SOIL SERIES

A REPORT ON FIELD RESEARCH IN SOIL SCIENCE

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

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

Sincere appreciation is expressed for materials and/or financial assistance or program support from several organizations including: Potash Institute of North America, Farmers Union Central Exchange, 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 Association, Minnesota Soil and Water Conservation Commission, 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, J.L. Shiely Company, The Tennessee Valley Authority and the North Central Forest Experiment Station.

The investigators also greatly appreciate the cooperation of the 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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DROUGHT AND THE 1977 SEASON

by Donald B. Baker and
Earl L. Kuehnast (DNR)

I. Soil Water

a. The Four Stages of Soil Water

Because plants are unable to use water directly but must absorb it through their roots, the importance of soil water reserves to agriculture cannot be over-emphasized.

The average picture of the soil water in agricultural soils consists of four stages as shown in Fig. 1. One is the relatively rapid and steady drawdown of the soil water reservoir that takes place approximately from June through August. This is the period when the precipitation is almost always insufficient for the crop needs, and the soil reserves are drawn upon. Thus, even in a normal year the soil water reserves play an essential part.

The next stage for soil water extends from September to the soil freeze-up, which occurs ordinarily in early December in the southern one-quarter of the state. Normally this is the major and most efficient of the recharge periods. Around 50% or more of the rainfall during this period remains in the soil for use in the following growing season (1). The remainder of the precipitation is lost as runoff or consumed by evapotranspiration.

While the soils are frozen from December to early April little water is added to the soil, and most of the over-winter precipitation is lost as runoff in the spring. In fact results from Minnesota indicate that no more than 25% of the winter precipitation enters the soil (1).

From the spring thaw until early June is the third of the three possible recharge periods. On the average about 15-20% of the precipitation in this period remains in the soil for the following June-August grand water consumption period. Thus, this is ordinarily second to the autumn recharge period in both relative and absolute terms.

b. Detailed Analysis of 1972-1976

In looking back over the last 5 years (1972-1976) it is apparent that very nearly optimum years with respect to both soil water and precipitation occurred in 1972 and 1973. Fig. 2 shows how the soil water during these two years varied from the 17 year mean water profile. It is to be noted that in both 1972 and 1973 the water content was very close to the mean. The combination of adequate precipitation and soil water was reflected in corn yields which averaged about 100 bushels per acre in the surrounding area of Redwood and Cottonwood counties (9).

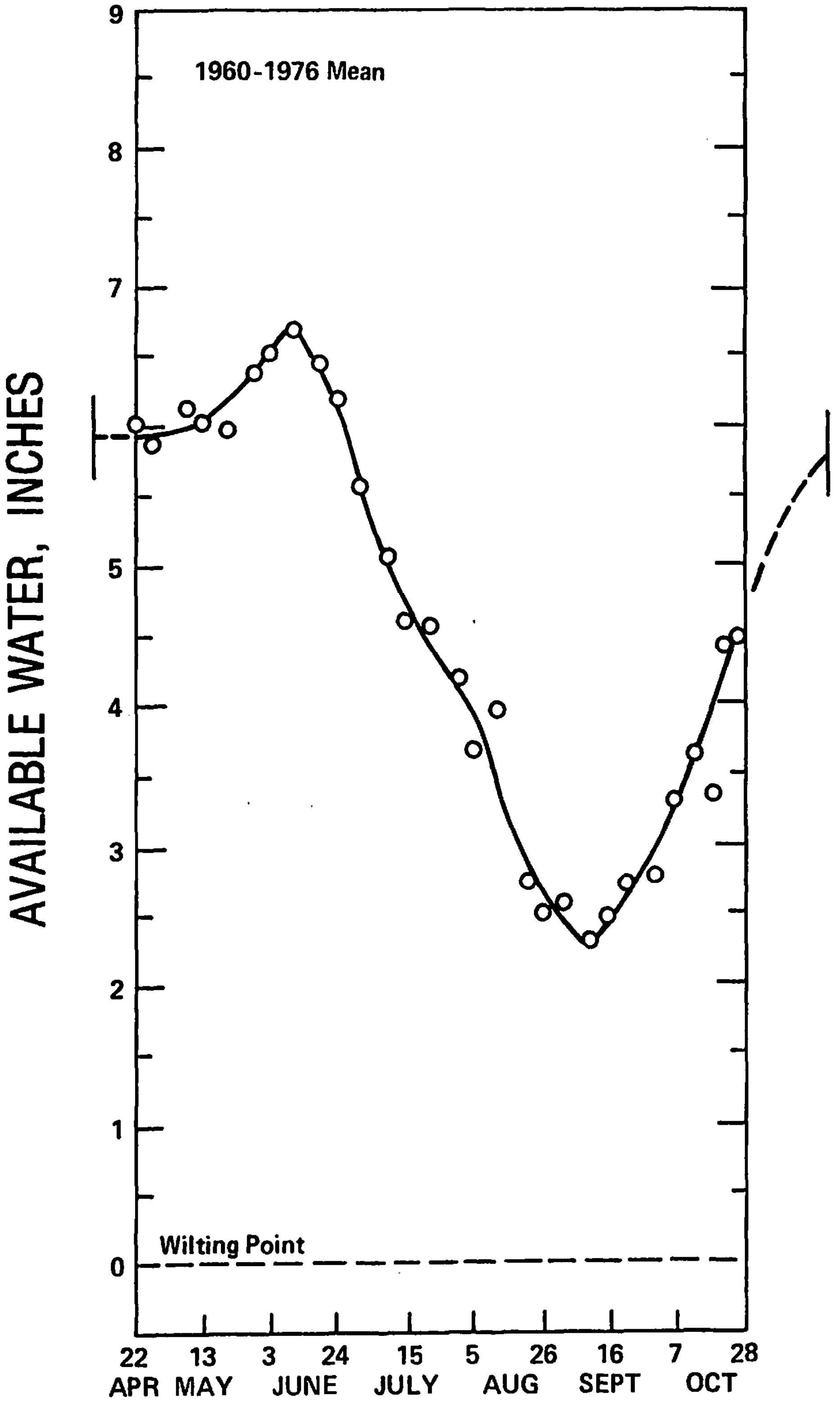

Fig. 1. The 1960-1976 mean total plant available soil water in a 5-foot column of soil under continuous corn at the Southwest Agricultural Experiment Station, Lamberton, between late April through October. The dashed lines represent assumed water contents, due to few soil samples, after the spring soil thaw (mean date April 5) and before soils freeze (mean date December 7).

