifoliate leaf at mid-to late bloom.

Table 4. Weekly 4-inch soil temperature averages as influenced by tillage method for soybeans following corn in 1980.

| Treatment | | Soil temperature[1/] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before planting | | After planting | | | | | |
| Tillage | Herb. | 4/28 -5/2 | 5/5 -10 | 5/19 -24 | 5/26 -31 | 6/2 -7 | 6/9 -14 | 6/16 -21 | 6/23 -28 |
| | | °F | | | | | | | |
| No tillage | Pre | 52.0 | 53.3 | 60.6 | 68.5 | 64.1 | 67.1 | 68.7 | 74.1 |
| Fall plow | Pre | 56.7 | 56.2 | 65.6 | 71.6 | 66.0 | 70.6 | 73.0 | 77.7 |
| Fall chisel | Pre | 52.3 | 53.5 | 61.6 | 69.2 | 64.3 | 67.9 | 70.0 | 75.0 |
| Spr. disk (2x) | Pre | 53.6 | 54.9 | 61.2 | 69.0 | 64.4 | 68.0 | 69.9 | 75.3 |
| Fall & Spr. disk | Pre | 53.6 | 54.3 | 61.3 | 69.2 | 64.1 | 67.3 | 69.5 | 74.7 |

1/ Average of maximum and minimum daily T.

Table 5. Influence of primary tillage-herbicide combinations for soybeans following corn on the emergence progress of the soybeans in 1980.

| Treatment | | Emergence Date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Herb. | 5/ 25 | 5/ 26 | 5/ 27 | 5/ 28 | 5/ 29 | 5/ 30 | 5/ 31 | 6/1 | 6/2 | 6/4 | 6/11 |
| | | % emerged | | | | | | | | | | |
| No tillage | Pre | 18 | 46 | 66 | 78 | 82 | 84 | 85 | 86 | 92 | 95 | 100 |
| Fall plow | Pre | 58 | 82 | 94 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 100 |
| Fall chisel | Pre | 13 | 53 | 77 | 88 | 92 | 94 | 96 | 96 | 98 | 98 | 100 |
| Fall chisel | PPI | 10 | 33 | 58 | 71 | 82 | 89 | 89 | 93 | 97 | 97 | 100 |
| Spr. disk (2x) | Pre | 11 | 44 | 67 | 78 | 84 | 84 | 91 | 94 | 96 | 98 | 100 |
| Spr. disk (2x) | PPI | 9 | 41 | 57 | 68 | 76 | 83 | 88 | 91 | 93 | 96 | 100 |
| Fall & Spr. disk | Pre | 14 | 50 | 70 | 83 | 86 | 88 | 90 | 91 | 93 | 95 | 100 |
| Fall & Spr. disk | PPI | 13 | 40 | 62 | 73 | 80 | 87 | 88 | 93 | 94 | 96 | 100 |

Emergence rate of the soybeans was greatly affected by the tillage treatments (Table 5). On the first day of measurement, 58% of the plants had emerged with moldboard plow tillage while no more than 18% had emerged with the reduced tillage treatments. Over 90% were emerged on the plowed treatment 12 days after planting (May 27) while it took 17 days with the chisel and disk systems and 18 days with no tillage to reach 90% emergence.

Fairly high corn residue levels were found after the 1979 crop (Table 6). The proportion of the residue incorporated cannot be estimated in 1980 because some of the residue blew off the no tillage plots during the winter. Fall chisel plowing did incorporate a significantly greater amount than the disk treatments with no difference between the fall plus spring disking and the double spring disk treatments.

Because of the high variability significant differences in early plant weight were not shown in 1980 (Table 6). However, a trend showing largest plants with moldboard plow tillage, intermediate with chisel and disk tillage and smallest with no tillage was evident. This may have been due possibly to the cooler soil temps and slower emergence rates.

Table 6. Influence of primary tillage-herbicide combinations for soybeans following corn on early growth, volunteer corn, population and soybean yield in 1980.

| Treatment | | Surface residue accuml'n | Early plant weight | Vol.[1] corn | Final popl'n | Seed Yield | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1980 | 1977-80 |
| Tillage | Herb. | | | | | HW[2] | Std.[3] | Std. Avg.[3] |
| | | T DM/A | g/plant | ppA | beans/ft. | bu/A | | |
| No tillage | Pre | 2.6 | 1.8 | 6 | 6.8 | 48.5 | 37.7 | 40.2 |
| Fall plow | Pre | .2 | 2.5 | 6 | 7.5 | 49.8 | 49.8 | 51.0 |
| Fall chisel | Pre | 1.2 | 2.1 | 6 | 7.6 | 46.4 | 49.7 | 49.9 |
| Fall chisel | PPI | | 2.0 | 6 | 7.2 | 51.6 | 50.8 | 51.1 |
| Spr. disk (2x) | Pre | 2.4 | 2.1 | 30 | 7.1 | 49.7 | 50.1 | 49.4 |
| Spr. disk (2x) | PPI | | 2.1 | 24 | 6.9 | 50.4 | 51.2 | 50.2 |
| Fall & Spr. disk | Pre | 2.6 | 2.2 | 6 | 7.4 | 49.4 | 48.0 | 49.0 |
| Fall & Spr. disk | PPI | | 2.3 | 30 | 6.8 | 49.8 | 48.3 | 49.5 |
| Significance: | | ** | NS | NS | * | ** | | |
| BLSD(.05) : | | .4 | | | .7 | 4.4 | | |
| CV(%) : | | 22. | 16. | 235. | 6.9 | 5.5 | | |
| Individual Factors | | | | | | | | |
| HW vs Std. | | | | | | 49.4 | 48.2 | |
| Significance: | | | | | | * | | |
| Till x Weed IA | | | | | | | | |
| Significance: | | | | | | ** | | |
| BLSD(.05) : | | | | | | 3.0 | | |

1/ Each clump of corn was counted as one plant.

2/ HW = handweeded.

3/ Std. = standard non-handweeded plots.

Volunteer corn was not a problem in any of the tillage treatments in 1980. A trend toward improved control with Treflan was not observed because of the high degree of variability and the few corn plants available (Table 6).

Slight differences in the final bean population were again found in 1980 (Table 6). Highest populations occurred with the plow, chisel-Pre and fall plus spring disk-Pre treatments. Lowest populations were associated with no tillage and the disk-PPI treatments. A trend toward reduced stand with the PPI (Treflan) treatments was noted in 1980. However, all stands were considered adequate for maximum yields.

Soybean yields were again depressed significantly by no tillage (Table 6). Yield differences among the other standard tillage-herbicide treatments did not exist. Highest yields were obtained, however, with the chisel and the double spring disk treatments with Treflan. When yields from the "standard" and handweeded areas were averaged over all tillage treatments, a significant advantage existed for handweeding. The highly significant tillage x weed interaction indicates that only the no tillage treatment benefited from handweeding and that this extra degree of weed control did not affect yields from the other tillage treatments. These results indicate that soybean yields can be optimized over a wide range of tillage systems provided that adequate weed control is maintained.

Four-year averages for the "standard" (non-handweeded) treatments indicate that excellent soybean yields can be obtained with reduced tillage systems following corn and with both PPI or preemergence grass herbicide programs (Table 6). Sizable yield reductions occurred with no tillage primarily because weed control was insufficient.

Nitrogen fixation, nodulation, root length, N uptake, seed oil and protein content are being evaluated by Mr. Ed Carter as partial fulfillment of his Master's Degree. A non-nodulating line planted in each treatment helps him assess the effect of the tillage treatments on the N status of the soybeans.

## SUMMARY

Optimum soybean yields were obtained in 1980 with reduced tillage systems. Surface residue accumulations of up to 2.6 T/A did influence soybean development somewhat. No tillage resulted in slightly cooler soils, smaller plants and very poor weed control (primarily broadleaves and some grasses). Nutrient uptake was affected by the tillage treatments but was adequate for optimum soybean yields. Volunteer corn populations were too small to evaluate the treatments thoroughly. These results indicate that soybean production following corn can be excellent with tillage systems that manage surface residue, thus, limiting soil erosion.

## ACKNOWLEDGMENT

Appreciation is extended to the Minnesota Soybean Research and Promotion Council for a three-year grant which allows us to pursue this study.

# CORRECTING CHLOROSIS OF SOYBEANS BY FOLIAR APPLICATION OF IRON

Gyles W. Randall
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University of Minnesota
Waseca, MN
1980

It has been estimated that about 400,000 acres in Minnesota have a sufficiently high pH to exhibit iron chlorosis symptoms. The major agronomic crop that is currently adversely affected by chlorosis induced Fe-deficiency is soybeans. Chlorotic soybeans are a common occurrence and in many instances major seed losses result.

The purpose of this study was to determine if the foliar application of some new iron compounds to the leaves of iron-chlorotic soybeans would correct the deficiency and result in significant yield improvement.

## Experimental Procedures

An experimental site was selected on the Orville Collins farm near Waldorf in Waseca County. Peterson 3800 soybeans had been planted in 30" rows. Weeds were controlled by 1 qt Treflan/A. The soybeans were severely chlorotic and were in the 2nd trifoliate stage with the 3rd trifoliate just beginning to emerge.

All foliar iron materials were applied between 0930 and 1100 hours on June 18. Temperatures were warm with partly cloudy skies. Treatments were replicated 8 times in single-row plots measuring 20' long. All materials were applied with a stainless steel hand sprayer at a gallonage rate of 50 gpa with X-77 at 0.25% v/v. The iron application rates (lb Fe/A) are shown in Table 1.

Nine days after iron application a hail storm passed thru the plot site and did result in some additional leaf loss of the already weakened plants. Visual observations were taken on June 23 and on July 8. Yields were obtained on September 30 by hand harvesting 16' of row per plot and threshing with a stationary soybean thresher.

## Results

Visual color response five days after iron application indicated some improvement in the green color of some of the leaves. Instead of a general color improvement, however, the darker green responses appeared as mottled splotches throughout the leaf tissue. The response also seemed to be more consistent with the sequestrene 138-Fe material than the other materials. Phytotoxic symptoms were not evident.

Three weeks after application and about 10 days after the hail storm, the visual responses were still mottled and were not consistent throughout the experiment. The hail may have lead to this mottled condition and did prevent any evidence of phytotoxicity symptoms because of the shredding of the leaf tissue.

Yield results shown in Table 1 were extremely variable (CV=68) and were not affected significantly (P=.10 level) by the iron treatments. The highest average yield resulted from the sequestrene 138-Fe treatment. All other treatments had at least two plots (reps) per treatment in which no yield was obtained. The standard error of the mean ($S_{\bar{x}}$) for each of the averages indicates greatest variability for the check, Hamp-Iron, NFE (.22 lb) and Perma Green treatments when expressed in relation to the mean.

Table 1. Influence of various iron products applied to the foliage of chlorotic soybeans in Waseca County in 1980.

| Iron Treatment Material | Rate | Seed Yield Avg. | Range | $S_{\bar{x}}$ [1] |
|---|---|---|---|---|
| | lb Fe/A | -------bu/A--------- | | |
| Check | 0 | 9.0 | 0.0-38.8 | 4.7 |
| Sequestrene 138-Fe | 0.15 | 16.0 | 0.5-42.4 | 5.0 |
| Hamp-Iron | 0.20 | 10.1 | 0.0-34.3 | 5.2 |
| Eagle Iron | 1.20 | 13.1 | 0.0-32.4 | 4.4 |
| NFE | 0.22 | 10.5 | 0.0-31.6 | 4.3 |
| NFE | 0.43 | 8.0 | 0.0-16.6 | 2.4 |
| Perma Green F21 | 0.20 | 11.0 | 0.0-33.0 | 4.5 |
| Significance: | | NS | | |
| CV(%) | : | 68. | | |

[1] Standard error of the mean.

Summary

Soybean yield variability was extremely high and may have been magnified by the hail damage shortly after the materials were applied. Yields were not improved statistically by the foliar application of these materials at the 2nd trifoliate stage. An economical response, however, was obtained with the sequestrene 138-Fe.

# Soil Inoculant

1980

Waseca, Minnesota

D.K. Langer, G.W. Randall and G.E. Ham

World Agrisearch Corporation markets the product "Soil Inoculant" which contains non-symbiotic forms of N fixing bacteria and blue-green algae. The product can be combined with pesticides or liquid fertilizers at application. World Agrisearch claims that their product "decomposes crop residues, builds soil humus, and accelerates the nitrogen cycle". They state that this totally natural and safe product makes available the nitrogen, phosphorus, potassium and secondary and trace elements needed for crop production. Another claim is that a more stable form of "nitrogen is slowly released all through the growing season for even feeding of the growing crop". The purpose of this study was to evaluate "Soil Inoculant" on corn and soybean production in south-central Minnesota.

## Experimental Procedures

### Corn

The study was established on a Nicollet clay loam soil which had corn removed as grain the previous year. Prior to establishment of the study, P and K fertilizer was applied to the area at a 120 + 200 lb/A rate, respectively, (oxide basis). Treatments were randomized in a six-replicate, 3 x 2 factorial design. Treatments included 0, 75, and 150 lb N/A with and without "Soil Inoculant". The "Soil Inoculant" was applied and incorporated with a field cultivator on May 9, 1980 at the recommended rate of 0.1 gal "Soil Inoculant" + 30 gal $H_2O$/A. Corn (Pioneer 3732) was planted at a rate of 29,900 ppA in 30-inch rows on May 14 with 1 lb Furadan/A and 140 lb 0-23-30/A as starter fertilizer. Chemical weed control consisted of 3½ lb Lasso and 3 lb atrazine/A applied preemergence.

The leaf opposite and below the ear was sampled from 10 plants at silking and submitted for N analysis. Final populations were determined from 35 feet of row in each plot. Silage samples taken from 15 feet of row at physiological maturity (black layer stage) were weighed for yield and submitted for N analysis. Grain yield, moisture and protein were determined on combine-harvested corn from the center two rows of each 6-row plot. Grain yields were converted to 15.5% moisture.

