SOIL SERIES

A REPORT ON FIELD RESEARCH IN SOIL SCIENCE

The 1977 edition of the "Bluebook" is a compilation of data collected and analyzed throughout Minnesota. Information was contributed by personnel of the Department of Soil Science including Extension Soil Specialists, Scientists at the branch stations of Crookston, Grand Rapids, Lamberton, Morris, Rosemount and Waseca; the "Sand Plain" experimental sites; and Soils and Crop area agents. Associated personnel from the Soil Conservation Service, the Soil and Water Research group of the SEA-USDA, the Tennessee Valley Authority, the Department of Natural Resources and the Departments in Agriculture also contributed information.

Some of the results are from 1976 experiments only and should be regarded on this basis. Since most data are from only 1976 studies, conclusions are not conclusive and are thus not for further publication without the written consent of the individual researchers involved.

Sincere appreciation is expressed for materials and/or financial assistance or program support from several organizations including: Potash and Phosphorus Institute of North America, CENEX, Farmland, Midland Cooperatives and Howe Incorporated, Minnesota Crop Improvement Association, National and State Soybean Associations, Minnesota Golf Course Superintendents Association, Minnesota Limestone Producers Association, U.S. Gypsum Corporation, Minnesota Plant Food and Chemicals Association, Minnesota Soil and Water Conservation Committee, The Minnesota Resources Commission, the Minnesota State Planning Agency, The Water Resources Research Center of the Graduate School, The Staples Vo-Tech Institute, The Red River Valley Potato and Sugar Beet Growers Associations, The Tennessee Valley Authority and the North Central Forest Experiment Station.

The investigators also greatly appreciate the cooperation of many county agents, farmers, technical assistants, secretaries and the representatives of the various firms and businesses who contributed time, land, machinery and materials and without whose support many of the results reported here would not have been possible.

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MINNESOTA SPRING SOIL MOISTURE SITUATION
SPRING 1978

E.L. Kuehnast (DNR) and D.G. Baker

General

Climatic conditions a year ago were the opposite of today; going into the winter of 1976-77 soil moisture was the lowest on record, based on the late summer and fall precipitation data which date from 1891. Beginning in late February 1977, however, the soil moisture situation was miraculously turned around. As a result of the heavy rains and snow melt in late February and March, all of which entered the soil, the upper part of the soil was recharged by planting time. Normal summer precipitation which occurred at very timely intervals gave much of Minnesota record crop yields.

Precipitation

Heavy late summer and fall rains across all but the southeastern part of the state made this period one of the wettest on record. In fact precipitation at a number of stations was the driest or near driest on record in 1976 but the wettest or near wettest in 1977. Some remarkable examples that can be cited include the following:

Annual Precipitation

Station	Records Began	1976		1977	
		Amount	Rank*	Amount	Rank**
Alexandria	1888	11.39 in.	2nd	35.36 in.	2nd
Grand Rapids	1915	17.98	3rd	38.00	1st
Minneapolis-St. Paul	1891	16.85	3rd	34.88	9th
Morris	1886	9.89	1st	34.07	1st
Wadena	1903	13.42	1st	33.93	4th
Waseca	1915	17.47	1st	40.98	3rd
Willmar	1898	12.53	1st	33.87	5th
Worthington	1892	16.55	5th	34.09	5th

* Ranked by driest years.

** Ranked by wettest years.

The late summer and fall precipitation of 1977 compares to the high amounts that fell in 1900, 1905, 1911, and 1971. Between August 30-September 30, 1977, there were four flash floods of 6 inches or more, a most uncommon event for this time of year.

Three exceptionally wet areas occurred due to the unusually high August-November precipitation. One is in the Ada-Fergus Falls area where precipitation was 17.18 inches at Ada and 15.74 inches at Fergus Falls; the second is in the Luverne-Worthington area with 18.56 and 15.74 inches, respectively; the third is the entire northeastern part of the state where 19 inches or more was received. The grestest amounts were measured at the Hoveland and Finland Forest Ranger Stations, 24.23 and 22.72 inches, respectively.

Soil Moisture

Throughout the state soil moisture as of February, 1978, is generally above to well above average in all but one area (see map). In the southeastern corner of the state soil moisture is slightly below average. This includes parts of Dodge, Olmsted, Wabasha, and Winona counties. (Grave diggers indicate below the 3-foot level generally dry soils.)

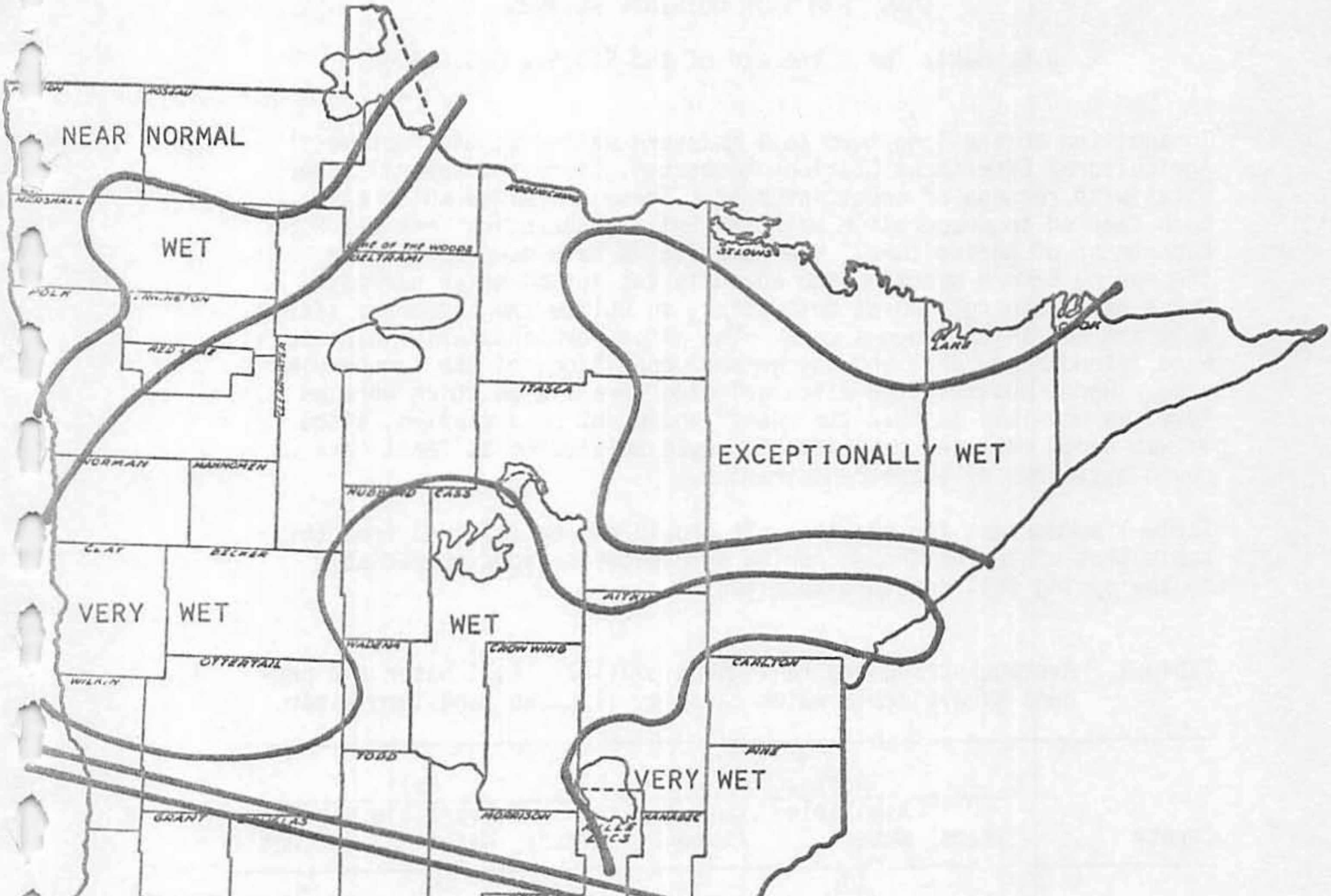
In the southern half of the state, with the exception of the southeast corner the soil moisture ranges from 1-4 inches above average.

The soils in parts of several southwestern counties - Rock, Nobles and Jackson - are the wettest and parts of Cottonwood, Watonwan, Brown, Nicollet and Sibley are also quite wet.

In the northern half of the state there are numerous areas of wet soils. Perhaps the wettest areas include the north-central and northeastern parts of the state. The soils in Becker, Clay, Mahnomen, Ottertail, Norman, Polk and Wilken are also very wet.

Delayed planting may occur this spring due to excess moisture and depressed soil temperatures. The much heavier than average snow cover in northwestern Minnesota, resulting from the two November 1977 blizzards, may further delay spring planting in that part of the state.

It should be remembered that the springs of both 1976 and 1977 were exceptionally early when warm and dry weather generally prevailed. These are not the usual spring conditions and the prudent farmer will not expect such conditions to continue.



The estimated inches of plant available water in medium to fine textured soils 5-feet deep at the beginning of spring, 1978. Southern Minnesota is shown in inches and Northern Minnesota is in general terms due to the highly variable soils, vegetation , and/or crops.

LONG TERM SOIL MOISTURE RECORDS

D.G. Baker (with the aid of the S.C.S., U.S.D.A.)

In addition to the long-term soil moisture record at the Southwest Agricultural Experiment Station, Lamberton, there are several other sites with records of great interest. These are sites which have been sampled in cooperation with the Soil Conservation Service, U.S. Department of Agriculture. The same fields have been sampled in the spring before planting and again in the autumn after harvest. Crops have been rotated at most sites, so unlike the Lamberton site they are not in continuous corn. The sites when initially selected were intended to represent the general conditions of the surrounding area. Where possible the sites selected were fields which were as level as possible so that the runoff would not be a problem, since it was hoped that the measurements could be used to at least make rough estimates of evapotranspiration.

Table 1 summarizes the results. It should not be inferred from this table that winter or frozen period precipitation adds appreciably to the spring soil moisture supplies.

Table 1. Average spring and fall plant available soil water and percent of available water capacity at seven long-term sites.

	Spring			Fall		
County	Years	Available Water	Capacity Percent	Years	Available Water	Capacity Percent
		In.	%		In.	%
Dodge	19	7.10	67	21	5.29	50
Mille Lacs	19	9.01	93	18	8.35	87
Redwood	18	6.00	61	18	4.42	45
Sibley	19	9.37	80	18	7.30	62
Todd	10	10.00	120	9	6.93	83
Wabasha	20	10.64	68	19	9.69	62
Watonwan	17	8.89	64	16	6.42	46

* Southwest Agricultural Experiment Station, U. of M.

Since the fall sampling is before the soil has frozen and the spring samples are obtained well after the soil has thawed, there is ample opportunity for the late fall and early spring rains to recharge the soil. Only in the late winter of 1977 were the soils recharged to any extent. This occurred due to a unique set of circumstances which included extremely dry soils - so dry that there was little or no ice to block the entrance of water - and a late February rainfall across the southern half of the state.

Tables 2-7 provide detailed information for each of the six sites.

The cooperation of the Soil Conservation Service, U.S. Department of Agriculture, and in particular the District Conservationist in each of the six counties is gratefully acknowledged. At the present time these six are the following:

Sample Site	District Conservationist
Dodge	Steven F. Crull
Mille Lacs	Wesley Cashman
Sibley	William J. Geary
Todd	Robert E. Krause
Wabasha	Roger W. Hoff
Watonwan	David E. Vold

Table 2. Soil moisture summary of Kasson silt loam, Dodge county, near Hayfield, sampled by S.C.S., U.S.D.A.

Field Capacity = 19.56 in 5 ft. of soil
Wilting Point = 8.97 in 5 ft. of soil
Available Water = 10.59 in 5 ft. of soil

Spring Date	Available Water	Fall Date	Available Water
5/15/58	5.30 in.	9/10/58	4.63 in.
5/1/59	4.58	9/16/59	3.72
5/23/60	12.08	10/18/60	4.64
5/4/61	7.45	9/28/61	2.60
5/21/62	4.92	9/24/62	5.04
4/17/63	6.47	11/12/63	6.45
4/20/64	8.38	10/27/64	5.44
5/6/65	7.94	11/18/65	6.13
5/23/66	7.49	11/17/66	3.64
4/28/67	5.49	11/22/67	3.19
4/30/68	4.17	12/4/68	8.18
5/12/69	8.65	--	--
5/4/70	9.60	11/25/70	8.91
5/11/71	7.47	12/6/71	7.29
6/14/72	7.87	11/30/72	9.04
5/24/73	9.43	11/2/73	8.82
1974	--	11/22/74	4.07
5/22/75	6.05	12/12/75	3.99
6/1/76	5.77	8/19/76	-0.19
5/12/77	5.72	11/14/77	4.88
Mean	7.10	Mean	5.29

Table 3. Soil moisture summary of Mora silt loam, Mille Lacs county, near Milaca, sampled by S.C.S., U.S.D.A.

Field Capacity = 14.28" in 5 ft. of soil
Wilting Point = 4.64" in 5 ft. of soil
Available Water = 9.64" in 5 ft. of soil

Spring Date	Available Water	Fall Date	Available Water
5/15/58	7.90	9/15/58	6.73
4/28/59	5.55	9/15/59	5.44
5/13/60	6.33	9/15/60	3.99
5/13/61	5.66	10/2/61	2.85
5/21/62	11.04	9/25/62	8.33
4/15/63	9.07[1]	11/6/63	6.32
4/17/64	6.25[2]	10/12/64	4.13
4/26/65	9.09	10/22/65	13.28
5/6/66	10.76	--	--
4/25/67	9.86	10/30/67	3.53
4/25/68	9.75	11/8/68	14.66
4/21/69	10.49[3]	10/23/69	4.15[2]
4/21/70	13.24	10/26/70	8.47
5/4/71	9.13	11/2/71	12.02
5/9/72	11.27	11/9/72	14.90
5/11/73	11.49	10/10/73	11.49
5/28/74	9.03	11/ /74	12.46
1975	--	1975	--
5/11/76	8.11	8/20/76	1.42
5/13/77	6.00	12/ /77	11.97
Mean	9.01	Mean	8.35

1. 5' depth is missing, not included in mean.
2. 4' and 5' depths are missing, not included.
3. 3', 4', and 5' depths are missing, not included.

Table 4. Soil moisture summary of Nicollet clay loam, Sibley county, near Winthrop, sampled by S.C.S., U.S.D.A.

Field Capacity = 22.93" in 5 ft. of soil
Wilting Point = 11.15" in 5 ft. of soil
Available Water = 11.78" in 5 ft. of soil

Spring Date	Available Water	Fall Date	Available Water
5/15/58	8.81 in.	9/11/58	5.67 in.
5/15/59	7.94	9/15/59	8.41
5/17/60	10.05	8/1/60	8.14
5/15/61	10.88	10/25/61	8.52
5/3/62	9.23	10/31/62	9.10
4/30/63	11.35	11/8/63	8.63
4/23/64	9.82	11/9/64	10.79
5/12/65	13.24	11/9/65	8.52
5/25/66	8.00	11/7/66	6.60
4/28/67	9.95	11/8/67	6.10
5/2/68	7.90	--	--
5/29/69	9.01	--	--
4/30/70	10.78	10/29/70	10.36
4/22/71	9.35	11/8/71	9.78
5/10/72	12.45	11/1/72	8.94
5/4/73	9.17	10/3/73	6.97
--	--	11/6/74	3.13
5/5/75	6.46	11/17/75	0.37
4/30/76	6.36	10/26/76	3.91
4/21/77	7.27	10/28/77	7.54
Mean	9.37	Mean	7.30

Table 5. Soil moisture summary of Blowers loamy fine sand, Todd county, near Bertha, sampled by S.C.S., U.S.D.A.

Field Capacity = 14.77" in 5 ft. of soil
Wilting Point = 6.44" in 5 ft. of soil
Available Water = 8.33" in 5 ft. of soil

Spring Date	Available Water	Fall Date	Available Water
5/29/68	7.71 in.	9/39/68	8.29 in.
5/19/69	14.54	--	--
5/8/70	7.23	10/20/70	4.03
5/10/71	13.77	10/28/71	7.56
5/10/72	13.94	10/6/72	10.12
5/8/73	11.10	10/15/73	10.59
5/2/74	10.51	10/23/74	4.13
5/1/75	9.68	10/16/75	1.77
5/12/76	4.39	8/9/76	4.74
4/27/77	7.18	10/6/77	11.16
Mean	10.00	Mean	6.93

Table 6. Soil moisture summary of Fayette silt loam, Wabasha county, near Kellogg, sampled by S.C.S., U.S.D.A.

Field Capacity = 24.26" in 5 ft. of soil
Wilting Point = 8.65" in 5 ft. of soil
Available Water = 15.61" in 5 ft. of soil

Spring Date	Available Water	Fall Date	Available Water
5/15/58	8.35	9/24/58	6.31
5/15/59	7.52	9/16/59	7.39
5/13/60	10.44	8/19/60	10.25
5/5/61	11.35	10/6/61	7.51
5/31/62	10.51	9/26/62	11.59
4/23/63	11.20	11/6/63	8.26
4/14/64	10.00	10/16/64	6.63
5/3/65	10.19	10/26/65	12.21
4/19/66	12.30	11/3/66	8.60
4/19/67	11.88	10/20/67	7.93
4/13/68	7.27	11/4/68	13.44
4/17/69	11.83	--	--
4/23/70	10.36	11/5/70	13.43
4/20/71	12.79	11/2/71	10.24
4/18/72	9.87	10/25/72	13.53
5/1/73	13.86	10/26/73	11.74
5/3/74	11.84	10/15/74	8.36
4/22/75	11.79	11/12/75	9.27
5/6/76	10.84	10/29/76	6.83
4/18/77	8.69	11/16/77	10.59
Mean	10.64	Mean	9.69

Table 7. Soil moisture summary of Nicollet clay loam, Watonwan county, near Butterfield, sampled by S.C.S., U.S.D.A.

Field Capacity = 24.67 in 5 ft. of soil
Wilting Point = 10.85 in 5 ft. of soil
Available Water = 13.82 in 5 ft. of soil

Spring Date	Available Water	Fall Date	Available Water
5/15/58	5.59 in.	9/15/58	0.54 in.
4/26/59	0.02	12/17/59	6.41
5/17/60	7.88	8/1/60	6.97
4/10/61	8.29	9/28/61	4.98
4/18/62	21.82	10/25/62	8.71
4/26/63	7.56	11/4/63	5.19
4/17/64	4.99	11/13/64	10.84
6/5/65	13.47	Fall/65	9.71
5/19/66	10.70	10/19/66	7.61
4/20/67	9.19	11/3/67	4.80
4/16/68	1.82	--	--
1969	--	--	--
1970	--	--	--
5/7/71	11.64	--	--
4/10/72	9.42	11/14/72	8.56
5/9/73	12.49	10/30/73	7.01
1974	--	10/25/74	7.09
5/5/75	10.53	10/2/75	4.39
5/3/76	7.22	10/26/76	1.14
5/2/77	8.45	10/28/77	8.75
Mean	8.89	Mean	6.42

SOIL MOISTURE AT LAMBERTON, MORRIS AND WASECA

W.W. Nelson, S.D. Evans, G.W. Randall and D.G. Baker

Soil moisture is now being monitored at the three Agricultural Experiment Stations, Southwest, West-Central and Southern, every two weeks during the growing season. As a result a detailed picture will soon be available at Morris and Waseca comparable to that at the Lamberton station where sampling first began in 1960. Fig. 1 shows the change in soil moisture at these three sites throughout the season. It is evident that there is no shortage of water. Based upon information from the long-term S.C.S. sites as well as the Lamberton record it is apparent that all stations were well above average by the end of the 1977 season. At Waseca, for example, it was noted that as early as September 24 the tiles were running. Lamberton, as of the last sample on Nov. 3, 1977, was about 1.5 inches above average.

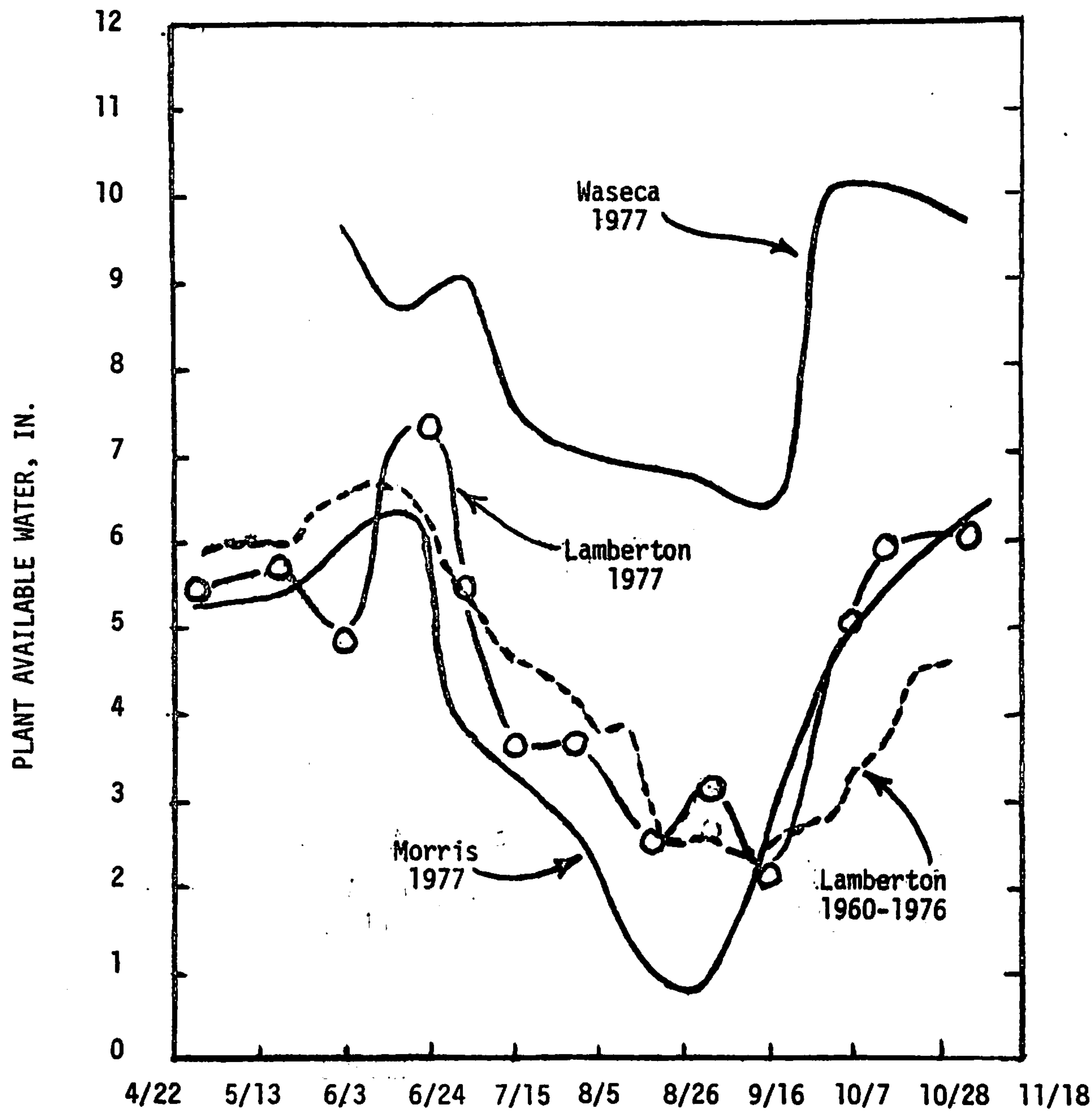


Fig. 1. The 1977 growing season soil moisture at Lamberton, Morris and Waseca.

THE FROZEN SOIL PERIOD

D.G. Baker

Soil temperatures have been monitored at the St. Paul campus microclimatology station since 1960. Under the plot that is kept bare of vegetation the duration of the frozen soil period is on the average a 134 day period. It extends from November 30 when the soil at 5 cm remains below 32°F until April 13 when the last vestige of a frozen soil at any depth disappears. It is interesting to note that the average date when the first 20 cm of the bare soil thaws is April 2. This shows that on the average there is a frozen layer that remains within the soil 11 days after the surface has thawed. The melting of this frozen layer within the soil is associated, of course, with the frequently observed springtime phenomenon of an apparent over night disappearance of water that had been standing in the fields.

A brief summary of the 17 years of overwinter soil freezing dates and depths at St. Paul under a bare plot of Waukegan silt loam is shown in Table 1.

Table 1. Summary of frozen soil data at St. Paul in a Waukegan silt loam plot bare of vegetation, Jan. 1960 - Dec. 1977.

	Date	Depth
Soil first remains continuously below 32°F	Nov. 30	5 cm*
Mean depth of 32°F	Dec. 15	39 cm
Mean depth of 32°F	Jan. 15	82 cm
Mean depth of 32°F	Feb. 15	104 cm
Maximum depth of 32°F	March 2	112 cm
Soil first remains continuously above 32°F	April 2	1-20 cm
Last occurrence of frozen soil	April 13	73 cm

* The 5 cm depth is used to define the commencement of the frozen period. Once frozen to this depth it is most unlikely that a thaw will occur until next spring. This is not true for shallower depths.

NITROGEN TREATMENT'S RELATIONSHIP TO SOIL pH AND POTATO PRODUCTION

Becker - 1977

C. J. Overdahl, W. E. Fenster and C. P. Klint[1/]

Lime in irrigation water causes a rapid rise in soil pH, especially on legumes. On potatoes, the problem may be less serious because of the acidifying effect of added nitrogen.

Plot work at the Becker Irrigation Farm was initiated in 1976 with three forms of nitrogen; ammonium nitrate, urea, and ammonium sulfate. The latter reduces pH faster than the other two. Soil pH readings will be determined annually. Two varieties, Norland and Russet Burbank, were used. The Norland variety received 200 pounds of N per acre since it is relatively early maturing and 300 pounds per acre were used on the Russets.

The calcium carbonate equivalent of the irrigation water was 42 pounds per acre inch, thus with 16.7 inches of irrigation, resulted in approximately 700 pounds per acre of very fine lime in 1976 and 483 pounds in 1977.

Nine soil tests were made in April 1976 before fertilizer application. The range of these test results were: pH 6.0 to 6.4; P 30 to 42; K 60 to 120; texture LS.

It is too early to draw conclusions of the effect of the nitrogen forms on controlling the soil pH and its possible effect on potato scab.

Table 1. The effect of three forms of nitrogen on yield of two varieties of potatoes (Becker Farm, 1976, 1977).

Treatment*	Norland Cwt/A		Russets Cwt/A	
	1976	1977	1976	1977
Check	146 a	109 a	180 a	138 a
Ammonium nitrate	319 b	300 b	398 bc	370 b
Urea	372 b	288 b	408 c	354 b
Ammonium sulfate	398 b	368 c	385 b	350 b
Trt. Sign.	**	**	**	**
BLSD (5%)	84	51	16	48
Rep.	ns	ns	ns	ns
C.V.	17.7	12.7	9.7	10.8

* Norland received 200# N/A.
  Russets received 300# N/A.

Table 2. The effect of three forms of nitrogen on soil pH of two varieties of irrigated* potatoes (Becker Farm, 1977).

Treatment**	Norland		Russets	
	Spring	Fall	Spring	Fall
		soil pH		
Check	6.3	6.4	6.3	6.4
Ammonium nitrate	6.0	6.2	6.0	5.9
Urea	6.2	6.4	6.3	6.1
Ammonium sulfate	6.1	5.8	6.1	5.9
BLSD (.01)		.2		.2

* Lime in irrigation water 1976, 700 lbs/acre; 1977, 483 lbs/acre.
** Norland received 200# N/A.
Russet Burbank received 300# N/A.

1/ Bob Schoper, Jerry Lensing and Glenn Titrud contributed greatly to organizing and the work effort on these plots.

INFLUENCE OF NITROGEN FORM, NITRIFICATION INHIBITORS, AND TREATMENT INCORPORATION ON YIELDS AND NITROGEN UTILIZATION OF CORN UNDER IRRIGATION

G.L. Malzer and J. Lensing

Several management alternatives are available for the producer concerned with nitrogen management for corn production under irrigation. Nitrogen forms methods of application, and timing of N applications are all factors which must be considered in effective nitrogen management. The use of nitrification inhibitors under irrigation also presents some new considerations in nitrogen management--can nitrification inhibitors be used in the irrigation water? Must they be incorporated into the soil to be effective? Are there differences with nitrogen forms? To investigate some of these questions a trial was established at the sand plains research farm at Becker, MN with the following objectives: 1) to compare the use of urea and 28% N solutions under irrigation, 2) to evaluate the use of N-serve and Terrazole with different nitrogen forms and 3) to determine the impact of surface applied and incorporated combinations of the previous treatments.

Experimental Procedures

Six treatments consisting of two nitrogen forms (urea and 28% nitrogen solutions), three nitrification inhibitor treatments (none, Terrazole-Olin corporation, and N-Serve-Dow Chemical) were applied to a Hubbard coarse sand in a randomized complete block design with four replications. Each main plot was split to provide an incorporated and non-incorporated comparison. Only one nitrogen rate, 120 # N/A was utilized in the treatments.

The experimental area had previously been fertilized with 340 # of 0-0-60 and incorporated by plowing. Treatments were applied on May 5, areas requiring incorporation were disced and the area planted with Minn. Hybrid 6304 (95 day Rel. Mat) in 30" rows at a seeding rate of 27,700 seeds/A. Herbicide applied as a tank mix of atrazine (1 # ai/A) and lasso (2 # 2 ai/A) provided good weed control. The irrigation schedule commenced the following day with a total of 11.95 inches of water being applied through irrigation and 21.83" through rainfall during the growing season.

Treatment effects on nitrogen utilization were evaluated by nitrogen analysis of the leaf opposite and below the ear at silking. Total nitrogen uptake was evaluated by collection of whole plant samples at physiological maturity. The samples were separated into stover and grain, separate weights obtained and samples collected for moisture and nitrogen analysis. Grain yields were obtained on October 19 by hand harvesting two 20 ft. rows and samples collected for moisture determination and nitrogen content.

General Results

Considerable differences were found in this experiment between nitrogen forms and incorporation of the treatments. In general the use of 28% urea-ammonium nitrate solutions were inferior to the use of a dry urea form of nitrogen. Incorporation of the nitrogen treatments in general significantly increased yields and nitrogen utilization.

The use of 28% nitrogen solution resulted in lower nitrogen content of the 6th leaf at silking (Table 1) along with reduced dry matter yields and lower nitrogen utilization (uptake) than the dry urea form of nitrogen (Tables 2 and 3). The use of nitrification inhibitors with the 28% solutions had relatively little influence in the solutions effectiveness suggesting that losses of nitrate nitrogen associated with the 28% solutions (25% nitrate nitrogen) early in the growing season may have resulted in the decreased effectiveness.

Incorporation of the nitrogen treatments in general resulted in higher yields and improved nitrogen utilization. This trend appeared to be especially important where nitrification inhibitors were included with the nitrogen application. With both inhibitors more positive results were obtained when the material was incorporated rather than left on the surface. This is probably related to the volatility of both chemicals investigated.

There also appears to be an interaction between nitrogen form, nitrification inhibitors, and incorporation. In many cases this was not statistically significant at the .05 level, but the trends suggest that both N-serve and Terrazole were effective with dry urea when incorporated into the soil. While Terrazole was effective with 28% solutions when incorporated and N-serve was not effective. These trends deserve closer examination in future research.

Table 1. Influence of nitrogen form, nitrification inhibitors and treatment incorporation on 6th leaf nitrogen content at silking, grain yield, and nitrogen utilization of the grain.

Treatment			6th Leaf	Corn Grain		
N Form	Inhibitor		N	Yield	N Content	N Removal
			%	bu/A	%	#/A
urea			2.57	139.8	1.26	84.4
urea	Terr.		2.52	136.3	1.13	73.1
urea	N-S		2.70	144.6	1.16	80.3
28%			2.17	124.5	1.16	68.3
28%	Terr.		2.30	125.6	1.22	74.1
28%	N-S		2.29	116.4	1.19	65.9
Signif.			*	NS	+	NS
B.L.S.D. (.05)			.33		.08	
Incorporation						
Incorporated			2.47	136.5	1.22	79.1
Non-incorporated			2.39	125.9	1.16	69.6
Signif.			NS	*	*	**
B.L.S.D. (.05)				9.0	.04	6.6
N Form x	Inhibitor x	Incorp.				
Urea	None	I	2.53	138.2	1.24	81.9
Urea	None	N-I	2.60	141.4	1.28	86.9
Urea	Terr.	I	2.72	148.0	1.15	80.5
Urea	Terr.	N-I	2.34	124.5	1.12	65.8
Urea	N-S	I	2.78	152.3	1.22	88.1
Urea	N-S	N-I	2.63	136.8	1.11	72.5
28% Soln	None	I	2.15	124.7	1.18	69.4
28% Soln	None	N-I	2.19	124.3	1.14	67.2
28% Soln	Terr.	I	2.32	137.2	1.32	87.1
28% Soln	Terr.	N-I	2.28	114.0	1.12	61.2
28% Soln	N-S	I	2.30	118.5	1.21	67.8
28% Soln	N-S	N-I	2.29	114.4	1.18	68.9
Signif.			NS	NS	*	NS
B.L.S.D. (.05)					.12	

Table 2. Influence of nitrogen form, nitrification inhibitors and treatment incorporation on dry matter production at physiological maturity.

Treatment			Dry Matter Production		
N Form	Inhibitor		Stover	Grain	Total
			-------------	T/A	-------------
Urea			3.29	3.30	6.59
Urea	Terr.		3.03	3.18	6.21
Urea	N-S		3.29	3.35	6.64
28%			3.12	2.79	5.92
28%	Terr.		3.01	2.86	5.87
28%	N-S		2.66	2.45	5.12
Signif.			*	*	**
B.L.S.D. (.05)			.36	.57	.85
Incorporation					
Incorporated			3.06	3.13	6.19
Non-incorporated			3.08	2.85	5.93
Signif.			NS	*	NS
B.L.S.D. (.05)				.21	
N Form x	Inhibitor x	Incorp.			
Urea	None	I	3.21	3.33	6.55
Urea	None	N-I	3.35	3.28	6.63
Urea	Terr.	I	2.96	3.43	6.39
Urea	Terr.	N-I	3.10	2.93	6.03
Urea	N-S	I	3.21	3.61	6.82
Urea	N-S	N-I	3.38	3.09	6.46
28% Soln	None	I	3.22	2.93	6.15
28% Soln	None	N-I	3.03	2.65	5.69
28% Soln	Terr.	I	3.17	3.04	6.20
28% Soln	Terr.	N-I	2.86	2.68	5.53
28% Soln	N-S	I	2.57	2.45	5.01
28% Soln	N-S	N-I	2.76	2.46	5.22
Signif.			NS	NS	NS
B.L.S.D. (.05)					

Table 3. Influence of nitrogen form, nitrification inhibitors and treatment incorporation on nitrogen content and nitrogen removal of total dry matter production at physiological maturity.

Treatment			N Conc.		N Removal		
N Form	Inhibitor		Stover	Grain	Stover	Grain	Total
			-------%------		---------#/A----------		
Urea			.62	1.20	41.5	80.0	121.5
Urea	Terr.		.55	1.44	33.6	90.8	124.4
Urea	N-S		.63	1.22	41.5	82.1	123.6
28%			.50	1.14	31.2	64.0	92.2
28%	Terr.		.51	1.22	31.2	70.4	101.6
28%	N-S		.51	1.16	27.4	57.2	84.6
Signif.			*	**	*	**	**
B.L.S.D. (.05)			.12	.07	9.4	14.4	22.3
Incorporation							
Incorporated			.58	1.20	35.7	76.0	111.7
Non-incorporated			.53	1.26	33.1	72.2	105.5
Signif.			*	+	NS	NS	NS
B.L.S.D. (.05)			.05	.05			
N Form x	Inhibitor x	Incorp.					
Urea	None	I	.64	1.15	41.6	77.0	118.6
Urea	None	N-I	.60	1.26	41.5	82.9	124.4
Urea	Terr.	I	.63	1.36	37.2	93.2	130.4
Urea	Terr.	N-I	.48	1.51	30.0	88.4	118.4
Urea	N-S	I	.72	1.23	46.3	89.2	135.5
Urea	N-S	N-I	.54	1.21	36.7	75.0	111.7
28% Soln.	None	I	.46	1.17	30.0	68.6	98.6
28% Soln	None	N-I	.53	1.12	32.5	59.5	92.0
28% Soln	Terr.	I	.49	1.18	31.4	72.0	103.4
28% Soln	Terr.	N-I	.53	1.28	31.0	67.8	98.8
28% Soln	N-S	I	.53	1.12	27.6	54.8	82.4
28% Soln	N-S	N-I	.49	1.19	27.3	59.7	87.0
Signif.			*	NS	NS	NS	NS
B.L.S.D. (.05)			.13				

MICRONUTRIENT AND SULFUR FERTILIZATION OF CORN UNDER IRRIGATION

G. L. Malzer, J. Lensing and R. Schoper

Micronutrients along with other plant essential elements apart from the traditional NPK type fertilizer are receiving much more interest on coarse textured soils under irrigation. Under these relatively low organic matter soils, receiving intensive production management inputs, and especially where high lime waters are used for irrigation purposes situations may develop where micronutrients may become limiting for crop production. A study was initiated at the Sand Plains Research Farm to investigate the potential needs of micronutrients and sulfur for corn production on these Hubbard coarse sand soils.

Experimental Procedures

Six treatments including a check, three micronutrients (Boron - 2#/A as Borax, Zinc - 10#/A as $ZNCl_2$ and Copper - 5#/A as $Cu(NO_3)2$ (25#S/A as $CaSO_4$) and a combination of all of the above were applied as broadcast applications at planting. All of the above treatment received 240 #N/A as urea in split applications during the growing season. An additional treatment to evaluate high nitrogen application rates under irrigation was also investigated with the application of 600# N/A in split applications.

The experimental area had been previously fertilized with phosphorus and potassium according to soil tests. Soil tests indicated a soil pH of 5.9, DTPA extractable Zn of 0.7 ppm (marginal) and extractable sulfate S of 11 ppm (adequate).

The experimental area was planted to corn (Minhybrid 6304) on May 5th at a population of 27,700 seeds/A. Weed control was accomplished with the use of an Atrazine and Lasso tank mix. Irrigation started the day after planting with a total of 34.78 inches of water coming from irrigation and rainfall during the growing season.

General Results

No positive yield responses to the application of micronutrients were found under the conditions experienced at Becker in 1977. An 18 bu/A response was found with the application fo 25# S/A but it was not significantly different at the 5% level (20.8) of confidence. There was no advantage to the utilization of very high nitrogen rates (600# N/A). Zinc although having a marginal soil test gave no yield response. Very high nitrogen applications resulted in a higher moisture grain at harvest in comparison to the other treatments. Applications of sulfur resulted in more efficient utilization of nitrogen with more N being removed with the grain.

TABLE 1 Influence of micronutrients, sulfur, and high nitrogen applications on yield and other grain parameters of corn under irrigation

Treatment	Corn Grain		
	Yield	D. M. at Harvest	N Removal
	bu/A	%	#/A
Control	160.3	81.9	114.3
B	150.8	81.9	104.4
Cu	159.5	81.6	114.9
Zn	150.0	79.5	109.3
S	178.6	79.6	129.4
Combination	149.0	82.2	110.6
600# N/A	146.4	78.4	108.6
Signif.	*	+	+
BLSD (.05)	20.8	2.9	16.4

INFLUENCE OF NITROGEN RATE, TIMING OF NITROGEN APPLICATION AND USE OF NITRIFICATION INHIBITORS FOR IRRIGATED SPRING WHEAT AND CORN

G.L. Malzer and J. Lensing

Nitrogen management for crops under irrigation is a key step not only in production output but also in efficient and economical use of nitrogen fertilizer. Because of the large potential losses of nitrogen that may occur through the leaching of nitrate nitrogen, not only rate of nitrogen application but timing of application may be critical. With the relatively recent commercial availability of chemicals known as nitrification inhibitors which are designed to minimize nitrate nitrogen losses another management tool is available to the producer.

In most cases, the most efficient time to apply nitrogen under irrigation is just prior to and in proportion to plant demand. Under many management operations this may not be physically possible or may not lend itself economically depending upon the climatic conditions. It was, therefore, the objectives of these experiments to: 1) evaluate the significance of both rate and timing of nitrogen application for wheat and corn production, and 2) determine the potential that nitrification inhibitors may have in minimizing nitrogen losses under irrigation.

Experimental Procedures

Two separate experiments one with wheat and one with corn were established at the Sand Plains Research Farm near Becker, Mn. Each experiment consisted of twenty-five treatments including a check, four rates of nitrogen, two methods of application, and three nitrification inhibitor treatments. A factorial arrangement 4 x 2 x 3(+1) was set out as four replications in a randomized complete block design the soil type was a Hubbard coarse sand with approximately 1% organic matter.

Wheat Experiment--Broadcast applications of phosphorus (80 #/A-0-45-0) and potassium (120 #/A-0-0-60) were made on March 24, 1977 and incorporated by plowing. Experimental treatments included a check (0 N) four rates of nitrogen (45, 90, 135, and 180 # N/A as urea) applied either in one preplant and incorporated operation or in split applications with two-thirds of the nitrogen being applied preplant and the second 1/3 applied at the boot stage of growth (June 6). Preplant experimental treatments were made on April 7, 1977 to plot areas of 12' x 20', incorporated by discing and the experimental area planted to Era spring wheat the same day. Wheat was seeded in 6" rows at a seeding rate of 2 bu/A with 20 #P_2O_5/A applied as a starter. All possible combinations of these treatments were applied with no coating onto urea or with coatings of N-serve or Terrazole at a rate of 0.5 # active ingredient/acre. Good weed control was achieved with the use of Brominal plus (0.25 #AI/A applied May 5).

Forage yields were taken on July 5 (soft dough stage) by harvesting three feet (6 rows) by nine ft. from each plot. Field weights were obtained and samples removed for moisture determination and nitrogen analysis.

The first irrigation water was applied on April 13 to aid germination with the normal irrigation schedule starting May 8 and going through July 11 with a total of 6.25 inches being applied through irrigation and 11.34 inches of water received by rainfall during this period.

Corn Experiment--A similar experiment was conducted with corn. Broadcast applications of 340 #/A of 0-0-60 were applied on March 24 and incorporated by plowing. Experimental treatments consisting of a check nitrogen rates of 60, 120, 180 and 240 # N/A as urea were applied in one preplant and incorporated application on May 4 or in split application. Split applications were applied on May 4 (preplant), May 26 (12" height), June 27 (36' height), and July 12 (early silking) in a ratio of 1/6, 1/6, 3/6, and 1/6 respectively. Treatment combinations either had no coating, N-Serve or Terrazole at 0.5 # A.I./A.with each treatment area being six rows wide and 30 ft. long.

Corn (Minhybrid 6304) was planted on May 5, in 30 inch rows at a population of 27,700 seeds/A. Starter fertilizer was applied at a rate of 20 # P_2O_5/A and 40 # K_2O/A. Good weed control was obtained with a tank mixture of Lasso (2 # AI /A) and Atrazine (1 # AI /A) applied on May 7.

Leaf samples from opposite and below the ear (6th leaf) at silking were taken from each plot on July 12, dried, and analyzed for kjeldahl nitrogen. Dry matter and nitrogen uptake were determined by harvesting one row 15 ft. long from each plot on September 8 and 9 (Physiological maturity). Ears were separated from the stalks, field weights obtained and samples removed for moisture determination and nitrogen analysis. Yields were obtained on October 18 and 19 by harvesting two rows 20' long. Field weights were obtained and samples collected for moisture and nitrogen concentration. Corn grain yields were adjusted to 15.5% moisture.

The irrigation program was started on May 8 and continued through Sept. 12 with a total of 11.95 inches of water being applied through irrigation and 21.83 inches coming through rainfall.

General Results

Information obtained from the wheat trial are presented in Tables 1 and 2 and data from the corn experiment in Tables 3, 4 and 5.

Wheat Experiment--Overall wheat yields were very good with significant yield responses (Table 1) upto and with 135 # N/A. Timing of nitrogen application had no influence on yield suggesting that the second split N application may have been applied too late. Nitrification inhibitor application for wheat had no positive influence on yields under the conditions experienced in 1977. In general yields were reduced with inhibitor application (N-serve) suggesting that the chemicals may have been too effective for a short growing season crop such as wheat. Although timing of nitrogen application had no influence on yield there were increases in both nitrogen concentration of the grain (increased protein) and increased nitrogen uptake as was also found with nitrogen rates. Increased wheat grain test weights were also found both with increased nitrogen applications rates and splitting of nitrogen applications.

Nitrogen rates and timing of nitrogen application significantly influenced wheat dry matter production and nitrogen utilization. Splitting of nitrogen resulted in reduced dry matter production while N concentration increased resulting in no net increase in nitrogen uptake. Nitrification inhibitors had no overall influence on dry matter production and total nitrogen utilization.

Corn Experiment--Excellent corn grain yields were obtained in 1977 with treatments ranging from 37 to 175 bu/A (Table 3). Nitrogen rates significantly increased yields, grain N and grain N removal with rates up to 180 # N/A. Splitting of nitrogen applications unlike the wheat significantly improved corn grain yields resulting in greater N removal. A significant interaction between timing of nitrogen application and the use of nitrification inhibitors were encountered. In general, there was no advantage to splitting nitrogen application and also using nitrification inhibitors. Split nitrogen applications as compared to single N application without nitrification inhibitors increased yield 15-28 bu/A depending on the nitrogen rate. The use of Terrazole with the urea nitrogen in one application in most cases approximated the yields that were obtained with split nitrogen applications. N-serve had no influence in this respect.

Nitrogen rates significantly increased dry matter production up to the 180 # N/A rate (Table 2). Splitting of the nitrogen decreased stover production and at the same time increased grain production with no influence on total forage production. Nitrification inhibitors had no overall influence on dry matter production.

Nitrogen content and nitrogen removal of the corn stover and grain (Table 3) were increased with nitrogen rates upto 240 # N/A Splitting of nitrogen also resulted in greater nitrogen utilization while the use of nitrification inhibitors generally reduced the nitrogen content and nitrogen removal with the stover portion of the plant.

Table 1. Influence of nitrogen rate, timing of nitrogen applictor, and nitrification inhibitors on Era wheat yield, nitrogen utilization and test weight.

Treatments			Wheat Grain			
N Rate	No. of Appl.	Inhibitor	Yield	N Conc.	N Removal	Test Wt.
#/A			bu/A	%	#/A	#/bu
0	-	0	17.8	2.34	24.8	59.9
45	1	0	40.2	1.98	47.7	59.3
45	1	N-S	35.4	2.00	42.2	59.2
45	1	Terr.	33.8	1.98	39.9	59.5
45	2	0	38.6	2.14	49.9	60.3
45	2	N-S	33.8	2.19	44.6	60.8
45	2	Terr.	38.6	2.22	50.8	60.9
90	1	0	53.8	2.16	69.6	60.3
90	1	N-S	48.6	2.24	65.4	60.2
90	1	Terr.	50.2	2.20	66.3	59.7
90	2	0	50.8	2.44	74.5	60.9
90	2	N-S	44.5	2.51	67.0	60.8
90	2	Terr.	45.7	2.46	67.3	60.9
135	1	0	55.3	2.40	80.0	60.0
135	1	N-S	55.1	2.62	86.4	60.2
135	1	Terr.	54.5	2.53	82.8	60.7
135	2	0	54.6	2.69	88.3	60.9
135	2	N-S	54.3	2.72	88.8	60.9
135	2	Terr.	56.1	2.61	88.2	60.8
180	1	0	59.0	2.56	90.5	60.1
180	1	N-S	60.3	2.67	96.7	59.9
180	1	Terr.	55.5	2.74	91.3	59.5
180	2	0	54.7	2.81	92.6	60.8
180	2	N-S	55.9	2.85	95.5	60.4
180	2	Terr.	57.2	2.92	100.3	60.8
Signif.			**	**	**	**
B.L.S.D. (.05)			5.4	.15	9.0	0.6
Factorial Arrangement						
N Rate - #/A						
45			36.7	2.09	45.8	60.0
90			48.9	2.33	68.4	60.5
135			55.0	2.60	85.7	60.6
180			57.1	2.76	94.5	60.3
Signif.			**	**	**	**
B.L.S.D. (.05)			2.2	.06	3.7	0.2
No. of Appl.						
One			50.1	2.34	71.6	59.9
Two			48.7	2.55	75.7	60.8
Signif.			NS	**	**	**
B.L.S.D. (.05)				.05	3.0	0.2
Inhibitor						
None			50.9	2.40	74.1	60.3
N-Serve			48.5	2.48	73.3	60.3
Terrazole			49.0	2.46	73.4	60.4
Signif.			+	*	N.S.	N.S.
B.L.S.D. (.05)			2.0	.06		

Table 2. Influence of nitrogen rate, timing of nitrogen application, and nitrification inhibitors on dry matter production and nitrogen utilization of Era wheat.

Treatments			Wheat Forage		
N Rate	No. of Appl.	Inhibitor	Dry Matter	N. Conc.	N Uptake
#/A			Ton/A	%	#/A
0	-	0	.98	1.24	24.0
45	1	0	2.24	1.20	54.0
45	1	N-S	2.04	1.05	42.4
45	1	Terr.	2.23	1.05	47.6
45	2	0	2.27	1.18	54.2
45	2	N-S	1.89	1.07	40.1
45	2	Terr.	2.08	1.16	48.2
90	1	0	3.20	1.25	79.6
90	1	N-S	3.11	1.23	75.8
90	1	Terr.	3.12	1.20	74.8
90	2	0	2.48	1.30	65.3
90	2	N-S	2.78	1.27	70.9
90	2	Terr.	2.58	1.31	67.2
135	1	0	3.52	1.43	100.8
135	1	N-S	3.29	1.31	85.5
135	1	Terr.	3.32	1.38	92.5
135	2	0	3.25	1.54	99.7
135	2	N-S	3.28	1.55	100.1
135	2	Terr.	3.28	1.57	103.3
180	1	0	3.73	1.37	102.0
180	1	N-S	3.48	1.74	120.7
180	1	Terr.	3.51	1.59	112.1
180	2	0	3.28	1.76	115.5
180	2	N-S	3.38	1.92	130.0
180	2	Terr.	3.06	1.82	111.6
Signif.			**	**	**
B.L.S.D. (.05)			.21	.22	15.6
Factorial Arrangement					
N Rate #/A					
45			2.12	1.12	47.8
90			2.88	1.26	72.3
135			3.32	1.46	97.0
180			3.40	1.70	115.3
Signif.			**	**	**
B.L.S.D. (.05)			.168	.08	6.4
No. of Appl.					
One			3.07	1.32	82.3
Two			2.80	1.45	83.8
Signif.			**	**	N.S.
B.L.S.D. (.05)			.12	.06	
Inhibitor					
None			3.00	1.38	83.9
N-Serve			2.90	1.39	83.2
Terrazole			2.90	1.39	82.2
Signif.			N.S.	N.S.	N.S.
B.L.S.D. (.05)					

Table 3. Influence of nitrogen rate, timing of nitrogen application, and nitrification inhibitors on 6th leaf nitrogen concentration, grain yield and nitrogen utilization of corn.

Treatments			6th Leaf	Corn Grain		
N Rate	No. of Appl.	Inhibitor	N. Conc.	Yield	N	N Removal
#/A			%	bu/A	%	#/A
0	-	0	1.33	37.3	1.08	18.7
60	1	0	2.01	93.3	1.08	48.4
60	1	N-S	2.22	92.9	1.03	45.4
60	1	Terr.	2.23	110.1	1.07	55.8
60	4	0	2.23	121.5	1.05	60.3
60	4	N-S	2.41	129.5	1.08	66.0
60	4	Terr.	2.24	111.0	1.14	59.8
120	1	0	2.86	144.1	1.30	89.3
120	1	N-S	2.66	142.9	1.24	84.1
120	1	Terr.	2.79	161.1	1.34	102.4
120	4	0	2.78	161.9	1.41	107.8
120	4	N-S	2.56	152.1	1.19	85.9
120	4	Terr.	2.66	153.2	1.24	89.9
180	1	0	2.68	160.4	1.30	99.2
180	1	N-S	3.00	145.0	1.42	97.9
180	1	Terr.	2.82	173.6	1.45	118.9
180	4	0	2.83	174.8	1.43	117.9
180	4	N-S	2.89	163.6	1.50	116.3
180	4	Terr.	2.74	169.7	1.44	116.0
240	1	0	3.08	142.5	1.50	100.4
240	1	N-S	2.93	158.5	1.46	109.1
240	1	Terr.	2.95	166.3	1.46	114.4
240	4	0	2.90	169.0	1.46	116.4
240	4	N-S	2.78	159.9	1.54	116.7
240	4	Terr.	2.92	168.7	1.46	116.5
Signif.			**	**	**	**
B.L.S.D. (.05)			.26	19.5	.10	14.5
Factorial Arrangement						
N Rate - #/A						
60			2.22	109.7	1.08	56.0
120			2.72	152.6	1.29	93.2
180			2.83	164.5	1.42	111.0
240			2.93	160.8	1.48	112.2
Signif.			**	**	**	**
B.L.S.D. (.05)			.10	7.9	.04	5.9
No. of Appl.						
one			2.68	140.9	1.30	88.8
Four			2.66	152.9	1.33	97.5
Signif.			NS	**	NS	**
B.L.S.D. (.05)				6.3		4.7
Inhibitor						
None			2.67	145.9	1.32	92.5
N-Serve			2.68	143.0	1.31	90.2
Terrazole			2.67	151.7	1.32	96.7
Signif.			NS	+	NS	+
B.L.S.D. (.05)				7.1		5.3

Table 4. Influence of nitrogen rate, timing of nitrogen, application and nitrification inhibitors on the stover and grain components of corn at physiological maturity.

Treatments			Corn Dry Matter		
N Rate	No. of Appl.	Inhibitor	Stover	Grain	Total
#/A			T/A		
0	-	0	1.75	0.76	2.51
60	1	0	2.87	2.17	5.04
60	1	N-S	2.68	2.26	4.94
60	1	Terr.	2.99	2.73	5.72
60	4	0	2.58	2.77	5.35
60	4	N-S	2.63	2.66	5.29
60	4	Terr.	2.80	2.69	5.49
120	1	0	3.42	3.53	6.95
120	1	N-S	2.89	3.01	5.90
120	1	Terr.	3.55	3.76	7.31
120	4	0	3.18	3.41	6.59
120	4	N-S	2.53	2.97	5.51
120	4	Terr.	2.76	3.48	6.25
180	1	0	3.44	3.40	6.84
180	1	N-S	3.66	3.53	7.19
180	1	Terr.	3.30	3.55	6.85
180	4	0	3.33	3.70	7.04
180	4	N-S	3.41	4.00	7.41
180	4	Terr.	2.95	3.59	6.55
240	1	0	3.53	3.50	7.02
240	1	N-S	3.53	3.79	7.32
240	1	Terr.	3.17	2.91	6.08
240	4	0	3.92	4.35	8.28
240	4	N-S	3.20	3.41	6.61
240	4	Terr.	3.34	3.48	6.82
Signif.			**	**	**
B.L.S.D. (.05)			.62	.57	1.07
Factorial Arrangement					
N Rate #/A					
60			2.76	2.55	5.30
120			3.06	3.36	6.42
180			3.35	3.63	6.98
240			3.45	3.57	7.02
Signif.			**	**	**
B.L.S.D. (.05)			.23	.23	.42
No. of Appl.					
One			3.25	3.18	6.43
Four			3.05	3.38	6.43
Signif.			*	*	*
B.L.S.D. (.05)			.17	.18	
Inhibitor					
None			3.28	3.35	6.64
N-Serve			3.07	3.20	6.27
Terrazole			3.11	3.27	6.38
Signif.			NS	NS	NS
B.L.S.D. (.05)					

Table 5. Influence of nitrogen rate, timing of nitrogen application, and nitrification inhibitors on nitrogen utilization of corn at physiological maturity.