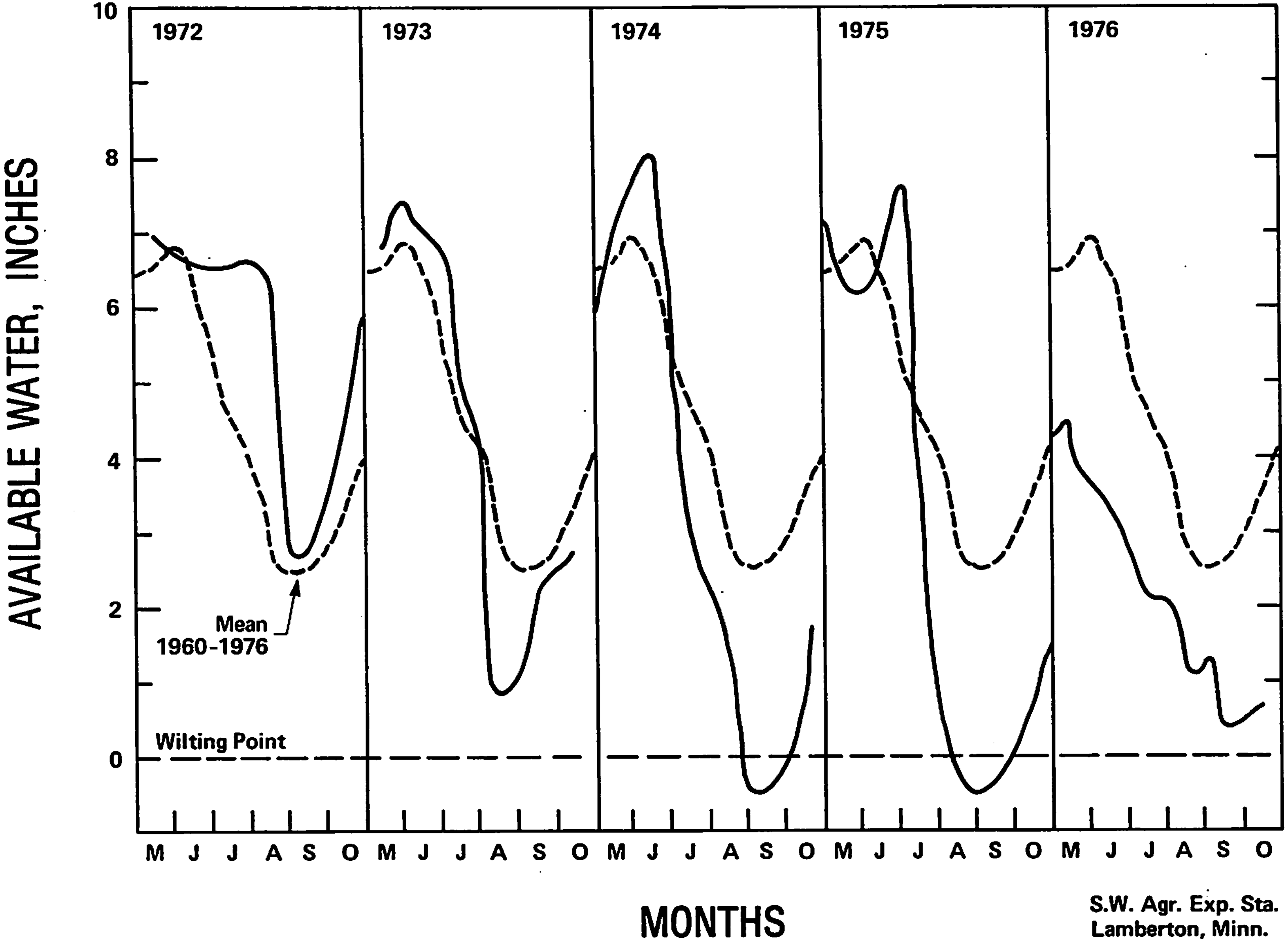

Fig. 2. The total plant available soil water in a 5-foot column of soil under continuous corn during two seasons of 100 bu./A. yield (1972 and 1973), two seasons of 60 bu./A. yield (1974 and 1975) and a season of about 25 bu./A. yield (1976) at the Southwest Agricultural Experiment Station, Lamberton. The dashed line is the 1960-1976 mean soil water content.

With deficient precipitation but adequate soil water supplies relatively acceptable yields can be obtained. This was true in both 1974 and 1975 in southwestern Minnesota. By the end of the water drawndown period, in late August to early September, all of the plant available water had been extracted from the soil due to insufficient summer rains. Corn yields in Redwood and Cottonwood counties averaged about 60-65 bushels per acre for the years of 1974 and 1975 (9).

The 1974 and 1975 soil water profiles at the Southwest Agricultural Experiment are remarkably alike and deserve special mention as they led up to the events of 1976. In both years rains of any real value ceased in a greater part of southwestern Minnesota from about the third week of June until mid-August and later. Due to the heavier than usual spring precipitation in both years the early season soil water reserves were higher than usual as shown in Fig. 2. The lack of precipitation during the very critical months of July and August caused the water reserves to be depleted to the point where the net plant available water was negative by late August in both 1974 and 1975. As a result, the water content of the soil under continuous corn at the Southwest Agricultural Experiment Station, and very probably much of southwestern Minnesota, was lower than any time during the previous 15 years.

Detail of the 1975 and 1976 precipitation seasons is shown in Fig. 3, for Lamberton, representing southwestern Minnesota, and in Fig. 4, for Morris, representing west-central Minnesota. These two stations, and in general the areas they represent, had contrasting 1975 seasons, normal at Morris but dry at Lamberton, and similar 1976 seasons with low precipitation at both. July is a particularly important month for corn growth and development because tasseling and silking occur in mid- to late July, and water supplies assume extreme importance at that time. Therefore, the occurrence of a precipitation deficit or low soil water supplies in the latter part of July is a serious matter. The reproductive period of soybeans occurs over a more extended period, and thus this crop is often less affected than corn by the short term dry spells common to July.

At Lamberton, Fig. 3, the cumulative precipitation was already 5.23 inches below average between the first of May and the end of July, 1975. By the end of July, 1976, the cumulative deficit had reached 16.67 inches. In contrast at Morris, Fig. 4, the 1975 precipitation season was about normal. However, in May, 1976, the precipitation fell well below the normal so that by the end of July the cumulative precipitation deficit was 7.91 inches.

For many parts of the state, but especially in the southwest and the extreme northwest, the September-November soil water recharge period of 1975 failed to make up the water shortage of the 1975 growing season. This is shown in Fig. 5, a map of the estimated departure from the mean of the soil water at the beginning of the 1975-76 winter period. Note that the departures are greatest in southwestern and extreme northwestern Minnesota. The northern one-quarter of the state, including the northwestern corner, received some above-normal, June, 1976, rains which were responsible in part for the high wheat yields in Kittson and Roseau counties in

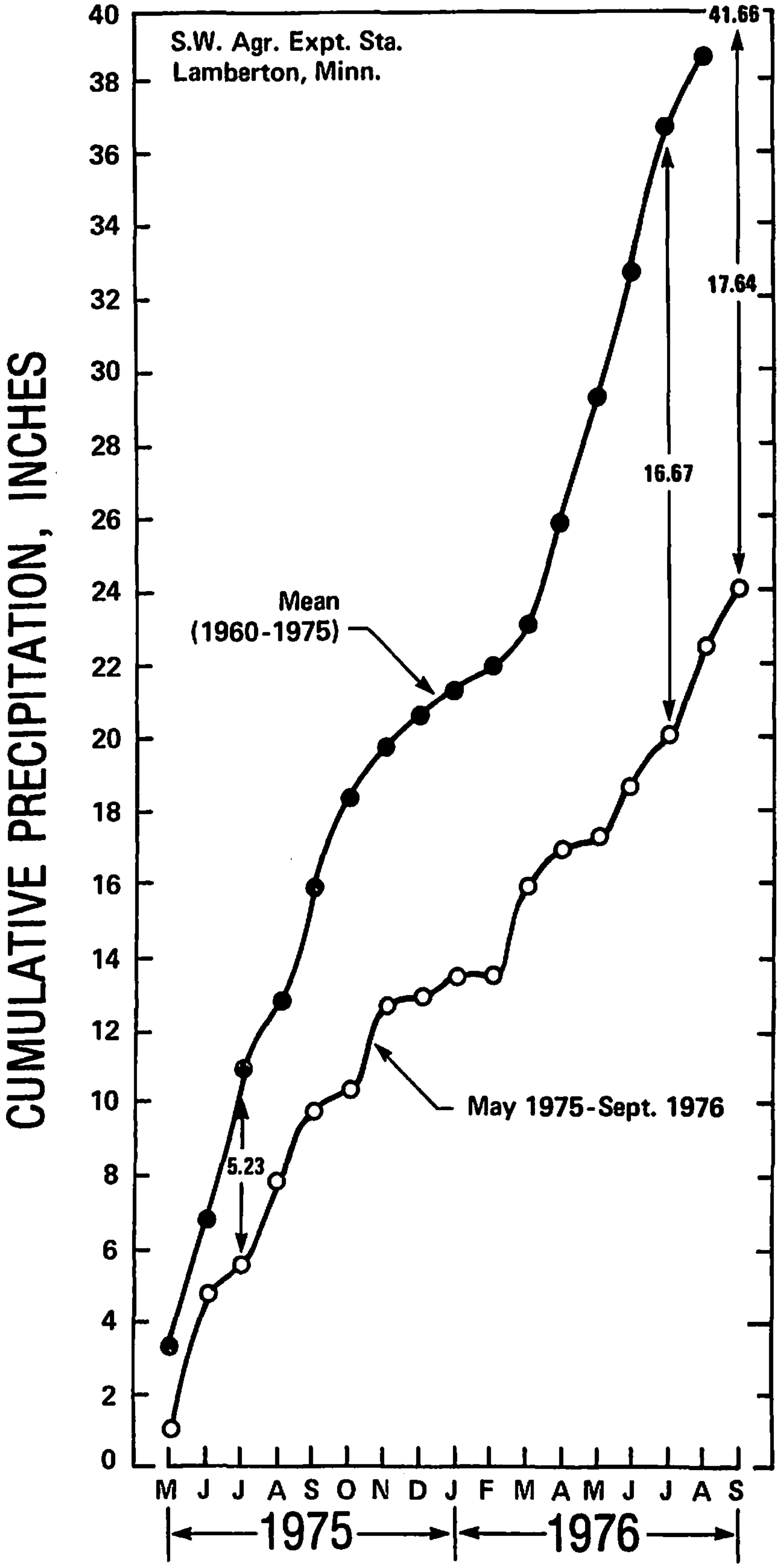

Fig. 3. The cumulative May, 1975--September, 1976, precipitation compared to the 1960-1975 cumulative mean at the Southwest Agricultural Experiment Station, Lamberton.