### Soybeans

Two different soybean lines (Hodgson 78 and 129-nonnod) were planted May 16 on a Webster clay loam soil at a rate of 5 beans/foot in 14-inch rows. This area received 120 + 200 lb P and K/A (oxide basis) the previous fall. Treatments were arranged in a six-replicate, randomized, complete-block design. The "Soil Inoculant" was soil-applied May 19 at the recommended rate of 0.1 gal "Soil Inoculant" + 30 gal $H_2O$/A. Chemical weed control consisted of 1 qt Treflan + 6 qts Amiben/A (PPI). Seed yield was determined on soybeans combine harvested from the center four rows of each 6-row plot.

## Results

### Corn

The data for each N rate shown in Table 1 are an average of each respective N rate over both "Soil Inoculant" treatments. Likewise the "Soil Inoculant" values are an average over all N rates. Nitrogen concentration in corn leaf and fodder continually increased with additional nitrogen. Neither leaf nor fodder nitrogen concentration showed a significant "Soil Inoculant" effect, or an interaction between N rate and "Soil Inoculant".

Silage and grain yields were optimized at the 75 lb N rate. Grain yield was not influenced by "Soil Inoculant" while silage yield showed a decrease with the addition of "Soil Inoculant" (P=.10). The nitrogen x "Soil Inoculant" interaction was not significant for either yield. Hot dry weather during late June and July created stress during pollination which added to the variability (high CV's) of this study. Grain moisture was not affected by "Soil Inoculant".

Grain protein content was increased with increasing N rate and by the "Soil Inoculant". The grain protein increase occurred with "Soil Inoculant" at the 0 and 150 lb N rates but not at the 75 lb N rate. These results indicate no positive, consistent effect of "Soil Inoculant" on corn production in south-central Minnesota and, thus, we could not recommend its use even though there was a slight grain protein advantage.

Table 1. Influence of "Soil Inoculant" on the nitrogen concentrations in the corn leaf and fodder, population, silage yield, grain yield, moisture and protein content at Waseca in 1980.

| Treatment | Nitrogen | | Final | Yield | | Grain | |
|---|---|---|---|---|---|---|---|
| | Leaf | Fodder | Popln. | Silage | Grain | Moist. | Protein |
| | ------%------- | | x $10^{-3}$ | T DM/A | bu/A | --------%-------- | |
| 0 lb N | 1.43 | .53 | 27.2 | 5.23 | 82.2 | 26.5 | 7.38 |
| 0 lb N + Soil Inoc. | 1.47 | .56 | 27.2 | 4.79 | 82.8 | 26.4 | 8.88 |
| 75 lb N | 2.06 | .62 | 26.8 | 7.08 | 108.6 | 26.4 | 8.75 |
| 75 lb N + Soil Inoc. | 2.12 | .64 | 27.8 | 7.11 | 111.0 | 26.4 | 8.75 |
| 150 lb N | 2.32 | .76 | 27.3 | 7.66 | 110.9 | 26.9 | 9.44 |
| 150 lb N + Soil Inoc. | 2.29 | .84 | 27.9 | 6.80 | 107.4 | 27.6 | 10.50 |
| Individual Factors | | | | | | | |
| N Rate (lb/A) | | | | | | | |
| 0 | 1.45 | .54 | 27.2 | 5.01 | 82.5 | 26.4 | 8.14 |
| 75 | 2.09 | .62 | 27.3 | 7.10 | 109.8 | 26.4 | 8.74 |
| 150 | 2.30 | .80 | 27.6 | 7.23 | 109.2 | 27.2 | 9.98 |
| Significance:[1/] | ** | * | NS | ** | ** | ** | ** |
| BLSD(.05) : | .09 | .16 | -- | .47 | 11.1 | .4 | .75 |
| Soil Inoc. | | | | | | | |
| No | 1.94 | .64 | 27.1 | 6.66 | 100.5 | 26.6 | 8.52 |
| Yes | 1.96 | .68 | 27.6 | 6.23 | 100.4 | 26.8 | 9.39 |
| Significance: | NS | NS | NS | + | NS | NS | ** |
| N x SI IA | NS | NS | NS | NS | NS | NS | NS |
| CV(%): | 6.3 | 30. | 7.6 | 9.8 | 14. | 2.0 | 10. |

[1/] **, * and + are significant at the 99, 95 and 90% levels, respectively.
NS = not significant at the 90% level.

## Soybeans

The "Soil Inoculant" was applied on two different soybean lines. Hodgson 78 is a well adapted, widely grown variety that symbiotically fixes nitrogen. The 129-nonnod line is not capable of nodulation and thus does not fix nitrogen. One would expect that if "Soil Inoculant" non-symbiotically fixes N that it would be demonstrated by higher yields with the nonnod line receiving "Soil Inoculant". Yields shown in Table 2 indicate no advantage for the use of "Soil Inoculant" with either line of soybeans. Thus, "Soil Inoculant" was not fixing or releasing sufficient N for improved soybean production. This is similar to our 1979 results as shown in the 2-year average.

Table 2. Influence of "Soil Inoculant" on two lines of soybeans for yield at Waseca in 1980.

| Line - Treatment | Yield 1980 | Yield 2-yr. avg. |
|---|---|---|
| 129 Nonnod - Check | 22.3 | 18.2 |
| 129 Nonnod - Soil Inoc. | 23.4 | 18.7 |
| Hodgson 78 - Check | 49.6 | 42.8 |
| Hodgson 78 - Soil Inoc. | 48.3 | 42.2 |
| Individual Factors | | |
| Line | | |
| Nonnod | 22.8 | |
| Hodgson 78 | 49.0 | |
| Significance: | ** | |
| Soil Inoc. | | |
| No | 36.0 | |
| Yes | 35.8 | |
| Significance: | NS | |
| Line x Soil Inoc. IA: | NS | |
| CV(%): | 6.1 | |

Summary

In 1980 corn leaf nitrogen, fodder nitrogen, silage yield, grain yield and grain moisture were not affected positively by "Soil Inoculant". Grain protein, however, was positively affected by the addition of "Soil Inoculant". "Soil Inoculant" showed no effect on soybean yield at Waseca in 1979 or 1980. These results indicate no support for the use of "Soil Inoculant" for corn and soybean production in south-central Minnesota.

# Soil Test Comparison Study

## Waseca, 1980

D. K. Langer, G. W. Randall and W. E. Jokela

Soil testing is one of the best and most economical methods of ascertaining the nutrient status of the soil. The test then serves as the basis for fertilizer recommendations for crops. Many private and public laboratories provide that service to Corn Belt farmers. The purpose of this study is to compare the soil analyses and fertilizer recommendations given by five regional laboratories for corn production in Southern Minnesota. Working with the laboratories in this comparison study we should be able to improve and standardize fertilizer recommendations for corn production.

## Procedures

Two experimental sites measuring 150' by approximately 300' were selected for sampling in October 1979. One of the sites had a history of high P and K fertilization while the other had not received P or K since 1974. The soil type in the former is a Nicollet clay loam while that in the latter is primarily Webster clay loam with some Nicollet clay loam. Both sites have been cropped to continuous corn. Tile lines spaced at 75' intervals provide excellent drainage at both sites. Neither site can be irrigated.

Four samples consisting of approximately 35 cores each were taken from each site. The sampling depth was 7 inches. All samples were oven-dried at 95°F, crushed and mixed thoroughly. The samples were then subdivided and sent out to the five laboratories. Soil analyses requested consisted of pH, OM, extractable $P_1$, exchangeable K, extractable S and the micronutrients generally tested by each laboratory. For the 1980 growing season the fertilizer recommendations were based on a yield goal of 180 bu/A corn. It was stipulated that all fertilizer would be broadcast-applied.

The six treatments consisted of the specific fertilizer recommendations from the five laboratories and a check (no fertilizer) treatment. These treatments were arranged in a six-replicate, randomized, complete-block design. Each plot measured 15' wide by 55' long. The appropriate fertilizer treatments were applied April 24 and 25. Corn (Pioneer 3732) was planted at the rate of 29,900 ppA in 30-inch rows on April 26 (medium testing site) and April 28 (very high testing site) with 1 lb Furadan/A and no starter fertilizer. Chemical weed control consisted of 3½ lb Lasso and 3 lb atrazine/A applied preemergence.

Ten random, small, whole plants were sampled from the four center rows of each plot, weighed and submitted for analyses. The leaf opposite and below the ear was sampled from ten plants at silking and submitted for analyses. Final populations were determined from 70' of row. Grain yield, moisture and protein were determined on corn harvested with a modified JD 3300 plot combine from the center two rows of each plot. Grain yields were converted to 15.5% moisture.

In September 1980 0-7" soil samples were taken from each treatment at each of the two sites and were sent to the laboratory of the respective treatment. The results obtained from these samples will be used for the 1981 growing season.

## Results

### Very high testing site

The soil test results and the accompanying recommended fertilizer program of each laboratory are shown in Table 1 for the very high testing site. This was designated as the very high testing site because the University of Minnesota Soil Testing Laboratory results indicate the soil test P and K levels to be very high. Nitrogen recommendations among the laboratories were quite similar while the P and K recommendations were substantially higher with the private labs. Various micronutrients were recommended by three of the four private labs.

Table 1. Soil test results and the recommended fertilizer programs for the very high testing site at Waseca in 1980.

| Test | Soil Test Results[1] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| pH | 5.6 | 5.5 | 6.5 | 6.3 | 5.4 |
| pH (buffer) | 6.6 | 6.5 | --- | 6.6 | 6.0 |
| Phosphorus | 34 VH | 36 H | 29 | 38 VH | 28 VH |
| Potassium | 163 M | 195 M | 181 | 151 H | 159 VH |
| Organic matter (%) | 4.1 H | 3.2 H | L | 2.7 | M |
| Calcium | 2012 M | 2850 H | --- | 2750 M | --- |
| Magnesium | 372 VH | 428 H | --- | 450 L | --- |
| Sulfur | 5 L | 18 L | 28 A | 10 M | 5 L |
| Iron | 46 VH | 87 H | 8+ A | 6 VH | --- |
| Manganese | 26 H | 37 H | 2+ A | 2.1 VH | --- |
| Zinc | 1.1 M | 1.0 L | 1.4 A | 1.2 M | 1.1 H |
| Copper | 1.0 M | 1.0 A | 0.4+ A | --- | --- |
| Boron | 0.7 L | 1.1 A | 2.9 S | --- | --- |
| ENR (lb/A) | 112 | --- | --- | 55 M | --- |
| C.E.C. (meq/100g) | 17.5 | 24.4 | --- | 18.4 | --- |

[1] All soil test results are stated in ppm unless noted otherwise. Each value is an average of 4 samples.

| Nutrient | Recommended Fertilizer Program[2] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| Nitrogen | 225 | 220 | 220 | 255 | 200 |
| Phosphorus ($P_2O_5$) | 45 | 60 | 65 | 60 | 30 |
| Potassium ($K_2O$) | 115 | 95[3] | 60 | 55 | 20 |
| Sulfur | 22 | 12 | --- | --- | --- |
| Iron | --- | --- | --- | .15[4] | --- |
| Manganese | --- | --- | --- | .15[4] | --- |
| Zinc | 6.0 | 8.0 | --- | .75[4] | --- |
| Copper | 0.5 | --- | --- | --- | --- |
| Boron | 1.0 | --- | --- | --- | --- |
| Lime (T/A) | 2.0 | 3.0 | --- | 2.0 | 7.0 |

[2] All values indicate pounds of nutrient recommended per acre for a yield goal of 180 bushels of corn per acre.

[3] Value includes maintenance recommendation, plus 50% of the buildup recommendation which was to be applied over a two-year period.

[4] As 6 qt/A of a material weighing 10 lb/gal and containing 5% Zn, 1% Fe and 1% Mn.

Grain yields were not affected by any of the fertilizer treatments (Table 2). Late June and July hot, dry weather created extreme stress during pollination which resulted in yields being much lower than normally expected. This also added to the lodging problem. Lodging was due primarily to the absence of N in the check treatment. Slight grain moisture differences were evident among the treatments.

Small whole plant micronutrient concentrations were higher with the treatments receiving fertilizer (Table 3). This is primarily due to the imbalance created by nitrogen deficiency in the plants of the check treatment. The boron application recommended by lab A shows up as a significant increase in concentration at this early growth stage.

Earleaf nutrient concentration differences among the five laboratory recommendation treatments were not found (Table 4). However, marked N deficiency and lower P levels of the plants in the check were shown. Some of the micronutrient concentrations in the earleaf show the effect of the N deficient plants in the check. There appears to be a trend toward higher Zn concentrations in those treatments that received a Zn application.

Table 2. Effect of fertilizer recommendations on corn lodging, final population, grain yield and moisture on the very high testing site.

| Lab | Fertilizer Recommendations | Lodging | Final Population | Grain Yield | Grain $H_2O$ |
|---|---|---|---|---|---|
| | lb/A[1] | % | ppA x $10^{-3}$ | bu/A | % |
| A | 225N +45P +115K +S+Zn+Cu+B | 6.2 | 26.0 | 97.8 | 27.2 |
| B | 220N +60P +95K +S+Zn | 5.2 | 25.7 | 100.1 | 27.7 |
| C | 220N +65P +60K | 5.4 | 25.6 | 106.5 | 26.9 |
| D | 225N +60P +55K +Fe+Mn+Zn | 2.4 | 26.4 | 102.1 | 27.4 |
| E(UM) | 200N +30P +20K | 3.5 | 24.9 | 107.1 | 26.8 |
| Check | | 72.8 | 24.9 | 95.6 | 26.7 |
| | Significance:[2] | ** | NS | NS | * |
| | BLSD(.05) : | 6.0 | | | 0.8 |
| | CV(%) : | 36. | 4.7 | 11. | 2.2 |

[1] P and K expressed on oxide basis.

[2] **, * and + are significant at the 99, 95 and 90% levels, respectively. NS = not significant at the 90% level.