Treatment			Corn Forage				
			N Content		N Removal		
N Rate	No. of Appl.	Inhibitor	Stover	Grain	Stover	Grain	Total
#/A			------%------		--------#/A----------		
0	-	0	.56	1.05	19.5	16.0	35.5
60	1	0	.55	1.03	31.4	45.3	76.7
60	1	N-S	.49	1.06	26.5	48.3	74.8
60	1	Terr.	.55	1.06	32.8	58.5	91.3
60	4	0	.58	1.03	30.0	56.8	86.8
60	4	N-S	.59	1.14	31.0	61.3	92.3
60	4	Terr.	.54	1.07	30.2	57.5	87.7
120	1	0	.60	1.26	41.5	89.0	130.5
120	1	N-S	.66	1.24	38.4	75.7	114.1
120	1	Terr.	.76	1.36	54.4	102.9	157.3
120	4	0	.78	1.38	49.7	94.2	143.9
120	4	N-S	.72	1.12	36.6	66.6	103.2
120	4	Terr.	.74	1.19	41.0	83.2	124.2
180	1	0	.67	1.29	46.0	87.9	133.9
180	1	N-S	.70	1.53	51.8	108.3	160.1
180	1	Terr.	.69	1.40	45.2	99.6	144.9
180	4	0	.96	1.44	63.1	107.0	170.1
180	4	N-S	.88	1.42	60.0	113.2	173.2
180	4	Terr.	.71	1.35	41.6	97.3	138.9
240	1	0	.92	1.41	64.2	98.9	163.1
240	1	N-S	.68	1.30	48.1	98.8	146.9
240	1	Terr.	.78	1.46	49.5	85.1	134.6
240	4	0	.90	1.49	70.8	129.5	200.3
240	4	N-S	.95	1.60	61.1	109.1	170.2
240	4	Terr.	.82	1.65	54.7	114.4	169.1
Signif.			**	**	**	**	**
B.L.S.D. (.05)			.12	.13	11.7	18.7	26.3
Factorial Arrangement							
N Rate - #/A							
60			.55	1.06	30.3	54.6	84.9
120			.71	1.26	43.6	85.3	128.9
180			.77	1.40	51.3	102.2	153.5
240			.84	1.48	58.1	106.0	164.1
Signif.			**	**	**	**	**
B.L.S.D. (.05)			.05	.05	4.6	7.5	10.6
No. of Appl.							
one			.67	1.28	44.1	83.2	127.3
four			.76	1.32	47.5	90.8	138.3
Signif.			**	+	+	*	*
B.L.S.D. (.05)			.04	.04	3.1	6.0	8.4
Inhibitor							
None			.74	1.29	49.6	88.6	138.2
N-Serve			.71	1.30	44.2	85.2	129.4
Terrazole			.70	1.32	43.7	87.3	131.0
Signif.			+	N.S.	*	NS	NS
B.L.S.D. (.05)			.04		4.5		

THE INFLUENCE OF NITRIFICATION INHIBITOR APPLICATION RATES AND NITROGEN RATES ON SPRING WHEAT PRODUCTION AND NITRIFICATION RATE UNDER IRRIGATION.

G. L. Malzer and T. Wagar

A considerable number of questions have arisen concerning the potential use of nitrification inhibitors for minimizing nitrate nitrogen losses under irrigation. To examine the influence of nitrification inhibitor application rates a field experiment was established in 1977 at the Sand Plains Research farm near Becker, Minnesota. The objectives of this study are to investigate the influence of nitrification inhibitor rates and nitrogen rates on irrigated spring wheat production and the corresponding influences on the rate of nitrification.

Experimental Procedures

Ten experimental treatments were established on a Hubbard coarse sand currently under irrigation management. Terrazole rates of 0, 0.125, 0.25, 0.50 and 1.0 lb/a in combination with 45 and 90 lbs. N/A were replicated four times in a randomized complete block design. Phosphorus (30# P_2O_5/A) and potassium (60# K_2O/A) were broadcast and incorporated prior to seeding. Nitrogen treatments were applied preplant in the form of urea and Terrazole-coated urea (Olin Corporation trademark). Following incorporation of nitrogen treatments, Era wheat was planted at the rate of 120 lbs./A with 20 lbs. P_2O_5/A as starter on April 7. Bromoxynil + MCPA was applied at 0.125 lbs./A for effective weed control. The experimental area received a total of 17.59 inches of water from rainfall and irrigation during the growing season.

The soil was sampled four times during the growing season to monitor soil ammonium concentration. Soil samples were taken from the 0-6" depth on May 21st and at three subsequent times at 15 day intervals. After collection the samples were dried in a forced air oven at 98^{o} F. and analyzed for soil ammonium concentrations.

Wheat was harvested, at maturity, on July 15. The grain from a 3' x 17' harvest area was bagged, dried, thrashed for yield determination and analyzed for nitrogen content.

Results

The yields obtained from three treatments (45 lbs. N/A + 0.25 lb. Terra./A, 90 lbs. N/A + 0.25 lb. Terra./A and 90 lbs. N/A + 1.0 lb. Terra./A) were significantly lower (Table 1) than other treatments within the same nitrogen rate. Examination of the experimental area with infrared photography and the corresponding relationship with the experimental design suggest that these differences may have been induced by the experimental area and not wholly by the treatments applied. Care should therefore be exercised when evaluating these treatments.

Nitrogen rates significantly increased yield and nitrogen content within the grain resulting in greater N removal. Terrazole rates had no significant influence on grain yields and nitrogen utilization although trends were established for increased yields with increasing rates of Terrazole. (Excluding the three aforementioned treatments.)

Soil Ammonium concentrations (Table 2) were significantly increased with the higher rate of nitrogen application. Increased Terrazole rates retained more nitrogen in the ammonium form for the first two soil samplings. There appeared to be very little advantage to application rates over ¼ to ½ pounds active ingredient/A. The nitrification reaction appeared to be complete by the third sampling (June 20th) with Terrazole rates having no influence on the reaction after that period of time.

Table 1. Effect of nitrogen rate and terrazole rate on wheat yield and nitrogen utilization at Becker, MN in 1977.

Treatment		Yield	N Content	N Removal
N-Rate	Terrazole Rate	bu/A	%	lbs/A
lbs/A				
45	0	36.6	1.80	39.7
45	1/8	38.8	1.77	41.2
45	1/4	32.2	1.83	35.4
45	1/2	40.2	1.81	43.6
45	1	41.9	1.88	47.5
45	0	53.8	1.93	63.0
90	1/8	54.1	2.18	71.1
90	1/4	46.3	2.15	60.4
90	1/2	54.6	2.14	70.1
90	1	48.6	2.09	61.3
Signif.		**	**	**
B.L.S.D. (.05)		6.8	0.29	13.6
C.V.		11.1	9.1	18.1
Factorial Arrangement N-Rate				
45 lbs N/A		38.0	1.82	41.5
90 lbs N/A		51.5	2.10	65.2
Signif.		**	**	**
B.L.S.D. (.05)		3.2	0.12	6.3
Terrazole Rate lbs/A				
0		45.2	1.87	51.4
1/8		46.5	1.98	56.1
1/4		39.2	1.99	47.9
1/2		47.4	1.98	56.8
1		45.3	1.98	54.4
Signif.		*	N.S.	N.S.
B.L.S.D. (.05)		5.5	-	-
NXT				
Signif.		N.S.	N.S.	N.S.
B.L.S.D.		-	-	-
C.V.		11.1	9.1	18.1

Table 2. Effect of nitrogen rate and terrazole rate on soil ammonium concentration throughout the season at Becker, MN in 1977.

Treatment		Sampling Dates			
N-Rate	Terrazole Rate	5/21	6/5	6/20	7/5
lbs/A		ppm NH_4			
45	0	7.5	9.2	1.4	0.8
45	1/8	7.5	10.1	1.4	1.9
45	1/4	7.8	8.3	1.0	1.2
45	1/2	7.2	8.2	2.0	1.8
45	1	13.5	10.9	1.6	2.7
45	0	5.8	9.2	1.9	2.4
90	1/8	10.9	9.9	1.3	3.2
90	1/4	18.1	8.9	1.4	2.7
90	1/2	13.8	14.5	1.7	1.2
90	1	13.8	14.5	2.5	1.7
Signif.		*	*	N.S.	N.S.
B.L.S.D. (.05)		8.5	5.4	-	-
C.V.		46.9	29.5	48.1	42.2

Factorial Arrangement	5/21	6/5	6/20	7/5
N-Rate				
45 lbs N/A	8.7	9.3	1.5	1.7
90 lbs N/A	12.4	11.4	1.6	2.2
Signif.	*	*	N.S.	N.S.
B.L.S.D. (.05)	3.2	2.0	-	-
Terrazole Rate lbs/A				
0	6.6	9.2	1.7	1.6
1/8	9.2	10.0	1.4	2.6
1/4	13.0	8.6	1.2	1.9
1/2	10.5	11.3	1.4	1.5
1	13.6	12.7	2.0	2.2
Signif.	+	+	N.S.	N.S.
B.L.S.D. (.10)	4.9	3.1	-	-
NXT				
Signif.	N.S.	N.S.	N.S.	N.S.
B.L.S.D.	-	-	-	-
C.V.	46.9	29.5	48.1	42.2

Navy Bean Inoculation Trials - 1977

M.C. Froberg and G.E. Ham

Eight strains of Rhizobium phaseoli (navy bean nodule bacteria) were used to inoculate Seafarer and Sanilac navy bean varieties at Becker. Many different strains of nodule bacteria exist and some are better nitrogen fixers than others. The differences among strains of Rhizobia are comparable to the differences among varieties of a crop. A randomized complete block design, replicated six times was used. All plots received 24 pounds of N per acre before planting and the plots were irrigated when necessary. The seed yields of Seafarer and Sanilac varieties were increased 589 pounds per acre (52%) and 738 pounds per acre (63%), respectively, by two different strains of nodule bacteria. These results indicate that inoculation is necessary for maximum yields and these results also indicate considerable variation among the nodule bacteria strains. Further research will be conducted to determine if the nodule bacteria strain - navy bean variety interaction is consistent over years.

Table 1. Effect of inoculation on navy bean yields at Becker in 1977.

Rhizobium strain	Navy Bean Variety Seafarer	Sanilac
	----------lbs/acre----------	
Check	1132bc*	1172cd
CIAT 40	1240d	1241d
CIAT 75	1721hi	1675h
CIAT 139	1141bc	966a
QA 1062	1458f	1761i
650R	1346e	1488fg
781R	1177ed	1225d
3621	1120bc	1071b
3644	1536g	1910j

* Seed yields followed by the same letter(s) are not significantly different at the 95% level.

WEATHER SUMMARY - 1977
Northwest Experiment Station, Crookston, Minnesota

After bringing in the new year with an extremely cold January, spring arrived early in the Red River Valley recording well above normal temperatures and average precipitation for February, March and April.

The average monthly temperature for January was 7.7°F below normal. This departure from normal can be attributed to a period of 12 consecutive days below zero. We may also remember that on only one day did the temperature reach a maximum of 4°F in a period of 22 days of subzero weather. The coldest day of 1977 was recorded January 16 with a reading of -43°F. This is second only to 1892 when the temperature plunged to -44°F. Along with the bitter cold weather, the Valley was engulfed by a blizzard on January 27 with 40 mph northwest winds plunging the wind chill factor to -78°F.

February brought with it relief from the bitter cold of January and set the stage for an early spring. February, March and April were all 7.5 degrees above normal in regard to average monthly temperature. The precipitation for the three months exceeded the long time averages.

The last spring frost occurred on May 7 marking the official beginning of the growing season. May recorded many days in the 80's and low 90's which were very unusual for this time of year. The earlier planted small grains suffered somewhat due to the extremely warm temperatures in mid to late May. The afternoon of May 26 may well be remembered for its "cloud burst" dumping of 2.08" of rain in a period of 2 hours. May 26 may also be remembered as the turning point from the previous droughty condition which prevailed in the Valley. By the end of May, we recorded 5.91" of precipitation which was 3.30" above normal. Only one other year, 1896, recorded more precipitation for the month of May with 8.13" of precipitation.

The remainder of the growing season, June through October, also followed the trend with above normal precipitation recorded. The same period also had slightly above average temperatures with the exception of August. August was cool and moist recording 17 days of rain and only 4 clear days. There were also 15 days of measurable precipitation in September of which the rainfall was light, but sufficient to halt small grain harvest. This period of weather caused some crop damage to grains not already harvested.

The first killing frost occurred on October 15 when the minimum temperature reached 27°F. The frost-free period for the 1977 growing season was 150 days which is 25 days longer than normal. The long growing season of 1977 caught some farmers with fall row crops of sunflowers and corn by surprise. The snowfall of November 7 and 8 arrived before the frost and never did melt. The blizzards of November 9, 19 and 20 dumped 17" of snow which has accumulated in the unharvested fields delaying a possible harvest until next spring.

November and December precipitation were also well above normal for the Crookston station. The total precipitation for 1977 was 29.85" which, compared to the average annual rainfall of 20.2", was almost 10" above normal. The wettest year on record for Crookston was in 1941 when 32.87" were recorded.

Table 1. Weather Summary for 1977 with Averages for Precipitation and Mean Temperatures for 1890-1973.

	Precipitation, Inches					Mean Temperature	
	snow	precip.				----------degrees--------	
	Inches	Inches	Rain	Total	1890-1973	1977	1890-1973
Jan.	10.2	.49	.00	.49	.56	-3.8	3.9
Feb.	17.5	1.21	.00	1.21	.54	15.7	8.2
Mar.	4.0	.65	.25	.90	.85	30.5	23.0
Apr.	0.3	T	.98	.98	1.53	49.2	41.4
May	0.0	.00	5.91	5.91	2.61	66.8	54.5
June	0.0	.00	3.68	3.68	3.61	65.3	64.5
July	0.0	.00	3.32	3.32	3.13	71.2	69.4
Aug.	0.0	.00	3.15	3.15	2.88	62.2	67.5
Sept.	0.0	.00	3.92	3.92	2.26	57.4	57.4
Oct.	0.0	.00	2.03	2.03	1.39	47.9	45.4
Nov.	30.8	2.29	.51	2.80	.76	24.8	26.9
Dec.	17.1	1.46	.00	1.46	.61	4.9	11.5
Total	79.9	6.10	23.75	29.85	20.73		39.5

NITROGEN RATE AND CARRIER COMPARISONS ON WHEAT

G. W. Wallingford and R. K. Severson

Nitrogen is usually the largest fertilizer cost in wheat production in Northwestern Minnesota. Ammonium nitrate has traditionally been the most common carrier of nitrogen used in this area, but in recent years nitrogen solutions and anhydrous ammonia have been taking over a large share of the nitrogen market. A fourth nitrogen source, urea, has seen limited use but should occupy a larger share of the market in the future.

An experiment which compared the four nitrogen materials at three nitrogen rates was established at two locations in 1977. One location was on a coarse-textured soil and the other on a fine-textured soil in the Red River Valley.

Nitrogen rates of 30, 60 and 90 lbs. N/A were used in a randomized complete block design with four replications. All materials were applied pre-plant and incorporated immediately after application. Fertilizer applications were made at the Red Lake county site on April 22 and on April 27 on the Kittson county site. Era wheat was used as the test crop at both locations.

Results

Both locations showed significant responses to nitrogen treatments. The Red Lake county site showed significant yield increases at the 90 N/A rate for all four materials. The 28% solution and anhydrous ammonia materials also showed a significant increase over the control at the 60 N/A rate. The 30 N/A rate of anhydrous ammonia was the only low rate which had a significant yield response.

At the Kittson county location all treatment were significantly different from the control with the exception of the 30 N/A rate of 28% solution. Table 1 gives the data for both locations.

Table 1. Wheat grain yields as affected by nitrogen material and rate at two locations in 1977.

Material	Rate	Kittson Co.	Red Lake Co.
	lbs N/A	Bu/A	Bu/A
Control	0	25.5	15.5
Ammonium	30	33.8	14.4
Nitrate	60	39.2	20.9
(34-0-0)	90	43.0	23.7
Urea	30	30.8	15.5
(46-0-0)	60	37.5	20.9
	90	41.2	24.0
Urea-Ammonium	30	26.8	18.1
Nitrate Solution	60	35.6	22.6
(28-0-0)	90	39.9	22.1
Anhydrous	30	34.7	22.8
Ammonia	60	40.4	22.9
(82-0-0)	90	42.3	28.2
Significance		*	*
BLSD		3.8	6.4
C.V. (%)		7.9	20.0

FALL VS. SPRING NITROGEN APPLICATIONS FOR WHEAT

G. W. WALLINGFORD AND R. K. SEVERSON

Losses of nitrogen by denitrification or by leaching can influence the efficiency of applying nitrogen in the fall. The fine-textured, high organic matter, poorly drained soils of the Red River Valley have potential for denitrification losses in late, wet springs that frequently occur in northwestern Minnesota.

A study was initiated in the fall of 1976 to compare fall vs. spring nitrogen applications, nitrogen carriers and rate of nitrogen on the yield of wheat. The study was located on the Northwest Experiment Station on a Wheatville loam soil.

Fall applications were made on October 25, 1976 and spring applications on April 29, 1977. Plots were planted on May 2 to Era wheat and were harvested on August 5 for grain yields.

Results

The grain yields for 1976 and 1977 are given in Table 1. Due to the dry conditions of 1976 and the early part of 1977 no significant yield differences were found.

Table 1. Wheat grain yields in 1976 and 1977 as affected by nitrogen material, rate, and time of application.

Material	N Rate	Fall		Spring	
	lbs./A.	1976	1977	1976	1977
Control	0	19.7	43.1	19.7	43.1
Ammonium	30	15.8	42.2	15.2	44.3
Nitrate	60	17.1	43.4	14.4	46.4
(34-0-0)	90	17.4	45.4	20.8	47.0
Urea	30	17.6	44.4	20.8	43.5
(46-0-0)	60	25.1	45.4	20.2	44.8
	90	20.9	48.2	15.0	43.9
Urea-Ammonium	30	20.4	46.7	16.7	45.2
Nitrate Solution	60	18.4	43.2	24.8	43.9
(28-0-0)	90	15.0	44.8	18.6	44.4
Anhydrous	30	20.7	43.0	18.7	43.3
Ammonia	60	18.1	46.0	18.6	43.6
(82-0-0)	90	15.2	42.5	21.3	43.8
Significance		N.S.	N.S.	N.S.	N.S.
BLSD C.O. %		27.2	9.9	27.2	9.9

PHOSPHORUS FERTILIZATION OF WHEAT IN THE RED RIVER VALLEY

G. W. WALLINGFORD AND R. K. SEVERSON

Fine textured soils of the Red River Valley used for sugarbeet production have been receiving large applications of phosphorus for many years. On soil testing medium to high in available phosphorus, it is becoming questionable whether wheat will respond to additional phosphorus applications. Data is needed to update wheat response to phosphorus applied either banded or broadcast.

An experiment was established in 1975 and continued through 1977 at the Northwest Experiment Station. A randomized complete block design with four replications and ten treatment was used in 1975 and 1976. Three additional treatments were added in 1977. The fertilizer was placed with the seed in the drill treatments. The broadcast applications were applied preplant and incorporated.

Additional nitrogen was applied so that all plots received a total of 60 lbs. N/A. Blanket applications of 40 lbs. K_2O/A were also applied. The treatments were applied and the plots planted with 1.5 bu/A of ERA wheat.

Results

The grain yield for 1975, 1976 and 1977 are given in Table 1. There were no significant differences between any of the treatments for the three years. There were also no visable growth differences between any of the treatments early in the season which has been regarded as a benefit of statter fertilization. Several more years of data are needed which hopefully will include a year when planting can be done earlier in the spring into cooler soils.

Table 1. Wheat grain yield as affected by phosphorus rate and method of application at Crookston in 1975, 1976, and 1977.

Material	Rate[a] lbs P_2O_5/A	Method	1975	1976	1977
Control		----	51.3	31.5	41.4
TSP	20	Band	52.1	32.4	42.0
TSP	20	Bd'cst	50.5	33.1	40.5
ASP	20	Band	49.9	28.6	43.8
Poly	20	Bank	----	----	42.7
TSP	40	Band	40.0	30.9	41.8
TSP	40	Bdcst	50.7	23.3	42.5
ASP	40	Band	45.5	33.0	43.1
Poly	40	Band	----	----	44.9
TSP	60	Band	48.8	32.8	41.9
TSP	60	Bdcst	54.2	29.8	39.2
ASP	60	Band	50.8	32.7	43.2
Poly	60	Band	----	----	43.2
Signficance			N.S.	N.S.	N.S.
C.V.(%)			7.4	17.8	9.9

[a] TSP = Triple superphosphate (0-44-0),
ASP = Amoniated superphosphate (18-46-0)
POLY = Polyphosphate (10-34-0)

WHEAT PRODUCTION AS AFFECTED BY COPPER ON ORGANIC SOILS 1977.

G. W. Wallingford, G. L. Malzer, R. K. Severson

The organic soils of Northwestern Minnesota are being developed into production agricultural land through land clearing and drainage. Grass seed production has been the primary agricultural crop produced successfully on these peat soils in the past 20 to 30 years. With the introduction of semi-dwarf wheat varieties into Minnesota, wheat production on peat had been unsuccessful. Through preliminarly studies with the addition of the macro nutrients plus the micro nutrient, copper was isolated as being the major limiting nutrient for successful wheat production.

Two experimental locations were established in 1977 in Roseau and East Polk counties. Three separate experiments were conducted at each of the two locations in 1977.

Experiment number one compared the affect of copper rate, carrier and method on wheat yield, pounds of dry matter per acre and total pounds of copper uptake per acre. The results for 1977 are given in Table 1 for the Roseau location and Table 2 for the East Polk county location in 1977.

Experiment number two was initiated to survey the effect of residual copper in soil over a period of years. Rates of copper-sulfate were applied from 0 to 192 lbs. of actual copper per acre on May 6 and seeded to Era wheat on May 7. Tables 3 and 4 give the yields of wheat obtained in bushels per acre, pounds of dry matter per acre, pounds of copper uptake per acre and ppm of copper remaining in the soil after the first year for the Roseau and East Polk county sites respectively.

Experiment number three was initiated at both locations to asses the possibilities of any interactions between copper and iron, zinc, manganese or all three in combination designated by a "blast" treatment. The data given in Tables 5 and 6 are the yields in bushels per acre, pounds of dry matter per acre, and total pounds of copper uptake per acre for the Roseau and East Polk county sites respectively.

Table 1. Wheat yields on organic soils as affected by copper rate, carrier and method at the Roseau location in 1977.

Material	lbs Cu/A	Bu/A	lbs DM/A	PPM Cu (whole plant)	Cu Uptake lbs Cu/A	PPM Cu (Flag Leaf)	PPM Cu Soil Residual (0-6")
Control		1.8	1171	.500	.0055	10.50	.425
$CuSO_4$							
Bdcst.	1.5	37.6	8180	.950	.0079	14.75	2.400
	3	41.0	8816	1.200	.0106	23.00	2.675
	6	41.0	8612	1.125	.0098	23.25	7.050
	12	46.9	9408	1.825	.0171	29.00	9.800
	24	42.3	9352	1.800	.0166	31.75	9.525
$CuSO_4$							
Band	.75	7.4	3835	.600	.0024	18.75	.575
	1.5	7.1	4824	.525	.0025	8.75	.450
	3	13.2	5045	.450	.0023	9.75	.525
	6	16.0	6016	.550	.0032	14.25	2.750
	12	18.4	4187	.550	.0024	8.00	.475
	24	16.9	6701	.600	.0042	14.25	.525
CuChelate							
Bdcst.	.375	25.2	6576	.575	.0039	11.75	.525
	.75	39.4	8396	.875	.0073	18.00	.800
	1.5	47.2	8798	1.225	.0111	26.75	.975
	3	48.0	9739	1.325	.0128	18.5	1.850
	6	49.9	9671	2.175	.0212	37.25	3.975
CuChelate							
Band	.375	23.2	4383	.625	.0028	11.75	.500
	.75	33.4	8567	.800	.0068	15.00	1.500
	1.5	41.7	6369	.925	.0062	14.50	1.450
Foliar	.15	22.2	6516	.925	.0065	10.00	.425
	.30	23.4	5888	.925	.0057	10.00	.525
Significance		**	**	**	**	**	**
BLSD		6.0	1910	.351	.0037	13.81	3.120
C.V.		16.2	21.1	28.1	38.0	51.2	88.3

Table 2. Wheat yields on organic soils as affected by copper rate, carrier and method at the East Polk county location in 1977.

Material	lbs Cu/A	Bu/A	lbs D.M./A	PPM Cu (whole plant)	Cu Uptake (lbs Cu/A)	PPM Cu (flaf leaf)
Control		.8	1395	.450	.0006	2.375
$CuSO_4$						
Bdcst.	1.5	20.8	7224	.775	.0056	1.525
	3	29.2	8494	1.200	.0104	2.000
	6	31.1	7802	.750	.0060	3.250
	12	35.6	8916	1.100	.0098	3.500
	24	36.3	8805	1.450	.0126	6.000
$CuSO_4$						
Band	.75	1.1	2258	.550	.0013	1.100
	1.5	2.6	3078	.475	.0015	1.500
	3	2.9	2831	.525	.0014	1.950
	6	3.6	3635	.575	.0021	1.900
	12	4.8	3208	.575	.0020	2.075
	24	7.0	4774	.550	.0026	1.850
Cu Chelate						
Bdcst.	.375	2.6	3021	.650	.0020	1.075
	.75	7.4	4656	.625	.0030	1.400
	1.5	20.2	5829	.825	.0050	1.250
	3	31.2	7092	.975	.0070	1.750
	6	35.6	8385	1.225	.0104	5.525
Cu Chelate						
Band	.375	2.8	3610	.575	.0021	1.400
	.75	9.2	5582	.675	.0039	1.400
	1.5	17.2	7769	.800	.0062	1.975
Foliar	.15	9.6	5355	.750	.0043	1.275
	.30	15.9	6064	1.200	.0074	1.400
Significance		**	**	**	**	**
BLSD		4.4	1402	.296	.0025	1.597
C.V.		23.3	20.1	27.6	39.4	52.9

Table 3. Wheat yields on organic soils as affected by rates of residual copper in the soil at the Roseau county location in 1977.

Rate	Bu/A	lbs D.M./A	ppm Cu	Cu Uptake	PPM Cu Soil Residual
(lbs Cu/A			(whole plant)	(lbs Cu/A)	(0-6")
0	3.2	2448	.450	.0011	1.425
3	34.9	6658	.925	.0062	2.825
6	44.9	8915	1.775	.0164	10.325
12	41.0	7645	1.175	.0095	10.600
24	52.1	9890	1.650	.0158	19.425
48	38.1	4312	1.275	.0095	52.100
96	43.6	8820	1.475	.0134	78.200
192	49.4	9426	1.800	.0174	244.450
Significance	**	**	**	**	**
BLSD	8.1	1831	.664	.0076	38.2
C.V. (%)	20.1	22.3	33.0	45.2	74.4

Table 4. Wheat yields on organic soils as affected by rates of residual copper in the soil at the East Polk county location in 1977.

Rate	Bu/A	lbs D.M./A	ppm Cu	Cu Uptake	PPM Cu Soil Residual
lbs Cu/A			(whole plant)	(lbs Cu/A)	(0-6")
0	6.1	4279	.800	.0038	2.625
3	13.5	7461	1.175	.0088	3.800
6	27.6	7888	1.325	.0105	18.975
12	32.3	7632	1.300	.0102	4.875
24	18.4	7480	1.575	.0125	8.400
48	21.0	6838	1.425	.0100	17.500
96	28.1	7753	1.275	.0096	36.525
192	28.8	7656	2.525	.0181	37.850
Significance	**	+	NS	NS	**
BLSD	11.1	2440 (.1)			22.0
C.V. (%)	34.2	22.8	59.7	60.7	86.3

Table 5. Wheat yields on organic soils as affected by micronutrients in combination with copper at the Roseau county location in 1977.

Material	Bu/A	lbs D.M./A	ppm Cu (whole plant)	Cu Uptake (lbs Cu/A)
Control (Cu)	44.8	7249	1.325	.0101
Fe	48.2	9190	3.150	.0290
Zn	47.6	9272	3.400	.0314
Mn	42.6	8568	1.800	.0154
Blast	46.4	7108	2.600	.0187
Significance	NS	NS	**	**
BLSD			.435	.0056
C.V. (%)	10.1	18.7	17.3	23.0

Table 6. Wheat yields on organic soils as affected by micronutrients in combination with copper at the East Polk county location in 1977.

Material	Bu/A	lbs D.M./A	ppm Cu (whole plant)	Cu Uptake (lbs Cu/A)
Control (Cu)	33.0	8312	.950	.0076
Fe	36.0	8818	1.675	.0147
Zn	40.6	9654	1.475	.0144
Mn	37.4	8324	1.100	.0093
Blast	39.6	9292	1.625	.0153
Significance		+	N.S.	+
BLSD	4.4	1059 (.10)		.006 (.10)
C.V. (%)	7.3	8.2	30.8	34.8

Table 8. Emmission spectrograph analysis of whole plant material on the residual copper trial at Roseau County location in 1977

Treatment lbs Cu/A	%P	%K	%CA	%MG	PPM AL	PPM FE	PPM NA	PPM MN	PPM ZN	PPM CU	PPM B
0	.534	1.60	.452	.499	22.97	108.13	124.80	76.12	87.63	.18	7.21
3	.272	1.37	.274	.318	13.55	54.34	71.01	42.60	41.84	.73	4.33
6	.257	1.42	.267	.299	16.87	53.56	47.46	47.58	34.84	1.80	4.66
12	.285	1.38	.256	.289	15.72	53.37	60.35	52.52	36.20	1.05	4.63
24	.284	1.53	.255	.270	16.02	50.60	63.21	43.92	37.59	1.51	4.27
48	.293	3.54	.248	.284	16.21	56.12	72.63	44.17	43.40	1.13	4.25
96	.240	1.14	.265	.298	16.63	54.54	49.52	49.93	40.70	1.33	5.07
192	.274	1.26	.285	.319	18.32	54.11	79.94	53.18	42.75	1.70	4.93
Significance	**	N.S.	**	**	**	**	N.S.	*	**	**	**
BLSD	.049		.027	.032	4.01	8.14		18.99	6.69	.83	1.26
C.V.	15.4	82.6	10.3	7.4	15.3	14.4	48.9	22.8	16.4	44.9	17.1

Table 7. Emmission spectrograph analysis of whole plant material on the micronutrient trial at the Roseau County location in 1977

Treatment	%P	%K	%CA	%MG	PPM AL	PPM FE	PPM NA	PPM MN	PPM ZN	PPM CU	PPM B
Control (Cu)	.238	1.09	.233	.275	19.30	47.59	76.97	42.87	33.86	1.03	3.41
Fe	.217	1.04	.254	.286	20.71	44.33	101.56	43.32	29.00	3.03	3.61
Zn	.221	3.33	.264	.292	24.36	44.76	66.95	50.26	33.59	3.21	4.33
Mn	.209	1.22	.269	.293	27.04	47.55	64.28	41.06	31.37	1.79	4.54
Blast	.229	3.14	.199	.249	16.63	42.37	65.13	42.23	33.56	2.45	3.29
Significance	+	N.S.	*	+	+	N.S.	N.S.	N.S.	N.S.	**	+
BLSD	.020		.044	.032	7.09					0.84	0.95
C.V.	6.1	146.6	11.1	7.8	22.7	6.9	37.9	16.0	10.1	16.0	17.2

VARIETAL SCREENING OF WHEAT, BARLEY AND OATS WITH AND WITHOUT COPPER AT TWO LOCATIONS IN 1977.

L. J. Smith, G. W. Wallingford, R. K. Severson

Two experimental locations were established in 1977 in Roseau and East Polk counties to evaluate the yields of a number of different varieties of wheat, oats and barley as they are affected by no copper vs. 12 pounds of actual copper per acre. The yield data for the two locations are given below.

Varietal screening of wheat, oats and barley with and without copper at two locations in 1977.

Variety	Roseau County		East Polk County	
	Cu	NoCu	Cu	No Cu
Wheat				
Era	23.7	0	33.8	0
Kitt	28.5	0	38.2	0
Olaf	28.5	0	30.7	0
1809	30.4	0	33.1	0
Ellar	30.7	0	42.0	0
Glenlea	23.0	0	-	-
Waldron	32.5	0	40.5	0
Prodax	26.1	0	26.6	0
Barley				
Larker	16.1	1.5	22.8	0
Beacon	37.1	20.8	-	-
Manker	35.4	34.1	45.2	3.8
Bonanza	18.4	5.3	34.3	0
Oats				
Nobel	36.9	8.3	40.1	9.7
Hudson	41.6	0	18.5	0
Dal	23.2	0	9.5	0
Lodi	26.5	0	6.4	0

CORN FERTILITY IN NORTHWESTERN MINNESOTA

G. W. WALLINGFORD AND R. K. SEVERSON

The area of corn production in Minnesota is moving steadily northward. Most corn in this area is grown on the coarse-textured soils east of the Red River Valley basin. Research on nitrogen, phosphorus, and potassium fertility of corn has been very limited in this area.

Two experimental locations were established in 1977 in Norman County north and east of Ada. The experimental design used in 1976 was followed again in 1977. The studies include a nitrogen rate study, a phosphorus rate and material study and a potassium rate study. A randomized complete block design with four replications was used. All fertilizer materials were applied per plant and incorporated. The nitrogen and potassium materials were urea and potassium cloride. The phosphorus rates were duplicated by using both triple superphosphate and a nitrogen-polyphosphate solution (10-34-0) as phosphorus materials. The fertilizer was applied on April 27 at the Berglind location and May 4 at the Gill location. Planting was done within one week after fertilizer applications were made. At the Berglind farm, the same location was used in 1977 as was used in 1975 and 1976 and the treatments were superimposed on the exact same plot area. The plots were hand harvested on September 21 at both locations by harvesting two twenty-foot sections of each plot.

Results

There were no significant differences due to treatment at either location in the phosphorus and potassium studies (Tables 1 and 2). In the nitrogen study, the Gill site had no significant yield differences but the Berglind site showed a yield response with the addition of twenty pounds of nitrogen.

Table 1. Corn yields as influenced by nitrogen, phosphorus and potassium at the Berglind Farm, Ada, Minnesota in 1975, 1976 and 1977

N Rate LBS/A	1975	1976	1977	P Rate LBS P_2O_5/A	1975	1976	1977	K Rate LBS K_2O/A	1975	1976	1977
0	39.4	59.3	34.4	0	91.2	84.9	93.4	0	96.1	94.9	109.1
20	53.3	67.4	57.5	20 TSP	77.0	83.6	94.0	40	82.6	95.7	102.5
40	56.5	69.5	66.3	20 POLY	90.0	87.3	100.7	80	97.4	97.9	109.8
60	54.8	65.6	76.7	40 TSP	69.5	85.0	101.8	120	86.0	95.2	116.5
80	86.0	80.2	93.6	40 POLY	76.1	82.7	110.5	160	90.9	99.1	103.7
100	66.4	85.9	98.2	60 TSP	85.4	92.7	109.8				
				60 POLY	93.5	83.6	103.9				
				80 TSP	64.8	86.9	100.5				
				80 POLY	72.1	88.0	89.4				
Significance	*	**	**		N.S.	N.S.	N.S.		N.S.	N.S.	N.S.
BLSD	27.1	14.2	16.5								
C.V.(%)	29.2	12.6	16.4		25.1	9.2	12.5		14.5	6.5	13.3

Table 2. Corn yields as influenced by nitrogen, phosphorus and potassium at the Gill Farm, Ada, Minnesota in 1976 and 1977.

N Rate LBS/A	1976	1977	P Rate LBS P_2O5/A	1976	1977	K Rate LBS K_2O/A	1976	1977
0	64.8	65.6	0	78.9	66.4	0	83.8	57.3
20	77.3	67.4	20 TSP	80.9	67.3	40	74.2	53.1
40	65.3	74.7	20 POLY	82.9	61.6	80	76.5	67.0
60	70.0	69.1	40 TSP	81.6	52.9	120	77.3	67.2
80	79.0	70.2	40 POLY	74.5	67.2	160	83.1	64.8
100	92.2	75.1	60 TSP	75.0	70.9			
			60 POLY	81.5	68.0			
			80 TSP	72.4	57.8			
			80 POLY	84.7	62.4			
Significance	*	N.S.		N.S.	N.S.		N.S.	N.S.
BLSD	16.1							
C.V.(%)	13.5	14.7		15.4	18.4		10.7	18.0

Fertilization of Annual Canarygrass

G. L. Malzer, W. Wallingford and R. Severson

In many cases the nutrient requirements for annual canarygrass are not well defined. It is believed that the nutrient requirement would be similar to those of barley, oats and other small grains, and the current fertilizer recommendations made by the University of Minnesota for annual canarygrass are based on this assumption. The objectives of this study were to: 1) investigate the nitrogen, phosphorus and potassium requirement of annual canarygrass and, 2) compare yield responses and optimum rates of fertilization for annual canarygrass with current soil test recommendations.

Experimental Procedure

A total of five experiments have been established to study the preceeding objectives--three in 1976 and two in 1977. Due to dry weather, poor stands, and inadequate weed control in 1976 no information was obtained. One location in 1977 was lost to severe volunteer wheat infestations. The data presented comes from the Bengston location in Kittson county.

Eighteen treatments including a check (no fertilizer) five levels of nitrogen (0, 40, 80, 120 and 160 # N/A as ammonium nitrate), three levels of phosphorus (0, 40, and 80 # P_2O_5/A) and two levels of potassium (0 and 100 # K_2O/A) were combined into a modified factorial arrangement with four replications into a randomized complete block design.

Treatments were applied as broadcast applications on April 22 and incorporated prior to seeding. Forage samples were taken from each plot on July 26 (soft dough stage), field wts recorded, and samples removed for moisture determination and analytical analysis for nitrogen, phosphorus and potassium concentrations. Seed yields were taken on September 16 by harvesting with a plot combine representive areas from each plot.

Results

Soil tests taken from the areas prior to fertilization indicated a 0-2 ft. nitrate test of 70, extractable phosphorus test of 29, an exchangeable potassium test of 600 + with a soil pH of 7.3. Current fertilizer recommendations for annual canarygrass under this condition would call for broadcast applications of 30 # N/A, 30 # P_2O_5/A and no additional potassium.

Seed yields, forage dry matter production and nutrient uptake for the location in Kittson county are presented in Tables 1 and 2. Seed yields were increased substantially with the addition of 40 # N/A. Nitrogen rates greater than 40 # N/A significantly depressed seed yields. These depressions in seed yield may be the result of several factors. High nitrogen fertilization rates stimulated forage dry matter production (Table 2) thus stimulating vegetative growth, increasing lodging problems and possibly decreasing seed set. Considerable variations were also noted in maturity due to fertilizer treatments. If the fertilizer treatments influenced the date of flowering to coincide with dry hot weather it is possible that yield reductions may have resulted in this manner.

Forage yields associated with crop production can often times give a good indications of not only seed yields but with elemental analysis can provide useful information concerning nutrient uptake and/or nutrient requirements for the crop. The nutrient uptake associated with 700-900 # of seed productions ranged from 35-70 # N/A, 8-11 # P/A and 75-150 # K/A. Highest removal of nutrients, however, may or may not coincide with highest seed production. One nutrient may also have an influence on another uptake. As an example, increasing rates of nitrogen fertilizer stimulated potassium uptake even though added potassium had no influence on yield.

In general, soil test results predicted the optimum rates of fertilization for the location investigated in 1977. Yields obtained in 1977 were, however, lower than desired. The nutrient requirements and optimum fertilization of annual canarygrass and it predictability with the use of soil tests at higher production levels remains to be investigated.

Table 1. Seed yields, nitrogen concentration and nitrogen removal by annual canarygrass as influenced by 18 fertilizer treatments. Kittson Co -- 1977

Fertilizer Treatment			Seed Parameters		
N	P_2O_5	K_2O	Yield	N content	N Removal
--------#/A---------			#/A	%	#/A
0	0	0	673	2.46	16.4
0	40	0	729	2.48	18.0
0	80	0	688	2.62	18.0
0	80	100	764	2.59	18.6
40	0	0	783	2.78	18.2
40	40	0	829	2.64	19.8
40	80	0	858	2.73	18.6
40	80	100	871	2.66	20.3
80	0	0	518	3.15	22.4
80	40	0	685	2.96	20.6
80	80	0	588	2.89	18.8
80	80	100	630	2.87	21.2
120	0	0	487	3.06	21.0
120	40	0	566	3.12	21.1
120	80	0	589	3.08	19.4
120	80	100	483	3.15	24.0
160	80	0	465	3.18	21.7
160	80	100	465	3.13	25.0
Signif.			**	**	*
BLSD .05			246	.20	7.4
Factorial Arrangement					
Nitrogen Rate - #/A					
		0	697	2.52	18.5
		40	824	2.72	22.2
		80	597	3.00	17.6
		120	580	3.09	17.6
Signif.			**	**	*
BLSD .05			129	.10	3.5
Phosphorus Rate # P_2O_5/A					
		0	615	2.86	17.1
		40	702	2.80	19.4
		80	706	2.83	19.7
Signif.			NS	NS	NS
BLSD .95					

Table 2. Dry matter production, and nutrient uptake by annual canarygrass forage at the soft dough stage as influenced by 18 fertilizer treatments. Kittson Co -- 1977

Fertilizer Treatment			Dry Matter Production	Nutrient Uptake		
N	P_2O_5	K_2O		N	P	K
--------#/A--------			---------#/A---------			
0	0	0	4460	33.3	9.5	104.4
0	40	0	4420	40.2	11.4	110.2
0	80	0	3050	27.5	8.1	86.6
0	80	100	3550	32.7	8.0	75.5
40	0	0	3900	37.2	8.4	119.6
40	40	0	4480	41.3	10.2	142.2
40	80	0	4650	40.3	10.8	138.8
40	80	100	4440	48.3	11.3	135.2
80	0	0	4560	56.8	9.9	147.0
80	40	0	3910	49.4	9.4	126.1
80	80	0	3810	40.2	9.0	120.0
80	80	100	3770	45.4	9.2	107.8
120	0	0	4770	70.2	10.9	143.7
120	40	0	4610	56.0	9.1	148.1
120	80	0	4530	59.3	11.1	133.3
120	80	100	3930	56.8	10.1	145.4
160	80	0	3690	56.6	9.3	113.5
160	80	100	3850	57.2	8.8	126.1
Signif.			*	**	NS	**
BLSD .05			1130	19.0		41.2
Factorial Arrangement						
Nitrogen Rate #/A						
		0	3980	33.7	9.7	100.4
		40	4350	39.6	9.8	133.6
		80	4090	48.8	9.4	130.9
		120	4640	61.9	10.4	141.7
Signif.			*	**	NS	**
BLSD .05			440	7.9		17.7
Phosphorus Rate # P_2O_5/A						
		0	4420	49.4	9.7	128.7
		40	4360	46.7	10.0	131.6
		80	4010	41.8	9.8	119.6
Signif.			+	NS	NS	NS
BLSD .05			330			

Eighteen Years of Field Experimentation with Nitrogen Source, Placement, and Time of Application to a Webster Loam Near Lamberton.

G. L. Malzer, W. W. Nelson, and R. Munter

(Annual reports of this experiment have been reported in Soil Series 74 through 97 and some of this information will not be included here).

The fertilizer treatments have now been annually applied to the same plot areas for 18 years. After ear corn removal and stalk cutting, the fall plowdown N treatments are broadcast on their respective plots and the entire area is then plowed to an approximate 12 inch depth. The fall surface N treatments are then broadcast, with no further working of the plowed area. Each plot is 20' x 77.5' and the 4 treatment replications are arranged in a randomized block.

Spring N treatments are broadcast before seedbed preparation late in April or in early May. The corn is drilled in 30" rows to produce approximately 20,000 plants/A, using a banded starter fertilizer of 8-24-12 at the rate of 180 lbs. over the entire experimental area, thus supplying an additional 14 lbs. N/acre to all plots. Herbicides and insecticides are also annually applied. Nitrogen sidedressing treatments are broadcast in June. Nitrogen concentrations present in the sixth or "index" leaf at silking were determined and are reported in Table 1.

Growing conditions in 1977 were considerably better than have been experienced over the past several years and the yields obtained in 1977 were among the highest yields obtained during the eighteen years of the experiment. This following a year in which severe drought restricted growth to such an extent that no yields were taken from the plot area in 1976. Ear corn was harvested on September 29 of this year. Yields and 6th leaf nitrogen concentrations are presented in Table 1.

Yields obtained in 1977 were excellent, with the check plots averaging over 140 bu/A/ No significant yield increases were obtained with nitrogen rates over 40 # N/A/ This is at least partically the result of the poor previous year and anticipated nitrogen carry-over.

SEVENTEEN YEAR AVERAGE

The average grain yields for the 18 years of this experiment are shown in Table 2. When only 40 lbs. of N/A was fall applied, surface application was slightly more effective than plow down with no differences between N sources. Plowing down 80 lbs. of N/A in the fall was much more effective than the lower N rates and approached the yields that were obtained with the highest treatment of fall applied N. The results from spring surface applied N were equivalent to (fall surface) or better than (fall plow down) the same rate of N applied in the fall. Side dressing N produced grain yields similar to those of the same rates of spring applied N. The heaviest side dressing treatments were equally effective as the rates plowed down the previous fall.

GENERAL CONCLUSIONS

1. Urea is as effective as ammonium nitrate for the production of corn on these medium textured non-calcareous soils.

2. Late fall surface applied N is at least equal to that plowed down, but where N fertilization rates are relatively low, spring or side-dressing N treatments appear more effective.

3. Where corn is grown annually on these soils good yields can be maintained with annual applications of 100 lbs N/A providing adequate amounts of P and K are also supplied. At this rate of application most of the N will be removed in the grain leaving relatively small amounts to be lost to the environment.

Table 1. Average N in sixth corn leaf and grain yield @ 15.5% moisture, from a Webster loam fertilized annually with NH_4NO_3 or urea (4 replications).

N applied annually in lbs/A[1]	% N 6th Leaf	Bu/A @ 15.5% Moisture				
		I	II	III	IV	Ave.
Check	2.46	146.9	141.1	128.1	148.7	141.2a
40-NH_4NO_3-fpd[2]	2.72	145.1	142.2	157.8	135.4	145.1ab
40-urea-fpd	2.73	167.6	154.4	167.8	171.1	165.2b
40-NH_4NO_3-fpd[3]	2.57	147.9	149.8	153.5	146.4	149.4ab
40-urea-fps	2.74	152.4	173.0	150.3	151.3	156.8ab
80-NH_4NO_3-fpd	2.72	143.9	163.0	161.0	160.2	157.0ab
80-urea-fpd	2.76	159.4	145.2	136.3	143.2	146.0ab
160-NH_4NO_3-fpd	2.85	149.1	162.5	158.0	129.4	149.8ab
160-urea-fpd	2.76	178.6	171.6	146.2	155.6	163.0b
40-NH_4NO_3-std[4]	2.62	149.2	156.2	171.1	163.3	160.0ab
40-urea-std	2.74	160.6	164.7	151.5	183.8	165.2ab
80-NH_4NO_3-std	2.78	166.3	178.4	151.0	155.9	162.9b
80-urea-std	2.80	175.9	156.4	151.9	164.7	162.2b
40-NH_4NO_3-sd[5]	2.63	139.4	152.0	165.4	158.6	153.9ab
40-urea-sd	2.66	176.8	159.3	159.6	165.9	165.4b
80-NH_4NO_3-sd	2.74	142.1	172.9	180.4	157.2	163.2b
80-urea-sd	2.74	153.9	156.4	180.0	160.8	162.8b
160-NH_4NO_3-sd	2.75	158.8	161.4	165.0	156.0	160.3ab
Significance	NS					*
C.V. (%)						7.1
BLSD (0.05)						20.9

[1]The entire area received an additional 14 lbs N/A as starter fertilizer annually (8-24-12 @ 180#/A).

[2]fpd -- fall plow down [3]fps -- fall plow surface [4]std -- spring top dress [5]sd -- side dress

*Any letter(s) different from another letter in a column indicates a significant difference between the means at the 5% level.

Table 2. Yields of ear corn during 18 years on a tiled Webster loam near Lamberton with annual applications of NH_4NO_3 or urea nitrogen at different rates, times, and placement. (Average of 4 replications)

N applied annually in lbs/A[1]	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
	Ear corn yield in bushels per acre									
Check	49.5	88.2	26.1	132.6	72.9	33.1	11.1	53.4	102.4	92.8
40 NH_4NO_3-fpd[2]	42.3	87.5	30.9	148.6	88.3	34.9	26.8	75.7	131.6	109.3
40 Urea - fpd	55.1	78.2	29.1	148.8	100.3	38.8	19.8	86.9	132.5	124.5
40 NH_4NO_3-fps[3]	49.0	96.7	29.6	140.1	101.5	45.6	24.3	75.1	135.2	124.6
40 Urea - fps	62.3	101.3	37.0	140.7	84.1	57.4	30.9	87.2	134.0	136.1
80 NH_4NO_3-fpd	67.4	97.9	43.6	149.6	100.8	63.4	47.3	114.3	131.2	146.8
80 Urea - fpd	61.7	76.9	36.7	154.5	104.9	73.0	37.8	117.2	142.6	144.3
160 NH_4NO_3-fpd	69.8	97.9	46.7	147.7	100.9	70.8	38.5	127.4	140.2	158.7
160 Urea - fpd	79.4	112.5	43.5	152.8	112.4	73.5	37.7	121.3	149.9	161.0
40 NH_4NO_3-std[4]	66.2	92.0	45.4	152.2	99.8	63.4	23.7	99.8	128.0	142.0
40 Urea - std	45.4	91.1	31.4	147.6	100.6	59.8	33.8	95.0	140.5	143.4
80 NH_4NO_3-std	59.3	90.0	32.7	149.2	112.5	74.2	49.0	128.3	144.7	159.5
80 Urea - std	57.7	99.1	40.5	149.3	115.7	84.4	41.8	128.6	138.7	155.9
40 NH_4NO_3- sd[5]	63.6	92.6	39.5	148.6	90.4	54.8	38.6	96.8	133.4	142.3
40 Urea - sd	57.7	95.6	24.9	142.3	94.1	48.4	50.4	86.1	132.2	143.3
80 NH_4NO_3- sd	50.4	98.4	46.7	140.7	113.0	68.1	43.8	101.6	137.7	140.3
80 Urea - sd	76.9	86.4	48.2	143.8	121.4	64.7	47.3	117.0	146.9	166.2
160 NH_4NO_3 - sd	40.7	97.4	77.7	151.7	109.5	77.6	51.4	120.2	141.5	148.3
Ave. annual corn yield in bu/A	58.6	93.3	39.4	147.5	101.3	60.3	37.8	101.8	135.7	140.9

[1] The entire area received an additional 14 lbs N/A as starter fertilizer annually (8-24-12 @ 180 #/A).

[2] fpd -- fall plow down [3] fps -- fall plow surface [4] std -- spring topdress [5] sd -- sidedress

Table 2 (continued). Yields of ear corn during 18 years on a tiled Webster loam near Lamberton with annual applications of NH_4NO_3 or urea nitrogen at different rates, times, and placement. (Average of 4 replications).

N applied annually in lbs/A[1]	1970	1971	1972	1973	1974	1975	1976	1977	17 year average
					Ear corn yield in bushels per acre				
Check	85.7	40.8	75.6	69.2	53.4	58.3	No	141.2	69.8
40 NH_4NO_3-fpd[2]	96.3	88.7	113.6	92.0	80.5	88.6		145.1	87.1
40 Urea-fpd	120.4	100.7	113.9	101.5	96.9	96.6	Yields	165.2	94.6
40 NH_4NO_3-fps[3]	122.5	81.5	109.9	93.0	88.3	78.2		149.4	90.9
40 Urea-fps	121.2	82.4	106.7	97.8	85.0	78.9	Taken	156.8	94.1
80 NH_4NO_3-fpd	134.7	108.0	143.1	121.7	103.6	89.2		156.9	107.1
80 Urea-fpd	141.4	107.8	140.1	117.9	107.2	96.9		146.0	106.3
160 NH_4-NO_3-fpd	141.7	120.2	147.6	121.0	113.1	90.4		149.8	110.7
160 Urea-fpd	140.4	110.6	151.7	114.9	105.1	82.4		163.0	112.5
40 NH_4NO_3-std[4]	125.6	84.0	117.0	104.0	82.8	88.0		160.0	98.5
40 Urea-std	118.9	94.6	116.5	97.1	94.5	89.0		165.2	97.9
80 NH_4NO_3-std	140.4	122.7	142.7	118.0	92.9	97.6		162.9	110.4
80 Urea-std	146.2	116.0	142.1	117.6	108.5	93.6		162.2	111.6
40 NH_4NO_3-sd[5]	127.1	104.5	136.0	99.1	82.7	91.8		153.8	99.5
40 Urea-sd	117.7	100.5	133.9	103.9	80.4	92.6		165.4	98.2
80 NH_4NO_3-sd	127.7	97.6	124.7	109.4	87.6	95.3		163.2	102.7
80 Urea-sd	140.5	124.4	149.8	124.0	95.6	90.1		162.8	112.1
160 NH_4NO_3-sd	136.9	104.2	150.0	117.1	105.5	91.3		160.3	110.7
Ave. annual corn yield in bu/A	127.0	99.4	128.6	106.6	92.4	88.3		157.2	100.8
Significance									**
C.V. (%)									9.0
BLSD (.05)									6.0

[1] The entire area received an additional 14 lbs N/A as starter fertilizer annually (8-24-12 @ 180 #/A)

[2] fpd -- fall plow down [3] fps -- fall plow surface [4] std -- spring topdress [5] sd -- sidedress

* Any letter(s) different from another letter in a column indicates a significant difference between the means at the 5% level.

WEST CENTRAL EXPERIMENT STATION - MORRIS

WEATHER SUMMARY - 1977

		Precipitation			Air Temperature			Soil (10 cm) Temperature	
Month	Period	1977	91-yr. av.	Dev. from av.	1977	91-yr. av.	Dev. from av.	1977	10-yr.av.
January	1-31	.82	.67	+ .15	-4.5	8.4	-12.9	10.8	20.7
February	1-28	1.48	.66	+ .82	18.1	12.8	+ 5.3	18.9	23.9
March	1-31	3.65	1.05	+2.60	31.9	26.7	+ 5.2	29.0	29.2
April	1-10	.29	.57	- .28	39.7	38.0	+ 1.7	35.2	
	11-20	1.06	.64	+ .42	57.7	44.3	+13.4	52.4	
	21-30	.55	1.10	- .55	52.8	48.2	+ 4.6	52.2	
Total or av.		1.90	2.31	- .41	50.1	43.5	+ 6.6	46.6	41.4
May	1-10	.26	.78	- .52	59.4	52.0	+ 7.4	60.0	
	11-20	.32	.96	- .64	70.4	55.6	+14.8	69.9	
	21-31	4.90	1.22	+3.68	68.0	59.9	+ 8.1	75.1	
Total or av.		5.48	2.96	+2.52	66.0	56.0	+10.0	68.5	57.1
June	1-10	.20	1.29	-1.09	66.0	63.2	+ 2.8	70.7	
	11-20	1.54	1.24	+ .30	66.6	66.5	+ 0.1	71.8	
	21-30	.98	1.36	- .38	67.8	68.3	- 0.5	74.0	
Total or av.		2.72	3.89	-1.17	66.8	66.0	+ 0.8	72.2	69.3
July	1-10	1.68	1.50	+ .18	70.8	70.0	+ 0.8	78.3	
	11-20	1.15	1.04	+ .11	74.0	71.4	+ 2.6	78.8	
	21-31	.69	1.03	- .34	70.5	71.6	- 0.9	78.5	
Total or av.		3.52	3.57	- .05	71.7	71.0	+ 0.7	78.5	76.7
August	1-10	.44	1.06	- .62	64.9	70.4	- 5.5	73.6	
	11-20	1.33	.92	+ .41	60.9	69.3	- 7.4	67.1	
	21-31	1.43	.97	+ .46	64.8	66.9	- 2.1	67.9	
Total or av.		3.20	2.95	+ .15	63.6	68.8	- 5.2	69.5	73.9
September	1-30	3.50	2.19	+1.31	58.6	59.1	- 0.5	61.3	61.5
October	1-31	3.25	1.59	+1.66	45.4	47.4	- 2.0	46.0	47.8
November	1-30	3.13	.94	+2.19	26.9	29.8	- 2.9	32.2	33.6
December	1-31	1.43	.67	+ .76	10.2	15.5	- 5.3	15.9	23.4
April-August Growing Season		16.82	15.68	+1.14	63.6	61.1	+ 2.5	67.2	63.8
January-December Annual		34.08	23.45	+10.63	42.2	42.1	- 0.1	45.9	46.7

RESIDUAL EFFECT OF HEAVY APPLICATIONS OF ANIMAL MANURES ON CORN GROWTH AND YIELD AND ON SOIL PROPERTIES

West Central Experiment Station - Morris

S. D. Evans, P. R. Goodrich, R. C. Munter, and R. E. Smith

The experiment initiated in 1970 was continued. Treatments and results in previous years are given in Soil Series 88, 89, 91, 95, 97, and 99. Manure was applied in 1970 and 1971 only. Fertilizer has been compared to the fertilized checks each year. In 1977 the sub-plot treatments were dropped.

