SOIL SERIES

A REPORT ON FIELD RESEARCH IN SOIL SCIENCE

The 1979 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 1978 experiments only and should be regarded on this basis. Since most data are from only 1978 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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TABLE OF CONTENTS

Page

1. Agricultural Meteorology Studies.....1

2. Minnesota Spring Soil Moisture Situation, March 1979.....13

Becker Experiments

3. Controlling Soil pH for Potatoes Under Irrigation (Limy Water) - 1978.....15

4. Micronutrient Tests on Alfalfa.....19

5. Micronutrient Fertilization of Potatoes and Corn Under Irrigation.....21

6. Influence of Nitrogen Form, Nitrification Inhibitors, and Treatment Incorporation on Yields, and Nitrogen Utilization of Corn Under Irrigation.....26

7. Influence of Nitrogen Rate, Timing of Nitrogen Application and Use of Nitrification Inhibitors for Irrigated Spring Wheat and Corn.....31

8. Influence of Nitrification Inhibitors and Nitrification Inhibitor Rates on the Production of Spring Wheat and Corn Under Irrigation.....40

9. Navy Bean Inoculation Trials--1978.....45

Crookston Experiments

10. Weather Summary--1978.....47

11. Copper Sulfate Carrier X Method of Application Study.....48

12. Wheat Production as Affected by Copper on Organic Soils.....49

13. Nitrogen Carrier X Rate X Application Time Study for Wheat-1978...52

Lamberton Experiments

14. Nineteen Years of Field Experimentation with Nitrogen Source, Placement, and Time of Application.....54

Morris Experiments

15. Weather Summary.....60

16. Continuous Corn Silage.....61

Page

17. Eco-Gro Studies on Corn.....62

18. Manure Rate Study.....65

19. Residual Effect of Heavy Applications of Animal Manures on Corn Growth and Yield and On Soil Properties.....72

20. Influence of Nitrogen on Forage Production, Nitrogen Utilization by Three Small Grain Varieties.....78

Rosemount Experiments

21. Pesticide Interaction Plots at Rosemount.....81

Staples Experiments

22. Alfalfa and Red Clover Potassium Trials.....84

23. Barley Fertilization Trials Under Irrigation at Staples in 1978.....87

24. Influence of Nitrogen Rate, Timing of Application and Use of Nitrification Inhibitors on Irrigated Corn at Staples.....93

25. N Rate Studies of Dryland and Irrigated Wheat and Oats With and Without Legume Underseeding, Staples 1978.....97

26. Water Quality Studies.....103

Waseca Experiments

27. Weather Data - 1978.....105

28. Postemergence Application of UAN(28% N) to Corn.....106

29. Corn Fertilization With Nitrogen Containing ACA.....111

30. Influence of Extend Applied With UAN(28% N) on Corn Production.....114

31. Symbex.....120

32. Use of Terrazole as a Nitrification Inhibitor in Fall vs. Spring Nitrogen Application Program For Corn Production in Southern Minnesota.....123

33. Amelioration of Iron Chlorosis by Coating Soybean Seeds With Iron KE-MIN.....126

Page

34. Conservation Tillage Study.....134

35. Lime Studies-Waseca, 1978.....141

Annual Canarygrass

36. Nitrogen Fertilization of Annual Canarygrass.....147

Corn

37. Foliar Fertilization of Corn.....149

38. Deep Sampling of Soils for Residual Nitrates and its Potential as a Diagnostic Technique for Corn Production in Southwestern Minnesota.....151

39. The Influence of Nitrate-Nitrogen of Southeastern Minnesota Soils and Response of Corn to Added Nitrogen Fertilizer-1978.....155

40. Nitrogen Carryover in the Soil Profile on Continuous Corn and Relationship to the Next Year's Yield.....159

41. Use of N-Serve in Fall vs. Spring Nitrogen Application Programs in Fine Textured Soils in Minnesota.....165

42. High Phosphorus and Potassium Rates for Continuous Corn.....172

43. Tillage Study Summary 1976-78 Lancaster, Wisconsin.....179

Grass Seed

44. Grass Seed Production as Influenced by Fertilization.....182

Pastures

45. Pasture Fertilization Trials.....192

Small Grain

46. Influence of Foliar Applications of Fertilizer Nutrients and Fungicide on the Yield and Protein Content of Small Grains-1978...200

47. N Rate, Source, and Incorporation Study.....204

48. Influence of Nitrate-Nitrogen Level of Various Soils of the Red River Basin and Their Response to Added Nitrogen Fertilizer-Wheat Fertility Research 1978.....207

49. The Yield and Protein Content of Era Wheat as Influenced by Starter Fertilizer at Several Farm Locations in Pennington County, Minnesota.....211

Page

Soil Analysis

50. DTPA Soil Extract Analysis for Metals.....214

Soybeans

51. Progress Report on Foliar Fertilizers on Soybeans.....219

52. Response of Soybean Genotypes to Foliar Fertilization.....221

Sugarbeets

53. Nitrogen Fertilization of Sugarbeets in West-Central Minnesota - 1978.....223

54. Nitrogen X Variety Interaction Trial on Sugarbeets.....230

Sunflowers

55. Fertilizer Trials on Sunflowers - 1978.....233

Wild Rice

56. Wild Rice Fertilization Research - 1978.....235

AGRICULTURAL METEOROLOGY STUDIES

Donald G. Baker

Several studies are underway that may be of interest to readers of the bluebook. None are complete and therefore only brief examples of each can be shown. They are as follows -

1. Soil Temperature
2. Solar Radiation Reception
3. Wind Climatology of Minnesota

SOIL TEMPERATURE

Analysis of the temperature records at St. Paul has begun again after a period of some years following the publication of "Spring Soil Temperatures" in 1966. This time the analysis will include all four seasons and more than the usual kinds of measurements. These measurements are all made at the agricultural weather station on the St. Paul Campus. The soil is Waukegan silt loam, a well drained loessial soil that is about 75 cm (30 in) thick and is underlain by sand and gravel to a depth greater than 50 m.

Fig. 1 shows the average monthly air temperature and soil temperatures at 10 cm (4 in) depth under bare and sod covers to illustrate several points. The 10 cm (4 in) depth was chosen since this is a common seeding depth and because a great concentration of roots, at least in the first half of a season, are found at this depth.

The presence of a cover such as grass sod throughout the year provides an appreciable amount of insulation during the winter. Thus not only are the winter temperatures under sod higher than both the air temperature and the bare soil temperature at 10 cm depth, but the sod minimum temperature lags the other minima by one month. It occurs in February rather than January. Also noteworthy is the fact that the temperatures under a bare soil at 10 cm depth are higher in the summer than either the air or 10 cm sod cover soil temperatures. During the summer the sod continues to act as an insulator. However, the lower temperatures undersod than under the bare soil are due more to the cooling effect of the evapotranspiration of the sod than the insulation provided by the sod and sod roots.

Fig. 2 illustrates the variability of temperatures. As expected the air temperatures show a greater degree of variability than the 4 cm soil temperatures, and the bare soil more variability than the sod covered soil.

A feature of special interest is that the greatest variation in air temperatures occurs in the winter and a minimum in July. A second minimum in the standard deviation of air temperatures occurs in November, generally the cloudiest month of the year. The winter maximum indicates that the greatest contrast in the air masses that pass the station occurs in the winter while the least is in July and November.

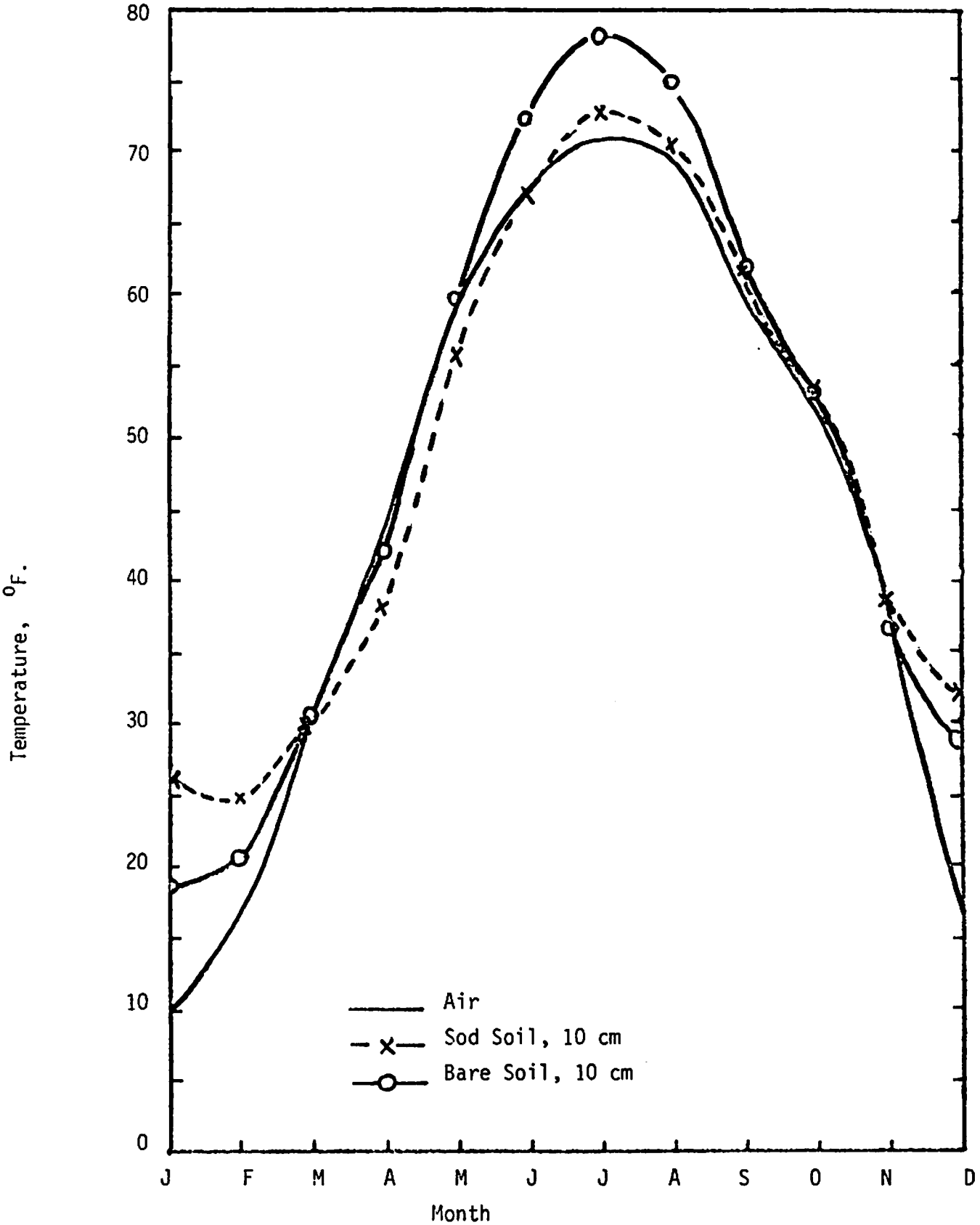


Fig. 1. Average Monthly Air and Soil Temperatures, St. Paul, Minn.

Fig. 2. Average Monthly Standard Deviation of Air and Soil Temperatures, St. Paul, Minn.

In contrast the variability of the soil temperatures is least in March. This is probably due to the March snow cover, usually the deepest of the year, which serves to insulate the soil from the changes occurring at the surface. It is most interesting that in the following month of April a large variability in the soil temperatures is shown. This, of course, is when the snow cover disappears, the soils thaw, and the warming of the soil begins. The bare soil shows a maximum temperature variability in August. It might be assumed that this is when the bare soil is the driest and the temperature can therefore fluctuate widely. This is not evident in the sod covered soil due to the insulating effect of the sod cover.

The average time of the occurrence of the maximum and the minimum temperature in July in the bare soil and in the air (in the temperature shelter) is shown in Fig. 3. The most obvious feature is the increasing lag in the occurrence of the temperature maximum and minimum with depth. Surface temperature measurements are not available, but the maximum could be expected at about solar noon. In mid-July solar noon at St. Paul occurs at about 12:18 Central Standard Time.

The data shown in Fig. 3 permit the calculation of two interesting soil physical parameters related to soil thermal properties. One is the velocity of the heat wave through the soil, and the other is the soil thermal diffusivity. The rate of the heat wave passage through the soil is about 6.7×10^{-4} cm sec^{-1}. This is the mean value for the maximum temperature to pass from 1-80 cm in July. In other words it takes 32.75 hours for the maximum temperature to move from the 1 cm to the 80 cm depth.

The velocity (v) of the heat wave equals the following:

$$v = \left(\frac{4\pi x}{P}\right)^{\frac{1}{2}}$$

where $x = k/pc$ = the thermal diffusivity, and P = the period of the daily heat wave. Since we now have a value for v we can solve for x. With $v = 6.7 \times 10^{-4}$ cm sec^{-1} it is calculated that $x = 0.0031$ cm^2 sec^{-1}.

The data (not shown) indicate a slightly faster movement through the soil with a sod cover, 7.8×10^{-4} cm sec^{-1}, and therefore the thermal diffusivity has a slightly higher value also, $x = 0.0042$ cm^2 sec^{-1}.

Ideally the data shown in Fig. 3 would plot as straight lines. That they do not indicates minor errors, perhaps in the temperature and depth measurements. Of greater importance, however, is the variation in the soil properties with depth which influence the transmission of heat. The data are averages for different soil moisture contents and thus represent a host of different conditions. At any particular time both the velocity of the temperature wave and the thermal diffusivity may differ appreciably from the calculated values obtained.

The complete analysis of the soil temperature data will emphasize conditions during the growing season.

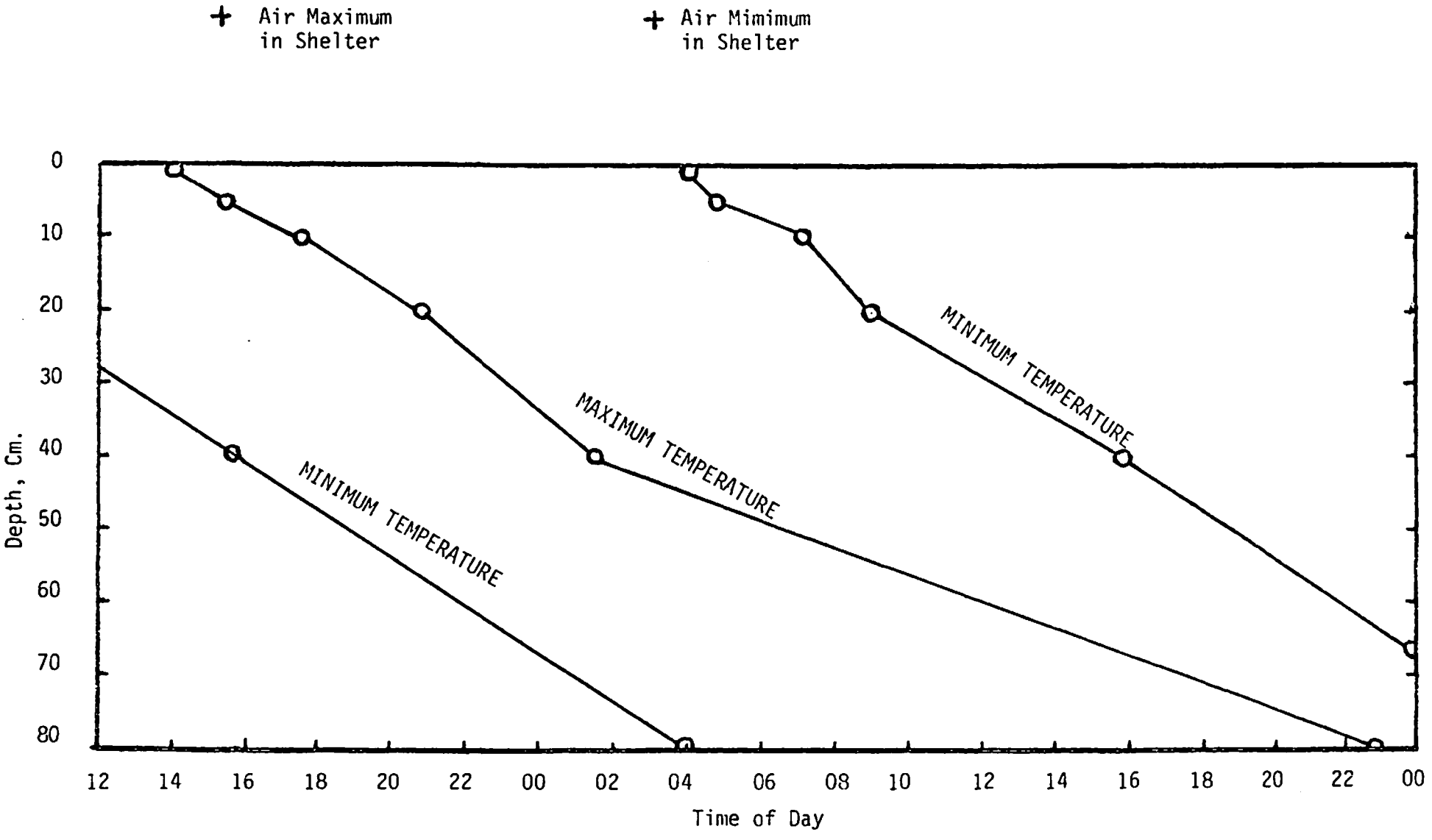


Fig. 3. Average Time of Occurrence of Maximum and Minimum Air and Bare Soil Temperatures, July, St. Paul, Minn.