Table 3. Effect of fertilizer recommendations on small plant growth and nutrient concentrations on the very high testing site.

| Lab | Small plant dry weight | Nutrient P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | g/plt. | % | | | | ppm | | | | |
| A | 6.7 | .321 | 5.14 | .37 | .27 | 320 | 71 | 47 | 6.9 | 8.5 |
| B | 6.8 | .324 | 5.02 | .37 | .27 | 305 | 71 | 49 | 6.8 | 7.2 |
| C | 6.7 | .325 | 5.01 | .38 | .27 | 321 | 70 | 45 | 6.8 | 7.2 |
| D | 6.9 | .317 | 5.24 | .36 | .27 | 304 | 72 | 46 | 6.3 | 6.7 |
| E(UM) | 7.0 | .311 | 4.98 | .37 | .27 | 350 | 67 | 44 | 6.6 | 7.0 |
| Check | 6.0 | .302 | 4.82 | .38 | .26 | 324 | 54 | 33 | 6.0 | 6.5 |
| Signif. : | NS | NS | NS | NS | NS | NS | ** | ** | * | ** |
| BLSD(.05): | | | | | | | 5 | 5 | .6 | .8 |
| CV(%) : | 13. | 6.0 | 6.4 | 4.5 | 5.3 | 11. | 6.9 | 9.3 | 6.8 | 9.0 |

Table 4. Effect of fertilizer recommendations on corn earleaf nutrient concentrations on the very high testing site.

| Lab | Nutrient N | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | ppm | | | | |
| A | 2.21 | .303 | 2.12 | .52 | .36 | 164 | 96 | 42 | 4.2 | 10.6 |
| B | 2.29 | .289 | 2.06 | .52 | .36 | 149 | 85 | 40 | 4.1 | 9.5 |
| C | 2.29 | .296 | 2.07 | .53 | .37 | 164 | 86 | 36 | 4.5 | 9.6 |
| D | 2.28 | .301 | 2.12 | .54 | .36 | 160 | 96 | 36 | 4.8 | 9.9 |
| E(UM) | 2.31 | .284 | 2.08 | .53 | .38 | 172 | 82 | 36 | 5.2 | 10.2 |
| Check | 1.70 | .203 | 1.94 | .55 | .37 | 137 | 49 | 21 | 3.0 | 8.8 |
| Signif. : | ** | ** | NS | NS | NS | ** | ** | ** | ** | NS |
| BLSD(.05): | .22 | .016 | | | | 10 | 12 | 5 | .5 | |
| CV(%) : | 8.7 | 5.5 | 6.4 | 7.0 | 6.3 | 5.8 | 13. | 12. | 11. | 11. |

Soil analyses conducted after the 1980 growing season again show similar N recommendations among the labs (Table 5). However, P and K recommendations from the private labs are still higher than the UM lab, but the differences are not as great as the previous year. All four private labs recommend either S or at least one micronutrient.

Table 5. Soil test results and the recommended fertilizer programs on the very high testing site at Waseca in 1981.

| Test | Soil Test Results[1] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| pH | 5.7 | 5.6 | 5.8 | 5.5 | 5.3 |
| pH (buffer) | 6.6 | 6.2 | 6.5 | 6.4 | 6.4 |
| Phosphorus | 29 H | 36 L | 29 | 37 VH | 20 H |
| Potassium | 141 M | 180 L | 120 | 158 H | 108 MH |
| Organic matter (%) | 3.8 H | 4.9 | M | 3.8 | H |
| Calcium | 2390 M | 2900 M | --- | 2405 VH | --- |
| Magnesium | 326 VH | 450 M | --- | 356 M | --- |
| Sulfur | 6 L | 15 M | 25 A | 7 L | 6 LM |
| Iron | 65 VH | 75.2 VH | 8+ A | 5.6 VH | --- |
| Manganese | 33 VH | 38.5 H | 2+ A | 2.1 VH | --- |
| Zinc | 2.1 M | 2.9 H | 1.0 M | 1.1 M | 1.3 H |
| Copper | 0.8 L | 1.0 M | 0.4+ A | --- | --- |
| Boron | 1.6 H | 1.2 H | 3.4 S | --- | --- |
| ENR (lb/A) | 106 | --- | --- | 95 M | --- |
| C.E.C. (meq/100g) | 19.0 | 27.8 | --- | 24.0 | --- |

[1] All soil test results are stated in ppm unless noted otherwise.

| Nutrient | Recommended Fertilizer Program[2] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| Nitrogen | 190 | 185 | 182 | 215 | 170 |
| Phosphorus ($P_2O_5$) | 35 | 60 | 56 | 75 | 50 |
| Potassium ($K_2O$) | 130 | 160[3] | 128 | 110 | 105 |
| Sulfur | 18 | 14 | --- | 13 | --- |
| Iron | --- | --- | --- | .12[4] | --- |
| Manganese | --- | --- | --- | .12[4] | --- |
| Zinc | --- | --- | 8 | .6 [4] | --- |
| Copper | 1 | --- | --- | --- | --- |
| Boron | --- | --- | --- | --- | --- |
| Lime (T/A) | 2.0 | 4.5 | 5.5 | 3.5 | 5.0 |

[2] All values indicate pounds of nutrient recommended per acre for a yield goal of 160 bushels of corn per acre.

[3] Value includes maintenance recommendation, plus 50% of the buildup recommendation which was to be applied over a two-year period.

[4] As 5 qt/A of a material weighing 10 lb/gal and containing 5% Zn, 1% Fe and 1% Mn.

Medium-high testing site

The soil test results and the accompanying recommended fertilizer program of each laboratory are shown in Table 6 for the medium-high testing site. This site was designated as the medium-high testing site because the UM laboratory results indicate the soil test P level to be medium and the soil test K level to be high. Nitrogen recommendations among the laboratories were quite similar while the P and especially K recommendations were substantially higher with the private labs. Sulfur and various micronutrients were recommended by three of the four private labs.

Table 6. Soil test results and the recommended fertilizer programs on the medium-high testing site at Waseca in 1980.

| Test | Soil Test Results[1/] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| pH | 6.4 | 6.4 | 6.7 | 6.8 | 6.4 |
| pH (buffer) | 6.7 | 6.8 | --- | 7.0 | --- |
| Phosphorus | 18 M | 16 L | 9 | 10 L | 9 M |
| Potassium | 144 M | 165 M | 145 | 100 L | 147 H |
| Organic matter (%) | 5.5 H | 3.6 H | M | 3.0 | M |
| Calcium | 2975 M | 4525 VH | --- | 4205 M | --- |
| Magnesium | 540 VH | 695 VH | --- | 795 M | --- |
| Sulfur | 6 L | 13 L | 20 A | 7 L | 14 H |
| Iron | 37 VH | 55 H | 8+ A | 6 VH | --- |
| Manganese | 13 M | 21 H | 2+ A | 2.1 VH | --- |
| Zinc | 1.1 M | 1.1 L | 1.4 A | 1.4 M | 1.1 H |
| Copper | 1.1 M | 1.1 A | .4+ A | --- | --- |
| Boron | 1.1 M | 1.4 A | 3.2 S | --- | --- |
| ENR (lb/A) | 140 | --- | --- | 67 M | --- |
| C.E.C.(meq/100g) | 21.8 | 31.0 | --- | 27.9 | --- |

1/ All soil test results are stated in ppm unless noted otherwise.

| Nutrient | Recommended Fertilizer Program[2/] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| Nitrogen | 210 | 220 | 195 | 215 | 200 |
| Phosphorus ($P_2O_5$) | 95 | 120[3/] | 135 | 105 | 80 |
| Potassium ($K_2O$) | 150 | 215[3/] | 120 | 140 | 25 |
| Sulfur | 22 | 21 | --- | 13 | --- |
| Iron | --- | --- | --- | .12[4/] | --- |
| Manganese | 0.5 | --- | --- | .12[4/] | --- |
| Zinc | 4.5 | 7.0 | --- | .6 [4/] | --- |
| Copper | 0.25 | --- | --- | --- | --- |
| Boron | --- | --- | --- | --- | --- |
| Lime (T/A) | 1.5 | 1.0 | --- | --- | --- |

2/ All values indicate pounds of nutrient recommended per acre for a yield goal of 180 bushels of corn per acre.

3/ Value includes maintenance recommendation, plus 50% of the buildup recommendation which was to be applied over a two-year period.

4/ As 5 qt/A of a material weighing 10 lb/gal and containing 5% Zn, 1% Fe and 1% Mn.

At this medium-high testing site the treatments that received fertilizer yielded significantly more than the check (Table 7). However, there were no significant yield differences among the fertilizer treatments (recommendations). Stress during pollination was also a problem at this site but because of greater soil water holding capacity was not as severe as at the previous site. Stalk lodging was greatly reduced by the addition of fertilizer.

Small plant growth was increased over the check by all treatments which received fertilizer (Table 8). The P concentration in the small plants showed almost a linear relationship to the amount of P fertilizer added. The K concentration was not as closely related to the amount of K applied. Magnesium showed an inverse relationship to K which would be expected from the K-Mg interaction. Increases in Mn and Zn concentration with the fertilizer treatments suggest a general N deficiency in the check plants.

Table 7. Effect of fertilizer recommendations on corn lodging, final population, grain yield and moisture on the medium-high testing site.

| Lab | Fertilizer Recommendations | Lodging | Final Population | Grain Yield | Grain $H_2O$ |
|---|---|---|---|---|---|
| | lb/A[1/] | % | ppA x $10^{-3}$ | bu/A | % |
| A | 210N +95P +150K +S+Mn+Zn+Cu | 10.1 | 27.1 | 135.5 | 25.9 |
| B | 220N +120P +215K +S+Zn | 7.0 | 27.0 | 127.5 | 26.2 |
| C | 195N +135P +120K | 6.2 | 27.2 | 136.5 | 25.6 |
| D | 215N +105P +140K +S+Fe+Mn+Zn | 8.9 | 27.0 | 128.7 | 26.1 |
| E(UM) | 200N +80P +25K | 10.8 | 27.5 | 133.2 | 25.4 |
| Check | | 48.8 | 27.2 | 115.1 | 25.3 |
| | Significance: | ** | NS | * | + |
| | BLSD(.05) : | 10.3 | | 14.1 | |
| | CV(%) : | 61. | 4.5 | 8.3 | 2.3 |

1/ P and K expressed on oxide basis.

Table 8. Effect of fertilizer recommendations on small plant growth and nutrient concentrations on the medium-high testing site.

| Lab | Small plant dry weight | Nutrient P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | g/plt. | % | | | | ppm | | | | |
| A | 6.2 | .343 | 3.11 | .58 | .56 | 242 | 56 | 44 | 9.4 | 7.9 |
| B | 6.7 | .349 | 2.95 | .57 | .54 | 231 | 60 | 42 | 9.1 | 8.0 |
| C | 6.8 | .371 | 3.17 | .58 | .56 | 246 | 60 | 42 | 8.9 | 7.7 |
| D | 6.8 | .351 | 3.09 | .59 | .57 | 265 | 57 | 44 | 9.0 | 7.6 |
| E(UM) | 6.4 | .343 | 2.47 | .61 | .65 | 246 | 58 | 42 | 9.2 | 7.3 |
| Check | 4.4 | .315 | 1.87 | .57 | .58 | 277 | 49 | 36 | 9.1 | 7.2 |
| Signif. : | ** | ** | ** | NS | * | + | ** | + | NS | NS |
| BLSD(.05): | 1.1 | .024 | .46 | | .06 | | 6 | | | |
| CV(%) : | 16. | 5.8 | 14. | 5.2 | 8.1 | 11. | 8.2 | 11. | 7.0 | 7.2 |

The N deficiency is clear in the earleaf N concentration (Table 9). The P concentration in the earleaf still showed a linear relationship to the amount of P added but the leaf P levels among the recommended P rates were not significantly different. Leaf K concentrations were significantly influenced by the laboratory recommendations. The U. of Minnesota (Lab E) recommendation did not increase leaf K over that of the check plot. The K-Mg interaction was again obvious. Magnesium, Mn and Zn nutrient concentrations in the check were all low due to the less vigorous N deficient plants. Although small plant and earleaf nutrient concentration differences were evident, the differences failed to be expressed in the final yield.

Table 9. Effect of fertilizer recommendations on corn earleaf nutrient concentrations on the medium-high testing site.

| Lab | Nutrient N | P | K | Ca | Mg | Fe | Mn | Zn | Cu | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | ppm | | | | |
| A | 2.44 | .250 | 1.28 | .62 | .59 | 115 | 62 | 30 | 4.4 | 11.4 |
| B | 2.46 | .265 | 1.37 | .63 | .60 | 117 | 70 | 29 | 4.5 | 10.9 |
| C | 2.41 | .262 | 1.27 | .61 | .59 | 115 | 62 | 26 | 4.4 | 10.4 |
| D | 2.45 | .257 | 1.24 | .63 | .59 | 117 | 65 | 29 | 4.4 | 11.3 |
| E(UM) | 2.38 | .244 | 1.03 | .62 | .68 | 117 | 61 | 26 | 4.6 | 10.8 |
| Check | 1.94 | .204 | 1.04 | .63 | .57 | 114 | 39 | 21 | 3.9 | 10.2 |
| Signif. : | ** | ** | ** | NS | ** | NS | ** | ** | NS | NS |
| BLSD(.05): | .23 | .022 | .13 | | .06 | | 8 | 4 | | |
| CV(%) : | 8.5 | 7.9 | 9.7 | 7.0 | 8.2 | 7.3 | 13. | 12. | 10. | 12. |

Soil analyses conducted for the medium-high testing site after the 1980 growing season for the 1981 season show somewhat similar N and P recommendations from the labs (Table 10). The K recommendations are higher with the private labs but the range is not as large as the previous year. Three of the four private labs recommend either S or a micronutrient.