I. Planting Information

Twenty-four rows of corn (var. Dekalb XL12) were planted in each plot on May 10, 1977. Furadan at 10 lbs./acre (1 lb./acre active ingredient) was applied to the entire area. Starter fertilizer consisting of 154 lbs./acre of 7-26-26 was applied to the fertilized treatment only. Nitrogen in the form of ammonium nitrate was applied to the fertilized plots to provide 110 lbs./acre of N on October 20, 1976. All plots were plowed on October 20, 1976. Lasso (2) and Bladex (2) were applied broadcast on May 11, 1977. The plots were sprayed with 2,4-D LV ester @ 1/2 lb./acre on June 20, 1977.

II. Soil Sampling and Analysis

A. 1976 measurements

The results of the analysis of the soil samples collected to a depth of 4 feet are given in Table 1.

1. $(NO_3 + NO_2)$-N - The SB and LB treatments continue to have higher levels than FE. The LH treatment is essentially the same as FE. For all treatments, levels in the 0 to 1-foot and 1- to 2-foot layers are higher than in the fall of 1975, while levels in the 2- to 3-foot and 3- to 4-foot layers are slightly lower.

2. Available P - Levels in the manure treated plots are much higher than in FE.

3. Extractable K - Levels in the 0 to 1-foot layer of the manure treated plots are much higher than FE. Below 1 foot the levels are essentially equal.

4. Extractable Na - The manure treated plots have higher levels of Na at all depths. The levels in 1976 are very similar to those obtained a year earlier in 1975.

5. Chloride - The levels in the manure treated plots have decreased substantially in the last year. However, the manure treated plots still have measureably higher chloride levels than FE.

6. Electrical conductivity - There have been no consistent changes in E.C. the last year. The manure treated plots continue to have slightly higher readings than FE.

B. 1977 measurements

The soils were sampled to a depth of 4 feet in the fall of 1977 but the results are not yet available.

III. Plant Tissue Analysis

A. Early whole corn plants (Table 2)

The manure treatments were significantly higher in K and lower in Mg than CK and FE. The SB and LB treatments were significantly higher in P than LH, CK, and FE. The FE and manure treated plots were not significantly different in Ca, Fe, Mn, and B. The Zn level in LB was significantly higher than in CK, SB, and LB.

B. Corn leaves at silking (Table 3)

The manure treatments were significantly higher in K and lower in Mg than CK and FE. The SB and LB treatments were significantly higher in P than all other treatments. The Zn levels in FE and LH were significantly higher than in all other treatments.

IV. Field and Plant Measurements (Table 4)

A. Early plant dry weight - The manure treated plots were significantly heavier than CK and FE.

B. Stalks broken below ear - The SB and LB treatments had the highest level of stalk breakage.

C. Ear moisture at harvest - The CK and FE treatments were wetter than the manure treatments.

D. Grain yield - There was a lot of variation and no significant differences, but the manure treated plots continue to yield nearly as well as the FE treatment.

E. Silage yield - The LB treatment was significantly higher yielding than CK, SB, and LH treatments.

V. Summary

The effects of the manure treatments applied in 1970 and 1971 are still quite apparent in soil and plant measurements. In most cases soil levels of nutrients continued to decrease, but the dry season in 1976 slowed the change. Plant analysis in 1977 again showed large effects on some nutrients, but all levels are in the satisfactory range. It appears that grain yields on the manure treated plots are starting to drop slightly below those on the fertilized plots.

Table 1. Effects of high rates of manure and commercial fertilizer six years (fall 1976) after application on the NO_3-N, available P, extractable Na, Cl, and electrical conductivity of a Tara soil profile.

Depth	CK	FE	SB	LB	LH
			$(NO_3 + NO_2)$-N, ppm		
0-1'	9.7	42.6	64.7	88.8	35.4
1-2'	0.9	53.6	94.5	184.3	62.3
2-3'	3.1	43.5	70.7	143.3	53.6
3-4'	5.8	9.3	39.2	93.3	27.7
			Available P, ppm		
0-1'	8.7	22.4	108.4	188.0	82.1
			Extractable K, ppm		
0-1'	141	157	422	365	262
1-2'	109	131	122	138	108
2-3'	97	103	100	96	97
3-4'	99	107	115	98	103
			Extractable Na, ppm		
0-1'	11.1	15.2	69.1	91.6	38.9
1-2'	17.5	29.9	129.3	166.0	65.5
2-3'	30.0	37.8	60.9	104.9	43.8
3-4'	34.0	39.7	48.7	65.5	40.9
			Cl^-, ppm		
0-1'	4.9	8.6	10.3	12.6	5.3
1-2'	2.9	15.0	43.1	60.1	16.8
2-3'	3.0	23.3	36.6	46.5	15.7
3-4'	2.6	3.9	30.3	34.2	7.4
			Electrical Conductivity, mmhos/cm		
0-1'	.245	.331	.477	.570	.303
1-2'	.220	.454	.696	1.030	.468
2-3'	.206	.421	.544	.765	.393
3-4'	.203	.252	.390	.573	.277

Table 2. Summary of analysis of early corn plant samples - 1977.

Treatment	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%				ppm				
CK	.43	2.48	.74	.75	2777	38.0	9.8	133	15.5
FE	.48	4.48	.57	.61	1846	52.3	7.4	107	8.7
SB	.71	5.68	.43	.40	1060	40.8	12.2	90	7.7
LB	.82	5.76	.46	.40	1037	39.6	5.1	75	9.9
LH	.59	5.21	.50	.44	1380	61.5	6.2	86	7.7
Significance:	**	**	*	**	**	*	NS	*	+
BLSD (.05)	.16	.81	.16	.10	798	14.6	-	36	-

Table 3. Summary of analysis of corn leaves at silking - 1977.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
CK	2.99	.32	1.68	.66	.66	327	18.2	10.8	103	7.4
FE	3.13	.36	2.22	.64	.61	302	24.9	7.2	75	8.5
SB	2.99	.58	2.80	.67	.42	315	16.7	9.3	117	8.6
LB	3.02	.67	2.93	.65	.39	558	18.0	5.9	80	8.8
LH	3.05	.40	2.63	.72	.40	358	23.7	6.6	94	7.5
Significance:	NS	**	**	NS	**	NS	**	NS	NS	NS
BLSD (.05)	-	.06	.28	-	.09	-	3.4	-	-	-

Table 4. Summary of plant measurements - 1977.

			Harvest Measurements		Grain		Silage		
Trt.	Early plant height inches	Early plants (10) dry wt. grams	Root lodged 30° or more %	Stalks broken below ear %	Ear moisture at harvest %	Yield @ 15.5% M. bu/A	Dry matter at harvest %	Silage yield (D.M.) lb/A	Ear wt. ÷ silage wt. %
CK	18.6	40.0	1.1	1.1	35.6	84.7	52.4	10041	59.9
FE	26.5	87.9	3.8	1.2	32.4	110.3	50.3	11917	59.1
SB	29.0	116.1	3.0	11.7	25.0	95.1	56.6	10374	55.9
LB	31.4	134.2	3.1	15.5	25.8	101.5	58.1	12940	55.8
LH	30.1	119.2	3.3	3.9	27.4	100.2	57.5	10713	54.2
Signif.:	NS	**	NS	+	**	NS	NS	*	NS
BLSD(.05)	-	19.3	-	-	2.4	-	-	1858	-

MANURE RATE STUDY

West Central Experiment Station - Morris

S. D. Evans, P. R. Goodrich, R. C. Munter, and R. E. Smith

The experiment initiated in 1972 was continued. Solid and liquid beef manures were applied and the effects were compared against check plots. Treatments and results from previous years are given in Soils Series 91, 95, 97, and 99.

I. Manure Application and Analysis

Manure was applied for the fifth time in the fall of 1976. Samples were taken at the time of application and were analyzed by the Animal Waste Laboratory in the Department of Agricultural Engineering. The amounts applied are given in Table 1. The chemical analyses of each manure are given in Table 2. Using these figures, the amount of each nutrient applied to each manure treatment was calculated and is given in Table 3.

II. Planting Information

The plots were planted to Dekalb XL12 on May 10, 1977. Furadan was applied at 10 lbs./acre (1 lb./acre active ingredient) to one-half of each main plot and the other half was left untreated. Starter fertilizer (consisting of 154 lbs./acre of 7-26-26) was used only on the fertilized treatment. Nitrogen had been applied prior to plowing to the fertilized treatment at a rate to give 110 lbs./acre of N. Lasso (2) + Bladex (2) were applied broadcast on May 11, 1977. The corn was sprayed with 2,4-D LV ester on June 20, 1977.

Table 1. Actual amounts of manure applied in the fall of 1976.

Treatment	Dry Weight	Wet Weight
	- tons/acre -	
SB1	6.994	33.333
SB2	13.989	66.667
SB3	20.983	100.000
LB1	2.026	18.844
LB2	4.051	37.687
LB3	6.077	56.531

Table 2. Average* analysis of manure samples applied in the fall of 1976.

Measurement	Unit†	Type of Manure SB	LB
pH	-	8.6	7.0
Total solids	%	21.0	10.7
Electrical conductivity	mmhos/cm	1.15	3.43
Total Kjeldahl N	%	4.6	7.1
NH_4^+-N	%	2.1	5.0
Organic N	%	2.5	2.0
Phosphates (PO_4-P)	%	3.23	3.73
Cl	%	6.75	1.48
Emission Spectograph			
P	%	2.39	1.34
K	%	7.01	2.84
Ca	%	3.02	1.66
Mg	%	1.17	.58
Na	%	2.78	.99
Fe	ppm	2131	898
Al	ppm	2760	356
Mn	ppm	387	119
Zn	ppm	255	105
Cu	ppm	172	23
B	ppm	76	29

* Values based on three samples each of SB and LB manure.
† Dry weight basis.

Table 3. Nutrients applied in 1976 for the 1977 crop year.

Treatment	SB1	SB2	SB3	LB1	LB2	LB3
			- lbs./acre -			
Total Kjeldahl N	643	1288	1930	288	575	863
NH_4-N	294	588	881	203	405	608
Org-N	350	699	1049	81	162	243
PO_4-P	452	904	1356	151	302	453
Cl	944	1888	2833	60	120	180
P	334	669	1003	54	109	163
K	981	1961	2942	115	230	345
Ca	422	845	1267	67	135	202
Mg	164	327	491	23	47	70
Na	389	778	1167	40	80	120
Fe	30	60	89	3.6	7.3	10.9
Al	39	77	116	1.4	2.9	4.3
Mn	5.4	10.8	16.2	0.5	1.0	1.4
Zn	3.6	7.1	10.7	0.4	0.9	1.3
Cu	2.4	4.8	7.2	0.09	0.19	0.28
B	1.1	2.1	3.2	0.12	0.23	0.35

III. Soil Sampling and Analysis

A. 1976 measurements

The results of some of the analyses are given in Table 4. Other measurements made were Bray #1 P, Na, and K. These latter measurements are not included in this report.

1. $(NO_3 + NO_2)$-N - The levels were much higher in the top foot of all treatments compared to a year earlier. This is probably due to the very warm season in 1976 and the poor crop. In the 3- to 4-foot zone only SB3 showed a measureable increase from a year earlier.

2. Chloride - In general, levels in the top 3 feet of the manure treated plots have increased greatly over a year earlier. In the 3- to 4-foot layer, changes are very small.

3. Conductivity - With SB, levels in the top 2 feet are much higher than a year earlier, while in LB levels in the top 3 feet are higher.

B. 1977 measurements

The soils were sampled to a depth of 10 feet in the fall of 1977 but the results are not yet available.

Table 4. Effect of two types of beef cattle manure and commercial fertilizer (fall 1976) on the $NO_3 + NO_2)$-N content, chloride content, and conductivity.

Depth	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3
				$(NO_3 + NO_2)$-N				
0-1'	24.1	47.1	110.5	244.3	360.0	74.8	148.0	205.7
1-2'	1.2	34.6	29.6	113.7	147.7	40.5	96.6	146.0
2-3'	8.1	21.6	23.0	56.1	81.6	25.7	26.6	72.0
3-4'	7.8	30.3	13.8	22.9	41.9	13.6	16.1	17.2
				Cl, ppm				
0-1'	10.3	23.0	73.7	136.9	193.1	40.2	63.8	78.5
1-2'	8.4	18.1	68.8	181.1	177.3	52.7	78.7	117.5
2-3'	14.0	11.5	49.3	103.4	101.8	26.2	26.9	61.2
3-4'	8.6	49.0	19.9	29.6	52.9	12.5	14.0	10.4
				Conductivity (mmhos/cm)				
0-1'	.240	.363	.695	1.188	1.708	.460	.761	.935
1-2'	.257	.322	.378	.753	.858	.384	.621	.798
2-3'	.258	.273	.325	.519	.606	.299	.324	.565
3-4'	.236	.363	.280	.314	.371	.239	.255	.266

IV. Plant Sampling and Analysis

A. Early whole corn plants (Table 5)

1. Phosphorus - All solid beef, LB2, and LB3 treatments were significantly higher in P than FE.

2. Potassium - CK was significantly lower in K than all other treatments.

3. Calcium - All SB treatments were significantly lower in Ca than FE.

4. Magnesium - All manure treatments were significantly lower in Mg than FE.

5. Iron - SB2, SB3, and all LB treatments were significantly lower in Fe than FE.

6. Zinc - Only SB1 and LB1 were significantly lower in Zn than FE.

7. Copper - CK was significantly higher in Cu than all other treatments.

8. Manganese - SB3 was significantly lower in Mn than FE and CK.

9. Boron - All SB treatments, LB2, and LB3 were significantly lower in B than CK.

Table 5. Summary of analysis of early corn plant samples - 1977.

Treatment	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%				ppm				
CK	.47	3.03	.59	.67	2062	44.5	14.7	114	16.5
FE	.46	4.20	.58	.55	1692	47.4	7.6	108	10.8
SB1	.57	5.29	.45	.42	946	30.7	5.5	89	5.7
SB2	.66	4.26	.40	.31	801	43.2	5.4	88	7.2
SB3	.71	5.15	.30	.28	648	44.5	5.1	72	8.1
LB1	.50	4.34	.56	.48	1505	32.9	6.7	108	10.4
LB2	.60	4.31	.55	.46	1101	37.3	7.4	114	7.1
LB3	.63	4.46	.49	.40	1101	43.1	5.1	122	8.1
Significance:	**	**	**	**	*	*	*	*	*
BLSD(.05)	.11	.99	.09	.06	797	12.2	5.2	34	6.8

B. Corn leaves at silking (Table 6)

1. Phosphorus - All SB treatments, LB2, and LB3 were significantly higher in P than FE.

2. Potassium - All SB treatments were significantly higher in K than FE.

3. Calcium - LB2 and LB3 were significantly higher in Ca than FE, while SB3 was significantly lower in Ca than FE.

4. Magnesium - All SB treatments and LB3 were significantly lower in Mg than FE.

5. Manganese - LB2 and LB3 were significantly higher in Mn than FE and CK.

6. Boron - SB3 and LB3 were significantly higher in B than FE and CK.

Table 6. Summary of analysis of leaves at silking - 1977.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
CK	3.22	.36	1.59	.55	.60	298	16.2	9.2	75	6.8
FE	3.25	.34	1.98	.56	.51	285	21.8	9.6	87	6.9
SB1	3.23	.41	2.33	.61	.43	293	18.3	8.1	108	7.2
SB2	2.98	.46	2.51	.56	.32	243	17.7	5.6	101	7.4
SB3	3.28	.58	2.81	.43	.24	274	27.5	13.2	88	10.2
LB1	3.26	.37	1.96	.63	.49	252	17.4	8.4	104	5.7
LB2	3.27	.42	2.06	.75	.47	280	17.3	8.3	132	8.4
LB3	3.40	.48	2.20	.69	.36	277	23.5	6.0	150	9.4
Significance:	NS	**	**	**	**	NS	NS	NS	**	**
BLSD(.05)	-	.07	.23	.11	.08	-	-	-	38	2.0

V. <u>Yield and Plant Measurements</u> (Table 7)

A. Early plant dry weight - LB3 was significantly heavier than FE. All manure treatments were significantly heavier than CK. There were no differences between manure treatments.

B. Silage dry matter - CK was significantly drier than SB3.

C. Grain and silage yields - There were no significant differences between treatments. Also the effect of the insecticide on grain yield was not significant (Table 8).

Table 7. Summary of 1977 plant measurements.

Treatment	Early plant height inches	Early plants (10) dry wt. grams	Harvest measurements: Root lodged 30° or more %	Harvest measurements: Stalks broken below ear %	Grain: Ear moisture at harvest %	Grain: Yield @ 15.5% M bu/A	Silage: Dry matter at harvest %	Silage: Silage yield (D.M.) lb/A	Silage: Ear wt. ÷ silage wt. %
CK	22.0	47.5	2.5	2.6	32.5	110.6	52.4	11196	59.7
FE	25.2	71.4	2.5	1.3	31.0	113.2	49.8	10749	60.5
SB1	28.6	105.0	1.2	1.7	29.3	121.9	51.7	11696	58.3
SB2	28.9	108.4	1.0	3.8	29.5	116.5	48.0	11302	59.5
SB3	27.6	96.2	4.3	3.0	30.3	127.6	45.2	12064	61.1
LB1	25.5	91.2	1.0	2.8	30.4	113.6	52.2	10707	61.6
LB2	29.6	107.7	0.8	3.3	29.7	116.8	51.5	11154	61.1
LB3	28.9	117.5	1.5	4.2	29.4	119.6	50.4	12593	65.0
Significance:	NS	**	NS	NS	+	NS	*	NS	NS
BLSD(.05)	-	40.3	-	-	-	-	6.4	-	-
+ Insecticide	N.M.[1]	N.M.	1.6	3.6	30.2	117.3	N.M.	N.M.	N.M.
- Insecticide	N.M.	N.M.	2.1	2.1	30.3	117.7	N.M.	N.M.	N.M.
Significance:	-	-	NS	NS	NS	NS	-	-	-
Interaction Significance:	-	-	NS	NS	NS	NS	-	-	-

[1] N.M. = not measured on the (-) insecticide treated portion of each main plot.

Table 8. Effect of insecticide on grain yield - 1977.

Main Plot Treatment	Insecticide	Grain Yield bu/A
CK	W	114.1
	W/o	107.2
FE	W	110.6
	W/o	115.7
SB1	W	113.2
	W/o	130.5
SB2	W	116.4
	W/o	116.6
SB3	W	130.9
	W/o	124.4
LB1	W	112.1
	W/o	115.1
LB2	W	119.3
	W/o	114.3
LB3	W	121.6
	W/o	117.6

NITROGEN FERTILIZATION OF WHEAT

West Central Experiment Station - Morris

S. D. Evans, G. L. Malzer, and R. L. Thompson

I. Plot Description and Planting Information

The experiment initiated in 1975 was continued on a new site. The soil type was again Doland silt loam. Prior to plowing in the fall of 1975, 100 lbs. of P_2O_5 and 100 lbs. of K_2O were broadcast. Samples were taken in the spring of 1977 prior to seeding to a depth of 2 feet. The samples averaged 69 lbs. NO_3-N/A. The nitrogen was spread by hand immediately before seeding with a press drill on April 22. The entire experiment was sprayed with Brominal plus on May 20. There was substantial hail damage on the plots on May 29. The plots were harvested on July 26.

II. Yield Results

The 1977 yields are given in Table 1. The varieties were significantly different with Waldron lower yielding than all other varieties. The check plot was significantly lower yielding than the 40-, 70-, and 100-lb. N rates. In general, within varieties the first increment of N gave the largest yield increase. For Era, Olaf, Waldron, and Crosby, the 100-lb. N rate gave the highest yield. However, the recommended N rate (70 lbs./A) gave nearly top yields in all cases.

Table 1. Effect of N rate and variety on yield of wheat at Morris, 1977.

Variety	N Rate - lbs./Acre 0	40	70	100	Average
	- Bu./Acre -				
Era	37.0	39.8	41.5	46.4	41.2
Olaf	33.6	42.3	45.3	47.7	42.2
Kitt	32.5	49.2	46.7	40.7	42.3
Waldron	21.0	28.0	30.9	34.3	28.5
Crosby	37.0	46.0	50.5	53.6	46.8
Botno	40.6	45.7	45.3	41.3	43.2
Average	33.6	41.8	43.4	44.0	

	Significance	BLSD(.05)
Varieties	**	6.6
N Rates	**	2.3
Interaction	**	3.2

III. Protein Results

The protein percentages from the 1977 plots are given in Table 2. Varieties and N rates both significantly affected percent protein. Era had the lowest protein of the hard red spring wheat varieties and Waldron had the highest level. Each increment of N caused a significant increase in percent protein. Within varieties the percentage protein consistently increased with increasing N. There was no interaction between varieties and N rates.

Table 2. Effect of N rate and variety on percent protein of wheat at Morris, 1977.

Variety	N Rate - lbs./Acre 0	40	70	100	Average
			- % Protein -		
Era	13.5	13.8	14.6	16.2	14.5
Olaf	14.0	15.0	15.7	16.4	15.3
Kitt	13.6	15.6	15.3	16.4	15.2
Waldron	16.7	17.2	17.4	18.4	17.4
Crosby	12.5	12.8	13.8	14.9	13.5
Botno	13.2	13.6	14.7	16.1	14.4
Average	13.9	14.7	15.3	16.4	

	Significance	BLSD(.05)
Varieties	**	0.6
N Rate	**	0.5
Interaction	NS	- -

IV. Bushel Weight

The test weight values are given in Table 3. Both variety and N rate significantly affected bushel wieght. Waldron was the lowest test weight hard red spring wheat variety and Olaf had the highest test weight. The two durums were significantly different. Increase in N rate brought about a slight decrease in test weight. Within the varieties Era, Olaf, and Kitt, there was some decrease in bushel weight with increasing N rate.

Table 3. Effect of N rate and variety on test weight of wheat at Morris, 1977.

Variety	N Rate - lbs./Acre 0	40	70	100	Average
			- lbs./bu. -		
Era	58.1	58.3	57.2	57.3	57.7
Olaf	59.2	60.3	59.0	57.8	59.1
Kitt	58.3	57.2	56.9	54.6	56.7
Waldron	55.7	54.5	54.7	55.0	55.0
Crosby	61.2	61.9	62.1	60.9	61.5
Botno	57.3	57.7	56.4	53.5	56.2
Average	58.3	58.3	57.7	56.5	

	Significance	BLSD(.05)
Varieties	**	1.6
N Rates	*	0.9
Interaction	NS	- -

INFLUENCE OF NITROGEN ON ROOT GROWTH AND NITROGEN UTILIZATION BY THREE SMALL GRAIN VARIETIES

G. L. Malzer, R. P. Schoper, C. A. Simkins, R. Heiner and S. Evans

The semi-dwarf varieties of hard red spring wheat account for the major portion of acreage in Minnesota planted to hard red wheat. The advent of these short stemed wheat varieties not only provided improved physical characteristics and a high yield potential, but also provided a plant system which was capable of responding to higher application rates of nitrogen without lodging. The reason why some semi-dwarf wheat varieties (especially Era) appear to be more responsive to nitrogen application is not well understood but it has been suggested that it may be a inter-relationship of a highly efficient rooting system along with its above ground physical characteristics. A trail was, therefore, established to investigate the root growth of different hard red spring wheat varieties as influenced by nitrogen application and to access if below ground parameters could be used in the selection of small grain varieties for efficient nitrogen utilization.

Experimental Procedures

Six treatments including three hard red spring wheat varieties were combined with two nitrogen treatments into a randomized complete block design with three replications and plots established at the West Central Experiment Station at Morris. The three wheat varieties were Chris (medium height), Era (semi-dwarf) and MN 7125 (Experimental semi-dwarf) with the nitrogen treatment to each being either zero or 120 # N/A as ammonium nitrate.

Dry matter production was determined at the "soft-dough" stage of growth and samples collected for nitrogen analysis. Samples for rooting distribution were collected from each plot at the time of forage sampling utilizing a coring technique. Samples were collected from over the row and from in-between the rows to a depth of four feet. Each core was divided into 8-6" increments and each sample consisted of a composite of three cores. The roots were later separated from the soil, photographed and root length determined by utilizing the techniques and equipment at the ARS-USDA research station at Morris, Minnesota. Soil samples were also collected to a depth of four feet at the same time as root harvest, separated into 6" increments and analyzed for nitrate nitrogen and moisture content. Grain yields, nitrogen content, and nitrogen removal was determined at maturity.

General Results

Preliminary soil tests indicated a very high residual nitrate nitrogen test on the experimental site used in 1977 so large difference in nitrogen treatments were not anticipated. No significant difference in dry matter production or grain yields were obtained with either the variety or nitrogen rate applied. Nitrogen removal in the forage and the protein content in the grain were significantly changed with both variety and nitrogen rate. Trends in the rooting patterns of each variety were mixed. When no nitrogen was applied the total root length of Chris and Era were very similar and MN 7125 only slightly higher. When nitrogen was applied, even on those high nitrate containing soils, total root length of Era and MN 7125 decreased while Chris increased slightly. The distribution of roots within the soil profile for MN 7125 was considerably different than the other varieties when no nitrogen was applied. When nitrogen was applied Era appeared to be much more efficient in extracting moisture from the soil than did the other two varieties. Data would suggest that the interaction of the rooting system of different varieties with nitrogen and other environment parameters deserves closer examination.

Table 1. Yield, nitrogen utilization, root length and root distribution of three wheat varieties as influenced by nitrogen fertilization.

Treatment		Forage		Grain			Root Length		Soil	
Variety	N Rate	Dry Matter	N Removal	Yield	Protein	N Removal	Total	Top 2 ft.	Moisture	NO_3^- -N
	# N/A	T/A	#/A	bu/A	%	#/A	0-4 ft. miles/A	% of total	0-2 ft. %	0-2 ft. #/A
Chris	0	1.79	73	41.1	17.1	74	13004	86.4	15.1	248
Chris	120	1.89	84	42.9	17.3	78	13682	83.8	16.7	284
Era	0	1.72	74	49.8	15.0	79	12928	89.5	17.1	242
Era	120	1.76	86	51.4	15.6	84	11308	87.6	15.6	366
MN7125	0	1.64	56	47.6	14.4	72	13797	75.2	16.6	205
MN7125	120	1.90	76	46.8	15.0	74	12326	84.3	16.6	360
Signif.		NS	*	NS	**	NS				
B.L.S.D. (.05)			16		0.2					

CONTINUOUS CORN SILAGE

West Central Experiment Station - Morris

Samuel D. Evans

I. Experimental Description

In 1965 an experiment was initiated on McIntosh silt loam to determine the effect of removal of continuous corn silage and fertilizer application on corn grain and corn silage yields and on soil properties. Rates of fertilizer used were 74 + 48 + 48 ($N + P_2O_5 + K_2O$) and 148 + 96 + 96. All plots received a broadcast application of 10 lbs./acre of zinc as zinc sulfate in the fall of 1965.

II. 1976 Soil Measurements

In the fall of 1976 samples were taken to plow depth in all plots. The results are given in Table 1.

A. Organic matter - No significant differences.

B. Organic carbon - No significant differences.

C. Bray #1 P - Much higher where more fertilizer used.

D. Potassium - Much higher where more fertilizer used; measureably higher where grain only removed.

E. ($NO_3 + NO_2$)-N - Much higher where more fertilizer used.

F. Zinc - Slightly lower where silage harvested at a high fertility level.

G. pH - No significant differences.

Table 1. Effect of 11 years of continuous corn silage on soil properties.

Treatment	Organic matter %	Organic carbon %	Bray #1 P ppm	K ppm	(NO_3+NO_2)-N ppm	Zn ppm	pH
Silage-low fertility	5.590	3.250	14.0	158	30	4.1	7.8
Silage-high fertility	5.494	3.194	32.7	179	76	3.8	7.8
Grain-low fertility	5.145	2.991	16.6	170	22	4.3	7.9
Grain-high fertility	5.237	3.045	33.4	189	66	4.4	7.7
Significance:	NS	NS	**	**	**	*	NS
BLSD(.05)	-	-	5.8	11	28	0.3	-

III. 1977 Operations

In 1977 the variety was Trojan TXS99. Furadan was applied at 1 lb./acre (active ingredient) at planting on April 29. Lasso at 2 lbs./acre and Bladex at 2 lbs./acre were applied broadcast on April 29. A hail storm on May 29 severely damaged the plots and they never fully recovered. Silage yields were taken on September 16 and grain yields on September 29.

IV. Silage Yields - Dry matter; tons/acre.

Treatment	1977 yield	1966-77 yield
Silage, low fertility	4.89	5.24
Silage, high fertility	4.97	5.62
Grain, low fertility	4.70	5.38
Grain, high fertility	5.47	5.81

V. Grain Yields - Bushels/acre @ 15.5% M.

	1977 yield	1966-77 yield
Grain, low fertility	84.66	86.35
Grain, high fertility	81.99	90.36

VI. Check Yields

Yields on an additional unfertilized, unreplicated check adjacent to the experimental area:

	1977 yield	1966-77 yield
Grain (0 + 0 + 0)	76.17 Bu/A	51.16 Bu/A
Silage (0 + 0 + 0)	4.17 Tons/A	3.75 Tons/A

VII. Discussion

A. The 11 years of continuous corn silage had no detrimental effect on any of the soil properties measured.

B. In 1977 there were no significant treatment effects. Yields on the check plots were substantially lower than on the fertilized plots.

C. The 12-year average yields again show no reduction in silage yields from growing continuous corn silage and show a response to fertilizer.

SULFUR FERTILIZATION OF ALFALFA

A.C. Caldwell and J.N. Lensing

Sulfur is an essential element for plant growth and is required in relatively large amounts by some crops such as alfalfa. Since there are areas in Minnesota where S deficiency does occur, investigations on S needs by crops in this state were conducted quite a few years ago, and then more recently by the Department of Soil Science. However, continuing research to a greater or lesser degree on most of the nutrient elements is necessary because of greater crop production (which means greater nutrient removal), the use of purer chemicals as fertilizers, cleaner air, and because of the introduction of fertilizer chemicals that may differ in characteristics (form, analysis, etc.).

In 1974 studies were begun on the response of some crops in Minnesota to a new granulated gypsum product from U.S. Gypsum. The soil on the experimental field located at Park Rapids, Minnesota is a Dorset sandy loam, testing 7 ppm available S, which would place it in the low to medium range in S supply for crops.

RESULTS

Alfalfa yields--The trial established in 1974 consisted of rates of either elemental or gypsum applied in a single application at the initiation of the experiment. The results shown in Table 1 reflect a substantial increase in yields due to sulfur. Four years after application, elemental S has emerged as a better source of S than gypsum when applied at equivalent rates as shown in Table 2. It seems likely that the more readily available SO_4 in gypsum has been taken up more rapidly than the less slowly available S in elemental S. Since SO_4 will move downward in the soil water, it is possible also that some S has been moved beyond the reach of the plants.

Sulfur content of alfalfa--The S content of 4-year old irrigated alfalfa as affected by rates and source of S is shown in Table 3. The S content of untreated alfalfa is below the critical level of 0.25% S. Also below this level is alfalfa from plots treated with 25 lbs S/A as gypsum. Sulfur in the plant has increased with increasing rate of S applied. As with yield, response to S has persisted longer when elemental S was used as the original S source rather than gypsum.

Table 1. Yields of 4-year old irrigated alfalfa as affected by sources and rates of sulfur at Park Rapids, MN in 1977.

S Treatment*		Cutting			
		First	Second	Third	Total
lbs S/A	Source	---------------Tons/A---------------			
0	-	1.12	1.29	1.07	3.48
25	gypsum	1.34	1.44	1.15	3.93
50	gypsum	1.74	1.53	1.09	4.36
100	gypsum	1.87	1.90	1.30	5.07
25	elemental	1.02	1.60	1.15	4.37
50	elemental	1.88	1.93	1.38	5.19
100	elemental	2.00	2.08	1.44	5.52

* S applied prior to planting in 1974.

Table 2. Yields of irrigated alfalfa during 3 years as affected by sources and rates of sulfur at Park Rapids, MN. (Total of cuttings).

S Treatment*		1975[1]	1976[2]	1977[2]
lbs S/A	Source	--------------Tons/A----------------		
0	-	2.25	4.25	3.48
25	gypsum	3.00	5.35	3.93
50	gypsum	3.08	5.54	4.36
100	gypsum	3.08	5.75	5.07
25	elemental	2.80	4.76	4.37
50	elemental	2.65	5.23	5.19
100	elemental	3.03	5.67	5.52

* S applied prior to planting 1974

1 Two cuttings

2 Three cuttings

Table 3. S content of 4-year old irrigated alfalfa as affected by source and rate of sulfur at Park Rapids, MN in 1977.

S Treatment*		First	Second	Third	Ave.
lbs S/A	Source	----------------	% S	----------------	
0	-	0.236	0.214	0.226	0.225
25	gypsum	0.254	0.216	0.222	0.231
50	gypsum	0.286	0.246	0.228	0.253
100	gypsum	0.321	0.300	0.275	0.299
25	elemental	0.295	0.252	0.232	0.260
50	elemental	0.316	0.280	0.283	0.293
100	elemental	0.364	0.340	0.326	0.343

* S applied prior to planting in 1974.

PESTICIDE INTERACTION PLOTS AT ROSEMOUNT

Russell S. Adams, Jr.

An experiment studying the effects of combinations of the insecticide Furadan, the herbicide, Atrazine, and soil pH in continuous corn was established for the fifth year in 1977. Treatments included five residual lime treatments, Furadan at 0, 1/2, and 2 pounds per acre; Atrazine at 0, 2, 4, and 8 pounds per acre and their combinations. Each treatment has been replicated four times. The plots have been managed so as to maximize both weed and corn root worm infestation.

The 1977 season was a year of adequate moisture. However, some nitrogen deficiency developed in late season and supressed yield. Cultivation gave excellent weed control and their was little insect infestation until late season. Consequently, chemical treatments did not give as pronounced increase in yields as in previous years.

Corn yields in 1976 (Table 1) generally reflected chemical treatments, but not as pronounced as in previous years. Yields in the no chemical treatments ranged from 100 to 112 bushels per acre. Whereas near normal Furadan (1/2 lb/A) and Atrazine (4 lb/A) yielded from 109 to 150 bu/A/ Most pronounced effects were in the high lime soils. The average increase was 21%. Five year averages (Table 2) ranged from 58 to 69 bu/A in the no chemical treatments and 80 to 98 bu/A in the more normal chemical applications or an increase of 30%.

No significant lodging occurred in any treatments in 1977. A study of corn root worms present could find few. However, the data in Table 3 show that viable corn root worms were shown to confirm the observations made in 1975 and 1976, i.e., Furadan was apparently not controlling the corn root worm in high lime treatments as lodging was heavy. Note in Table 3 that Furadan markedly reduced corn root worm counts in soils receiving no lime, gave less control in moderately limed soils and no control in heavily limed soils. Work is being conducted in the laboratory to determine if differential microbial decay may be a factor.

In the 1976 report we observed that velvet leaf was increasing relative to giant foxtail. In 1977 there was a recession. The Broadleat Giant Foxtail ratio averaged 0.15 in the no chemical treatments, with broadleaf weeds (excepting one treatment) accounting for 10% or less of the total weed population. Apparently velvet leaf is either favored by drought or we are experiencing a cyclic fluctuation.

Table 1. The amount of lodging, weed growth, and corn yields in Atrazine-Furadan-soil pH studies at Rosemount, Minnesota, 1977.

Rate of Furadan and lime status	No Atrazine			2 lbs/A Atrazine			4 lbs/A Atrazine			8 lbs/A Atrazine		
	Lodging %	Weeds tons/A	Corn bu/A	Lodging %	Weeds tons/A	Corn bu/A	Lodging %	Weeds tons/A	Corn bu/A	Lodging %	Weeds tons/A	Corn bu/A
No lime--somewhat acid (~pH 5.4)												
Furadan 0 lbs/A	10	1.21	103	0	0.10	110	2	0.01	99	0	.00	100
1/2	0	0.10	110	0	0.10	107	2	0.04	109	0	.00	113
2	10	0.77	107	2	0.04	117	0	0.11	135	2	.00	138
Moderate lime, slightly acid (~pH 6.3)												
Furadan 0 lbs/A	4	0.66	100	0	0.44	102	8	0.01	129	10	.00	118
1/2	2	0.44	102	0	0.20	119	0	0.01	133	0	0.02	106
2	0	0.62	115	0	0.10	110	0	0.02	128	0	.00	130
Well limed, near neutral (~pH 6.8)												
Furadan 0 lbs/A	8	0.70	112	0	0.23	115	0	0.04	111	0	0.01	115
1/2	0	0.44	120	0	0.10	132	0	0.02	136	0	.00	115
2	2	0.35	116	2	0.17	122	0	0.02	113	0	.00	111
Heavily limed--slightly alkaline (~pH 7.2)												
Furadan 0 lbs/A	0	0.89	100	7	0.08	104	0	0.01	112	0	.00	121
1/2	2	0.40	119	0	0.14	124	8	0.11	125	2	0.04	106
2	0	0.31	115	2	0.02	125	0	0.02	150	2	.00	127

Table 2. The amount of lodging, weed growth and corn yields in Atrazine-Furadan-soil pH studies at Rosemount, Minnesota, 5 year average.

	No Atrazine			2 lbs/A Atrazine			4 lbs/A Atrazine			8 lbs/A Atrazine		
Rate of Furadan and lime status	Lodging %	Weeds tons/A	Corn bu/A	Lodging %	Weeds tons/A	Corn bu/A	Lodging %	Weeds tons/A	Corn bu/A	Lodging %	Weeds tons/A	Corn bu/A
No lime--somewhat acid (~pH 5.4)												
Furadan 0 lbs/A	45	1.44	58	41	0.80	77	44	0.36	80	31	0.20	83
1/2	20	1.47	68	26	0.54	84	27	0.53	80	26	0.17	91
2	16	1.09	77	32	0.65	86	12	0.55	87	29	0.13	95
Moderate lime--slightly acid (~pH 6.3)												
Furadan 0 lbs/A	35	1.64	69	41	0.65	74	35	0.27	90	44	0.06	92
1/2	37	1.18	64	29	0.57	85	21	0.43	98	32	0.16	88
2	19	1.41	75	18	0.72	82	13	0.25	92	17	0.18	95
Well limed, near neutral (~pH 6.8)												
Furadan 0 lbs/A	40	1.16	66	30	0.71	77	36	0.20	85	35	0.08	96
1/2	32	1.09	82	27	0.72	83	30	0.39	94	38	0.07	95
2	20	.87	77	16	0.63	94	22	0.30	96	20	0.09	93
Heavily lime, slightly alkaline (~pH 7.2)												
Furadan 0 lbs/A	49	1.36	65	48	0.29	84	42	0.12	88	40	0.04	88
1/2	29	1.17	82	34	0.36	92	32	0.15	96	31	0.05	95
2	32	0.73	83	35	0.28	91	24	0.15	102	31	0.02	101

Table 3. Influence of soil pH and pesticide treatment on corn root worm counts in 1977.

Pesticide Treatment	No lime somewhat acid (pH 5.4)	Moderate lime near netural (pH 6.7)	Heavily limed slightly alkaline (pH 7.2)
		(number/1000gm soil)	
None	2.82	2.51	1.66
2 lbs/A Furadan	0.39	0.65	2.24
2 lbs/A Furadan and 8 lbs/A Atrazine	0.12	0.52	1.20

NITROGEN TRIALS ON BARLEY UNDER IRRIGATION
Staples - 1976

G. Nelson, A. C. Caldwell, R. Schoper

An experiment on barley was conducted under irrigation on a sandy loam soil at the CMDIR station at Staples, Minnesota. The experiment was designed to study the effect of nitrogen on yield and protein content of barley.

A randomized complete block design with three replications of five treatments was used. The treatments each differed in the amount of nitrogen applied per acre.

Treatment No.	1	-	0 lbs.	N/A	
"	2	-	40 "	"	
"	3	-	80 "	"	
"	4	-	120 "	"	(80 + 40)
"	5	-	160 "	"	(80 + 80)

Nitrogen applications were applied prior to seeding, with the second of the split applications applied just before early boot. All nitrogen was applied as ammonium nitrate. In addition, the entire experimental area received 60 pounds K_2O/A and 10 pounds S/A applied as gypsum.

The plot was spring plowed. On April 4, the plot was harrowed twice and packed. On April 6, the plot was fertilized, harrowed, and seeded to Manker Barley at a rate of 96 pounds per acre. Good weed control was achieved with ¼ pound bromoxynil plus ¼ pound MCPA per acre applied at the four leaf stage.

Grain yield, percent protein and percent plump kernels are given on the following table. The data indicates that 80 pounds of N/A provided the greatest yield with a protein content low enough to allow the barley to be used for malting purposes.

Effect of nitrogen fertilization on yield, plumpness, and protein content of barley.

Treatment Lbs. N/A	Bu/A	% Plump	% Protein
0	50.5	72.3	10.4
40	63.4	76.3	12.1
80	68.2	75.3	11.6
80 + 40	79.6	73.3	13.8
80 + 80	84.9	75.6	14.3
Significance	**	ns	**
BLSD (.05)	12.6	--	.8
C.V.	9.8	3.2	3.2

INFLUENCE OF TIMING OF NITROGEN APPLICATION ON NITROGEN UPTAKE BY IRRIGATED CORN AND NITROGEN IN GROUND WATERS

A. C. Caldwell, J. Gerwing, G. Buzicky, M. Wiens

An experiment was established on a Sverdrup sandy loam at the CMDIR station at Staples, Minnesota, in the spring of 1977 to study the effects of timing of N fertilizer applications on N uptake by irrigated corn and the movement of N into shallow ground water.

In the fall of 1976, three wells were drilled to the aquifer (15 feet below the soil surface) in each plot. The well screens were placed 2 feet below the top of the aquifer. In spring, a 90 day hybrid was planted at 26,000 seeds per acre in 30 inch rows. All plots received 150 lbs/A K as potassium chloride, 30 lbs/A P as superphosphate, and 20 lbs/A S as gypsum. Nitrogen was applied at 160 lbs/A as urea in one application at planting or in smaller allotments through the growing season. The N in the split application was applied in four allotments, 20 lbs as starter, 40 lbs when the corn was 9 inches tall, and 50 lbs each when the corn was 2 feet tall and at tasseling. Subplots were treated with ^{15}N labeled urea for use as a tracer. Irrigation water was applied twice a week, amounting to 1 inch per week early in the season and increasing to 2 inches per week as the season progressed. The irrigation schedule was adjusted for significant rainfalls.

Whole plant yields were obtained by sampling the corn when it reached physiological maturity. All plant material was analyzed for total N and plant material from ^{15}N treated subplots was also analyzed for percent ^{15}N. Ground water was sampled from the wells twice a week and analyzed for NO_3-N.

Whole plant yields were not different between the two N application methods, both yielding 6.70 tons of dry matter per acre. Total N removed by the crop was 147 lbs from the one time application treatment and 153 lbs from the split N application, the latter amount being larger due to a higher percent N in the plant tissue from that treatment.

^{15}N analysis showed that 30.1% of the fertilizer N was recovered in the plant when the N was applied at one time at planting while 52.1% of the applied N was recovered in the plant when the N was applied in split applications during the growing season.

Nitrate nitrogen concentration in the ground water below the split application treatment decreased during the growing season while the NO_3-N concentration in the ground water below the one time spring applied N treatment increased 7 ppm.

NITROGEN TRIAL ON SPRING WHEAT

UNDER IRRIGATION AT STAPLES IN 1977

A. C. Caldwell, J. N. Lensing, R. P. Schoper, M. Wiens

As a continuation of spring wheat trials initiated in 1974, a variety by nitrogen experiment was conducted under irrigation on a sandy loam soil at Staples in 1977. In 1977, a split plot design, replicated four times with varieties as main plots and nitrogen rates as split plots was used. Era, Kitt, Angus, and 70-170 were the semi-dwarf spring wheat varieties grown. Nitrogen rates of 0, 75, and 125 lbs N/A were applied as split applications (2/3 applied prior to seeding and 1/3 applied at early boot stage). All nitrogen was applied as ammonium nitrate. In addition to nitrogen treatments 20 lbs. P_2O_5/A was applied with the seed. Also 60 lbs K_2O/A and 10 lbs S/A as gypsum was broadcast over the experimental area.

Grain yields in 1977 were lower than expected from 25-57 bu/A (Table 1) as compared to a range of 32-77 bu/A produced in 1976. The lower yield may be due to high temperatures and/or inadequate water at flowering and seed filling stage as indicated by the low test weights of the wheat.

There was a significant varietal difference in yield potential, protein content and test weight. Yield was significant increased with 75 lbs N/A and highest protein content achieved at 125 lbs N/A. With an increase in N rate there was a trend of decreasing test weight.

Forage yields were collected at the soft dough stage to determine total dry matter yield, percent nitrogen in tissue and total N removal. The results of these measurements are shown in Table 2.

Table 1. Effect of variety and N rate on yield, grain protein, and test weight of wheat at Staples, 1977.

Treatment	Yield	Grain Protein	Test Weight
Variety	Bu/A.	%	lbs/bu.
Era	45	14.2	57.9
Kitt	41	16.0	55.6
Angus	33	16.9	55.8
70-170	46	15.1	58.7
Significance	**	**	**
BLSD (.05)	5	0.8	1.0
Rate			
0 # N/A	28	13.9	57.7
75 # N/A	47	15.7	57.0
125 # N/A	49	17.0	56.3
Significance	**	**	**
BLSD (.05)	4	0.4	0.7
Interaction			
Era x 0 # N/A	34	12.6	58.3
Era x 75 # N/A	47	14.2	58.5
Era x 125 # N/A	54	15.7	57.0
Kitt x 0 # N/A	25	14.2	57.4
Kitt x 75 # N/A	47	16.6	55.8
Kitt x 125 # N/A	52	17.4	53.6
Angus x 0 # N/A	21	15.3	56.1
Angus x 75 # N/A	39	16.9	55.5
Angus x 125 # N/A	40	18.5	55.9
70-170 x 0 # N/A	30	13.6	59.0
70-170 x 75 # N/A	57	15.3	58.4
70-170 x 125 # N/A	51	16.4	58.7
Significance	NS	NS	**
BLSD (.05)	-	-	1.5
C.V., %	12.6	3.6	1.5

Table 2. Effect of variety and N rate on dry matter yield; % N in tissue, and total N removal of wheat forage at Staples, 1977.

Treatment	Yield	N Content	N Removal
Variety	Tons/A	%	lbs/A
Era	2.57	1.22	64
Kitt	2.64	1.50	80
Angus	2.48	1.38	70
70-170	2.64	1.29	70
Significance	NS	*	*
BLSD (.05)	-	0.21	13
Rate			
0 # N/A	1.77	1.19	42
75 # N/A	2.87	1.33	76
125 # N/A	3.10	1.53	95
Significance	**	**	*
BLSD (.05)	.30	0.14	10
Interaction			
Era x 0 # N/A	1.78	1.10	39
Era x 75 # N/A	2.79	1.24	69
Era x 125 # N/A	3.14	1.34	84
Kitt x 0 # N/A	1.77	1.38	50
Kitt x 75 # N/A	2.81	1.38	76
Kitt x 125 # N/A	3.32	1.74	115
Angus x 0 # N/A	1.66	1.18	40
Angus x 75 # N/A	2.68	1.33	70
Angus x125 # N/A	3.10	1.61	100
70-170 x 0 # N/A	1.88	1.08	41
70=170 x 75 # N/A	3.20	1.38	88
70-170 x 125 # N/A	2.85	1.43	81
Significance	NS	NS	NS
C.V., %	16.9	13.1	18.8

N RATE STUDIES OF DRYLAND AND IRRIGATED WHEAT AND OATS WITH AND WITHOUT LEGUME UNDERSEEDING, STAPLES 1977

H. Meredith, M. Wiens, R. Schoper and J. Lensing

1977 was the third crop year of studies investigating the effect of various rates of nitrogen on oat and wheat yields under irrigation.

A dryland N rate study was initiated in 1977 to evaluate the impact of nitrogen on the yields of wheat and oats. The study evaluating the effect of red clover as an underseeding and as a plowdown crop prior to seeding was continued.

The objectives of the study are:

a) evaluate effect of applied N on yield of wheats and oats under dryland and irrigated condition

b) evaluate effect of applied N on yield of irrigated wheat and oats with red clover underseeding

c) evaluate effect of applied N on yield of irrigated wheat following plowdown of an established stand of red clover.

Stout oats, Era wheat and Lakeland red clover represented the varieties of the respective crops. The experiment consists of a randomized complete block design with four replications and four N rates. Urea was used as the source of N. N rates were 0, 40, 80 and 120 pounds per acre for oats. Wheat received 0, 60, 120 and 180 pounds N per acre.

N was applied to oats in two applications. One-half just prior to seeding and one-half immediately preceeding boot formation.

Wheat received one-third of the N prior to seeding, one-third at stooling and one-third before boot formation.

All plots received a broadcast application of 425 pounds of K per acre in early April. Urea was incorporated by harrowing. Desired seeding rate was wheat, 120; oats, 96; and red clover, 16 pounds per acre.

Plots were moldboard plowed on March 28, harrowed twice and packed on April 4. Seeding was begun on April 5 and completed on April 7.

The oats was harvested July 15-18, wheat was harvested on July 25.

Table 1. Oat grain yield, Staples 1975, 1976 and 1977.

	1975		1976		1977		
Lbs N/A	Oats[1]	Oats[2]	Oats[1]	Oats[2]	Oats[1]	Oats[2]	Oats[3]
	----- BU/A -----		------ BU/A -----		---------- BU/A ----------		
0	24.0	24.0	54.4	85.7	44.7	84.1	31.5
40	35.8	44.8	84.0	87.7	90.2	101.2	63.4
80	40.8	51.8	100.9	90.2	106.5	110.2	59.8
120	34.8	41.0	111.2	93.2	114.2	100.8	62.4
Treatments	*	NS	**	NS	**	*	*
BLSD (05)	4.3	--	28.5	--	10.0	-	20.3
C.V.	17.3	29.9	20.1	15.9	7.6	11.4	22.7

[1] Chemical weed control (irrigated).

[2] Seeded with red clover companion crop (irrigated).

[3] Chemical weed control (dryland).

Table 2. Oat forage yield, percent protein and lbs N removed per acre, Staples 1977.

	Oats, Irrigated[1]			Oats-Red Clover, Irrigated			Oats, Dryland[1]		
Lbs N/A	Tons D.M./A	Percent Protein In Forage	N-lbs/A Removed In Forage	Tons D.M./A	Percent Protein In Forage	N-lbs/A Removed In Forage	Tons D.M./A	Percent Protein In Forage	N-lbs/A Removed In Forage
0	1.1	5.8	20.4	3.0	5.6	52.8	.8	7.0	18.6
40	2.6	6.2	51.4	3.1	7.3	73.3	1.6	7.4	37.9
80	3.3	5.8	61.5	3.2	8.1	83.3	1.7	9.5	52.9
120	3.6	8.0	91.2	3.2	8.6	87.6	1.7	10.2	55.8
Treatments	**	**	**	NS	**	**	**	**	**
BLSD (.05)	.32	1.0	13.3	-	1.1	12.0	.38	0.7	10.2
C.V.	8.2	10.0	15.8	7.2	9.9	10.5	16.4	5.4	16.2

[1] Chemical weed control.

Table 3. Oats, grain - percent protein, N removed, test weight, and straw data, Staples, MN 1977.

	Straw T/A			Straw % Protein			Straw Lbs N Removed/A		
Lbs N/A	1/	2/	3/	1/	2/	3/	1/	2/	3/
0	.6	2.1	.5	1.7	3.3	1.9	3	23	3
40	1.2	2.0	1.0	1.5	3.3	1.9	6	21	6
80	1.5	2.3	1.0	2.3	3.6	3.2	11	27	11
120	1.7	2.3	1.0	2.9	4.0	3.7	16	30	12
Treatments	**	NS	**	**	NS	**	**	NS	**
BLSD (.05)	.25	.	.4	.4	-	.5	2.5	-	4.2
C.V.	4.1	19	26	13	25	13	18.3	39	33

1/ Chemical weed control (irrigated).

2/ Red clover companion crop (irrigated).

3/ Chemical weed control (dryland).

Table 3. Oats, grain - percent protein, N removed, test weight, and straw data, Staples, MN 1977.

	% Protein			Lbs N Removed/A			Test Wt Lbs/bu		
Lbs N/A	1/	2/	3/	1/	2/	3/	1/	2/	3/
0	13.4	13.2	13.6	46	57	22	36.1	37.6	34.1
40	13.3	14.2	14.6	61	73	48	34.5	34.6	35.0
80	13.9	15.5	16.4	76	88	50	32.8	35.5	36.1
120	15.6	16.1	16.4	91	83	52	32.4	33.5	34.0
Treatments	*	**	*	**	**	**	NS	NS	NS
BLSD (.05)	1.8	1.3	2.1	11.1	15.1	14.6	-	-	-
C.V.	7.4	5.7	8.2	11.1	12.5	21.3	10.0	6.0	7.1

1/ Chemical weed control (irrigated).

2/ Red clover companion crop (irrigated).

3/ Chemical weed control (dryland).

Table 4. Wheat grain yield, Staples, MN 1975, 1976 and 1977.

	1975			1976			1977			
Lbs N/A	Wheat 1/	Wheat 2/	Lbs N/A	Wheat 1/	Wheat 2/	Wheat 3/	Wheat 1/	Wheat 2/	Wheat 3/	Wheat 4/
	BU/A			BU/A			BU/A			
0	7.3	5.0	0	24.3	53.0	59.1	28.7	51.0	53.2	9.4
40	18.0	13.0	60	53.0	58.3	70.0	47.3	49.8	58.5	16.9
80	21.3	16.5	120	66.4	55.2	69.2	64.6	52.3	57.5	21.6
120	24.0	17.0	180	68.0	56.7	66.7	68.9	41.3	58.6	19.6
Treatments	**	**		**	NS	*	**	NS	NS	**
BLSD (.05)	5.8	4.1		8.1	-	7.6	8.1	-	-	3.6
C.V.	21.1	20.8		10.2	12.6	6.8	10.3	19.8	13.5	13.8

1/ Chemical weed control (irrigated).

2/ Red clover underseeding (irrigated).

3/ Established red clover stand plowed down, chemical weed control (irrigated).

4/ Chemical weed control (dryland).

Table 5. Wheat forage yield, percent protein and lbs N removed per acre, Staples 1977.

Lbs N/A	Wheat, Irrigated 1/ Tons D.M./A	Wheat, Irrigated 1/ Percent Protein In Forage	Wheat, Irrigated 1/ N-lbs/A Removed In Forage	Wheat-Red Clover, Irrigated 2/ Tons D.M./A	Wheat-Red Clover, Irrigated 2/ Percent Protein In Forage	Wheat-Red Clover, Irrigated 2/ N-lbs/A Removed In Forage
0	.9	6.6	20	2.9	7.2	69
60	2.3	6.0	45	3.0	8.4	81
120	3.0	8.5	83	2.9	10.0	95
180	3.3	9.4	98	3.1	11.2	111
Treatments	**	**	**	NS	**	*
BLSD (.05)	.26	1.25	16.2	-	1.9	24.2
C.V.	7.4	10.6	17.5	4.8	13.1	16.5

1/ Chemical weed control.

2/ Underseeding of red clover.

3/ Chemical weed control following plowdown of an established stand of red clover.

Table 5. Wheat forage yield, percent protein and lbs N removed per acre, Staples 1977. (continued)

	Wheat, Irrigated[3]			Wheat, Dryland		
Lbs N/A	Tons D.M./A	Percent Protein In Forage	N-lbs/A Removed In Forage	Tons D.M./A	Percent Protein In Forage	N-lbs/A Removed In Forage
0	2.6	7.5	62	.6	8.2	15
60	3.0	8.9	87	1.4	9.8	43
120	3.0	9.5	92	1.4	12.3	57
180	2.9	11.4	107	1.6	12.2	64
Treatments	NS	**	**	**	**	**
BLSD (.05)	-	1.73	19.8	.21	1.52	9.1
C.V.	9.8	11.6	14.3	11.0	11.0	13.6

1/Chemical weed control.

2/Underseeding of red clover.

3/Chemical weed control following plowdown of an established stand of red clover.

Table 6. Wheat grain - percent protein, N removal and test weight, Staples, MN 1977.