SOLAR RADIATION

Solar radiation reception at the St. Paul agricultural weather station continues to be measured. Currently measurements include the fluxes of incoming short and longwave radiation, outgoing short and longwave radiation, diffuse radiation, and net radiation. Soon the measurement of radiation reception on an inclined surface will be added.

Studies of special interest to solar collector design include the distribution of hourly radiation values during the year; a second one is a comparison between the amount of radiation incident on a surface perpendicular to the sun and that incident on a horizontal surface. Examples of both will be shown.

The maximum, median,and mean amounts of radiation received on the hour on a horizontal at St. Paul for the period 1971-1977 are shown for the week of June 18-24 in Fig. 4. The distribution of these hourly values is shown in Fig. 5. It is obvious in both Fig. 4 and Fig. 5 that the mean fails to divide the population into two equal parts, since the mean is not equal to the median. This fact is of importance when it comes to determining the probability of occurrence of the hourly values. Because the hourly values are not normally distributed then the mean and standard deviation lose their value as descriptive and useful statistics.

An interesting feature relative to the ratio of the median hourly values (on all days, 1971-1977) to the clear-day hourly values is shown in Table 1. Curiously, the ratio for the three

Table 1. Ratio of the median hourly values of solar radiation, 1971-1977, to clear-day hourly values on four days of the year at St. Paul.

Date	Ratio
March 21	0.73
June 21	0.73
September 21	0.73
December 21	0.51

days (March 21, June 21, and September 21) remains constant while on December 21 the ratio is substantially different. Why the first three days should have ratios exactly alike, except as a matter of chance, is not known at this time. The low ratio for December 21 simply seems to be a reflection of the greater cloudiness that is usually associated with the months of November and December.

The calculated amount of clear-day radiation incident on horizontal surfaces and surfaces oriented perpendicular to the sun's rays is shown in Fig. 6 for December 21. The advantage to having a solar collector oriented perpendicular to the solar rays is obvious. The radiation incident upon horizontal and perpendicular surfaces is also being calculated for the 15th day of each month plus the equinoxes and solstices. As shown in Fig. 6 the calculations will were made for both the direct beam and the diffuse radiation. It is also our intention to compare the results of different solar radiation calculation methods used to obtain direct beam and diffuse radiation with measured values.

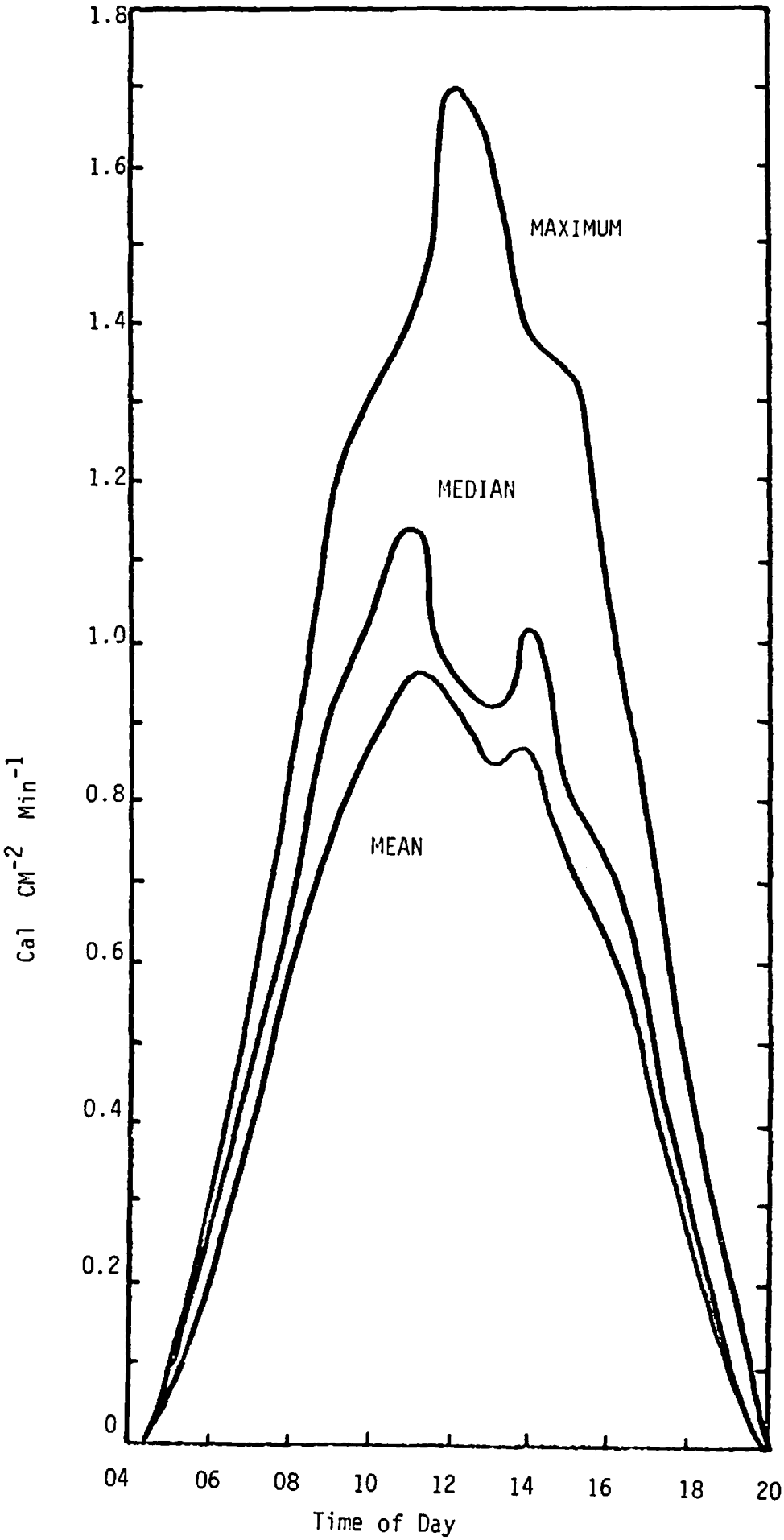


Fig. 4. Mean, Mediam and Maximum Hourly Solar Radiation Values, June 18-24, 1971-1977, St. Paul.

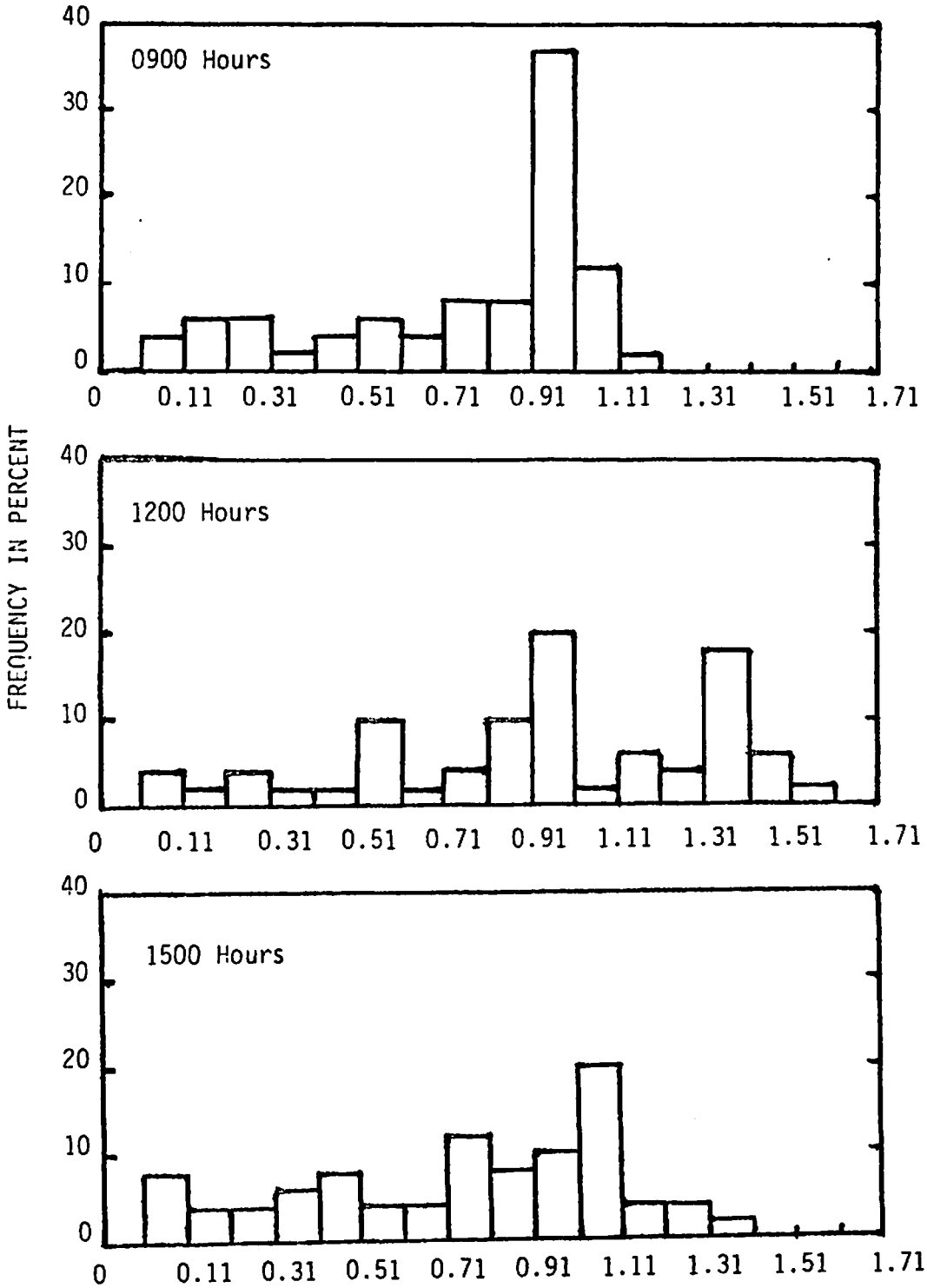


Fig. Frequency Distribution of Hourly Solar Radiation Values, June 18-24, 1971-1977, St. Paul Minn.

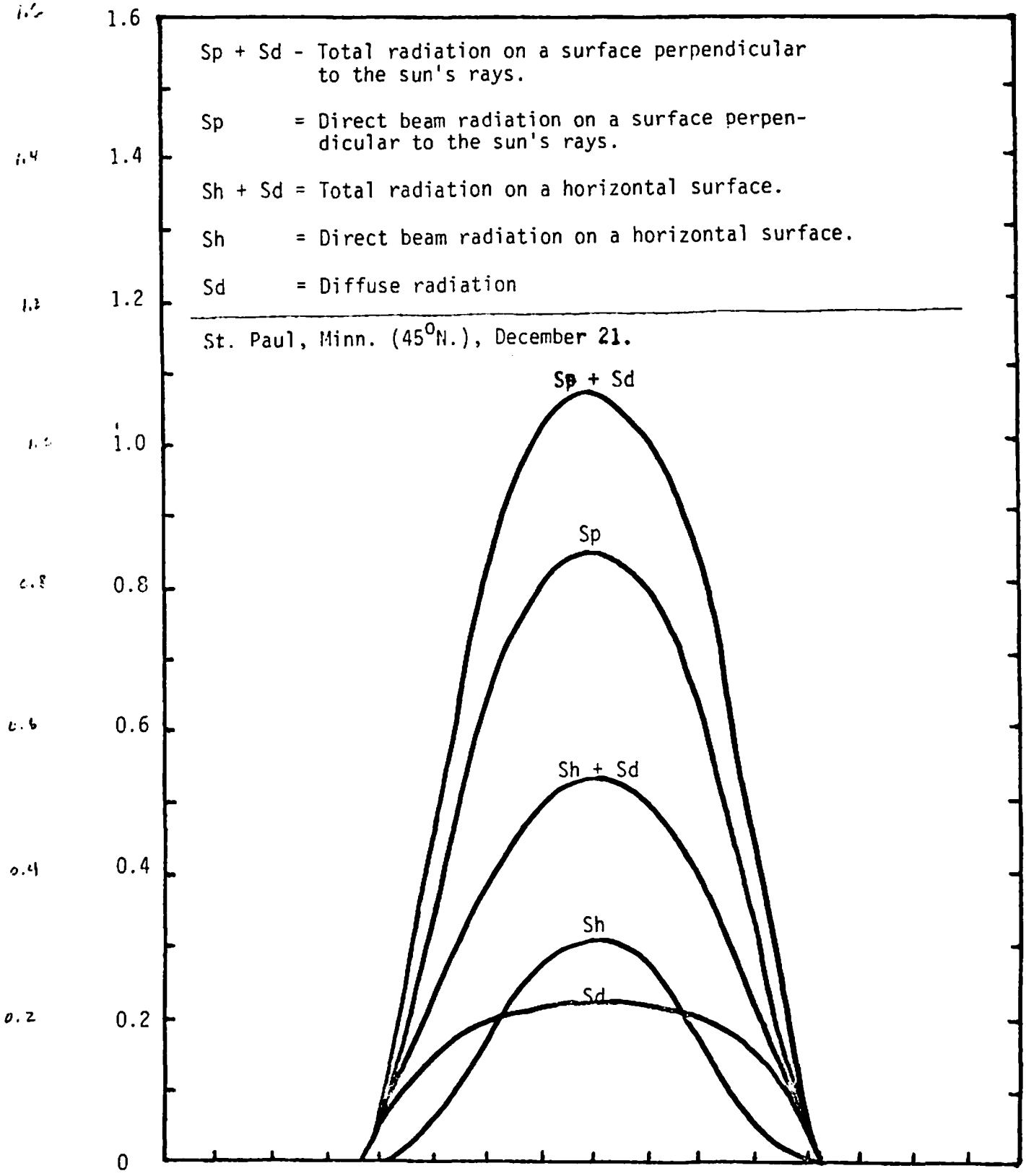


Fig. 7. Calculated amount of direct diffuse and total solar radiation received on horizontal surfaces and perpendicular to the sun at 45°N.

WIND

Just as solar energy is looked upon as an untapped source of energy that would be an excellent source given a satisfactory means of capturing and storing it, so too is wind energy. For this reason we are also studying the climatology of wind. It is our desire to provide the kind of information that an engineer can use to determine the availability and reliability of the wind as an energy source.

A number of different analyses of the available wind data have been made. A few of the results are shown in Table 2.

Table 2. Wind patterns at Minneapolis-St. Paul, 1951-1960.*

Month	Average Speed, mph.	Resultant Direction	Vector Speed, mph.	Constancy of Wind, %
January	10.5	285°	2.1	20.0
April	13.2	337°	1.7	12.9
June	11.4	150°	1.6	15.5
September	10.9	207°	2.4	22.1
December	10.7	279°	2.0	18.8
Annual	11.2	252°	0.9	8.4

*Calculations are based upon raw data from the National Weather Service Statio

The average wind speed is lowest in July and August (not shown) and is at a maximum in April. The secondary maximum is in November (not shown). Both April and November are months when the polar front lies over the region and storm activity is at a maximum. The resultant wind direction shows the monsoon-like character of the wind in Minnesota; that is, it shows a seasonal wind shift. For example, from November through April the resultant wind is westerly or northwesterly, while from May through August it is southeasterly to southerly. The constancy of the wind is never very great, as any resident can verify, because of the number of storm systems and the rapidity with which they move through the area. This, of course, brings about a rapid fluctuation in wind direction. Generally the wind is most constant in August (from 153° or SSE) and least constant in May, when all directions are nearly equally represented.

It is apparent a wind-mill or turbine to be most effective should be constructed so that it moves with the change in wind direction. Or if it is rigid then it should be constructed with the rotor in a horizontal plane so the wind direction is unimportant with respect to the capture of wind energy.

Other calculations are being made which include the amount of wind power available in different wind speed classes and times of the year. The power within wind speed classes is important since there are wind speeds above and below which most mills or turbines cannot operate. These kind of data and monthly wind roses are being determined for seven other stations besides Minneapolis-St. Paul. Examples of the monthly wind roses for the Minneapolis-St. Paul National Weather Service station are shown for January, Fig. 7, and July, Fig. 8. It is apparent that Minnesota undergoes a seasonal wind shift as is also shown in Table 2.