Table 10. Soil test results and the recommended fertilizer programs on the medium-high testing site at Waseca in 1981.

| Test | Soil Test Results[1/] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| pH | 6.5 | 6.9 | 6.8 | 6.5 | 6.5 |
| pH (buffer) | 6.7 | --- | --- | 7.0 | --- |
| Phosphorus | 14 M | 24 L | 22 | 24 M | 12 MH |
| Potassium | 163 L | 180 L | 120 | 228 H | 100 MH |
| Organic matter (%) | 4.2 H | 7.4 | M | 4.2 | H |
| Calcium | 4300 H | 5600 H | --- | 6090 VH | --- |
| Magnesium | 577 VH | 770 M | --- | 1038 H | --- |
| Sulfur | 6 L | 14 L | 25 A | 8 M | 7 MH |
| Iron | 37 VH | 39.4 H | 8+ A | 5.6 VH | --- |
| Manganese | 21 H | 16.1 H | 2+ A | 2.1 VH | --- |
| Zinc | 1.3 M | 1.9 H | 1.1 A | 1.7 M | 1.2 H |
| Copper | 1.0 M | 0.9 M | 0.4+ A | --- | --- |
| Boron | 1.7 H | 1.5 H | 3.4 A | --- | --- |
| ENR (lb/A) | 114 | --- | --- | 110 H | --- |
| C.E.C.(meq/100g) | | 35.0 | --- | | --- |

1/ All soil test results are stated in ppm unless noted otherwise.

| Nutrient | Recommended Fertilizer Program[2/] Lab A | Lab B | Lab C | Lab D | Lab E (UM) |
|---|---|---|---|---|---|
| Nitrogen | 185 | 185 | 182 | 200 | 170 |
| Phosphorus ($P_2O_5$) | 80 | 90[3/] | 56 | 90 | 80 |
| Potassium ($K_2O$) | 125 | 195[3/] | 128 | 110 | 105 |
| Sulfur | 18 | 16 | --- | --- | --- |
| Iron | --- | --- | --- | .12[4/] | --- |
| Manganese | --- | --- | --- | .12[4/] | --- |
| Zinc | 3 | --- | --- | .6 [4/] | --- |
| Copper | --- | --- | --- | --- | --- |
| Boron | --- | --- | --- | --- | --- |
| Lime (T/A) | 1.5 | --- | --- | 0.5 | --- |

2/ All values indicate pounds of nutrient recommended per acre for a yield goal of 160 bushels of corn per acre.

3/ Value includes maintenance recommendation, plus 50% of the buildup recommendation which was to be applied over a two-year period.

4/ As 5 qt/A of a material weighing 10 lb/gal and containing 5% Zn, 1% Fe and 1% Mn.

## SUMMARY

There were substantial differences among the laboratories fertilizer recommendations at both sites. Nitrogen recommendation among laboratories were generally similar, but P and K recommendations for the 1980 crop were substantially higher for the private laboratories. Sulfur and various micronutrient recommendations were also provided by the private labs.

Small growing plants showed some uptake response to the micronutrients and K recommended. Earleaf nutrient concentrations among the lab recommendations were not significantly different except for K on the medium-high testing site. Grain yield differences were not observed among the 5 lab recommendations at either site.

Extreme plant stress due to hot, dry conditions during pollination resulted in yields well below our goal. These low yields coupled with the lack of large yield response over the check resulted in the cost of the fertilizer not being offset by the yield response to that fertilizer addition (Table 11).

Table 11. Effect of fertilizer recommendations on yield value, fertilizer cost and the resulting economic difference on both the very high testing site and medium-high testing site at Waseca in 1980.

| | Very High Testing Site | | | | Medium-High Testing Site | | | |
|---|---|---|---|---|---|---|---|---|
| Lab | Yield | Value @$3/bu | Fert.[1/] cost | Diff.[2/] | Yield | Value @$3/bu | Fert.[1/] cost | Diff.[2/] |
| | bu/A | ----------$/A---------- | | | bu/A | ----------$/A---------- | | |
| A | 98 | 294 | 71 | 223 | 136 | 408 | 83 | 325 |
| B | 100 | 300 | 69 | 231 | 128 | 384 | 99 | 285 |
| C | 106 | 318 | 56 | 262 | 136 | 408 | 77 | 331 |
| D | 102 | 306 | 71 | 235 | 129 | 387 | 87 | 300 |
| E(UM) | 107 | 321 | 40 | 281 | 133 | 399 | 53 | 346 |
| Check | 96 | 288 | 0 | 288 | 115 | 345 | 0 | 345 |

[1/] Using May 1, 1980 prices for each nutrient expressed as dollars/lb as follows: N, .15; $P_2O_5$, .25; $K_2O$, .12; S, .21; Mn, .71; Zn, .89; Cu, 2.40; B, 1.52.

[2/] Yield value @$3/bu - fertilizer cost = difference.

Conclusions from the 1980 study can be summarized as follows:

1. Fertilizing to meet very high yield goals under limited moisture conditions is not practical.

2. Application of high rates of P and K to soils already testing very high is not practical.

3. No benefit or response was obtained with the addition of S or the micronutrients even though they were recommended by some laboratories.

# NITRATE NITROGEN IN THE SOIL PROFILE AND THE RESPONSE OF CORN TO NITROGEN FERTILIZATION IN SOUTHEASTERN MINNESOTA - 1980

W. E. Jokela, M. O'Leary, and J. Lensing

Studies conducted from 1977 to 1979 showed a relationship between the amount of nitrate nitrogen in the soil profile and the corn yield increase from the application of a standard rate of nitrogen fertilizer.

In 1980 the experiment was changed to include variable nitrogen rates. The objectives of the 1980 study are: 1) to determine the influence of nitrate nitrogen in the soil profile on the yield response of corn to nitrogen fertilization, 2) to determine the optimum nitrogen rate for corn grown on southeastern Minnesota soils, and 3) to monitor nitrate nitrogen in the soil profile with different rates of nitrogen.

## Experimental Procedures

In each of seven southeastern Minnesota counties a site was selected in a field to be planted to corn, avoiding fields where alfalfa was the preceding crop or where manure had been applied in the past year. All the plot areas had been in corn the previous year except the Goodhue County one which was in soybeans. The seven farmer cooperators are list in table one along with the county location, soil type, and soil organic matter content of each plot area. The Webster and Floyd-Clyde soils in Steele and Dodge Counties are poorly drained. All the other soils are well drained silt loam soils. Soil fertility levels were generally high with the following range of test values: pH 6.1-7.5, P 30-93 lbs/A, K 167-329 lbs/A. Fertilizer other than nitrogen was applied by the farmer according to his own program.

Each site was sampled in late April to a depth of 5 feet and samples were divided into one-foot increments for nitrate testing. Three 1½ inch cores were taken from each rep. Six rates of nitrogen (0, 50, 100, 150, 200, 250 lbs/A) in four replications were broadcast as urea and incorporated with tillage. In addition a small amount of nitrogen (10 to 20 lbs/acre) was applied to all plots in the starter. Planting was done by the farmer-cooperator. Earleaf samples were taken at early silking from the 0, 50, 100, and 150, lbs/acre N treatments. Grain was harvested from 2-20 foot rows per plot at maturity and yields were determined. Five foot soil samples were taken after harvest from the 0, 100, and 200 lbs/acre N treatment plots (2 cores per plot) and analyzed for nitrate nitrogen.

## Results and Discussion

Grain yields and earleaf nitrogen content are shown in Table 2. Yields with nitrogen ranged from 135 to 160 bu/acre except in Dodge County where midsummer drought severely reduced yields. Three locations - Goodhue, Olmsted, and Steele - showed a statistically significant yield response to nitrogen at the 50 to 100 lb/acre rate. These yield responses were reflected in the earleaf nitrogen content. The Houston County site also showed a substantial yield increase with nitrogen, though it was not statistically significant. Earleaf nitrogen and visual observation also indicated a response. At the Wabasha County location severe nitrogen deficiency symptoms were observed in some of the check and low nitrogen plots, but the high variability resulted in no significant response.

Spring and fall soil profile nitrates are shown in Table 3. The 0 to 2 foot spring nitrates range from 39 to 88 lbs/acre with none extremely high or low. The four sites that showed a yield and/or earleaf N response were below 60 lbs/acre nitrate-N in the 0 to 2 foot depth, which is the range in which yield responses were observed in previous years. All responsive sites had less than 150 lbs/acre of nitrate-N in the 5 foot depth. The Winona County location was below 60 lbs/acre in the 0 to 2 foot depth and below 150 in the 0 to 5 foot depth but did not show N response.

Most sites showed little or no increase in nitrate in the soil profile from spring to fall with the addition of 100 lbs/acre nitrogen, which was equal to or greater than the optimum N rate. The 200 lb/acre nitrogen rate, which was excessive in all cases, resulted in an increase of nitrate in the soil profile in 4 of the 7 locations.


Summary

Yield and/or earleaf nitrogen content response to nitrogen occurred in four our of seven locations in 1980, with visual indications of a repsonse in a fifth one. The amount of nitrate nitrogen in the soil profile showed some general relationship to nitrogen response, but it was not consistent at all sites. There was little or no accumulation of nitrate in the soil profile at the end of the season with the application of 100 lbs/acre of nitrogen, a rate that was adequate for maximum yields in this study. A build up of nitrate did result from the application of an excessive rate (200 lbs/acre) at four locations.


Table 1

| Cooperator | County | Soil Type | Soil Organic Matter (%, 0 - 6") |
|---|---|---|---|
| A. Moenning | Dodge | Floyd-Clyde silty clay loam | 6.7 |
| V. Jokela | Goodhue | Seaton silt loam | 3.4 |
| M. Hoschiet | Houston | Mt. Carroll silt loam | 2.9 |
| R. Randall | Olmsted | Port Byron silt loam | 3.9 |
| A. Abbe | Steele | Webster clay loam | 5.9 |
| E. Graner | Wabasha | Seaton silt loam | 2.1 |
| A. Redig | Winona | Seaton silt loam | 2.4 |

Table 2 - Influence of nitrogen rate on grain yield and nitrogen content of earleaf at seven locations in southeastern Minnesota - 1980.

| N Rate* (lb/A) | Location (county) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Dodge | Goodhue | Houston | Olmsted | Steele | Wabasha | Winona |
| | Yield (bu/A) | | | | | | |
| 0 | 97.7 | 140.5 | 110.2 | 130.6 | 106.9 | 133.4 | 121.2 |
| 50 | 109.6 | 157.0 | 135.8 | 144.1 | 112.2 | 147.2 | 128.1 |
| 100 | 89.4 | 160.7 | 127.3 | 146.8 | 130.1 | 136.7 | 135.4 |
| 150 | 96.8 | 163.0 | 134.9 | 148.2 | 139.7 | 151.6 | 138.1 |
| 200 | 98.9 | 161.0 | 137.9 | 151.7 | 134.5 | 146.5 | 133.6 |
| 250 | 108.5 | 161.1 | 137.0 | 150.7 | 128.0 | 144.1 | 127.8 |
| Signif. | ns | + | ns | ** | ** | ns | ns |
| BLSD (.05) | - | 16.3 | - | 11.4 | 15.8 | - | - |
| | Earleaf N (%) | | | | | | |
| 0 | 2.60 | 1.83 | 2.49 | 2.68 | 2.16 | 2.39 | 2.64 |
| 50 | 2.62 | 2.40 | 2.84 | 2.80 | 2.30 | 2.44 | 2.50 |
| 100 | 2.64 | 2.66 | 2.93 | 2.90 | 2.40 | 2.53 | 2.62 |
| 150 | 2.72 | 2.69 | 2.78 | 3.05 | 2.66 | 2.80 | 2.73 |
| Signig. | ns | ** | + | * | * | ns | ns |
| BLSD (.05) | - | .26 | .33 | .24 | .29 | - | - |

*All plots received an additional 10 to 20 lbs/acre nitrogen as a starter.

Table 3 - Residual nitrate nitrogen in the soil profile in the spring and the influence of nitrogen rate on nitrate nitrogen in the soil profile in the fall after harvest. 7 locations in southeastern Minnesota - 1980.

----------Nitrate - Nitrogen (lb/A)----------

| Depth (ft.) | Dodge County Spring | Dodge County Fall N Rate (lb/A) 0 | 100 | 200 | Goodhue County Spring | Goodhue County Fall N Rate (lb/A) 0 | 100 | 200 | Houston County Spring | Houston County Fall N Rate (lb/A) 0 | 100 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | 33 | 29 | 43 | 58 | 28 | 16 | 34 | 40 | 17 | 20 | 22 | 21 |
| 1-2 | 48 | 12 | 36 | 56 | 14 | 8 | 22 | 42 | 22 | 18 | 10 | 12 |
| 2-3 | 33 | 11 | 34 | 56 | 12 | 8 | 8 | 13 | 22 | 14 | 8 | 14 |
| 3-4 | 29 | 21 | 26 | 44 | 13 | 8 | 8 | 9 | 15 | 10 | 9 | 16 |
| 4-5 | 29 | 30 | 25 | 41 | 16 | 8 | 10 | 13 | 11 | 10 | 14 | 14 |
| 0-2 | 81 | 41 | 79 | 114 | 42 | 24 | 56 | 82 | 39 | 38 | 32 | 33 |
| 0-5 | 172 | 103 | 164 | 255 | 83 | 48 | 82 | 117 | 87 | 72 | 63 | 77 |

| | Olmsted County Spring | Olmsted County Fall N Rate (lb/A) 0 | 100 | 200 | Steele County Spring | Steele County Fall N Rate (lb/A) 0 | 100 | 200 | Wabasha County Spring | Wabasha County Fall N Rate (lb/A) 0 | 100 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | 30 | 28 | 39 | 40 | 33 | 32 | 48 | 66 | 32 | 20 | 41 | 38 |
| 1-2 | 26 | 12 | 36 | 52 | 20 | 11 | 26 | 52 | 56 | 12 | 42 | 38 |
| 2-3 | 38 | 10 | 33 | 67 | 19 | 10 | 25 | 44 | 76 | 15 | 24 | 55 |
| 3-4 | 29 | 18 | 52 | 48 | 20 | 11 | 23 | 32 | 98 | 34 | 66 | 84 |
| 4-5 | 18 | 22 | 32 | 38 | 18 | 14 | 16 | 25 | 86 | 59 | 98 | 90 |
| 0-2 | 56 | 40 | 75 | 92 | 53 | 53 | 74 | 118 | 88 | 32 | 83 | 66 |
| 0-5 | 141 | 90 | 192 | 245 | 110 | 78 | 138 | 219 | 348 | 140 | 271 | 295 |

| | Winona County Spring | Winona County Fall N Rate (lb/A) 0 | 100 | 200 |
|---|---|---|---|---|
| 0-1 | 34 | 18 | 24 | 24 |
| 1-2 | 18 | 9 | 14 | 16 |
| 2-3 | 14 | 8 | 10 | 14 |
| 3-4 | 14 | 8 | 10 | 19 |
| 4-5 | 15 | 9 | 13 | 15 |
| 0-2 | 52 | 27 | 38 | 40 |
| 0-5 | 92 | 52 | 71 | 88 |

# Deep Sampling Of Soils For Residual Nitrates And Its Potential As A Diagnostic Technique For Corn Production In Southwestern Minnesota

G.L. Malzer, G. Holcomb, W.W. Nelson, and S. Evans

The rate of fertilizer nitrogen recommended for corn production in Minnesota are currently based upon yield goal and previous cropping history. In many respects depending on the climatic conditions, these recommendations have the potential of being either too high or too low. Research experiments were therefore, established with the following objectives: 1) To determine if the residual nitrates within the top five feet of soil or to a lesser depth could be used in predicting nitrogen fertilizer requirements for corn; 2) To evaluate fall vs spring soil sampling; 3) to ascertain the importance of nitrate accumlation and movement within the soil profile.