Lbs. N/A	% Protein				Lbs N Removed/A				Test Wt, Lbs/Bu			
	1/	2/	3/	4/	1/	2/	3/	4/	1/	2/	3/	4/
0	11.8	12.2	13.4	14.4	35	65	75	14	61	59	59	60
60	11.8	14.7	15.3	15.7	58	77	94	28	59	57	58	59
120	14.3	15.9	15.7	17.6	97	87	95	40	58	57	57	60
180	15.5	16.7	16.4	18.6	112	72	101	38	59	55	56	59
Treatments	**	**	**	**	**	NS	+	**	+	**	NS	NS
BLSD (.05)	1.0	1.2	1.1	.7	12.1	-	-	7.0	-	2.0	-	-
C.V.	4.9	5.2	4.8	3.4	10.7	19.0	13.9	15.4	2.2	2.2	3.1	2.0

1/ Chemical weed control (irrigated).

2/ Seeded with underseeding of red clover (irrigated).

3/ Chemical weed control following plowdown of an established stand of red clover (irrigated).

4/ Chemical weed control (dryland).

Table 7. Wheat straw data, Staples, MN 1977.

Lbs N/A	Straw T/A			Straw Lbs/Bu Grain			Grain/Straw			% Protein Straw			Straw Lbs N Removed		
	1/	2/	3/	1/	2/	3/	1/	2/	3/	1/	2/	3/	1/	2/	3/
0	.9	1.7	.2	60	66	38	1.0	.91	1.6	2.5	2.6	3.6	7.2	15.8	2.2
60	1.7	2.0	.55	72	70	66	.83	1.2	.91	2.1	2.8	3.9	12.1	20.7	7.5
120	2.4	2.2	.55	75	77	54	1.2	.78	1.1	2.7	4.2	5.1	22.8	32.2	10.4
180	2.0	2.3	.71	59	80	72	1.0	.75	.82	3.6	4.2	5.6	26.1	34.5	14.3
Treatments	**	*	**	-	-	-	-	-	-	*	**	**	**	**	**
BLSD (.05)	.5	.3	.2	-	-	-	-	-	-	.9	.3	.8	6.2	3.8	4.5
C.V.	17.8	10.1	21.9	-	-	-	-	-	-	20.4	6.3	11.0	23.6	9.9	33.0

1/ Continuous small grain, chemical weed control (irrigated).

2/ Following plow-down of an established crop of red clover chemical weed control (irrigated).

3/ Chemical weed control (dryland).

Table 8. Grain-straw makings of small grain yields, Staples, MN 1977.

Wheat

Lbs N/A	Wheat (irr)[1/]		Wheat-Red Clover (irr)		Wheat, Plowdown Clover[1/]		Wheat (dryland)[1/]	
	% Grain	% Straw	% Grain	% Straw	% Grain	% Straw	% Grain	% Straw
0	49.3	50.7	60.7	39.3	57.2	47.8	39.0	61.6
60	54.4	45.6	62.3	37.7	53.9	46.1	52.1	47.9
120	55.5	44.5	62.8	37.2	56.2	43.8	47.2	52.8
180	49.3	50.7	69.2	30.8	57.2	42.8	54.5	45.5

Oats

Lbs N/A	Oats (irr)[1/]		Oats-Red Clover (irr)		Oats (dryland)[1/]	
	% Grain	% Straw	% Grain	% Straw	% Grain	% Straw
0	46.4	53.6	60.9	39.1	50.5	49.5
40	45.9	54.1	54.3	45.7	49.3	50.7
80	47.6	52.4	56.8	43.2	52.1	47.9
120	48.1	51.9	58.8	41.2	50.5	49.5

[1/] Chemical weed control.

Table 9. Rainfall, irrigation and open pan evaporation data by month, Staples.

	Inches Rainfall	Inches Irrigation	Rainfall + Irrigation	Ave. Pan Evaporation/Day
April	2.8	2.20	5.0	.20 1/
May	5.1	4.65	9.75	.28
June	3.1	6.4	9.5	.24
July	4.5	2.5	7.0	.27
Total In.	15.5	15.75	31.25	28.3 1/

1/ April 17-30 only.

Ratio: $\frac{\text{Rainfall + Irrigation}}{\text{Pan Evaporation}} = \frac{31.25}{28.3} = 1.1$ (1977)

$= \frac{31.3}{29.5} = 1.06$ (1976)

$= \frac{22.0}{24.5} = 0.89$ (1975)

Water Quality Studies

H. Meredith, M. Wiens, and R. C. Munter

Water samples were analyzed at different locations and at different intervals following pumping to better understand water quality and the potential alteration of soil characteristics.

Of greatest importance is the alkalinity of water. Most of the irrigation water is being applied to coarse textured soils in Minnesota. Typically these soils have low exchange capacity and an initial pH less than 6.0.

Tables 1 and 2 contain the analysis of Ca CO_3 equivalent and sulfur content in pounds per acre inch from 32 wells in Hubbard and 2 from Becker counties. Sulfur range was .4 - 1.6 lbs. S/Acre inch. Total alkalinity expressed as $CaCO_3$ equivalent range was 13-58. The average sulfur content of these samples was .68 pounds S/Acre inch water. The average $CaCO_3$ equivalent of the water was 20.5 Lbs./Acre inch water. Many of the irrigators reported pumping 16 acre inces of water in 1977. Using average values, this would equate to 10.9 pounds S/Acre and 328 Lbs. $CaCO_3$ equivalent/Acre.

Data of other locations sampled in 1977 appears in Tables 3 and 4.

The N rate-small grain study at Staples is an excellent exercise in determining the effect of varying the pH of the soil via irrigation. Countering the pH effect of the alkalinity in the water is the pH depression offered by the conversion of urea to nitric acid in the soil. The data in Tables 5 and 6 contrast the pH change from August 1976 to August 1977. Blocks 1 and 1A have received nitrogen three years.

The soil pH initially was 5.8. The surface soil in plot 1A showed the greatest differential in pH, one-half unit. Data by W. H. Pierre[1] indicates about 1.15 pounds of $CaCO_3$ was required to neutralize the acidity of one pound of N under a continuous corn culture.

Data indicate the south well at Staples is delivering about 36 pounds of $CaCO_3$ equivalent per acre inch, Table 3. After three years this area has received 52 inches of irrigation water or 1872 pounds of fine $CaCO_3$ equivalent.

The zero N plots have increased in pH from 5.8 to 6.7 while the highest N rate has increased to pH 6.2. Therefore, the difference in pH is attributed to the nitrogen or 0.5 pH unit.

Soil analyses data appear in Tables 8 and 9.

[1] Pierre, W. H. "N-Contributor to Soil Acidity-How Much?" 22nd Annual Fertilizer and Ag Chemical Dealers Conference, January 13-14, 1970, pp 13-135.

Table 1. Water Quality Studies

Farmer	County	Township	Section	Description	Depth of well	1st yr. Pumped	Gal/hr	Prin. Crop	S Lbs/A in.	$CaCO_3$ (Lime) Lbs/Ac in.	pH	Date 77
Manloves	Hubbard	Hubbard	20	NE¼	105	1977	650	Corn-alf	.5	19	7.2	8/29
Manloves	"	"	21	W½	155	1976	1100	"	.9	14	7.8	8/29
Manloves	"	"	21	SE¼	85	1976	700	Corn	.9	14	8.1	8/29
M.M.Beelne	"	"	25	NW¼	56	1977	940	Corn, D. beans	.56	16	8.0	8/29
M.M.Beelne	"	"	25	SE¼	130	1977	920	Corn	.56	16	8.0	8/29
M.M.Beelne	"	Crow Wing	30	SW¼	154	1977	1020	Dry beans	.75	14	8.3	8/29
P. Pohl	"	"	8	SW¼	182	1976	1000	Corn-alf	.4	23	8.2	8/29
S. Pike	"	Hubbard	15		130	1977	1300	Corn, D. beans	1.2	24	8.0	8/30
S. Pike	"	"	22	NE¼	50	1972	800	Corn-alf	.56	14	8.0	8/31
G. Bolton	"	"	23	SW¼	160	1977	800	Corn, D. beans	.4	20	8.0	8/30
F. Bliss	"	"	14	NE¼	170	1977	1200	Corn, D. beans	.63	20	8.0	8/30
F. Bliss	"	"	13	W½	174	1976	1350	Corn	.5	14	8.0	8/30
Ron Griffith	Becker	Osage	36	NE¼	110	1977	800	D. beans	.9	25	8.0	8/31
Lance Larson	"	"	34	SE¼	60	1977	750	D. beans	.5	24	8.0	8/31
Ron Griffith	Hubbard	SA Run	5	NE¼	108	1976	800	Corn, D. beans	.5	24	8.0	8/31
Ron Griffith	"	Todd	32	SE¼	160	1977	900	Corn, Beans	1.0	27	8.0	8/31
Chas.Andress	"	Wh.Dak.	32	SW¼	103	1976	800	Corn, D. beans	.5	17	8.0	9/8
M.Svenson	"	Crow Wing	6		75-80	1977	780	Corn	.5	24	8.0	9/12
Curt Corkste	"	Todd	21	NE¼	131	1977	800	Corn	.5	24	8.1	9/15
Boyd Steams	Becker	Carnsihit			140	1977	1400	Corn,D.bean	.5	27	8.0	9/15
Don Rooney	"	Pine Point	6	SW¼	130	1976	1000	Corn-alf	.5	25	8.1	9/15

Table 2. Water Quality Studies

Farmer	County	Township	Section	Description	Depth of well	1st yr. Pumped	Gal/hr	Prin. Crop	S Lbs/A in.	$CaCO_3$ (Lime) Lbs/Ac in.	pH	Date 77
Korst, E.	Hubbard	Hubbard	24	NW¼	60	1975	800	Pot., Corn	.7	18	8.0	8/22
Benham	"	"	21	NE¼	212	1975	800	Pot., Corn	.5	24	8.1	8/22
Buckholtz,N.	"	"	29	NE¼	134	1977	1000	Pot., Corn	1.0	22	8.1	8/22
Pollock	"	"	33	SE¼	168	1977	800	Pot., Corn	1.3	13	8.1	8/22
Norman, E.	"	"	35	SE¼	64	1974	800	Pot., Corn	.6	17	7.9	8/22
Shores	"	"	27	NW¼	119	1977	800	Pot., Corn	1.1	23	7.9	8/22
Korst, W.	"	"	23	NE¼	60	1975	800	Pot., Corn	.8	16	8.3	8/22
Fischer	"	"	33	SW¼	166	1977	800	Pot., Corn	Sample lost			8/22
Norman, M.	"	"	35	SW¼	150	1977	600	Pot., Corn	.6	19	8.1	8/22
Blanchard	"	"	24	SW¼	117	1977	800	Pot., Corn	.8	16	8.1	8/22
Vic	"	St. Rives	11	SE¼	90	1976	800	Pot., Corn	1.3	21	8.2	8/22
Johnson	"	Hubbard	28	SW¼	186	1977	800	Pot., Corn	.7	58	8.4	8/22
Normand, W.	"	"	34	SE¼	61	1977	600	Pot., Corn	1.6	24	8.1	8/22

Table 3. Water Sample Analyses at Staples Station 1977.

Date	Location	Sulfur Lbs/A In.	Total Alkalinity Lbs $CaCO_3$/A in.
5/17/77	C. Well	1.5	36
6/9/77	L. Grove	1.8	43
8/8/77	S. Well	.8	41
7/25/77	S. Well	.5	39
7/29/77	S. Well	.5	32
"	S. Well	.6	31

Table 4. Summary of Water Analyses 1977

No.	County	Location	SO_4 S (Lbs/A. in.)	Spec. cond. (µmhos @ 25°C)	Total Alkalinity Lbs $CaCO_3$/ Acre-inch	B (ppM)	Ca (ppm)	Mg (ppm)	Cl (ppM)	NO_3^- + NO_2^- Nitrogen (ppM)
1	Wadena	Carlson	.72	82	8.6	.02	25	4.4		
2	Wadena	South	1.04	251	20	.05	32	14		
3	Wadena	Home	.81	148	28	.05	41	23		
4	Kandi-yohi	Buer (1)		412	26					
5	"	Buer (2)		398	27					
6	Meeker	Met (1)	5.3	357	24.3	.02			3.0	< .01
7	Meeker	Met (2)	5.3	343	24.2	.02			3.2	< .01
8	Ramsey	N Co. Line	.6		59.6					

Table 5. Soil pH [1/] and N Treatments Identified by Blocks, Staples, Minn. 1976.

Lbs N/A	1	1A	3
	- - - - - pH - - - - - -		
0	6.3	6.2	6.3
60	6.2	6.2	6.4
120	6.2	6.1	6.2
180	6.0	6.0	6.2

[1/] Soils samples August 1976.

Table 6. Soil pH and Treatments Identified by Blocks, Staples, Minn. 1977 [1/].

Lbs N/A	1 [1/]	1A [1/]	2 [1/]	2A [1/]	3 [1/]	3A [1/]
	- - - - - - - - - - - - - - - pH - - - - - - - - - - - - - - -					
0	6.6	6.7	6.3	6.5	7.0	6.6
60	6.5	6.5	6.3	6.5	6.9	6.7
120	6.5	6.3	6.4	6.2	7.0	6.6
180	6.4	6.2	6.2	6.2	7.0	6.5

[1/] Soils Sampled August 1977.

Table 7. Soil pH and Depth of Horizon, Staples, Minn. 1977.

Depth, Inches	pH	P	K
0-3	7.0	71	555
3-6	6.8	38	580
6-9	6.5	40	331
9 12	6.2	20	150

Sampled Fall 1977.

Table 8. P [1] Soil Test Values from Same P Treatments, Staples, Minn. 1977.

Lbs N/A	1	1A	2	2A	3	3A
0	31	48	27	28	34	34
60	31	34	24	23	32	32
120	35	36	23	24	33	34
180	33	31	23	25	34	32

1/ No P applied 1975 and 1976. 20 # P_2O_5 applied at seeding 1975. Sampled August 1977.

Table 9. K [1] Soil Test Values from Same K Treatments, Staples, Minn. 1977.

Lbs N/Ac	1	1A	2	2A	3	3A
0	467	488	418	484	326	358
60	431	472	346	361	324	324
120	397	477	396	393	352	316
180	435	368	378	401	325	299

1/ Sampled August 1977

K_2O Applied: 1977 - 510 Lbs/A
1966 - 600 Lbs/A
1975 - 500 Lbs/A

SOUTHERN EXPERIMENT STATION - WASECA
WEATHER DATA - 1977

Month	Period	Precipitation 1977	Precipitation Normal	Avg. Air Temp. 1977	Avg. Air Temp. Normal	Growing Degree Days 1977	Growing Degree Days Normal
		inches		°F			
January	1-31	.49	.73	-2.2	12.9		
February	1-28	1.06	.96	21.0	17.5		
March	1-31	4.37	1.94	36.6	28.5		
April	1-30	3.46	2.48	52.2	45.6		
May	1-10	.79		58.9		112.5	
	11-20	2.40		70.7		205.0	
	21-31	2.77		69.7		213.5	
	Total	5.96	3.86	66.6	57.7	531.0	323
June	1-10	.31		65.6		156.5	
	11-20	2.72		66.2		162.5	
	21-30	1.25		70.1		197.0	
	Total	4.28	4.75	67.4	67.1	516.0	521
July	1-10	.78		72.7		222.5	
	11-20	1.04		75.0		236.5	
	21-31	2.43		69.2		211.5	
	Total	4.25	4.02	72.4	71.4	670.5	637
August	1-10	.35		67.4		175.0	
	11-20	1.31		61.4		123.5	
	21-31	1.95		65.2		169.0	
	Total	3.61	3.60	64.6	69.7	467.5	583
September	1-30	6.15	3.45	61.0	60.3	363.0	310
October	1-31	4.34	1.89	45.8	50.3		44
November	1-30	1.53	1.25	31.1	32.9		
December	1-31	1.66	1.02	13.6	19.0		
Year	Jan-Dec	41.16	29.95	44.2	44.4	2553.0	2418
Growing Season	May-Sept	24.25	19.68	65.3	65.3	2548.0	2374

Notes:

1) Highest temp. on July 6 - 94°

2) Highest 24-hour precipitation on Sept. 24 - 2.66"

3) Frost on October 2

4) Third highest yearly rainfall on record

USE OF TERRAZOLE AS A NITRIFICATION INHIBITOR IN FALL VS. SPRING NITROGEN APPLICATION PROGRAMS FOR CORN PRODUCTION IN SOUTHERN MINNESOTA

G. L. Malzer and G. W. Randall

The use of nitrification inhibitors on the heavy wet 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 Terrazole (Olin Corporation) has shown nitrificide characteristics and was evaluated under field conditions at the Southern Experiment Station at Waseca, MN in 1977. The objectives of the trial were to evaluate not only rate of nitrogen application but also timing of application with emphasis being placed upon fall vs. spring application with and without the use of Terrazole.

Experimental Procedures

Thirteen treatments including a control, two rates of nitrogen (75 and 150 # N/A) and three times of application (2 Fall -- Oct. 1 and Nov. 1 of 1976 and 1 spring -- April 28, 1977) were combined with and without Terrazole (0.5 # a.i/A) with all combinations of the nitrogen treatments. Nitrogen was applied as broadcast and incorporated applications of urea with Terrazole added as a coating onto the urea prior to application. All treatments were replicated five times and arranged in a randomized complete block design. Corn (Pioneer 3709) was planted into the experimental area in early May in 30" rows and at a seeding rate of approximately 24,000 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 for calculation of nitrogen removal. Corn grain yields were collected by hand harvesting two 20' rows from each plot and collecting subsamples for moisture determination and Kjedahl nitrogen (protein) content. Soil samples were also collected from the surface 0-1 ft. depth from all treatments receiving 150 # N/A at approximately two week interval after the application of the nitrogen and samples analyzed for ammonium and nitrate nitrogen. Soil samples were obtained to a depth of five feet at approximately month intervals from the same plots to monitor nitrate movement and accumulation in the soil profile.

Results

Nitrogen content of the 6th leaf was significantly increased with increasing rates of nitrogen although grain yields and total nitrogen removal with the grain was not influenced with nitrogen rates over 75 # N/A. Nitrogen removal with the grain was significantly reduced with the second fall nitrogen application as compared to the early fall treatment or the spring application. The exact cause for this is unknown but may be related to the soil physical conditions at the time of application. Use of Terrazole had no significant influence on nitrogen utilization or grain and dry matter yields.

Nitrogen content of the grain and stover portions of the total dry matter production was significantly increased with nitrogen rate although only the stover nitrogen removal and total nitrogen removal was significantly increased. The second fall application again resulted in a depressed nitrogen content of the grain as compared to the other two dates of application. Terrazole had no influence on nitrogen content or total nitrogen utilization by the corn crop.

In general very few responses (yield as nitrogen utilization) were found above the first application rate of nitrogen indicating that nitrogen was not a major factor in limiting production under the conditions experienced in this study in 1977. A positive response to a nitrification inhibitor would probably not be anticipated under these conditions.

Table 1. Influence of date and rate of nitrogen application and the use of Terrazole as a nitrification inhibitor on Leaf N content, corn grain yield, nitrogen removal and dry matter production-- Waseca, MN 1977.

Treatment			6th Leaf	Corn Grain		Silage Dry Matter		
Date of Appl.	N Rate	Terrazole	N	Yield	N Removal	Grain	Stover	Total
	#/A	0.5 #ai/A	%	bu/A	#/A	--------T/A----------		
Control	-	-	2.51	154.5	106	3.74	3.94	7.68
Oct. 1	75	No	2.71	153.2	114	3.87	4.75	8.62
Oct. 1	75	Yes	2.65	158.1	116	3.95	4.95	8.90
Oct. 1	150	No	2.76	151.2	116	3.98	4.47	8.45
Oct. 1	150	Yes	2.79	150.4	116	3.92	5.01	8.93
Nov. 1	75	No	2.67	144.1	102	3.88	4.80	8.68
Nov. 1	75	Yes	2.71	152.3	109	4.25	4.91	9.16
Nov. 1	150	No	2.74	146.2	112	3.60	4.53	8.12
Nov. 1	150	Yes	2.87	142.5	105	4.03	4.60	8.63
April 28	75	No	2.64	150.7	111	4.02	4.88	8.90
April 28	75	Yes	2.57	148.9	113	3.67	4.66	8.33
April 28	150	No	2.71	151.3	115	4.16	4.98	9.14
April 28	150	Yes	2.78	154.9	115	4.13	4.96	9.09
Signif.			*	NS	*	NS	+	NS
B.L.S.D. (.05)			.21		12.1		.68	
Factorial Arrangement								
Date of Appl.								
Oct. 1			2.73	153.2	115	3.93	4.80	8.73
Nov. 1			2.74	146.3	107	3.94	4.71	8.65
April 28			2.67	151.4	114	4.00	4.97	8.86
Signif.			NS	NS	**	NS	NS	NS
B.L.S.D. (.05)					5			
N Rate - #/A								
75			2.66	151.2	111	3.94	4.83	8.76
150			2.77	149.4	113	3.97	4.76	8.73
Signif.			**	NS	NS	NS	NS	NS
B.L.S.D. (.05)			.09					
Terrazole 0.5 # a.i/A								
No			2.70	149.4	112	3.92	4.73	8.65
Yes			2.73	151.2	112	3.99	4.85	8.84
Signif.			NS	NS	NS	NS	NS	NS
B.L.S.D. (.05)								

Table 2. Influence of date and rate of nitrogen application and the use of Terrazole as a nitrification inhibitor on dry matter nitrogen content and total nitrogen removal--Waseca, MN 1977.

Treatment			Dry Matter Production				
			N Content		N Removal		
Date of Appl.	N Rate	Terrazole	Grain	Stover	Grain	Stover	Total
	#/A	a.s #ai/A	-------%-------		-----------#/A-----------		
Control	-	-	1.46	.63	109	50	159
Oct. 1	75	No	1.57	.73	122	70	192
Oct. 1	75	Yes	1.55	.73	122	73	195
Oct. 1	150	No	1.62	.86	129	76	205
Oct. 1	150	Yes	1.63	.86	128	86	214
Nov. 1	75	No	1.50	.74	116	72	188
Nov. 1	75	Yes	1.51	.70	128	69	197
Nov. 1	150	No	1.62	.94	116	85	201
Nov. 1	150	Yes	1.56	.78	126	73	199
April 28	75	No	1.56	.80	125	79	204
April 28	75	Yes	1.60	.77	117	72	189
April 28	150	No	1.60	.82	133	81	215
April 28	150	Yes	1.57	.84	130	83	213
Signif.			**	**	NS	**	*
B.L.S.D. (.05)			.06	.12		18	34
Factorial Arrangement							
Date of Appl.							
Oct. 1			1.59	.80	125	76	202
Nov. 1			1.55	.79	122	75	196
April 28			1.58	.81	126	79	205
Signif.			*	NS	NS	NS	NS
B.L.S.D. (.05)			.03				
N Rate - #/A							
75			1.55	.75	122	72	194
150			1.60	.85	127	81	208
Signif.			**	**	NS	*	*
B.L.S.D. (.05)			.02	.04		6	11
Terrazole							
No			1.58	.82	124	77	201
Yes			1.57	.78	125	76	201
Signif.			NS	NS	NS	NS	NS
B.L.S.D. (.05)							

ROTATION NITROGEN STUDY

Waseca, 1975-1977

Gyles W. Randall

Increasing the efficiency of fertilizer N along with reducing fertilizer N recommendations by improved diagnostic techniques, symbiotic N fixation, crop rotation, etc. are goals which are gaining widespread research support throughout the United States. The adoption of crop rotations or sequences may play a vital role in the conservation of N. The purpose of this study is to determine the N needs of corn following corn, soybeans, wheat and wheat interseeded with alfalfa in a crop sequence study.

EXPERIMENTAL PROCEDURES

The crop sequences (continuous corn, corn-soybean, corn-wheat and corn-wheat + alfalfa) were begun in 1974 on a Webster clay loam. Each N plot within each crop sequence is 15' wide (6 rows) by 50' long. In the fall of 1974, rates of N (0, 40, 80, 120, 160 and 200 lb N/A) were applied broadcast as urea and plowed down immediately. Nitrogen rates were applied similarily in the fall of 1975. For the 1977 corn crop, N was applied as anhydrous ammonia in the spring. Wheat annually received 50 lb N/A as urea before planting. Broadcast P and K (0 + 50 + 100 lb P_2O_5 and K_2O/A) was applied annually to all plots. Row P and K (0 + 30 + 45 lb P_2O_5 and K_2O/A) was applied to the corn.

Corn was planted in 30" rows at 26,100 ppA in early May each year. The hybrid was Pioneer 3780 in 1975 and 1976 and Pioneer 3709 in 1977. Era wheat and Hodgson soybeans were planted in late April and in mid-May, respectively, each year. A non-winter hardy alfalfa was planted with the wheat in 1974 and 1975. Beginning in 1976 Agate was the alfalfa variety used.

Each year weeds were chemically controlled along with one cultivation of the corn. A combination of 3 qt Lasso plus 2½ lb Bladex/A was applied preemergence each year for corn. Soybeans received 3 qt Lasso plus 5 qt Amiben/A applied preemergence. Broadleaf weeds in the wheat were controlled with ¼ lb MCPA plus ¼ lb Bromoxynil/A. Wheat + alfalfa received no herbicide.

All corn plots regardless of the preceding crop received a band-applied insecticide at planting. The insecticide rotation included Furadan at 1 lb/A in 1974 and 1976 and Counter at 1 lb/A in 1975 and 1977.

Leaf samples were taken at silking from rows 2 and 5 of each six-row plot while rows 3 and 4 were mechanically harvested for yield. Grain moisture and protein data were obtained on the harvested samples.

Soil NO_3-N analyses were conducted on samples taken in increments of 1' to a depth of 5' each fall. The treatments sampled included all 0 and 160 lb N rates for corn plus random samples from the soybeans, wheat and wheat + alfalfa areas.

All plots were moldboard plowed in early November each year.

RESULTS

Corn yields with varying rates of N following the four previous crops are shown in Table 1. Yields in 1975 were somewhat low due to the dry conditions from July thru October. However, corn yields following corn in 1974 were about 25 to 35 bu/A lower than corn following soybeans, wheat or wheat + alfalfa. Sporadic response to N was obtained up to the 80-lb N rate.

In 1976, yields were quite low due to the driest year in recorded history (records were begun at Waseca in 1914). About a 55 bu/A advantage was shown for corn following soybeans, wheat or wheat plus alfalfa rather than following corn. This yield advantage remained about the same regardless of N rate.

Yields in 1977 were high and reflected about a 20 to 30 bu/A advantage when following soybeans, wheat or wheat plus alfalfa. This advantage was greater at the lower N rates and somewhat narrower at the 200 lb rate. Yields were optimized with the 80-lb N rate except with continuous corn when 120 lb N/A was needed.

Three-year yield averages (Table 1) over all N rates indicate a 41 bu/A yield advantage for corn following soybeans, 38 following wheat, and 36 following wheat + alfalfa as compared to continuous corn.

SUMMARY

These results indicate significant and economic yield depressions associated with continuous corn as compared to corn following soybeans, wheat or wheat plus alfalfa, regardless of N rate. Leaf and soil NO_3-N analysis (not included in this report) indicate only slight affects of the previous crop. Hence, causative reasons or explanations must lie with factors other than soil fertility.

Table 1. Corn yields following various crops at Waseca in 1975, 1976 and 1977.

		Corn yield following			
N rate		Corn	Soybeans	Wheat	Wheat + Alfalfa
lb N/A		----------------bu/A----------------			
			1975		
0		56.3	84.0	82.7	96.3
40		59.7	110.2	86.1	94.5
80		75.9	98.3	97.8	103.0
120		68.6	101.3	102.7	102.2
160		84.3	124.4	104.9	124.3
200		83.3	111.0	106.3	108.2
	Avg.	71.4	104.9	96.8	104.8
			1976		
0		35.0	86.9	86.5	88.5
40		44.6	99.0	103.2	93.1
80		42.5	107.5	107.2	97.6
120		41.9	102.9	96.2	100.6
160		43.7	104.4	97.0	94.6
200		50.2	104.8	100.6	102.5
	Avg.	43.0	100.9	98.4	96.2
			1977		
0		96.8	145.6	147.3	120.2
40		124.2	158.4	158.6	140.4
80		129.5	165.0	167.0	161.2
120		143.4	168.3	171.6	161.4
160		147.3	174.3	168.3	168.2
200		151.1	171.1	171.2	163.0
	Avg.	132.0	163.8	164.0	152.4
			1975-77 AVG.		
0		62.7	105.5	105.5	101.7
40		76.2	122.5	116.0	109.3
80		82.6	123.6	124.0	120.6
120		84.6	124.2	123.5	121.4
160		91.8	134.4	123.4	129.0
200		94.9	129.0	126.0	124.6
	Avg.	82.1	123.2	119.7	117.8

POSTEMERGENCE APPLICATION OF UAN (28% N) TO CORN

Waseca, 1977

G. W. Randall

Urea-ammonium nitrate (UAN) solutions are rapidly gaining acceptability in Minnesota as a source of nitrogen fertilizer. One of the common uses of UAN is to combine herbicides with the N solution and to apply both in one application, commonly called "weed and feed". Another possible usage for UAN is a late postemergence treatment in areas where N has been lost by denitrification or leaching. Sometimes this late treatment is placed over the top of corn or banded as a substitute for side-dressing anhydrous ammonia. The purpose of this study was to increase the efficiency of N fertilizer applied as UAN to corn by determining the:

1) maximum rate of UAN applied postemergence to corn without significant plant damage and/or yield loss.

2) optimum stage of corn growth or method of application for greatest N efficiency.

3) possible synergistic effect of UAN and atrazine on corn production.

EXPERIMENTAL PROCEDURES

A randomized complete-block experiment with 20 treatments (Table 1) and five replications was continued again in 1977 on a Webster clay loam at the Southern Experiment Station. Broadcast P and K (0+50+100 N+P_2O_5+K_2O/A) was applied to corn stalks and plowed down in October 1976. Supplemental N as ammonium nitrate was added to each plot to bring the total N amount to 150 lb N/A (except trt 3 which received 200 lb N/A). The ammonium nitrate was broadcast and disked in before planting.

Corn (Pioneer 3710) was planted in 30-inch rows at 24,200 ppa on May 13. Starter fertilizer (140 lb/A of 0-23-30) and insecticide (1 lb Counter/A) were used. Weeds were chemically controlled with Lasso plus Bladex (3 + 2½ lb/A).

UAN was applied over the top of the corn with a calibrated bicycle sprayer at the 5-leaf (June 7) and 8-leaf (June 20) stages. UAN was applied at the 5-leaf stage in 1977 because of rainfall and wet soils during the 4-leaf stage. Skies were clear and temperatures warm (89 and 72^{o}F, respectively) on both days. Atrazine was mixed with the UAN and applied at the rate of 2 lb/A at the 5-leaf stage (trts 18, 19 & 20). At the 12-leaf stage premeasured amounts of UAN were sidedress-applied by hand (July 5). No cultivation followed the sidedress application.

Early plant growth as affected by the application at the 5-and 8-leaf stages was determined on 10 plants from the border rows of each plot on June 20 and July 12. All other data were obtained from the center two rows of each four-row plot.

RESULTS

Topdress applications to emerged corn at the 5-leaf stage did affect the vigor and growth of the plants slightly more than in 1976 when the UAN was applied at the 4-leaf stage. Twenty-four hours after UAN application leaves showed increased burn with increasing UAN rates. When atrazine was added to the 60 and 90-lb N treatments, the degree of leaf burn was similar to the 120 and 150-lb N rates without atrazine, respectively. The 120-lb N rate with atrazine produced severe leaf burn, necrosis and twisting (onion-leafing) of the plants.

Early plant growth measured 13 days after application at the 5-leaf stage showed significant stunting with all UAN rates including only 30 lb N/A (Table 1). Plant weights were reduced 10, 23, 33, 42 and 50% by the 30, 60, 90, 120 and 150-lb N rates, respectively. Adding 2 pounds atrazine/A to the 60, 90 and 120-lb N rates reduced weights from the 150-lb soil treatment by 36, 42 and 61%, respectively, and resulted in significant weight reductions when comparing equal N rates.

The early stunting was less apparent 5 weeks after application. Plant weights from the 30, 60 and 90 lb N rates as UAN were not different from the soil-applied treatments. However, the 120 and 150-lb rates without atrazine and all rates with atrazine were still significantly smaller (Table 1).

At the 8-leaf stage, topdressed UAN resulted in more severe burning and lasting necrosis than comparable rates applied at the 5-leaf stage. Plant weight measured 22 days after application was reduced by all UAN treatments (Table 1). Weight reductions of 10, 17, 13, 23 and 30% were found with the 30, 60, 90, 120 and 150-lb N rates, respectively. Plant height on 7/12 was significantly shorter for all UAN rates of 60 lb or greater.

Sidedress application of UAN at the 12-leaf stage (only 7 days before the weights were taken on 7/12) resulted in the largest plants at that time, which indicates that the plants were not suffering from any N deficiency before the late sidedressing.

Plant heights to the top of the tassel and to the base of the ear in mid-August were influenced more by the stage of application than by the rate of application (Table 1). The significant UAN rate by plant growth stage interaction (IA) shows the strong stunting effect of the 120 and 150-lb rates at the 8-leaf stage but not at the 5 or 12-leaf stages.

Table 1. Effect of post-emergence application of UAN on growth and height of corn at Waseca in 1977.

Treatments				Plant Growth		Plant Height		
	N rate[1/]		Growth[2/]			Top	Tassel	Ear
No.	UAN	AN	stage	6/20[3/]	7/12[4/]	7/12	8/19	8/19
	----lb N/A----		leaf	----g/plant----		--------inches-------		
1	0	0	pre		111.	83	92	40
2	0	150	"	16.8	129.	85	92	41
3	0	200	"		121.	86	91	41
4	30	120	4	15.2	123.	84	91	40
5	30	120	8		112.	83	91	39
6	60	90	4	12.9	119.	83	90	38
7	60	90	8		104.	82	90	38
8	60	90	12		119.	84	91	39
9	90	60	4	11.3	116.	85	92	40
10	90	60	8		109.	81	90	38
11	90	60	12		119.	85	91	40
12	120	30	4	9.8	103.	81	89	37
13	120	30	8		96.	78	86	34
14	120	30	12		116.	84	93	42
15	150	0	4	8.4	104.	79	89	37
16	150	0	8		87.	75	84	33
17	150	0	12		113.	83	93	42
18	60 + 2 At	90	4	10.7	113.	82	90	37
19	90 + 2 At	60	4	9.7	103.	80	88	37
20	120 + 2 At	30	4	6.6	93.	78	89	37
	Significance:			**	**	**	**	**
	BLSD (.05) :			1.6	10.	3	3	2
	CV (%) :			12.	8.	3.	3.	5.
Individual Factors								
	UAN Rate (lb N/A)							
	60				114.	83	90	39
	90				115.	83	91	39
	120				105.	81	90	38
	150				101.	79	89	37
	Significance:				**	**	NS	*
	BLSD (.05) :				6.	1.6	--	1.5
	Growth Stage							
	4-leaf				110.	82	90	38
	8-leaf				99.	79	88	36
	12-leaf				117.	84	92	41
	Significance:				**	**	**	**
	BLSD (.05) :				5.	1.4	1.4	1.1
	Rate X Stage IA				NS	NS	**	**

1/ Supplemental N as AN (ammonium nitrate) was added to each plot to total 150 lb N/A except trt. 3 which received 200 lb N.

2/ Because of wet conditions in 1977 UAN was applied at the 5-leaf stage rather than at the 4-leaf stage.

3/ 13 days after application at the 5-leaf stage.

4/ 35 days and 22 days after application at the 5-and 8-leaf stages, respectively.

Nitrogen in the leaf opposite and below the ear at silking was significantly influenced by the N treatments (Table 2); although many were not significantly higher than the check which was quite high (2.62). No difference existed between the 4 and 8-leaf stages of application but both stages were significantly higher than the check when all rates were averaged. UAN application at the 12-leaf stage did not result in leaf N concentrations significant from the check and reflects the insufficient time for uptake between this late application and the time of sampling.

Grain yields in 1977 were quite uniform within treatments throughout the experiment (Table 2). Even though early growth was stunted by the UAN applications at the 5-leaf stage, no yield reductions were found. Significant yield depressions occurred with UAN applied at the 8-leaf stage, especially at the higher UAN rates. At the 5 and 12-leaf stages yield was not decreased by higher UAN rates; hence, the significant UAN rate by growth stage interaction. Sidedressed UAN at the 12-leaf stage resulted in yields equal to the soil-applied N and the UAN applied at the 5-leaf stage. Yields from the check treatment (0 lb N/A), the 90, 120 and 150-lb N rates of UAN applied at the 8-leaf stage, and the 120-lb N rate of UAN plus atrazine applied at the 5-leaf stage were reduced significantly from the 150-lb soil-applied treatment (no. 2). The 150-lb N rate of UAN applied at the 8-leaf stage actually depressed the yield 16 bushels below the corn which received no N.

Grain moisture at harvest, an indication of maturity, was not affected by the UAN treatments.

Grain N (protein) was influenced significantly by the UAN treatments (Table 2); however, only 3 treatments were significantly higher than the check. Protein was somewhat low ranging from 8.1 to 9.4%. Highest protein levels were found with the 12-leaf side-dress application which is evidence of sufficient N uptake that was not shown earlier by leaf N analyses. In addition to depressed plant growth and grain yields, protein levels were lowest when UAN was topdressed at the 8-leaf stage, especially at the higher rates. Perhaps this was due not only to the general stunting of the plant but also to loss of N (volatilization) from UAN on the leaves of the plants. This may have resulted in inadequate N for the crop late in the season.

SUMMARY

UAN applied to the growing corn plant did result in phytotoxic effects. When applied at the 5-leaf stage, the effects were more severe than in 1976 at the 4-leaf stage, were magnified by increasing N rate, but generally were not permanent and did not appear to reduce corn yields. When applied at the 8-leaf stage, the severity of the leaf burn was again increased with increasing N rate. However, these effects were longer lasting and did result in decreased yields at rates greater than 60 lb N/A. Combining atrazine with UAN at N rates greater than 90 lb/A and applying at the 5-leaf stage did result in a significant yield reduction.

Table 2. Effect of post-emergence application of UAN on leaf N, corn grain yield, grain moisture and grain N at Waseca in 1977.

No.	N rate[1/] UAN	N rate[1/] AN	Growth[2/] stage	Leaf N	Grain Yield	Grain Moisture	Grain N
	----lb N/A----		leaf	%	bu/A	-------%-------	
1	0	0	pre	2.62	134.7	23.9	1.37
2	0	150	"	2.76	150.1	24.2	1.43
3	0	200	"	2.82	144.7	24.4	1.50
4	30	120	4	2.76	147.7	23.9	1.40
5	30	120	8	2.93	147.6	23.6	1.43
6	60	90	4	2.90	152.7	23.9	1.44
7	60	90	8	2.93	142.4	23.6	1.38
8	60	90	12	2.70	150.8	23.9	1.48
9	90	60	4	2.87	150.8	23.8	1.45
10	90	60	8	2.98	135.0	23.6	1.38
11	90	60	12	2.80	148.5	23.6	1.47
12	120	30	4	2.80	147.8	24.2	1.44
13	120	30	8	2.95	126.8	23.9	1.35
14	120	30	12	2.65	149.0	23.9	1.42
15	150	0	4	2.98	149.3	24.0	1.40
16	150	0	8	2.85	118.6	23.4	1.30
17	150	0	12	2.78	148.9	24.1	1.42
18	60 + 2 At	90	4	2.78	153.8	23.7	1.41
19	90 + 2 At	60	4	2.93	145.1	24.3	1.38
20	120 + 2 At	30	4	3.10	137.5	24.1	1.37
	Significance:			**	**	NS	**
	BLSD (.05) :			.22	11.1		.10
	CV (%) :			6.	6.	2.	5.

Individual Factors

	Leaf N	Grain Yield	Grain Moisture	Grain N
UAN Rate (lb N/A)				
60	2.84	148.6	23.8	1.43
90	2.88	144.8	23.7	1.43
120	2.80	141.2	24.0	1.40
150	2.87	138.9	23.9	1.38
Significance:	NS	*	NS	*
BLSD (.05) :		6.4		.05
Growth Stage				
4-leaf	2.89	150.2	24.0	1.43
8-leaf	2.92	130.7	23.6	1.36
12-leaf	2.73	149.3	23.9	1.45
Significance:	**	**	+	**
BLSD (.05) :	.08	4.8		.04
Rate X Stage IA	NS	+	NS	NS

1/ Supplemental N as AN (ammonium nitrate) was added to each plot to total 150 lb N/A except trt. 3 which received 200 lb N.

2/ Because of wet conditions in 1977 UAN was applied at the 5-leaf stage rather than at the 4-leaf stage.

CORN-SOYBEAN TILLAGE

Waseca, 1977

G. W. Randall

A field experiment was initiated in 1973 to evaluate tillage systems under a corn-soybean rotation in south central Minnesota. Twelve tillage treatments were established in a randomized, complete-block design with four replications for corn and four for soybeans each year. The two crops simply rotate from one area to the other each year. The experiment is located on a Webster clay loam with a 0-2% slope. Tile lines spaced 75' apart lie perpendicular to the rows.

Fall primary tillage operations were conducted October 28, 1976. The spring primary tillage treatments were performed on April 28 and the secondary treatments on the date of planting.

Broadcast P and K (40+80 lb P_2O_5+K_2O/A) were applied in October, 1976. Nitrogen (150 lb N/A as ammonium nitrate) was broadcast on May 5 to the corn area.

Corn (Pioneer 3710) was planted at a rate of 24,200 ppA on May 7. A John Deere Max-Emerge planter with 2" fluted coulters was used to plant the plots which did not receive primary tillage. For those plots which did receive primary tillage, the fluted coulters were removed. Starter fertilizer was not applied. Chemical weed control consisted of 3 lb Lasso/A and 2½ lb Bladex/A applied preemergence. Surface residue did not prevent cultivation in 1977, therefore, each treatment was cultivated once. Yields were obtained by combine harvesting two center rows from each plot.

Soybeans (Corsoy) were planted at a rate of 8.5 beans/foot of row on May 14. The planter and procedures used were the same as those described above for corn. Weeds were controlled with 3 lb Lasso/A and 2½ lb Amiben/A. All treatments received one cultivation. Heavy rains on May 17 and May 30 drowned the soybeans in 2 of the 4 replications. Yields were obtained by combine harvesting four center rows from each plot in the remaining two replications.

EXPERIMENTAL TREATMENTS

The 12 tillage treatments are listed in Table 1. Six of the treatments (No. 1, 2, 6, 7, 9 and 10) are conducted continuously; regardless of crop. The other six treatments take on a "systems" approach to tillage whereby the primary tillage method varies with the crop in the rotation.

Table 1. Tillage treatments in the corn-soybean rotation tillage study at Waseca in 1977.

Trt. No.	for SOYBEANS following CORN Primary	Secondary	for CORN following SOYBEANS Primary	Secondary
1	NONE	NONE	NONE	NONE
2	Fall Plow	f. cult.	Fall Plow	f. cult.
3	" "	" "	Fall Chisel	" "
4	" "	" "	Spr. "	" "
5	" "	" "	Zero	Zero
6	Spr. Plow	disk & f. cult.	Spr. Plow	f. cult.
7	Fall Chisel	disk	Fall Chisel	" "
8	" "	"	Zero	Zero
9	Spr. Chisel	"	Spr. Chisel	disk
10	Spr. Disk	"	Spr. Disk	"
11	Fall Chisel	f. cult.	Fall f. cult.	f. cult.
12	Fall Disk	disk	Fall Plow	" "

RESULTS: CORN

Differences in seedbed condition at planting were again noticed in 1977. The best seedbed resulted from either the fall chisel, field cultivate, spring disk or fall plow treatments. Here the soil was moist, firm, easy to work and provided a good seed-soil contact. Large clods were not present. Seedbed condition with the other primary tillage treatments ranked no tillage> spring chisel> spring moldboard plow. Large clods resulted from the latter treatment.

Heavy rainfall shortly after planting (2.25" on May 15-17) reduced the clod size and resulted in good seed to soil contact in all treatments. Consequently, emergence of the seedlings was quite uniform among the treatments and emergence data were not taken.

Because of the early spring, grassy weed growth was prevalent. On those areas receiving spring tillage the growth was curtailed by both the tillage and herbicides. However, the treatments that did not receive spring tillage did show some weed growth not controlled by the preemergence herbicides.

Early plant growth differences among the treatments were significant at the 99% level (Table 2). Continuous no tillage resulted in significantly smaller plants than all other treatments. The excellent early growth obtained in 1977 with spring primary tillage was not consistent with past years and probably reflects the timely rain and good seed to soil contact mentioned earlier.

Final population was affected only slightly (90% level) by the treatments (Table 2). Lowest and highest populations were obtained with the no tillage and spring disk treatments, respectively.

Table 2. Influence of tillage methods following soybeans on corn production at Waseca in 1977.

Tillage Treatment			Early plant growth	Final popl'n	Moisture at harvest	Yield	
No.	Primary	Secondary				1977	1974-77
			g/plant	x 1000	%	----bu/A-----	
1	NONE	NONE	7.8	20.5	27.6	138.4	113.0
2	Fall plow	f. cult.	10.7	21.2	27.4	158.8	134.7
3	Fall chisel	" "	11.1	22.2	27.5	161.6	137.8
4	Spr. "	" "	11.8	21.8	26.9	163.0	129.4
5	Zero	Zero	10.3	21.6	26.8	161.3	136.6
6	Spr. plow	f. cult.	9.6	21.4	28.5	158.4	124.4
7	Fall chisel	" "	10.0	21.6	27.7	155.0	130.0
8	Zero	Zero	9.8	20.9	27.5	141.8	125.4
9	Spr. chisel	disk	9.8	21.9	27.3	153.0	127.5
10	Spr. disk	"	10.0	22.6	27.0	154.1	135.7
11	Fall f. cult.	f. cult.	9.5	21.0	27.5	158.9	137.1
12	Fall plow	" "	9.8	22.6	27.4	161.1	135.4
		Significance:[1/]	**	+	**	**	**
		BLSD (.05) :	1.0		0.8	9.5	10.0
		CV (%) :	7.3	4.3	1.8	4.3	5.1

[1/] ** = significant at the 99% level; NS = not significant at the 90% level.

Grain moisture at harvest was influenced by tillage (Table 2) with the spring plow treatment resulting in significantly wetter corn than all other treatments.

Grain yields (Table 2) were also affected significantly by the tillage treatments. Lowest yields were obtained with the continuous no tillage (trt. 1) and no tillage-fall chisel system (trt. 8). All other treatments resulted in significantly higher yields, and in contrast to previous years, were not significantly different from each other. This again reflects the influence of timely rainfall when conducting primary spring tillage. Yield was correlated with early plant growth in 1977 (r = +.526). The linear regression of Yield = 111.8 bu/A + 4.37 EPG (g/plant) fits the 1977 data.

Four-year corn yield averages show consistently reduced yields with continuous no tillage (Table 2). Intermediate yields were obtained with continuous spring plowing (no. 6), spring chiseling (no. 9), fall chiseling (no. 7) and with the no tillage-fall chisel (no. 8) and spring chisel-fall plow (no. 4) systems. The two highest yields were obtained when the soybean ground was either fall chiseled or fall field cultivated provided that the ground had been fall plowed for the previous soybean crop.

Leaf samples taken at the silking stage show significant effects of the tillage treatments on plant K, Ca, and Mg (Table 3). Plant K was highest anytime that moldboard plowing was included in the two-year tillage system. Continuous moldboard tillage generally resulted in slightly higher K levels than when used on an alternate year basis. Intermediate K levels were obtained with continuous chisel plowing and disking treatments and with the chisel-no tillage system. Continuous no tillage showed significantly lower plant K than all other treatments except no. 8 and was considerably below the sufficiency level of 1.60%. This may have been partially responsible for the reduced yield with this treatment. The interaction between K and both Ca and Mg was very evident. Other nutrients were not affected by the tillage treatments but were considered to be adequate for optimum plant growth.

Surface residue accumulations and soil temperatures were not taken in 1977 because of the heavy, intense rains which resulted in some flooding and movement of residue after planting.

Table 3. Influence of tillage methods following soybeans on nutrient concentrations in the corn earleaf at Waseca in 1977.

Treatment			Nutrient								
No.	Primary	Secondary	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			---------%---------				----------ppm----------				
1	NONE	NONE	.31	1.38	.76	.60	320	46	24	6.8	10
2	Fall plow	f. cult.	.32	1.99	.68	.44	311	58	23	7.4	11
3	Fall chisel	" "	.31	1.77	.72	.51	324	51	23	7.6	10
4	Spr. "	" "	.32	1.84	.68	.47	329	54	23	7.9	10
5	Zero	Zero	.32	1.85	.67	.46	316	41	22	7.0	10
6	Spr. plow	f. cult.	.33	2.03	.69	.42	314	56	22	7.8	11
7	Fall chisel	" "	.34	1.63	.76	.61	356	55	23	7.6	10
8	Zero	Zero	.32	1.54	.77	.58	302	47	23	7.1	10
9	Spr. chisel	disk	.33	1.65	.73	.57	320	52	24	7.7	11
10	Spr. disk	"	.32	1.62	.73	.57	322	52	24	7.6	11
11	Fall f. cult.	f. cult.	.32	1.84	.70	.50	326	47	22	7.4	11
12	Fall plow	" "	.32	2.01	.71	.45	328	61	21	7.8	11
		Significance:	NS	**	*	**	NS	NS	NS	NS	NS
		BLSD (.05) :		.19	.08	.07					
		CV (%) :	4.8	7.9	6.2	9.4	7.7	17.1	7.9	9.3	9.4

RESULTS: SOYBEANS

Soybean plant population was not affected by the tillage treatments (Table 4).

Yields were generally highest anytime moldboard plowing was part of the tillage system; regardless of fall or spring timing (Table 4). Somewhat lower yields were found with the fall and spring chisel and disk treatments. This relationship is similar to the trend which began to develop in the fourth year of the study. As in all previous years the continuous no tillage treatment resulted in the lowest yield.

Five-year yield averages show the highest yield resulting from the fall plow-fall chisel system (Table 4). Slightly lower yields were obtained with the continuous fall and spring chisel systems as compared to the fall moldboard plow-fall chisel system. However, no yield differences were observed between the continuous chisel systems and any of the other systems involving the moldboard plow. Spring disking the cornstalks annually resulted in optimum yields and provides the farmer with an alternative of a low-energy consuming tillage system for soybean production. Because of poor weed control, lowest yields were obtained with continuous no tillage. Weed control with all of the other systems was excellent.

Because of only two replications in 1977, no leaf samples were taken for analytical analysis.

Table 4. Influence of tillage methods following corn on soybean production at Waseca in 1977.

No.	Treatment Primary	Treatment Secondary	Popl'n	Yield 1977	Yield 1973-77
			beans/ft	----bu/A-----	
1	NONE	NONE	6.9	48.6	38.6
2	Fall plow	f. cult.	7.5	55.4	45.5
3	" "	" "	7.3	54.2	46.4
4	" "	" "	7.1	55.1	44.8
5	" "	" "	7.2	53.8	45.2
6	Spr. plow	disk & f. cult.	7.2	55.5	45.3
7	Fall chisel	disk	7.3	51.9	43.2
8	" "	"	7.4	51.6	43.9
9	Spr. chisel	"	7.0	51.2	43.2
10	Spr. disk	"	7.4	49.8	44.0
11	Fall chisel	f. cult.	6.5	51.1	44.3
12	Fall disk	disk	6.8	53.2	44.7
		Significance:	NS	**	**
		BLSD (.05) :		2.7	2.5
		CV (%) :	9.2	2.3	4.4

RESULTS: SOIL P AND K DISTRIBUTION

Soil samples were taken in early August from between the rows in eight of the tillage systems and from six replications (two reps in soybeans and four in corn). All samples consisted of six cores and were divided into 0-2", 2-4", 4-6", 6-9" and 9-12" increments.

Results shown in Table 5 indicate a very uniform P and K distribution in the 0-9" profile with the continuous moldboard plow system (no. 2). The systems which included moldboard plowing every other year (no.'s 3 and 5) also showed uniform P and K distributions within this zone. The no tillage, chisel, and disk systems (no.'s 1, 7, 8, 10 and 11) showed high P and K accumulations in the top 2 inches and some accumulation in the 2-4" zone. Soil test P and K in the 4-6, 6-9 and 9-12" zones were low and were not influenced by chiseling or disking as compared to continuous no tillage.

These results indicate the importance of building-up the soil test levels in the plow-layer before a farmer switches to a reduced tillage system. Neither the chisel nor disk systems incorporated the broadcast P and K below 4". If conditions exist where the soil test is low or the fertility is accumulated in the top 2 or 4" and root development in this surface zone is limited because of dryness, compaction, etc., then nutrient deficiencies may develop which could limit yields severely. Strong emphasis on good management including fertility and weed control must be given when considering reduced tillage systems.

Table 5. Distribution of soil test P and K in the soil profile as influenced by five years of tillage in a corn-soybean sequence at Waseca.

No.	Tillage Treatment for SOYBEANS	Tillage Treatment for CORN	Depth (inches) 0-2	2-4	4-6	6-9	9-12
			-----Bray P_1 (ppm)------				
1	None	None	29	16	13	9	5
2	Fall plow	Fall plow	18	17	19	16	7
3	" "	Fall chisel	22	18	20	13	5
5	" "	None	22	15	17	14	4
7	Fall chisel	Fall chisel	27	17	13	9	4
8	" "	None	30	18	13	9	3
10	Spr. disk	Spr. disk	29	15	11	8	3
11	Fall chisel	Fall f. cult.	30	20	14	13	5
			-----Exch. K (ppm)------				
1	None	None	216	118	104	98	82
2	Fall plow	Fall plow	121	113	120	120	99
3	" "	Fall chisel	136	128	134	117	104
5	" "	None	129	110	115	103	86
7	Fall chisel	Fall chisel	156	116	102	97	93
8	" "	None	185	115	102	96	84
10	Spr. disk	Spr. disk	176	124	103	103	98
11	Fall chisel	Fall f. cult.	175	124	106	96	85

CONSERVATION TILLAGE STUDY

Waseca, 1977

G. W. Randall 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. 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 7 the moldboard and chisel plow plots were field cultivated once.

Corn (Pioneer 3709) was planted in the till-plant plots at a rate of 24,000 ppA on May 6. Because of wet soils the no till, fall plow and fall chisel plots were planted 1 day later on May 7. A John Deere planter equipped with 2" fluted coulters was used for the no-tillage treatment. The fluted coulters were removed for the plow and chisel treatments. A Buffalo till planter was used for the till-plant treatments.

Broadcast P and K were applied at a rate of 0+40+80 (lb N+P_2O_5+K_2O/A) in October, 1976. Nitrogen (175 lb N/A as ammonium nitrate) was broadcast on May 5. Starter fertilizer (13+32+42 lb N+P_2O_5+K_2O/A) and an insecticide (1 lb Counter/A) were applied to all plots at planting. Chemical weed control consisted of 3 lb Lasso and 2½ lb atrazine/A applied pre-emergence. Treatments 2, 3, 4, and 5 were cultivated in mid-June. Weed control was excellent in all cultivated treatments. Yields were taken by combine harvesting four rows from each plot.

RESULTS

Significant differences in final population and yield were found among the five treatments (Table 1). Due primarily to a shallow planting depth (1¼-1½"), the till planted plots had about 10 percent fewer plants than those plots planted with the John Deere Max-Emerge planter. Following planting a significant rainfall event did not occur for 8 days. This allowed some of the more shallow seeds as well as those that were not pressed as firmly by the Buffalo till planter press wheel to dry out shortly after they began to germinate. This 10% population reduction illustrates how important proper seeding depth and seed-soil contact is in obtaining good stands.

Table 1. Influence of tillage methods on continuous corn production at Waseca in 1977.

Treatment	Final popl'n	Kernel Length	Kernel Weight	Moist.	Yield	1975-77 Avg. Yield
	x 1000	in./10	g/100	%	-----bu/A-----	
No tillage (Fluted Coult.)	21.0	4.65	34.08	22.6	136.9	95.0
Fall plow, f. cult.	21.6	4.69	34.35	22.1	162.0	118.0
Fall chisel, disk, f. cult.	22.1	4.59	34.92	22.3	159.6	104.0
Till plant (Ridge)	19.5	4.72	34.85	22.2	155.0	118.0
" " (No Ridge)	19.1	4.72	34.78	22.4	149.4	117.0
Significance:	+	NS	NS	NS	**	
BLSD (.05) :					9.8	
CV (%) :	7.1	2.1	2.2	1.5	4.3	

Yields in 1977 were much higher and the effect of the tillage treatments was somewhat different than in 1975 or 1976. Lowest and highest yields were obtained with the no tillage and fall moldboard plow treatments, respectively. Lack of good weed control along with reduced plant vigor (size) appeared to be the major problem in the no tillage plots. No significant yield differences were found among the fall plow, fall chisel and till-plant (ridge) treatments. This is in contrast to previous years when yields from fall chiseling were substantially lower. Perhaps the addition of the secondary disking before field cultivating (speculated as being necessary in the 1976 report) contributed to the improved performance with chiseling. Also, the moisture conditions at and following planting were improved over 1975 and 1976. Till-planting without ridging resulted in a lower yield than either fall moldboard plowing or chiseling in 1977. The slightly lower yields associated with the till-plant treatments may have been due primarily to the 10% lower final population in this year of adequate moisture.