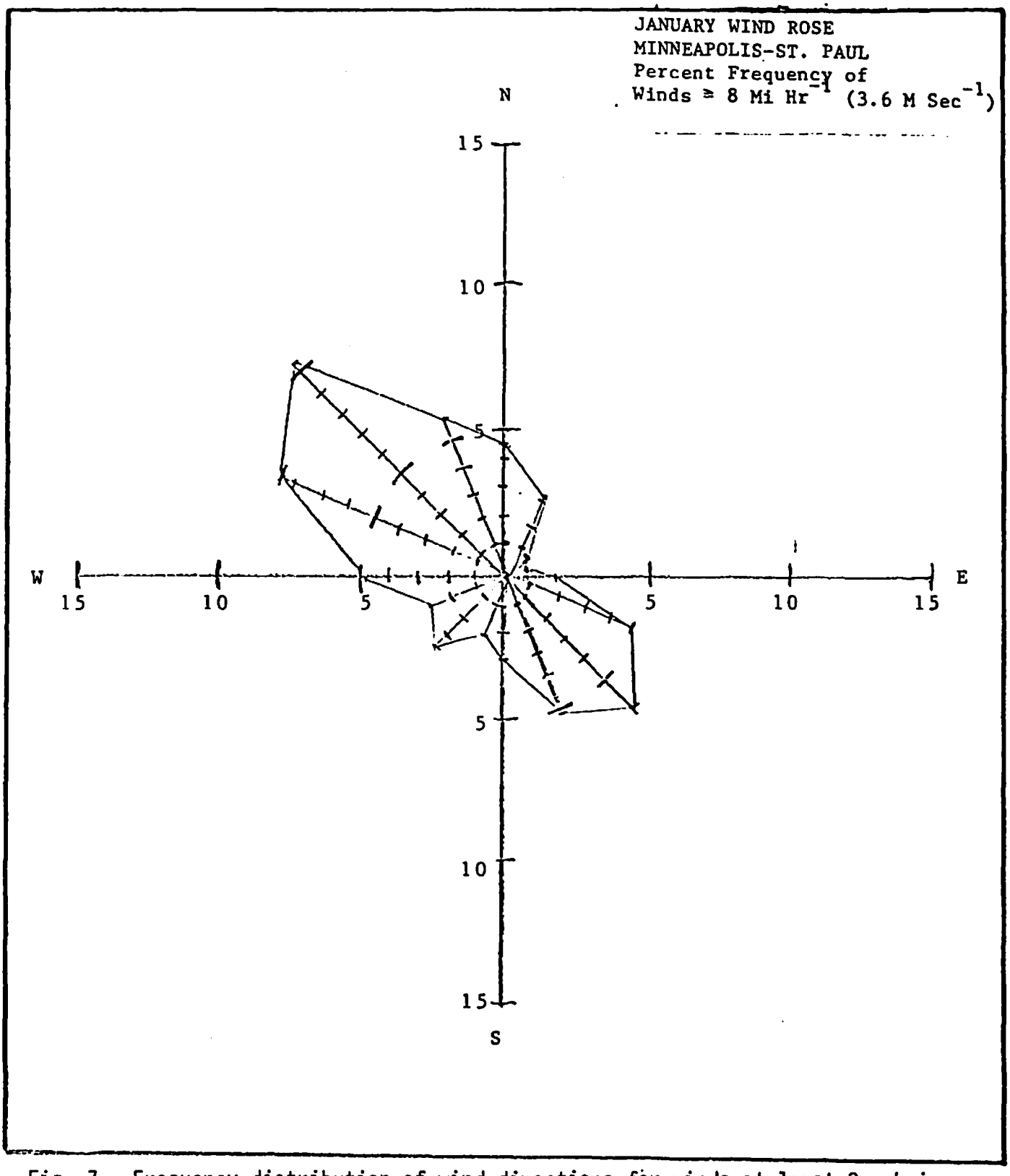


Fig. 7. Frequency distribution of wind directions for winds at least 8 mph in January at Minneapolis-St. Paul, 1951-1960.

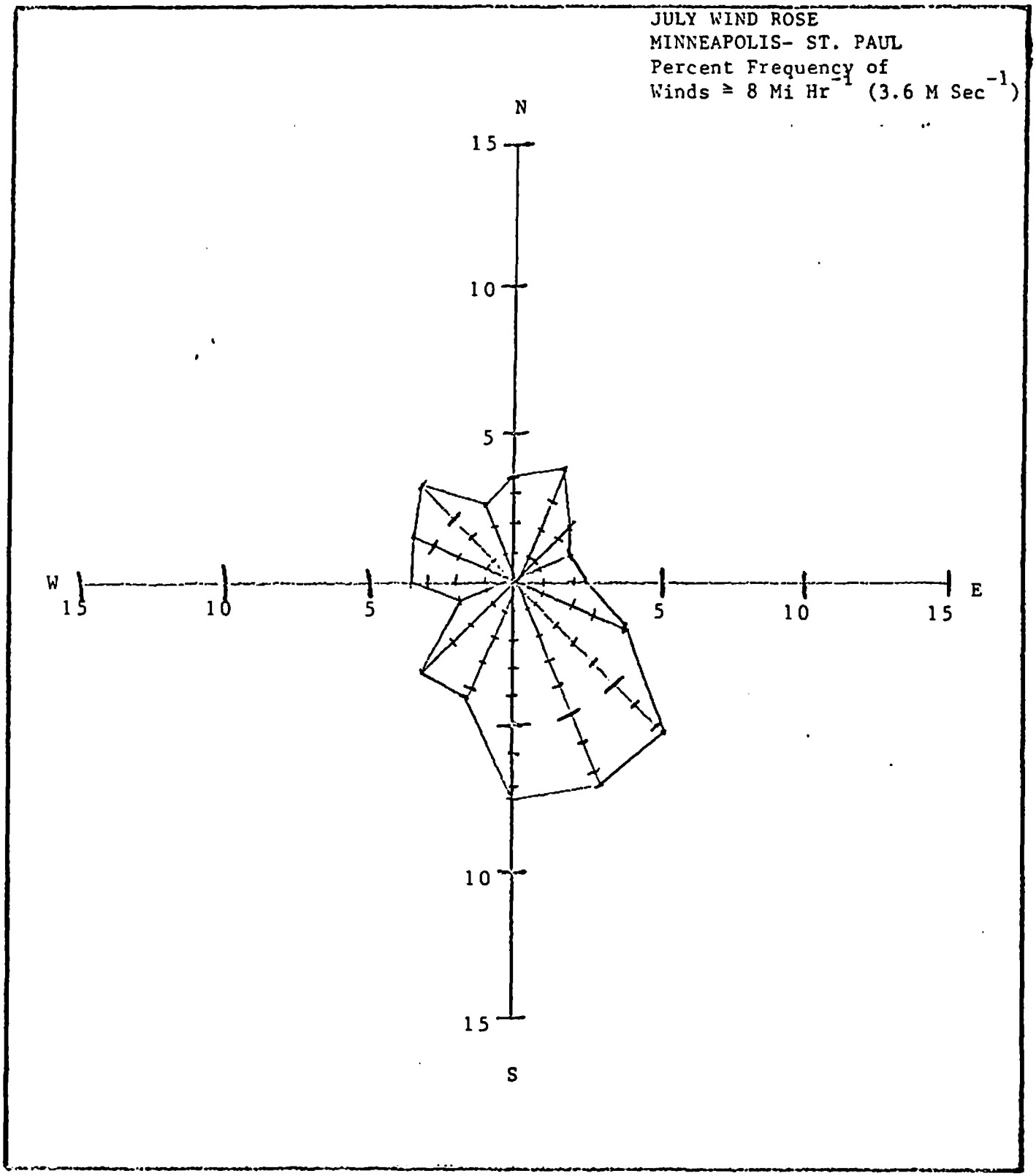


Fig. 8. Frequency distribution of wind direction for winds at least 8 mph in July at Minneapolis-St. Paul, 1951-1960.

MINNESOTA SPRING SOIL MOISTURE SITUATION MARCH 1979

D. Ruschy(Soil Sci. Dept.), E.L. Kuehnast(Minn. Dept. of Natural Res.), D.G. Baker(Soil Sci. Dept.)

Climatic conditions a year ago were quite different from today. Going into the winter of 1977-78 soil moisture was exceptionally high, nearly at the maximum water holding capacity for plants except in west-central and the southeast, but even here the soil moisture was also above normal. The 1978 crop season across the state as a whole was nearly ideal for the farmers with excellent spring soil moisture conditions, a warm and early spring for planting, timely and near or above normal summer rains with few exceptions, and a dry fall giving ideal harvesting weather.

PRECIPITATION:

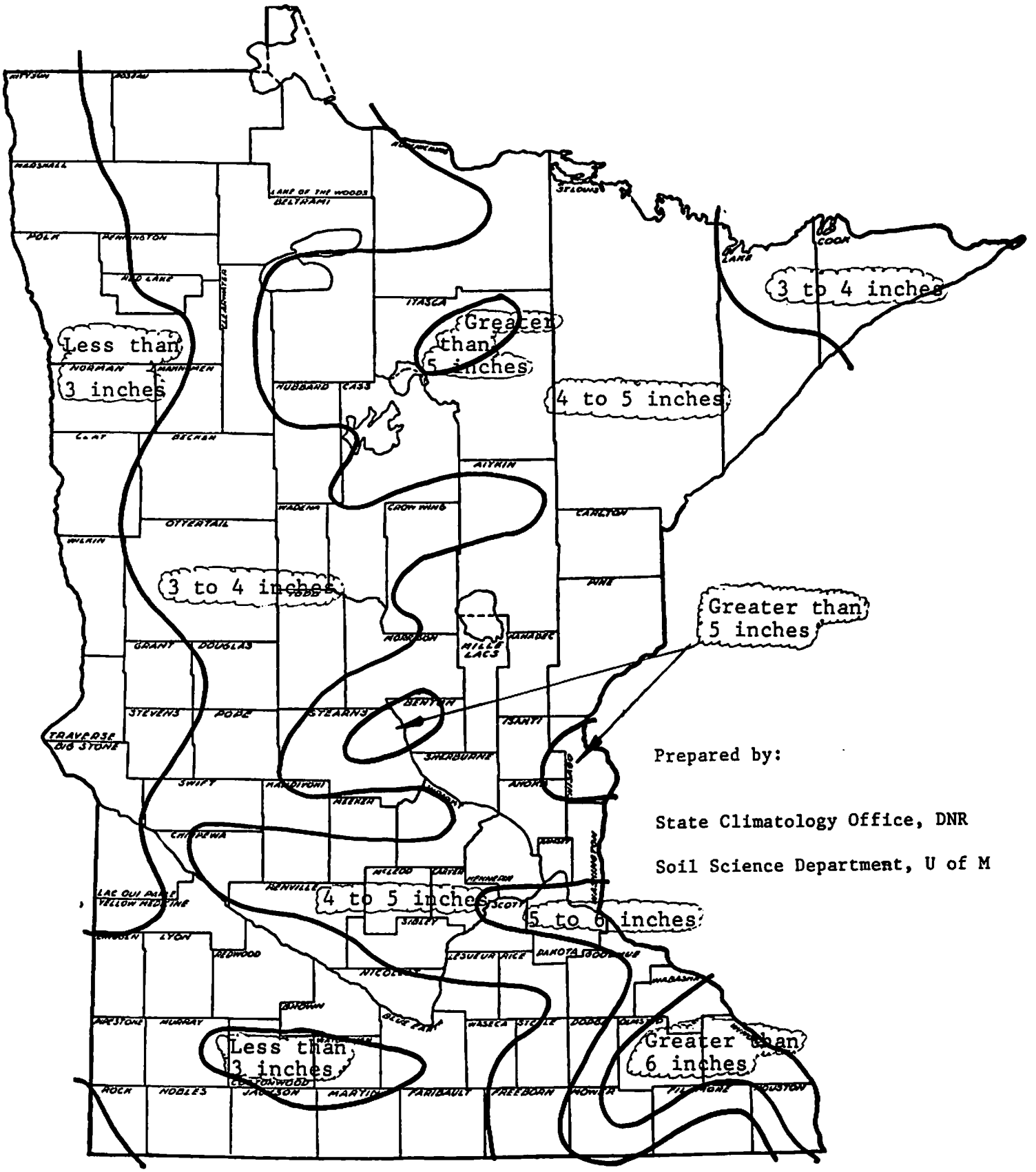
Precipitation across the state during September through Nevember, 1978, was generally below normal, exceptions being the southeastern part of the state and a strip north of the Minnesota River which averaged more than one inch above normal. The greatest September to November precipitation was 11.96 inches at Rochester and the least 1.92, at Halstad (north of Fargo).

SOIL MOISTURE:

Results of combined soil and precipitation measurements are shown in the accompanying figure. Except perhaps for some very localized spots the soils entered the winter of 1978-79 with no areas either excessively wet or dry. The wettest area is centered around Olmsted county in the southeast. Relatively dry soils are found in a 50-mile wide strip along the western border from Canada south to Yellow Medicine County, a small area that is essentially limited to Cottonwood and Watonwan Counties, and the extreme northeast in Lake and Cook Counties.

Top soil moisture was generally short across the state going into winter particularly along the western border. Presently the water content in the snow cover is generally greater than 3 inches, and with continued normal precipitation nearly 5 inches of water can be expected in the snow cover by April.

The dry top soil condition coupled with lots of water in the snow cover means that during the spring snow melt the drier top soils in western Minnesota will absorb more moisture than is ordinarily absorbed under average moisture conditions.



Estimated soil moisture in inches in the top 5 feet of soil.
Based on medium to fine soils. February 1979

CONTROLLING SOIL pH FOR POTATOES UNDER IRRIGATION (LIMY WATER) 1978

C. J. Overdahl and R. P. Schoper 1/

Lowering pH with Nitrogen

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 is expected to reduce pH faster than the other two. Soil pH readings are determined in the fall annually. Two varieties, Norland and Russet Burbank, are 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 averages 42 pounds per acre inch. The irrigation water supplied 721 pounds per acre of very fine lime in 1976, 483 pounds in 1977 and 386 in 1978.

Initial 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; K60 to 120; soil texture loamy sand.

1/ The efforts of Jerome Lensing, Mike O'Leary, and Glenn Titrud in organizing the field work is gratefully acknowledged.

Table 1. The effect of three forms of nitrogen on yield of two varieties of potatoes (Becker Farm, 1976, 1977, 1978).

Treatment*	Norland			Russets		
	Cwt/A			Cwt/A		
	1976	1977	1978	1976	1977	1978
Check	146 a	109 a	89 a	180 a	138 a	121 a
Ammonium nitrate	319 b	300 b	256 b	398 bc	370 b	373 c
Urea	372 b	288 b	234 b	408 c	354 b	330 b
Ammonium sulfate	398 b	368 c	320 c	385 b	350 b	379 c
Trt. Sign.	**	**	**	**	**	**
BLSD (5%)	84	51	27	16	48	21
Rep.	ns	ns	ns	ns	ns	ns
C. V.	17.7	12.7	8.1	9.7	10.8	4.7

*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 and 1978).

Treatment**	Norland			Russets		
	Spring	Fall	Fall	Spring	Fall	Fall
			Soil pH			
	1977	1977	1978	1977	1977	1978
Check	6.3	6.4	6.5	6.3	6.4	6.3
Ammonium nitrate	6.0	6.2	5.9	6.0	5.9	5.9
Urea	6.2	6.4	6.0	6.3	6.1	6.0
Ammonium sulfate	6.1	5.8	5.6	6.1	5.9	5.3
Significance	ns	**	**	ns	**	**
BLSD (.01)		.2	.3		.2	.2

* Calcium carbonate in irrigation water 1976, 721 lbs/acre; 1977, 483 lbs/acre; 1978, 386 lbs/acre.

** Norland received 200# N/A.
Russet Burbank received 300# N/A.

Because ammonium sulfate has double the acidifying effect of the other 2 forms of nitrogen, it is not surprising to see this form of nitrogen causing a greater lowering of pH. Table 2 shows that ammonium sulfate has reduced pH significantly more than urea or ammonium nitrate.

Tuber yield in Table 1 shows that ammonium sulfate plots produced significantly higher yield with Norlands in 1977 and 1978. Gypsum at 300 pounds per acre has been added to all plots to prevent compounding of sulfur as a nutrient in ammonium sulfate. It is possible, however, that sulfur has affected yield from the ammonium sulfate treatment. A greater quantity of gypsum will be added in 1979.

Dr. Neal Anderson of the Plant Pathology Department observed no serious scab problem on the tubers in these plots in 1978.