## Experimental Procedures

Eight locations were established in the fall of 1979 on farmer cooperator fields (Table 1) in Southwestern MN. At each location, four nitrogen treatments (with four replications) were applied as ammonium nitrate at rates of 0,40,60 and 100 #N/A. Due to the wet fall of 1979 no deep (0-5') soil samples were obtained. Soil samples were, however, collected from the control plots (zero N/A) in the spring. Samples were collected to a depth of five feet in increments of one foot, analyzed for nitrate nitrogen and soil moisture (Table 3). All cooperators were asked to follow normal management practices for the areas except for nitrogen fertilization or manure application. Treatments were evaluated by obtaining leaf samples from opposite and below the ear at silking for nitrogen analysis, grain yields and nitrogen utilization by grain (Table 2).

## General Results

Of the eight locations established for 1980, one location was lost to early harvest (location 2); three locations showed significant positive yield increases due to nitrogen application, and four locations revealed no significant yield response to applied nitrogen. Yields and nitrogen utilization appeared to be highly correlated with soil nitrate nitrogen. Yield potential as well as soil nitrate nitrogen must be considered when determining when a location will respond to additional fertilizer nitrogen.

Observations over four years - The development of a soil test for predicting nitrogen availability to corn appears to be a promising technique. The quantity of nitrate nitrogen contained within the soil profile is highly correlated with grain yield. It also appears that the availability of the nitrogen is also highly correlated with soil moisture. For these reasons the positioning of the nitrates within the soil profile have a considerable impact on the availability of nitrate nitrogen deeper in the profile. Adjustments in soil nitrates based upon soil moisture have provided much higher correlations with yeild than total soil nitrates going down through the profile. In addition to adjusted soil nitrates, an estimate of mineralizable nitrogen has assisted a great deal in making better predictions of corn grain yields. More information will be forthcomming concerning an operational model for predicting fertilizer nitrogen needs.

Table 1. Location number, cooperator and county of the experimental site.

| Location No. | Cooperator | County |
|---|---|---|
| 1 (2) | Cornelius Boerboom | Lyon |
| 2 (3) | Clarence Feste | Murry |
| 3 (13T) | Werner Fisher | Redwood |
| 4 (13S) | Werner Fisher | Redwood |
| 5 (4) | Donald Lensing | Redwood |
| 6 (6) | Carsten Madsen | Lincoln |
| 7 (9) | Lawrence Quade | Cottenwood |
| 8 (12) | Don Werner | Pipestone |

Table 2. Influence of nitrogen treatments on grain yield, leaf N at silking, grain N and grain nitrogen removal at seven locations in S.W. Minnesota.

| Nitrogen Rate | Location No. 1 | 3(T) | 4(5) | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| #/A | Yield - bu/A | | | | | | |
| 0 | 160.6 | 153.6 | 158.6 | 86.1 | 124.4 | 134.8 | 63.2 |
| 40 | 153.9 | 148.6 | 162.2 | 114.1 | 140.3 | 139.2 | 68.0 |
| 60 | 173.5 | 157.0 | 163.8 | 141.1 | 141.8 | 129.3 | 81.8 |
| 100 | 169.2 | 155.5 | 167.6 | 152.3 | 135.9 | 129.0 | 85.5 |
| Significance | + | NS | NS | * | + | NS | NS |
| BLSD (.05) | 15.2 | - | - | 39.5 | 12.6 | - | - |
| | Leaf N % | | | | | | |
| 0 | 2.30 | 2.56 | 2.41 | 1.32 | 2.66 | 1.73 | 2.32 |
| 40 | 2.43 | 2.62 | 2.40 | 1.76 | 2.65 | 2.08 | 2.47 |
| 60 | 2.48 | 2.45 | 2.35 | 1.78 | 2.64 | 2.15 | 2.51 |
| 100 | 2.50 | 2.69 | 2.43 | 2.15 | 2.80 | 2.23 | 2.52 |
| Significance | NS | NS | NS | ** | NS | * | * |
| BLSD (.05) | - | - | - | 0.38 | - | 0.33 | 0.16 |
| | Grain % N | | | | | | |
| 0 | 1.30 | 1.61 | 1.68 | 1.16 | 1.34 | 1.37 | 1.88 |
| 40 | 1.41 | 1.52 | 1.64 | 1.11 | 1.42 | 1.52 | 1.94 |
| 60 | 1.39 | 1.57 | 1.78 | 1.31 | 1.50 | 1.61 | 1.90 |
| 100 | 1.44 | 1.71 | 1.78 | 1.28 | 1.50 | 1.69 | 1.85 |
| Significance | NS | NS | + | NS | NS | NS | NS |
| BLSD (.05) | - | - | 0.12 | - | - | - | - |
| | N- Removal with Grain - #/A | | | | | | |
| 0 | 99.1 | 117.5 | 126.7 | 46.4 | 79.1 | 88.5 | 55.8 |
| 40 | 102.6 | 107.2 | 125.6 | 61.7 | 94.4 | 100.0 | 63.0 |
| 60 | 114.1 | 117.3 | 138.0 | 87.5 | 100.3 | 98.0 | 73.2 |
| 100 | 115.1 | 125.7 | 141.2 | 93.4 | 96.4 | 102.3 | 74.8 |
| Significance | + | NS | NS | * | * | NS | NS |
| BLSD(.05) | 13.1 | - | - | 31.7 | 15.8 | - | - |

Table 3. Residual nitrate nitrogen content by depth at seven experimental locations in S.W. Minnesota measured in the spring prior to planting.

| Depth -Ft- | Nitrate Nitrogen - #/A depth increments Locations 1(Soybeans) | 2(Soybeans) | 3&4(Soybeans) | 5(Corn) | 6(Soybeans) | 7(Soybeans) | 8(Flat) |
|---|---|---|---|---|---|---|---|
| 0-1 | 48 | 41 | 54 | 9 | 61 | 60 | 78 |
| 1-2 | 19 | 29 | 18 | 5 | 31 | 26 | 44 |
| 2-3 | 28 | 49 | 103 | 10 | 32 | 18 | 36 |
| 3-4 | 45 | 71 | 15 | 32 | 32 | 22 | 24 |
| 4-5 | 57 | 80 | 13 | 60 | 27 | 18 | 22 |
| Total | 197 | 270 | 203 | 116 | 183 | 144 | 204 |

(  ) = previous crop

# SULFUR AND MAGNESIUM TRIALS ON IRRIGATED CORN IN CENTRAL MINNESOTA - 1980*

W. E. Jokela and M. O'Leary

In the last few years a large acreage of cropland in central Minnesota has been put under irrigation. This has increased the yield potential of these coarse-textured soils from a marginal corn yield of 70 or 80 bu/acre to as much as 150 bu/acre.

However, in the past two years there have been numerous reports of good farm operators experiencing serious production problems on substantial parts of their irrigated continous corn acreage. Preliminary soil and plant analysis suggested that deficiencies of sulfur and possibly magnesium may be responsible.

The objective of this study is to evaluate nutrient needs that have been limiting irrigated corn production in central Minnesota, specifically, to determine the effect of different rates and sources of sulfur and/or magnesium on increasing irrigated corn yields.

## Experimental Procedures

Two farm sites were selected in Wadena and Morrison Counties where irrigated corn production problems have occurred in the past. They are representative of a large area of sand and loamy sand soils under irrigation in central Minnesota. Both fields were in corn for at least four years. A sulfur trial was conducted at the Wadena County site and a sulfur and a magnesium trial at the Morrison County location. A randomized complete block design with four replications was used in all three trials.

### Wadena County

This trial was located on a low organic matter, sand texture soil on the farm of Norm Baker. Broadcast sulfur treatments were 0, 25, and 50 lbs/acre of actual sulfur from three sources - gypsum, elemental sulfur ("Agri-Sul" - 90% S), and a mixture of gypsum and elemental sulfur. The high rates and different sources were used because of concern that under these irrigated conditions leaching of the sulfate form of sulfur might be causing deficiency conditions later in the season. Sulfur was applied in the spring and incorporated with two diskings. Nitrogen management on the whole plot area consisted of 80 lbs/acre N pre-plant as urea and 90 lbs/acre sidedressed as anhydrous ammonia on June 17. Adequate potash (150 lbs/acre $K_2O$) was also applied. Corn was planted on May 8 at a population of approximately 18,000 by the farmer-cooperator. Starter was applied at rate of 100 lbs/acre of 10-20-40. Soil test results, shown in Table 1, indicate low sulfur in the 0-6 and 6-12 inch depth.

### Morrison County

A sulfur and a magnesium trial were located on adjacent areas on a low pH, low organic matter, sand textured soil on the farm of Joe Kroll. The sulfur treatments were broadcast rates of 0, 25, and 50 lbs/acre from two sources - gypsum and elemental sulfur ("Agri-Sul, 90% S). Starter fertilizer was applied to all plots, with half of each plot receiving 200 lbs/acre of 8-10-30 and half receiving 200 lbs/acre of 8-10-30 - 6.5 S (13 lbs/acre actual sulfur). (Due to impurities the "no sulfur" starter actually contained 2.5% sulfur, enough to supply 5 lbs/acre). The magnesium trial consisted of four broadcast treatments 0, 50, and 100 lbs/acre of magnesium as magnesium chloride, and four tons/acre of dolomitic limestone (CCE 85%, 36% passing 60 mesh screen). All treatments were applied preplant and incorporated with two passes of a field cultivator.

*This project supported in part by funds from CENEX.

Both areas received adequate rates of potash and either magnesium or sulfur (150 $K_2O$, 75 Mg on S plots, 50 S on Mg plots). Nitrogen application consisted of 160 lbs/acre N an anhydrous ammonia (80 on 6/11 and 80 on 6/20) plus 16 lbs/acre in the starter.

Pioneer 3906 variety was planted by the farmer cooperator on April 29 at a population of 22,000 plants/acre. Sulfur and magnesium soil tests, shown in Table 1, were in the low range on both trials. Soil test levels for all nutrients except potassium showed very little change with depth.

Wadena and Morrison County

In all three trials earleaf samples were taken at early silking on selected treatments. Grain was harvested by hand (2-20 ft. rows/plot) at maturity and yields calculated.

## Results and Discussion

Wadena County

Plant analysis results and grain yields are shown in Table 2. Yields were low and variable and there were no significant differences due to treatment. Major causes of the low yields were low and uneven plant population and large amounts of volunteer corn.

Some yellowing was observed in late June, nine days after anhydrous ammonia had been sidedressed. This was a temporary condition that improved later, apparantly as the sidedressed N took effect. Nutrient concentration in the earleaf at silking showed adequate levels of sulfur and nitrogen and no differences between the check and the 50 lbs/acre treatment from gypsum.

Morrison County

Grain yields and earleaf nutrient concentrations are shown in Tables 3 and 4. Yields averaged over 120 bu/acre in both the sulfur and the magnesium trials but there was no significant response to any treatment. Some irregular areas showed drought stress in mid summer, apparantly due to soil differences, but yields were still maintained quite well. Earleaf nutrient concentrations were all adequate and not affected by treatment.

The magnesium plots were sampled at harvest to determine what effect the various treatments had on the magnesium level in the surface layer. Results are shown in Table 4. Variability was quite high, but the plots receiving dolomitic lime tested higher in magnesium than the other treatments. Based on an average magnesium content of dolomitic limestone of 11.5% and assuming that the material of 60 mesh or finer is available the first year (36% for this lime), 4 tons of this dolomitic limestone would provide over 300 lbs of actual magnesium. This may explain why magnesium soil test level was increased compared to the other treatment. It also gives some evidence that dolomitic limestone may give some benefit in correcting a magnesium deficiency within a year of application. The pH on the limed plots was also increased to 6.0 compared to an average of 5.5 on the unlimed plots.

## Summary

The results of the three trials in 1980 showed no yield increase from the application of sulfur or magnesium. Concentration of both nutrients in the earleaf at silking was adequate and not affected by treatment. At the Wadena County location the low and variable yields were limited by other production problems, specifically plant population and volunteer corn. At the Morrison County site yields were much better. The cooperator indicated that his entire farm averaged 125 bu/acre in 1980, about the same as those in the trial, compared to yields of 70 to 90 bu/acre in the two previous seasons. Improved weather, fewer pest problems, and possibly some management factors contributed to the increased production. Temperature and moisture conditions may have created optimum conditions for release of sulfur by mineralization during the season.

Table 1. Soil test results from sulfur and magnesium trials. Wadena and Morrison County. Spring, 1980.*

Wadena Co.

| Depth inches | Texture | pH | O.M. % | P | K | Mg | Zn | S |
|---|---|---|---|---|---|---|---|---|
| | | | | ---lbs/A---- | | | - ppm - | |
| 0 - 6 | S | 6.4 | 1.5 | 70 | 246 | 188 | .6 | 6 |
| 6 - 12 | S | 5.8 | L | 59 | 231 | 195 | - | 5 |

Morrison Co.