Highest three-year yield averages were obtained with the moldboard plow and both till-plant treatments with no significant difference among them (Table 1). Because of poor yields in 1975 and 1976, average yields with chisel plowing were significantly lower. Consistent low yields over all three years resulted in an average yield of only 95 bu/A for no tillage.

In an attempt to determine if 1977 yield differences were due to various kernel characteristics, kernel length and weight of the harvested grain were determined. Significant differences in length or weight were not found among the treatments (Table 1). No differences in grain moisture were observed either.

Small plant growth differences were not statistically significant because of the variability (Table 2). The correlation between early plant growth and grain yield was not significant (r = -.057).

Table 2. Influence of tillage methods for continuous corn on early plant growth and surface residue accumulation at Waseca in 1977.

Treatment	Early plant growth	Surface residue
	g/10 plants	T DM/A
No tillage (Fluted Coult.)	91.0	2.1[1/]
Fall plow, f. cult.	94.5	Trace
Fall chisel, "	88.2	1.7
Till plant (Ridge)	104.8	2.1
Till plant (No Ridge)	89.0	3.1
Significance:	NS	
CV (%) :	21.1	

1/ Wind blew some material off.

Surface residue from the preceding corn crop showed an accumulation of up to 3 tons dry matter per acre after planting with the till-plant (no ridge) system (Table 2). Accumulation on the no-till plots would be expected to be near or slightly greater than with the till-plant (no ridge) system but some residue was blown off those plots. Approximately 2 tons residue/A remained after planting with both the chisel and till-plant ridge systems.

Soil temperatures measured by thermocouples were affected by the surface residues (Table 3). Prior to planting the 4-inch soil temperatures were warmest with the moldboard plow, intermediate with the ridged system and lowest with the no tillage system. Temperatures in the ridged system were taken directly in the ridge and not in the lower inter-row area. Other temperatures were measured at random throughout the plots.

After planting soil temperatures remained highest with moldboard plowing for 1 week. However, temperatures in the till-planted plots equalled temperatures in the moldboard plots within 10 days. Fall chiseling, till planting without a ridge and no tillage showed very consistent, slightly cooler temperatures for the five-week period following planting.

Table 3. Soil temperature (4" average) as influenced by tillage practices at Waseca in 1977.

Tillage Treatment	Preplant 4/15 -23	4/24 -30	5/1 -3	Post Plant 5/8 -14	5/15 -21	5/22 -28	5/29 -6/4	6/5 -10
	°F							
No tillage	56.5	57.1	59.0	64.4	69.7	71.5	67.2	72.8
Fall plow	57.7	58.7	60.2	66.8	69.6	72.8	67.6	73.9
Fall chisel				65.0	68.8	71.9	67.0	73.1
Till plant (R)	57.1	57.8	59.9	66.1	69.7	72.9	67.8	74.0
Till plant (NR)				65.2	68.9	72.0	67.2	73.2

Leaf samples were taken from the leaf opposite and below the ear at silking. Nutrient concentrations were not affected by the tillage systems although a trend toward lower K concentrations was shown with the no tillage and till-plant (no ridge) systems (Table 4). All concentrations were considered sufficient for optimum plant growth.

Table 4. Influence of tillage methods for continuous corn on the nutrient concentration in the earleaf at Waseca in 1977.

Treatment	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
No tillage	2.64	.29	1.87	.62	.37	184	40	25	6.2	8.7
Fall plow	2.74	.32	2.22	.66	.34	187	58	25	7.1	9.5
Fall chisel	2.74	.32	2.12	.66	.36	192	57	26	6.7	9.4
Till plant (R)	2.76	.32	1.98	.70	.41	193	48	28	6.6	9.3
Till plant (NR)	2.74	.30	1.82	.67	.44	189	50	28	7.0	10.0
Significance:	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%) :	5.0	7.1	11.4	11.5	17.3	12.9	31.3	12.3	16.4	11.5

Soil samples were taken from all plots in 6-inch increments to a depth of 3 feet in late July and again in 12-inch increments to a depth of 5 feet in early November. All samples were immediately dried and analyzed for NO_3-N. Results shown in Table 5 indicate marked differences in the NO_3-N concentration among depths in the profile and substantial differences in the NO_3-N concentration and total NO_3-N among the tillage treatments. High plant N demand at the July sampling time more-than-likely accounted for lower NO_3-N values in the top 12". By early November lowest NO_3-N concentrations were found in the 12-24" zone.

Table 5. Nitrate-N distribution in the soil profile on July 29 and November 2, 1977 as influenced by tillage at Waseca.

Depth	No tillage	Fall plow	Fall chisel	Till-plant Ridge	Till-plant No ridge
inches	ppm				
			July 29, 1977		
0-6	7.4	9.4	6.9	12.6	13.1
6-12	6.5	15.4	7.2	12.7	11.8
12-18	10.0	30.4	15.3	21.2	22.5
18-24	17.9	39.4	25.3	36.4	32.0
24-30	25.8	39.6	29.6	42.2	44.4
30-36	26.6	32.9	28.0	38.3	40.6
lb NO_3-N/A in 0-36" profile[1/]	189	335	225	326	329
			November 2, 1977		
0-12	20.2	31.3	27.4	24.6	19.4
12-24	8.3	19.0	11.6	13.1	9.9
24-36	11.4	42.4	13.1	20.2	19.3
36-48	29.6	33.0	36.9	56.6	39.4
48-60	28.3	30.5	28.1	40.5	33.0
lb NO_3-N/A in[1/]					
0-36" profile	160	371	208	231	195
0-60" profile	391	625	468	619	485

[1/] Assuming 2 million lb soil/every 6" depth of soil

Total NO_3-N amounts in the 0-36" profile in July were decreased by 44 and 33% with the no tillage and fall chisel treatments, respectively, when compared to the moldboard treatment. Both till-plant systems showed equal NO_3-N amounts to the moldboard system. By early November the NO_3-N contained in the 0-60" profile was reduced when compared to the moldboard treatment by 38, 25 and 22% with the no tillage, fall chisel and till-plant (no ridge) systems, respectively. The till-plant (ridge) and the moldboard systems were not different in the total NO_3-N; however, the distribution of NO_3-N was concentrated below 36" with the till-plant system while the nitrates were more evenly distributed throughout the profile with the moldboard system.

The NO_3-N amounts shown in Table 5 are extremely high and do reflect possible carryover from 1975 and 1976 when yields were low. However, the magnitude of the differences among tillage treatments does suggest the need for future studies to investigate the interaction between tillage x nitrogen fertilization.

Soil samples were also taken from between the rows in all plots in late July to a depth of 12" and divided into 0-2, 2-4, 4-6, 6-9 and 9-12" increments. In addition, similar samples were taken from within the corn rows from the moldboard plow and till-plant systems. Results from between the rows show that both P and K were most evenly distributed throughout the profile with the moldboard plow treatment and to a lesser degree with the chisel treatment (Tables 6 and 7). The other treatments showed high surface accumulations.

Within-row sampling as compared to between-row sampling showed increased P concentration and improved P distribution with the till-plant (ridge) system. Soil test K within the row was not influenced by this system. Within-row sampling from the moldboard plow treatments showed lower P and K concentrations than between-row sampling. These results would indicate a more desirable distribution of P and K within the row with the ridged till-plant system than with the non-ridged system.

Table 6. Soil test P distribution in 1977 between and within the corn rows as influenced by three years tillage at Waseca.

Depth	No tillage	Fall plow	Fall chisel	Till-plant Ridge	Till-plant No ridge
inches	Bray P_1 (ppm)				
			Between rows		
0-2	36	17	27	31	20
2-4	18	22	22	17	11
4-6	15	28	16	13	10
6-9	10	20	10	9	10
9-12	4	5	2	3	3
			Within row		
0-2		18		41	28
2-4		14		23	12
4-6		18		14	9
6-9		13		14	7
9-12		6		8	6

Table 7. Soil test K distribution in 1977 between and within the corn rows as influenced by three years tillage at Waseca.

Depth	No tillage	Fall plow	Fall chisel	Till-plant Ridge	Till-plant No ridge
inches	Exch. K (ppm)				
			Between rows		
0-2	244	156	240	258	204
2-4	122	188	177	152	118
4-6	113	209	134	122	118
6-9	115	190	123	121	112
9-12	107	136	111	114	112
			Within row		
0-2		158		254	220
2-4		124		130	109
4-6		126		101	99
6-9		119		97	90
9-12		97		85	82

LIME PLOTS, WASECA, 1977

John Grava, G. W. Randall, C. J. Overdahl, R. P. Schoper, J. N. Lensing

Investigations on effects of liming on crop yield, chemical composition of plant tissue and chemical properties of the soil were continued at the Southern Experiment Station. Liming experiments have been conducted with corn since 1971, with soybeans and alfalfa since 1972.

CORN

Dolomitic limestone was applied to the continuous corn experiment in spring of 1971. The experiment was relimed in spring of 1975 because the soil pH had not been increased to 6.5, considered to be optimun for corn production on mineral soils. Soil samples were collected on June 15 and June 21. The results are reported in Table 1. All corn plots received the following cultural practices in 1977:

Tillage: Moldboard plow in fall 1976;

Fertilizer: 183 + 72 + 122 lb/acre of plant nutrients expressed as N, P_2O_5, K_2O;

Insectice: Counter, 1 lb/A;

Herbicide: 3 lb Lasso and 2.4 lb Bladex per acre;

Pioneer 3709 corn was planted on April 29. Plant population: 24,200 plants/A. The plots were harvested on October 20.

Liming increased pH values of the soil at 0-6 inch and 6-12 inch depths (Table 1). It required reliming with 7.5 or 10 tons of limestone per acre to reach the desired 6.5 level of soil pH. Liming had no effect on the yield or moisture content of corn grain (Table 2). Dolomitic limestone treatments of 2.5 tons per acre or more decreased manganese concentration of sixth leaf at tasseling from 118 to 54 ppm (Table 6).

SOYBEANS

The liming experiment with continuous soybeans was established in spring of 1972 and was relimed at the end of 1975 growing season. Soybean plots received the following cultural treatments in 1977:

Tillage: Chisel plowed in fall 1976;

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[1]See "Report on Field Research in Soils", Soil Series 88, March 1972, pp. 140-141; Soil Series 89, March 1973, pp. 154-159; Soil Series 91, March 1974, pp. 190-197; Soil Series 95, March 1975, pp. 148-156; Soil Series 97, March 1976, pp. 134-142; Soil Series 99, March 1977, pp. 142-150, for results obtained in previous years.

Fertilizer: None;

Herbicide: 1 lb Treflan and 2.5 lb Amiben preemergence;

Wells variety was planted on May 14 with a population of 6 beans/foot. However, a poor stand of the original planting developed due to a heavy rain which caused some crusting, and to jack rabbit damage. The plots were cultivated once on June 8 and replanted with Evans variety that same day. Plant population was 8 beans/foot. Variability developed among plots due to jack rabbit damage again. The plots were harvested on October 18.

Liming had no effect on soybean yield (Table 3), or on the chemical composition of the trifoliate leaves (Table 7).

ALFALFA

The liming experiment with alfalfa was established in spring of 1972. Vernal alfalfa was grown for four years. Roundup, a non-selective herbicide, was applied at 1/2 gal/acre in August 1975 to kill quackgrass, perennial weeds and alfalfa. Plot area was plowed in August. Dolomitic limestone was applied in November 1975 and disked in April 1976. Eptam herbicide was applied at 3 lb/acre rate and Agate alfalfa was seeded on April 20 at 16 lb/acre. No fertilizer was applied at establishment. Two cuttings were taken in 1976. Fertilizer, at a rate of 0 + 50 + 120 expressed as N, P_2O_5 and K_2O was applied on July 8, 1977. Alfalfa was harvested on the following dates: 5/27, 7/5 and 8/18. Yield was not significantly increased by lime applications (Table 4). Liming resulted in slight changes in the concentration of some plant nutrient elements of alfalfa tissue (Table 8). Manganese concentration was decreased by liming in all three cuttings while boron content was decreased in tissue of first and third cutting alfalfa. Aluminum concentration in tissue was decreased at third cutting. There were slight increases of magnesium and potassium found in the tissue of some cuttings.

SUMMARY AND CONCLUSIONS

Three liming experiments with corn, soybeans and alfalfa, grown continuously, have been conducted at the Southern Experiment Station since 1971 or 1972. The experimental area includes two fine textured soils (Le Sueur clay loam and Cordova silty clay loam). The surface soil ranges in pH from 5.5 (soybean, alfalfa areas) to 5.7 (corn area) and has a lime requirement of 6.5 tons/acre (SMP Buffer Index 6.1). At a 30-36 inch depth, the subsoil is neutral. Free carbonates are found at 36-42 inch depth.

Relatively high yields of all three crops have been produced in the experimental areas with good cultural practices and proper fertilization. However, liming has not affected crop yields (Table 5).

Concentration of some microelements in plant tissues has been reduced by the application of lime. This is to be expected, considering the effect of higher soil pH on the availability of manganese and zinc. However, even the highest lime rates have not decreased the concentration of these nutrient elements to such extent so as to cause deficiencies.

Table 1. Soil Test Results of the Corn Plot Area, Waseca Lime Plots[1]

Lime Treatments tons/A	Soil Depth inches	pH	SMP Buffer Index	Extractable P pp2m	Exchangeable K pp2m
0	0-6	5.3	5.9	66	286
	6-12	5.3	6.1	62	270
	12-18	5.8	6.6	10	228
	18-24	6.0	6.8	5	227
	24-30	6.3	6.6	6	222
	30-36	6.6	6.7	9	219
2-5	0-6	5.9	6.2	73	295
	6-12	6.0	6.3	52	255
	12-18	5.8	6.5	27	258
	18-24	5.9	6.6	7	246
	24-30	6.3	6.8	6	230
	30-36	6.5		7	223
5-0	0-6	6.2		72	295
	6-12	6.1	6.4	58	258
	12-18	6.0	6.6	9	221
	18-24	6.1	6.7	5	224
	24-30	6.3	6.9	5	233
	30-36	6.5	7.0	7	230
7.5	0-6	6.4	6.5	68	271
	6-12	6.3	6.4	40	243
	12-18	5.9	6.4	9	212
	18-24	6.1	6.6	5	214
	24-30	6.4	6.8	5	213
	30-36	6.8	6.7	7	215
10	0-6	6.5		77	265
	6-12	6.4		59	257
	12-18	6.0	6.4	19	247
	18-24	6.0	6.7	6	243
	24-30	6.3	6.8	5	242
	30-36	6.7	6.9	5	234

[1]Samples collected on June 15 and 21, 1977; means of 6 replications

Table 2. Yield and moisture content of corn grain, Waseca lime plots, 1977

Rate of Lime tons/acre	Yield bu/acre	Moisture %
0	157[1]	22.3
2.5	152	22.6
5	156	22.6
7.5	150	22.7
10	149	22.8
Significance	NS	NS
CV%	4.5	1.9

[1]Ave of 6 replications

Table 3. Yield of soybeans, Waseca lime plots, 1977

Rate of Lime ton/acre	Yield bu/acre
0	39[1]
2.5	40
5	41
7.5	38
10	38
Significance	NS
CV%	8.4

[1]Ave of 6 replications

Table 4. Yield of Alfalfa, Waseca Lime Plots, 1977

Rate of Lime tons/acre	Hay Yield 1st Cutting	2nd Cutting	3rd Cutting	Total
	---tons/acre---			
0	1.81	1.83	1.39	5.03
2.5	1.78	1.72	1.39	4.89
5	1.76	1.55	1.30	4.62
7.5	1.82	1.80	1.39	5.01
10	1.75	1.64	1.36	4.75
Significance	NS	NS+	NS	NS
C.V., %	6.6	9.9	7.1	6.8

[1]Ave of 6 replications; 12% moisture

(+ significant at 10% level)

Table 5. Effect of liming on yields of continuous corn, soybeans and alfalfa, Waseca lime plots

Rate of lime tons/acre	Yield Average: Corn 1971-1977	Soybeans 1972-1977	Alfalfa 1973-1977
	---bu/acre---		tons/acre
0	125	41	3.9
2.5	119	40	4.0
5.0	118	40	3.9
7.5	122	41	4.0
10.0	120	41	4.0
Significance	NS	NS	NS

Table 6. Chemical composition of 6th corn leaf at tasseling, Waseca lime plots, 1977

Rate of Lime	P	K	Ca	Mg	Al	Fe	Zn	Cu	Mn	B
tons/acre	----% in dry matter-----				--------------ppm in dry matter--------					
0	0.31	2.47	.55	.31	60	194	32	5.1	118b*	8.9
2.5	0.29	2.52	.48	.32	52	170	28	4.4	74a	7.1
5.0	0.30	2.37	.54	.37	52	179	25	4.0	65a	8.8
7.5	0.28	2.64	.50	.37	56	166	23	4.5	56a	7.4
10.0	0.32	2.46	.53	.39	51	180	22	4.8	54a	8.2
Significance	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
BLSD (.05)	-	-	-	-	-	-	-	-	28	-
CV, %	18.1	17.3	28.9	14.3	20.6	26.6	29.8	25.0	31.8	37.3

*Any letter(s) different from another letter in a column indicates a significant difference between means at the 5% level.

Table 7. Chemical composition of soybean trifoliate leaves, Waseca lime plots, 1977

Rate of Lime	P	K	Ca	Mg	Al	Fe	Zn	Cu	Mn	B
tons/acre	-------% in dry matter---				--------------ppm in dry matter--------					
0	0.46	2.34	1.34	0.52	84	181	45	6.1	48	45
2.5	0.46	2.31	1.30	0.50	79	187	44	6.2	54	48
5.0	0.48	2.27	1.28	0.52	84	193	47	5.5	50	43
7.5	0.44	2.12	1.29	0.51	82	187	41	5.9	51	46
10.0	0.50	2.31	1.17	0.50	76	195	49	5.4	46	43
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD	-	-	-	-	-	-	-	-	-	-
CV, %	9.2	6.4	9.6	6.7	13.3	7.4	13.4	15.3	9.4	9.6

Table 8. Chemical composition of alfalfa, Waseca lime plots, 1977

Rate of Lime	P	K	Ca	Mg	Al	Fe	Zn	Cu	Mn	B
tons/acre	----% in dry matter-----				------ppm in dry matter--------					
					First Cutting					
0	0.29	2.15b	1.80	0.37	621	773	33	5.5	43b	44b
2.5	0.29	2.11ab	1.76	0.36	571	682	32	5.1	31a	42b
5.0	0.31	2.06ab	1.84	0.39	553	667	33	5.4	35ab	42b
7.5	0.29	1.95a	1.72	0.37	529	620	33	4.6	26a	36a
10.0	0.30	2.20b	1.67	0.36	532	622	34	4.6	33a	36a
Significance	NS	*	NS	NS	NS	NS	NS	NS	*	**
BLSD (.05)	-	.16	-	-	-	-	-	-	9	4.70
CV,%	5.4	4.5	7.5	7.6	9.0	8.3	8.0	11.0	16.5	7.4
					Second Cutting					
0	0.30	2.35ab	1.92	0.35a	355	457	38	5.9	57b	48
2.5	0.32	2.51b	2.05	0.38ab	434	560	39	6.3	44ab	50
5.0	0.31	2.28ab	1.95	0.38ab	388	504	37	6.1	37a	43
7.5	0.32	2.11a	2.10	0.40b	504	635	40	6.1	39a	45
10.0	0.31	2.44b	2.01	0.37ab	380	512	40	5.9	44ab	41
Significance	NS	*	NS	*	NS	NS	NS	NS	*	NS
BLSD (.05)	-	.25	-	.04	-	-	-	-	14	-
CV, %	8.3	6.4	7.9	5.6	24.3	19.3	8.8	19.0	18.6	10.9
					Third Cutting					
0	0.28	2.24	1.68	0.28	414ab	529	37	5.8	69b	39b
2.5	0.30	2.24	1.64	0.29	420ab	529	33	5.1	40a	36ab
5.0	0.30	2.10	1.74	0.30	459b	587	33	4.9	42a	36ab
7.5	0.30	2.21	1.65	0.29	348a	456	32	5.0	35a	34a
10.0	0.30	2.29	1.61	0.29	335a	448	32	4.4	36a	33a
Significance	NS	NS	NS	NS	*	NS	NS	NS	**	**
BLSD (.05)	-	-	-	-	104	-	-	-	11	4
CV, %	5.5	6.3	9.4	7.1	18.6	16.5	21.7	15.5	21.8	7.5

INFLUENCE OF BIURET CONTENT OF FOLIAR FERTILIZERS ON SOYBEAN SEED YIELD

W.D. Poole, G.W. Randall and G.E. Ham

This study was designed to evaluate the influence of the biuret content of urea as a factor that may reduce the yield response of soybeans to foliar fertilizer. The total quantity of nutrients added was 80+8+24+6 (N+P+K+S, respectively) in 4 applications. The nitrogen was supplied as urea, some potassium and the sulfur as potassium sulfate and the phosphorus and additional potassium as potassium polyphosphate. Various levels of biuret were added to reagent grade urea to give levels of biuret in the urea up to 4% of the nitrogen.

Seed yields were not reduced significantly by biuret additions to the foliar fertilizer (Table 1). Based on these results we do not see the biuret content of the urea as a factor in causing increased "leaf burn" or reduced yields.

Table 1. Influence of biuret on soybean seed yield.

Treatment	Seed Yield, bu/acre
Control	62
N+P+K+S only	60
N+P+K+S (0.25% biuret)	60
N+P+K+S (0.50% biuret)	61
N+P+K+S (1.00% biuret)	61
N+P+K+S (2.00% biuret)	59
N+P+K+S (4.00% biuret)	60
4.00% biuret only	59

SOYBEAN NITROGEN FERTILIZER STUDIES

G.E. Ham and G.W. Randall

Several soybean genotypes were compared with common varieties for their response to 200 pounds of nitrogen per acre as urea. Planting was done on May 10 in 15-inch rows. Seed yields of 11 genotypes were increased significantly (Table 1). The seed yield of 1 genotype was decreased significantly and the seed yields of the other 12 genotypes were not changed significantly.

The seed yields of the widely planted varieties Corsoy and Hodgson were not increased significantly which agrees with earlier studies. Further studies are necessary to determine if the other genotypes will respond to fertilizer nitrogen consistently over years. The yield differential between the highest yielding genotype without fertilizer nitrogen (M-69-122) and the highest yielding genotype with fertilizer nitrogen (M-70-9) was only 3 bushels per acre which indicates that maximum seed yields may be obtained without adding fertilizer nitrogen. Alternatively, this indicates that soil nitrogen plus symbiotic nitrogen fixation are providing sufficient nitrogen for maximum seed yield.

Table 1. Effect of nitrogen fertilizer on soybean seed yield at Waseca.

Soybean genotype**	Fertilizer N (urea) applied 0	200 lbs N/A	Nitrogen Response
Coles	60	61	1
Corsoy	60	59	-1
Harcor	58	60	2
Hark	55	59*	4
Hodgson	46	47	1
Steele	48	55*	7
Swift	44	49*	5
A73D8	49	58*	9
A73D22	56	57	1
A74-102011	58	53*	-5
A74-201006	52	60*	8
A75-102032	58	63*	5
M-68-49	51	52	1
M-68-333	54	59*	5
M-69-36	50	57*	7
M-69-122	61	60	-1
M-69-128	49	52	3
M-69-197	55	53	-2
M-69-239	57	58	1
M-70-9	57	64*	7
Dt-2	49	52	3
L-2	52	55	3
12-055	48	52*	4
13-825	48	55*	7

* Seed yield of fertilizer nitrogen treatment significantly different from control.

** 12- and 13- genotypes obtained from Dr. D.E. Green, Iowa State University; A- genotypes were obtained from Dr. W.E. Fehr, Iowa State University; M- genotypes obtained from Dr. J.W. Lambert, University of Minnesota.

Soybean Inoculation Trials

G.E. Ham, W.C. Lindemann, C.K. Kvien and G.W. Randall

Soybean seeds were coated with single strains of Rhizobium japonicum by CelPril Industries (Table 1). In addition, granular inoculants containing single strain inoculants were applied with the seed at planting (Table 1).

Soybean seed yields were not increased significantly with either seed-coated inoculants or granular inoculants. Nodules are being serotyped to determine the recovery of added rhizobia. These results are consistent with our earlier conclusions that soybean seed yields cannot be increased by inoculation if a nodulated soybean crop has been grown on a field during the last 4 or 5 years. Research on new processes of soybean inoculation are continuing.

Table 1. Influence of inoculating soybeans with Rhizobium japonicum (soybean nodule bacteria) at Waseca, MN.

Rhizobium japonicum strain	Inoculant application method	Seed yield bu/acre
Control	-	47
110	seed coated	44
110	soil-10 lbs/acre	41
110	soil-50 lbs/acre	42
110	soil-100 lbs/acre	41
138	seed coated	44
138	soil-10 lbs/acre	46
138	soil-50 lbs/acre	47
138	soil-100 lbs/acre	45
140	soil-10 lbs/acre	40
140	soil-50 lbs/acre	44
140	soil-100 lbs/acre	45
143	seed coated	43
143	soil-10 lbs/acre	41
143	soil-50 lbs/acre	43
143	soil-100 lbs/acre	42
507	soil-10 lbs/acre	43
507	soil-50 lbs/acre	43
507	soil-100 lbs/acre	42
61A76[b]	soil-10 lbs/acre	43
61A76	soil-50 lbs/acre	42
61A76	soil-100 lbs/acre	42
SM31[c]	soil-10 lbs/acre	46
SM31	soil-50 lbs/acre	44
SM31	soil-100 lbs/acre	44
SM35[c]	soil-10 lbs/acre	46
SM35	soil-50 lbs/acre	45
SM35	soil-100 lbs/acre	44

[a]Obtained from USDA Culture Collection, Beltsville, MD.

[b]Obtained from Dr. J.C. Burton, The Nitragin Company, Milwaukee, WI.

[c]Obtained from Dr. W.J. Brill, Dept. of Microbiology, Univ. Wisconsin, Madison, WI.

INFLUENCE OF SULFUR ON YIELD OF ALFALFA GROWN UNDER IRRIGATION ON A LOAMY SAND IN KANDIYOHI COUNTY, MINNESOTA

W. E. Fenster and R. Schoper

The fertilizer sulfur needs of many of the agronomically important crops in southern and western Minnesota have been extensively studied. To date, significant yield increases have not been realized as a result of sulfur application. However, with the higher analysis fertilizers which contain lower amounts of sulfur, and the large crop removal, it is felt that continued monitoring of sulfur needs is warranted. With this in mind, a sulfur demonstration plot was established in Kandiyohi County on the Del Johnson farm.

Experimental Procedures:

Soil samples were analyzed in the Soil Testing Laboratory and the results were as follows: texture - loamy sand; reaction - 6.5; organic matter - medium; extractable phosphorus - 56 lbs./A; exchangeable potassium - 150 lbs./A; and sulfur - 17 ppm. Three rates of sulfur (0, 50, and 100 lbs./A), applied as fortified gypsum, were used and each treatment was replicated five times in a randomized complete block design. The experimental site was irrigated and alfalfa was the test crop.

Results:

The alfalfa yields and percent sulfur in the plant tissue were not significantly altered as a result of sulfur applications. It is generally accepted that a level of 0.3 percent sulfur in alfalfa tissue is sufficient for maximum yields. Percentage sulfur in the tissue varied from 0.38 to 0.46, well above the level necessary for optimum production. Yield and percent sulfur are given in the following tables.

Table 1. Yield and percent sulfur in plant tissue as influenced by varying rates of sulfur on alfalfa grown under irrigation on a loamy sand in Kandiyohi County, Minnesota - 1976.

Treatment	1st Cutting		2nd Cutting		Total Yield
lbs/A S	Yield T/A	Tissue %S	Yield T/A	Tissue %S	T/A
0	2.0	.43	2.1	.38	4.1
50	1.9	.43	2.1	.39	4.0
100	1.9	.43	2.1	.40	4.0
Signif. (.05)	ns	ns	ns	ns	ns

Table 2. Yield and percent sulfur in plant tissue as influenced by varying rates of sulfur grown under irrigation on a loamy sand in Kandiyohi county, Minnesota - 1977.

Treatment	1st Cutting		2nd Cutting		3rd Cutting		Total
	Yield	Tissue	Yield	Tissue	Yield	Tissue	Yield
lbs/A S	T/A	%S	T/A	%S	T/A	%S	T/A
0	1.5	.40	1.8	.40	1.5	.41	4.8
50	1.5	.41	1.8	.44	1.4	.43	4.7
100	1.6	.41	1.9	.46	1.5	.42	5.0
Signif. (.05)	ns	ns	ns	ns	ns	ns	ns

FOLIAR FERTILIZATION OF CORN

G.L. Malzer, J. Behm, S. Evans and W.W. Nelson

Considerable interest in foliar fertilization of crops has been aroused with the dramatic yield increases with soybeans that were found by Dr. John Hanway of Iowa State University. This has not only simulated additional work with soybeans but has created interest in other crops as well. It was the objective of this trial to determine if foliar applications of NPKS solutions made to corn after tasseling could be beneficial in increasing yields and protein content of corn.

Experimental Procedures

Two experiments, one at the West Central Experiment Station at Morris and one at the Southwest Experiment Station at Lamberton, were initiated in 1977. Six treatments were established at Morris and eight at Lamberton. The experimental areas were areas which had been planted as bulk corn on each station, and had therefore received normal NPK soil treatments as required by soil tests. The experimental areas in both cases had been previously cropped with soybeans. The treatments established consisted of a control, two rates of NPKS solutions, and two dates of application. The NPKS solution contained nutrients in the ratio of 6:2.3:3.7:0.6, and was made up using urea, potassium polyphosphate, and potassium sulfate. Treatment rates were based upon nitrogen applied, but should not be interpreted as just nitrogen application. The treatment rates consisted of 20 #N/A and 40 #N/A with these rates applied either on July 18 and August 1 at Morris and July 11 and July 25 at Lamberton. A treatment where 20 #N/A was applied early and 20 #N/A applied late to the same area was included at both locations. Rates of 10 #N/A applied both early and late was included in the experiment at Lamberton. All treatments were applied with a high-boy sprayer with a minimum of 20 gal/A of solution being applied. Minimum plot sizes were six thirty-inch rows, 200 ft. long with two replications of each treatment. All foliar applications were made mid- to late-afternoon.

At harvest four subsamples of yield were obtained from each plot by hand-harvesting two 20 ft. rows. Subsamples from each were collected for moisture determination and nitrogen analysis.

General Results

No significant responses to foliar application of NPKS solutions were found with corn at either location in 1977. In general, even the lower rates of applied solution resulted in tissue leaf burn, and the basic trend was for reduced yields with increasing rates of solution application. The nitrogen concentration within the grain (protein) although not significant at the 5% level, tended to increase with the foliar applications at Lamberton. With the lowest rate of application (10 #N/A) at Lamberton virtually all of the applied N was accounted for in the grain. Part of this was accounted for in the increased nitrogen concentration in the grain and part due to small increases in yield. The influence of application time during the day as well as during the season and the impact of small more frequent applications deserve further consideration.

Table 1. Yield, nitrogen content of grain and nitrogen removal by corn grain as influenced by rate, and time of NPKS foliar application to corn after silking.

Treatments	Corn Grain		
	Yield	N content	N removal
#N/A[1/]	bu/A	%	#/A
	West Central Experiment Station		
Control	101.7	1.70	82
20 July 18	100.9	1.68	80
40	93.9	1.71	76
20 August 1	99.0	1.75	82
40	100.2	1.77	84
20 July 11 + 20 August 1	92.3	1.76	77
Significance	NS	NS	NS
	Southwest Experiment Station		
Control	145.2	1.57	108
20 July 11	136.1	1.65	106
40	126.5	1.68	100
20 July 25	137.6	1.70	110
40	140.3	1.70	112
20 July 11 + 20 July 25	135.9	1.68	108
10 July 11	149.1	1.69	119
10 July 25	146.7	1.69	117
Significance	NS	NS	NS

1/ NPKS solutions - see experimental procedures for ratios.

THE INFLUENCE OF NITRATE NITROGEN CONTENT OF SOUTHEAST MINNESOTA SOILS ON RESPONSE OF CORN TO ADDED NITROGEN FERTILIZER

-1977-

C. Simkins, R. Schoper, J. Lensing

Farmers and County Extension Directors in 7 Southeast Minnesota counties cooperated with University of Minnesota Soils staff to determine the level of nitrate nitrogen in fields planted to corn for the 1977 growing season. Additionally, farmers maintained control or check areas in their fields which allowed for determination of response of corn to additions of nitrogen fertilizer. Trials were conducted in Dodge, Goodhue, Houston, Olmsted, Steele, Wabasha and Winona counties.

NITRATE NITROGEN LEVELS IN THE SOIL - 1977

Prior to planting and prior to application of nitrogen fertilizer, soil samples were taken to a depth of five feet and analyzed for nitrate nitrogen. Analysis were made on increments at six different depths

0-6", 6-12", 12-24", 24-36", 36-48", and 48-60"

The level of nitrate nitrogen to a five foot depth for each cooperators' field is shown in Table 1.

Total nitrate nitrogen in the various soil profiles ranged from 44 to 440 pounds per acre five feet. 18 out of 21 locations had more than 100 pounds per acre five feet. The following data is significant in respect to the quantity of nitrate nitrogen at various depths.

% of nitrate nitrogen 0-24" = 68%

% of nitrate nitrogen 0-36" = 83%

Six of the sites had more than 40 pounds of nitrate nitrogen in the 36 to 60" depth.

Table 1. Nitrate nitrogen levels in several Southeast corn fields, Spring, 1977.

Cooperator	0-6"	6-12"	12-24"	24-36"	36-48"	48-60"	Total 0-5'
Dodge Co.							
Darr	26	39	43	14	12	12	146
Moenning	23	35	95	23	13	13	202
Rehwaldt	27	29	59	27	13	13	168
Goodhue Co.							
Bodin	9	9	9	20	30	10	87
Quiggle	18	16	47	21	16	18	136
Voxland	23	21	42	34	15	20	155
Houston Co.							
Beranek	11	9	34	24	18	19	115
Davison	39	20	22	8	7	7	103
Hemstead	46	43	155	67	17	13	341
McCormick	23	16	37	8	6	8	98
Schroeder	31	30	54	26	22	24	187
Olmsted Co.							
Randall	57	40	31	8	6	6	148
Pagel	21	10	32	32	-	-	95
Steele Co.							
Abbe	63	82	45	35	13	12	250
Pichner	30	30	46	19	12	9	146
Strodtman	33	44	145	110	68	40	440
Klennenson	31	52	73	41	23	22	242
Wabasha Co.							
Cerise	9	9	7	6	6	7	44
Drysdale	33	36	49	50	27	27	222
Graner	19	25	57	8	7	7	123
McNallen	15	13	20	24	14	19	105
Winona Co.							
Redig	21	35	58	45	22	20	201

Fertilizer Use by Cooperators

In general, each cooperator applied some phosphrous and potassium fertilizer at at planting time. In addition, nitrogen fertilizer was applied prior to planting except on four control areas in each field. Nitrogen application ranged from 70 to 198 lbs. of nitrogen per acre. One cooperator applied 20 tons of liquid manure per acre prior to planting.

Yields of Corn Grain on Non-Nitrogen

and Nitrogen Fertilized Areas

Cooperator	N Lbs/A	No Nitrogen	Nitrogen
Darr	170	114	126
Moenning	140	125	124
Rehwaldt	160	147	151
Quiggle	182	143	148
Voxland	150	130	145
Beranek	170	168	174
Davison	140	132	132
Hemstead	170	113	114
McCormick	150	140	141
Schroeder	198	132	142
Randall	92	144	145
Pagel	100	103	107
Abbe	150	141	146
Pichner	140	90	106
Strodtman	125	134	139
Klennenson	125	129	134
Cerise	Manure	121	170
Drysdale	100	132	135
Graner	70	133	142
Redig	Manure	147	148

Yields of corn grain on most sites were not significantly increased by nitrogen fertilizer application. In Wabasha county on the Cerise farm, where the nitrate nitrogen level was 44 pounds per acre five feet, a rather substantial increase of nearly 50 bushels per acre was obtained with manure applications.

Results would indicate that soil profiles containing more than 100 pounds of nitrate nitrogen per acre five feet can supply sufficient nitrogen for the level of production obtained under climatic conditions in the 1977 growing season.

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, S. Evans

The rates 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. It was, therefore, the objectives of this study to: 1) 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) evaluate fall vs. spring soil sampling as well as fertilization; and 3) acertain the importance of nitrate accumulation and movement within the soil profile.

Experimental Procedures

Twelve locations in Southwestern Minnesota were established in the fall of 1976. One location was located on the Southwest Experiment Station-Lamberton, (2) on the West-Central Experiment Station-Morris; and, (9) on farmer cooperators fields (Table 1). At each location eight treatments with two replications were established. Four treatments were applied in the fall as 0, 40, 80, and 120 #N/A as ammonium nitrate, and similar treatments were established in the spring at each location. Soil samples were collected prior to fertilization to a depth of five feet in increments of one foot except for the surface which was separated into six inch increments and all samples were analyzed for nitrate nitrogen (Table 2). Applications of phosphorus and potassium were applied as needed according to soil test recommendations. Cooperators were asked to follow normal management practices for the areas except for nitrogen fertilization or manure application.

The influence of the residual nitrates and nitrogen treatments were evaluated by nitrogen analysis of the leaf opposite and below the ear at silking (6th leaf), grain yields and nitrogen removal with the grain. Small plant samples and silage yield were also taken and evaluated but are not presented in this report.

General Results

The results from the 1977 cropping year are presented in Tables 2-5. Leaf nitrogen concentrations at silking (Table 2) indicate that only four locations out of twelve responsed to the application of nitrogen and only two or possibly three of these locations were low enough to anticipate reduced yields because of inadequate nitrogen.

Only two locations of the twelve established gave significant yield increases with the application of additional nitrogen (Table 3). In both cases these locations had the lowest leaf nitrogen concentrations earlier in the summer. Nitrogen removal in the grain generally followed grain yield, but grain protein normally increased in addition if a yield increase was obtained.

Yields and crop response to nitrogen application appeared to be highly correlated with soil nitrate nitrogen. No yield responses were obtained from any location when the average nitrate nitrogen concentration per foot of soil within the five foot profile was over eight parts per million (approx. 160 # NO_3-N/A on a five ft. basis). Both location showing a nitrogen response obtained yields in excess of 140 bu/A/ Other locations which had low soil nitrate concentrations but had no yield response to added nitrogen were much lower in yields and yield potentials were probably not obtained because of some other factor such as moisture, plant density, variety or numerous other factors.

As can be seen in Table 5 nitrate concentrations within the profile at each location changed between fall and spring sampling. In general many of the nitrates present in the surface in the fall had been moved down to depth of two to three feet by the following spring. The significance of nitrate nitrogen distribution within the soil profile and its effect on the depth to which sampling should be done remain to be investigated. Information obtained thus far would suggest that deep sampling of soils for residual nitrate could become a useful tool in predicting fertilizer nitrogen needs.

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

Location No.	Cooperator	County
1	Charles Anderson	Yellow Medicine
2	Cornelius Boerboom	Lyon
3	Clarence Feste	Murray
4	Donald Lensing	Redwood
5	Lamberton Station	Redwood
6	Carsten Madsen	Lincoln
7	Morris Station "A"	Stevens
8	Morris Station "B"	Stevens
9	Lawrence Quade	Cottonwood
10	Paul Schoper	Cottonwood
11	Wayne Schwitter	Chippewa
12	Donald Werner	Pipestone

Table 2. Nitrogen concentration of the leaf opposite and below the ear at mid-silking at 12 locations in S.W. Minnesota as influenced by nitrogen treatment

Treatment		Leaf N Concentrations Location No.											
N Applied	N Rate	1	2	3	4	5	6	7	8	9	10	11	12
	#/A	%											
fall	0	1.77	2.50	2.86	2.78	2.39	2.88	2.92	3.06	2.29	2.62	2.85	2.97
fall	40	2.38	2.70	3.08	2.78	2.39	2.84	3.03	2.94	2.47	2.86	2.88	2.96
fall	80	2.41	2.40	3.28	2.91	2.64	2.84	2.93	2.88	2.57	2.83	2.86	2.85
fall	120	2.60	2.56	3.15	2.75	2.81	2.91	2.98	3.04	2.69	2.80	3.00	3.08
spring	0	2.09	2.68	3.10	2.90	2.61	2.96	2.78	2.92	2.32	2.70	2.71	2.97
spring	40	2.16	2.42	2.94	2.77	2.76	2.80	2.80	2.91	2.50	2.78	2.79	3.06
spring	80	2.44	2.61	3.28	2.86	2.54	2.90	2.98	2.91	2.46	2.82	2.80	3.00
spring	120	2.54	2.78	2.98	2.98	2.91	2.84	3.20	3.09	2.94	2.90	3.02	3.20
signif.		**	+	NS	NS	NS	NS	NS	NS	*	NS	+	NS
BLSD .05		.25	.23							.40		.19	

Table 3. Grain yield at 12 locations in S.W. Minnesota as influenced by nitrogen treatment.

Treatment		Grain Yield -- 15.5% Moisture Location No.											
N Applied	N Rate	1	2	3	4	5	6	7	8	9	10	11	12
	#/A	bu/A											
fall	0	108	109	105	135	144	143	102	130	139	116	124	125
fall	40	135	113	97	142	136	126	109	144	153	123	123	131
fall	80	138	115	100	138	131	125	101	148	174	117	116	124
fall	120	153	116	98	131	130	132	103	133	152	121	117	131
spring	0	101	109	97	137	157	132	102	123	141	126	119	123
spring	40	132	117	115	127	154	123	106	129	163	129	112	124
spring	80	132	121	109	129	120	135	109	133	159	124	105	115
spring	120	140	117	108	121	156	119	104	132	174	121	121	122
Signif.		*	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
BLSD .05		27								18			

Table 4. Nitrogen removal by the grain at 12 locations in S.W. Minnesota as influenced by nitrogen treatment.

Treatment		Grain Nitrogen Removal											
		Location No.											
N Applied	N Rate	1	2	3	4	5	6	7	8	9	10	11	12
	#/A	#N/A											
fall	0	54	87	89	100	99	109	83	112	86	102	93	93
fall	40	86	89	77	115	103	96	95	125	110	109	102	108
fall	80	82	89	84	116	100	97	85	125	126	101	88	100
fall	120	97	82	85	114	102	101	84	113	119	109	93	106
spring	0	48	82	76	109	112	102	84	108	104	107	92	98
spring	40	81	90	102	112	112	94	84	110	113	117	90	103
spring	80	82	92	87	106	94	110	93	111	104	107	81	92
spring	120	96	84	96	111	123	94	92	112	127	110	96	103
Signif.		*	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
BLSD .05		33								14			

Table 5. Soil nitrate concentrations by depth and previous cropping history of 12 locations in Southwestern Minnesota.

	Nitrate Nitrogen Concentration Location No.											
Depth	1		2		3		4		5		6	
	fall	spring	fall	spring	fall	spring	fall	spring	fall	spring	fall	spring
ft.	ppm											
0-.5	6	4	8	11	-	12	54	9	24	5	30	12
.5-1	3	4	10	13	-	20	34	23	20	13	29	49
1-2	1	5	6	10	-	20	17	32	8	19	15	45
2-3	1	2	6	9	-	27	20	34	4	17	13	28
3-4	1	2	6	7	-	23	16	17	4	9	14	15
4-5	1	1	5	5	-	17	6	6	4	8	14	11
Previous crop	soybeans		soybeans		oats		wheat		soybeans		corn	

	7		8		9		10		11		12	
0-.5	28	13	72	3	17	6	56	5	28	13	13	4
.5-1	17	16	27	14	11	6	40	11	7	12	13	21
1-2	4	16	4	19	4	11	14	32	3	10	14	14
2-3	4	7	5	14	4	10	13	18	4	6	9	15
3-4	3	3	8	8	5	6	14	13	2	6	3	5
4-5	3	3	7	7	6	4	13	11	2	2	3	4
Previous Crop	Corn		Corn		Soybeans		Wheat		Sugarbeets		Flax	

USE OF N-SERVE IN FALL VS. SPRING NITROGEN APPLICATION PROGRAMS ON FINE TEXTURED SOILS OF MINNESOTA

G. L. Malzer, G. W. Randall, W. W. Nelson, S. Evans, and W. Wallingford

A considerable interest has developed over the last several years concerning the use of N-Serve as a nitrification inhibitor with ammonium forming fertilizers on the fine textured soils of Minnesota. On many of these fine textured soils depending on the climatic conditions encountered and internal soil drainage, losses of nitrate nitrogen may occur through denitrification, resulting in a loss of a portion of plant available nitrogen and, therefore, a potential for yield reductions. With the normally cool wet spring conditions which are encountered on most of these soils there may also be a considerable advantage in time management, associated with earlier nitrogen fertilization, and yield increases due to earlier planting dates with fall applications of nitrogen. This condition exists provided that nitrogen losses are not severe in the interum period. If nitrification inhibitors are capable of minimizing the production of nitrate with fall nitrogen applications they may have the advantage of minimizing potential nitrate nitrogen losses as well as increasing the length of time that would be available in the fall to apply nitrogen (prior to 50-55^{o} soil temperatures).

Experiments were, therefore, established at four University of Minnesota Experiment Stations with the following objectives: 1) to evaluate the importance of timing of nitrogen application (fall vs. spring) on yield components and nitrogen utilization of corn and spring wheat; 2) to determine the importance of soil temperature on the rate of nitrification with early and late applied nitrogen; and 3) to examine the influence of N-Serve on yield components, nitrogen utilization by the crops, and its influence on the rate of nitrification within the soil.

Experimental Procedures

Four similar experiments were established one each at the Southern Experiment Station at Waseca, the Southwest Experiment Station at Lamberton, the West Central Experiment Station at Morris and the Northwest Experiment Station at Crookston. Each experiment consisted of four times of nitrogen application (3 fall and 1 spring) two rates of nitrogen in addition to a check and all potential nitrogen treatments and times of application either had N-Serve at 0.5 # ai/A applied with it or contained no N-Serve. Times and rates of nitrogen application were adjusted for each experimental site to conform with the geographic area. The experimental treatments at each location are included in Table 1.

Each experimental site was fertilized with phosphorus and potassium according to soil test recommendations prior to establishment of treatments. All nitrogen applications were made with anhydrous ammonia with N-Serve injected into the tank for the appropriate treatments. Anhydrous knife spacings were 30" for corn production and approximately 15" for wheat. All primary tillage was done prior to the first nitrogen application with only secondary tillage prior to planting. Several areas within each plot received no tillage after nitrogen application for use in collection of soil samples from the anhydrous application zones.

In order to follow the rate at which the ammonium nitrogen was converted to nitrate nitrogen soil samples were collected and analyzed from a 0-1 ft. depth over the anhydrous injection area at approximately one week intervals following nitrogen application. Soil samples were also collected and analyzed at monthly intervals to a depth of five feet in order to follow nitrate nitrogen accumulation within the soil profile (see supplement).

Treatment influences on nitrogen utilization by the crop evaluated in several manners. Corn leaf samples from opposite and below the ear at silking were collected and analyzed for Kjeldahl nitrogen content. Forage dry matter production and nitrogen removal was measured by hand harvesting 15' of row from the corn plots, separation of samples into ear and stover components, field weights obtained and nitrogen content and moisture determined from subsamples. Grain yields were obtained by either hand harvesting or machine harvesting known areas from each plot and then determination of the nitrogen content (protein) by Kjeldahl analysis for calculation of nitrogen removal.

Results

In general relatively few major differences in yields and nitrogen utilization by the crops were encountered during the growing season in 1977. Most of the information would suggest that nitrogen was not the most limiting factor in production.

The nitrogen content of the leaf opposite and below the ear at silking was significantly influenced by timing and rate of nitrogen application at 2 out of 3 locations (Table 2). The spring nitrogen application was as good as any other time of application with one of the fall treatments not being as effective, but the earliest application not necessarily being the worst. N-Serve increased the nitrogen content of the 6th leaf at the Morris site but in all cases the nitrogen contents were above what would be considered limiting.

Grain yields (Table 3) were influenced very little by treatments. Only the experimental site at Waseca gave any significant yield increase with nitrogen and that was between the control and the first rate of nitrogen (75 # N/A). The early fall application of nitrogen at Waseca reduced corn grain yields. Nitrogen removal with the grain (Table 3) was influenced in a similar manner as yields.

Although N-Serve had very little influence in altering yields and plant utilization of nitrogen in 1977 it did have a considerable influence in keeping more of the applied nitrogen in the ammonium form (Table 5). In general the later nitrogen was applied in the fall the greater the ammonium concentration the following spring. The retension of nitrogen in the ammonium form in the spring following fall application without N-Serve, however, was not as large as anticipated. N-Serve was capable of keeping 10-40 percent more of the original nitrogen in the ammonium form than when no nitrification inhibitor was applied. Whether this influence will have any positive benefits on yield and nitrogen utilization by the crop depends on the environmental conditions encountered prior to and during the growing season which may result in nitrogen losses as well as crop demand and the expected response to applied fertilizer nitrogen.

Table 1. Experimental Treatments with fall vs. spring nitrogen applications and N-Serve.

Experimental Location	Nitrogen Rate[1]	Date of Appl.		N-Serve Rate	Test Crop
	#/A	1976-77		# AI/A	
Waseca	0	9/10	10/5	0, 1/2	Corn
	75	11/1	4/25		(Pioneer 3709)
	150				
Lamberton	0	9/15	10/1	0, 1/2	Corn
	50	11/1	4/29		(Pioneer 3780)
	100				
Morris	0	8/25	9/24	0, 1/2	Corn
	40	10/26	4/26		(Dekalk XL12)
	80				
Crookston	0	8/17	9/5	0, 1/2	Wheat
	40	10/19	5/3		(Era)
	80				

[1] applied as anhydrous ammonia

Table 2. Nitrogen content of the leaf opposite and below the ear at silking as influenced by nitrogen rate timing of nitrogen application and use of N-Serve.

Treatment[1]			6th Leaf N Content		
Date of N Appl.	N Rate	N-Serve	Waseca	Lamberton	Morris
		D.S. #ai/A		%	
Control	zero	no	2.42	2.72	2.86
Early Fall	Med	No	2.61	2.87	3.03
Early Fall	Med	Yes	2.59	2.89	3.28
Early Fall	High	No	2.67	3.00	2.96
Early Fall	High	Yes	2.65	2.93	3.16
Mid Fall	Med	No	2.60	2.90	2.77
Mid Fall	Med	Yes	2.53	2.95	2.95
Mid Fall	High	No	2.67	3.08	2.91
Mid Fall	High	Yes	2.64	3.05	3.01
Late Fall	Med	No	2.56	3.14	2.96
Late Fall	Med	Yes	2.59	2.94	2.98
Late Fall	High	No	2.77	3.34	3.08
Late Fall	High	Yes	2.68	3.09	2.95
Spring	Med	No	2.58	2.89	3.06
Spring	Med	Yes	2.56	3.06	3.12
Spring	High	No	2.64	3.13	3.00
Spring	High	Yes	2.65	3.19	2.94
Signif.			*	**	+
B.L.S.D. (.05)			.20	.24	.15
Factorial Arrangement					
Applicate Date					
Early Fall			2.63	2.92	3.11
Mid Fall			2.61	3.00	2.91
Late Fall			2.65	3.12	2.99
Spring			2.61	3.07	3.03
Signif.			NS	**	*
B.L.S.D. (.05)				.11	.13
Nitrate Rate					
Med			2.58	2.95	3.02
High			2.67	3.10	3.00
Signif.			**	**	NS
B.L.S.D. (.05)			.06	.08	
N-Serve					
No			2.64	3.04	2.97
Yes			2.61	3.01	3.05
Signif.			NS	NS	+
B.L.S.D. (.05)					.08

1 See Table 1 for dates and rates of nitrogen application.

Table 3. Influence of nitrogen rate, timing of nitrogen application, and N-Serve on grain yields--1977

Treatments[1]			Grain Yields			
Date of N Appl.	N Rate	N-Serve	Waseca	Lamberton	Morris	Crookston
		0.5 # ai/A	---	bu/A	---	---
Control	zero	no	139.8	128.1	118.1	18.6
Early fall	med	no	144.2	128.5	117.8	22.2
Early fall	med	yes	148.2	129.0	108.2	19.4
Early fall	high	no	150.0	137.6	110.5	16.2
Early fall	high	yes	149.5	130.6	114.3	19.1
Mid fall	med	no	152.4	139.2	114.0	19.2
Mid fall	med	yes	156.0	131.2	116.4	18.9
Mid fall	high	no	154.5	133.6	114.2	19.7
Mid fall	high	yes	156.9	130.5	108.4	17.9
Late fall	med	no	145.0	129.8	112.4	20.1
Late fall	med	yes	147.5	141.2	108.6	20.4
Late fall	high	no	150.2	128.7	111.7	16.8
Late fall	high	yes	155.9	133.4	109.8	15.8
Spring	med	no	155.1	135.1	110.2	23.2
Spring	med	yes	155.1	132.1	118.8	22.0
Spring	high	no	152.0	132.0	114.3	20.2
spring	high	yes	154.5	139.2	112.4	18.7
Signif.			*	NS	NS	NS
B.L.S.D. (.05)			13.4			
Factorial Arrangement						
Application Date						
Early fall			148.0	131.4	112.7	19.2
Mid fall			154.9	133.8	113.3	18.9
Late fall			149.6	133.3	110.6	18.2
Spring			154.1	134.6	113.9	21.0
Signif.			*	NS	NS	NS
B.L.S.D. (.05)			5.4			
Nitrogen Rate						
Med			150.4	133.4	113.3	20.7
High			152.9	133.2	111.9	18.0
Signif.			NS	NS	NS	**
B.L.S.D. (.05)						1.6
N-Serve						
No			150.4	133.1	113.1	19.7
Yes			152.9	133.5	112.1	19.0
Signif.			NS	NS	NS	NS
B.L.S.D. (.05)						

[1] See Table 1 for dates and rates of nitrogen application.

Table 4. Influence of nitrogen rate, timing of nitrogen application and N-Serve on nitrogen removal with the grain.

Treatments			Grain N Removal			
Date of N Appl.	N Rate	N-Serve	Waseca	Lamberton	Morris	Crookston
		0.5 # AI/A	#/A			
Control	zero	no	92.0	100.1	88.5	34.7
Early fall	med	no	104.3	100.2	90.6	40.7
Early fall	med	yes	109.2	101.5	82.2	36.2
Early fall	high	no	109.3	100.6	84.3	31.1
Early fall	high	yes	106.0	110.1	86.8	36.6
Mid fall	med	no	106.3	113.3	84.4	37.3
Mid fall	med	yes	110.6	106.0	87.9	36.4
Mid fall	high	no	110.1	110.5	86.3	35.7
Mid fall	high	yes	116.4	109.2	81.7	33.2
Late fall	med	no	106.3	108.6	84.2	37.2
Late fall	med	yes	104.0	112.0	80.3	38.2
Late fall	high	no	112.2	105.0	86.4	32.6
Late fall	high	yes	111.8	107.5	85.3	31.3
Spring	med	no	113.9	112.5	84.8	43.5
Spring	med	yes	108.4	113.5	90.2	40.3
Spring	high	no	111.9	108.7	88.4	38.2
Spring	high	yes	116.1	120.9	88.5	37.7
Signif.			*	+	NS	NS
B.L.S.D. (.05)			13.0	13.6		
Factorial Arrangement						
Application Date						
Early fall			107.2	103.1	86.0	36.1
Mid fall			110.9	109.8	85.1	35.7
Late fall			108.6	108.3	84.1	34.8
Spring			112.6	113.9	88.0	40.0
Signif.			NS	*	NS	+
B.L.S.D. (.05)				6.2		3.7
Nitrogen Rate						
Med			107.9	108.4	85.6	38.7
High			111.7	109.1	86.0	34.5
Signif.			+	NS	NS	**
B.L.S.D. (.05)			3.3			2.8
N-Serve						
No			109.3	107.4	86.2	37.0
Yes			110.3	110.1	85.4	36.2
Signif.			NS	NS	NS	NS
B.L.S.D. (.05)						

Table 5. Influence of timing of nitrogen application and the use of N-Serve on the persistence of ammonium nitrogen within the soil at early spring.