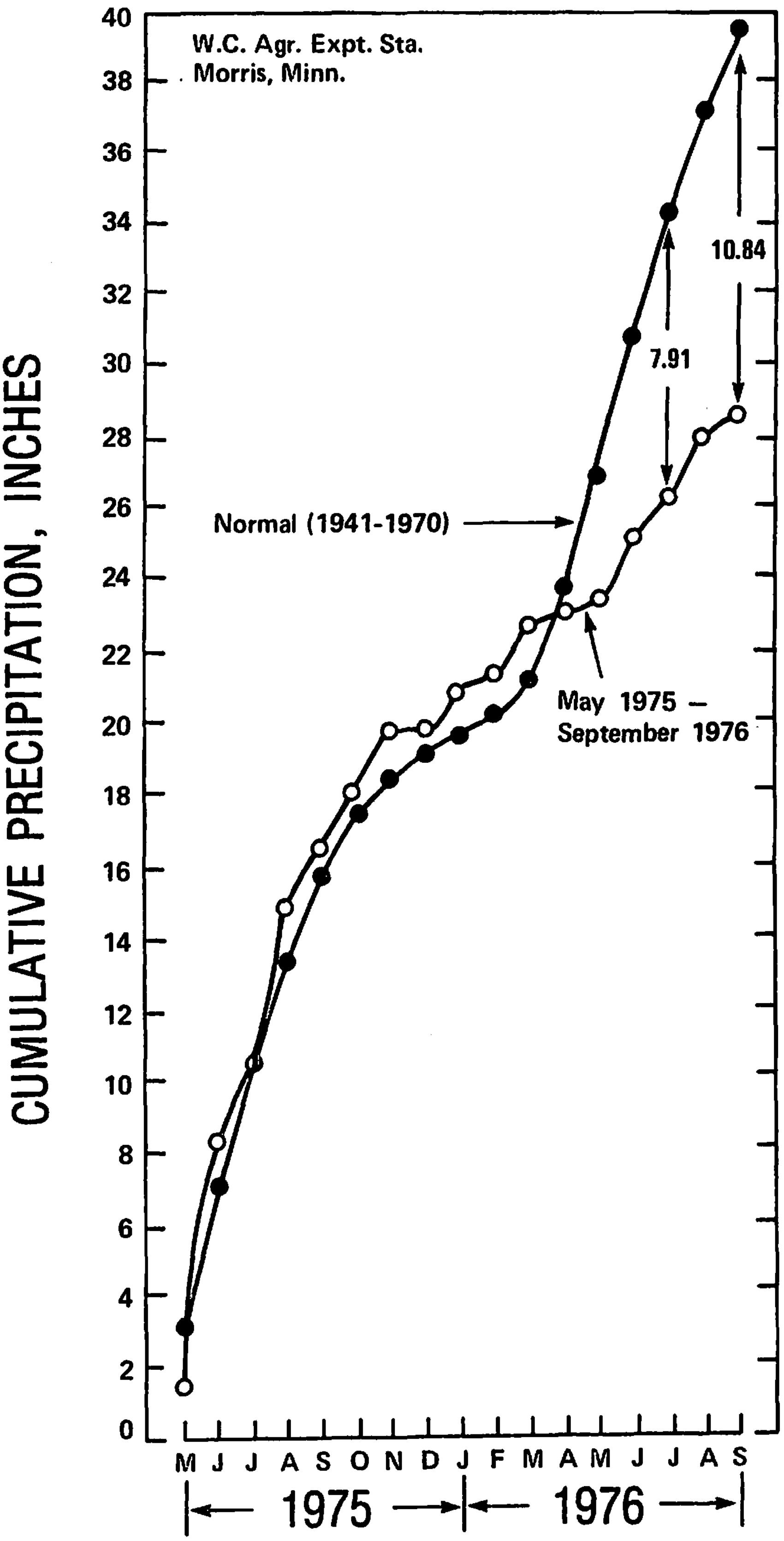

Fig. 4. The cumulative May, 1975--September, 1976, precipitation compared to the 1941-1970 cumulative normal at the West Central Agricultural Experiment Station, Morris.

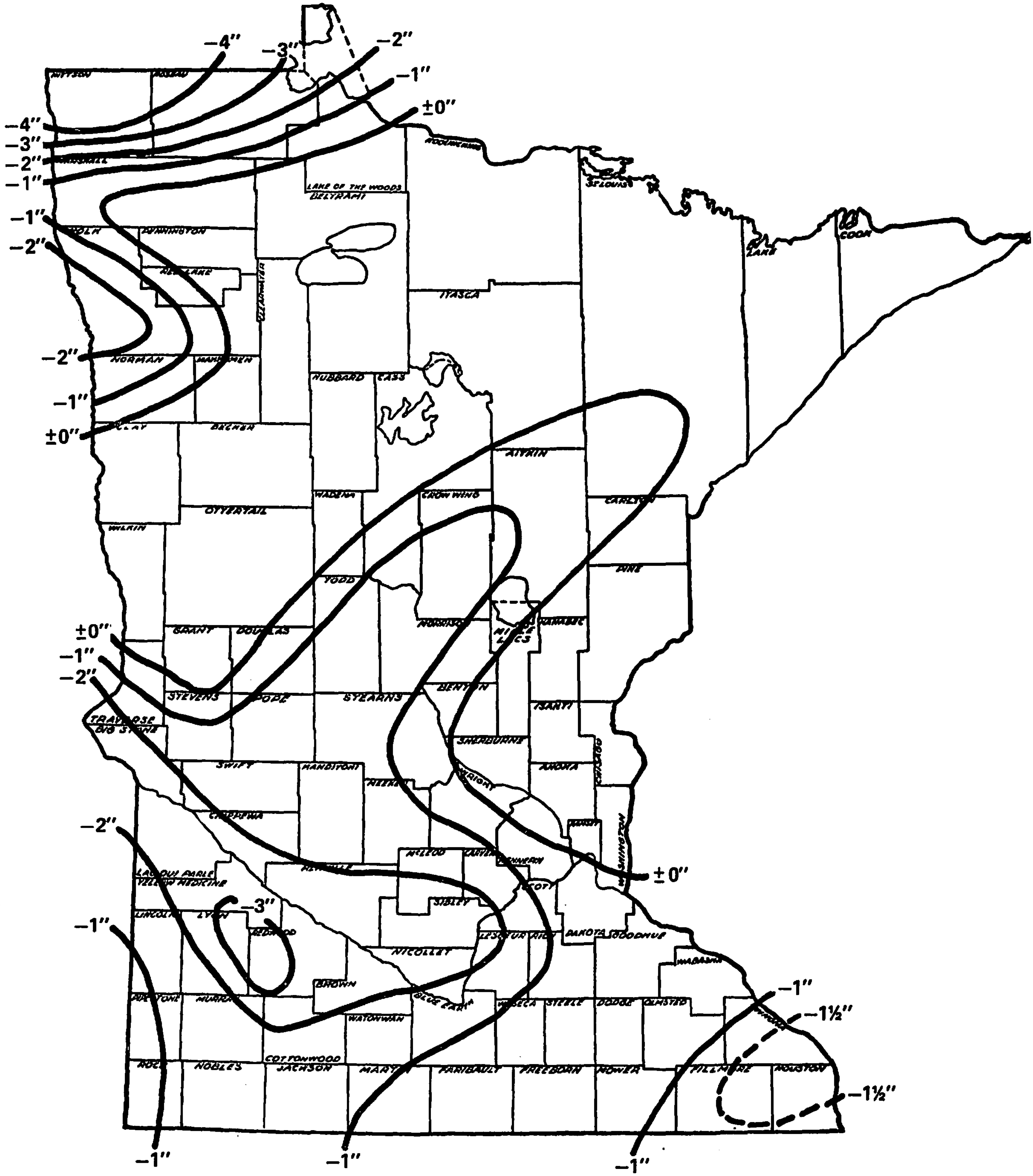

Fig. 5. The estimated departure of the soil water from the mean at the end of the September-November, 1975, soil water recharge period.

1976. However, in the remainder of the state the 1976 spring recharge, with a few exceptions, simply failed to materialize. As a result the growing season of 1976 throughout a great share of the state, and most particularly in the west-central and southwest areas, began with the soil in an unusually low water content. With few exceptions this situation failed to improve throughout the season.