Sulfur Trial

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 - 6 | S | 5.6 | .8 | 94 | 190 | 64 | .7 | 5 |
| 6 - 12 | S | 5.4 | L | 94 | 91 | 58 | - | 5 |
| 12 - 24 | S | 6.2 | L | 73 | 84 | 66 | - | 5 |

Magnesium Trial

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 - 6 | S | 5.4 | 1.0 | 102 | 230 | 72 | .7 | 4 |
| 6 - 12 | S | 5.7 | L | 84 | 128 | 103 | - | 4 |

*Average of two samples.

Table 2. Grain yield and earleaf nutrient concentration of irrigated corn as affected by rate and source of sulfur. Wadena County (Baker). 1980.

| Sulfur (S) Applied* lbs/A | Earleaf Nutrient Concentration % S | % N | Yield bu/A |
|---|---|---|---|
| 0 | .21 | 3.1 | 81.4 |
| 25 E | | | 90.6 |
| 50 E | | | 77.5 |
| 25 G | | | 82.9 |
| 50 G | .24 | 3.4 | 95.4 |
| 25 M | | | 87.0 |
| 50 M | | | 75.1 |
| Significance | ns | ns | ns |
| C.V. | | | 13.4 |

*E = elemental S ("Agri-Sul"), G = gypsum, M = mixture (½ from elemental S, ½ from gysum)

Table 3. Grain yield and earleaf sulfur concentration of irrigated corn as affected by rate and source of sulfur. Morrison County (Kroll). 1980.

| Sulfur (S) Applied* lbs/A | Earleaf Sulfur Concentration % | Yield bu/A |
|---|---|---|
| Broadcast | | |
| 0 | .23 | 122.5 |
| 25 E | | 123.5 |
| 50 E | | 122.5 |
| 25 G | | 118.6 |
| 50 G | .24 | 128.0 |
| Significance | ns | ns |
| Starter | | |
| No sulfur | .24 | 123.0 |
| With sulfur | .23 | 123.0 |
| Significance | | ns |
| C.V. | | 7.0 |

*E = elemental S ("Agri-Sul"), G = gypsum

Table 4. Grain yield, earleaf nutrient concentration, and magnesium soil test as affected by rate and source of magnesium. Morrison County (Knoll). 1980.

| Magnesium (Mg) Treatment | Earleaf Nutrient Concentration | | | | | | | Yield bu/A | Mg Soil Test 10/80 lbs/A |
|---|---|---|---|---|---|---|---|---|---|
| | ---------%---------- | | | | ------ppm----- | | | | |
| | P | K | Ca | Mg | Zn | Cu | B | | |
| 0 | .29 | 2.02 | .48 | .23 | 30 | 8 | 8 | 128.4 | 86 |
| 50 lbs/A* | .28 | 1.99 | .47 | .22 | 33 | 9 | 7 | 122.8 | 72 |
| 100 lbs/A* | .29 | 1.95 | .49 | .25 | 33 | 7 | 7 | 125.6 | 90 |
| Dolomitic Lime** (4 tons/A) | .28 | 1.99 | .50 | .26 | 27 | 8 | 9 | 133.5 | 124 |
| Significance | ns | ns | ns | ns | ns | ns | ns | ns | * |
| BLSD (.05) | - | - | - | - | - | - | - | - | 35 |
| C.V. | 4.8 | 6.7 | 14.3 | 22.2 | 14.0 | 26.0 | 20.8 | 6.0 | 22.1 |

*Applied as MgCl.
**Lime analysis: CCE = 85%, 36% passing 60 mesh screen.

# TILLAGE STUDY SUMMARY
## 1979-1980 Lancaster, Wisconsin

W. Paulson, Supt., A.E. Peterson, J.B. Swan, R. Higgs

Location: Northwest corner of Lancaster Experimental Farm on north side of County Rd.
Soil: Rosetta silt loam, 9 percent north slope
Moderately eroded
Experimental Design: RCB, 3 reps
Previous crop: Corn
Plot size: 90 ft. wide by 100 ft. long

| Year | Date Planted | Average Population: Buffalo Till | Chisel Plow | Slot Plant | Conv | Starter Fertilizer |
|---|---|---|---|---|---|---|
| 1979 | May 16 | 22940 | 20650 | 21452 | 20612 | 120 lbs/ac of 7-23-5 |
| 1980 | May 9 | 22204 | 21261 | 21402 | 21285 | |

### 1979 ADDITIONAL DATA

Weed control:
a) Atrazine 2 lbs/acre, Prowl 2 qts/acre — broadcast as preemergence
b) Banvel ¼ pt/acre for velvet leaf control — broadcast at 4-inch ht, postemergence
c) Atrazine 1 lb + oil 1 qt - postemergence - 1 ft. high
d) on slot plant only
2 qts Lorox directed spray at 2½ ft. corn height

Residue Prior to Tillage: Cornstalks from 1978 + 20 T/acre manure
entire area received light disking on April 20.

N: Anhydrous ammonia (injected) 100 lbs/ acre N applied preplant

Hybrid: Pioneer 3780 (100 day R.M.) Harvest 10/29/79.

### 1980 ADDITIONAL DATA

Weed control:
a) Aatrex Nine-O 2 lbs/ acre
Lasso 2 qts/acre

Residue Prior to Tillage: Cornstalks

Conv. plots plowed and disked on 5/2/80
Chisel plowed plots on 5/8/80

N: Urea - Dry 5/2/80 @ 200 lbs/acre

Hybrid: Pioneer 3747.

Tillage Trials, Lancaster, Experiment Station,
Lancaster, Wisconsin.
J.B. Swan, A.E. Peterson, W.H. Paulson, R. Higgs

1979 CORN YIELDS Bu/Ac.

| Tillage | Rep | | | | |
|---|---|---|---|---|---|
| TMT | I | II | III | Σ | Avg. |
| Buffalo-till | 145.2 | 166.9 | 174.7 | 468.8 | 162.3 |
| Chisel plow | 161.2 | 165.8 | 154.0 | 481.0 | 160.3 |
| Slot plant (Disked) | 154.4 | 160.3 | 174.3 | 489.0 | 163.0 |
| Conventional (Plow Disk) | 163.4 | 165.2 | 177.4 | 506.0 | 168.7 |
| Rep Σ | 624.2 | 658.2 | 680.4 | 1962.8 | |
| Rep Avg. | 156.0 | 164.6 | 170.1 | 163.5 | |

ANOVA - RCB

| Source | DF | SS | MS | F | |
|---|---|---|---|---|---|
| Block (B-1) | 2 | 400.6067 | 200.3033 | 2.60 | NS F.10=3.46 |
| TMT (t-1) | 3 | 115.427 | 38.476 | 0.50 | NS F.10=3.29 |
| Error (B-1) (t-1) | 6 | 462.433 | 77.072 | | |
| Total | 11 | 978.4667 | | | |

Tillage Trials, Lancaster Experiment Station, Lancaster, Wisconsin

1980 CORN YIELD Bu/Ac.

| Tillage TMT | Rep I | Rep II | Rep III | TMT Total | Avg. Bu/Ac |
|---|---|---|---|---|---|
| Buffalo till | 157.8 | 166.9 | 145.1 | 469.8 | 156.6 |
| Chisel plow | 156.8 | 142.4 | 151.6 | 450.8 | 150.3 |
| Slot plant | 149.7 | 145.8 | 142.1 | 437.6 | 145.9 |
| Conventional (Plow-Disk) | 163.6 | 164.2 | 145.9 | 473.7 | 157.9 |
| Rep Total | 627.9 | 619.3 | 584.7 | 1831.9 | |
| Rep Avg. | 157.0 | 154.8 | 146.2 | 152.7 | |

ANOVA - RCB

| Source | DF | SS | MS | F | |
|---|---|---|---|---|---|
| Block | 2 | 261.45 | 130.7233 | 2.37 | NS F.10=3.46 |
| TMT | 3 | 284.58 | 94.86 | 1.72 | MS F.10=3.29 |
| Error | 6 | 329.7467 | 54.96 | | |
| Total | 11 | 875.7692 | | | |

CF=279,654.8008

1979-1980 Totals Bu/Ac

| Tillage | 1 | 2 | 3 | Σ | Avg. Bu/ac |
|---|---|---|---|---|---|
| Buffalo till | 303.0 | 333.8 | 319.8 | 956.6 | 159.4 |
| Chisel Plow | 318.0 | 308.2 | 305.6 | 931.8 | 156.3 |
| Slot plant | 304.1 | 306.1 | 316.4 | 926.6 | 154.4 |
| Conventional | 327.0 | 329.4 | 323.3 | 979.7 | 163.3 |
| Rep Σ | 1252.1 | 1277.5 | 1265.1 | 3794.7 | |
| Rep Avg. | 156.5 | 159.7 | 158.1 | 158.1 | |

ANOVA For Yrs 1979 & 1980
(From Torrie Steel p. 248)

| | Source | df | SS | MS | F |
|---|---|---|---|---|---|
| | Blocks (R) | 2 | 40.33 | 20.17 | 0.41 |
| I | Tillage (T) | 3 | 299.5713 | 99.857 | 2.04 N.S. |
| | Error | 6 | 293.25 | 48.875 | |
| | Subtotal I | 11 | 633.1512 | | |
| | Years (C) | 1 | 713.9504 | 713.95 | 8.59* |
| II | | | | | F.05=5.99 |
| | RC | 2 | 621.72 | 310.86 | 3.74 Sig at 10%<br>F.10=3.46<br>F.05=5.14 |
| | TC | 3 | 100.43 | 33.48 | 0.40 |
| | Error b | 6 | 498.94 | 83.16 | |

Conclusions: No significant interaction between tillage TMT and years (TC). Interaction of Reps and years (RC) was significant at 10% level

# THE EFFECT OF THREE NITROGEN PRODUCTS ON SOIL pH IN THE GREENHOUSE

Curtis J. Overdahl, Todd King, Micheal O'Leary

A sulfur containing nitrogenous waste product from 3M was compared to urea and ammonium sulfate. Corn was grown in the greenhouse with a loamy sand soil from the Becker irrigation farm. Two separate trials were conducted during January and through March 1980.

The project was funded by the 3M Company to determine beneficial or possible undersirable effects of the waste product.

A complete report has been made to the 3M Company a copy of which is available in the soils Extension Office. This is an abridged report that only presents the effect of the nitrogen materials on plant content of various elements and the effect on soil pH and soil sulfur. Major emphasis is placed on the effect of lime and nitrogen on the availability of phosphorus under extremes of too high and too low a soil pH of the two different trials. Both trials were replicated six times, watered daily and carefully randomized on the greenhouse bench.

## Trial 1

The original soil test for trial one was as follows: pH = 5.0, P = 21, K = 70, S = 5. Fifty pounds per acre of $P_2O$, and 365 pounds of $K_2O$ were mixed in for all pots. Calcium oxide at 3300 pounds per acre was also added to the soil for all pots.

After the first trial growing corn was completed the P test was 61 and K test 161. The pH and sulfur tests varied with the nitrogen treatments as follows:

| Product | N | | S |
|---|---|---|---|
| | ppm | pH | ppm |
| none | 0 | 7.8 | 5 |
| 3M | 30 | 7.7 | 18 |
| | 60 | 7.5 | 33 |
| | 90 | 7.3 | 40+ |
| | 180 | 7.0 | 40+ |
| A.S. | 30 | 7.6 | 21 |
| | 60 | 7.5 | 34 |
| | 90 | 7.4 | 40+ |
| | 180 | 7.1 | 40+ |
| urea | 30 | 7.9 | 4 |
| | 60 | 7.8 | 5 |
| | 90 | 7.7 | 4 |
| | 180 | 7.8 | 4 |

The 3M product was basically a liquid ammonium-sulfate at 7.1% N. The pH values decrease from the increasing rate of nitrogen for the 3M and A.S. products but for the brief time of the greenhouse trial (3 weeks) the urea had no effect on pH. Since urea contained no sulfur it had no effect on soil sulfur, but the sulfur containing nitrogen product sharply increased soil sulfur content.

The second greenhouse trial was conducted the same as the first, except no lime was added to the soil. In the first trial the corn turned a purple color and it was believed that the lime raised the pH too high.

Approximately the same soil was used as in the first trial except surprisingly the starting

pH was 5.1. After the completion of the second trial the P test was 34 and the K test 244, the pH and S test varied with nitrogen treatment as follows:

| Product | N ppm | pH | S ppm | soluble salts m-mhos |
|---|---|---|---|---|
| none | 0 | 5.1 | 3 | 1.6 |
| 3M | 30 | 5.0 | 15 | 1.2 |
| | 60 | 4.8 | 33 | 1.6 |
| | 90 | 4.7 | 40+ | 1.5 |
| | 180 | 4.6 | 40+ | 2.6 |
| A.S. | 30 | 4.9 | 18 | 0.9 |
| | 60 | 4.7 | 35 | 1.1 |
| | 90 | 4.6 | 40+ | 1.8 |
| | 180 | 4.5 | 40+ | 2.7 |
| urea | 30 | 5.0 | 5 | 1.1 |
| | 60 | 5.1 | 3 | 1.2 |
| | 90 | 5.1 | 3 | 1.0 |
| | 180 | 5.5 | 4 | 1.0 |

It can be seen that the pH again decreased with increasing nitrogen levels but at a considerably lower level than in the first trial where lime had been added. There is again a great increase in soil sulfur from the two sulfur containing products and apparently a moderate rise in soluble salts, except for urea.