Treatment		% of original NH_4^+-N			
Date of N Appl.	N-Serve	Waseca	Lamberton	Morris	Crookston
	0.5 # AI/A	May 19	June 1	May 18	May 14
		%			
Early fall	no	12	6	9	20
Early fall	yes	37	30	32	19
Mid fall	no	19	11	13	17
Mid fall	yes	40	51	24	36
Late fall	no	22	16	22	13
Late fall	yes	32	23	44	32
Spring	no	59	43	43	64
Spring	yes	38	80	58	80

PHOSPHORUS PLACEMENT ON CORN

G.L. Malzer, S. Evans, and W. Wallingford

Evidence from other states suggest that phosphorus fertilizer placement may be important in efficient phosphorus use, especially on soils which are known to have a high phosphorus "fixings" capacity. On these soils broadcast applications of phosphorus may be rendered unavailable to the present crop more rapidly than would a more concentrated application of the same amount of fertilizer in a smaller volume of soil. Trials were, therefore, established on two high pH soils in western Minnesota to investigate the influence of phosphorus placement and rate of phosphorus application on yield and phosphorus utilization of corn on soils already testing medium to high in phosphorus.

Experimental Procedures

Seven treatments including a check, two rates of phosphorus (30# and 60# P_2O_5/A) and three methods of application were established at West Central Experiment Station at Morris and the Northwest Experiment Station at Crookston. The three methods of application included a broadcast application, a "row" application in a small zone similar to a starter application, and a "band" application approximately 10-12 inches wide. Each method was applied at the two phosphorus rates and incorporated prior to planting. Corn was planted into 30 inch rows with the bands being in close proximity to the rows.

Influence of the treatments on phosphorus utilization were evaluated by collecting small plant samples (12" ht.) and leaf samples from opposite and below the ear at silking for elemental analysis. Yields were also obtained by hand harvesting known areas from each plot.

General Results

No significant yield responses were obtained with any of the phosphorus treatments. Dry weather at the Crookston location along with poor early growth of the crops at each location limited yields. The phosphorus concentration in the 6th leaf at silking (Table 1) would suggest that there is no advantage under the experimental conditions encountered at Morris and Crookston to wide band applications of phosphorus. The rates and methods of application also had an influence on the elemental concentrations of several other nutrients at Morris but the significance of this remains to be investigated.

Table 1. - Influence of phosphorus placement and rate on corn grain yield and elemental composition of the 6th leaf at silking

Treatment		Grain Yield		6th Leaf Composition											
				P		Mg		Fe		Zn		Cu		Mn	
P_2O_5	Method	Morr.	Crook	Morr.	Crook.	Morr.	Crook.	Morr.	Crook.	Morr.	Crook.	Morr.	Crook.	Morr.	Crook
#/A				%		%		ppm							
0	--	117.6	56.9	.35	.60	.61	.92	242	203	19	17	10	14	112	115
30	row	123.4	59.9	.39	.59	.64	.89	265	190	18	15	10	12	124	123
60	row	114.4	57.0	.38	.57	.76	.90	269	191	18	16	9	12	119	124
30	band	116.1	57.2	.33	.61	.61	.96	234	185	17	16	9	12	98	132
60	band	111.7	56.7	.36	.65	.70	.03	240	199	18	16	8	14	113	132
30	broadcast	117.1	57.1	.36	.59	.58	1.03	264	199	19	16	9	12	106	133
60	broadcast	119.6	56.6	.37	.64	.62	.96	241	211	18	17	8	12	106	123
Signif.		NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
B.L.S.D. (.05)						.12									
Factorial Arrangement															
Placement															
row		118.9	56.8	.38	.62	.70	.99	267	205	18	16	9	12	121	128
band		113.9	56.9	.34	.58	.66	.90	237	191	18	15	8	12	106	124
broadcast		118.4	57.0	.36	.63	.60	.95	253	192	18	16	9	13	106	132
Signif.		NS	NS	+	NS	*	NS	NS	NS	NS	NS	+	NS	*	NS
B.L.S.D. (.05)				.03		.08						1		13	
Rate															
30		118.9	57.1	.36	.60	.61	.96	255	192	18	16	9	12	109	129
60		115.2	56.7	.37	.62	.70	.93	250	200	18	16	8	12	113	126
Signif.		NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	NS	NS	NS
B.L.S.D. (.05)						.06						1			

HIGH PHOSPHORUS AND POTASSIUM RATES FOR CONTINUOUS CORN

Gyles W. Randall, Samuel D. Evans and Wallace W. Nelson

EXPERIMENTAL PROCEDURES

Ten P and K treatments (Table 1) were applied at three branch experiment stations (Southern Experiment Station, Waseca; Southwest Experiment Station, Lamberton; and West Central Experiment Station, Morris) in Minnesota. A randomized, complete-block design with four replications was used. The 50-pound rates were estimated to be "maintenance" rates, and the 0, 100 and 150-pound rates provide the response curves for each element. Treatments 5 and 8 will receive P and K, respectively, every third year for the duration of the experiment. Treatments 9 and 10, applied in the fall of 1973, will not receive P and K again until either P or K starts to become limiting (determined via soil test, tissue test or yield). All other treatments will be applied annually.

Table 1. Phosphorus and potassium treatments applied in the high P and K rate study in Minnesota.

Trt.	Application Year (Fall)				
No.	1973	1974	1975	1976	1977
	lbs. P_2O_5 + K_2O				
1	0 + 0	0 + 0	0 + 0	0 + 0	0 + 0
2	0 + 100	0 + 100	0 + 100	0 + 100	0 + 100
3	50 + 100	50 + 100	50 + 100	50 + 100	50 + 100
4	100 + 100	100 + 100	100 + 100	100 + 100	100 + 100
5	150 + 100	0 + 100	0 + 100	150 + 100	0 + 100
6	100 + 0	100 + 0	100 + 0	100 + 0	100 + 0
7	100 + 50	100 + 50	100 + 50	100 + 50	100 + 50
8	100 + 150	100 + 0	100 + 0	100 + 150	100 + 0
9	150 + 100	0 + 0			
10	100 + 150	0 + 0			

Treatment numbers 2, 3, 4, 5, 6, 7, 8 were broadcast on cornstalks and plowed down at all locations in the fall of 1976. Phosphorus was applied as CSP (0-46-0) and K as muriate of potash (0-0-60). Starter fertilizer was not used.

Specific experimental procedures used at each of the stations are presented in Table 2. Management practices providing for optimum yields were employed at each location. Nitrogen rates were slightly higher than optimum.

Table 2. Experimental procedures for the high P and K rate study on continuous corn at the three branch stations in 1977.

Variable	Lamberton	Morris	Waseca
Planting date	5/6	4/29	5/2
Row spacing	30"	30"	30"
Population	24,000	22,000	24,000
Hybrid	Pioneer 3780	DeKalb XL12	Pioneer 3710
Nitrogen rate	70# N	80# N	200# N
Herbicide	2½# Eradicane/A +1.5# Bladex(Bdct)	2# Lasso + 2# Bladex/A (Bdct)	3# Lasso + 2.5# Bladex/A (Bdct)
Insecticide	1# Counter/A	1# Furadan/A	1# Dyfonate/A
Harvest date	9/28	9/19	9/22

RESULTS AND DISCUSSION

Soil samples were taken at the end of the 1977 growing season. After four years of application, soil test P was affected significantly at all three locations (Table 3). There appeared to be a linear response to annual P application. Soil test P was always lowest with treatments 1 and 2, which received no P, and treatments 9 and 10, which only received an initial application in 1973. Intermediate P levels were found with treatment 5 (150 lb P_2O_5 every third year) at Morris and Waseca and at all locations with treatment 3 (50 lb P_2O_5 annually). Highest soil test P values were associated with the annual 100 lb P_2O_5 treatments at all locations. Use of the 1:50 soil to Bray P_1 solution ratio on the calcareous Aastad soil at Morris indicates high amounts of extractable P in this soil; over twice that indicated by the 1:10 ratio.

Soil test K was influenced by the K treatments at Lamberton and Morris but not at Waseca (Table 3). These results are identical to 1976. As with P there appears to be somewhat of a linear response to the annual K applications but the relationship is not as exact. Soil pH differences were small and did not appear to be related to the P and K treatments.

Approximately 5-6 weeks after planting, ten plants randomly selected from each plot were measured, harvested, dried and weighed to determine early plant growth. Early plant growth (weight and height) was increased significantly (P=.01) by the P and K treatments at all three locations (Table 4). Both plant weight and height were generally lowest with the check treatment (no. 1), the 0 P_2O_5 treatment (no. 2) and the two treatments which haven't been applied since 1973 (nos. 9 and 10). The growth response at all locations was due primarily to P. Early weight was increased over the 0 P_2O_5 rate (no. 2) by the 50, 100 and 150 lb P_2O_5 rates by 6, 26 and 6% at Lamberton, 16, 38 and 39% at Morris, and 21, 40 and 36% at Waseca, respectively. No effect of K was noticed except at the Morris location.

Table 3. Soil test values as influenced by four year's application of the P and K treatments.[1/]

Treatment		pH			P				K		
No.	Description[2/]	La	Mo	Wa	La	M_{10}	M_{50}	Wa	La	Mo	Wa
	lb $P_2O_5+K_2O/A$				------------		lb/A				------------
1	0 + 0	5.9	7.7	5.8	38	15	37	20	195	320	210
2	0 + 100	5.8	7.7	5.8	31	15	38	22	240	445	225
3	50 + 100	6.3	7.6	5.7	42	33	76	32	235	385	230
4	100 + 100	5.8	7.7	5.9	55	52	116	39	225	395	245
5	150 + 100	6.0	7.6	5.8	54	36	83	32	235	385	225
6	100 + 0	5.8	7.7	5.9	54	50	116	34	180	315	200
7	100 + 50	5.9	7.7	5.8	50	48	110	37	205	375	215
8	100 + 150	5.9	7.5	5.7	54	63	134	37	225	375	215
9	0 + 0	6.2	7.6	5.8	38	25	61	21	205	330	205
10	0 + 0	5.9	7.8	6.0	44	18	48	21	210	350	220
Significance:[3/]		NS	+	*	**	**	**	**	**	**	NS
BLSD (.05) :				0.2	13	9	20	6	30	55	
CV (%) :		5	3	2	19	18	18	16	8	10	9

[1/] Samples were taken in October before the 1977 treatments were applied.
[2/] Rates applied in fall of 1976 for 1977 crop.
[3/] **, *, and + are significant at the 99, 95 and 90% levels, respectively; ns = not significant at the 90% level.

Table 4. Early plant growth characteristics as influenced by high P and K rates at the three experimental sites in 1977.

Treatment		Weight			Height		
No.	Description	La	Mo	Wa	La	Mo	Wa
	lb $P_2O_5+K_2O/A$		g/dry plant			----inches------	
1	0 + 0	9.0	5.1	10.2	21	22	29
2	0 + 100	8.5	5.6	9.6	21	24	30
3	50 + 100	9.0	6.5	11.6	21	25	32
4	100 + 100	10.7	7.7	13.4	22	26	34
5	150 + 100	9.0	7.8	13.1	22	26	34
6	100 + 0	10.2	7.6	12.2	22	25	32
7	100 + 50	9.8	7.0	12.2	22	25	33
8	100 + 150	10.9	8.2	12.8	22	27	33
9	0 + 0	8.4	6.1	9.3	21	24	29
10	0 + 0	9.0	5.7	8.9	22	24	30
Significance:		**	**	**	**	**	**
BLSD (.05) :		1.5	1.1	1.2	0.9	2.0	1.4
CV (%) :		10.	11.	8.	3.	5.	3.

Because of the sizable early plant growth effects at Waseca, the small plant samples were chemically analyzed. Concentrations of P and Mg were affected significantly (P=.01 and .05, respectively) by the P and K treatments (Table 5). Plant P appeared to increase linearly with P rate while plant Mg decreased with increasing K rate. Plant K was not influenced.

Table 5. Effect of high P and K rates on the nutrient concentrations in the small whole plants at Waseca in 1977.

No.	Treatment Description	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb P_2O_5+K_2O/A	-----	%	-----		-----		ppm	-----	
1	0 + 0	.41	3.47	.47	.39	480	82	47	8	11
2	0 + 100	.42	3.70	.43	.32	490	86	44	9	11
3	50 + 100	.46	4.01	.37	.28	480	81	42	8	12
4	100 + 100	.48	3.43	.38	.27	400	85	38	6	11
5	150 + 100	.51	4.03	.32	.26	370	65	39	5	10
6	100 + 0	.47	3.81	.46	.39	410	74	39	5	9
7	100 + 50	.48	3.50	.37	.29	420	73	41	6	12
8	100 + 150	.48	3.66	.38	.28	450	81	41	6	12
9	0 + 0	.43	3.10	.43	.35	470	88	41	8	16
10	0 + 0	.44	3.60	.42	.34	470	93	48	9	13
	Significance:	**	NS	NS	*	+	NS	NS	**	+
	BLSD (.05) :	.06			.10				2.6	
	CV (%) :	9.	17.	27.	18.	13.	22.	14.	23.	20.

Uptake of P and K by the small plants was affected significantly (P=.01) by the treatments (Table 6). A linear response to P rate was obtained; whereas, K rate had little influence on K uptake. This would further indicate that early growth differences were due to phosphate application rather than potash.

Table 6. Effect of high P and K rates on the P and K uptake by small corn plants at Waseca in 1977.

No.	Treatment Description	Uptake P	Uptake K
	lb P_2O_5+K_2O/A	--mg/plant---	
1	0 + 0	42	353
2	0 + 100	41	362
3	50 + 100	53	474
4	100 + 100	65	459
5	150 + 100	67	530
6	100 + 0	58	469
7	100 + 50	58	429
8	100 + 150	61	469
9	0 + 0	40	288
10	0 + 0	40	320
	Significance:	**	**
	BLSD (.05) :	8	116
	CV (%) :	11.	18.

Leaf analyses showed significant effects of the P and K treatments at the Morris and Waseca locations (Table 7). High variability in the analyses from Lamberton negated any significant effects. At Morris leaf P was increased with increasing P rate. Leaf K was related to K rate but did not correspond as closely to K rate as leaf P did to P rate. Leaf Mg was reduced by increasing K rate. At Waseca increasing K rate resulted in higher leaf K and lower leaf Mg. At all three locations leaf K was greater when no P was applied (trt. no. 1) than when the 100-lb P_2O_5 rate (trt. no. 6) was applied. Zinc concentrations at Lamberton and Morris were much lower than those found in 1976 and are now approaching deficiency levels. This may be due only to time of sampling or N nutrition. However, a broadcast Zn SO_4 treatment should be applied if these lower levels appear again in 1978.

No significant differences in final population were found among the 10 treatments at any of the locations (Table 8). The incidence of broken stalks was affected at Morris (Table 8). Those plots receiving higher rates of K had increased numbers of broken stalks at harvest. A disease which occurred rapidly within a few days in early September and caused premature death appeared to be the causal factor for the broken stalks.

Silage and grain yields and grain moisture (an indication of maturity at harvest) are given in Table 9. Silage yields at Lamberton and Waseca were not influenced significantly; however, a slight response to K (P=.10) was found at Morris. Grain yields after four years of treatment application were not affected significantly at any of the locations, although a trend was evident at Waseca. Yields at Morris may have been influenced slightly by the aforementioned disease problem. Grain moisture at harvest was affected by the treatments only at the Morris location, giving further indication of the premature death caused by disease.

Table 7. Effect of high P and K rates on the nutrient concentrations in the corn leaf at the three experimental sites in 1977. [1/]

Treatment No.	Description	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb $P_2O_5+K_2O$/A	%				ppm				
					Lamberton					
1	0 + 0	.23	1.93	.61	.38	185	63	24	6	6
2	0 + 100	.20	2.26	.50	.29	175	48	21	6	6
3	50 + 100	.24	2.45	.67	.37	160	48	18	6	8
4	100 + 100	.22	2.12	.54	.30	180	49	19	5	7
5	150 + 100	.21	2.10	.58	.32	155	53	19	6	6
6	100 + 0	.22	1.86	.61	.36	180	59	20	6	7
7	100 + 50	.21	2.15	.53	.31	185	49	19	5	6
8	100 + 150	.20	2.01	.54	.31	185	49	19	5	6
9	0 + 0	.22	2.03	.63	.37	180	54	19	6	7
10	0 + 0	.23	2.09	.62	.36	180	51	22	7	7
	Significance:	NS	NS	NS	NS	NS	NS	NS	NS	NS
	CV (%) :	19	17	20	18	11	18	13	19	18
					Morris					
1	0 + 0	.31	1.91	.56	.61	225	66	24	10	9
2	0 + 100	.31	2.05	.55	.56	235	59	24	9	9
3	50 + 100	.35	2.20	.60	.56	240	65	24	11	10
4	100 + 100	.34	2.12	.60	.58	240	70	19	10	11
5	150 + 100	.34	1.92	.58	.62	225	68	20	9	9
6	100 + 0	.35	1.79	.63	.68	230	68	18	9	11
7	100 + 50	.36	2.04	.62	.60	245	74	21	10	11
8	100 + 150	.36	1.89	.63	.55	235	62	19	9	9
9	0 + 0	.33	1.78	.58	.71	230	74	22	10	10
10	0 + 0	.32	1.92	.57	.63	230	65	24	10	10
	Significance:	**	**	NS	*	NS	*	*	NS	NS
	BLSD (.05) :	.02	.19		.10		10	5		
	CV (%) :	4	6	8	10	35	9	14	12	12
					Waseca					
1	0 + 0	.33	1.96	.63	.42	230	100	29	11	10
2	0 + 100	.33	2.08	.60	.34	220	103	32	9	12
3	50 + 100	.34	2.15	.60	.34	230	115	30	9	12
4	100 + 100	.34	1.94	.63	.34	215	108	24	9	12
5	150 + 100	.35	1.78	.69	.35	215	127	26	8	13
6	100 + 0	.35	1.61	.71	.42	220	116	24	8	11
7	100 + 50	.34	1.80	.66	.37	215	121	24	9	11
8	100 + 150	.36	2.21	.61	.36	250	106	30	8	12
9	0 + 0	.35	1.93	.66	.40	230	115	28	9	12
10	0 + 0	.34	1.94	.65	.41	230	102	29	10	12
	Significance:	NS	**	NS	**	NS	NS	NS	NS	NS
	BLSD (.05) :		.36		.05					
	CV (%) :	6	11	12	10	11	16	21	19	17

1/ Leaf opposite and below the ear at silking.

Table 8. Population and broken stalks at harvest as influenced by high P and K rates in 1977.

Treatment		Final population			Broken stalks		
No.	Description	La	Mo	Wa	La	Mo	Wa
	lb P_2O_5+K_2O/A	plants/A x 10^3			------%-------		
1	0 + 0	22.0	19.0	22.2	1/	16.6	1/
2	0 + 100	21.3	19.1	21.0		32.4	
3	50 + 100	20.0	19.0	20.9		35.4	
4	100 + 100	20.9	19.0	21.6		43.8	
5	150 + 100	21.6	19.1	22.5		32.7	
6	100 + 0	21.6	19.1	21.2		24.7	
7	100 + 50	20.2	19.0	22.1		34.5	
8	100 + 150	20.7	19.0	20.1		37.4	
9	0 + 0	20.9	19.1	22.0		21.7	
10	0 + 0	20.9	19.1	22.2		14.9	
	Significance:	NS	NS	NS		*	
	BLSD (.05) :					21.1	
	CV (%) :	8	1	8		40	

1/ Data not taken because stalk problems were not evident.

Table 9. Corn yields and moisture at harvest as influenced by high P and K rates in Minnesota in 1977.

Treatment		Silage yield			Grain yield			Grain moisture		
No.	Description	La	Mo	Wa	La	Mo	Wa	La	Mo	Wa
	lb P_2O_5+K_2O/A	T DM/A			-------bu/A--------			-------%--------		
1	0 + 0	6.63	5.82	6.62	130.5	102.4	148.7	24.3	21.0	26.0
2	0 + 100	6.31	6.15	7.33	121.8	98.4	159.0	23.8	19.7	26.3
3	50 + 100	6.22	6.00	7.27	119.5	101.4	155.6	24.6	19.5	26.4
4	100 + 100	6.06	6.32	7.05	136.2	98.0	157.7	22.5	18.4	25.9
5	150 + 100	6.38	6.14	7.07	119.5	97.2	159.9	24.2	18.9	26.2
6	100 + 0	6.40	5.50	6.62	114.5	94.1	158.4	24.0	17.6	26.1
7	100 + 50	6.28	5.96	6.96	128.1	97.4	158.1	23.5	19.0	26.3
8	100 + 150	6.32	6.23	6.97	125.2	98.4	160.2	23.8	17.6	26.1
9	0 + 0	6.04	5.82	6.95	122.2	99.8	157.6	24.3	18.6	26.2
10	0 + 0	6.20	6.16	6.96	122.4	102.8	156.6	24.3	19.4	26.1
	Significance:	NS	+	NS	NS	NS	NS	NS	*	NS
	BLSD (.05) :								2.4	
	CV (%) :	7	6	6	11	6	5	7	7	1

PASTURE FERTILIZATION TRIALS, GOODHUE COUNTY - 1976 AND 1977

C. J. Overdahl

Pasture trials at two locations were initiated in Goodhue County in the spring of 1976. The plots were located on the Dale Flueger and Jim Bryan farms. The purpose of the study was to observe benefits from rates and application times for nitrogen. Also, a comparison between ammonium nitrate and urea was made, as well as a measure of P and K needs. Yields were evaluated by clipping four times during the summer. Plots were fenced and no grazing was permitted.

The Flueger farm has mostly bromegrass, with some legume remaining, apparently from a previous improvement. The Bryan pasture appears to have a predominance of bluegrass, resulting in short growth during July 1976 and a clipping at this time could not be made. In 1977, the lack of grazing on the Bryan farm seemed to give the alfalfa a chance for revival and a thin stand of alfalfa occurred in all plots.

Data in the following tables are a progress report for 1976 and 1977.

The fine cooperation of Jim Bryan and Dale Flueger are gratefully acknowledged. Also, the efforts of Bob Schoper, Jerome Lensing, research associates in the Soil Science Department, and Brian Schreiber, County Extension Agent in Goodhue County, are greatly appreciated. Without their help, the work wouldn't have been done.

This project was financed by the generous support of St. Paul Ammonia Products.

Table 1a. Relationship of nitrogen treatments to pasture yield at the Bryan farm, Goodhue Co., 1976 and 1977.

N	P_2O_5	K_2O	Bryan* lbs/A		N response over check		Protein lbs/A	
			1976	1977	1976	1977	1976	1977
0	40	40	1642	3071	-	-	229	466
30	40	40	2248	3542	606	471	328	545
60	40	40	2685	3284	1043	213	378	518
90	40	40	3775	4555	2133	1484	642	769
120	40	40	4054	5138	2412	2067	680	888

Table 1b. Relationship of nitrogen treatments to pasture yield at the Flueger farm, Goodhue Co., 1976 and 1977.

N	P_2O_5	K_2O	Flueger* lbs/A		N response over check		Protein** lbs/A	
			1976	1977	1976	1977	1976	1977
0	40	40	3646	2383	-	-	440	373
30	40	40	4789	3133	1143	750	660	483
60	40	40	5301	3926	1655	1543	843	690
90	40	40	7110	4868	3464	2485	1250	931
120	40	40	6767	4881	3121	2498	1210	988

* 3 cuttings at Bryan's and 4 at Flueger's, 1976; 4 cuttings at Bryan's and 3 at Flueger's, 1977.

** N removed times 6.25.

Discussion and summary

This was the last year for the Bryan plots, the Flueger plot will be continued one more year.

1. Significant increases in pasture yield were obtained from nitrogen additions. On the Bryan farm, the highest yield both years was from the 120 pounds of nitrogen per acre, but this was not significantly higher than 90 pounds per acre. On the Flueger farm, 90 pounds of nitrogen per acre gave approximately equal yields to 120 pounds. The same results occurred in 1976.

2. Protein yield increases follow the increases in grass yield and are directly in line with the nitrogen treatments.

3. Split applications did not yield higher than one application of the total amount in the spring.

   The large yields are usually in the first or second cutting which also gave the largest increases due to nitrogen treatment. Higher yields were obtained in midsummer from midsummer application, but the increases were not large enough to make up for the large early yields.

4. Soil tests of medium or high in P and high or very high in K resulted in no yield increases from additions of these two elements.

5. There was no significant difference in pasture yields where ammonium-nitrate and urea were compared. Sixty pounds per acre of nitrogen in two 30 pound applications were compared in this trial at both farms.

6. It would appear that approximately 90 to 100 pounds per acre of nitrogen, annually, along with a small amount of phosphorus and potassium for insurance, would be a highly satisfactory fertilizer program for grass pasture and best protein production.

GRASS SEED PRODUCTION AS INFLUENCED BY FERTILIZATION

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High production costs and concern for energy conservation and environmental quality make correct fertilizer use important. Therefore, it is most important that information on efficient use of commercial fertilizers is available.

Past research has supplied information on nutrient requirements of grasses, on soil fertility, and on rates and time of fertilizer application. But as new materials or new varieties become available or as new problems arise, additional investigations are needed.

Research during 1977 consisted of (a) nitrogen source comparison on mineral soils, (b) nitrogen rate study on peat, and (c) copper study with Kentucky bluegrass on peat. Six trials with Timothy and Kentucky bluegrass were conducted on growers' fields in Roseau and Lake of the Woods counties. Fertilizer effects were determined by yield measurements and chemical analysis of grass tissue.

A. WEATHER CONDITIONS DURING 1976/77 GROWING SEASON

Comments on weather conditions are based on measurements of the U. S. Weather Station at Roseau, observations and soil temperature determinations at the Magnusson farm at Roseau (table 1, fig. 1).

September and October of 1976 were cool and relatively dry, with about 3 inches of rainfall below normal. During a twelve day period, from October 16 to 27, air temperature ranged from 1° to 40° F. Also November through January the temperature was below normal. It ranged from 5 to 10 degrees below the normal temperature. During November the precipitation was about 1 inch below normal and the air temperature was 5 degrees below normal. The area received below normal snowfall. From February to July the temperature was either normal or above normal. May had about normal rainfall, with temperatures about 13 degrees above normal. During June 3.71 inches of rainfall were measured which is slightly above normal. Generally, during the period from August 1976 to July 1977 nearly 5 inches less precipitation than normal were received at Roseau while the average air temperature was about 6.5 degrees F. below normal. Weather data of previous growing seasons (1964/65 and 1973/74) indicate that during good seed production seasons nearly 22 inches of precipitation are received at Roseau. In contrast, about 16 inches of precipitation were measured at Roseau during 1976/77 growing season.

Soil temperature (under sod at 3-inch depth) during May ranged from 44 to 74° F. Maximum soil temperature rose to 84° F. during the middle of July. During the second half of July and during August, maximum temperature ranged from 66 to 83° F. while minimum temperature measured from 55 to 68° F.

Prepared for presentation at the Grass Seed Institute, Roseau, March 22, 1978.

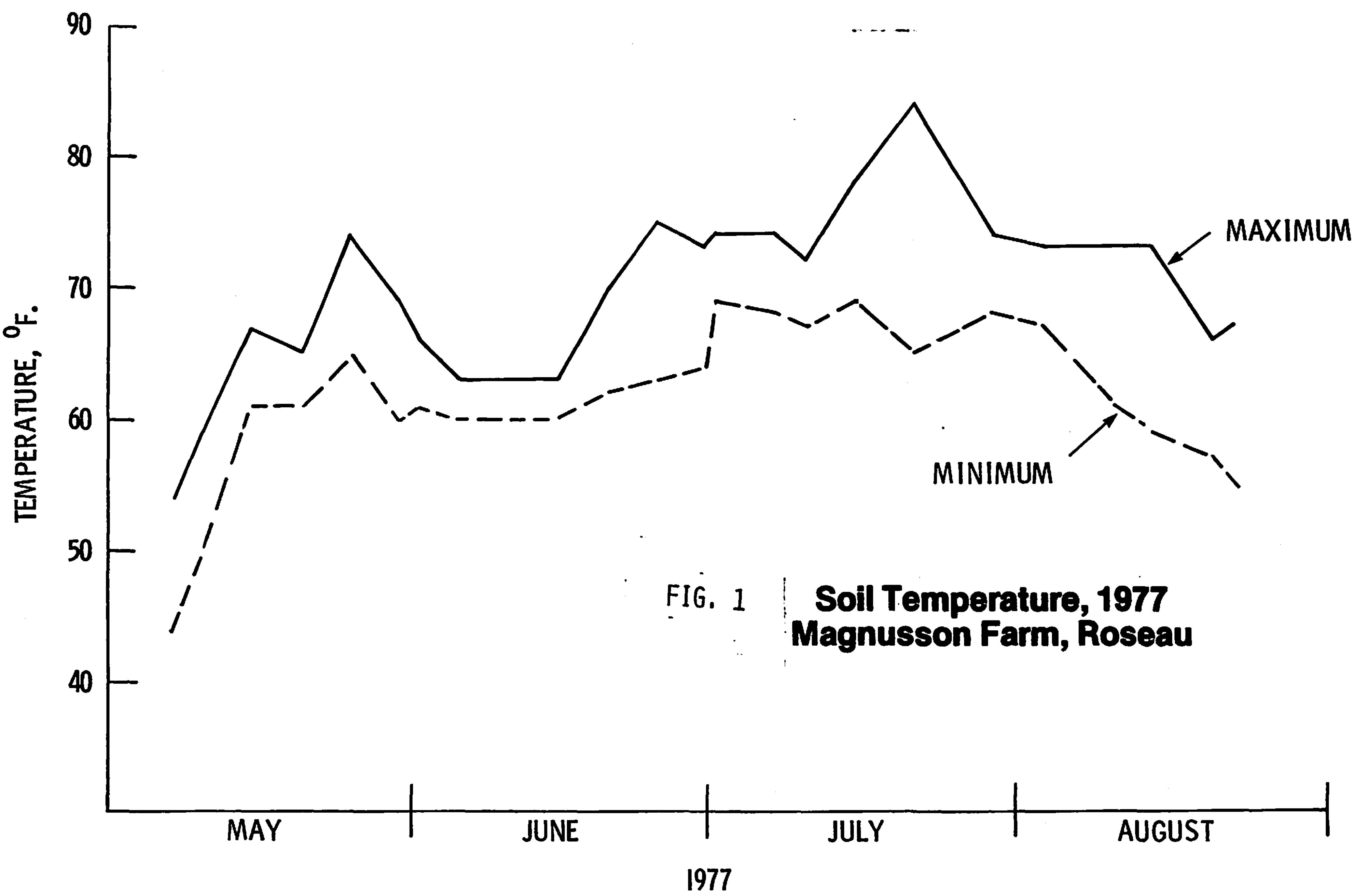

FIG. 1 Soil Temperature, 1977
Magnusson Farm, Roseau

B. NITROGEN SOURCE COMPARISON

Three field experiments, established in fall of 1975, were conducted on growers' fields. The soils contained 14-25 lb/acre of nitrate-N in the top two feet, considered to be a relatively low level (table 2). The nitrate-N concentration in the main root zone (0-3 inches) was less than 3.6 pp2m. The soils were calcareous with pH values near 8 (table 3).

Both nitrogen fertilizers were applied at rates of 50 or 100 lb of N per acre, either on October 12 or April 4. All plots received a 0+40+40 treatment. Fertilizer materials were applied with a 3-foot Gandy spreader.

Kampe II timothy yielded about 200 to 475 pounds of seed per acre (table 4). Ammonium nitrate gave a greater yield than urea by 44 pounds. Optimum yield was produced with 100 lb/acre of nitrogen and fall fertilization was superior to spring. There was a higher N concentration of tissue from 100 lb/acre N and spring application but no concentration differences were related to N source.

Timfor timothy seed yield ranged from about 300 to 700 lb/acre (table 5). Ammonium nitrate was slightly superior N source to urea. Optimum yield was produced with 100 lb/acre of nitrogen and spring fertilization was somewhat superior to fall. Nitrogen concentration of grass tissue was increased by the application of the higher rate of N and by fertilization in the spring.

Park Kentucky bluegrass yield (table 6) was extremely low, ranging from 40 to 150 pounds per acre, because of drought. Higher yields resulted from the use of the higher rate of N and fall fertilization but the form of fertilizer had no effect on seed yield. Increased N concentration in grass tissue resulted from ammonium nitrate, the use of higher rate and spring application compared to the respective treatment counterparts.

A field demonstration was conducted on the Erickson farm with S-51 timothy involving three N sources: anhydrous ammonia, ammonium nitrate and urea. Fertilizer materials were applied on October 13, 1976. Knives were set 12 inches apart for the anhydrous ammonia application.

All three nitrogen sources were equally effective in increasing either the seed yield or the N concentration in grass tissue when applied at the 100 lb/acre rate of N (table 7). Ripping-up of the sod with applicator knives did not affect the yield appreciably.

Table 1. Precipitation and Temperature Data for the 1976/77 Growing Season as Measured at Roseau Weather Station (KRWB Radio)*

Period	Precipitation (Inches) Total	Precipitation (Inches) Departure From Normal	Air Temperature (°F) Average	Air Temperature (°F) Departure From Normal	GDD $T_b = 40^oF$
1976 Aug.	3.72	.50	65.8	.9	733
Sept.	.34	-2.27	54.5	-.1	363
Oct.	.07	-1.15	37.0	-7.5	128
1976 Nov. to 1977 Apr.	3.24	-1.38	16.5	-.08	253
1977 May	2.43	-.02	64.7	12.8	764
June	3.71	.29	62.2	.4	666
July	2.28	-1.17	67.2	0	842
Total	15.79	-5.20			3749
Average			30.7	-6.5	
Normal (1941-70)	20.99		37.2		3329

*Calculated from Climatological Data, Minnesota, Vol. 82 and 83, 1976 and 1977, U.S. Dept. of Commerce.

NOTE: Data for January and February represent averages because precipitation was not recorded.

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 NO_3-N in 0-24"
		------NO_3-N pp2m--------			LBS/A
Knochenmus Kampe II timothy+	silty clay loam	3.5	3.9	17.3	24.7
G. Kveen Park K. bluegrass+	peat	2.5	2.1	15.0	19.6
Erickson S-51 timothy+	silt loam	2.8	2.8	12.8	18.4
Helmstetter Bros. Park K. bluegrass#	sandy loam	1.8	1.5	10.6	13.9
Hedlund Timfor timothy#	silty clay loam	2.0	2.1	10.2	14.3

+ Fall sampling - October 12, 1976

Spring sampling - April 27, 1977

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
Knochenmus	0-3	SICL	7.8	51	365
Kampe II timothy	3-6	SIL	8.0	17	215
	6-24	SIL	8.3	5#	95
Erickson	0-3	SIL	8.0	20	110
S-51 timothy	3-6	SIL	8.1	14	80
	6-24	SL	8.4	5#	50
Helmstetter Bros.	0-3	SL	7.9	60	339
Park K. bluegrass	3-6	SL	8.1	20	165
	6-24	LS	8.1	12#	118
Hedlund	0-3	SICL	8.1	12	223
Timfor timothy	3-6	SICL	8.2	11	144
	6-24	SICL	8.4	5#	85
Kveen	0-3	P	7.8	36	300
Park K. bluegrass	3-6	P	7.6	8#	43
Habstritt	0-3	P	6.7	14	200
Nugget K. bluegrass	3-6	P	6.5	4	31

Bray - 1 P, 1:50 soil/solution ratio.

Table 4. Effects of nitrogen source, rate and time of application on seed yield and N concentration in tissue of Kampe II timothy, Louis Knochenmus Farm, Roseau County, 1977

Treatment	Seed yield lbs/acre	N percent in dry matter
(a) Source		
Urea	274a	3.91
Ammonium nitrate	318b	3.88
Significance	*	NS
BLSD (0.05)	39	
(b) Rate		
50 lbs/acre N	258a	3.67a
100 lbs/acre N	334b	4.12b
Significance	*	**
BLSD (0.05)	62	.14
(c) Date		
October 12, 1976	348b	3.82a
April 4, 1977	245a	3.97b
Significance	**	**
BLSD (0.05)	79	.07
C.V.	17	3

Values followed by different letter(s) are significantly different (5% level).

Symbols indicating significance: NS Non significant
* Significant at 5% level
** Highly significant at 1% level.

All plots received 0 + 40 + 40 lbs/acre of P_2O_5 and K_2O.

Table 5. Effects of nitrogen source and time of application on seed yield and N concentration of Timfor timothy on a silt loam soil, Dell Hedlund Farm, Roseau County, 1977.

Treatment	Seed yield lbs/acre	N percent in dry matter
(a) Source		
Urea	454a	2.95
Ammonium nitrate	521b	3.03
Significance	**	NS
BLSD (0.05)	32	
(b) Rate		
50 lbs/acre N	339a	2.66a
100 lbs/acre N	636b	3.32b
Significance	**	**
BLSD (0.05)	73	.06
(c) Date		
October 12, 1976	445a	2.90a
April 4, 1977	529b	3.09b
Significance	*	*
BLSD (0.05)	53	.12
(d) Interaction		
October 12 x 50 lbs/acre N	317	2.61a
x 100 lbs/acre N	574	3.19c
April 4 x 50 lbs/acre N	361	2.72b
x 100 lbs/acre N	698	3.46d
Significance	NS	*
BLSD (0.05)		.09

Values having same letter are not significantly different (5% level).

All plots received 0 + 40 + 40 lb/acre of P_2O_5 and K_2O.

Table 6. Effects of nitrogen source, rate and time of application on seed yield and N concentration in tissue of Park Kentucky Bluegrass, Helmstetter Bros. Farm, Lake of the Woods County, 1977.

Treatment	Seed yield lbs/acre	N percent in dry matter
(a) Source		
Urea	86	1.93a
Ammonium nitrate	102	2.30b
Significance	NS	**
BLSD (0.05)		.12
(b) Rate		
50 lbs/acre N	70a	1.83a
100 lbs/acre N	118b	2.40b
Significance	**	**
BLSD (0.05)	13	.15
(c) Date		
Oct. 13, 1976	121b	2.04a
April 18, 1977	67a	2.19b
Significance	**	*
BLSD (0.05)	17	.13
C.V.	25	8

Values followed by different letter are significantly different at the 5% level.

All plots received 0 + 40 + 40 lb/acre of P_2O_5 and K_2O.

Table 7. Effect of three nitrogen fertilizers on seed yield and N concentration in tissue of S-51 Timothy, Erickson Farm, 1977.

Treatment	Seed yield lb/acre	N percent in dry matter
Check	60a	2.19a
Check and knife	83a	2.34a
Anhydrous ammonia	317b	3.39b
Ammonium nitrate	348b	3.37b
Urea	298b	3.42b
Significance	**	**
BLSD (0.05)	97	0.26

Values followed by different letters are significantly different at 5% level.

All fertilizer materials were applied at 100 lb/acre N rate.

C. NITROGEN RATE STUDY ON PEAT

In field experiments conducted on growers' fields during 1960's, nitrogen rates of 20 to 30 pounds per acre often caused severe lodging of bluegrass on peat. Consequently, growers were advised not to exceed 15 lb/acre of N. In experiments conducted during 1974 and 1975, however, maximum yields were produced with 40-80 lb/acre of nitrogen.

A field experiment with Park Kentucky bluegrass on peat was established in fall of 1975 to futher investigate effectiveness of different N rates. Twenty pounds of N were sufficient to produce optimum yield of 459 lb/acre.

In fall of 1976, the experiment was shifted to a different area within the same field as used for 1975-76 experiment. Five nitrogen rates were used: 0, 20, 40, 60, 80 lb/acre and the treatments were replicated four times. All plots received uniform 0+40+40 lb/acre phosphate and potash treatment.

Relatively low seed yield was produced at this location, probably due to drought (table 8). Although fertilization with nitrogen did increase seed yield above the check, there was no advantage to apply more than 20 lb/acre of N. The N concentration in grass tissue increased according to the nitrogen rates.

Table 8. Effect of fertilization on the seed yield and N concentration in tissue of Park Kentucky Bluegrass on peat, Gus Kveen Farm, Roseau County, 1977.

N rate lb/acre	Seed yield lbs/acre	N percent in dry matter
0	75a	2.28a
20	139b	2.60b
40	130b	2.70b
60	157b	2.94c
80	141b	3.20d
Significance	**	**
BLSD (0.05)	32	.21

Values followed by different letters are significantly different at 5% level.

All plots received 0 + 40 + 40 lb/acre of P_2O_5 and K_2O.

D. COPPER STUDY ON PEAT

The importance of copper fertilization in seed production of Kentucky bluegrass on peat was investigated in two field experiments during 1977. Copper sulfate and copper chelate were dissolved in water and sprayed to 10 x 20 ft. plots on April 19. The treatments were replicated 6 times.

Lack of moisture caused the seed yield to be very low at both locations. Park K. bluegrass on the Kveen farm yielded less than 120 lb/acre of seed, and the Nugget yield on Habstritt farm did not exceed 30 lb/acre. The seed yield of grass was not affected by fertilization with copper.

Copper concentration in tissue of Park K. bluegrass was as low as 2 ppm, but was increased by the application of either 50 lb/acre of Cu sulfate or 4 lb/acre of Cu chelate (table 9). Copper chelate applications to Nugget K. bluegrass did not increase the Cu concentration in tissue, but the Cu sulfate treatment increased the concentration from 3 to 29 ppm Cu.

Table 9. Copper concentration of Kentucky bluegrass tissue on peat as affected by fertilization with copper, Roseau County, 1977.

Copper Treatment	Cooperator and variety: G. Kveen Park	Cooperator and variety: Habstritt Nugget
	---------Cu, ppm in dry matter---------	
None	2a#	3a
50 lb/a copper sulfate	5b	29b
2 lb/a copper chelate	3a	5a
4 lb/a copper chelate	4b	7a
Significance	**	**
BLSD (0.05)	.8	8.5

Average of 6 replications.

Copper treatments were made on April 19, 1977.

SUMMARY AND CONCLUSIONS

Six field experiments with timothy and Kentucky bluegrass were conducted on growers' fields in northwestern Minnesota. The main objective of these studies was to determine the effects of urea, ammonium nitrate and anhydrous ammonia applications, nitrogen rate, and fertilization with copper on plant tissue and seed yield of grasses.

Weather conditions during 1976-77 growing season were less than optimum. Nearly 5 inches of precipitation below normal were recorded at Roseau from August 1976 to July 1977. Kentucky bluegrass seed yields were seriously affected by drought, particularly on mineral soils.

Ammonium nitrate was slightly superior to urea as a nitrogen source to timothy. Optimum seed yields were produced with 100 lb/acre of N with no clear cut advantage to either fall or spring application.

Optimum seed yield of Park Kentucky bluegrass on peat was produced with 20 pounds per acre of nitrogen.

The seed yield of K. bluegrass was not affected by copper additions.

ACKNOWLEDGMENTS

Grateful acknowledgments are made to the following cooperators and University personnel for their valuable assistance during 1977 in obtaining the information pertaining to grass seed production:

Messrs. Douglas Erickson, Habstritt Bros., Dell Hedlund, Louis Knochenmus, Gustav Kveen, Roseau County; Everett and George Helmstetter, Lake of the Woods County; Dr. Laddie Elling, Messrs. Jerome Lensing, Tim Wagar, Mike O'Leary, Donn Vellekson, George Nelson, University of Minnesota.

Potato Tillage
R. R. Valley Potato Research Farm
G. R. Blake and Dennis Askin
1977

	Conventional	No-till
	Potatoes, pounds 1/	
	15,770	13,310
	17,560	13,390
	13,390	14,430
	16,110	
	20,010	
Totals	82,840	41,130
Pounds/acre	19,145	19,011
	Clods, pounds	
	145	340
	225	260
	255	245
	260	
	240	
Totals	1,125	845
Pounds/acre	260	391

1/ 24 rows conventional, 12 rows no-till were harvested. Row spacing, 38 inches; row length, 2,480 feet.

INFLUENCE OF FOLIAR APPLICATIONS OF FERTILIZER NUTRIENTS AND FUNGICIDE ON THE YIELD AND PROTEIN CONTENT OF SMALL GRAINS

C. A. Simkins, extension soils specialist; R. P. Schoper, assistant soils extension specialist; G. W. Randall, soils scientist, Southern Experiment Station, Waseca; S. D. Evans, soils scientist, West Central Experiment Station, Morris; H. L. Bissonnette, extension plant pathologist

Recent investigations of spray applications of N, P, K and S on soybeans by Dr. Hanway and others has renewed the interest in foliar feeding of crops.

A review of literature reveals that the foliar feeding of crops has been investigated by several scientists during the early 1950's. Most of the research, however, was limited to foliar applications of nitrogen and phosphorus.

Based on the quantity of plant nutrients required to increase a crop yield a given amount, it would appear that the greatest opportunity lies in foliar feeding of oil seed and other high protein crops. It may, however, be more economical to use foliar feeding on crops where the quantity of plant food nutrients needed to bring about an increase in yield requires significantly less N, P, K and S, i.e., soybeans versus rice or wheat; approximately 8 pounds N per 100 pounds soybeans, 1.5 pounds N per 100 pounds rice, 3 pounds N per 100 pounds wheat. This small quantity of spray would also allow for a larger acreage to be covered by the flight of an aircraft.

It is of particular interest to the researchers that investigations indicate that the application of fungicides on small grains often results in economical increases in yield when leaf rust, Septoria leaf blotch, and Helminthosporium are kept under control.

The timing of the application of fungicides for disease control would appear to nearly coincide with the recommended time for foliar applications of plant food nutrients for small grains. The combined application of plant nutrients and fungicides might prove to be additive in their ability to increase yields and quality of small grains.

STUDIES CONDUCTED

Trials were established at the experimental stations at Morris, Crookston, and Waseca. Treatments were as follows:

1. Control.

2. Foliar application of nutrients at flag leaf stage and 10 and 20 days later.

3. Fungicide applied at flag leaf stage and 10 and 20 days later.

4. Combinations of treatments 2 and 3.

SITE SELECTIONS

The sites for these studies were specifically selected to represent fields of high fertility. The NO_3-N level at all locations contained more than 100 pounds NO_3-N in the top 2 feet. Additionally, the P and K soil test levels were very high.

TREATMENT FORMULATION

Urea, potassium polyphosphate, and potassium sulfate were combined to develop a foliar spray which would contain plant nutrients similar to the small grain crops. The following quantities were used:

	Pounds per ton
Urea	260
Potassium polyphosphate	177
Potassium sulfate	58
Water	1,505

This formulation resulted in a ratio of the nutrient elements of 6-2.3 and 3.7 for N, P_2O_5 and K_2O. Additionally, the formula supplied .5 percent sulfur. The material was applied at the rate of 26.4 gallons per acre or 250 pounds per acre. The quantity of nitrogen, phosphorus, potassium, and sulfur applied per acre was 15, 6, 9, and 1.3, respectively.

A fungicide--Manzate 200--was applied at the rate of 2 pounds per acre alone and in combination with the fertilizer nutrients.

YIELDS OF SMALL GRAIN

Table 1 shows a summary of the yields of small grain. Yields at the Crookston experimental site are not shown because of the extreme variability of plant growth at the site.

Data from these trials show no increase in yield due to spray applications of plant nutrients. At the Waseca location, grain yields of wheat were significantly decreased by the application of 45 pounds of nitrogen per acre in combination with the other fertilizer nutrients.

Table 1. Yields of small grain as influenced by foliar applications--Minnesota--1977

Treatment lbs/A	Waseca Wheat	Morris Wheat	Morris Oats	Morris Barley
	--Bu/A--			
0	41	52	55	60
15	39	52	60	60
30	39	54	59	60
45	36	53	58	61
Sig.	**	ns	ns	ns
No Fungicide	39	51	53	60
Fungicide	38	55	63	59
Sig.	ns	**	**	ns

Table 2. Protein content of wheat as influenced by foliar application--Minnesota--1977

Treatment	% Protein--Wheat Waseca	% Protein--Wheat Morris
0	16.1	15.1
15	16.1	15.1
30	16.5	15.4
45	17.8	15.9
Sig.	**	*

The application of fungicide at the rate of 2 pounds per acre applied at the flag leaf stage and 10 and 20 days later resulted in significant increases in yield of wheat and oats at the Morris location. There was no significant interaction between the foliar nutrient spray and the fungicide.

PROTEIN CONTENT OF SMALL GRAIN

The protein content of wheat was significantly increased by the foliar application of plant nutrients at Waseca as well as Morris. The protein content of the barley and oats crop has not been determined at this date. It is anticipated that the nitrogen content of the wheat straw will also be determined.

RESPONSE OF SOYBEAN GENOTYPES TO FOLIAR FERTILIZATION

W.D. Poole, G.W. Randall and G.E. Ham

Foliar fertilization of soybeans has resulted in increased seed yields in some cases. However, lack of consistent yield increases is a concern shared by many. One of the factors that may be involved in the inconsistent yield increases is soybean genotype. This study was conducted to compare soybean genotypes for response to foliar fertilizer.

Foliar fertilization was conducted with the nitrogen supplied as urea; some potassium and the sulfur comes from potassium sulfate; and the phosphorus and additional potassium was supplied as potassium polyphosphate. The total quantity of nutrients supplied was 80+8+24+6 (N+P+K+S, respectively) in 4 applications.

Seed yields were not increased significantly in these studies which agrees with the lack of response in the other studies with these same fertilizer materials.

Table 1. Influence of foliar fertilization on soybean seed yield.

Soybean* genotype	Location					
	Waseca		Rosemount		Becker	
	No Foliar	Foliar	No Foliar	Foliar	No Foliar	Foliar
	bu/acre					
Hodgson	51	49	54	57	50	48
Hodgson M-75-1	53	50	58	60	--	--
Swift (Corsoy)**	46	46	56	57	--	--
Steele (Corsoy R-3)	45	48	48	42	--	--
12-22-1 (12-7-1)	47	49	49	53	--	--
12-22-2 (12-7-2)	45	45	43	48	--	--
13-3-1 (M-68-333)	51	50	46	46	--	--
13-3-2 (M-69-197)	44	46	47	47	--	--
13-40-1 (12-25-1)	48	48	44	42	--	--
13-40-2 (12-25-2)	43	43	43	44	--	--
13-61-1 (13-72-1)	45	45	46	51	--	--
13-61-2 (13-72-2)	43	43	44	47	--	--
13-84-1 (13-82-1)	46	49	47	47	--	--
13-84-2 (13-82-2)	39	43	43	41	--	--
M-68-49	44	44	53	49	--	--
M-68-176	--	--	--	--	56	51
M-68-213	--	--	--	--	45	44
M-69-36	44	46	42	41	--	--
M-69-124	--	--	--	--	54	47
M-69-128	--	--	--	--	51	50
M-69-129	--	--	--	--	58	56
M-69-264	--	--	--	--	55	53

* -M- genotypes obtained from J.W. Lambert, University of Minnesota; 12- and 13- genotypes obtained from D.E. Green, Iowa State University (-1 genotypes are semideterminate and -2 genotypes are indeterminate).
** Variety or genotype in parentheses grown at Waseca.

SOYBEAN YIELD IMPROVEMENT WITH FOLIAR FERTILIZER

W.D. Poole, G.E. Ham and G.W. Randall

Foliar fertilization is not a substitute for a good soil fertility program of soil applied fertilizers. Rather, foliar fertilization is in addition to soil applied fertilizers with other top management factors such as narrow rows and high-yielding varieties. If all other factors are optimum, foliar fertilization can result in increased yields.

The time of application is important and the best time to apply foliar fertilizers to soybean leaves is between the time when the top pods start filling and when about half of the leaves have turned yellow. Generally, 2-4 foliar fertilizer applications at least a week apart give the best results. One large application would probably "burn" the leaves severely and reduce the yield response to foliar fertilization. Research is continuing to evaluate single applications of nutrients compared to 2-4 applications.

The rate per application for an acre of soybeans is up to 20 pounds of nitrogen, 2 pounds of phosphorus (4 pounds of P_2O_5), 6 pounds of potassium (8 pounds of K_2O) and 1 pound of sulfur. Urea supplies the nitrogen; some potassium and the sulfur comes from potassium sulfate; and the phosphate and additional potassium comes from potassium polyphosphate. All four nutrients (nitrogen, phosphorus, potassium and sulfur) must be in the solution. Omitting any one of the nutrients decreases the yield response. In studies during 1977 these fertilizer materials were compared to conventional fertilizers that are cheaper and more readily available (10-34-0 and UAN or 28% N solution). In addition, B alone, benlate micronutrients, and the growth regulator TIBA were combined with N+P+K+S. The benlate was included since it had increased soybean yields in Illinois studies under conditions where pod and stem blight existed. Boron was included to determine the influence it may have on soybean seed yield. Several commercial products available for foliar fertilization of soybeans were applied according to the recommendations on the label (Na-Churs, Folian II, Bayfolan and Seaborne + F).

No fertilizer treatment increased soybean seed yields significantly across all locations and varieties. Folian II increased the seed yields of both varieties at Waseca and Hodgson variety at Becker and these were the only significant yield increases. The UAN or 28% N solution in place of urea resulted in severe leaf burn and reduced seed yields in all cases.

Each application should contain not more than 20 pounds of nitrogen in order to avoid leaf burn which results in yield reductions. A minimum of 12-15 pounds of nitrogen should be applied to increase soybean seed yields significantly since the smaller the quantity of nitrogen applied, the less likely are the chances of obtaining a yield response. A 60-bushel soybean crop contains about 300 pounds of nitrogen (240 pounds in the grain and 60 pounds in the leaves, stems and pods).

Foliar fertilization of soybeans should be conducted on an experimental basis until several questions have been answered. Evaluation in commercial soybean production on a limited scale is necessary since the experimental sites represent only a small sampling of environments. The yield responses obtained so far indicates that foliar fertilization has potential for increasing soybean seed yields. However, the yield increases are not consistent and dependable.

TABLE 1: Influence of various foliar fertilizers on 1977 soybean seed yields

Foliar Fertilizer Treatment	Number Appli-cations	Fertilizer Applied N+P+K+S	Waseca		Becker		Rosemount	
			Corsoy	Hodg-son	Evans	Hodg-son	Evans	Hodg-son
		lbs/acre	bu/acre					
Control	--	--	60	54	50	56	57	61
Surfactant	4	--	60	58	51	54	55	68
NPKS[a]	2	40-4-12-3	59	53	51	57	57	57
NPKS[a]	3	60-6-18-4.5	60	56	48	57	57	64
NPKS	4	80-8-24-6	61	57	48	53	54	63
10-34-0+urea+KS	4	80-8-24-6	59	55	45	52	55	65
10-34-0+UAN+KS	4	80-8-24-6	55	47	37	48	47	58
NPKS[a]+Benlate	4	80-8-24-6 +1.0 Benlate	64	53	45	56	58	60
NPKS[a]+Boron	4	80-8-24-6+0.4B	60	57	46	57	50	62
Ammonium sulfate+PK	4	80-8-24-6	60	57	47	56	55	64
Potassium sulfite+NP	4	80-8-24-6	62	57	46	53	56	68
NPKS[a]+micronutrients	4	80-8-24-6	58	50	41	48	47	64
NPKS[a]+TIBA	4	80-8-24-6	59	53	49	51	46	65
TIBA	1	--	55	51	47	57	49	63
Na-Churs[b]	4	9-8-7.5-0	59	55	48	55	58	63
Na-Churs+NKS	4	80-8-24-6	61	56	46	55	51	64
Folian II[c]	1	12-2.5-5-0.5	65	59	48	53	56	66
Folian II	1	24-5-10-1	59	57	46	55	54	61
Bayfolan[d]	2	--	59	55	50	54	57	65
Seaborne+F[e]	1	0.14-0.02-0.03 -0	60	55	49	54	55	64

[a]Iowa State formulation; [b]9-18-9; [c]12-6-6; [d]11-8-5; [e]6-3-3, N-P_2O_5-K_2O, respectively.

EVALUATION OF MAJOR NUTRIENT NEEDS OF SUGARBEETS IN WEST-CENTRAL MINNESOTA - 1977

R. P. Schoper, W. E. Fenster and O. M. Gunderson

Accurate prediction of nitrogen needs for optimum production of sugarbeets has been of prime importance in all sugarbeet producing areas. Sugarbeets do not have a built-in mechanism which automatically triggers sugar accumulation at a certain point in the growing season. Therefore, roots increase in sugar content only after a shortage of a primary growth factor exists such as heat units, water or essential nutrients. Of these growth factors, the control of an essential element such as nitrogen has proven to be the most effective.

In order to produce the highest possible yield of gross sugar per acre, nitrogen fertilizer is generally needed. However, if excess nitrogen is applied, it also increases the level of impurities, which decreases the processors extraction rate and lowers the percent sucrose in the root. It is generally agreed that in order to produce the highest possible sugar content only enough nitrogen fertilizer should be used so that a deficiency of nitrogen exists four to six weeks prior to harvest.