The 1976 soil water picture in Fig. 2 at the Southwest Agricultural Experiment Station at Lamberton was a disaster for three reasons. As noted earlier, the 1975 autumn soil water recharge period failed to make up the 1975 growing season losses; the 1976 spring recharge period failed to materialize; and, third, the growing season precipitation was very low. The end result was a yield averaging about 25 bushels of corn per acre compared to about 60 bushels per acre in 1974 and 1975 and about 100 bushels per acre in 1972 and 1973.

The corn yields in Redwood and Cottonwood counties for 1972-1976 permit an assessment to be made of the two growing season sources of water: precipitation and stored soil water. With adequate supplies of both in 1972 and 1973 yields were about 100 bushels per acre; with only stored soil water in adequate supply in 1974 and 1975 yields were about 60 bushels per acre; and in 1976 with inadequate supplies of both the yield was but 25 bushels.

A comparison of the total soil water at the end of the major water consumption period in 1976 with the same period in 1974 and 1975, Fig. 2 introduces an apparent paradox. That is, in the drought year of 1976 how could the late August soil water content be higher than in late August of either 1974 or 1975? The answer is that the corn plant population in 1976 was about 5,000 corn plants per acre compared to a more usual 20-25,000 plants per acre in other years. Equally important is the fact that the fewer corn plants of 1976 failed to develop roots of adequate density to exploit the little soil water that was present.

c. Recharge for the 1977 Growing Season

It was noted earlier that in an average year the soil, after reaching the lowest water content of the year in late August or early September, is recharged principally by the September-November rains. Such was not the case in 1976. On a national scale it is evident from Fig. 6 that a large precipitation deficient area occurred during September-November which coincided all too closely with the North Central drought as mapped in late August, 1976. It is evident that some of the California drought area was also in a rain deficient region.

Details of the autumn precipitation can be seen in larger scale in Fig. 7. The areal extent and location of the precipitation deficiencies were such that more than just the southwest and west-central areas have to be included where the drought is serious. This is true for the north-central and northeast where the precipitation was from 4 to 6 inches below normal. In effect the September-November recharge period was a failure. Of the total precipitation

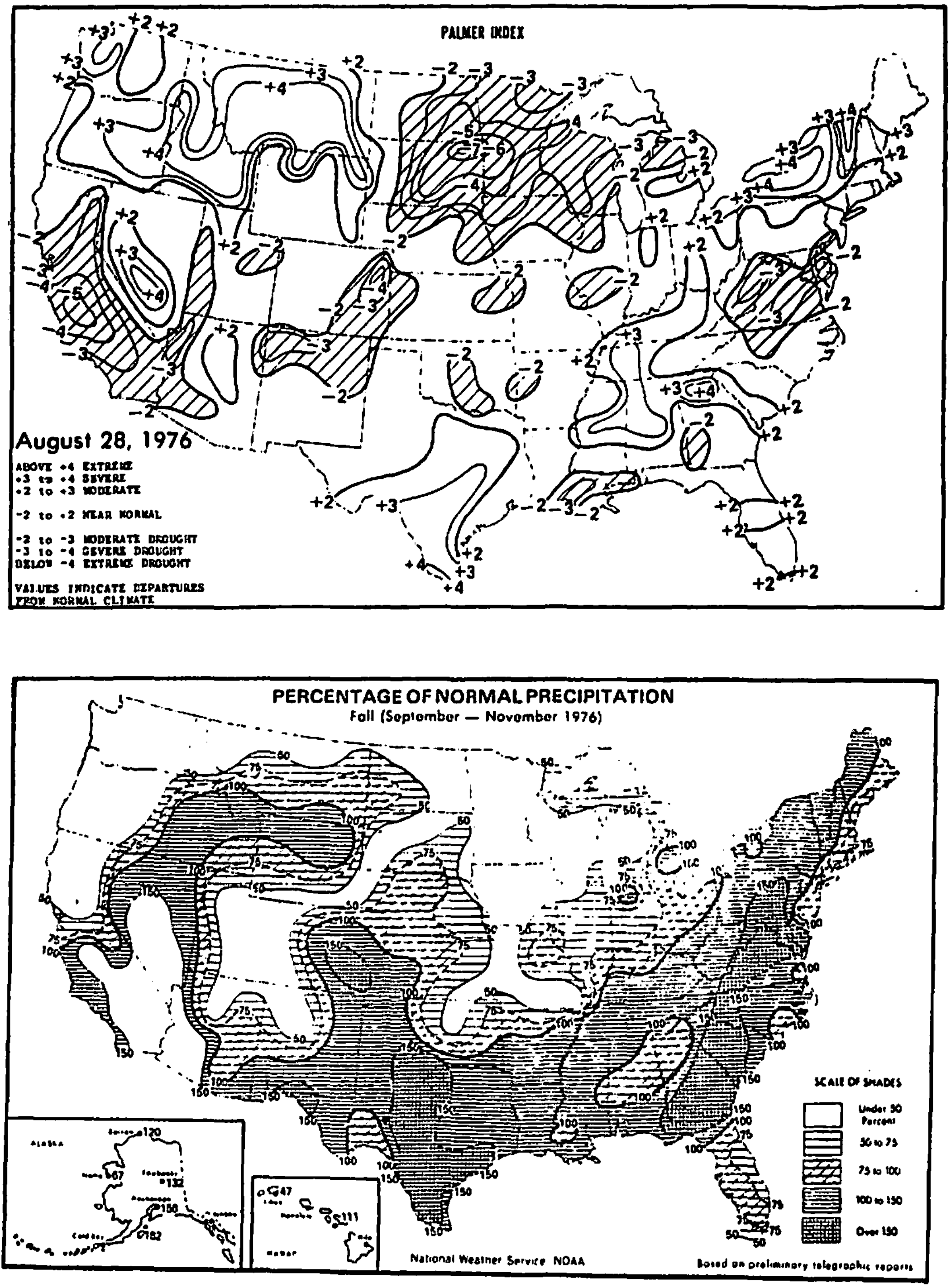

Fig. 6. The lower picture is the percent of the normal September-November precipitation received in the United States in 1976. Note how the area receiving 50% or less of normal coincides with the areal extent of the 1976 drought in the North-Central region (upper picture) at the end of August. The figures are courtesy of the Weekly Weather and Crop Bulletin issues of August 31 and December 14, 1976.