Plant analysis.

| Product | N ppm | 1st trial % N | P | K | S | 2nd trial % N | P | K | S |
|---|---|---|---|---|---|---|---|---|---|
| 3M | 180 | 2.14 | .19 | 3.57 | .37 | 1.96 | .10 | 4.65 | .29 |
| A.S. | 180 | 1.95 | .19 | 3.24 | .20 | 1.77 | .11 | 4.45 | .21 |
| urea | 180 | 1.70 | .21 | 3.75 | .16 | 2.13 | .11 | 4.18 | .13 |
| adequate | | 2.70 | .40 | 3.00 | .20 | 2.70 | .40 | 3.00 | .20 |

When the second trial was harvested the corn again was turning purple. Plant analysis would indicate that low phosphorus was the problem. The very high pH had P averaging at .20% while at the low pH the P averaged about .10%.

A third trial will be conducted with the same soil source. The pH will be held at close to neutral as possible.

It was difficult to draw final conclusions as to comparitive values of the three nitrogen products, although there appeared to no harmful effects from the waste product. Growth results were the same for all three products.

# THE EFFECT OF THREE NITROGEN PRODUCTS ON LAWN GRASS GROWTH AND NUTRIENT CONTENT

Curtis J. Overdahl, Todd King, Michael O'Leary

A sulfur containing nitrogenous waste product from 3M was compared to urea and ammonium sulfate on a grass lawn at the Becker irrigation farm. The project was funded by the 3M Company to further study beneficial or possible undesirable effects of the waste product following two corn trials in the greenhouse using Becker soil. It is anticipated that the 3M product might find greater use as a lawn fertilizer rather than for farm fields.

Lawn grass dry weights were determined June 6, June 19, July 24, and August 20. The nitrogen was applied May 20.

A complete report has been made to the 3M Company and a copy is available in the Soils Extension Office. Only specific points will be presented here.

Dry weight yields according to cuttings were as follows:

| Product | N lbs/acre | cuttings 1 | 2 | 3 | 4* |
|---|---|---|---|---|---|
| | | lbs/acre | | | |
| none | 0 | 266 | 147 | 306 | 729 |
| 3M | 120 | 541 | 435 | 515 | 743 |
| A.S. | 120 | 608 | 503 | 692 | 836 |
| urea | 120 | 526 | 313 | 711 | 737 |

*the higher yield apparently due to larger interval in time since last clipping

Only the high nitrogen rate is shown for each product. The nitrogen had dissipated by August since it had no effect on the 4th cutting.

The growth appearances were the same for the three products.

Plant analysis.

The comparison of nitrogen and sulfur contents, at the highest nitrogen rate and with none, for four different cuttings.

| Product | N lbs/A | cuttings 1 | 2 | 3 | 4 | cuttings 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|
| | | % N | | | | % S | | | |
| none | 0 | 2.2 | 2.1 | 2.4 | 1.8 | .24 | .21 | .31 | .22 |
| 3M | 120 | 4.1 | 3.6 | 3.0 | 2.0 | .37 | .30 | .33 | .21 |
| A.S. | 120 | 4.0 | 3.8 | 3.2 | 2.1 | .35 | .27 | .33 | .21 |
| urea | 120 | 4.0 | 3.2 | 2.8 | 2.0 | .30 | .20 | .34 | .22 |

The nitrogen and sulfur contents for the 120 pound rate are about the same as the untreated plots at the time of the fourth cutting.

Plots were replicated four times and complete statistical analysis was run. There were no apparent differences from the three products in growth or in plant analysis, except lower sulfur from urea.

# FERTILIZATION OF GRASSES GROWN FOR SEED PRODUCTION

A PROGRESS REPORT
December 19, 1980

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Research with cool season grasses during 1980 included: 1) a nitrogen source comparison study on mineral soils, 2) a nitrogen rate study on peat, and 3) a copper study on peat. Six trials with Kentucky bluegrass and timothy were conducted on growers' fields in Roseau and Lake of the Woods counties. Effects of fertilization were determined by measuring the yield and by chemical analysis of grass tissue.

## A. WEATHER CONDITIONS DURING THE 1979/80 GROWING SEASON

Extreme drought that hit much of northwestern Minnesota had a most damaging effect on the production of grass seed. The seedset of Kentucky bluegrass was so poor that most growers did not even harvest their fields. Timothy also was hit hard and only a few fields yielded more than 100 pounds of seed per acre.

Generally, during the period from August 1979 to July 1980, only 12 inches of total precipitation, or 9 inches below normal, was recorded at Roseau (Table 1). Actually there was a precipitation deficit of nearly 11 inches because, as indicated by previous records, top seed yields are produced during those growing seasons when the weather in the area is on the cool side and the precipitation is about 2 inches above normal. The growing season was characterized by dry weather conditions in the fall, below normal snowfall during winter and extremely low rainfall during April, May and June. According to Earl Kuehnast, State Climatologist (personal communications), the precipitation of 2.4 inches, recorded during April, May, June was the second lowest in the 78 year long history of weather recording at Roseau.

Table 1. Precipitation and temperature data for the 1979/80 growing season as measured at Roseau Weather Station (KRWB Radio)*.

| Period | Precipitation (inches) Total | Departure from Normal | Air Temperature (°F) Average | Departure from Normal | GDD $T_b$=40°F |
|---|---|---|---|---|---|
| 1979 Aug. | 1.59 | -1.63 | 57.9 | -7.0 | 555 |
| Sept. | 0.45 | -2.16 | 54.2M‡ | -0.4 | 426 |
| Oct. | 1.40 | 0.18 | 35.5 | -9.0 | 28 |
| 1979 Nov. to 1980 Apr. | 3.24 | -1.75 | 16.6 | -0.2 | 111 |
| 1980 May | 0.24 | -2.21 | 58.0 | 6.1 | 558 |
| June | 1.75 | -1.49 | 61.5 | -0.8 | 645 |
| July | 3.35 | 0.16 | 68.0 | -0.1 | 868 |
| Total | 12.02 | -8.97 | | | 3191 |
| Average | | | 36.2 | -1.0 | |
| Normal (1941-1970) | 20.99 | | 37.2 | | |

*Calculated from Climatological Data, Minnesota, Vol. 85 and 86, 1979 and 1980, U.S. Dept. of Commerce.

‡ M = less than 10 days record missing

Note: Data for the period from November to March represent averages for the Northwest Division.

Table 2. Amount of nitrate-N in the soil collected from 0-3, 3-6, and 6-24 inch depths.+

| Location | Soil Texture | Sampling depth, inches 0-3 | 3-6 | 6-24 | Total Nitrate-N in 0-24" |
|---|---|---|---|---|---|
| | | --- Nitrate-N, pp2m--- | | | lb/A |
| Helmstetter Bros. Park K. bluegrass | SL | 1.8 | 1.8 | 10.1 | 13.7 |
| Kveen Heidemij timothy | CL | 2.0 | 1.9 | 9.8 | 13.7 |
| Erickson Climax timothy | SIL | 2.1 | 5.1 | 12.0 | 19.2 |
| Kveen Park K. bluegrass | P | 2.9 | 1.0 | 3.8 | 7.7 |

+ samples collected on October 8-10, 1979.

## B. NITROGEN SOURCE COMPARISON

Three field experiments were conducted with Heidemij and Climax timothy, and Park Kentucky bluegrass to evaluate the effectiveness of anhydrous ammonia, urea and ammonium nitrate as sources of nitrogen. The soils contained 14 to 19 lbs/acre of nitrate in the top two feet (Table 2). This amount of nitrate is relatively low when compared to the levels commonly found after some cultivated crops or fallow. The main root zone of grasses (0-3 inches) contained less than 3 pp2m nitrate-N. The soils were calcareous with pH values near 8 (Table 3).

The objectives of this investigation were: 1) to determine effectiveness of the nitrogen source, 2) to determine sod injury from anhydrous ammonia injection.

All dry fertilizer materials were applied on October 8-10, 1979. Urea (46-0-0) and ammonium nitrate (34-0-0) were applied to 10 x 40 ft. plot areas with a 5-foot Gandy spreader. A 0+40+40 fertilizer treatment was made across all plots. Anhydrous ammonia (82-0-0) was applied with commercial applicators with the knives set 15-inches apart to 24 x 40 ft. plot areas. Anhydrous ammonia was applied to the Park Kentucky bluegrass trial during the first half of October, while the application to both timothy fields was delayed until May 2, 1980. All nitrogen treatments were replicated six times.

Heidemij Timothy produced a relatively low yield (Table 4). The application of 90 lbs/acre of nitrogen increased the N concentration of grass tissue and the yield of seed. Although ammonium nitrate treatments tended to have the highest yield and N content, statistically, all sources were equally effective.

Climax Timothy produced less than 100 pounds of seed per acre (Table 5). While fertilization with nitrogen increased the N% in tissue, it had no effect on the yield.

Park Kentucky Bluegrass on the Helmstetter Bros. farm was not harvested because of extremely poor growth and seedset. It was estimated that most plots would yield only 20 to 40 lbs/acre of seed. Nitrogen concentration of grass tissue collected from N treatments was relatively high. Tissue from the urea plots had the lowest N levels among the nitrogen fertilizers.

Table 3. Soil test results of samples collected from 0-3, 3-6 and 6-24 inch depths.+

| Location | Sampling Depth (inches) | Texture | pH | Extractable P pp2m | Exchangeable K pp2m | DTPA Extractable Cu ppm |
|---|---|---|---|---|---|---|
| Helmstetter Bros. | 0-3 | SL | 7.6 | 45 | 132 | |
| Park K. bluegrass | 3-6 | SL | 7.9 | 11 | 58 | |
| | 6-24 | SL | 8.0 | 9# | 49 | |
| Kveen | 0-3 | CL | 8.0 | 21 | 200 | |
| Heidemij timothy | 3-6 | L | 8.3 | 7# | 152 | |
| | 6-24 | CL | 8.3 | 3# | 154 | |
| Erickson | 0-3 | SIL | 8.0 | 23# | 211 | |
| Climax timothy | 3-6 | SIL | 8.1 | 17# | 168 | |
| | 6-24 | SIL | 8.2 | 7# | 61 | |
| Kveen | 0-3 | P | 7.3 | 43 | 190 | |
| Park K. bluegrass | 3-6 | P | 7.4 | 9 | 44 | |
| (N-Rate trial) | 6-24 | P | 6.9 | 9 | 43 | |
| Kveen | 0-3 | P | 7.7 | 55 | 236 | 1.3 |
| Park K. bluegrass | 3-6 | P | 7.5 | 10# | 27 | 0.7 |
| (copper trial) | | | | | | |
| Kveen | 0-3 | P | 6.4 | 51 | 488 | 1.3 |
| Newport K. | 3-6 | P | 6.4 | 50 | 181 | 1.3 |
| bluegrass | | | | | | |
| (copper trial-check plots) | | | | | | |

+ samples collected on October 8-10, 1979.

# 1:50 soil/solution ratio.

Table 4. Effect of nitrogen treatments on seed yield and N concentration in tissue of Heidemij timothy, Gus Kveen farm, Roseau County, 1980.

| Treatment | Seed Yield lb/acre | N Percent in Dry Matter |
|---|---|---|
| Check | 60 | 2.15 |
| Ammonium Nitrate + Knife | 154 | 3.29 |
| Ammonium Nitrate | 198 | 3.33 |
| Anhydrous Ammonia | 154 | 3.11 |
| Urea | 161 | 3.03 |
| Significance | ** | ** |
| BLSD (0.05) | 64 | 0.36 |
| C.V., % | 36 | 11 |

Nitrogen materials were applied at a rate of 90 lb. N/acre, dry materials were applied on October 9, 1979, anhydrous ammonia was applied on May 2, 1980; all plots received 0+40+40 lb/acre of $P_2O_5$ and $K_2O$.

Table 5. Effect of nitrogen treatments on seed yield and N concentration in tissue of Climax timothy, Douglas Erickson farm, Roseau County, 1980.

| Treatment | Seed Yield lb/acre | N Percent in Dry Matter |
|---|---|---|
| Check | 88 | 2.28 |
| Ammonium Nitrate + Knife | 99 | 3.20 |
| Ammonium Nitrate | 71 | 3.25 |
| Anhydrous Ammonia | 91 | 2.91 |
| Urea | 87 | 3.00 |
| Significance | ns | ** |
| BLSD (0.05) | -- | 0.33 |
| C.V. % | 38 | 8 |

Nitrogen materials were applied at a rate of 90 lb. N/acre, dry materials were applied on October 9, 1979, anhydrous ammonia was applied on May 2, 1980; all plots received 0+40+40 lb/acre of $P_2O_5$ and $K_2O$.

Table 6. Effect of nitrogen treatments on N concentration in tissue of Park Kentucky bluegrass, Helmstetter Bros. farm, Lake of the Woods County, 1980.

| Treatment | N Percent in Dry Matter |
|---|---|
| Check | 1.38 |
| Ammonium Nitrate + Knife | 2.82 |
| Ammonium Nitrate | 2.83 |
| Anhydrous Ammonia | 2.68 |
| Urea | 2.05 |
| Significance | ** |
| BLSD (0.05) | 0.22 |
| C.V. % | 9 |

Nitrogen materials were applied at a rate of 120 lb. N/acre on October 9, 1979; all plots received 0+40+40 lb/acre of $P_2O_5$ and $K_2O$.

C. NITROGEN RATE STUDY ON PEAT

A field experiment with Park Kentucky bluegrass on peat was established in the fall of 1975 to investigate the effectiveness of different N rates. Nitrogen rates included 0, 20, 40, 60 and 80 lb/acre, and the treatments were replicated four times. All plots received uniform 0+40+40 lb/acre phosphate and potash treatment. Fertilizer materials were applied with a Gandy spreader on October 10.

The seedset was extremely poor and no yield measurements were taken. The grass tissue, at heading time, contained a relatively high concentration of N. Nitrogen content of tissue was increased significantly by the application of 40 or more pounds of N per acre (Table 7).

Table 7. Effect of fertilization on N concentration in tissue of Park Kentucky bluegrass on peat, Gus Kveen farm, Roseau County, 1980.

| Nitrogen Rate lb/acre | N Percent in Dry Matter |
|---|---|
| 0 | 2.49 |
| 20 | 2.65 |
| 40 | 2.75 |
| 60 | 2.90 |
| 80 | 2.93 |
| Significance | ** |
| BLSD (0.05) | 0.24 |
| C.V. % | 6 |

Ammonium nitrate (34-0-0) was applied on October 10, 1979; all plots received 0+40+40 lb/acre of $P_2O_5$ and $K_2O$.