Lowering pH with Elemental Sulfur

Elemental sulfur was added on irrigated land on the Jerry Zimmerman farm in Sherburne County in the spring of 1978. This was broadcast and incorporated at varying rates to observe the effect of sulfur in reducing soil pH where potato scab is a problem. Table 3 shows sulfur rates and related pH measured in the fall of 1978. This trial will be followed-up for potato yield in 1979.

Table 3. The effect of elemental sulfur on soil pH on a Hubbard sandy loam. (Sherburne County, 1978)

Sulfur Treatment lbs/A	Mean Soil pH
0	5.4
500	5.2
1,000	5.0
2,000	4.6
3,000	4.7

Table 4. Elemental analyses of upper mature leaves of 2 varieties of potatoes according to nitrogen forms. Becker Farm, July 7, 1978.

	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%				ppm				
Norlands									
None	.35	4.72	2.03	.61	357	146	16	5	32
AN	.31	4.70	1.45	.49	176	169	17	6	39
Urea	.32	4.72	1.49	.51	235	176	19	6	40
AS	.29	4.83	1.35	.45	238	370	20	6	39
Russets									
None	.33	4.23	1.16	.61	406	56	16	8	31
AN	.30	4.50	1.03	.58	221	140	17	6	25
Urea	.32	4.10	.99	.61	201	98	18	7	23
AS	.30	4.28	.77	.45	213	264	19	7	33
Common Ranges for most research*	.20	4.0	2.0	.50	70	30	20	-	30
	.40	8.0	4.0	.80	150	50	40	-	40
Intermediate level**	.20	5.8	---	.40	---	40	17	3	--

* Soil Testing and Plant Anaylsis. SSSA p. 368
** Diagnostic Criteria. H. D. Chapman. University of California

Average of 4 reps for each variety

MICRONUTRIENT TESTS ON ALFALFA

Becker, MN 1978

C. J. Overdahl and Jerome Lensing

Micronutrient trials on both irrigated and unirrigated alfalfa were established at Becker in the spring of 1977. Dairy farmers are seeking information on the micronutrient needs on sandy textured soils, generally with neutral or slighly acid pH. The plot was located on a Hubbard loamy coarse sand.

One rate of each nutrient was compared to none or to a complete mixture of all micronutrients. The nutrients and rates were applied in April 1977 as follows:

Material	Nutrient	Content %	Rate/acre
sodium molybdate	molybdenum (Mo)	39.6	4 oz
solubor	boron (B)	20.5	2 lbs
copper sulfate	copper (Cu)	25.2	10 lbs
zinc sulfate	zinc (Zn)	36	10 lbs
iron chelate 138	iron (Fe)	6	.6 lbs
manganese sulfate	manganese (Mn)	32.5	10 lbs

Sulfur at 100 pounds per acre was applied across all plots, except the "no-sulfur" plots, as fortified gypsum (2/3 gypsum, 1/3 elemental S). Sulfur was omitted on a special plot in each replicate to get an idea about sulfur needs. In the spring of 1977 340 pounds per acre of K_2O was applied to all plots. Phosphorus tests were very high (30 to 45 range), no phosphorus was added. The pH ranged from 6.1 to 6.3, but 500 to 1000 pounds of lime each year would be added in the irrigation water, depending on the amount of irrigation. No lime was added. After the second cutting in 1978, 240 pounds of K_2O was added to keep potassium levels high. The initial K test was less than 100 pounds of exchangeable K per acre. The irrigated and unirrigated plots were each replicated 4 times.

Alfalfa yields at 15 percent moisture in 1978 from the 3 cuttings are shown in Table 1.

The efforts of Glenn Titrud and Mike O'Leary are gratefully acknowledged.

Table 1. Alfalfa yields from micronutrient treatments in 1977. Becker, MN. non-irrigated plots, 1978.

Micronutrient Treatments per acre	Alfalfa yield Tons/acre 1st cut	2nd cut	3rd cut	Total
None	1.04	1.72	.92	3.68
Mo 4 oz	.94	1.67	.89	3.50
B 2 lbs	1.09	1.60	.88	3.57
Cu 10 lbs	1.08	1.70	.90	3.68
Zn 10 lbs	1.03	1.64	.88	3.56
Fe 0.6 lb	1.07	1.76	.92	3.75
Mn 10 lbs	1.01	1.68	.88	3.56
"shot-gun" all above	.99	1.70	.88	3.57
no-sulfur[1/]	.98	1.58	.82	3.38
Significance	ns	ns	ns	ns
BLSD (5%)	-	-	-	-

[1/] "no sulfur" plot had a significantly lower yield on the second cutting at 5% level compared to no micronutrient treatment yield.

Table 2. Alfalfa yields from micronutrient treatments in 1977. Becker, MN. irrigated[1/] plots. 1978.

Micronutrient Treatments per acre	Alfalfa yield Tons/acre 1st cut	2nd cut	3rd cut	Total
None	1.27	1.84	.84	3.95
Mo 4 oz	1.39	1.99	.97	4.35
B 2 lbs	1.38	1.88	.95	4.21
Cu 10 lbs	1.36	1.89	.91	4.16
Zn 10 lbs	1.25	1.80	.90	3.95
Fe 0.6 lb	1.43	2.14	.97	4.54
Mn 10 lbs	1.33	1.96	.88	4.17
"shot-gun" all of above	1.32	1.96	.97	4.25
no-sulfur	1.34	1.84	.94	4.12
Significance	ns	ns	ns	ns

[1/] irrigated plot was watered regularly in 1977, but high rainfall (28.5 inches during growing season) permitted omitting of irrigation in 1978.

Micronutrient Fertilization of Potatoes and Corn Under Irrigation

G.L. Malzer, T. Graff, J. Lensing and G. Titrud

The need for micronutrient fertilization and application of fertilizers other than those which supply N, P, and K continue to be of concern to the producers of potatoes and corn as well as other crops on the coarse textured soils under irrigation. Because of the intensive management operations, high yield potentials, and often low nutrient supplying capacities of these soils, conditions may develop where yield reductions due to the lack of an essential nutrient other than N, P, or K may occur. Three separate experiments were established at the Sand Plains Research farm at Becker, MN. in 1978 to assess the significance of certain plant nutrients other than N, P, and K on yield and nutrient composition of the plant tissue for potatoes and corn.

EXPERIMENTAL PROCEDURES

Seven treatments, including a control, four micronutrient treatments, and two macronutrient treatments were established in a randomized complete block design with four replications. Rates and types of fertilizer applied included: 5 lbs Copper/A as $Cu(NO_3)_2$, 2 lbs Boron/A as Solubor, 25 lbs of Sulfur/A as $CaSO_4$, 75 lbs of Magnesium/A as $MgCl_2$, 10 lbs of Zinc/A as $ZnCl_2$, and 3 lbs of Manganese/A as $MnCl_2$. All treatments were applied as preplant broadcast and incorporated treatments.

The soil was a Hubbard coarse sand with a pH of 6.3, Bray P-1 of 32, exchangeable K, Ca, Mg of 186, 1260, and 250#/A, DTPA extractable Zn, Mn, and Cu of 1.7, 17 and .53 ppm organic matter content of 2.5% and water extractable SO_4-S of 15 ppm. The entire area was spring plowed, and the two experiments with potatoes sprayed with 3½ lbs/A of Eptam (54 gal/A) incorporated for weed control. Fertilizer treatments were applied, incorporated by discing and the potatoes planted on April 27th. Norlands were planted in nine inch spacings utilizing 36 inch rows, while Russet Burbanks were planted in 12" spacings with the same row width. At the time of planting starter was used at 1200 lbs/A of 8-10-30 and an insecticide, Temik 15G banded at 14 lbs/A. Lorox herbicide was applied on May 16th at 1½ lbs/A (54 gal/A spray) for additional weed control. Sidedressing treatments of nitrogen were made on May 30 (170 lbs/A of 34-0-0) and on June 17 (220 lbs/A of 34-0-0), along with hilling at the last sidedressing. Samples of the youngest mature potato leaves were obtained 69 days after planting for nutrient composition. The Norland potatoes were harvested on Aug. 31 and the Russet Burbanks on Sept. 21. Irrigation water was applied during the period of June 6 through August 17th with a total addition of 8.35 inches. Precipitation during the period of May-Aug. was 17.3 inches and May-September was 22.6 inches.

Utilizing the same treatments, a third experimental area was planted to corn. The area had been fertilized with 550 lbs/A of 8-10-30 prior to planting on May 5. A commercial corn variety (Pioneer 3901) was planted in 30 inch rows at a population of 30, 700 seeds/A. Starter fertilizer at the rate of 150 lbs/A of 8-10-30 was utilized at planting time followed by a tank mix (54 gal/A) of Atrazine (1 lb/A a.i.) and Lasso (1½ lbs/A a.i.) for weed control. Sidedressing applications of nitrogen were made on June 1 (230 lbs/A of 34-0-0) and June 23 (320 lbs/A of 34-0-0) for a total addition of 243 lbs of N/A for the season. In addition to the 22.6 inches of

precipitation received during the growing season an additional 9.45 inches was added through irrigation during the period of June 6th through September 5th.

General Results

Preliminary soil tests from the experimental area would suggest that large yield response due to addition of the nutrient elements under investigation would not be anticipated. As expected, no significant yield increases were obtained with either the Norland or Russet Burbank potatoes as well as with corn. Yield levels were high in all three experiments. Increased nutrient concentrations in the potato leaves due to direct nutrient application were observed for copper with the Norland potatoes and for Zn, Cu and B with Russet Burbank potatoes. Increased concentrations of Zn and B in the leaf opposite and below the ear at silking as well as increased B levels in the silage stover were obtained due to the treatments. In all cases nutrient concentrations were deemed adequate for good plant growth.

Table 1. Influence of micronutrient fertilization (also Mg and S) on tuber yield and nutrient concentration of youngest mature leaf 69 days following planting for Norland and Russet Burbank potatoes.

Treatment	Tuber Yield	Leaf Concentration N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Co
	cwt/A	%					ppm							
Norland Potatoes														
Control	402	4.93	.39	4.57	1.48	.82	63	148	49	101	21	7	34	3
Cu	431	4.82	.39	4.55	1.69	.86	63	288	71	114	22	10	36	3
B	420	4.99	.38	4.48	1.41	.76	38	132	28	114	22	7	37	3
S	389	5.08	.38	4.46	1.53	.85	71	153	45	100	21	7	32	3
Mg	378	5.09	.40	4.54	1.26	.77	43	136	44	86	24	7	31	3
Zn	414	4.97	.38	4.40	1.70	.94	82	161	55	115	24	7	33	3
Mn	415	4.89	.38	4.57	1.53	.85	70	151	33	106	22	7	33	3
Signif.	NS	NS	NS	NS	(.10)	NS	NS	NS	NS	NS	NS	**	NS	NS
BLSD(.05)	-	-	-	-	.29	-	-	-	-	-	-	1	-	-
Russet Burbank Potatoes														
Control	427	5.13	.37	4.01	.81	.64	124	166	39	84	22	6	27	3
Cu	419	5.01	.37	4.19	.86	.67	99	150	64	76	22	7	26	3
B	446	5.04	.37	4.25	.80	.60	109	154	45	85	22	6	30	3
S	435	5.01	.36	4.21	.84	.63	118	160	53	84	22	5	27	3
Mg	407	5.17	.35	4.04	.78	.63	109	155	54	78	22	5	26	3
Zn	437	5.13	.38	4.28	.83	.66	99	150	45	72	25	6	26	3
Mn	424	4.92	.35	4.20	.86	.65	120	160	47	87	21	5	27	3
Signif.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	NS
BLSD(.05)	-	-	-	-	-	-	-	-	-	-	2	1	3	-

Table 2. Influence of micronutrient fertilization (also Mg and S) on corn grain yield, dry matter production, and elemental composition of the leaf opposite and below the ear at silking.

Treatment	Harvest Grain: Yield 15.5% M	Harvest Grain: Dry Matter	Harvest Grain: N Removal	Dry Matter (Physiological Maturity): Stover	Dry Matter: Grain	Dry Matter: Total	N Removal: Stover	N Removal: Grain	N Removal: Total
	bu/A	%	#/A	T/A					
Control	195.5	61.4	143.9	4.52	4.71	9.23	72.5	135.6	208.1
Cu	193.9	65.1	137.2	4.36	4.48	8.84	73.6	124.5	198.2
B	195.2	61.2	127.6	4.18	4.42	8.60	80.3	125.7	206.0
S	194.2	63.7	137.4	4.30	4.64	8.94	63.5	130.7	194.2
Mg	197.3	64.4	134.5	4.25	4.33	8.58	59.7	126.5	186.2
Zn	202.2	63.0	137.8	4.09	4.58	8.67	73.3	133.7	207.0
Mn	195.2	60.8	139.1	4.43	4.55	8.98	65.6	127.0	192.7
Signif.	NS	NS	NS	NS	NS	NS	*	NS	NS
BLSD(.05)							14.4		

	Leaf Nutrient Composition: N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	%					ppm						
Control	3.05	.33	2.79	.51	.23	59	138	64	98	25	13	8
Cu	3.14	.34	2.95	.48	.21	60	136	61	98	25	14	8
B	2.99	.34	2.65	.49	.23	58	136	64	88	24	13	10
S	3.08	.34	3.02	.50	.19	59	142	59	104	25	14	8
Mg	2.95	.32	2.89	.48	.27	63	180	73	83	24	12	8
Zn	2.88	.30	2.76	.46	.22	71	145	66	72	32	11	8
Mn	2.88	.32	3.00	.47	.23	70	140	70	85	25	12	8
Signif.	*	+	+	NS	NS	NS	NS	NS	NS	**	NS	*
BLSD(.05)	.20	.03 (.10)	.26 (1.[illegible])							4		1

Table 3. Elemental composition of Silage Stover and Harvest grain as influenced by micronutrient (also Mg & S) fertilization

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B
	Silage Stover-Elemental Concentration											
	%					ppm						
Control	.80	.08	1.71	.34	.14	139	148	77	87	17	12	6
Cu	.84	.08	1.77	.36	.15	134	145	78	94	19	13	6
B	.96	.08	1.82	.36	.14	129	130	82	102	15	14	10
S	.74	.07	1.85	.32	.11	129	122	78	87	15	12	8
Mg	.70	.07	1.82	.32	.16	104	109	77	78	16	11	5
Zn	.90	.08	1.74	.36	.14	119	120	78	92	20	14	6
Mn	.74	.07	1.76	.37	.20	121	119	82	77	19	11	6
Signif.	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
BLSD(.05)	.08											2
	Corn Grain-Elemental Concentration											
Control	1.56	.31	.46	.04	.13	4	22	52	7	25	4	1
Cu	1.50	.31	.46	.04	.13	4	23	58	6	25	5	1
B	1.38	.29	.43	.04	.12	4	23	31	8	24	5	2
S	1.50	.30	.46	.04	.13	4	24	42	8	24	5	1
Mg	1.44	.30	.45	.05	.12	4	24	42	7	25	5	1
Zn	1.44	.31	.45	.05	.13	5	25	43	8	28	5	2
Mn	1.50	.29	.46	.03	.12	4	21	40	7	24	4	1
Signif.	*	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
BLSD(.05)	.09						2					

Influence of Nitrogen Form, Nitrification Inhibitors, and Treatment Incorporation on Yields, and Nitrogen Utilization of Corn Under Irrigation

G.L. Malzer, T.J. Graff and J. Lensing

A number of management alternatives are available for the producer concerned with nitrogen management for corn production under irrigation. The producers must be concerned not only with rates of nitrogen, but must also be prepared to consider timing of application, form of nitrogen, and method of application. The use of nitrification inhibitors under irrigation also presents some new considerations in nitrogen management. The most common method for application of nitrification inhibitors is with simultaneous application of anhydrous ammonia. Under irrigation, nitrogen application may take place in several manners, ranging from one single application at some point during growing season to many small applications which may be facilitated through the irrigation water. With such management systems, a variety of fertilizer nitrogen forms may be utilized. Utilization of nitrification inhibitors under such diverse systems creates a number of questions, such as: Can nitrification inhibitors be applied with the irrigation water? Do they react differently with nitrogen forms other than anhydrous ammonia? Must the products be incorporated to be effective? To investigate some of these concerns a trial was established at the Sand Plains Research Farm near Becker, MN. with the following objectives: 1) to compare the use of urea and 28% nitrogen solutions under irrigation, 2) to evaluate the use of N-Serve (Dow Chemical) and Terrazole (Olin corporation) with different nitrogen forms, and 3) to determine the impact of surface applied and incorporated combinations of the previous treatments.