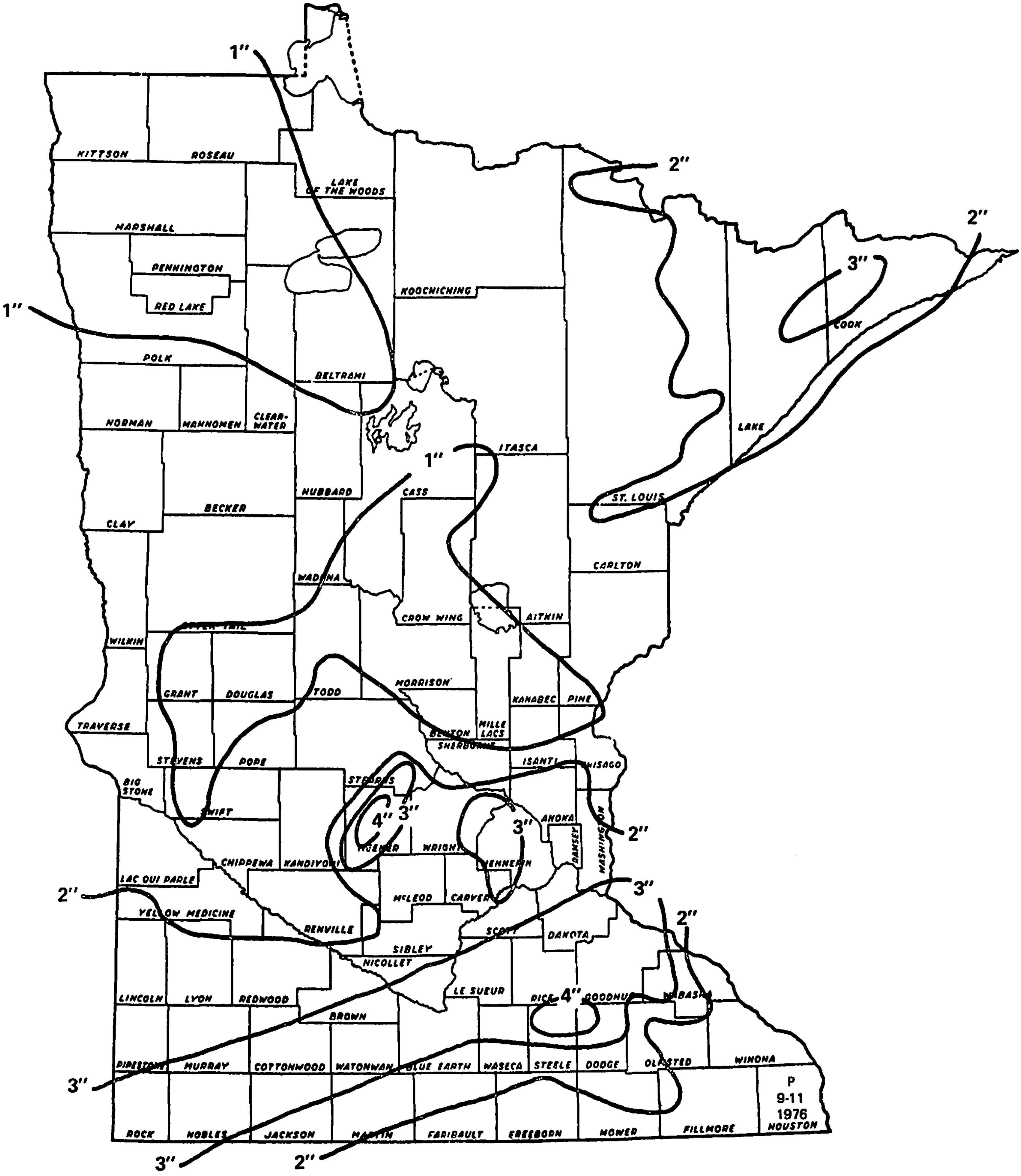

Fig. 7. Total precipitation for the period September-November, 1976.

that did fall during this critical autumn period, only in a few small areas was the precipitation in excess of normal evapotranspiration losses estimated to be 2.5-3.0 inches for the period.

The shortage of the growing season and autumn rains is reflected in the soil water profiles shown in Fig. 8. At some sites the water is indeed at a critically low level as, for example, in Lyon county where the upper 27 inches are below the wilting point. All of the soils are at a lower water content than last year, except the Sibley county site. Of particular concern is the low water content in the subsoil, since it is these reserves which normally are the prime crop water source during the critical months of July and August. The gravity of the dry subsoils lies in the difficulty in rebuilding these reserves. Rains of some magnitude are required since evaporation losses soon dissipate the value of small rainfalls. The importance of the spring rains looms larger and larger this year as a result of the absence of the 1976 fall recharge. Unfortunately, spring rains are ordinarily less efficient than those of autumn. There are several reasons for this. The primary one is that the solar radiation is considerably higher in late spring than in the autumn (the sun reaches its zenith in June) thus providing energy for the greater evaporation. Another reason is that spring rains often fall upon an already saturated topsoil. A third, but perhaps less important reason, is that the spring rains may be more intense and thus more subject to runoff losses.

At all sites sampled the water content is well below the mean fall content as shown in Table 1. In comparing the soil water departures in Table 1 with the September-November precipitation shown in Fig. 7, it is apparent that at most localities the soil is drier than the precipitation departures would indicate. This has occurred because the shortages in soil water were carried over from the summer period. Although soil water records are not available previous to 1960, the indications are that most soils in Minnesota have not been so dry as today since National Weather Service records began in 1891.

For the moment at least in the Red River valley the dry soils and the very limited amount of the fall, 1976, precipitation is probably not a matter of immediate concern. That is, the very level terrain plus the fine textured soils in the valley result in the all too frequent problem of surplus water. For this reason the drier than usual soils, at least until planting has been completed, may be looked upon with favor. Nevertheless, the fact remains that the subsoil reserves are depleted and must be replenished if a crop is to be raised.

d. Remarks on Groundwater Supplies

That the drought is more than of concern only to agriculture becomes evident upon viewing Fig. 9 which is a well record from the Grand Rapids area. The precipitous drop of the height of the

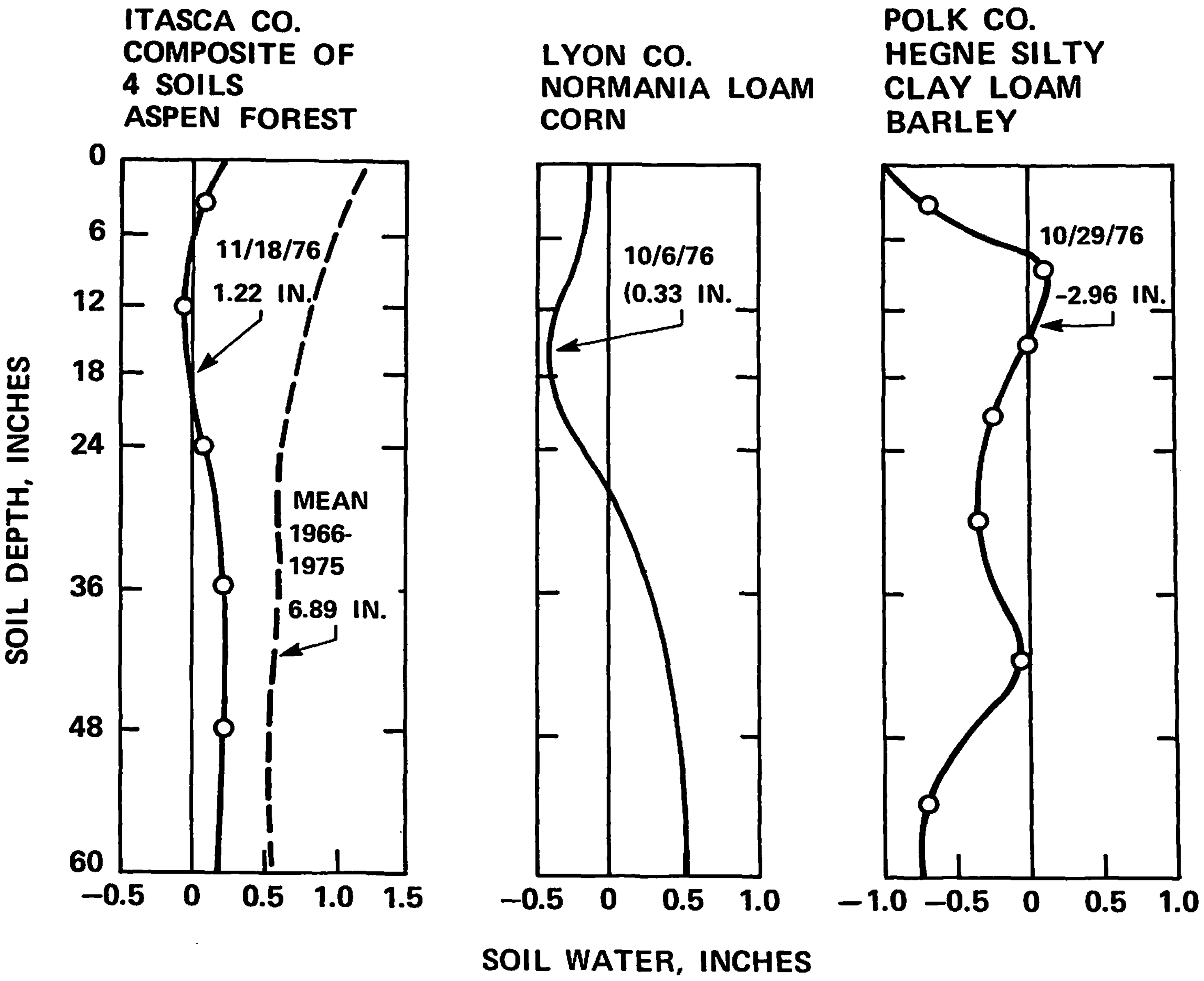

Fig. 8. Plant-available soil water profiles at nine locations in Minnesota, fall, 1976.