## D. COPPER STUDY ON PEAT

A field experiment with Newport Kentucky bluegrass on peat was established in the fall of 1978. The soil contained 1.3 ppm DTPA extractable copper in the top 3 inches (Table 3), indicating a relatively low availability of this micronutrient. Copper treatments included two sources (copper sulfate and copper chelate), single application made in the fall of 1978 (residual) and an annual application (made either in fall or spring). The treatments were arranged in a split-plot design with the time of application as main plots, and the subplots consisting of residual and annual treatments. All treatments were replicated four times. Copper sulfate and copper chelate were dissolved in water and sprayed on 10 x 20 ft. plot areas. Because of extremely heavy regrowth of the grass in the fall of 1979, the application of copper materials was delayed until May 13, 1980 after the field had been burned.

Although there was considerable amount of vegetative growth, the Newport Kentucky bluegrass on peat did not develop any panicles and produced no seed. While the residual treatments, made during the fall of 1978, tended to have higher Cu concentrations of grass tissue than the control, the copper content was increased significantly only by the annual applications (Table 8).

Another copper trial with Park Kentucky bluegrass was established in the spring of 1980. Because of drought, growth was poor and the grass was not harvested for seed. Copper spray treatments on May 13 resulted in exceptionally high Cu concentrations in the tissue: 161 ppm from Cu-sulfate, 30 ppm from Cu-chelate, compared to 2 ppm Cu from control plots. Since the area had received very little rain and the vegetative growth was very poor, it is likely that most of the copper from spring application was still on the plant at sampling time.

Table 8. Copper concentration of Newport Kentucky bluegrass tissue as affected by fertilization with Cu, Gus Kveen farm, Roseau County, 1980.

| Copper Treatment | Copper, ppm in Dry Matter |
|---|---|
| None | 1.52 |
| 50 lb/acre Copper Sulfate - Residual[1)] | 5.32 |
| " " " - Annual[2)] | 30.13 |
| 6 lb/acre Copper Chelate - Residual[1)] | 3.51 |
| " " " - Annual[2)] | 8.35 |
| Significance | ** |
| BLSD (0.05) | 7.50 |
| C.V. % | 53 |

1) Residual treatments were made once either in fall 1978 or spring 1979.

2) Annual treatments were made either in fall 1978 or spring 1979, and on May 13, 1980.

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# PASTURE FERTILIZATION TRIALS

Washington Co., 1978, 1979, & 1980

Morris Station, 1979, & 1980

C. J. Overdahl, Jerome Lensing and Micheal O'Leary

A pasture trial was initiated at the Kelly farms in Washington County, managed by Morris Grogan. The objective of one trial was to document magnesium levels which might be related to grass tetany in cattle. Magnesium content and relationship to potash treatments, to added dolomitic lime and to magnesium sulfate applications were studied. A nitrogen trial was also conducted at this site and was adjacent to the magnesium plot. This plot had varying nitrogen treatments to 120 pounds and is a continuation of the nitrogen trials in Goodhue County. Plots were fenced to prevent grazing.

A bromegrass plot was established at the Morris Station in 1979 in cooperation with Dr. Sam Evans to observe urea benefits topdressed on a high pH soil. Urea and ammonium were applied to split plots. This was continued in 1980.

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Table 1 The effect of potash, magnesium (Epson salts), and dolomotic limestone on dry matter yield of grass pasture. Kelly Farms 1980.

| | dry matter yields | | | |
|---|---|---|---|---|
| | Cuttings | | | |
| | 1 | 2 | 3 | total |
| Lime 4 T/A* | 4679 | 903 | 373 | 5955 |
| No lime | 4354 | 1013 | 274 | 5641 |
| Significance | ns | ns | ns | ns |
| BLSD (05) | - | - | - | - |
| *lime added spring 1978. | | | | |
| lbs $K_2O$/A | | | | |
| 0 | 4468 | 1083 | 290 | 5841 |
| 160 | 4670 | 810 | 308 | 5788 |
| 320 | 4542 | 1028 | 352 | 5921 |
| 640 | 4364 | 854 | 375 | 5594 |
| 1000 | 4507 | 1068 | 334 | 5909 |
| 1000 + 100# Mg/A | 4546 | 904 | 286 | 5736 |
| Significance | ns | ns | ns | ns |
| BLSD (.05) | - | - | - | - |

*potash added spring 1978 and 1980.

4 Emission spectrograph analysis 1st cutting, Kelly farms, Washington Co. 1980.

| Trt. | % | | | | ppm | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | K | Ca | Mg | Al | Fe | Mn | Zn | Cu | B |
| Lime | | | | | | | | | | |
| No lime | .26 | 3.06 | .25 | .14 | 38 | 73 | 171 | 31 | 7 | 9 |
| Lime 4 T/A | .25 | 2.98 | .25 | .17 | 38 | 72 | 73 | 26 | 5 | 9 |
| Significance | ns | ns | ns | ns | ns | * | * | * | ns | ns |
| BLSD (.05) | - | - | - | - | - | .6 | 24 | 2 | - | - |
| Lbs. $K_2O$/A* | | | | | | | | | | |
| 0 | .25 | 1.92 | .33 | .21 | 42 | 73 | 97 | 29 | 7 | 11 |
| 160 | .24 | 2.59 | .27 | .16 | 39 | 69 | 104 | 27 | 5 | 9 |
| 320 | .24 | 2.97 | .27 | .16 | 41 | 76 | 131 | 28 | 6 | 8 |
| 640 | .27 | 3.65 | .23 | .13 | 37 | 73 | 126 | 30 | 7 | 8 |
| 1000 | .27 | 3.54 | .22 | .12 | 39 | 75 | 138 | 28 | 7 | 9 |
| 1000 + 100 # Mg/A | .25 | 3.43 | .18 | .15 | 31 | 67 | 137 | 28 | 6 | 9 |
| Significance | ns | ** | ** | ** | ns | ns | ** | ns | ns | ns |
| BLSD (.05) | - | .32 | .05 | .03 | - | - | 21 | - | - | - |

*Lime added 1979, potash added 1978 and 1980.

4 . Emission analysis 2nd cutting, 1980.

| Trt | % | | | | ppm | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | K | Ca | Mg | Al | Fe | Mn | Zn | Cu | B |
| No lime | .29 | 3.08 | .33 | .19 | 40 | 72 | 185 | 24 | 7 | 12 |
| Lime 4 T/A | .30 | 3.06 | .31 | .22 | 39 | 73 | 87 | 21 | 6 | 9 |
| Significance | ns | ns | ns | + | ns | ns | + | ns | ns | ns |
| BLSD (.05) | - | - | - | .02 | - | - | 89 | - | - | - |
| Lbs. $K_2O$/A | | | | | | | | | | |
| 0 | .30 | 1.77 | .44 | .28 | 44 | 75 | 117 | 25 | 6 | 18 |
| 160 | .31 | 2.80 | .36 | .22 | 42 | 73 | 113 | 23 | 6 | 9 |
| 320 | .29 | 3.08 | .36 | .22 | 39 | 72 | 132 | 23 | 6 | 9 |
| 640 | .30 | 3.58 | .27 | .16 | 37 | 71 | 132 | 22 | 7 | 9 |
| 1000 | .29 | 3.53 | .25 | .13 | 38 | 73 | 144 | 22 | 7 | 11 |
| 1000 + 100 # Mg/A | .31 | 3.65 | .24 | .20 | 36 | 71 | 179 | 23 | 7 | 9 |
| Significance | ns | ** | ** | ** | * | ns | ** | ns | ns | ns |
| BLSD (.05) | - | .50 | .05 | .05 | 4 | - | 25 | - | - | - |

4c. Emission, spectrograph analysis of pasture grass, Kelly Farms, Washington County 1980. 3rd cutting.

| Trt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No lime | .31 | 2.19 | .47 | .21 | 55 | 80 | 242 | 22 | 4 | 7 |
| Lime 4 T/A | .33 | 2.19 | .45 | .27 | 62 | 86 | 121 | 21 | 3 | 6 |
| Significance | ns | ns | ns | * | ns | ns | * | ns | ns | ns |
| BLSD (.05) | - | - | - | .04 | - | - | 43 | - | - | - |
| Lbs. $K_2O$/A | | | | | | | | | | |
| 0 | .31 | 1.61 | .62 | .32 | 65 | 88 | 142 | 23 | 3 | 7 |
| 160 | .32 | 2.08 | .51 | .26 | 54 | 76 | 152 | 22 | 3 | 7 |
| 320 | .31 | 2.34 | .55 | .27 | 56 | 77 | 180 | 23 | 3 | 7 |
| 640 | .32 | 2.35 | .36 | .18 | 66 | 88 | 195 | 19 | 3 | 5 |
| 1000 | .33 | 2.34 | .36 | .17 | 52 | 82 | 198 | 20 | 4 | 5 |
| 1000 + 100 # Mg/A | .32 | 2.43 | .36 | .24 | 57 | 87 | 223 | 22 | 4 | 5 |
| Significance | ns | ** | ** | ** | ns | ns | * | ns | ns | ns |
| BLSD (.05) | - | | | .05 | - | - | 47 | - | - | - |

Table 5. Soil test average of two samples per plot at 0 to 3 and 3 to 6 inch depths, according to lime and potash treatments. Kelly Farms, Washington County, 1980.

| | Potash Treatment Per Acre | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | 160 | | | 320 | | | 640 | | | 1000 | | | 1000 + Mg | | |
| | pH | P | K | pH | P | K | pH | P | K | pH | P | K | pH | P | K | pH | P | K |
| | 0 to 3 inches depth 1980 | | | | | | | | | | | | | | | | | |
| No lime | 5.3 | 12 | 73 | 5.2 | 12 | 114 | 5.3 | 9 | 196 | 5.4 | 18 | 502 | 5.4 | 13 | 600+ | 5.5 | 15 | 544 |
| Lime | 6.8 | 17 | 94 | 6.8 | 8 | 162 | 6.8 | 12 | 255 | 6.7 | 10 | 414 | 6.8 | 19 | 588 | 6.8 | 15 | 489 |
| | 3 to 6 inches depth 1980 | | | | | | | | | | | | | | | | | |
| No lime | 5.5 | 7 | 55 | 5.6 | 11 | 62 | 5.6 | 6 | 104 | 5.6 | 10 | 360 | 5.6 | 9 | 504 | 5.6 | 9 | 386 |
| Lime | 5.9 | 10 | 84 | 6.2 | 8 | 91 | 6.1 | 8 | 181 | 6.1 | 7 | 324 | 6.2 | 10 | 489 | 6.2 | 10 | 460 |

| Avg. pH | 1980 | |
|---|---|---|
| | 0-3" | 3-6" |
| No lime | 5.4 | 5.6 |
| 4 T/A | 6.8 | 6.1 |

Table 6. Soil tests average of 2 samples per plot at 0 to 3 and 3 to 6 inch depths, according to lime and potash treatments. Kelly farms, Washington Co., 1978 & 1979.

| | Potash treatment per acre | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | 160 | | | 320 | | | 640 | | | 1000 | | | 1000 + Mg | | |
| | pH | P | K | pH | P | K | pH | P | K | pH | P | K | pH | P | K | pH | P | K |
| **0 to 3 inch depth 1978** | | | | | | | | | | | | | | | | | | |
| No lime | 5.2 | 24 | 192 | 5.2 | 39 | 270 | 5.2 | 21 | 314 | 5.4 | 42 | 548 | 5.4 | 26 | 580 | 5.4 | 31 | 600† |
| Lime | 6.2 | 28 | 263 | 6.3 | 28 | 207 | 6.1 | 28 | 340 | 6.2 | 23 | 490 | 6.0 | 27 | 555 | 6.2 | 23 | 600 |
| **3 to 6 inch depth 1978** | | | | | | | | | | | | | | | | | | |
| No lime | 5.4 | 16 | 155 | 5.4 | 26 | 195 | 5.4 | 13 | 160 | 5.4 | 28 | 314 | 5.4 | 18 | 426 | 5.3 | 16 | 360 |
| Lime | 5.6 | 22 | 201 | 5.6 | 15 | 129 | 5.4 | 16 | 236 | 5.5 | 15 | 264 | 5.5 | 21 | 375 | 5.5 | 16 | 479 |
| Avg. P & K 0-6" | | 23 | 203 | | 27 | 200 | | 20 | 263 | | 27 | 404 | | 23 | 484 | | 22 | 510 |
| **0 to 3 inch depth 1979** | | | | | | | | | | | | | | | | | | |
| No lime | 5.2 | 11 | 65 | 5.1 | 16 | 212 | 5.2 | 9 | 135 | 5.2 | 19 | 308 | 5.2 | 16 | 371 | 5.3 | 16 | 294 |
| 4 T/A | 6.4 | 17 | 139 | 6.5 | 17 | 122 | 6.5 | 19 | 205 | 6.4 | 24 | 328 | 6.4 | 24 | 420 | 6.5 | 16 | 328 |
| **3 to 6 inch depth 1979** | | | | | | | | | | | | | | | | | | |
| No lime | 5.6 | 9 | 44 | 5.3 | 15 | 152 | 5.5 | 8 | 96 | 5.3 | 17 | 252 | 5.5 | 14 | 271 | 5.4 | 13 | 323 |
| 4 T/A | 5.6 | 15 | 110 | 5.7 | 12 | 75 | 5.7 | 15 | 137 | 5.6 | 14 | 267 | 5.6 | 19 | 308 | 5.6 | 13 | 297 |
| Avg. P & K 0-6" | | 13 | 89 | | 15 | 140 | | 13 | 143 | | 19 | 289 | | 18 | 343 | | 15 | 311 |

| Avg. pH | 1978 | | 1979 | |
|---|---|---|---|---|
| | 0-3" | 3-6" | 0-3" | 3-6" |
| No lime | 5.2 | 5.4 | 5.2 | 5.4 |
| 4 T/A | 6.2 | 5.6 | 6.4 | 5.6 |