Presently two methods of predicting the proper rate of fertilizer nitrogen are available. The first is simply an estimate of the residual nitrogen level based on past cropping history. This method requires no soil sampling and thus holds the advantage of being easy to use. The main disadvantage is that it only provides a long-term estimate of residual nitrogen and, due to the dynamic nature of soil nitrogen, is probably not accurate more than 50 percent of the time. The second method is known as the nitrate-nitrogen soil test. It is obtained by taking 15 to 20 soil cores per field to a depth of two feet. This collection of soil can then be measured for residual nitrogen. This method has the advantage in prediction accuracy since it can measure the year to year variations in residual soil nitrogen.

Presently an on-going study is underway in west-central Minnesota working with the problem of predicting fertilizer nitrogen requirements for optimum yield and sugar content of sugarbeets. Specific objectives of this study are: a) to correlate residual soil nitrate levels to optimum fertilizer nitrogen rate, b) to determine the optimum sampling depth for correlation of the nitrate-nitrogen test to sugar yield, c) to demonstrate the relationship of soil nitrate-nitrogen levels and fertilizer nitrogen rates on sugar content and impurity index, and d) to observe the critical level of nitrate-nitrogen in sugarbeet petioles at various points in the growing season.

In addition to the nitrogen studies, work is also underway to determine the need for phosphorus and potassium fertilizers. Specific objectives of these studies are: a) to correlate and calibrate soil test phosphorus and potassium levels with the response of sugarbeets to phosphorus and potassium fertilizer and, b) to correlate tissue phosphorus and potassium concentration with soil test phosphorus and potassium levels.

NITROGEN INVESTIGATIONS

Methods and Materials: Four locations were selected in west-central Minnesota for nitrogen correlation-calibration studies in 1977. One experiment was established in Grant, Swift, Chippewa and Renville counties. The representative soils were Roliss loam in Grant, Tara silty clay loam in Chippewa, and Winger silty clay loam in Swift and Renville counties.

The experimental design consisted of nitrogen rates of 0, 50, 100, 150 and 200 pounds per acre arranged in a 5 x 5 Latin square design. Nitrogen treatments, applied as ammonium nitrate, were broadcast and incorporated in the soil in late October. In addition, phosphorus and potassium were broadcast according to soil test recommendations.

Fifty soil cores were taken to a depth of 5 feet at each of the four locations in late October, 1976. Increments of 0-6", 6-12", 12-24", 24-36", 36-48", and 48-60" were analyzed for nitrate-nitrogen. In addition, soil analyses were made on a composite sample of the 0-6" depth for available phosphorus, exchangeable potassium and zinc.

Young-mature petioles were sampled 5 times in 2-week intervals beginning on July 19 to monitor nitrate-nitrogen in the tissue. Emission spectrographic analyses were made to ascertain nutrient levels in the plant tissue.

All plots were hand-harvested the second week of October. Representative samples from each plot were transported to North Dakota State University where the sugarbeets were processed through the tare laboratory.

Results and Discussion: In contrast to 1976[1/], improved soil moisture and early season temperatures allowed for above average sugar yields at all experimental locations. In the 1977 trials, the use of nitrogen fertilizer increased yield at the Renville and Swift county locations (Tables 2 and 3), which had medium soil nitrate levels, and decreased sugar yield on the Chippewa and Grant county locations (Tables 4 and 5), which tested very high in soil nitrates. It is of interest to note that in all cases excess use of nitrogen fertilizer increased the amino nitrogen in the sugarbeet brei. Since amino nitrogen interferes with crystallization in processing, a drastic reduction in the percent recoverable sugar is created.

Nitrate concentrations in the young-mature petioles at various times in the growing season was strongly related to the soil nitrate level and the amount of nitrogen fertilizer used (Figure 1). It is of special interest to note the nitrate concentration in the petioles at the August 30 sampling, which is approximately 6 weeks prior to harvest. At this time, the Grant and Chippewa locations, which had very high soil nitrate levels, had petiole concentrations well in excess of the desired 1,000 ppm level.

[1/] See "1976 Sugarbeet Research and Extension Reports", pp. 190-199.

Table 1. Soil nitrate-nitrogen levels at the experimental locations in the fall of 1976.

Soil Depth	Soil Nitrate-Nitrogen Levels			
	Grant Co.	Swift Co.	Chippewa Co.	Renville Co.
inches	lbs. NO_3-N/A			
0-6	123	40	38	37
6-12	20	23	38	24
12-24	46	15	164	34
24-36	50	12	40	34
36-48	27	13	13	19
48-60	19	13	12	17
Past crop	wheat	wheat	sweet corn	soybeans

Table 2. Effect of various rates of nitrogen on sugarbeet root yield, percentage sugar, gross sugar per acre, amino nitrogen and percent recoverable sugar. Renville County, Minnesota - 1977.

Nitrogen Rate	Roots	Sugar	Gross Sugar	Amino Nitrogen	Recoverable Sugar
lbs/A	T/A	%	lbs/A	ppm	%
0	26.1	16.2	8418	451	90
50	27.4	15.8	8620	538	89
100	28.3	14.9	8442	663	87
150	29.9	14.6	8716	729	85
200	29.8	14.0	8352	881	83
Significance	**	**	ns	**	
BLSD (.05)	2.1	.7	-	127	

Soil Nitrate Test (0-2') - 95 lbs/A

Table 3. Effect of various rates of nitrogen on sugarbeet root yield, percentage sugar, gross sugar per acre, amino nitrogen and percent recoverable sugar. Swift County, Minnesota - 1977.

Nitrogen Rate	Roots	Sugar	Gross Sugar	Amino Nitrogen	Recoverable Sugar
lbs/A	T/A	%	lbs/A	ppm	%
0	19.0	17.3	6578	447	91
50	21.4	16.6	7136	512	90
100	21.7	16.5	7178	491	90
150	22.8	15.8	7188	681	88
200	23.5	15.6	7316	692	87
Significance	*	**	ns	**	
BLSD (.05)	3.0	.7	-	102	

Soil Nitrate Test (0-2') - 78 lbs/A

Table 4. Effect of various rates of nitrogen on sugarbeet root yield, percentage sugar, gross sugar per acre, amino nitrogen and percent recoverable sugar. Chippewa County, Minnesota - 1977.

Nitrogen Rate	Roots	Sugar	Gross Sugar	Amino Nitrogen	Recoverable Sugar
lbs/A	T/A	%	lbs/A	ppm	%
0	21.6	15.9	8182	763	87
50	21.0	16.1	8116	799	87
100	22.3	15.4	7766	912	85
150	20.6	15.2	7584	957	84
200	21.3	14.6	6688	986	83
Significance	ns	**	**	*	
BLSD (.05)	-	.7	702	142	

Soil Nitrate Test (0-2') - 240 lbs/A

Table 5. Effect of various rates of nitrogen on sugarbeet root yield, percentage sugar, gross sugar per acre, amino nitrogen and percent recoverable sugar. Grant County, Minnesota - 1977.

Nitrogen Rate	Roots	Sugar	Gross Sugar	Amino Nitrogen	Recoverable Sugar
lbs/A	T/A	%	lbs/A	ppm	%
0	20.3	14.3	5804	945	81
50	21.8	14.1	6118	960	81
100	20.7	13.7	5756	1046	79
150	22.0	13.9	5976	1050	78
200	21.3	14.1	6146	1127	77
Significance	ns	ns	ns	ns	
BLSD (.05)	-	-	-	-	

Soil Nitrate Test (0-2') - 189 lbs/A

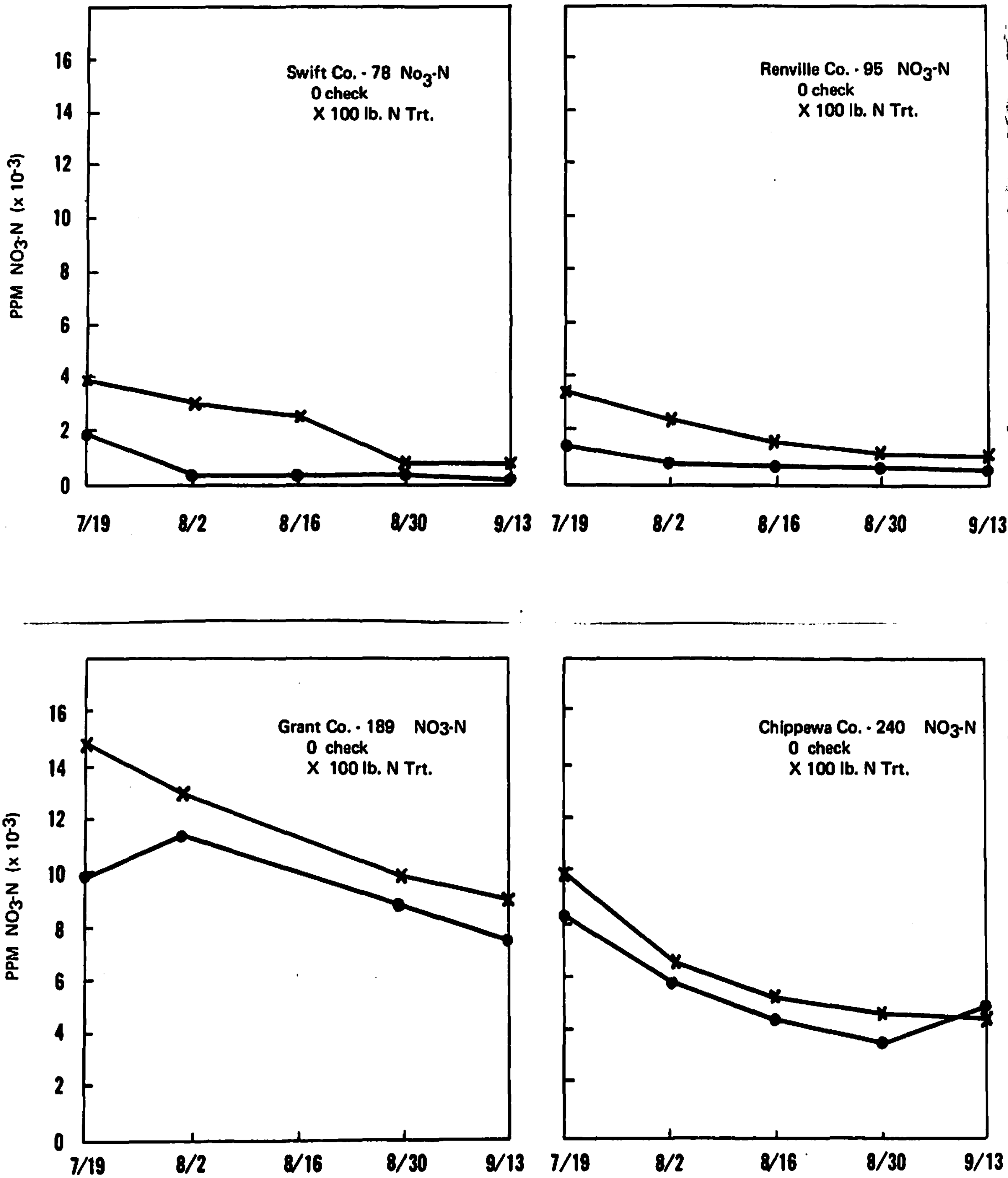

Figure 1. Effect of soil nitrates and fertilizer nitrogen on the NO_3-N concentration in sugarbeet petioles at various sampling dates and locations.

PHOSPHORUS AND POTASSIUM INVESTIGATIONS

Methods and Materials: One phosphorus and one potassium experiment was established on a Tara silty clay loam soil in Chippewa County.

Soil analyses indicated that phosphorus and potassium levels were medium and very high, respectively.

The experimental design consisted of potassium rates of 0, 100, 200, 300 and 400 pounds per acre and phosphorus rates of 0, 25, 50, 75 and 100 pounds per acre arranged in a 5 x 5 Latin square design. In addition, a starter-no starter split plot design was superimposed over the Latin square in the phosphorus experiment. Phosphorus and potassium treatments were broadcast in late October.

Young-mature petioles were sampled on August 16 to check the effect of fertilizer treatments on the concentration of phosphorus and potassium in the tissue.

All plots were hand-harvested the second week of October and representative samples from each plot were processed through the tare laboratory at North Dakota State University.

Results and Discussion: In the 1977 trials, no response to either broadcast phosphorus or potassium was noted (Tables 6 and 7). The lack of response to the addition of fertilizer potassium was predicted due to the very high soil test level, which is typical of most of the west-central Minnesota soils. However, in the case of fertilizer phosphorus, a response to 100 pounds P_2O_5 per acre was predicted based on Minnesota's present recommendations. Further calibration tests will be necessary in order to contemplate any adjustments in the present recommendation.

The percent P in the young-mature petioles was significantly influenced by broadcast phosphorus, but showed little response to the use of starter fertilizer (Table 6). In the potassium trial, the percent K in the petiole was increased over an already sufficient level in the check treatment (Table 7).

ACKNOWLEDGEMENTS

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Special recognition should also be given to Jerome Lensing, Tim Wager, Mike O'Leary and George Nelson in the Soil Science Department, University of Minnesota, for their untiring efforts and attention to the field phase of this project.

Table 6. Effect of various rates of phosphorus on petiole phosphorus level, root yield, percentage sugar, gross sugar yield, impurity index and percent recoverable sugar. Chippewa County, Minnesota - 1977.

Phosphorus Rate lbs/A	Petiole Phosphorus %	Roots T/A	Sugar %	Gross Sugar lbs/A	Impurity Index	Recoverable Sugar %
0	0.14	23.5	14.2	6670	1044	84
25	0.15	23.4	14.1	6570	1093	84
50	0.16	22.9	14.0	6416	1086	84
75	0.17	23.2	14.3	6614	1025	85
100	0.18	23.3	14.1	6580	1013	85
Significance	**	ns	ns	ns	ns	ns
BLSD (.05)	0.02	-	-	-	-	-
No Starter	0.15	23.5	14.3	6714	1029	85
Starter	0.16	23.0	14.0	6436	1076	84
Significance	ns	ns	*	ns	ns	ns
BLSD (.05)	-	-	0.29	-	-	-

Soil Test (available P) - 19 lbs/A

Table 7. Effect of various rates of potassium on petiole potassium level, root yield, percentage sugar, gross sugar yield, impurity index and percent recoverable sugar. Chippewa County, Minnesota - 1977.

Potassium Rate lbs/A	Petiole Potassium %	Roots T/A	Sugar %	Gross Sugar lbs/A	Impurity Index	Recoverable Sugar %
0	2.65	25.7	14.5	7464	1143	83
100	2.88	25.1	14.7	7354	1146	83
200	2.99	25.3	14.6	7396	1162	83
300	2.96	25.1	14.7	7378	1123	83
400	3.37	22.1	15.0	6662	1109	83
Significance	+	ns	ns	ns	ns	
BLSD (.05)	-	-	-	-	-	

Soil Test (exchangeable K) - 396 lbs/A

WILD RICE FERTILIZATION RESEARCH - 1977

A PROGRESS REPORT
January 6, 1978

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Research was continued during 1977 on fertilization, nutrient requirement and water quality. Soil, water and air temperatures, and quality of paddy water were monitored during growing season to obtain information on the environment in which wild rice grows. Nitrogen rate studies were conducted on mineral soil at Grand Rapids with two varieties in first production year, and with three varieties in second production year. Three fertilization experiments were established on peat with a third year stand in Aitkin county to study N, P, K rates and to explore effectiveness of foliar fertilization. Plant samples were collected and analyzed to learn more about nutrient requirement of the plant.

A. WEATHER AND PLANT DEVELOPMENT

The growing season of 1977 was unusual in that it started quite early and higher than normal temperature advanced plant development ahead of the usual pattern. At Grand Rapids, for example, the average air temperature (see table 1) was above normal in April (+8.3^o), May (+11.1^o), June (+2.0^o) and July (+1.8^o). Then in August cool weather (at Grand Rapids average air temperature -4.9^o below normal) slowed down plant development and, in some locations, affected filling of grain.

Soil, water and air temperatures were measured at three locations by 3-point automatic sensing and recording thermographs (see Fig. 1, 2, 3). Temperature measurements at the Grand Rapids and Aitkin county locations were discontinued in July because of instrument malfunction.

The air and water temperatures fluctuated much more than the soil temperatures. The mineral soil at Grand Rapids also showed greater temperature fluctuation than the two organic soils. The mean water temperatures were 2 to 10^{o}F above those of mean soil temperatures. The daily air and water temperatures fluctuated by as much as 30 or 40^{o}F.

In 1977, the peat soil in Aitkin county warmed up earlier than in 1976. Soil temperature on May 5 of 1977, for example, was 54^o compared to 42^{o}F on the same date in 1976. This earlier soil warm-up hastened germination and plant development. Plant development, generally, was 7 to 10 days ahead of 1976 up until early grain formation when cooler temperatures slowed it down. Wild rice in Aitkin county reached maturity in mid-August (Fig. 4).

At Grand Rapids, when compared with the normal (for a period 1931-60), all months from April through July in 1977 were warmer and consequently had a greater number of Growing-Degree-Days (see Fig. 5).

Table 1. Average air temperature as measured at three U.S. weather stations.[1)]

Station Year	April	May	June	July	August	5 Month Average	GDD T_b=40
	Month						
	average air temperature, °F						
Fosston, Polk Co.							
Normal[2)]	41.0	54.6	63.6	69.4	67.5	59.2	2955
1974	41.0	50.5	63.4	71.6	62.8	57.9	2744
1975	34.8	55.7	61.9	70.5	64.6	57.5	2852
1976	46.6	54.9	66.8	68.8	70.9	61.6	3315
1977	49.1	66.4	64.6	70.3	60.6	62.2	3446
Grand Rapids, N.C. School							
Normal	39.9	52.7	62.0	67.4	65.1	57.4	2681
1974	41.6	49.4	62.7	70.7	62.8	57.4	2670
1975	34.7	57.0	62.2	71.5	65.2	58.1	2951
1976	47.1	54.4	66.1	68.2	67.4	60.6	3166
1977	48.2	63.8	64.0	69.2	60.2	61.1	3284
Aitkin							
1974	42.9	49.8	63.1	71.1	63.3	58.0	2770
1975	39.0M	59.4M	64.4M	72.1	66.2M	60.2	3141
1976	47.5	54.8	66.8	69.3M	68.1	61.3	3267
1977	48.3M	64.4M	65.4M	70.3M	61.0	61.9	3446

1) Source: Climatological Data, Minnesota, Vol. 80, 81, 82, 83, (1974-77), U.S. Dept. of Commerce.

2) Normals for the period 1931-60.

3) M = less than 10 days record missing.

FIG. 1 GRAND RAPIDS - MEAN AIR, WATER, AND SOIL TEMPERATURES - 1977

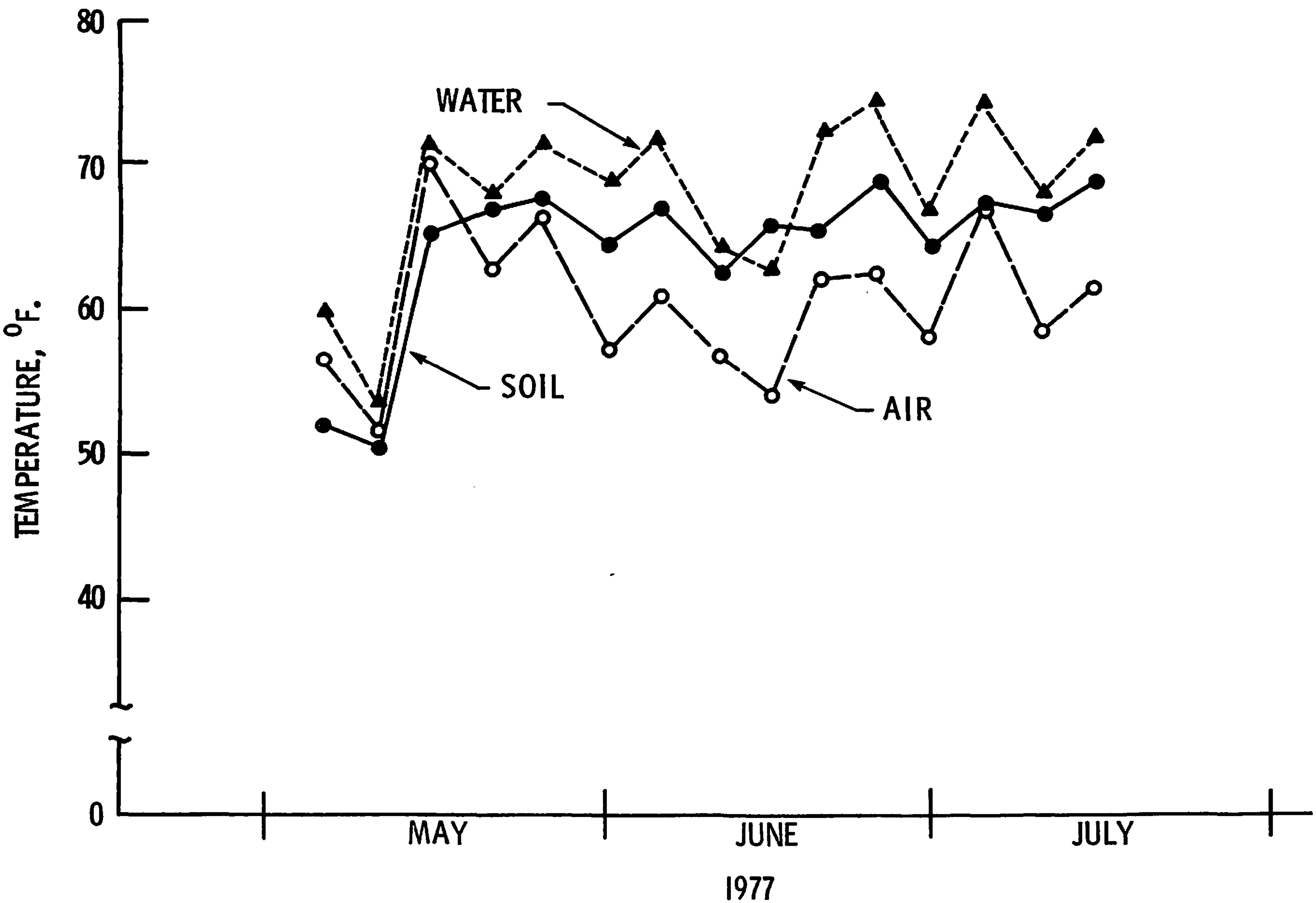


FIG. 2 KOSBAU BROS., AITKIN CO. - MEAN AIR, WATER, AND SOIL TEMPERATURES - 1977

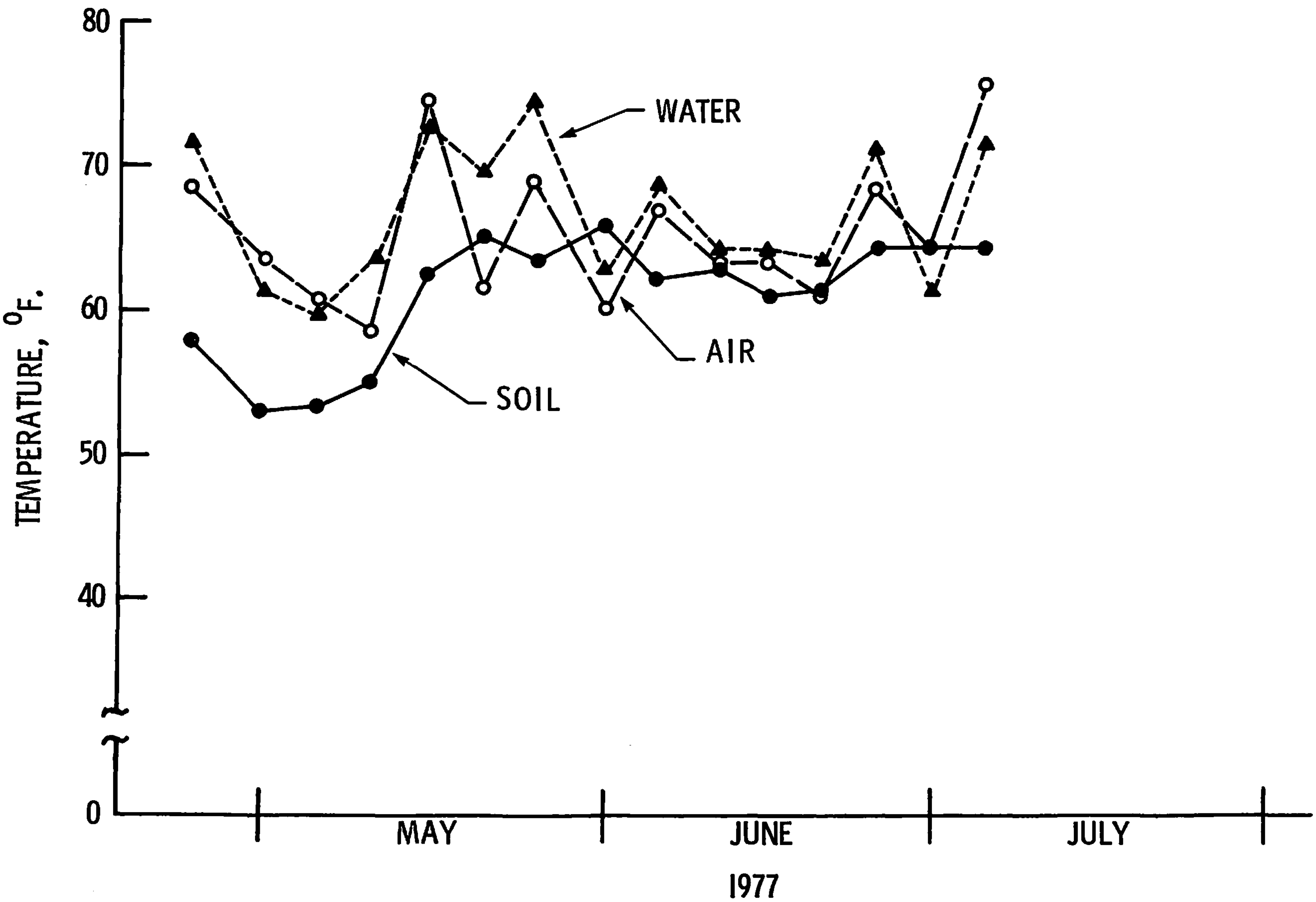
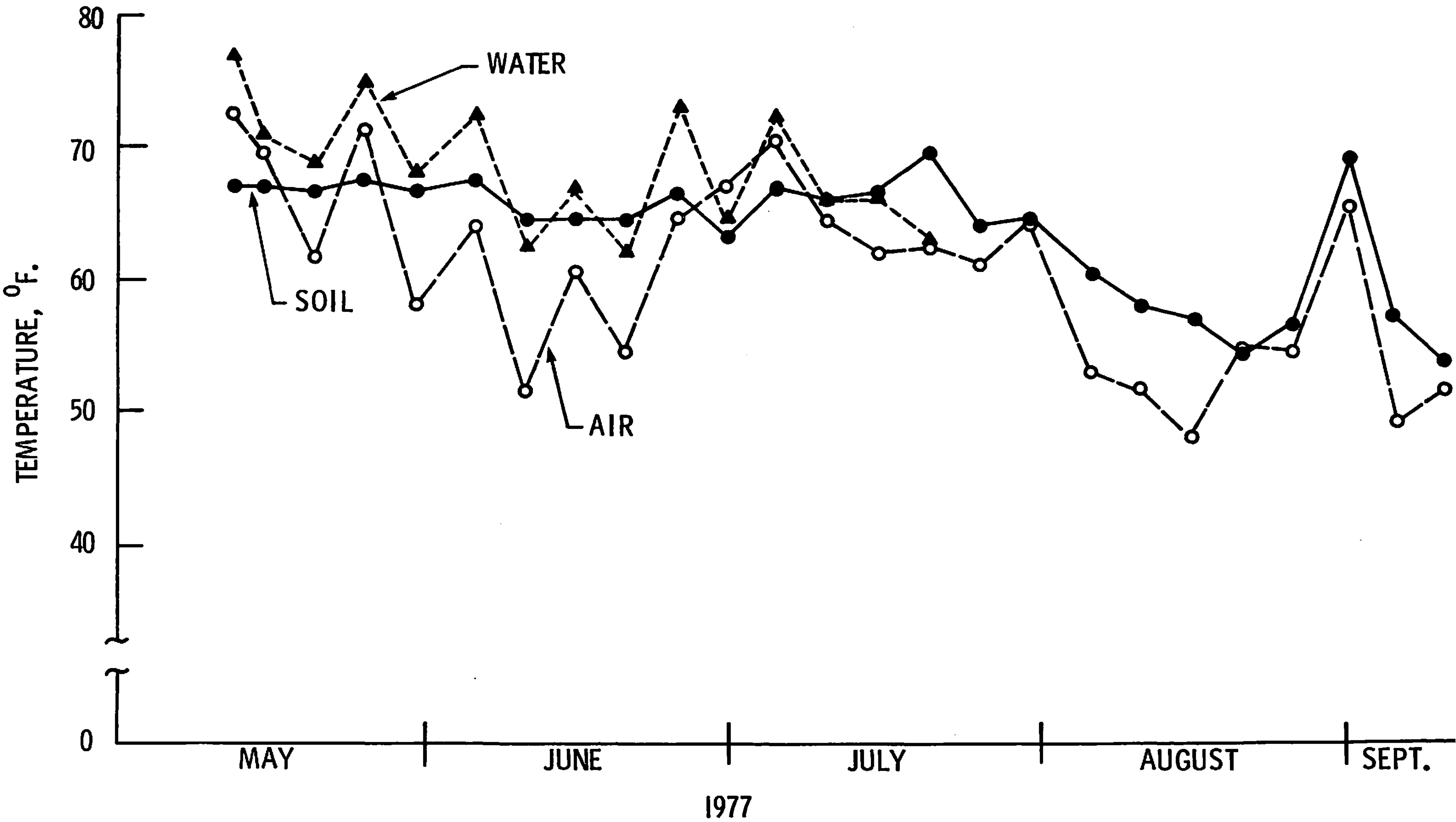


FIG. 3 IMLE AND GUNVALSON, GULLY, MINN. - MEAN AIR, WATER AND SOIL TEMPERATURES - 1977



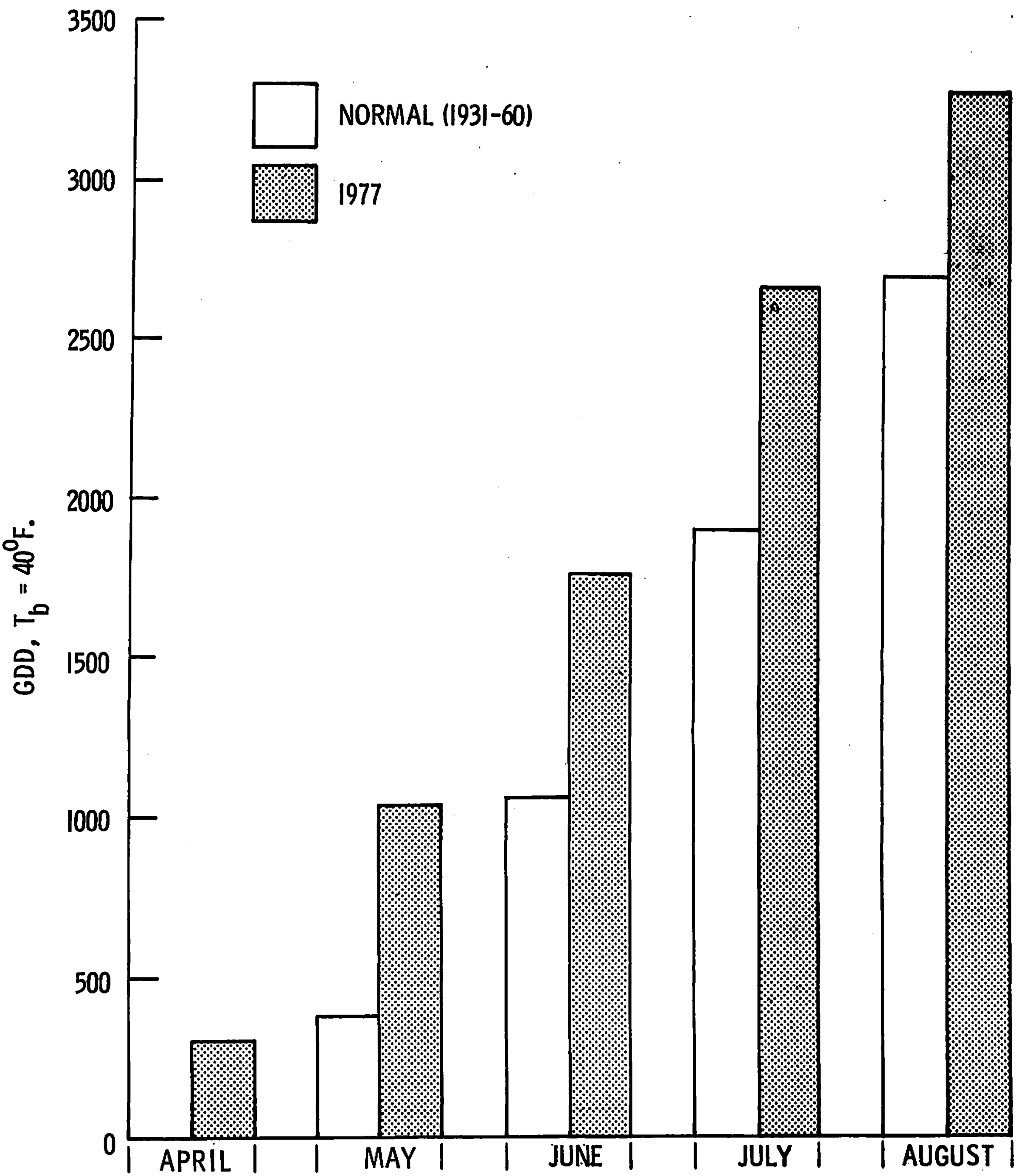
220

FIG. 4

WILD RICE DEVELOPMENT
K2 VARIETY, KOSBAU BROS., AITKIN CO. - 1977

	STAGES OF DEVELOPMENT	DAYS	DATE
VEGETATIVE GROWTH PHASE	0 EMERGENCE	0	APRIL
	1 FLOATING LEAF	18	MAY
	2 2ND AERIAL LEAF	31	
	3 EARLY TILLERING	42	JUNE
	4 MID TILLERING	49	
REPRODUCTIVE GROWTH PHASE	5 JOINTING	55	
	6 BOOT	62	
	7 EARLY FLOWERING	69	
	8 MID FLOWERING	79	JULY
	9 LATE FLOWERING	89	
	10 EARLY GRAIN FORMATION	99	
	11 MATURITY	118	AUGUST

FIG. 5 CUMULATIVE GROWING DEGREE DAYS, GRAND RAPIDS



B. CHEMICAL CHARACTERISTICS OF PADDY WATER

The quality of paddy water is of interest to the grower as well as to state and federal agencies. The grower may be concerned, for example, with the concentration of sulfate in the water. Plant response to fertilization may be related to nutrient levels found in the water. Public control agencies may want to know levels of nitrogen and phosphorus present in the water when it is released during draining of paddies.

Water samples were collected from several sites at three different paddy locations during 1977 growing season. At Grand Rapids, samples were collected from two experimental paddies used for N rate studies on a mineral soil. Source of water is the Prairie River. Water was also sampled at several sites within Kosbau Bros. paddies in Aitkin county. Paddies, at this location, derived water from the Little Willow River via a diversion ditch. One sampling site was located at the beginning of the diversion ditch, near the river, the other site was near a water intake pump at the far end of the diversion ditch. Four other sampling sites were located within two paddies, one a production paddy and the other paddy in which three fertilization trials were conducted. Water passed through two other production paddies before entering the research paddy. Wild rice was thinned on May 17 and it reached the jointing stage on June 14. The third sampling location was in the Gunvalson and Imle paddies near Gully. These paddies derived water from the Clearwater River.

Water samples were collected and stored in 250 ml polyethylene bottles to which a preservative had been added (2 ml of mercuric chloride solution, made up by dissolving 40 mg $HgCl_2$/L, to 250 ml of sample). Chemical analyses were made by the Research Analytical Laboratory, University of Minnesota. Information on location, sampling dates and the chemical composition of water are given in tables 2, 3, and 4.

The alkalinity of water is its capacity to neutralize acid. The results, in this report, indicate alkalinity obtained by titration with a combination of indicators having an endpoint of pH 5.0. In most natural waters, the alkalinity is practically all produced by dissolved carbonate and bicarbonate ions. Some organic acids also may contribute to titratable alkalinity. The values for alkalinity follow closely to those of hardness.

The hardness is calculated by multiplying calcium and magnesium concentrations by factors, adding up and is expressed as $CaCO_3$, mg/liter. Water from the Clearwater River is very hard (329 mg/L). The water from the Prairie River and the Little Willow River is moderately hard, with values of 118 and 101 mg/L, respectively. At Gully and at Grand Rapids, the values for alkalinity and hardness of paddy water were nearly the same as those found in the river water. In Aitkin county on peat, however, the paddy water showed 50% lower Ca and Mg contents than the river water, and a 3- to 7-fold decrease in alkalinity and hardness. Consequently, the Kosbau paddies had soft water with hardness values ranging from 28 to 46 mg/liter.

At Grand Rapids (table 2), concentrations of total N, P and K in paddy and river water were nearly the same, and remained relatively constant during the season. Total N concentration in the water ranged from 0.3 to 1.7 ppm, total P from 0.02 to 0.12 ppm, and K concentration did not exceed 2.3 ppm.

At Gully (table 4), the nutrient concentrations in the river and the paddy water were very similar. Total N and P contents were slightly higher than those measured at Grand Rapids. Potassium concentration of the water at Gully ranged from 1.6 to 8.8 ppm.

Paddy water at the Aitkin county location had considerably higher concentrations of total N, P and K than found in the river water (table 3). Total N concentration of paddy water ranged from 3.1 to 6.4 ppm compared to 0.8- 2.6 ppm found in samples collected from the diversion ditch.

Total P concentration in paddy water also was considerably higher than that of river water. Phosphorus levels were especially high at thinning time and towards the end of season. (Experimental Paddy thinned on 5/17, 7:30 AM; 3rd Production Paddy was thinned on 5/17, 8:00 PM). These increases probably resulted from agitation of water and soil during the thinning operation, and from water evaporation during the later part of growing season. Total P concentration of the water from diversion ditch ranged from less than 0.01 to 0.15 ppm while levels of 0.4 to 3.3 ppm were found in the paddy water. Potassium concentration of paddy water was nearly 7 times higher than that of river water and gradually decreased towards the end of growing season. Potassium levels of 20 ppm in the paddy water measured in mid-April, had decreased to 6- 10 ppm at the end of June.

The water in paddies at Grand Rapids and in Aitkin county did not contain appreciable amounts of sulfate. The sulfate concentration in the water at Gully, however, was relatively high, ranging from 85 to 342 ppm.

Table 2. Chemical composition of water collected from wild rice paddies during 1977 growing season. Location: Grand Rapids

Sample No.	Sampling Date	Location	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
6.	5/3	PR	139	118	0.4	< 0.1	< 0.01	0.08	0.08	11.7*	27.7	11.9	1.5
10.	5/13	EP #1			0.3			0.06					2.3
11.	5/13	EP #4			0.6			0.07					1.5
12.	5/13	PR			0.4			0.05					1.5
30.	5/19	EP #1			0.7			0.09					1.8
31.	5/19	EP #4			1.0			0.08					1.6
38.	6/1	EP #1			.7			.03					1.2
39.	6/1	EP #4			.7			.03					1.2
40.	6/1	PR			1.0			.01					2.0
46.	6/8	EP #1			.8			.06					1.5
47.	6/8	EP #4			.3			.02					1.5
48.	6/8	PR			.2			.01					1.6
58.	6/14	EP #1			.9			.02					1.2
59.	6/14	EP #4			.5			.01					1.5
60.	6/14	PR			.4			.02					1.4
69.	6/28	EP #1	76	82	1.7	0.16	< 0.01	0.12	0.05	2	22.2	6.5	1.6
68.	6/28	EP #4	90	88	0.7	0.13	< 0.01	0.09	0.04	< 2	23.5	7.0	1.3
67.	6/28	PR	93	99	0.8	0.07	0.01	0.04	0.01	< 2	27.6	7.2	1.4
75.	7/12	EP #1			1.2			< 0.01					1.7
76.	7/12	EP #4			0.9			< 0.01					1.3
74.	7/12	PR			0.6			< 0.01					1.1

* ppm sulfate - S x 3 = ppm sulfate (SO_4)

Abbreviations and description of sampling sites at Grand Rapids

- PR Prairie River
- EP #1 Experimental paddy No. 1, 2nd year stand
- EP #4 Experimental paddy No. 4, 1st year stand

Table 3. Chemical composition of water collected from wild rice paddies during 1977 growing season. Location: Kosbau Bros., Aitkin County

Sample No.	Sampling Date	Location	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
1.	4/12	DD	96	101	0.86	0.16	< 0.1	< 0.01	< 0.01	4.9*	26.6	8.3	2.5
2.	4/12	WI	97	106	1.33	0.22	< 0.1	< 0.01	< 0.01	4.9	27.8	8.9	2.4
3.	4/12	PP #3	10	28	5.66	1.08	0.4	1.72	1.10	5.4	6.6	2.8	17.9
4.	4/12	EP-D	26	44	3.87	0.75	< 0.1	0.41	0.23	1.9	11.0	4.1	18.6
5.	4/12	EP-1	27	46	4.02	0.74	< 0.1	0.42	0.19	2.6	11.5	4.2	20.3
7.	5/3	DD			1.80			0.04					2.0
8.	5/3	EP-D			3.40			0.57					14.7
9.	5/3	EP-1			4.20			0.61					14.7
16.	5/13	DD			4.60			0.04					1.3
17.	5/13	WI			4.60			0.09					1.4
18.	5/13	PP #3			5.3			2.14					15.4
19.	5/13	EP-D			3.9			0.78					14.9
20.	5/13	EP-1			4.2			0.82					17.2
21.	5/18	DD 5:30 PM			2.6			0.08					1.8
22.	5/18	WI 5:00 PM			1.7			0.15					1.4
23.	5/18	EP-1 4:00 PM			4.6			0.92					18.1
24.	5/18	EP-2 4:00 PM			4.9			0.94					18.9
25.	5/18	EP-D 4:30 PM			5.0			1.00					20.6
26.	5/18	PP #3 4:45 PM			5.0			2.91					17.5
27.	5/19	EP-1 5:00 PM			4.4			1.10					20.6
28.	5/19	EP-2 5:00 PM			4.9			1.02					20.6
29.	5/19	EP-D 5:15 PM			4.6			0.80					20.6
32.	5/24	EP-1			5.28			1.30					19.4
33.	5/24	EP-2			4.98			1.02					21.1
34.	5/24	EP-D			4.91			1.18					20.3
41.	6/1	EP-1			4.0			.92					19.3
42.	6/1	EP-D			3.9			1.26					17.2
43.	6/1	DD			2.4			.07					.5
44.	6/1	WI			1.7			.05					1.0
45.	6/1	PP #3			4.3			2.91					19.3
49.	6/8	EP-1			3.1			1.14					9.8
50.	6/8	EP-D			2.9			.95					9.2
51.	6/8	DD			1.1			.11					.4
52.	6/8	WI			1.3			.07					.3
53.	6/8	PP #3			2.6			2.00					8.4
54.	6/14	EP-1			3.4			1.32					15.2
55.	6/14	EP-2			3.5			1.41					17.2
56.	6/14	EP-D			3.3			1.15					9.2
57.	6/14	DD			0.9			0.02					0.1
61.	6/28	DD	358	112	1.5	0.16	0.03	0.01	0.02	< 2	29.3	9.5	0.1
62.	6/28	WI	114	120	1.2	0.16	< 0.01	0.08	0.03	< 2	31.7	9.9	0.2
63.	6/28	PP #3	15	32	6.4	3.65	< 0.01	2.77	2.34	< 2	7.7	3.2	6.0
64.	6/28	EP-D	23	44	4.1	0.70	< 0.01	1.55	1.19	< 2	10.3	4.5	9.2
65.	6/28	EP-1	15	41	9.3	2.80	0.01	3.30	2.32	< 2	9.7	4.1	10.5
66.	6/28	EP-2	20	38	12.5	4.32	0.01	12.10	3.56	< 2	9.4	3.6	19.3
72.	7/12	DD			1.06			< 0.01					0.1
73.	7/12	EP-D			9.16			1.40					12.8

* ppm sulfate - S x 3 = ppm sulfate, SO_4, (4.9 x 3 = 14.7 ppm sulfate).

Abbreviations and description of sampling sites at Kosbau Bros.

- DD Diversion Ditch at bridge near Little Willow River
- WI Water intake near new shed
- PP #3 Third production paddy from shed
- EP-D Ditch on east side of experimental paddy
- EP-1 Experimental paddy, sample 1
- EP-2 Experimental paddy, sample 2

Table 4. Chemical composition of water collected from wild rice paddies during 1977 growing season. Location: Gunvalson and Imle, Gully

Sample No.	Sampling Date	Location	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
13.	5/12	PP-T	203	495	2.5	0.11	< 0.1	0.06	< 0.01	114*	118.0	48.7	8.8
14.	5/12	PP-I	235	362	1.1	0.06	< 0.1	0.03	< 0.01	39.4	87.8	34.6	5.5
15.	5/12	CR	233	329	4.6	0.13	< 0.1	0.08	0.04	29.6	80.1	31.3	5.4
36.	5/31	PP-T			2.6			0.06					7.5
37.	5/31	PP-I			2.3			0.04					7.2
35.	5/31	CR			1.1			0.09					2.9
70.	6/29	PP-T	218	560	4.0	0.28	< 0.01	0.27	0.03	80.5	138.0	52.4	5.5
71.	6/29	PP-I	216	302	1.2	0.13	< 0.01	0.06	0.01	28.2	74.0	28.2	1.6

* ppm sulfate - S x 3 = ppm sulfate (SO_4)

Abbreviations and description of sampling sites at Gully

- CR Clearwater River
- PP-T Production paddy near thermograph
- PP-I Production paddy near inlet

Note: Heavy rain on 5/30

C. NITROGEN RATE AND VARIETY STUDIES ON MINERAL SOIL

Two experiments were conducted on a mineral soil at the North Central Experiment Station, Grand Rapids. Experiment 1 (First Year Stand) was established in spring of 1977 with two early maturing varieties: Experimental 1 and K2. Experiment 2 (second year stand) has been established in spring of 1976 with K2, M3 and Johnson wild rice varieties.

FIRST YEAR STAND[1)]

The experimental paddy was in fallow during 1976 and was fumigated with methyl bromide in fall of 1976. Four rates of nitrogen were used in this experiment: 0, 20, 40 and 80 pounds per acre. Urea (46-0-0) was applied with a 3-foot Gandy spreader on April 29 and incorporated into the soil by rototilling. Phosphorus and potassium were not applied because relatively high availability of these nutrient elements was indicated by soil tests (pH 5.6, P 64, K 220). Two early maturing varieties, Experimental 1 and K2, were grown. A split-plot design was used in this experiment with the N rates as main plots and varieties as subplots. Each plot, containing one N rate and both varieties, occupied a 14 x 16 ft. area. Each N treatment was replicated 5 times. The wild rice was planted in rows one foot apart on May 3. Plant population in this experiment was 2-3 plants per square foot. Water level was maintained at about 8-12 inches. Ten plants were selected at random from each plot at jointing stage (Exp. 1 on 6/20; K2 on 6/27), and five plants at late flowering (Exp. 1 on 7/21; K2 on 7/28) for weight measurements and plant analysis. Copper sulfate (15 pounds per acre) was applied to control algae. The plants were seriously damaged by hail on June 27 when Exp. 1 was in boot with some panicles emerging, and K2 was in the jointing stage. A 4 x 10 foot square area from each plot was hand-harvested for yield determination.

The K2 variety outyielded the Exp. 1 by 410 pounds per acre (table 5). It should be pointed out, however, that Exp. 1 was more advanced in development than K2 when the hail storm occurred and may have received more serious damage. Highest yield was produced with 40 pounds per acre of nitrogen. Generally, 20 pounds per acre of N have been sufficient during first production year. In this case, however, additional N may have been required for plant recovery from hail.

At jointing, individual plants of K2 had accumulated more dry matter than those of Exp. 1 (table 6). At the late flowering stage, the K2 variety had accumulated about 4 grams more dry matter per plant than the Exp. 1. The application of nitrogen resulted in greater production of dry matter.

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1) This experiment was conducted in cooperation with Dr. W. Anson Elliott, Department of Agronomy and Plant Genetics.

Table 5. Effect of nitrogen application on the yield of the two wild rice varieties, Grand Rapids, 1st year stand,1977

Variety	N Rate, LB/Acre 0	20	40	80	Average (variety)
	Grain Yield, LB/Acre				
K2	807[1)]	920	952	887	892
Exp. 1	416	492	551	470	482
Average (Rate)	612	706	752	679	

1) 7% moisture

(a) Variety — Grain yield, LB/Acre

Variety	Grain yield, LB/Acre
K2	892
Exp. 1	482
Significance	**
BLSD (0.05)	59

(b) N rate, LB/Acre

N rate, LB/Acre	
0	612
20	706
40	752
80	679
Significance	+
BLSD (0.1)	98

Table 6. Effect of nitrogen application on plant weight of two varieties at jointing and late flowering, Grand Rapids, 1st year stand, 1977

Development stage and variety	N Rate, LB/Acre 0	20	40	80	Average (variety)
	Dry matter, grams per plant				
(a) Jointing					
K2	4.42	4.27	4.51	3.98	4.30
Exp. 1	3.51	3.08	3.09	3.42	3.28
Average (Rate)	3.96	3.67	3.80	3.70	
Significance (variety)	**				
BLSD (.05)	0.55				
(b) Late Flowering					
K2	13.63	15.84	18.32	16.20	16.00
Exp. 1	11.25	11.36	11.58	13.38	11.89
Average (Rate)	12.44	13.60	14.95	14.74	
Significance (variety)	**				
BLSD (.05)	1.70				

Table 7. Effect of nitrogen application on N concentration in 2nd leaf at jointing, Grand Rapids, 1st year stand,1977

Variable		N % in dry matter
(a) N rate, LB/Acre		
0		4.13[1)]
20		4.21
40		4.34
80		4.80
Significance		NS
(b) Variety		
K2		4.14
Exp. 1		4.60
Significance		*
BLSD (.05)		0.34
(c) Interaction		
N Rate x	Variety	
0	K2	3.73
0	Exp. 1	4.53
20	K2	4.03
20	Exp. 1	4.39
40	K2	4.09
40	Exp. 1	4.59
80	K2	4.71
80	Exp. 1	4.89
Significance		NS
CV%		6

1) Average of 20 plants per variety.

SECOND YEAR STAND

The nitrogen-variety experiment, established in spring of 1976, was continued in 1977. Three wild rice varieties were grown: the early maturing K2 and M3, and the late maturing Johnson wild rice. Three N rates were used: 0, 40, 80 pounds per acre. To minimize cross-pollination, the Johnson wild rice was placed between the two earlier maturing varieties and each variety was grown in a 48 x 72 foot area separated by a 10 feet wide alley from the adjoining variety. Individual plots were 12 x 14 feet in size. Each N treatment was replicated five times. Straw was disked and rototilled into the soil. Urea was applied on April 29 and rototilled into the soil. The stand was not thinned and an excessive plant population resulted for the M3 variety (12 plants per square foot). Plant population for the K2 and Johnson varieties was only 5 plants per square foot. Phosphorus and potassium were not applied because of relatively high soil test levels (pH 5.6, P 64, K 240). Water level was maintained at about 8-12 inches. Ten plants were selected from each plot at jointing, and five plants at late flowering for weight measurements and plant analysis. Copper sulfate (15 pounds per acre) was applied to control algae. Pesticides were used to control disease and rice worm. At the jointing stage, plants were seriously damaged by hail which occurred on June 27. The plants, generally, were shorter than previous years at this location, probably due to hail damage and high temperatures.

Wild rice responded well to nitrogen treatments and exhibited height and color differences, particularly the K2 and Johnson varieties. Plants in N0 plots were shorter and lighter in color than those receiving either N40 or N80 treatments. The M3 lodged quite badly because of excessive plant density. There was moderate lodging in the N80 treatment plots of the Johnson and K2 varieties.

Grain yields of all three varieties, were about 50% below those of the previous year probably due to hail damage. Johnson wild rice out yielded K2 and M3 varieties due to later harvest date which resulted in more mature grain and better filled grain. Highest yield of K2 variety was obtained with 80 pounds per acre of N (table 8). Overall, 80 pounds of N per acre increased the grain yield by 100 pounds per acre over the N0 treatment.

Nitrogen concentration in second leaf at jointing was increased in all varieties by N applications (table 9). Total N uptake by the plants of K2 and Johnson varieties, at the late flowering stage, was increased by the N80 treatment (table 10).

Table 8. Effect of nitrogen application on the yield of three wild rice varieties, Grand Rapids, 2nd year stand, 1977

N Rate LB/Acre	Variety K2	M3	Johnson	Average (Rate)
	Grain Yield, LB/Acre			
0	290[1)]	331	311	311
40	295	344	475	371
80	386	377	473	412
Average (Variety)	324	351	420	
significance	+	NS	NS	
BLSD (0.10)	80			
CV%	19	16	29	

1) 7% moisture

Table 9. Effect of nitrogen application on N concentration in 2nd leaf at jointing, Grand Rapids, 2nd year stand, 1977

N Rate LB/Acre	Variety K2	M3	Johnson	Average (Rate)
	N% in dry matter			
0	3.60[1)]	2.77	3.28	3.22
40	4.13	3.32	4.06	3.84
80	4.51	3.66	4.30	4.16
Average (Variety)	4.08	3.25	3.88	
Significance	**	**	**	
BLSD (0.05)	0.39	0.47	0.48	
CV%	7	10	9	

1) Average of 50 plants

Table 10. Effect of nitrogen application on total uptake of N by the wild rice plant at late flowering, Grand Rapids, 2nd year stand, 1977

N Rate LB/Acre	Variety K2	M3	Johnson	Average (Rate)
	— N in milligrams per plant —			
0	69[1)]	71	78	73
40	84	103	117	102
80	102	115	163	127
Average (Variety)	85	96	120	

1) Average of 25 plants

	K2	M3	Johnson
Significance	+	NS	+
BLSD (0.10)	24		59
CV%	22	39	39

D. FERTILIZATION STUDIES ON PEAT

Three fertilizer experiments, carried out in a Kosbau Bros. paddy in Aitkin county during 1976, were continued in 1977. A third year stand of K2 was used. Fertilizer was applied to 12 x 12 foot plot areas in fall of 1976 and was incorporated into the soil by rototilling. The paddy was flooded on April 12. Rice was thinned once by airboat on May 17 when most plants were in floating leaf stage. Plant population at early tillering was 4-5 plants per square foot. Copper sulfate (20 pounds per acre) was applied on June 8 to control algae. Paddy was sprayed with chemicals to control blight and rice worm. There was no lodging and no damage was caused by rice worm or blackbirds, but there were some bare spots in some plot areas. A 4 x 4 foot area was hand-harvested from each plot for yield measurement on August 16. There was a general lack of response to fertilizer treatments at this location in 1977. Perhaps this was related to the relatively high concentrations of nutrient elements found in the paddy water (table 3). Total N ranged from 3.1 to 6.4 ppm, total P from 0.4 to 3.3 ppm, and potassium concentrations as high as 20 ppm were found in the paddy water early in the season.

Table 11. Depth of peat and soil test values of experimental areas, Kosbau Bros., Aitkin County[1)]

Area	Depth of peat inches	Soil test results for 0-6 inch depth		
		pH	extractable P pp2M	exchangeable K pp2M
NP Trial	18-21-11	4.4	15-18	100-115
NK Trial	8-11	4.6	29-40	93-137
Foliar - Fertilization	7-11-18	4.6	20	100

1) Samples collected on 10/7/76.

NP RATE TRIAL

The NP experiment was located in an area within the paddy where the peat layer was thickest, ranging from 18-21 inches on the north side and gradually decreasing to 11 inches on the south side. Water depth in this portion of paddy was greatest and grain yields were higher than in the other experimental areas. Three nitrogen rates were used: 0, 40, 80 pounds per acre, with urea as the N source. Concentrated superphosphate (0-46-0) was used to supply phosphorus, applied at three rates: 0, 40, 80 pounds P_2O_5 per acre. All plots received 60 pounds K_2O per acre. Fertilizer treatments were replicated six times.