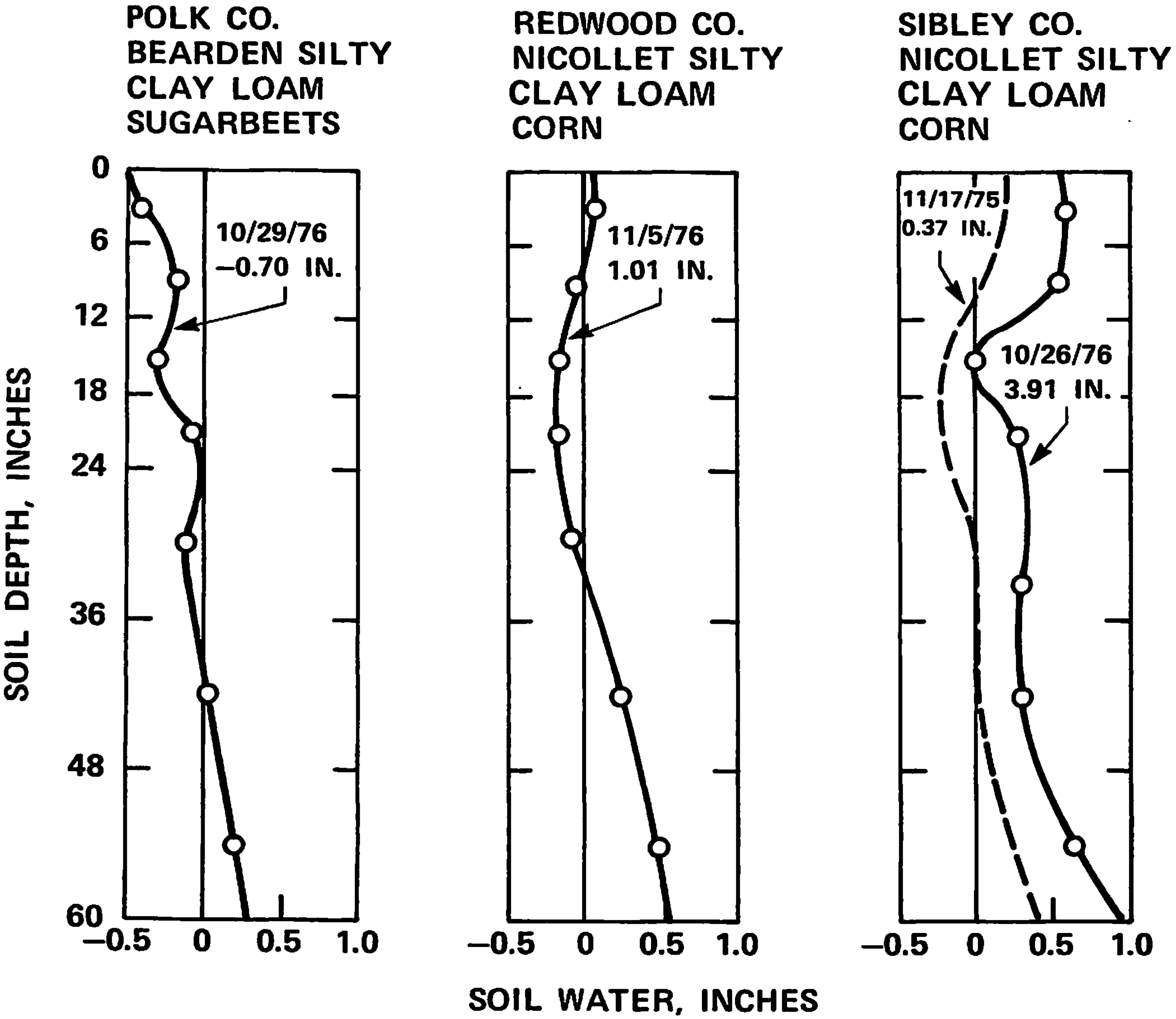

Fig. 8. (Continued).

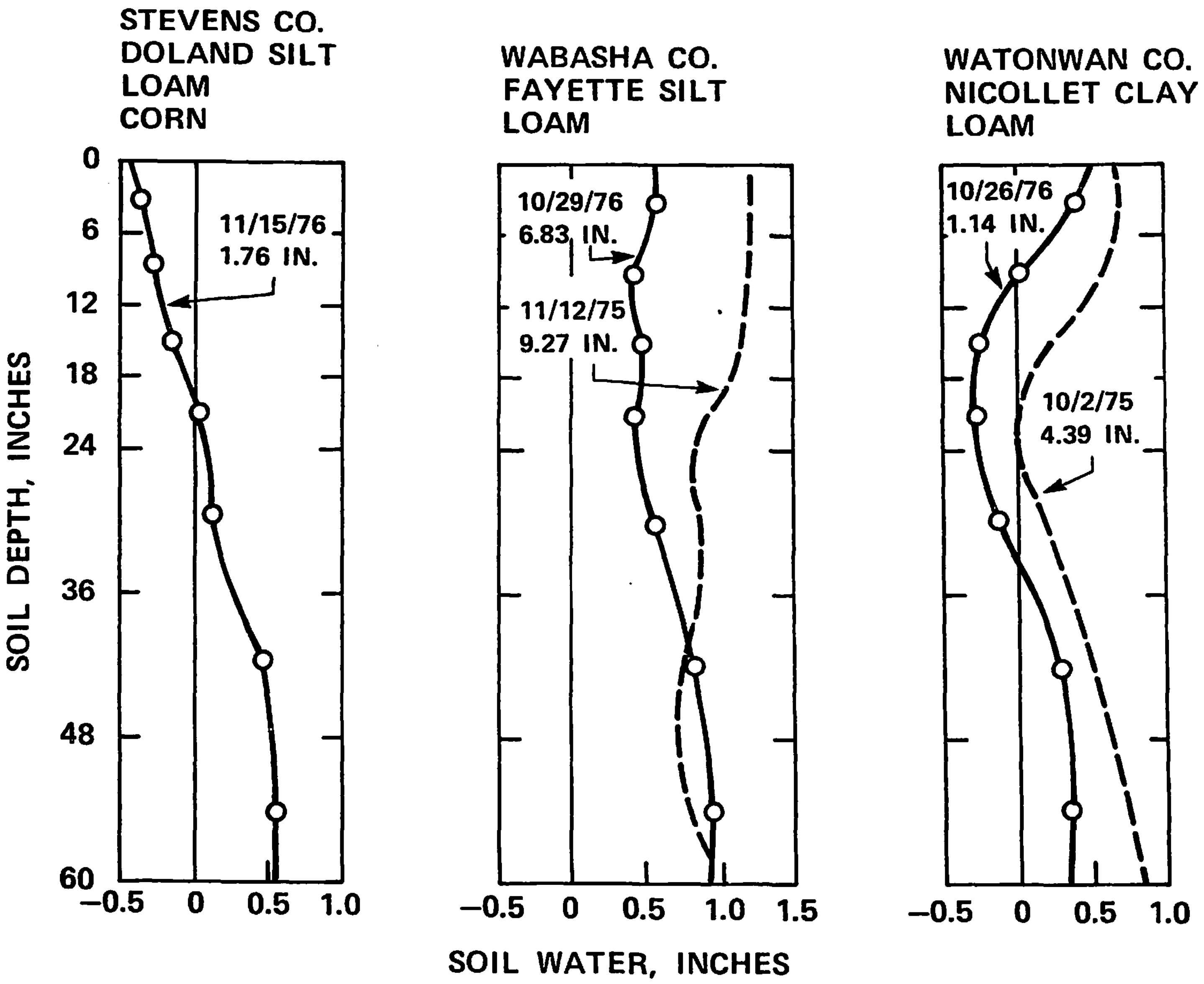

Fig. 8. (Continued).

Table 1. Plant available water in a 5-foot column of soil, fall, 1976.

County	Town	Soil	Crop	Amount of Water, Inches		
				Present	Mean	Departure
Dodge[1]	Dodge Center	Kasson	Alfalfa	0.0*	5.7	-5.7
Itasca[2]	Grand Rapids	Composite[5]	Aspen forest	1.2	6.9	-5.7
Lyon[3]	Clarkfield	Normania	Corn	0.3	5.6**	-5.3
Mille Lacs[1]	Milaca	Milaca	Hay	0.0*	8.7	-8.7
Polk[4]	Crookston	Bearden	Sugarbeets	-0.7	5.6	-4.9
Polk[4]	Crookston	Hegne	Barley	-3.0	5.6	-2.6
Polk[4]	Crookston	Wheatville	Barley	2.4	5.6	-3.2
Redwood[4]	Lamberton	Nicollet	Corn	1.0	5.6	-4.6
Sibley[1]	Winthrop	Nicollet	Corn	3.9	7.3	-3.4
Stevens[4]	Morris	Doland	Corn	1.8	5.6**	-3.8
Stevens[4]	Morris	Hammerly	Corn	1.1	5.6**	-4.5
Todd[1]	Long Prairie	Blowers	Corn	1.5*	6.6	-5.1
Wabasha[1]	Kellogg	Fayette	Corn	6.8	10.0	-3.1
Watonwan[1]	Butterfield	Nicollet	Corn	1.1	6.7	-5.6