Experimental Procedures

A total of eight main treatments were replicated four times and arranged in a split block design to generate 16 treatment comparisons. Six of the main treatments consisted of two nitrogen forms (urea and 28% nitrogen solution) with three nitrification inhibitor treatments (none, N-Serve-0.5#ai/A, Terrazole-0.5#ai/A). In the above treatments all nitrification inhibitor applications were made as coatings onto urea prior to application or were mixed into 28% nitrogen solution prior to application. Two additional main treatments were established with urea, where urea was broadcast on the soil prior to a spray application of the nitrification inhibitor treatments. Each main plot was split to provide an incorporated (discing) and a non-incorporated comparison. All treatments received a total of 120#N/A in a spring preplant application. The experimental area had been previously fertilized with 300#/A of K-$MgSO_4$ (0-0-22), 260#/A of 0-0-60, and incorporated by plowing on April 4th. Treatments were applied on April 27, and areas requiring incorporation were disced immediately after application. Corn (Pioneer 3901) was planted into the experimental area on May 5 at a rate of 30,700 seeds/A in 30" rows. Starter fertilizer at 150#/A of 0-18-36 was utilized at planting. A tank mix of Atrazine (1#ai/A) and Lasso (1½#ai/A) was utilized for weed control. The irrigation program was initiated on June 5 and continued through September 6 with a total of 8.75 inches of water being applied through irrigation and 22.31 inches coming through rainfall.

Leaf samples from opposite and below the ear at 50% silking were taken from each plot on July 6, 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 7 and 8 (Physiological maturity). Ears were separated from the stalks, field weights obtained and samples removed for moisture determination and nitrogen analysis. Yields were obtained on September 21 and 22 by hand harvesting two rows 20' long. Field weights were obtained and samples collected for moisture and nitrogen determination. Corn grain yields were adjusted to 15.5% moisture.

General Results

Nitrogen concentration in the leaf opposite and below the ear at 50% silking, yield, and nitrogen removal with the yield grain are reported in Table 1. The general nitrogen status of the corn plant as reflected with the nitrogen content of the leaf at silking and grain yield suggested that the nitrogen availability from the urea treatments was greater than when 28% nitrogen solution. This does not in itself suggest that urea is a superior fertilizer to 28% nitrogen solution, but reflects the timing and initial chemical form of the nitrogen fertilizer. Nitrogen solution (28%) is a mixture of urea and ammonium nitrate (approx. 50-50) fertilizers. As applied, therefore, approximately 25% of the nitrogen fertilizer in the solution will be applied as nitrate nitrogen. This nitrate nitrogen is immediately susceptable for losses through leaching (or denitrification) if the climatic conditions develop. The remaining 75% of the nitrogen in the 28% nitrogen solution as well as 100% of the nitrogen in urea must be transformed from the ammonium form to the nitrate form(nitrification) before leaching or denitrifications can occur. The differences observed between urea and 28% nitrogen solutions are probably due to loss of the nitrate nitrogen from the solution, which were intensified because of the early spring application. The use of both nitrification inhibitors, N-Serve and Terrazole, produced yield responses in excess of 50 bu/A, but only when the treatments were incorporated. No positive yield responses were obtained with either inhibitor unless the treatments were incorporated, and when effective both chemicals produced similar results. Separate applications of fertilizer followed by spraying and incorporation of the chemical produced similar results as when the chemicals were coated onto urea. Both nitrification inhibitors when incorporated were effective and produced yield responses with urea and 28% nitrogen solution. Larger yield responses were obtained with urea than with 28% solutions because of nitrogen losses from the nitrate portion of the fertilizer. Nitrification inhibitors are not effective in minimizing nitrogen losses when the nitrogen initially starts out in the nitrate form.

Dry matter production, nitrogen content and nitrogen removal, in general followed similar trends as to those which were established with yields. As would be expected, those treatments which improved nitrogen availability and higher yields also produced corn grain with a lower moisture content at harvest (higher dry matter). Total nitrogen removal by the stover and grain ranged from 63#N/A with 28% solution to 124#N/A when N-Serve was applied with urea and incorporated, suggesting that nitrification inhibitors when utilized properly can lead to improved nitrogen utilization and yield increases when used in those areas which demonstrate substantial nitrogen losses.

Table 1. Influence of nitrogen form, nitrification inhibitors and treatment incorporation on leaf nitrogen concentration, grain yield and nitrogen utilization by the grain.

Treatments 1/			Leaf	Corn Grain			
N Form	Inhibitor	Incorporation	N	Yield	DM at Harvest	N Content	N Removal
			%	bu/A	%	%	#/A
Urea	-	Yes	1.59	100.7	59.2	.98	47.0
Urea	-	No	1.54	91.8	60.3	1.00	43.6
28%	-	Yes	1.15	77.7	58.1	.92	34.1
28%	-	No	1.30	76.4	55.2	.95	34.8
Urea	Terr.	Yes	2.11	144.5	64.6	1.16	79.2
Urea	Terr.	No	1.50	85.4	57.9	.95	38.3
Urea	N-S	Yes	2.24	154.6	63.6	1.16	84.9
Urea	N-S	No	1.66	93.0	58.0	.95	41.9
28%	Terr.	Yes	1.44	111.8	61.1	1.06	56.2
28%	Terr.	No	1.17	83.1	58.5	1.01	39.6
28%	N-S	Yes	1.34	115.6	59.4	.95	52.7
28%	N-S	No	1.55	91.2	58.7	1.01	43.3
Urea	Terr.(Spray)	Yes	2.12	151.8	64.8	1.14	82.1
Urea	Terr.(Spray)	No	1.32	90.4	58.8	.94	40.1
Urea	N-S(Spray)	Yes	2.05	136.8	65.1	1.07	69.2
Urea	N-S(Spray)	No	1.12	85.0	57.2	.97	39.1
Significance			**	**	**	**	**
BLSD(.05)			.27	16.9	3.0	.07	9.3
N Form x Inhibitor							
Urea	-		1.57	96.2	59.8	.99	45.3
28%	-		1.22	77.1	56.7	.94	34.4
Urea	Terr.		1.80	115.0	61.3	1.05	58.7
Urea	N-S		1.95	123.8	60.8	1.06	63.4
28%	Terr		1.31	97.4	59.8	1.04	47.9
28%	N-S		1.44	103.4	59.1	.98	48.0
Urea	Terr.		1.72	121.1	61.8	1.04	61.1
Urea	N-S		1.58	110.9	61.2	1.02	54.1
Significance			**	**	**	**	**
BLSD(.05)			.13	18.0	2.3	.05	9.6
Incorporation							
Yes			1.76	124.2	62.0	1.06	63.2
No			1.39	87.0	58.1	.97	40.1
Significance			**	**	**	**	**
BLSD(.05)			.27	8.2	1.3	.03	4.7

1/ All treatments received 120#N/A preplant.

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

Treatments[1/]			Corn Forage Production				
			Dry Matter Yield			Dry Matter at Harvest	
N Form	Inhibitor	Incorporation	Stover	Grain	Total	Stover	Grain
			T/A			%	
Urea	-	Yes	2.61	2.10	4.70	28.6	51.0
Urea	-	No	2.67	2.10	4.77	29.2	52.0
28%	-	Yes	2.16	1.65	3.81	28.8	49.6
28%	-	No	2.34	1.83	4.17	28.4	50.5
Urea	Terr.	Yes	3.23	3.04	6.27	30.4	54.3
Urea	Terr.	No	2.75	2.06	4.81	31.2	50.8
Urea	N-S	Yes	3.32	3.11	5.42	30.0	54.0
Urea	N-S	No	2.76	1.94	4.70	29.8	49.3
28%	Terr.	Yes	2.72	1.80	4.53	32.0	50.7
28%	Terr.	No	2.43	1.67	4.09	27.1	49.5
28%	N-S	Yes	2.52	2.12	4.64	26.4	51.0
28%	N-S	No	2.86	2.09	4.95	29.6	53.5
Urea	Terr.(Spray)	Yes	3.63	3.15	6.77	31.8	57.7
Urea	Terr.(Spray)	No	2.68	2.24	4.91	28.3	51.5
Urea	N-S(Spray)	Yes	3.15	2.64	5.78	29.6	54.3
Urea	N-S(Spray)	No	2.45	1.83	4.28	29.0	50.0
Significance			**	**	**	NS	*
BLSD(.05)			.46	.61	.74		4.6
N Form x Inhibitor							
Urea	-		2.64	2.10	4.74	28.9	51.5
28%	-		2.25	1.74	3.99	28.6	50.0
Urea	Terr.		2.99	2.55	5.54	30.8	52.6
Urea	N-S		3.04	2.52	5.56	29.9	51.7
28%	Terr.		2.57	1.74	4.31	29.6	50.1
28%	N-S		2.69	2.10	4.79	28.0	52.3
Urea	Terr.		3.15	2.69	5.84	30.1	54.6
Urea	N-S		2.80	2.23	5.03	29.3	52.2
Significance			*	**	**	+	NS
BLSD(.05)			.57	.54	1.02	3.8	
Incorporation							
Yes			2.92	2.45	5.37	29.7	52.8
No			2.62	1.97	4.58	29.1	50.9
Significance			**	**	**	NS	**
BLSD(.05)			.21	.27	.35		1.9

[1/] All treatment received 120#N/A preplant.

Table 3. Influence of nitrogen form, nitrification inhibitors and treatment incorporation on nitrogen content and nitrogen removal of corn forage at physiological maturity.

Treatments[1/]			Corn Forage				
			N Content		N Removal		
N Form	Inhibitor	Incorporation	Stover	Grain	Stover	Grain	Total
			%		#/A		
Urea	-	Yes	.46	1.01	43.5	42.7	86.2
Urea	-	No	.42	1.02	38.8	43.2	82.0
28%	-	Yes	.41	.95	31.6	31.8	63.4
28%	-	No	.43	.95	36.0	34.9	70.9
Urea	Terr.	Yes	.44	1.08	55.7	65.5	121.2
Urea	Terr.	No	.45	.97	42.8	39.9	82.7
Urea	N-S	Yes	.44	1.10	55.9	68.9	124.8
Urea	N-S	No	.38	1.05	35.1	41.1	76.2
28%	Terr.	Yes	.39	.94	35.3	34.0	69.3
28%	Terr.	No	.40	.95	32.9	31.8	64.7
28%	N-S	Yes	.52	1.03	48.5	43.6	92.1
28%	N-S	No	.41	.93	40.7	39.2	79.9
Urea	Terr.(Spray)	Yes	.39	1.06	52.8	66.9	119.7
Urea	Terr.(Spray)	No	.45	1.06	44.5	48.1	92.6
Urea	N-S(Spray)	Yes	.38	.98	44.4	51.7	96.1
Urea	N-S(Spray)	No	.42	.96	36.4	35.5	71.9
Significance			**	NS	*	*	**
BLSD(.05)			.05		9.1	16.8	20.9
N Form x Inhibitor							
Urea	-		.44	1.02	41.2	42.9	84.1
28%	-		.42	.95	33.8	33.4	67.2
Urea	Terr.		.44	1.02	49.3	52.7	102.0
Urea	N-S		.41	1.07	45.5	55.0	100.5
28%	Terr.		.39	.94	34.1	32.9	67.0
28%	N-S		.46	.98	44.6	41.4	86.0
Urea	Terr.		.42	1.06	48.6	57.5	106.1
Urea	N-S		.40	.97	40.4	43.6	84.0
Significance			*	**	*	**	**
BLSD(.05)			.04	.05	19.5	12.5	14.7
Incorporation							
Yes			.43	1.02	46.0	50.6	96.6
No			.42	.99	38.4	39.2	77.6
Significance			NS	*	**	**	**
BLSD(.05)				.03	3.9	6.9	9.2

[1/] All treatment received 120#N/A preplant.

Influence of Nitrogen Rate, Timing of Nitrogen Application and Use of Nitrification Inhibitors for Irrigated Spring Wheat and Corn.

G.L. Malzer, T.J. Graff and J. Lensing

Nitrogen management on the coarse textured irrigated soils of Minnesota is a primary management decision that all producers must consider if they are to maximize profits from their operations. Efficient nitrogen management along with other inputs should result in high yields at reduced inputs and therefore increased profits for the producer. Because of the high probability that these areas of Minnesota may receive large amounts of precipitation in the spring and early summer, coupled with the water that is added through irrigation, the risk is great that appreciable quantities of nitrate nitrogen may be removed from the rooting zone by leaching prior to the time of plant need. These fertilizer nitrogen losses not only cost the producer money in the investment but may also result in reduced yields, and contamination of shallow aquifers with nitrate nitrogen. Efficient nitrogen management must therefore take many things into consideration including nitrogen rate, nitrogen form, timing of application and method of application.

In most cases the most efficient time to apply nitrogen is just prior to and in proportion to plant demand. Under many management operations this may not be physically possible or economically feasible. When the crop is growing rapidly, plant demands may exceed the rate at which nitrogen can be applied through an irrigation system, thus potentially limiting production. The commercial availability of products known as nitrification inhibitors may provide another tool in nitrogen management for the producer under irrigation. These products are designed to slow the rate at which fertilizer ammonium nitrogen is converted to nitrate nitrogen, thereby minimizing the losses of nitrate nitrogen which may occur during the season. The objective of these experiments were 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 2½% organic matter.

Wheat Experiment

Broadcast applications of Potassium-Magnesium Sulfate (300#/A 0-0-22) and phosphorus (90#/A 0-46-0) were made on April 4, 1978 and incorporated by plowing. Nitrogen experimental variables included a check (0N) and four rates of nitrogen (45, 90, 135 and 180 #N/A) as urea. Nitrogen was applied as single preplant applications on April 11 or as split application with 2/3 as preplant and 1/3 of the nitrogen rate applied at the early boot stage of growth (June 5). Nitrification inhibitor treatments included: fertilizer alone, fertilizer with N-Serve (Dow Chemical - 0.5#ai/A), and fertilizer with Terrazole (Olin Corporation - 0.5 #ai/A) at the pre-

ceding rates and times of application. Preplant fertilizer treatments were broadcast over the plot area (12' x 20') and incorporated immediately by discing. (Split application were incorporated by irrigation). All nitrification inhibitor treatments were applied as coatings onto the urea fertilizer. The experimental area was planted with spring wheat (Era) on April 11 at the rate of 2 bu/A in 6" rows. Starter fertilizer was applied as 20# P_2O_5/A with the seed at planting. Brominal plus (0.25#ai/A) was applied on May 16th for weed control.

Forage yields were taken on July 18 (soft dough stage) by harvesting three feet (6 rows) by 15 feet (45 ft^2) from each plot. Field weights were obtained and samples removed for moisture determination and nitrogen analysis. Yield samples were obtained on August 2 by harvesting 45 square feet of plot, and yields determined by thrashing after all samples were air dried(95^oF).

The first irrigation water was applied on May 26 with the final irrigation on July 25. A total of 5 inches of irrigation was applied in 1978 with an additional 15.63 inches of rainfall received during this period.

Corn Experiment

A similar experiment was conducted with corn. Broadcast applications of potassium-magnesium sulfate (300#/A of 0-0-22) and potassium (260#/A 0-0-60) were made and incorporated by plowing on April 4th. Experimental treatments consisting of a check, nitrogen rates of 60, 180 and 240 #N/A as urea were applied in one preplant and incorporated application on April 27 or in split application. Split applications were applied on April 27 (preplant), June 8 (12" height), June 27 (36" height), and July 17 (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# ai/A with each treatment area being six rows wide and 30 ft. long.

Corn (Pioneer 3901) was planted on May 5, in 30 inch rows at a population of 30,700 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 (1½ # ai/A) and Atrazine (1 #ai/A) applied on May 6.

Leaf samples from opposite and below the ear at 50% silking were taken from each plot on July 6, 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 7 and 8 (Physiological maturity). Ears were separated from the stalks, field weights obtained and samples removed for moisture determination and nitrogen analysis. Yields were obtained on September 21 and 22 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 June 5 and continued through Sept. 6 with a total of 8.75 inches of water being applied through irrigation and 22.31 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 in 1978 were not as good as 1977 because of poor stooling. No significant yield increases (Table 1) were obtained above 90 #N/A. The highest rate of N application (180#N/A) resulted in a significant yield reduction. Timing of nitrogen application (splitting of applications) had no influence on yield suggesting that fertilizer nitrogen losses from this experiment were not excessive. Although timing of nitrogen application had no influence on yield, nitrogen concentration in the grain (protein) was increased with split applications. Similar to 1977, use of nitrification inhibitors with nitrogen for wheat had no positive influence on yields. Test weights of the grain at harvest were significantly reduced with increasing rates of nitrogen applications.

Dry matter production of the wheat forage was significantly increased with nitrogen rates up to 135#N/A. Timing of nitrogen application tended to lower production suggesting that the second application should have been applied earlier in the growth stage of the plant. The nitrogen content of the forage was significantly increased with increasing nitrogen rate, timing of application and to a lesser extent with nitrification inhibitors. In general, the use of nitrification inhibitors for wheat production under the conditions tested in 1978 were of very little value.