Phosphorus concentration in second leaf at jointing ranged from 0.55-0.64%, and P uptake at late flowering ranged from 63-83 mg per plant. Neither of these two chemical characteristics within the plant were significantly affected by phosphorus treatments. Little or no visual differences in plants, related to either N or P treatments, were observed during the growing season.

Grain yièlds ranged from 589- 790 pounds per acre (table 12). Although the N40 and N80 treatments, combined with either the P0 or the P40 treatments, tended to be related with higher grain yield, the differences were not significant.

Table 12. Effect of nitrogen and phosphorus application on grain yield of wild rice, Kosbau Bros.,1977

P Rate	N Rate LB/Acre			Average
P_2O_5, LB/Acre	0	40	80	(P Rate)
	Grain yield, LB/Acre			
0	589[1)]	710	790	696
40	663	640	738	680
80	696	746	666	703
Average (N Rate)	649	699	731	

1) 7% moisture

Significance NS

NK RATE TRIAL

Exchangeable potassium in the experimental area ranged from 93-137 pp2m, considered to be relatively low to medium (table 11). Depth of peat ranged from 8-11 inches. Nitrogen treatments consisted of the following rates: 0, 40, 120 pounds per acre. Potassium was applied at rates of 0, 60 and 200 pounds K_2O per acre. Urea and muriate of potash were the fertilizer materials used in this experiment. All plots received 40 pounds P_2O_5 per acre. Fertilizer was applied by hand during fall of 1976 and incorporated into the soil by rototilling.

At jointing, no visual plant responses to fertilizer treatments were evident. The N concentration in second leaf at jointing, however, was significantly higher in plants from N120 treatment than in plants from N0 treatment (table 13). At the boot stage, there were typical color and height differences observed associated with N treatments. Plants in N0 treatment plots were shorter and lighter in color than those receiving N treatments. Nitrogen uptake at late flowering ranged from 117-189 mg per plant, but the differences were not significantly different. Response of wild rice to K treatments was not detected by visual observation. Potassium concentration in second leaf at jointing was relatively high and, generally, not affected by the application of K (table 14). Potassium uptake, at late flowering, ranged from 317 to 489 mg per plant. The yield of wild rice, in this experiment, ranged from 372 to 454 pounds per acre. Neither nitrogen nor potassium treatments had any effect on the yield (table 15).

Table 13. Effect of NK application on N concentration in 2nd leaf at jointing, Kosbau Bros., 1977

K Rate K_2O, LB/Acre	N Rate, LB/Acre 0	40	120	Average (K Rate)
	N% in dry matter			
0	4.14[1)]	4.76	4.54	4.48
60	4.07	3.86	4.39	4.11
200	4.17	4.34	4.67	4.39
Average (N Rate)	4.13	4.32	4.53	

1) Average of 30 plants

Significance +

BLSD (0.10) 0.44

Table 14. Effect of NK application on K concentration in 2nd leaf at jointing, Kosbau Bros., 1977

K Rate K_2O, LB/Acre	N Rate, LB/Acre 0	40	120	Average (K Rate)
	K% in dry matter			
0	3.48[1)]	3.26	3.41	3.38
60	3.54	3.67	3.58	3.60
200	3.52	3.48	3.47	3.49
Average (N Rate)	3.51	3.47	3.49	

1) Average of 30 plants

Significance +

BLSD (0.10) 0.24

Table 15. Effect of nitrogen and potassium application on grain yield of wild rice, Kosbau Bros., 1977

K Rate K_2O, LB/Acre	N Rate, LB/Acre 0	40	120	Average
	Grain yield, LB/Acre			
0	438[1)]	438	454	443
60	398	402	381	394
200	372	448	448	423
Average	403	429	428	

1) 7% moisture

Significance NS

FOLIAR FERTILIZATION TRIAL

The foliar fertilization experiment, established in 1976, was continued in 1977. It was expanded to six replications per treatment. Soil application of fertilizer (40+40+60) was made during fall of 1976 and incorporated into the soil. The same production practices were followed as used in NK and NP trials. Fertilizer solution was sprayed on 12 x 12 foot plot areas with a backpack sprayer at a rate of 330 ml per plot (equivalent to 26.4 gallons per acre or 250 pounds per acre rate). Spraying pressure was maintained at 30 psi by using a carbon dioxide cylinder. The formulation, fertilizer materials used and costs were discussed, in detail, in the 1976 Wild Rice Research Progress Report. In 1977, foliar fertilizer applications were made on the following dates:

1st spraying, 6/21 -- at boot stage,
2nd spraying, 7/8 -- mid-flowering,
3rd spraying, 7/22 -- early grain formation.

No "leaf burn" damage was observed in this trial during 1977.

Although the total amounts of N, P and K contained by wild rice at late flowering were higher in plants receiving two or three sprayings than those with no foliar application, the differences were not significant. Wild rice yield was increased slightly by foliar fertilization (table 16). The most effective treatment consisted of soil application (40+40+60), and two foliar applications (30+12+18+2.6 S) made at mid-flowering and early grain formation.

Foliar fertilization of wild rice is not a recommended practice at the present time. With the varieties and production know-how that are available today, nutrient requirements of the plant can be satisfied effectively and more economically by conventional soil applications of NPK and N topdressing. But there is a potential that should be explored by continued investigation of this new practice. First, the positive trends in wild rice yield obtained in the 1976 and 1977 trials look promising. Secondly, growers already are applying pesticides and topdress-N by airplane or helicopter. So there is a possibility of combining these operations, thus, making foliar fertilization more economical than it is today.

ACKNOWLEDGMENTS

Grateful acknowledgments are made to following cooperators and University personnel for their valuable assistance during 1977 in obtaining information reported here: Messrs. Franklin and Harold Kosbau, Aitkin county; Messrs. Paul Imle and John Gunvalson, East Polk county; Dr. Wm. Matalamaki and the Staff, North Central Experiment Station, Grand Rapids; Drs. W. Anson Elliott and E. A. Oelke, Messrs. Daniel Kirick, Henry Schumer, Gary Linkert, Mark Weinberger and Loren Nickelson, University of Minnesota.

Table 16. Effect of foliar and soil application of fertilizer on grain yield of wild rice, Kosbau Bros., 1977

Foliar Application	Total Plant Nutrients Applied, LB/Acre				Soil Application		
Number	N	P_2O_5	K_2O	S	None	40+40+60	Average (Foliar)
					Grain yield, LB/Acre		
None	None				530[1)]	560	545
1 x	15 +	6 +	9 +	1.3	-	548	548
2 x	30 +	12 +	18 +	2.6	-	628	628
3 x	45 +	18 +	27 +	3.9	556	495	526
Average (soil)					543	558	

1) 7% moisture;

Significance NS

COMPARISON OF PROMESOL 30 AND CALCIUM CARBONATE

C. J. Overdahl

County Extension Directors and farmers frequently ask about the performance of Promesol 30 as a liming material. This is a liquid product composed primarily of trihydroxy glutaric acid with approximately 9 percent calcium and 7 percent nitrogen.

To observe what effect the product has on soil pH, an experiment was initiated comparing Promesol 30 to analytical grade calcium carbonate on two Minnesota soils. The pH of the Promesol 30 used in this trial was 8.0.

Soils were a Hubbard loamy sand from the Becker Irrigation Farm and a LeSueur silty clay loam from the Waseca Experiment Station. After treatment, soils were stored with moisture held at field capacity for six weeks in small pots. They were then air dried and the pH was determined. The results are shown in tables 1 and 2.

Results

The tables show pH values from each of four replications on two acid soils. The calcium carbonate powder changed the soil pH in direct relationship to the treatment rate. For an approximate comparison between analytical grade calcium carbonate and agricultural lime, which is coarser, the rates of calcium carbonate shown in the tables should be doubled, a half ton analytical grade equals about one ton of ag lime.

The Promesol 30 had no effect on soil pH, even at 127 gallons per acre. This was a theoretical value needed to equal one ton of lime.

These results are the same as was obtained by Dr. T. R. Peck at the University of Illinois and Dr. Roy Flannery at Rutgers University.

These latter two researchers also related the product to crop yield and some experiments measured the effect on cation exchange capacity and calcium content.

Table 1. Promesol 30 effect on soil pH compared to calcium carbonate analytical grade.

LeSueur silty clay loam from Waseca, MN.

Reps	Calcium Carbonate tons/acre							
	0	1/2	1½	3	4½	6	12	24
	soil pH							
1	5.1	5.3	5.7	6.3	6.9	6.8	7.3	7.4
2	5.2	5.5	5.8	6.3	6.7	6.9	7.0	-
3	5.2	5.4	5.7	6.3	6.2	6.9	7.1	-
4	5.2	5.4	5.6	6.3	6.6	6.9	7.1	-
	Promesol 30 gallons/acre							
	0	2½	5	7½	10	20	40	127
	soil pH							
1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.0
2	5.2	5.0	5.1	5.1	5.0	5.1	5.1	5.0
3	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1
4	5.2	5.1	5.1	5.2	5.2	5.2	5.2	5.2

Table 2. Promesol 30 effect on soil pH compared to calcium carbonate analytical grade.

Hubbard loamy sand from Becker Irrigation Farm.

Reps	Calcium Carbonate tons/acre							
	0	1/2	1½	3	4½	6	12	24
	soil pH							
1	5.3	5.7	6.4	7.0	7.2	6.9	7.4	7.7
2	5.4	5.8	6.5	7.0	7.2	7.5	7.5	-
3	5.4	5.8	6.5	6.9	7.2	7.4	7.5	-
4	5.5	5.9	6.3	6.9	7.2	7.4	7.6	-
	Promesol 30 gallons/acre							
	0	2½	5	7½	10	20	40	127
	soil pH							
1	5.3	5.4	5.2	5.3	5.2	5.3	5.2	5.2
2	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2
3	5.4	5.3	5.2	5.2	5.2	5.3	5.3	5.2
4	5.5	5.3	5.2	5.3	5.2	5.4	5.2	5.0

Field Experiments with Gypsum

Crop Yields
1977

G.R. Blake and Jerome Lensing

Gypsum	Corn Dodge	Steele	Goodhue	Blue Earth	Soybeans Dodge
T/A		Bu/A			Bu/A
0	127.1	91.1	143.4	144.5	28.9
1	114.9	93.2	136.0	165.9	30.7
4	117.5	97.5	140.7	152.1	29.2
Signif.	*	NS	NS	NS	NS
L.S.D. 0.05	8.8				

Modulus of Rupture
Fayette Silt Loam
1976

G.R. Blake

The following data result from three separate methods of soil packing. Gypsum was thoroughly mixed with the soil, previous to preparing briquets at the rates indicated.

In one method the soil was dried and put into frames in a loose condition. Briquets were saturated in a tray by capillarity for one hour. They were then placed in an oven at 50^{O}D overnight and dessicated for one hour.

In each of the remaining methods the soil was moistened and packed into frames at 25 and 100 psi saturated by capillarity for one hour, dried in an oven at 50^{O}D overnight and dessicated one hour.

Soil Condition	Loose Soil	Packed, 25 p.s.i.		Packed, 100 p.s.i.		
Gypsum, T/A	1	0	1	0	1	10
	0.119	1.668	1.167	2.468	1.309	2.065
	0.082	1.399	1.221	2.456	1.432	1.777
	0.193	1.396	1.043	2.527	1.681	1.951
	0.216	1.504	1.108	2.513	1.468	1.814
	0.196		1.264	2.412	1.546	
				2.708		
Sums	0.806	5.967	5.803	15.085	7.436	7.607
Means	0.161	1.492	1.161	2.514	1.487	1.902

In another experiment Fayette silt loam in a plastic condition was worked with a spatula to destroy all aggregates and was then put into molds and dried. Mean moduli of rupture for 29 samples without and 37 samples with 16 T/A gypsum were 33.43 and 33.44 respectively (Data Book 51:19).

Modulus of Rupture*

Fayette Silt Loam
Gypsum Rate, T/A
1976

	Modulus of Rupture at Gypsum Rates Shown			
	0	2	8	16
	1.166	1.318	1.230	1.201
	0.985	1.519	1.111	1.060
	0.987	1.450	1.307	1.284
	1.196	1.446	1.222	1.336
	1.188	1.351	0.947	1.291
	1.313	1.454	0.930	1.313
	1.233	1.396	0.840	1.199
	0.645	0.892	1.345	0.732
	0.596	0.907	1.599	0.917
	0.781	0.885	1.242	0.794
	0.722	0.951	1.424	1.054
	1.283	1.262	1.125	0.932
	1.136	1.167	1.100	0.841
	0.982	1.016	1.035	1.014
	1.110	1.062	1.106	1.106
	1.017	1.251	1.077	1.125
	0.951	1.304		1.108
	1.103	1.212		0.973
	0.861	1.251		1.026
	0.960	1.050		0.628
	0.754	1.260		1.014
	0.835			
Totals	21.804	25.404	18.640	21.948
Means	0.991	1.210	1.165	1.045

*Soil placed in molds in loose condition. See data book 51:11

Plant Tissue Analysis
ICP Optical Emission Spectroscopy

Robert C. Munter and Robert A. Grande
Research Analytical Laboratory
Department of Soil Science

Plant tissue and grain samples submitted to the Research Analytical Laboratory in 1977 were analyzed by either of two emission spectrometers. In September 1977 the Jarrell-Ash 1.5 meter solution-rotating disk optical emission spectrometer (SRD-OES) was replaced by a radio frequency inductively coupled argon plasma optical emission spectrometer (ICP-OES). Both instruments were used on plant material throughout the summer of 1977. The Jarrell-Ash spectrometer was put into service in 1966 by Gordon Pryor under the direction of Dr. Larry Smith, Department of Agronomy, and an interdepartmental committee which included Dr. Dick Rust of our department. In 1972 the administration of the spectrometer was transferred to Soil Science and integrated into this laboratory. Table 1 shows a summary of sample volume that was handled by the Jarrell-Ash spectrometer during its period of use.

In November 1976 we initiated a request through our department to Director Keith Huston of the Agricultural Experiment Station to purchase an ICP spectrometer, because the older unit was becoming out-dated, and the greater sensitivity of the ICP would provide the additional capability of multielement analysis on a wide variety of material including soil extracts and water. An ICP spectrometer was purchased from Applied Research Laboratories of Sunland, California, with $70,000 funding from the Experiment Station. The spectrometer was installed in early 1977, and we spent the next several months quantifying spectral line interference, establishing technique, and analyzing customer soil extracts. On July 1, 1977 we began to accept plant tissue samples for ICP analysis. The responsibility for the operation of the ICP was given to Robert Grande.

The new spectrometer is giving us more reliable results than the older one, but since the change from one to another of different design occurred in the midst of some research projects, data comparability has been of concern. The data is generally comparable. The agreement on the NBS orchard leaves SRM is very good with the exception of Fe and Al. The differences for Fe and Al appear to be largely due to the different approach taken in calibration. The older spectrometer was initially calibrated against plant material supplied by Dr. A.L. Kenworthy of Michigan State and later included the reference material supplied by Dr. J.B. Jones of Ohio State (material in Table 5). In 1971 the NBS Orchard SRM 1571 was added to the calibration set. The new ICP spectrometer is calibrated against "pure" chemical standard solutions obtained commercially because the ICP has fewer interferences and is capable of handling a wider variety of materials. If any element in the plant material ash is not completely released by 2N HCl, low recovery will result. This appears to be the situation with our ICP analysis for Fe and Al which shows recoveries of between 50-90% for the four currently available National Bureau of Standards botanical reference materials. These results are not unlike those reported by other laboratories. Higher recoveries of Fe and Al can be obtained by ashing at higher temperatures or by wet acid digestion of the sample or ash but loss of certain other elements will occur.

Table 1 Departments serviced and numbers of samples analyzed on the Jarrell-Ash 1.5 meter direct reading emission spectrometer by G.R. Pryor

Instrument in service 1966 to September 1977

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977*
Soil Science	2,230	Not catagorized	6,947	5,273	5,196	7,163	4,129	4,601	3,593	6,416	5,796	8,809
Agronomy	9,269		10,143	7,431	7,947	3,130	348	617	1,096	1,016	1,395	970
Interdepartmental	(under Soil Science up to 1972)						1,200	1,245	1,985	1,273	2,329	1,020
College of Forestry	1,100		1,989	422	-	551	2,723	2,101	2,150	628	1,393	1,169
Animal Science	140		405	413	3,123	542	218	1,440	977	731	245	606
Horticulture	100		353	962	212	539	632	723	164	962	2,049	722
Ag Engr.	-		-	-	-	608	665	244	303	144	-	-
ARS	-		-	-	-	-	-	2,402	1,609	2,194	1,716	1,070
U.S. Forest Service (NCFES)			-	-	-	-	110	1,365	2,591	545	463	2,100
Entomology	-		-	-	-	465	3,082	-	-	-	-	-
N.D. State U.	-		-	-	-	-	-	-	-	-	1,905	-
Other:	1,119		387	136	579	165	573	208	220	597	560	491
Food Science, Plant Pathology, Botany, Zoology, Department of Natural Resources, Medicine, Veterinary Medicine, Archeology, Geology, Limnology, Agricultural Engineering, Fisheries and Wildlife												
Yearly Totals	13,958	13,349	20,224	15,183	16,830	13,163	13,726	14,907	14,984	14,506	17,782	19,581

Total samples analyzed by emission spectroscopy during twelve year period-----188,193

Total samples analyzed on Jarrell-Ash spectrometer from January 1, 1966 to September, 1977-----179,964
(Instrument permanently shut down September, 1977. Replaced by ARL ICP spectrometer)

Total elemental determinations (12 elements per sample)-----2,159,568

Average labor, supplies and maintenance costs per sample-----$1.20
(Instrument operation costs only; does not include sample preparation)

Average labor, supplies and maintenance costs per element-----$ .10

Average depreciation of capital investment per sample-----$ .24

Average depreciation of capital investment per element-----$ .02

*includes 8,229 samples analyzed on the new ICP emission spectrometer

Following is a series of tables listing the results we obtained on the ICP spectrometer for a variety of plant tissue materials that have been analyzed by other refereed methods.

Table 2 gives the values obtained by ICP-OES analysis in this laboratory for the NBS tomato, spinach, pine, orchard leaves, and bovine liver standard reference materials. The low values obtained for Na on the orchard leaves are the same as those we obtain by atomic absorption.

Table 3 shows the long term precision for 21 NBS orchard leaves samples analyzed over a 10 week period. Two different dilutions (5 and 10x) of ash from 36 samples of NBS reference material were submitted as unknowns by Dr. Robert Dowdy and reported as short term since they were analyzed over a 2½ hour period. Data reported by ICP-OES analysis at Georgia and an AOAC spark emission study are shown for comparison. Short and long term precision as shown in this table includes any subsampling and sample preparation error. An example of instrumental error is shown in Table 4 where the high concentration calibration standard was analyzed 12 times as an unknown over a 3 hour period during the analysis of 41 plant tissue samples. Normalization and recalibration of the calibration curve took place during this run as shown.

Table 5 gives the values obtained by ICP-OES analysis in this laboratory for alfalfa, tomato, and wheat samples that were obtained from Ohio State in 1967.

Table 6 gives the value obtained by ICP-OES analysis in this laboratory for 12 plant tissue samples obtained from the Inter-Institute Committee (CII) Bondy, France. The assigned means are those obtained by a CII referee study which included several laboratories employing atomic absorption spectroscopy and other methods.

Table 7 lists the elements that have spectral interferences, the interfering element, and the quantitative amount of interference.

Table 8 compares the detection limits measured by the ICP spectrometer to the atomic absorption spectrometer limits expressed in commercial literature. Also listed are the more realistic lower limits expressed as LQD for the ICP spectrometer and Sensitivity and LOCR for atomic absorption spectrometry.

Summary

No conclusions are drawn from the raw data shown in the tables. All analyses were treated as customer unknowns so they would realistically represent our work. The areas of discrepancy will be explored to separate analytical differences from preparation method differences.

All concentrations reported in ppm unless shown otherwise.

Table 2 ICP-OES determinations on NBS botanical standard reference material[a]

	Tomato Leaves (SRM 1573)		Spinach Leaves (SRM 1570)		Pine Needles (SRM 1575)		Orchard Leaves (SRM 1571)		Bovine Liver (SRM 1577)	
element	assigned NBS value	found n=2 mean	assigned NBS value	found n=2 mean	assigned NBS value	found n=2 mean	assigned NBS value	found n=2 mean	assigned NBS value	found n=2 mean
P %	0.34 ± 0.02	0.32	0.55 ± 0.02	0.51	0.12 ± 0.02	0.117	0.21 ± 0.01	0.192	-	0.985
K %	4.46 ± 0.03	4.47	3.56 ± 0.03	3.58	0.37 ± 0.02	0.381	1.47 ± 0.03	1.51	0.97 ± 0.06	0.966
Ca %	3.00 ± 0.03	3.05	1.35 ± 0.03	1.40	0.41 ± 0.02	0.440	2.09 ± 0.03	2.10	(0.012)*	0.012
Mg %	(0.07)	0.691	-	0.916	-	0.123	0.62 ± 0.02	0.620	(0.060)	0.057
Al	(1,200)	356	870 ± 50	452	545 ± 30	488	-	132[b]	-	6.03
Fe	690 ± 25	438	550 ± 20	490	200 ± 10	124	300 ± 20	200	270 ± 20	230
Na	-	338	-	13,909	-	15.8	82 ± 6	34.2	2,430 ± 130	2,174
Mn	238 ± 7	218	165 ± 6	168	675 ± 15	705	91 ± 4	90.2	10.3 ± 1.0	8.31
Zn	62 ± 6	65.8	50 ± 2	54.2	-	77.0	25 ± 3	30.2	130. ± 10	138
Cu	11 ± 1	9.6	12 ± 2	11.6	3.0 ± 0.3	3.1	12 ± 1	13.5	193 ± 10	76
B	(30)	37.0	(30)	28.0	-	18.0	33 ± 3	33.5	-	1.0
Pb	6.3 ± 0.3	8.0	1.2 ± 0.2	3.0	10.8 ± 0.5	13.5	45 ± 3	50.0	0.34 ± 0.08	1.2
Ni	-	1.0	(6)	5.4	(3.5)	2.6	1.3 ± 0.2	1.2	-	0.09
Cr	4.5 ± 0.5	1.6	4.6 ± 0.3	2.2	2.6 ± 0.2	1.85	2.6 ± 0.3	1.2	-	0.44
Cd	(3)	2.6	(1.5)	1.5	(<0.5)	0.28	0.11 ± 0.01	0.15	0.27 ± 0.04	0.23
Co	(0.6)	0.58[b]	(1.5)	2.0	(0.1)	0.94	(0.2)	0.22[b]	(0.18)	1.6

[a]1.0 gm oven dried (85°C) and dry ashed at 485°C for 10 hrs. Ash dissolved in 10 ml 2N HCl. The bovine liver was treated the same except that it was stored in a desicator rather than oven dried. The ash from the liver was a consolidated mass of char.
[b]n=2 has greater than 10% difference.
*Brackets indicate not certified

Table 3

Short and Long Term Precision Study and
Comparative Results in the Analysis of NBS Orchard Leaves Reference Material by Plasma Emission at Minnesota
in Reference to Plasma Emission Values from Georgia and Spark Emission Values from an AOAC Collaborative Study

Concentration Means	Dilution used	P %	K %	Ca %	Mg %	Al ppm	Fe ppm	Na ppm	Mn ppm
Assigned Mean by NBS		.21	1.47	2.09	.62	-	300	82	91
Assigned Range by NBS		.20-.22	1.44-1.5	2.06-2.12	.60-.64	-	280-320	76-88	87-95
[1]ICP - Long Term U of M	10x	.194	1.53	2.15	.640	126	193	44	93
[2]ICP - Short Term U of M	5x	.192	1.49	2.09	.625	122	176	50	88
[2]ICP - Short Term U of M	10x	.195	1.55	2.26	.666	131	191	52	96
[3]ICP - Georgia	20x	.22	1.60	1.99	.62	234	183	140	101
[4]Spark - AOAC	5-10x	.19	1.38	1.97	.63	215	241	206	94
Standard Deviation									
ICP - Long Term	10x	.007	.056	.070	.023	14	22	2	5
ICP - Short Term	5x	.004	.032	.029	.020	7	6	2	2
ICP - Short Term	10x	.007	.041	.041	.011	7	7	2	2
ICP - Georgia	20x	.005	.07	.07	.02	79	12	50	2
Spark - AOAC	5-10x	.03	.17	.20	.04	49	62	183	27
Relative Standard Deviation (%C.V.)									
ICP - Long Term	10x	3.5	3.6	5.6	3.6	11	11	4	5
ICP - Short Term	5x	2.1	2.2	1.4	1.9	5	3	3	2
ICP - Short Term	10x	3.7	2.6	1.8	1.7	5	4	4	2
ICP - Georgia	20x	2.2	4.4	3.5	2.2	34	7	36	2
Spark - AOAC	5-10x	16.8	12.4	10.3	5.9	23	26	89	28
Spectra Interferences, Computer Corrected for "Long and Short Term" Data Above									
Interfering Elements		Cu	-	-	Ca	Ca	Mn/Cu/Al	-	Fe
Concentration Error (ppm) (in above ICP Long Term Means)		<10	0	0	<5	47-86	<0.2	0	0.56

Continued Next Page

Table 3 Continued

Concentration Means	Dilution used	Zn ppm	Cu ppm	B ppm	Pb ppm	Ni ppm	Cr ppm	Cd ppm	Co ppm
Assigned Means by NBS		25	12	33	45	1.3	(2.3)	0.11	(0.2)
Assigned Range by NBS		22-28	11-13	30-36	42-48	1.1-1.5	-	0.9-.13	-
[1]ICP - Long Term U of M	10x	28.3	12.7	33.8	51.7	1.66	1.3	0.32	0.00-3
[2]ICP - Short Term U of M	5x	26.9	11.5	33.2	44.7	1.54	1.6	0.24	-
[2]ICP - Short Term U of M	10x	29.2	11.8	35.0	47.7	1.60	1.8	0.25	-
[3]ICP - Georgia	20x	28	17	41	48	-	2.9	0.41	0.2
[4]Spark - AOAC	5-10x	28	15	32	-	-	-	-	-
Standard Deviation									
ICP - Long Term	10x	1.4	0.4	0.7	2.5	0.23	0.18	0.08	0.7
ICP - Short Term	5x	1.4	0.4	0.7	1.4	0.13	0.27	0.03	-
ICP - Short Term	10x	1.3	0.4	0.7	1.2	0.26	0.18	0.07	-
ICP - Georgia	20x	5	4	7	5	-	0.73	0.15	0.06
Spark - AOAC	5-10x	6	3	5	-	-	-	-	-
Relative Standard Deviation (%C.V.)									
ICP - Long Term	10x	5	3	2.2	4.8	14	14	25	24
ICP - Short Term	5x	5	4	2.0	3.1	8	17	14	-
ICP - Short Term	10x	5	3	2.0	2.6	16	10	27	-
ICP - Georgia	20x	18	24	1.7	10.4	-	26	37	26
Spark - AOAC	5-10x	22	17	15.6	-	-	-	-	-
Spectra Interferences, Computer Corrected for "Long and Short Term" Data Above									
Interfering elements		Cu/Mg	-	Fe/K	-	-	Mn	Cu/Fe	Fe
Concentration Error (ppm) (in above ICP Long Term Means)		.12-.16	0	.35-.8	0	0	.04-.28	.01-.15	.04-.1

[1]Long term, 21 samples analyzed over 10 week period, 11/9/77-1/25/78. 1 g ashed at 485° for 10 hrs.
[2]Short term, 36 samples analyzed over a 2½ hr period. Slow ashed at 450°C for 24 hrs. Submitted by R. Dowdy, ARS
[3]Georgia, J.B. Jones, Elemental Analysis----Plant Tissue Ash by Plasma Emission Spect., Comm. Soil Sci. and Plant Anal. (Vol. 8, No. 4, 1977)
[4]AOAC, J.B. Jones, Collaborative study by 11 spark emission spectrograph laboratories, Jour. of the AOAC (Vol 58, No. 4, 1975)

Table 4

Precision Evaluation

Analyses of high standard solution* as an unknown at 12 different times over a 3 hour period during the analysis of 41 plant tissue samples** (Concentration in µg/ml in 2N HCl)

Time lapse min.	Time diff. min.	K 2000	Ca 3000	Mg 1000	Al 100	Fe 100	Mn 100	Zn 100	Cu 10.0	B 10.0	Pb 10.0	Ni 10.0	Cd 10.0	Co 10.81
0		1947	2914	973	109	97.3	97.4	9.77	9.74	9.68	9.70	9.73	9.74	10.5
	2													
2		1980	2949	994	101	98.7	99.3	9.95	9.88	9.87	9.90	9.89	9.87	10.6
	13													
15		1950	2922	991	103	98.6	97.4	9.86	9.85	0.83	0.89	9.83	9.84	10.6
	10													
25		1953	2941	1002	103	99.3	99.8	9.92	9.94	9.92	9.90	9.91	9.92	10.6
	5													
30		1876	2844	975	100	96.5	98.3	9.67	9.65	9.60	9.66	9.64	9.65	10.2
	4													
34		1867	2843	974	99.8	96.8	99.0	9.68	9.70	9.65	9.61	9.61	9.60	10.3
	15	Calibration "normalized" by computer on blank and high standard												
49		2017	3030	1004	98.5	100.8	99.8	10.01	10.13	10.06	10.02	10.08	10.05	10.9
	3													
52		2001	3036	1013	104.9	101.7	97.4	10.10	10.17	10.12	10.07	10.12	10.10	11.02
	15													
67		1998	3046	1019	94.7	102.2	96.4	10.15	10.22	10.18	10.17	10.16	10.16	11.23
	3													
70		1958	2983	1004	95.3	100.3	96.4	9.96	10.03	9.98	9.96	9.96	9.97	10.92
	13	Calibration "normalized" by computer on blank and high standard												
83		2018	3018	996	89.2	100.3	100.6	9.93	10.03	10.05	9.98	10.01	9.99	10.93
	2													
85		2044	3072	1019	89.2	101.7	103.9	10.06	10.19	10.29	10.15	10.15	10.15	11.02
	26	Noon break - Recalibrated - New calibration curve fit by computer on blank and high standard												
111		1987	2984	986	102.6	98.9	97.9	9.83	9.94	9.90	9.82	9.89	9.87	10.55
	17													
128		1997	3010	1003	94.5	99.7	98.8	9.92	10.08	10.03	9.92	9.96	9.94	10.65
	28													
159		1975	2992	994	100.7	100.0	93.5	9.96	10.06	9.97	9.88	9.91	9.91	10.57
	26													
185		1942	2969	993	99.6	99.6	94.6	9.89	10.03	9.90	9.85	9.85	9.86	10.48
$\bar{x}$		1969	2972	996	99.1	99.5	98.2	9.92	9.98	9.94	9.90	9.92	9.91	10.69
s		47.9	67.1	14.5	5.37	1.70	2.44	0.13	0.17	0.19	0.16	0.17	0.16	0.28
RSD%		2.4	2.3	1.5	5.4	1.7	2.5	1.3	1.7	1.9	1.6	1.7	1.6	2.6

*It is standard practice to run the high standard as an unknown between every 10-20 samples. If any element concentration is off more than 5% of the calibrated value, a blank and high standard are run using the "normalizing" subroutine in the computer.

**The plant tissue samples run during this period are those in Tables 2 and 5.

Table 5 ICP-OES determinations on OARDC[a] referee plant tissue materials[b]

element	Alfalfa			Tomato			Wheat		
	Assigned		ICP found	Assigned		ICP found	Assigned		ICP found
	Mean	Range	Mean(n=2)	Mean	Range	Mean(n=2)	Mean	Range	Mean(n=2)
P %	[c]0.30	0.29-0.31	0.286	0.52	0.49-0.55	0.448	0.17	0.16-0.18	0.142
	[d]0.30	0.26-0.35		0.52	0.44-0.60		0.17	0.13-0.21	
K %	1.24	1.17-1.31	1.38	3.43	3.30-3.56	3.66	1.53	1.42-1.64	1.82
	1.25	1.07-1.43		3.66	2.64-4.68		1.53	1.19-1.87	
Ca %	1.61	1.53-1.69	1.68	4.14	3.88-4.40	4.84	0.17	0.16-0.18	0.197
	1.46	1.17-1.75		4.16	2.89-5.43		0.20	0.11-0.29	
Mg %	0.33	0.31-0.35	0.378	0.98	0.94-1.02	0.947	0.07	-	0.084
	0.32	0.26-0.38		0.90	0.74-1.06		0.07	0.04-0.10	
Al	81	80-82	43.4[e]	105	99-111	146	38	36-40	42.9
	81	55-107		109	50-168		38	27-49	
Fe	118	112-124	125	195	183-207	102	64	61-67	66.2
	122	89-155		188	105-271		70	46-94	
Na	630	626-634	522	2340	2251-2429	2270	200	196-204	43.2
	681	473-889		2811	2101-3521		224	61-387	
Mn	41	39-43	44.2	566	538-594	568	81	76-86	89.8
	42	31-53		580	488-672		82	70-94	
Zn	-	-	36.3	-	-	141	-	-	22.6
Cu	11	10-12	8.2	20	19-21	12	5	-	3.6
	11	6-16		21	12-30		6	2-10	
B	27	26-28	34	91	85-97	89	3	-	2.2
	30	20-40		94	68-120		4	0-9	

[a]OARDC - Ohio Agricultural Research and Development Center, Ohio State University. This material was distributed by J.B. Jones in 1967 for atomic emission analysis by 17 participating laboratories including this facility. These samples have been used as calibration standards on the Jarrell-Ash spectrometer.
[b]1.0 gm oven dried at (85°c) and dry ashed at 485°C for 10 hrs. Ash dissolved in 10 ml 2N HCl.
[c]Mean after removing outliners greater than 10% of the mean.
[d]Mean without removing outliners.
[e]n=2 has greater than 10% difference.

Table 6 Comparison of analyses of CII botanicals[a] by ICP-OES analysis at Minnesota[b] with ICP-OES at Applied Research Laboratories, Sunland California[c] against assigned French CII (Committee Inter-Institute) values obtained by other methods including atomic absorption spectrometry

	Orange (Spain)				Vigne (France				Codia discolor (N. Calidonia)			
element	CII assigned mean	CII assigned range[e]	ICP Calif n=2 mean	ICP Minn n=2 mean	CII assigned mean	CII assigned range	ICP Calif n=2 mean	ICP Minn n=2 mean	CII assigned mean	CII assigned range	ICP Calif n=2 mean	ICP Minn n=2 mean
P%	.15	.142-.166	.126	.148	.207	.197-.216	.218	.200	.025	.021-.029	.020	.020
K%	1.51	1.41-1.67	1.51	1.58	1.23	1.15-1.30	1.29	1.23	.37	.334-.399	.370	.381
Ca%	4.91	4.71-5.06	4.4	5.03	2.55	2.44-2.73	2.60	2.58	.83	.794-.868	.727	.834
Mg%	.32	.296-.341	.264	.311	.28	.263-.298	.278	.284	.28	.273-.298	.259	.292
Al	-	-	612	221	-	-	366	223	-	-	255	248
Fe	472	433-497	354	382	265	239-304	246	250	87	81.1-95.5	92.7	58.0
Na[f]	380	-	-	266	260	-	-	164	1400	-	-	1296
Mn	75	69.9-80.4	66.6	68.3	196	184-203	188	180	653	630-680	415	522
Zn	70	61.9-75.1	52.0	128	75.5	66.8-81.8	78.1	108	11.3	10.1-12.9	8.6	19.1
Cu	8.5	7.3-9.7	5.8	13.2	880	793-979	848	864	4.69	3.75-5.95	3.1	3.4
B	39.5	-	-	42	48	-	-	42	25	-	-	27
Pb	-	-	7.8	7.2	-	-	18	18	-	-	3.0	.18
Ni	-	-	1.6	2.1	-	-	1.6	1.4	-	-	>200	200
Cr	-	-	1.1	.68	-	-	.9	.44	-	-	>5	4.4
Cd	-	-	-	0.0	-	-	-	0.0	-	-	-	0.0
Co	-	-	0.5	1.8	-	-	.5	.02	-	-	>20	28

Continued--

Table 6 Continued

element	Eucalyptus (Spain) CII assigned mean	Eucalyptus (Spain) CII assigned range	Eucalyptus (Spain) ICP Calif n=2 mean	Eucalyptus (Spain) ICP Minn n=2 mean	Cotton (Africa) CII assigned mean	Cotton (Africa) CII assigned range	Cotton (Africa) ICP Calif n=2 mean	Cotton (Africa) ICP Minn n=2 mean	Olive (Spain) CII assigned mean	Olive (Spain) CII assigned range	Olive (Spain) ICP Calif n=2 mean	Olive (Spain) ICP Minn n=2 mean
P %	.085	.076-.093	.078	.084	.36	.343-.382	.365	.352	.083	.080-.089	.078	.084
K %	.68	.630-.759	.741	.739	1.84	1.76-1.89	1.84	1.81	.51	.44-.58	.56	.540
Ca %	1.56	1.46-1.68	1.31	1.68	3.1	2.88-3.27	3.2	3.04	2.59	2.47-2.74	2.61	2.81
Mg %	.21	.191-.224	.190	.218	.41	.396-.430	.429	.408	.13	.125-1.38	.131	.135
Al	-	-	246	65.4[d]	-	-	320	178	-	-	373	138
Fe	102	94.5-110.9	89.5	100	404	382-452	339	250	169	152-191	166	147
Na[f]	1700	-	-	1750	500	-	-	371	80	-	-	20.5
Mn	574	538-602	307	580	220	207-229	215	190	48	44.8-53.3	50.7	44.3
Zn	12.4	10.3-15.3	10.3	18.3	127	114-137	103	118	15	14.5-17	13.9	23[d]
Cu	8.4	6.8-9.4	6.3	6.4	15	136-16.5	14.4	12	37	33.5-38.5	37.8	42
B	35	-	-	36	25	-	-	25	18	-	-	17
Pb	-	-	5.9	1.3	-	-	6.7	2.6	-	-	7.4	7.9[d]
Ni	-	-	2.7	3.4	-	-	1.7	1.05[d]	-	-	.9	.9[d]
Cr	-	-	.4	.11	-	-	1.0	.56	-	-	.5	.18
Cd	-	-	-	.1[d]	-	-	-	.09[d]	-	-	-	0.0
Co	-	-	.3	0.0	-	-	.7	.43[d]	-	-	.2	.52

Continued--

Table 6 Continued

ele-ment	Palm (Africa) CII assigned mean	Palm (Africa) CII assigned range	Palm (Africa) ICP Calif n=2 mean	Palm (Africa) ICP Minn n=2 mean	Peach (France) CII assigned mean	Peach (France) CII assigned range	Peach (France) ICP Calif n=2 mean	Peach (France) ICP Minn n=2 mean	Corn (Spain) CII assigned mean	Corn (Spain) CII assigned range	Corn (Spain) ICP Calif n=2 mean	Corn (Spain) ICP Minn n=2 mean
P%	.165	.160-.172	.149	.158	.292	.271-.301	.276	.276	.219	.204-.231	.204	.206
K%	.885	.815-.940	.852	.907	2.19	2.06-2.31	2.25	2.24	1.94	1.79-2.01	1.86	1.92
Ca%	.80	.766-.834	.696	.815	2.15	2.05-2.27	1.98	2.26	1.12	1.07-1.18	.986	1.11
Mg%	.295	.283-.309	.269	.306	.475	.449-.497	.475	.486	.36	.351-.375	.344	.355
Al	-	-	182	166	-	-	263	175	-	-	-	158
Fe	197	187-212	156	183	302	264-334	223	244	259	242-276	227	214
Na[f]	170	-	-	126	260	-	-	134	1700	-	-	1640
Mn	631	602-658	117	604	81	77.6-88.1	84.3	76.3	66	61.5-70.7	63.6	55.2
Zn	23	19.9-26.2	19.0	47.2[d]	28	23.2-32.3	24.0	39.6	27	24.5-31.6	22.6	72.8[d]
Cu	8.9	7.1-10.5	5.9	9	15	131-17.5	14.3	14	11.4	10.2-13.4	6.5	10.5
B	15	-	-	14	38	-	-	40	23	-	-	23
Pb	-	-	3.4	2.3[d]	-	-	5.5	2.5	-	-	4.4	2.6
Ni	-	-	.5	.89	-	-	1.2	.86[d]	-	-	.6	.56[d]
Cr	-	-	.5	.19	-	-	.6	.33	-	-	.9	.28
Cd	-	-	-	0.0	-	-	-	.20[d]	-	-	-	0.0
Co	-	-	(.2)	0.0	-	-	.3	0.0	-	-	.3	0.0

Continued--

Table 6 Continued

element	Apple, Golden (Belgium)				Apple, Cox's (France)				Hevea (Ivory Coast)			
	CII assigned		ICP Calif n=2	ICP Minn n=2	CII assigned		ICP Calif n=2	ICP Minn n=2	CII assigned		ICP Calif n=2	ICP Minn n=2
	mean	range	mean	mean	mean	range	mean	mean	mean	range	mean	mean
P%	.16	.157-.170	.148	.158	.177	.170-.183	.169	.165	.26	.246-.269	.252	.260
K%	1.45	1.37-1.52	1.46	1.51	1.04	.949-1.12	1.05	.987	.93	.886-.988	.978	1.00
Ca%	1.27	1.20-1.36	1.18	1.34	2.14	2.06-2.22	1.96	2.12	1.08	.987-1.148	.912	1.11
Mg%	.29	.269-.303	.278	.297	.29	.280-.311	.282	.282	.33	.307-.355	.331	.358
Al	-	-	162	113[d]	-	-	1045	672	-	-	109	86.9
Fe	308	277-345	216	188	1120	1028-1281	1047	726	160	135-183	143	150
Na[f]	160	-	-	90.7	570	-	-	228	100	-	-	51.7
Mn	47	41.9-51.5	46.1	45.2	136	130-142	136	122	162	153-168	147	162
Zn	29	26.0-34.5	26.1	38.8	79	69.1-84.6	79.1	92.6	37.7	34.4-37.4	36.3	56.3
Cu	8.2	6.9-9.9	7.1	7.7	173	146-208	175	171	14.8	131-17.8	16.5	14.8
B	29	-	-	30	33	-	-	32	58	-	-	60
Pb	-	-	11	12	-	-	22	24	-	-	6.0	1.8
Ni	-	-	4.9	5.3	-	-	4.3	4.0	-	-	1.6	1.8
Cr	-	-	.6	.24	-	-	2.3	1.1	-	-	.6	.20
Cd	-	-	.3	.13	-	-	1.0	.28	-	-	.6	0.0
Co	-	-	-	0.0	-	-	-	0.0	-	-	-	0.0

[a]CII materials provided by M. Pinta, Office Da La Recherche Scientifique et Technique Autre-Mer, Services Scientifiques Centraux Bondy, France. ref: "Applied Spectroscopy," vol. 32, no. 1, Jan/Feb 1978 pp1-30.

[b]1.0 gm oven dried (85°C) and dry ashed at 485°C for 10 hrs. Ash dissolved in 10 ml 1N HCl.

[c]1.0 gm dry ashed at 200°C for 8 hrs. followed by HNO_3 acid treatment and ashing again at 485°C for 20 min. Taken up in 1.25N HCl. As reported in "Applied Spectroscopy," vol. 32, no. 1, Jan/Feb 1978, pp1-30.

[d]n=2 has greater than 10% difference

[e]range=$\bar{x}\pm$Std. Dev.

[f]Assigned Na values by CII were from one determination and reported with reservation and for information only.

Table 7

Measured Spectral Interferences in the ICP Spectrometer[a]

effect of (x)		on channel (y)	error in channel (y) of (x)
	(x)	(y)	ppm
1ppm	Ca	Al	0.00230 - 0.0040
"	Mg	Zn	0.00025
"	Na	Zn	0.00000 - 0.0002
"	Cu	Zn	0.00920
"	Fe	B	0.00140 - 0.0043
"	Fe	Cd	0.00068 - 0.0001
"	Cu	Cd	0.00090 - 0.0011
"	Fe	Co	0.00020 - 0.0005
"	Mn	Cr	0.00040 - 0.0031
"	Fe	Hg	0.00038 - 0.0067
"	Cu	P	0.43000 - 0.8800
"	Mn	Fe	0.00135
"	Al	Fe	0.00053

[a]All 20 elements were aspirated as single element 2N HCl solutions (x), several times over a 6 month period, and the effect of element (x) was measured in element channel (y). Only those interferences that are significant in biological material, soil extracts, and water samples are reported here.

On-line computer software corrections are made for these interferences.

Concentrations of interfering elements used were as follows: 500 ppm for Ca and Mg, 200 ppm for Fe, and 100 ppm for Cu, Mn, Al and sodium.

Table 8

Comparison of Detection Limits and Practical Lower Concentration Limits between ICP-OES, FAAS, and SRD-OES Methods

		Detection Limits		Practical Lower Limits			
				Flame Atomic Absorption			
ICP Wave-length	Ele-ment	ICP-OES[a] Range µg/ml	Flame Atomic Absorption (FAAS) µg/ml	Sensi-tivity[c] µg/ml	LOCR[d] µg/ml	ICP LQD[e] µg/ml	SRD-OES LLR[f] µg/ml
2136.2	P	0.003-0.245	not applicable	-	-	1.23	20
7664.9	K	0.07-0.312	0.005	0.04	0.1-2	1.56	100
4226.7	Ca	0.006-0.094	0.003	0.08	0.2-20	0.470	20
2790.7x2	Mg	0.016-0.046	0.0005	0.007	0.02-2	0.230	10
3961.5x2	Al	0.005-0.058	0.1[g]	1	5-100	0.290	1
2599.4x2	Fe	0.003-0.008	0.02	0.12	0.3-10	0.040	2
5890.0x2	Na	0.01-0.221	0.002	0.015	0.03-1	1.11	30
2576.1x2	Mn	0.001-0.004	0.01	0.05	0.1-10	0.020	1
2025.5x2	Zn	0.003-0.010	0.005	0.02	0.05-2	0.050	0.1
3247.5x2	Cu	0.003-0.010	0.01	0.1	0.2-10	0.050	0.1
2497.7x2	B	0.003-0.006	6[g]	40	-	0.030	0.2
2203.5x2	Pb	0.02-0.067	0.05	0.5	1-20	0.335	4
2316.0x2	Ni	0.01-0.031	0.02	0.15	0.3-10	0.155	4
2677.2x2	Cr	0.001-0.005	0.02	0.1	0.2-10	0.025	4
2265.0x2	Cd	0.004-0.006	0.02	0.025	0.05-2	0.030	1
3453.0x2	Co	0.2	0.03	0.2	0.5-10	1.00	4
2536.5x2	Hg	0.02-0.057	0.5	7.5	20-300	0.285	-
1937.6x2	As	0.1-0.316	0.1[h]	0.8	5-50	1.58	4
1960.9x2	Se	0.1-0.879	0.1[h]	0.5	2-50	4.40	-

[a] Measured by this laboratory. In general, the lowest concentration shown is in single element solutions. The larger value was the latest data obtained 3-21-78 on multielement solutions in 2N HCl.

[b] Values taken from commercial literature for single element solutions in D.I. water.

[c] Sensitivity defined as ug/ml that gives a 1% absorption signal.

[d] LOCR is defined as the lower optimum concentration range (Manual of methods for chemical analysis of water and wastes, EPA-62516-74-003).

[e] LQD is defined in ICP literature as the lowest quantitatively determinable concentration or 5x the detection limit.

[f] Lowest limit reported, solution rotating disk optical emission spectrometer.

[gh] Nitrous oxide and argon-hydrogen flame respectively.

WATER SOFTENING AND LIME WASTES FROM THE MINNEAPOLIS WATER DEPARTMENT

C. P. Klint and C. J. Overdahl*

Large cities have lime disposal problems in the water softening process. From 10 to 12 truckloads of a limy material from the Minneapolis water treatment facility at Fridley need to be disposed of daily.

Several thousand tons of material are added to river water and are consumed yearly. This creates a waste product of calcium carbonate and magnesium hydroxide. The lime yield is about 1¼ tons of dry material per million treated gallons of water.

Representatives of the Fridley plant contacted the University of Minnesota Soil Science Department and the Anoka County Extension Office seeking help on what uses this product might have in agriculture.

The product used in the treatment process is brought in by the carload as calcium oxide. The softening process of the Mississippi River water is about as follows: calcium oxide + water yields calcium hydroxide. Calcium hydroxide reacts with the river water hardness (calcium bi-carbonate) and precipitates calcium carbonate plus water. There is also a reaction with the magnesium bi-carbonate in the water with calcium hydroxide to yield calcium carbonate plus magnesium carbonate and water. The magnesium carbonate will further react with calcium hydroxide to form magnesium hydroxide and calcium carbonate. The latter two compounds are the waste product to be disposed. Some other elements are also extracted from the river water.

These other elements vary with analysis. A report from the Serco Sanitary Engineering Laboratories, Inc. using standard methods for examination of wastewater and according to EPA methods for chemical analysis of water and wastes, 1974, gave the following analysis on dry weight basis for these other elements which appear to be in small quantity:

	ppm	%
Cyanide	3.3	.0003
Manganese	932.0	.0932
Iron	3163.0	.3163
Arsenic	6.3	.0006
Cadmium	13.0	.0013
Hexavalent chromium	6.	.0006
Copper	16.0	.0016
Lead	67.0	.0067
Zinc	50.0	.0050
Mercury	0.23	.000023
Sulfate	1998.0	.1998

pH = 9.6

* Area Extension Agent, Soils, Anoka, and Extension Specialist, Soils, respectively, University of Minnesota.

A separate report gave the average calcium carbonate content as 89.5% and magnesium hydroxide as 3.13%. The University of Minnesota Soil Testing Laboratory reported a 90.6% calcium carbonate equivalent.

Field Trials in Anoka County

Field application was first tried in the fall of 1974. The material contained 66% water and 33% solids. It spread quite easily with a manure spreader. The application rate was 10 tons per acre of waste or about 3.3 tons per acre of dry matter. The soil pH of a check area in the fall of 1975 was 6.3 and the treated area had a pH of 6.7. This initial effort revealed that the material would probably be a satisfactory liming product.

Further efforts were made in the greenhouse with additional field trials to check for possible harmful effects when higher rates were used. Plant tissue analysis was also made to get an opinion on whether some of the possible harmful ingredients were absorbed in any quantity by the plant.

Greenhouse and Second Field Trial

In the second series of trials, lime wastes were applied to the soil for greenhouse study in April 1976. Soybeans and rye were planted in May 1976. Soils were sampled to determine pH in October 1976. Soil treatment rates on a dry weight basis and the corresponding pH values were as follows:

Waste lime Rate/A	pH
Peat soil (greenhouse)	
Check	6.3
2 tons	6.8
4 "	7.0
12 "	7.6
Sandy loam soil (greenhouse)	
Check	6.3
2 tons	7.6
4 "	7.6
8 "	7.9
16 "	8.0
32 "	8.0
64 "	8.3
128 "	8.5
Sandy loam soil (field)	
Check	6.3
2 tons	6.4
4 "	6.8
8 "	7.0
16 "	7.4

Observations revealed no positive or negative effect generally on plant growth or appearance. At waste treatment above 64 tons per acre on the sandy loam soil, soybeans showed some abnormal coloring.

Rye and soybeans were planted in both the greenhouse pots and in the field trial. The plant analysis from the University of Minnesota Soil Science Department plant analysis laboratory is shown in the following tables.

Summary

In these limited experiments, there were several interesting relationships of lime rates to plant nutrient content, but in line with what is expected. Since no adverse effects were observed, a preliminary opinion would be that this lime waste would be a satisfactory liming material and disposal on farms having acid soils would be a reasonable approach. Research should be conducted from other lime waste sites where some heavy metals may be in higher concentrations.

RYE

Greenhouse

	%				ppm											
	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	PB	Ni	Cr	Cd	Co
Check	.25	2.2	1.4	.30	248	307	1025	376	21	6	27	4	4	1.0	.20	1.9
4 ton	.18	1.51	.75	.63	154	252	1298	323	22	6	24	4	3	.92	.23	1.5
16 "	.11	.88	1.8	.93	103	773	1092	59	15	7	23	6	6	1.4	.59	2.0

RYE

Field

Check	.15	1.16	.74	.18	399	1225	71	269	31	3	26	6	2	1.1	.47	1.3
4 ton	.29	1.53	.58	.31	274	1170	79	92	40	4	18	5	3	1.0	.35	1.7
16 "	.23	1.65	.56	.27	317	1099	94	125	31	4	14	6	2	1.2	.38	1.9

Standard levels for rye

Suff.	.21	1.51	.21	.21	-	11	-	16	21	6	6	-	-	-	-	-
Excess	.81	5.50	-	-	400	550	-	350	151	71	56	-	-	-	-	-

SOYBEANS

Greenhouse

Check	.36	1.67	1.9	.67	200	315	813	74	34	11	45	4	8	.9	.22	2.6
4 ton	.19	.94	1.09	1.02	105	171	169	46	21	7	33	3	5	.7	.31	1.7
16 "	.20	.96	.48	1.27	121	191	1189	28	23	8	25	3	5	.7	.33	1.1

SOYBEANS

Field

Check	.20	1.57	.90	.58	175	562	58	75	34	6	26	5	3	.8	.3	1.3
4 ton	.30	1.60	.57	.320	194	903	63	88	43	5	21	4	3	.8	.4	1.4
16 "	.35	1.74	.49	.40	52	291	24	47	43	7	28	3	3	.5	.2	1.6

Standard levels for soybeans

Suff.	.26	1.51	.36	.26	-	51	-	21	21	10	21	-	-	-	-	-
Excess	.81	5.50	3.00	2.00	-	750	-	550	150	70	100	-	-	-	-	-

EFFECT OF WEX ON CROP YIELDS

W. Fenster, G. Randall, W. Nelson, S. Evans and R. Schoper

The product Wex is a wetting agent which, when applied to the soil, is claimed to increase the yield of various field crops by aiding soil nutrient availability. Specifically, claims are made for Wex as an agent which helps crops achieve their genetic potential by releasing more soil nutrients, increasing trace mineral uptake, enhancing fertilizer activity, and aiding in superior root development.

With these claims in mind, experiments were conducted during 1976 and 1977 using Wex as a soil additive on corn, soybeans and wheat at the Waseca, Lamberton and Morris Experiment Stations.

EXPERIMENTAL PROCEDURE

The experiments were located on a Webster clay loam at Waseca, Nicollet silty clay loam at Lamberton and a Forman clay loam at Morris.

The treatments, arranged in a randomized, complete-block design, were replicated six times in each experiment at Waseca and Morris and five times at Lamberton. In 1976, the treatments consisted of a check, 8 and 16 oz. of Wex per acre at all locations on corn, soybeans and wheat. In 1977, the treatments consisted of a check, 16 oz. of Wex and 16 oz. per acre of an experimental surfactant named MGJ-A for corn and wheat and MGJ-B for soybeans. All treatments were applied preplant and incorporated with the soil at Lamberton and surface applied at Waseca and Morris. In all cases, adequate N, P and K treatments were applied and good weed and insect control were maintained.

RESULTS AND DISCUSSION

The yield data for wheat, soybeans and corn are presented in Tables 1-3. There were no significant yield differences among treatments for any of the crops, at any of the locations, for either 1976 or 1977.

Various other criteria were used to aid in determining whether Wex improved plant growth. The data from these measurements, which included stand counts, early plant growth, percentage of essential nutrients in the plant at various stages of growth and percent protein in the wheat grain, will be presented in the future in the form of a soil series.

Table 1. Effect of varying levels of Wex on wheat yields.

Treatment Material	Rate	Waseca 1976	Waseca 1977	Lamberton 1976	Lamberton 1977	Morris 1976	Morris 1977
	oz/A	bu/A					
Check		55	42	25	49	25	47
Wex	8	54		25		26	
Wex	16	53	43	26	49	26	48
MGJ-A	16		45		49		47
Significance (.05)		ns	ns	ns	ns	ns	ns

Table 2. Effect of various levels of Wex on soybean yields.

Treatment Material	Rate	Waseca 1976	Waseca 1977	Lamberton 1976	Lamberton 1977	Morris* 1977
	oz/A	bu/A				
Check		36	53	17	46	29
Wex	8	37		16		
Wex	16	37	53	17	49	30
MGJ-B	16		53		47	31
Significance (.05)		ns	ns	ns	ns	ns

* 1976 yields lost due to hail damage.

Table 3. Effect of varying levels of Wex on corn yields.

Treatment Material	Rate	Waseca 1976	Waseca 1977	Lamberton 1976	Lamberton 1977	Morris* 1977
	oz/A	bu/A				
Check		77	137	23	142	117
Wex	8	70		22		
Wex	16	71	137	25	139	107
MGJ-A	16		132		140	113
Significance (.05)		ns	ns	ns	ns	ns

* 1976 yield lost due to hail damage.