1. Samples courtesy of the Soil Conservation Service, U.S.D.A.
2. Data courtesy of Forest Service, U.S.D.A., Grand Rapids
3. Sample courtesy of G. Holcomb, Area Soils Agent, Marshall
4. Samples and data courtesy of Agric. Expt. Sta., U. of M., at Crookston Lamberton and Morris
5. Composite sample of 4 soils

* Estimated from August measurements

** Estimated from Southwest Agric. Expt. Sta. data.

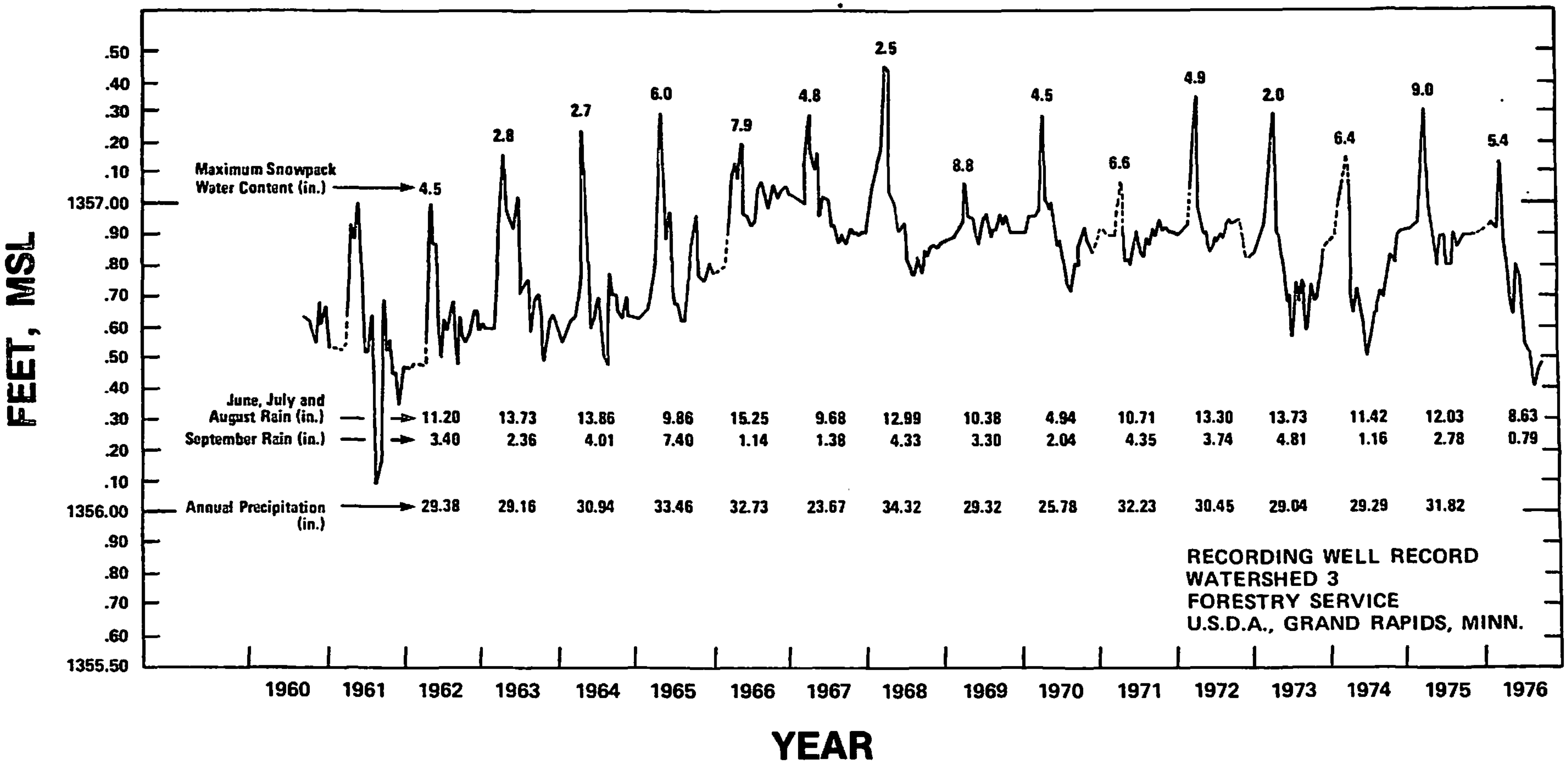

Fig. 9. Recording well record at Grand Rapids, 1960-1976.

water in 1976 is a matter of real concern with respect to water supplies in many parts of Minnesota and particularly in the northeast and north-central areas. Already there are reports of serious shortages in northeastern Minnesota, and there seems little reason not to expect other areas to begin making similar reports.

It should be realized that groundwater supplies, as distinguished from soil water, will show a considerable lag in returning to normal, since the deficits cannot be made up easily or rapidly. When rains of sufficient quantity to be of value do arrive the soil will absorb the precipitation first. Only when the soil reserves are replenished will the groundwater and lakes begin to fill. As a result a lag of at least one year and perhaps several more will be required before groundwater reserves and lake levels return to normal.

II. Rainfall and Soil Water Predictions for 1977

a. Meteorological and Climatological Forecasts

The usual type of meteorological prediction cannot be made for any period longer than about two weeks in advance, much less 3, 6 or even 12 months in advance. Thus, any kind of forecast for the 1977 season must rest upon historical records and probabilities derived from such records. For example, historical records in southwestern and west-central Minnesota indicate that for any one year the probability of low yields induced by weather factors range from about 1 in 4 years to 1 in 10 years of having yields reduced at least 10% below the mean (4).

Another kind of study showed that weather events once established tend to persist in western Minnesota for 26-30 months, while in eastern Minnesota no such tendency was found (8). In this regard there does indeed seem to be a recurrence of low precipitation periods every 20-25 years, in some records at least. Fig. 10 shows evidence of such a condition in the precipitation data from the Twin Cities and selected northern Minnesota stations. If such a regular periodicity does exist it would greatly aid in preparing for these times of low precipitation. Fig. 10 shows that the occurrences of these low precipitation periods do show sufficient regularity that they probably can be forecast accurately for a particular decade. However, the raw data from which the smoothed Minneapolis-St. Paul data in Fig. 11 was obtained shows the inherent difficulty in forecasting low precipitation for any one year (Fig. 11). For example, while the lowest annual precipitation on record for St. Paul occurred in 1910, the highest (or second highest if the 1849 total is in error) occurred just one year later in 1911.

Although there has yet to be a cause and effect relationship established between sunspot numbers and dry periods, their apparent coincidence remains an intriging feature to many investigators. No forecast advantage in the use of sunspot numbers seems to be present, since the occurrence of the major maximum, for example, varies at least ±5 years about the approximate 22 year mean. Thus, their application as a forecast tool, while