Corn Experiment

Excellent corn yields were obtained in 1978 with treatments ranging from 59 to 196 bu/A(Table 3). Nitrogen management in order to minimize nitrogen losses, was extremely critical in 1978. Yield reductions of up to 55 bu/A were encountered at the recommended nitrogen rates (180#N/A) for these soils under irrigation where nitrogen was applied as a single preplant application versus several applications during the growing season. Highest yields were obtained at 180#N/A when nitrogen was applied during the growing season. Nitrogen rate of 240#/A in a single application was 26 bu/A lower than 180#N/A in split applications, indicating that nitrogen losses with early applications were substantial. Timing of nitrogen application as well as rate of nitrogen application were both important in high yields. The use of nitrification inhibitors appeared to minimize nitrogen losses by 50-60% and as would be expected gave the best results under conditions where nitrogen losses were severe (spring preplant). A significant (.05) yield increase was also obtained when Terrazole was applied with the split applications of N at the 60 lb/A rate suggesting that nitrogen losses may occur under conditions of presumed good nitrogen management. Both N-Serve and Terrazole were effective at minimizing nitrogen losses and therefore increasing yields where nitrogen losses occurred.

Dry matter production increases (Table 4) from the treatments, followed much the same trends as were found with grain yield. When nitrogen was applied in split applications increased production was obtained up to 180#N/A, while responses up to 240#N/A were observed with single nitrogen applications. This again tends to reflect the severe nitrogen losses that were encountered with the early spring nitrogen application on these soils in 1978.

Nitrogen utilization by the corn plant was highly related to nitrogen availability and obtained yield (Table 5). Nitrogen content in the stover did not appear to reflect yield and nitrogen availability to the extent that was found with grain nitrogen. Both yield components were, however, significantly influenced and when combined with yield to evaluate total nitrogen removal produced some large differences. Total nitrogen removal was significantly influenced again by nitrogen rate, timing of nitrogen application, and the use of nitrification inhibitors when nitrogen losses appeared to occur.

Table 1. Influence of Nitrogen Rate, Timing of Nitrogen Application, and Nitrification Inhibitors on ERA Wheat Yield, Nitrogen Utilization, and Test Weight.

Treatment			Wheat Grain			
N Rate	No. of Appl.	Inhibitor	Yield	N. Conc.	N removal	Test Wt.
#/A			bu/A	%	#/A	#/bu
0	-	0	16.2	2.69	26.1	57.0
45	1	0	31.4	2.34	44.0	56.0
45	1	N-S	31.8	2.29	43.6	55.5
45	1	Terr.	31.8	2.29	43.8	56.2
45	2	0	30.4	2.57	46.9	56.0
45	2	N-S	31.1	2.49	46.5	56.0
45	2	Terr.	32.8	2.42	47.7	56.7
90	1	0	42.2	2.59	65.7	55.7
90	1	N-S	42.2	2.60	65.6	56.0
90	1	Terr.	40.4	2.73	66.1	55.0
90	2	0	40.9	2.62	64.4	55.8
90	2	N-S	43.2	2.60	67.0	56.2
90	2	Terr.	36.3	2.78	60.9	54.4
135	1	0	41.0	2.94	72.4	54.3
135	1	N-S	41.4	2.80	69.7	55.1
135	1	Terr.	[illegible]	3.04	72.4	54.4
135	2	0	42.4	3.01	76.4	54.6
135	2	N-S	41.2	3.12	77.2	54.0
135	2	Terr.	41.6	2.95	73.5	55.6
180	1	0	40.8	2.87	70.2	54.0
180	1	N-S	37.1	3.10	68.6	53.3
180	1	Terr.	39.2	3.05	71.8	54.6
180	2	0	36.0	3.14	67.8	51.9
180	2	N-S	35.9	3.20	68.7	51.9
180	2	Terr.	39.0	3.24	75.8	52.5
Significance			**	**	**	**
BSLD(.05)			5.4	0.15	8.4	1.7
FACTORIAL ARRANGEMENT						
N-Rate - #/A						
45			31.5	2.40	45.4	56.1
90			40.9	2.65	65.0	55.5
135			41.2	2.98	73.6	54.6
180			38.0	3.10	70.5	53.0
Significance			**	**	**	**
BLSD(.05)			2.1	.06	3.4	0.6
No. of Appl.						
One			38.3	2.72	62.8	55.0
Two			37.6	2.84	64.4	54.6
Significance			NS	**	NS	NS
BLSD(.05)				.06		
Inhibitor						
None			38.1	2.76	63.5	54.8
N-Serve			38.0	2.77	63.4	54.7
Terrazole			37.6	2.81	64.0	54.9
Significance			NS	NS	NS	NS
BLSD(.05)						

Table 2. Influence of Nitrogen Rate, Timing of Nitrogen Application, and Nitrification Inhibitors on Dry Matter Production and Nitrogen Utilization by Era Wheat.

Treatments			Wheat Forage			
N Rate	No. of Appl.	Inhibitor	--- Dry Matter---		N. Conc.	N Uptake
#/A			T/A	%	%	#/A
0	-	0	0.92	54.9	1.02	18.6
45	1	0	2.32	59.9	.83	38.5
45	1	N-S	2.38	58.2	.89	42.4
45	1	Terr.	2.54	54.8	1.05	53.0
45	2	0	1.94	54.5	1.02	38.9
45	2	N-S	1.87	57.6	1.01	37.6
45	2	Terr.	2.21	54.7	.98	43.0
90	1	0	3.00	52.9	1.02	72.4
90	1	N-S	2.73	52.3	1.21	65.8
90	1	Terr.	2.62	54.4	1.25	65.6
90	2	0	2.95	50.4	1.17	69.0
90	2	N-S	2.87	51.5	1.36	77.5
90	2	Terr.	2.85	52.4	1.22	69.5
135	1	0	3.48	49.6	1.33	92.7
135	1	N-S	3.27	50.1	1.44	93.1
135	1	Terr.	3.24	50.3	1.26	81.6
135	2	0	3.09	49.7	1.43	88.7
135	2	N-S	3.08	49.3	1.47	90.7
135	2	Terr.	2.86	48.4	1.41	80.3
180	1	0	3.10	48.3	1.35	83.8
180	1	N-S	2.88	48.8	1.44	82.3
180	1	Terr.	2.99	47.9	1.56	93.1
180	2	0	2.94	46.3	1.66	98.1
180	2	N-S	3.40	45.4	1.62	110.8
180	2	Terr.	2.88	48.0	1.63	93.4
Significance			**	**	**	**
BLSD(.05)			0.52	3.9	0.13	14.6
Factorial Arrangement						
N-Rate - #/A						
45			2.21	56.5	0.96	42.2
90			2.84	52.3	1.23	70.0
135			3.17	49.6	1.39	87.9
180			3.04	47.5	1.54	93.6
Significance			**	**	**	**
BLSD(.05)			0.20	1.5	0.05	5.9
No. of Appl.						
One			2.88	52.3	1.23	72.0
Two			2.75	50.7	1.33	74.8
Significance			+	**	**	NS
BLSD(.05)			0.14	1.5	0.05	
Inhibitor						
None			2.85	51.4	1.25	72.8
N-Serve			2.81	51.7	1.31	75.0
Terrazole			2.77	51.4	1.30	72.4
Significance			NS	NS	+	NS
BLSD(.05)					0.05	

Table 3. Influence of Nitrogen Rate, Timing of Nitrogen Application, and Nitrification Inhibitors, on Leaf Nitrogen Concentration, Grain Yield, and Nitrogen Utilization of Corn.

Treatments			Leaf	Corn Grain			
N Rate	No. of Appl.	Inhibitor	N	Yield 15.5%M	DM at harvest	N Conc.	N Removal
#/A			%	bu/A	%	%	#/A
0	-	0	1.14	58.8	56.6	1.02	28.5
60	1	0	1.38	89.0	60.3	1.10	46.3
60	1	N-S	1.78	119.3	65.4	1.08	61.0
60	1	Terr.	1.46	98.4	62.1	0.98	46.0
60	4	0	2.14	117.0	61.8	1.09	60.6
60	4	N-S	2.14	126.9	62.5	1.08	64.9
60	4	Terr.	2.12	137.4	63.0	1.09	70.8
120	1	0	1.47	105.4	61.3	1.02	50.8
120	1	N-S	2.20	150.4	67.1	1.20	86.8
120	1	Terr.	2.19	145.3	65.5	1.13	77.8
120	4	0	2.78	167.4	64.4	1.21	95.7
120	4	N-S	2.82	181.4	65.0	1.35	116.1
120	4	Terr.	2.72	179.0	64.6	1.41	119.7
180	1	0	2.07	136.3	62.9	1.04	67.4
180	1	N-S	2.63	169.2	66.6	1.26	101.2
180	1	Terr.	2.38	169.6	64.5	1.28	102.4
180	4	0	2.97	190.8	65.8	1.46	131.4
180	4	N-S	2.93	191.4	65.3	1.45	131.4
180	4	Terr.	2.92	195.5	66.4	1.43	132.7
240	1	0	2.56	169.6	64.3	1.30	104.7
240	1	N-S	2.96	181.0	64.2	1.54	131.3
240	1	Terr.	2.92	186.0	66.7	1.49	130.8
240	4	0	2.97	191.0	62.6	1.46	131.5
240	4	N-S	3.11	189.9	67.2	1.50	134.8
240	4	Terr.	2.96	190.2	64.9	1.53	138.0
Significance			**	**	**	**	**
BLSD(.05)			0.18	14.9	3.2	0.06	10.1
Factorial Arrangement							
N-Rate - #/A							
60			1.84	114.7	62.5	1.07	58.3
120			2.36	154.8	64.6	1.22	91.0
180			2.65	175.5	65.2	1.32	111.1
240			2.91	184.6	65.0	1.47	128.5
Significance			**	**	**	**	**
BLSD(.05)			0.08	5.7	1.2	0.03	4.2
No. of Appl.							
One			2.17	143.3	64.2	1.20	83.8
Four			2.72	171.5	64.5	1.34	110.6
Significance			**	**	NS	**	**
BLSD(.05)			0.08	5.9		0.03	4.3
Inhibitor							
None			2.29	145.8	62.9	1.21	86.0
N-Serve			2.57	163.7	65.4	1.31	103.3
Terrazole			2.46	162.7	64.7	1.29	102.3
Significance			**	**	**	**	**
BLSD(.05)			0.07	5.0	1.0	0.02	3.6

Table 4. Influence of Nitrogen Rate, Timing of Nitrogen Application and Nitrification Inhibitors on Corn Dry Matter Production and Moisture Relations at Physiological Maturity.

Treatments			Corn Forage Production				
			Dry Matter Production			Dry Matter at Harvest	
N Rate	No. of Appl.	Inhibitor	Stover	Grain	Total	Stover	Grain
#/A			------- T/A		----------	-------- %	----------
0	-	0	1.66	1.31	2.97	25.6	46.2
60	1	0	2.40	2.04	4.43	27.0	51.7
60	1	N-S	2.82	2.11	4.93	29.4	50.8
60	1	Terr.	2.71	2.18	4.88	30.0	53.4
60	4	0	2.81	2.91	5.72	28.2	52.1
60	4	N-S	3.13	3.09	6.23	28.3	52.7
60	4	Terr.	3.35	3.37	6.72	30.1	54.1
120	1	0	3.12	2.81	5.93	29.9	53.2
120	1	N-S	3.40	3.33	6.73	29.3	55.6
120	1	Terr.	3.69	3.34	7.03	33.0	56.0
120	4	0	3.80	4.02	7.82	30.4	53.6
120	4	N-S	3.98	4.35	8.33	29.6	55.6
120	4	Terr.	4.37	4.65	9.02	33.1	56.0
180	1	0	3.26	2.82	6.08	29.0	52.8
180	1	N-S	3.82	3.78	7.61	31.2	55.2
180	1	Terr.	3.73	3.76	7.48	29.9	56.1
180	4	0	4.40	4.40	8.80	32.4	54.8
180	4	N-S	4.12	4.61	8.74	30.4	56.0
180	4	Terr.	4.03	4.58	8.61	30.3	55.1
240	1	0	4.16	4.07	8.22	30.0	55.2
240	1	N-S	3.99	4.26	8.26	28.5	56.1
240	1	Terr.	4.04	4.40	8.44	28.6	56.1
240	4	0	3.88	4.34	8.22	27.4	54.3
240	4	N-S	3.98	4.14	8.11	32.1	55.5
240	4	Terr.	4.24	4.54	8.78	29.6	54.9
Significance			**	**	**	**	**
BLSD(.05)			0.46	0.46	0.82	4.1	2.7
Factorial Arrangement							
N-Rate - #/A							
60			2.87	2.62	5.48	28.8	52.5
120			3.73	3.75	7.48	30.9	55.0
180			3.89	3.99	7.89	30.6	55.0
240			4.05	4.29	8.34	29.3	55.4
Significance			**	**	**	**	**
BLSD(.05)			0.19	0.19	0.33	1.4	1.1
No. of Appl.							
One			3.43	3.24	6.67	29.7	54.4
Four			3.84	4.08	7.92	30.1	54.5
Significance			**	**	**	NS	NS
BLSD(.05)			0.19	0.19	0.34		
Inhibitor							
None			3.48	3.43	6.90	29.3	53.4
N-Serve			3.66	3.71	7.37	29.4	54.7
Terrazole			3.77	3.85	7.62	30.5	55.2
Significance			**	**	**	NS	**
BLSD(.05)			0.18	0.17	0.31		1.0

Table 5. Influence of Nitrogen Rate, Timing of Nitrogen Application, and Nitrification Inhibitors, on Nitrogen Utilization of Corn at Physiological Maturity.

Treatments			Corn Forage				
			N Content		N Removal		
N Rate	No. of Appl.	Inhibitor	Stover	Grain	Stover	Grain	Total
#/A			%		#/A		
0	-	0	.46	1.08	27.7	28.3	56.0
60	1	0	.40	1.02	35.4	41.7	77.1
60	1	N-S	.42	1.05	41.3	44.7	86.0
60	1	Terr.	.39	1.09	38.3	47.6	85.9
60	4	0	.50	1.07	57.0	62.6	119.6
60	4	N-S	.51	1.09	63.7	67.4	131.1
60	4	Terr.	.49	1.16	65.8	78.3	144.1
120	1	0	.54	1.05	64.7	59.4	124.1
120	1	N-S	.42	1.12	57.5	74.7	132.2
120	1	Terr.	.44	1.12	61.9	74.8	136.7
120	4	0	.57	1.16	88.9	93.5	182.4
120	4	N-S	.55	1.32	91.2	115.3	206.5
120	4	Terr.	.66	1.46	118.8	136.2	255.0
180	1	0	.44	1.06	54.0	60.1	114.1
180	1	N-S	.46	1.22	71.2	92.8	164.0
180	1	Terr.	.49	1.27	73.8	96.1	169.9
180	4	0	.63	1.50	111.2	132.0	243.2
180	4	N-S	.70	1.50	121.9	138.8	260.7
180	4	Terr.	.67	1.47	115.9	134.5	250.4
240	1	0	.53	1.19	87.4	96.8	184.2
240	1	N-S	.67	1.41	110.3	119.8	230.1
240	1	Terr.	.61	1.33	102.6	116.7	219.3
240	4	0	.76	1.50	124.9	130.3	255.2
240	4	N-S	.74	1.50	120.9	124.2	245.1
240	4	Terr.	.80	1.48	140.5	134.0	274.5
Significance			**	**	**	**	**
BLSD(.05)			.06	0.08	13.6	12.7	24.3
Factorial Arrangement							
N-Rate-#/A							
60			.45	1.08	50.2	57.0	107.2
120			.53	1.21	80.5	92.3	172.8
180			.57	1.34	91.3	109.0	200.3
240			.69	1.40	114.4	120.3	234.7
Significance			**	**	**	**	**
BLSD(.05)			.02	.03	5.6	5.2	10.0
No. of Appl.							
One			.49	1.16	66.5	77.1	143.6
Four			.63	1.35	101.7	112.3	214.0
Significance			**	**	**	**	**
BLSD(.05)			.02	.03	5.8	5.4	10.4
Inhibitor							
None			.55	1.20	77.9	84.6	162.5
N-Serve			.56	1.28	84.7	97.2	181.9
Terrazole			.57	1.30	89.7	102.3	192.0
Significance			NS	**	**	**	**
BLSD(.05)				.30	5.2	4.6	8.9

Influence of Nitrification Inhibitors and Nitrification Inhibitor Rates on the Production of Spring Wheat and Corn Under Irrigation.

G.L. Malzer, T.J. Graff and J. Lensing

The use of nitrification inhibitors for minimizing nitrogen losses from soils, generates many concerns regarding management of the products themselves in order to obtain the desired results. At the present time, recommended rates of application for commercially available nitrification inhibitors (N-Serve) suggest optimum rates of ¼-½ # active ingredient/acre. To investigate the importance of rate of application for nitrification inhibitors, a field trial was conducted in 1978 at the Sand Plains Research Farm near Becker, MN. The objectives of the trial were to evaluate the influence of two nitrification inhibitors (N-Serve-Dow Chemical company and Terrazole-Olin corporation) at five different rates of application on the yield, and nitrogen utilization characteristics of spring wheat and corn grown under irrigation.

Experimental Procedures

Two separate experiments each consisting of ten experimental treatments including two nitrification inhibitors (N-Serve and Terrazole) at five rates of application (0, 1/8, 1/4, 1/2 and 1 #active ingredient/A) were applied to a Hubbard coarse sand. The treatments within each experiment were replicated four times and arranged in a randomized complete block design. In the first experiment the above treatments were applied with 45 #N/A as urea in a spring application. After immediate incorporation of the fertilizer coated material the area was seeded to spring wheat (Era-2bu/A). The second experimental area had the same nitrification inhibitor treatments and experimental design but was applied with 120 #N/A and was planted to corn (Pioneer 3901 - 30,700 seeds/A). Both experimental areas had been previously fertilized according to soil test recommendations (Wheat - 300 #/A 0-0-22 $K \cdot MgSO_4$, 90#/A 0-46-0 with 20# P_2O_5 applied with starter and corn 300#/A -0-0-22, 250#/A 0-0-60 and 150#/A of 0-18-36 as a starter at planting.) Weed control was accomplished with an application of Brominal plus (0.25#ai/A) on May 16 for wheat and mixture of Lasso (1½#ai/A) and Atrazine (1#ai/A) on May 6 for corn.

Wheat was harvested for grain on August 2 by removing 45 ft^2 from each experimental plot and yields determined after drying and thrashing. Grain was analyzed for kjeldahl nitrogen. To characterize nitrogen utilization and production on the area planted in corn the following samples were taken: 1) The leaf opposite and below the ear at silking (July 12) for N content 2) Total corn forage production at physiological maturity (September 7 and 8); stover and grain components for dry matter production and nitrogen utilization and 3) Final grain yields (September 21 and 22) and nitrogen analyses. Soil samples were obtained from the corn experimental area at three different times to characterize the influence of the treatments on nitrification (disappearance of ammonium N) within the soil.

The experimental area in wheat received a total of 20.63 inches of rainfall plus irrigation while the corn area received a total of 31.06 inches during the growing season.

General Results

The information obtained from the wheat trial is presented in Table 1, and data from the corn experiment is in Tables 2 and 3.

Wheat Experiment - Similar to the results that were obtained from the experiment with nitrogen rates and timing of nitrogen application, very little positive response to the use of nitrification inhibitors were obtained. Increasing nitrification inhibitor rates had no significant (.05) influence on wheat yield test weight or nitrogen utilization. The significant difference (.10) that was obtained because of a low grain N content with N-Serve at the ½#ai/A rate established no trends.

Corn Experiment - Considerable nitrogen losses from the corn experimental area are evident from the yield increases that were obtained with both nitrification inhibitors as rates of application were increased. Yield responses in excess of 50 bu/A were obtained with both inhibitors. As a general rule a trend for increased yield was observed with increasing inhibitor rates. Statistically there was no yield advantage to application rates of either inhibitor over ½#ai/A. Although not significant with the yield grain, leaf nitrogen concentrations suggest that N-Serve was more effective at the lower application rates than was Terrazole. Total nitrogen removal by the corn forage at physiological maturity summarizes the potential advantages and importance of nitrification inhibitor rate on nitrogen utilization. Both inhibitors resulted in increased uptakes of 55-65 pounds of additional N/A under the conditions encountered, however, the rates of application that were the most efficient were not the same rates for each inhibitor. The soil ammonium concentrations (Table 3) would suggest that N-Serve may have delayed nitrification longer into the growing season than Terrazole.

Table 1. Influence of nitrification inhibitors and nitrification inhibitor rates on spring wheat yields and nitrogen utilization.

Treatment 1/		Wheat Grain			
Inhibitor	Inhibitor Rate	Yield	Test Wt.	N Content	N Removal
	#/A	bu/A	#/bu	%	#/A
N-Serve	0	31.8	55.7	2.48	47.1
N-Serve	1/8	35.8	54.8	2.42	51.9
N-Serve	1/4	34.3	56.3	2.52	52.0
N-Serve	1/2	34.0	56.3	2.36	48.2
N-Serve	1	30.6	56.2	2.57	47.1
Terrazole	0	34.6	56.7	2.39	49.5
Terrazole	1/8	34.1	56.3	2.42	49.5
Terrazole	1/4	36.7	56.2	2.36	51.9
Terrazole	1/2	35.1	56.4	2.44	51.2
Terrazole	1	33.4	56.1	2.40	48.0
Significance		NS	NS	NS	NS
BLSD(.05)					
Inhibitor x Inhibitor Rate					
N-Serve alone					
Significance		NS	NS	+	NS
BLSD(.05)				.15	
Terrazole alone					
Significance		NS	NS	NS	NS
BLSD(.05)					

1/ All treatments received 45#N/A as urea in a preplant application.

Table 2. Influence of Nitrification Inhibitors and Nitrification Inhibitor Rates on Corn Grain Yield, Nitrogen Utilization and Total Dry Matter Production.

Treatment 1/		Corn Grain				Leaf	Corn Forage-Physiological Maturity							
							Stover			Grain			Total	
Inhibitor	Inhibitor Rate	Yield	N	D.M.	N Removal	N	Yield	N	N Removal	Yield	N	N Removal	Yield	N Removal
	#/A	bu/A	%	%	#/A	%	T/A	%	%/A	T/A	%	#/A	T/A	#/A
N-Serve	0	108.2	1.02	60.0	52.2	1.44	2.95	.39	43.3	2.56	.97	49.5	5.51	92.8
N-Serve	1/8	135.8	1.11	62.3	71.2	2.28	3.01	.43	50.2	2.83	1.01	57.4	5.84	107.6
N-Serve	1/4	149.2	1.21	66.1	85.5	2.27	3.20	.46	59.1	3.17	.99	62.9	6.37	122.0
N-Serve	1/2	140.8	1.02	61.8	68.6	2.20	3.52	.49	68.5	3.49	1.14	79.6	7.01	148.1
N-Serve	1	158.4	1.17	67.7	87.6	2.22	3.42	.42	58.0	3.54	1.09	77.2	6.96	135.1
Terrazole	0	100.2	1.06	61.0	50.8	1.36	2.93	.41	44.6	2.57	.94	48.7	5.50	93.3
Terrazole	1/8	115.7	1.12	61.6	62.8	1.94	3.12	.41	48.8	2.85	.97	55.9	5.97	104.7
Terrazole	1/4	123.6	1.03	62.4	60.4	1.65	3.14	.41	50.1	2.97	.99	58.9	6.11	109.0
Terrazole	1/2	137.2	1.16	64.0	75.1	2.26	3.22	.43	53.8	3.04	1.09	66.6	6.26	120.4
Terrazole	1	151.6	1.19	63.4	85.2	2.45	3.61	.47	68.7	3.65	1.18	86.8	7.26	155.5
Significance		**	**	**	**	**	*	*	**	**	**	**	**	**
BLSD(.05)		24.7	.10	4.4	16.4	.26	.44	.06	9.2	.42	.10	12.2	.76	18.9
Inhibitor x Inhibitor Rate														
N-Serve Alone														
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD(.05)		23.2	.07	5.8	13.4	.28	.38	.06	8.7	.28	.08	8.2	.55	14.0
Terrazole Alone														
Significance		*	+	NS	*	**	+	*	**	*	*	**	*	**
BLSD(.05)		28.6	.12		20.2	.24	.46	.05	10.2	.65	.14	18.0	1.10	25.6

1/ All treatments received 120#N/A as urea in a spring preplant application.

Table 3. Influence of Nitrification Inhibitors and Nitrification Inhibitor Rates on Soil Ammonium Concentration in the 0-6" depth three times after application.

Treatment 1/		Soil Ammonium Conc. (0-6")		
Inhibitor	Inhibitor Rate	June 5	June 20	July 6
	#/A	ppm-NH_4-N		
N-Serve	0	11.1	7.2	8.6
N-Serve	1/8	14.6	9.4	8.4
N-Serve	1/4	19.6	7.4	9.4
N-Serve	1/2	28.6	10.8	12.0
N-Serve	1	34.0	29.6	16.5
Terrazole	0	6.6	3.9	10.8
Terrazole	1/8	12.0	6.2	10.3
Terrazole	1/4	19.0	5.9	10.8
Terrazole	1/2	19.6	5.2	7.4
Terrazole	1	30.6	18.4	11.1
Significance		+	**	+
BLSD(.05)		20.1	5.2	5.3
Inhibitor x Inhibitor Rate				
N-Serve Alone				
Significance		NS	**	*
BLSD(.05)			7.1	6.3
Terrazole Alone				
Significance		+	**	NS
BLSD(.05)		16.7	4.3	

1/ All treatments received 120#N/A as urea in a spring preplant operation.

Navy Bean Inoculation Trials - 1978

M.C. Severson, S. Sparrow and G.E. Ham

More efficient nitrogen fixing bacteria (Rhizobium phaseoli) seem to be one of the means of obtaining efficiency and stability of navy bean yields. Many different strains of nodule bacteria for navy beans (Rhizobium phaseoli) exist and their nitrogen fixing ability varies depending on a number of factors including the host plant. Some rhizobia induce nodule formation but then fail to fix nitrogen while other rhizobia provide sufficient nitrogen for excellent plant growth. A randomized complete block design was used with 6 replications. All plots received 36 pounds of nitrogen per acre from fertilizer before planting and the plots were irrigated when necessary. The plots were planted on May 21-23 in 14 inch rows.

As shown in Table 1, CIAT strain 404 produced the maximum grain yield increase at Becker compared to the uninoculated control (102% or 840 pounds per acre for Seafarer variety and 76% or 813 pounds per acre for Upland variety). Table 2 shows that seed yield decreased as the number of rhizobia per inch of row was decreased. These results indicate that inoculation with extremely large numbers of rhizobia is necessary for maximum yields and these results indicate considerable variation among the rhizobia strains for nitrogen fixation and seed yield.

Table 1. Influence of Rhizobium phaseoli strains on navy bean yields at Becker in 1978.

Rhizobium phaseoli strain	Navy Bean Variety			
	Becker		Rosemount	
	Seafarer	Upland	Seafarer	Upland
	lbs/acre			
Check	822abc*	1066ab*	2522a*	2740a*
CIAT 57	1179d	1680c	2600a	2821a
CIAT 75	851abc	968a	2439a	2795a
CIAT 255	918bc	901a	2862a	2667a
CIAT 404	1662e	1879d	2839a	2795a
CIAT 676	1520e	1782cd	2837a	2870a
IP736A1	679a	1093ab	2839a	2939a
Nit127K51	857abc	881a	2451a	2769a
Nit127K54	701ab	919a	2597a	2783a
3644	847abc	1084ab	2846a	2861a
Allen 413-2	924bc	1245b	2807a	2810a
IQ423	740ab	872a	2885a	2575a
QA1062	1001cd	1088ab	2562a	2950a

*Seed yields within a variety followed by the same letter(s) are not significantly different at the 95% level. Do not compare yields between the two varieties.

Table 2. Influence of *Rhizobium phaseoli* inoculation rate on navy bean yields at Becker in 1978.

Rhizobium phaseoli strain	Number rhizobia per inch of row	Navy Bean Variety			
		Becker		Rosemount	
		Seafarer	Upland	Seafarer	Upland
		lbs/acre			
Control	0	753a*	871a*	2635a	2292a
CIAT 75	10^6	974ab	1108b	2831ab	2763b
	10^4	875a	984ab	2786ab	2750b
	10^2	845a	973ab	2753ab	2426ab
	10	645a	869a	2652ab	2515ab
	1	762a	964ab	2794ab	2256ab
650R	10^7	1208b	1071ab	2963b	2830b
	10^5	760a	967ab	2866ab	2419ab
	10^3	764a	958ab	2626a	2344ab
	10	682a	865a	2888ab	2209ab
	1	843a	910ab	2682ab	2415ab
3644	10^6	790a	948ab	2781ab	2691b
	10^7	926a	1138b	2768ab	2398ab
	10^2	825a	998ab	2904ab	2429ab
	10	587a	984ab	2788ab	2147ab
	1	718a	785a	2849ab	2233ab

*Seed yields within a variety followed by the same letter(s) are not significantly different at the 95% level. Do not compare yields between the two varieties.

1978 Weather Summary - Crookston, Minnesota

The 1978 weather reflects average temperature and is highlighted by well below normal precipitation. There have only been 10 years previously since 1890 that 15 inches or less precipitation were recorded at the Crookston station. Two all-time high temperature records were also broken in 1978.

The first 3 months of 1978 were below normal in regard to temperature, and precipitation was well below normal through June recording a 5 inch departure from normal for the first 6 months of the year.

July and August were the only two months in 1978 which recorded above normal precipitation. We received 2.77 inches of rain on July 18 and 19 bringing the total for the month .60 inch above average. August was 1.32 inches above normal with 2.44 inches of rain recorded on the 15th.

Two record high temperatures were recorded in August and September. On August 12 the mercury climbed to 95°F. surpassing the old record of 94°F. set in 1970. September 8 also recorded a high of 95°F. which was 2°F. higher than the previous record of 93°F. set in 1931.

September, October and November also followed the 1978 trend of below normal precipitation recording 2 inches below normal for the three month period. Cold temperatures also prevailed in November with a -25°F. reading on November 30 being the second coldest day in the history of the station next to -29°F. recorded in 1896.

The last frost in 1978 was on May 1 and the first frost occurred September 27 setting the growing season of 149 days in 1978 which is 24 days longer than normal for Northwest Minnesota.

Table 1. Weather Summary for 1978 with Averages for Precipitation and Mean Temperatures for 1890-1973.

	Precipitation					Mean Temperature degrees	
	Snow Precip.						
	Inches	Inches	Rain	Total	1890-1973	1978	1890-1973
Jan.	3.0	.14	-	.14	.56	-2.4	3.9
Feb.	1.3	.07	-	.07	.54	2.8	8.2
Mar.	2.0	.15	-	.15	.85	21.1	23.0
Apr.	2.5	.13	.52	.65	1.53	42.0	41.4
May	-	-	1.49	1.49	2.61	60.0	54.5
June	-	-	2.24	2.24	3.61	64.5	64.5
July	-	-	3.73	3.73	3.13	69.3	69.4
Aug.	-	-	4.20	4.20	2.88	69.2	67.5
Sept.	-	-	1.66	1.66	2.26	63.2	57.4
Oct.	-	-	.11	.11	1.39	47.7	45.4
Nov.	10.2	.60	.02	.62	.76	20.5	26.9
Dec.	10.5	.91	-	.91	.61	5.8	11.5
Total	29.5	2.00	13.97	15.97	20.73	38.6	39.5

Copper Sulfate Carrier x Method of Application Study

G. E. Varvel and R. K. Severson

Copper deficiency in small grains has been a problem on some of the organic soils in northern Minnesota. This deficiency has been corrected with the addition of copper to the soil. However, recent information has shown that problems may occur if the copper is applied as copper sulfate in the granular form. The experimentation with copper sulfate has involved dissolving it in water and then applying it. For this reason it was felt that a comparison of the two methods was needed.

Experimental Methods:
A completely random design with 5 replications was used. The experiment was located at the Kveen farm in Roseau County. The plots were fertilized and Era wheat was planted on May 9, 1978 and harvested on August 31, 1978.

Results:
Results shown in the table below are an indication of the severe copper deficiency that was present at the location. Significant differences in yield were obtained between carriers and application methods. No differences were obtained between the treatments with starter and those without starter fertilizer or between the different granule sizes of copper sulfate.

$CuSO_4$ Carrier	Method	Starter (15-30-15)	Yield
		lbs/A	Bu/A
Control	---	0	0.2
Control	---	100	0.2
Small Granule	Band	0	4.7
" "	"	100	0.1
" "	Brdcst.	0	0.7
" "	"	100	2.7
Large Granule	Band	0	2.2
" "	"	100	1.9
" "	Brdcst.	0	1.0
" "	"	100	1.0
Liquid	Band	0	5.9
"	"	100	5.8
"	Brdcst.	0	12.4
"	"	100	16.9
Significance			**
B.L.S.D.			2.0
C.V.			46.4

Wheat Production as Affected by Copper on Organic Soils

G. E. Varvel, G. L. Malzer, R. K. Severson

The organic soils of northwestern Minnesota are being developed into productive agricultural land through land clearing and drainage. Most of these soils have been in grass seed or wild rice production, but as more acres have been cleared, interest in growing other crops has developed. Problems, especially with spring wheat, were encountered. Preliminary studies with the addition of the macro nutrients and also the micro nutrients isolated copper as being the major limiting nutrient for wheat production on these soils. Based on this discovery, experimental locations were established in both Roseau and East Polk counties in 1977. Three separate experiments were conducted at each location.

Experiment number one was established to determine the affect of copper rate, carrier and method of application on wheat yield and pounds of dry matter production. Results are presented in Table 1 for the Roseau location and in Table 2 for the East Polk location.

Experiment number two was established to determine the affect of copper by itself and in combination with iron, zinc and manganese on wheat yield and dry matter production. Results are presented in Table 3 for the Roseau location and in Table 4 for the East Polk location.

Experiment number three involves the residual affect of copper applied in 1977 on wheat yield. Results are presented in Table 5 for the Roseau location. The East Polk location was lost due to the severe infestation of Canadian thistle.

Table 1. Wheat yield and dry matter production as affected by copper rate, carrier and application method at the Roseau County location.

Carrier	Rate	Application Method			
		Broadcast		Band	
		Yield	Dry Matter	Yield	Dry Matter
	lbs Cu/A	Bu/A	lbs/A	Bu/A	lbs/A
Control	0	0.5	700	0.5	700
$CuSO_4$	0.75	---	---	1.3	1754
	1.5	8.4	3410	1.6	2168
	3.0	15.1	4445	3.7	2766
	6.0	17.9	4241	4.0	2722
	12.0	17.3	5390	4.5	3531
	24.0	13.6	3044	2.3	1558
Cu Chelate	0.375	3.8	2321	19.0	5337
	0.75	10.0	3281	25.8	5839
	1.5	24.4	5219	38.2	7746
	3.0	35.8	6619	---	---
	6.0	40.3	7147	---	---
Significance		**	**	**	**
B.L.S.D. (.05)		3.2	930	3.2	930
C.V.		17.9	18.4	17.9	18.4

Table 2. Wheat yield and dry matter production as affected by copper rate, carrier and application method at the East Polk County location.

Carrier	Rate	Application Method			
		Broadcast		Band	
		Yield	Dry Matter	Yield	Dry Matter
	lbs Cu/A	Bu/A	lbs/A	Bu/A	lbs/A
Control	0	2.3	---	2.3	---
$CuSO_4$	0.75	---	---	1.3	1821
	1.5	22.4	5403	2.2	1712
	3.0	33.6	5594	3.2	3132
	6.0	39.2	6072	4.0	2940
	12.0	42.1	6665	9.1	2697
	24.0	43.4	7321	10.4	4367
Cu Chelate	0.375	8.0	2956	10.0	3923
	0.75	19.7	4045	19.2	5043
	1.5	28.5	5295	30.5	5036
	3.0	45.1	6490	---	---
	6.0	44.8	6831	---	---
Significance		**	**	**	**
B.L.S.D. (.05)		8.2	1307	8.2	1307
C.V.		30.6	23.1	30.6	23.1

Table 3. Wheat yield and dry matter production as affected by micronutrients in combination with copper at the Roseau County location.

Material	Rate	Yield	Dry Matter
	lbs/A	Bu/A	lbs/A
Cu	12	11.8	5832
Cu + Fe	12 + 10	27.9	6348
Cu + Zn	12 + 5	25.7	6087
Cu + Mn	12 + 10	30.4	8296
Cu + Fe + Zn + Mn	12 + 10 + 5 + 10	31.1	86.47
Significance		**	*
B.L.S.D. (.05)		3.3	2388
C.V.		9.1	20.1

Table 4. Wheat yield and dry matter production as affected by micronutrients in combination with copper at the East Polk County location.

Material	Rate	Yield	Dry Matter
	lbs/A	Bu/A	lbs/A
Cu	12	56.2	9686
Cu - Fe	12 + 10	56.5	8878
Cu + Zn	12 + 5	49.5	9006
Cu + Mn	12 + 10	56.0	9814
Cu + Fe + Zn + Mn	12 + 10 + 5 + 10	53.4	9140
Significance		N.S.	N.S.
C.V.		10.7	8.9

Table 5. Wheat yield as affected by residual copper from copper applied in 1977 at the Roseau County location.

1977 Applied Copper	Yield
lbs/A	Bu/A
0	0
3	34.6
6	34.2
12	34.4
24	32.9
48	35.1
96	34.9
192	31.1
Significance	N.S.
B.L.S.D.	3.6
C.V.	9.2

Nitrogen Carrier x Rate x Application Time Study for Wheat - 1978

G. E. Varvel and R. K. Severson

This is a continuation of a study initiated in 1976 and continued in 1977. Results from 1976 and 1977 were inconclusive due to high nitrate-nitrogen soil tests. Those results are presented in the 1978 Bluebook.

Experimental Procedures:

The treatments included in this study were the same as the previous two years. A randomized complete block design with four replications was used. Fall applications were made on October 25, 1977 and spring applications on April 27, 1978. Era wheat was planted on April 28, 1978 and the study was harvested on August 1, 1978. The study was located at the Northwest Experiment Station on a Hegne silty clay. Soil test results for the site were: pH - 8.3, nitrate-nitrogen (0-2') - 50 lbs/A, available phosphorus (10:1) - 20 lbs/A and extractable potassium - 225 lbs/A.

Results:

Protein content and grain yields as affected by the treatments are shown in Table 1. Significant increases in both protein content and yield were obtained with increasing amounts of nitrogen. Significant differences in protein content and yield were also obtained between nitrogen carriers when compared at the different dates of application.

Table 1. The effects of nitrogen carriers, rates and application times on yield and protein content of Era wheat.

		Application Time			
		Fall		Spring	
Carrier	N Rate	Yield	Protein	Yield	Protein
	lbs./A	Bu./A	-%-	Bu./A	-%-
Control	0	28.5	11.7	28.5	11.7
Ammonium	30	44.0	13.2	35.1	11.0
Nitrate	60	46.2	13.3	45.6	13.1
(34-0-0)	90	52.6	13.9	52.8	13.1
Urea	30	36.9	12.3	42.0	12.4
(46-0-0)	60	42.6	12.9	47.3	13.9
	90	48.6	13.0	55.2	13.8
UAN	30	33.2	11.7	43.0	13.2
Solution	60	40.2	12.9	47.5	13.3
(28-0-0)	90	43.2	12.3	56.3	14.3
Anhydrous	30	43.7	13.3	44.1	13.9
Ammonia	60	51.2	13.8	52.5	13.1
(82-0-0)	90	56.3	13.7	52.2	15.1
Significance		**	*	**	*
B.L.S.D. (.05)		8.1	0.4	8.1	0.4
C.V.		13.0	10.4	13.0	10.4

	Application Time			
	Fall		Spring	
Carrier	Yield	Protein	Yield	Protein
	Bu./A	-%-	Bu./A	-%-
Ammonium Nitrate	47.6	13.4	44.5	12.4
Urea	42.7	12.7	48.1	13.4
UAN	38.8	12.3	48.9	13.6
Anhydrous Ammonia	50.4	13.6	49.6	14.0
Significance	**	*	**	*
B.L.S.D. (.05)	4.4	1.1	4.4	1.1

Nitrogen Rate	Yield	Protein
lbs./A	Bu./A	-%-
30	40.2	12.6
60	46.6	13.3
90	52.1	13.6
Significance	**	**
B.L.S.D. (.05)	2.4	0.7

Nineteen 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 103 and some of this information will not be included here).

The fertilizer treatments have now been annually applied to the same plot areas for 19 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 along with individual plot yields in table 1. Nitrogen concentration and nitrogen removal with the yield grain and total dry matter production are presented in table 3.

The yields obtained in 1978 were above average when considering the long term previous average for this experiment. Treatment averages in 1978 appeared to follow the trends which had been established with the long term average yields. This suggests that the residual influence from the 1976 drought which was obvious in the 1977 information had not carried over into the 1978 growing season.

EIGHTEEN YEAR AVERAGE

The average grain yields for the nineteen years of this experiment are shown in table 2. When only 40 lbs. of N/A was fall applied, urea was slightly better than ammonium nitrate with very little difference due to incorporation.

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. At the 40#N/A rate applied in the spring there was no difference between urea and ammonium nitrate. Urea applied in the fall produced similar yield as with spring applications although ammonium nitrate applied in the fall was inferior to spring application at the 40#N/A rate of application.

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[1] in lbs/A	% N 6th Leaf	Bu/A @ 15.5% Moisture				
		I	II	III	IV	Ave.
Check	1.65	84.7	59.8	64.2	51.4	64.6
40-NH_4NO_3-fpd[2]	2.23	98.6	120.6	83.9	89.3	98.1
40-urea-fpd	2.38	118.6	125.2	91.5	105.5	110.2
40-NH_4NO_3-fpd[3]	1.88	113.7	115.5	84.6	91.6	101.4
40-urea-fps	2.15	100.5	92.6	94.2	118.3	101.4
80-NH_4NO_3-fpd	2.69	130.7	138.2	125.4	119.3	128.4
80-urea-fpd	2.66	132.6	130.4	108.1	123.1	123.6
160-NH_4NO_3-fpd	2.93	126.5	135.7	118.6	136.3	129.3
160-urea-fpd	2.86	136.2	114.8	118.9	127.8	124.4
40-NH_4NO_3-std[4]	2.32	74.8	122.0	86.6	106.1	97.4
40-urea-std	2.28	125.9	101.2	94.4	94.2	103.9
80-NH_4NO_3-std	2.53	120.2	133.6	119.6	94.9	117.1
80-urea-std	2.66	127.8	134.8	123.6	123.3	127.4
40-NH_4NO_3-sd[5]	2.54	111.1	107.6	104.6	103.7	106.8
40-urea-sd	2.12	113.8	90.2	108.8	106.3	104.8
80-NH_4NO_3-sd	2.64	121.8	106.4	94.1	120.0	110.6
80-urea-sd	2.98	125.1	128.4	118.0	135.3	126.7
160-NH_4NO_3-sd	2.92	135.5	139.3	122.2	107.1	126.0
Significance	**					**
C.V. (%)	6.4					10.6
BLSD (0.05)	.20					15.2

[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 tilled 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	1978	18 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	64.6	69.6
40 NH_4NO_3-fpd[2]	96.3	88.7	113.6	92.0	80.5	88.6		145.1	98.1	87.7
40 Urea-fpd	120.4	100.7	113.9	101.5	96.9	96.6	Yields	165.2	110.2	95.5
40 NH_4NO_3-fps[3]	122.5	81.5	109.9	93.0	88.3	78.2		149.4	101.3	91.5
40 Urea-fps	121.2	82.4	106.7	97.8	85.0	78.9	Taken	156.8	101.4	94.5
80 NH_4NO_3-fpd	134.7	108.0	143.1	121.7	103.6	89.2		156.9	128.4	108.6
80 Urea-fpd	141.4	107.8	140.1	117.9	107.2	96.9		146.0	123.6	107.2
160 NH_4-NO_3-fpd	141.7	120.2	147.6	121.0	113.1	90.4		149.8	129.3	111.8
160 Urea-fpd	140.4	110.6	151.7	114.9	105.1	82.4		163.0	124.4	113.1
40 NH_4NO_3-std[4]	125.6	84.0	117.0	104.0	82.8	88.0		160.0	97.4	98.4
40 Urea-std	118.9	94.6	116.5	97.1	94.5	89.0		165.2	103.9	98.3
80 NH_4NO_3-std	140.4	122.7	142.7	118.0	92.9	97.6		162.9	117.1	110.7
80 Urea-std	146.2	116.0	142.1	117.6	108.5	93.6		162.2	127.4	112.5
40 NH_4NO_3-sd[5]	127.1	104.5	136.0	99.1	82.7	91.8		153.8	106.8	99.9
40 Urea-sd	117.7	100.5	133.9	103.9	80.4	92.6		165.4	104.8	98.5
80 NH_4NO_3-sd	127.7	97.6	124.7	109.4	87.6	95.3		163.2	110.6	103.2
80 Urea-sd	140.5	124.4	149.8	124.0	95.6	90.1		162.8	126.7	113.0
160 NH_4NO_3-sd	136.9	104.2	150.0	117.1	105.5	91.3		160.3	126.0	111.5
Ave. annual corn yield in bu/A	127.0	99.4	128.6	106.6	92.4	88.3		157.2	111.2	101.4
Significance									**	**
C.V. (%)									10.6	8.8
BLSD (.05)									15.2	5.2

[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.

Table 3. Nitrogen content and removal with yield grain and total dry matter production - continuous corn - 1978.

	Yield Grain		Dry Matter Production		
Treatment	N Content	N Removal	Yield	Stover N	Total N Removal
#N/A	%	#/A	T/A	%	#/A
Control	1.12	34.6	4.64	.40	59.4
40 NH_4NO_3-fpd[2]	1.21	56.1	5.91	.44	88.0
40 Urea-fpd	1.26	65.6	6.39	.49	102.4
40 NH_4NO_3-fps[3]	1.20	57.5	5.88	.40	84.9
40 Urea-fps	1.40	67.4	6.36	.48	105.3
80 NH_4NO_3-fpd	1.56	94.8	7.22	.57	142.7
80 Urea-fpd	1.40	81.9	6.90	.58	127.7
160 NH_4NO_3-fpd	1.68	102.6	7.91	.77	177.0
160 Urea-fpd	1.71	100.4	7.90	.78	175.7
40 NH_4NO_3-std[4]	1.18	53.7	5.92	.48	88.1
40 Urea-std	1.33	65.7	6.82	.41	101.3
80 NH_4NO_3-std	1.42	82.4	6.77	.50	122.7
80 Urea-std	1.50	90.2	7.31	.59	141.1
40 NH_4NO_3-sd[5]	1.26	63.8	6.36	.48	100.4
40 Urea-sd	1.38	68.8	5.99	.44	100.2
80 NH_4NO_3-sd	1.56	81.4	6.22	.60	125.4
80 Urea-sd	1.53	91.7	7.02	.59	138.8
160 NH_4NO_3-sd	1.68	100.1	7.04	.70	157.0
Significance	**	**	**	**	**
BLSD(.05)	0.10	11.3	1.22	.07	18.6
CV (%)	12.7	11.6	10.1	10.6	12.2

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-sidedress

WEST CENTRAL EXPERIMENT STATION - MORRIS

WEATHER SUMMARY - 1978

		Precipitation			Air Temperature			Soil (10 cm) Temperature	
Month	Period	1978	91-yr. av.	Dev. from av.	1978	91-yr. av.	Dev. from av.	1978	10-yr. av.
January	1-31	.37	.67	- .30	- 0.3	8.4	-8.9	6.6	20.7
February	1-28	.38	.66	- .28	5.8	12.8	-7.0	10.9	23.9
March	1-31	.78	1.05	- .27	24.8	26.7	-1.9	27.0	29.2
April	1-10	1.55	.57	+ .98	38.4	38.0	+0.4	36.0	
	11-20	.72	.64	+ .08	38.9	44.3	-5.5	37.9	
	21-30	.53	1.10	- .57	47.6	48.2	-0.6	42.9	
Total or av.		2.80	2.31	+ .49	41.6	43.5	-1.9	39.0	41.4
May	1-10	.78	.78	0	49.9	52.0	-2.1	49.4	
	11-20	.33	.96	- .63	59.1	55.6	+3.5	58.2	
	21-31	1.37	1.22	+ .15	65.6	59.9	+5.7	66.0	
Total or av.		2.48	2.96	- .48	58.5	56.0	+2.5	58.1	57.1
June	1-10	.36	1.29	- .93	58.4	63.2	-4.8	62.4	
	11-20	1.20	1.24	- .04	66.4	66.5	-0.1	71.1	
	21-30	3.96	1.36	+2.60	68.7	68.3	+0.4	72.6	
Total or av.		5.52	3.89	+1.63	64.5	66.0	-1.5	68.7	69.3
July	1-10	.99	1.50	- .51	69.2	70.0	-0.8	73.6	
	11-20	.58	1.04	- .46	70.9	71.4	-0.5	79.1	
	21-31	.51	1.03	- .52	67.5	71.6	-4.1	75.6	
Total or av.		2.08	3.57	-1.49	69.1	71.0	-1.9	76.1	76.7
August	1-10	1.12	1.06	+ .06	65.5	70.4	-4.9	74.0	
	11-20	.40	.92	- .52	71.4	69.3	+2.1	70.6	
	21-31	1.11	.97	+ .14	69.5	66.9	+2.6	74.8	
Total or av.		2.63	2.95	- .32	68.8	68.8	0	75.3	73.9
September	1-30	3.03	2.19	+ .82	63.3	59.1	+4.2	66.9	61.5
October	1-31	.08	1.59	-1.51	45.8	47.4	-1.6	49.6	47.8
November	1-30	1.25	.94	+ .31	26.7	29.8	-3.1	34.3	33.6
December	1-31	.46	.67	- .21	10.4	15.5	-5.1	22.2	23.4
April-August Growing Season		15.51	15.68	- .17	60.6	61.1	-0.5	63.6	63.8
January-December Annual		21.86	23.45	-1.59	40.1	42.1	-2.0	44.8	46.7