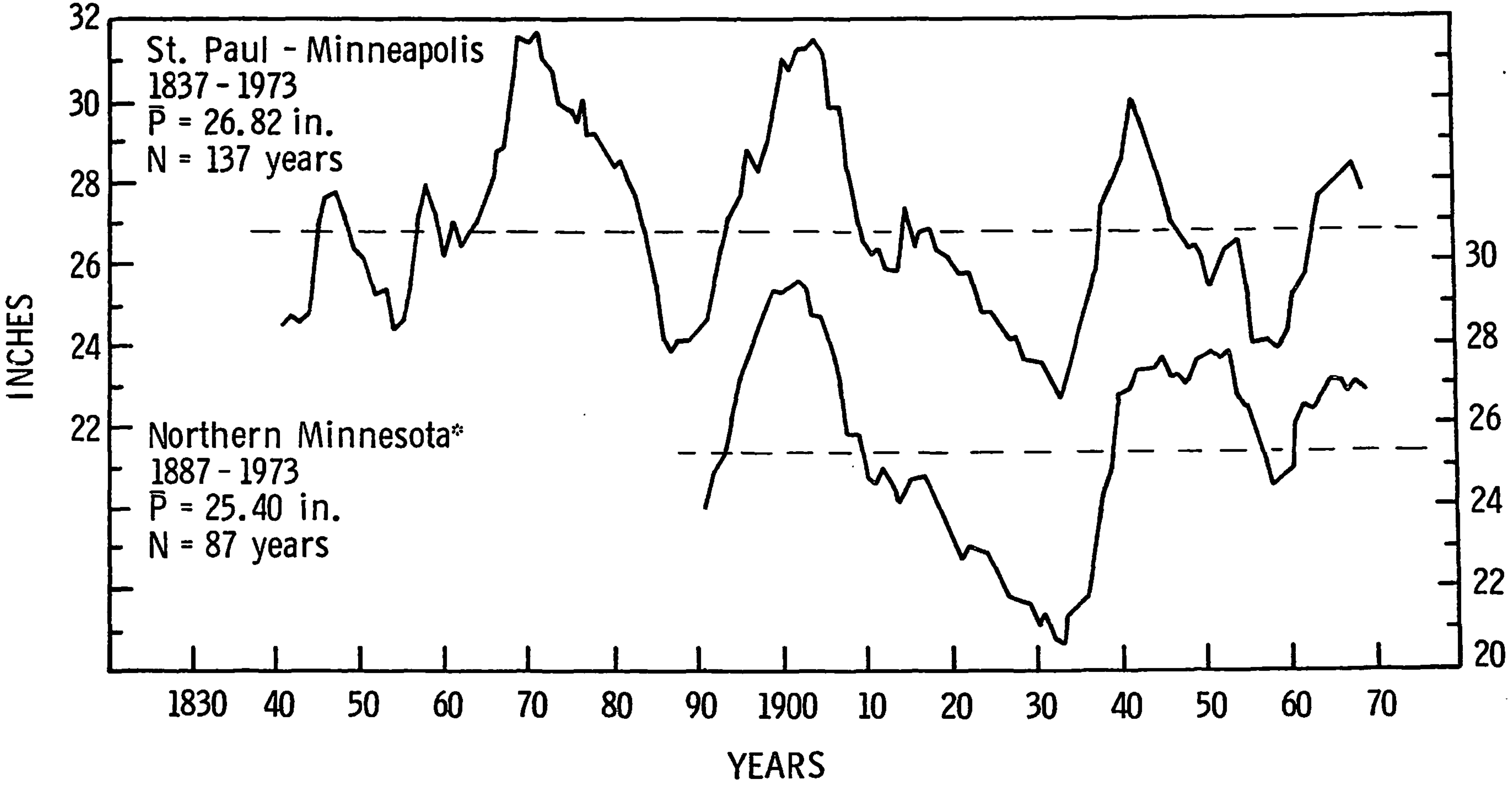

Fig. 10. The upper curve is the same data shown in Figure 3 but smoothed with the normal curve smoothing function of length 2σ = 9 years. This procedure serves to reduce the "noise" of the year to year variation and permit trends to be observed. The lower curve is the smoothed average of five northern Minnesota stations listed in Figure 4.

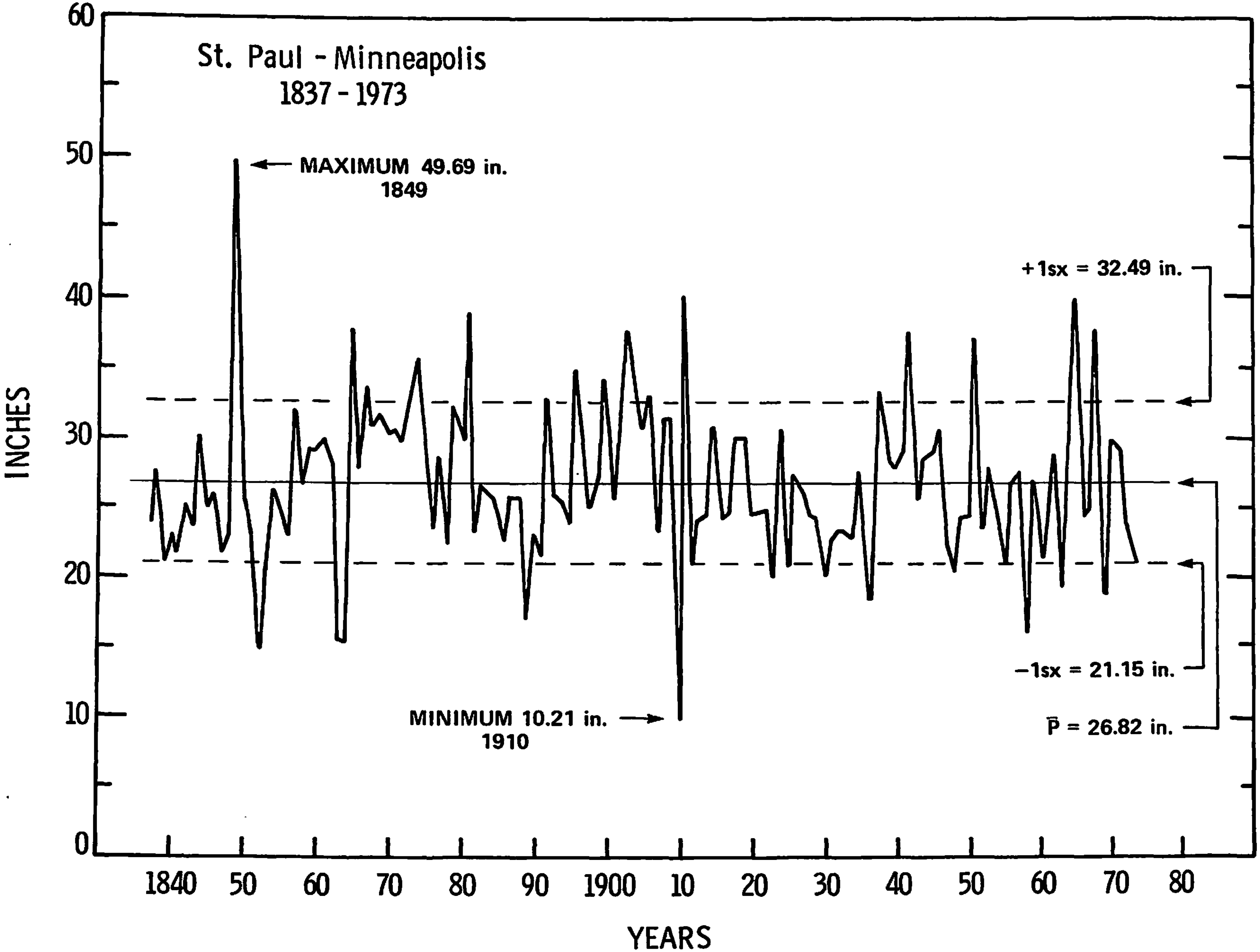

Fig. 11. Total annual precipitation received at St. Paul-Minneapolis from 1837-1973. The data are from combined records of Fort Snelling, St. Paul, Minneapolis, and the Minneapolis-St. Paul International Airport. The mean for the 137 years is 26.82 inches, and the mean plus and minus one standard deviation equals 32.49 and 21.15 inches, respectively. Inspection of the original records indicate that serious observation errors probably occurred in parts of 1848 and 1849. Therefore the 1849 maximum of 49.69 inches is questionable.

acceptable for a particular decade, is unacceptable for the prediction of drought in a particular year.

It is also noteworthy that the areal extent and location of a drought varies greatly both between years and within the same season. Such variation further complicates the forecasting problem.

In any case there is no method, including sunspot occurrences or climatological probabilities, that permits a forecast to be made for a specific year, such as the 1977 growing season, in advance of it. However, it might be inferred from historical records, persistence and probability studies, that probably 1976 was the peak drought year, and that the drought intensity will decrease markedly in 1977. The persistence study cited earlier would tend to substantiate the latter point, for the drought is in its second or third year depending upon the locality.

b. More Variable Weather in the Future?

Both of the previously cited studies point out something that should not be forgotten, which is that precipitation becomes increasingly marginal and variable in moving westward across the state. Also according to one study recently made (6) the Corn Belt has undergone a remarkable succession of good weather seasons that extended from approximately 1957-1972. The abnormally high and uniform yields during this period are illustrated in Fig. 12. It shows the simulated corn yields for five Midwestern states (not including Minnesota) assuming 1973 technology could have been available each year. An amazing feature of the recent climate is shown which, if true, has important ramifications. That is, the Corn Belt has undergone a most unusual series of years from 1957-1973 which resulted in the uniformally high yields shown. A somewhat similar but briefer period in the Minnesota climate is shown in Fig. 13 to have occurred beginning with the 1966 season and extending to the end of the study period in 1973 (4).

No individual climatic element, such as temperature and precipitation, seems to have exhibited a behavior which would explain the results obtained. However, there is no reason not to accept the results, since the plant is an excellent integrator of the various effects of the climate. The simulated crop yields shown in Fig. 12 and 13 show something that the more usual study of the climatic elements could not show.

For the Corn Belt as a whole Fig. 12 shows two very important things. One is that there has been nearly a generation of farmers who have operated in an era lacking real climatic adversity. A second point is that in this same period the combination of technology plus good agricultural weather has resulted in the seemingly ever increasing corn production of recent years.

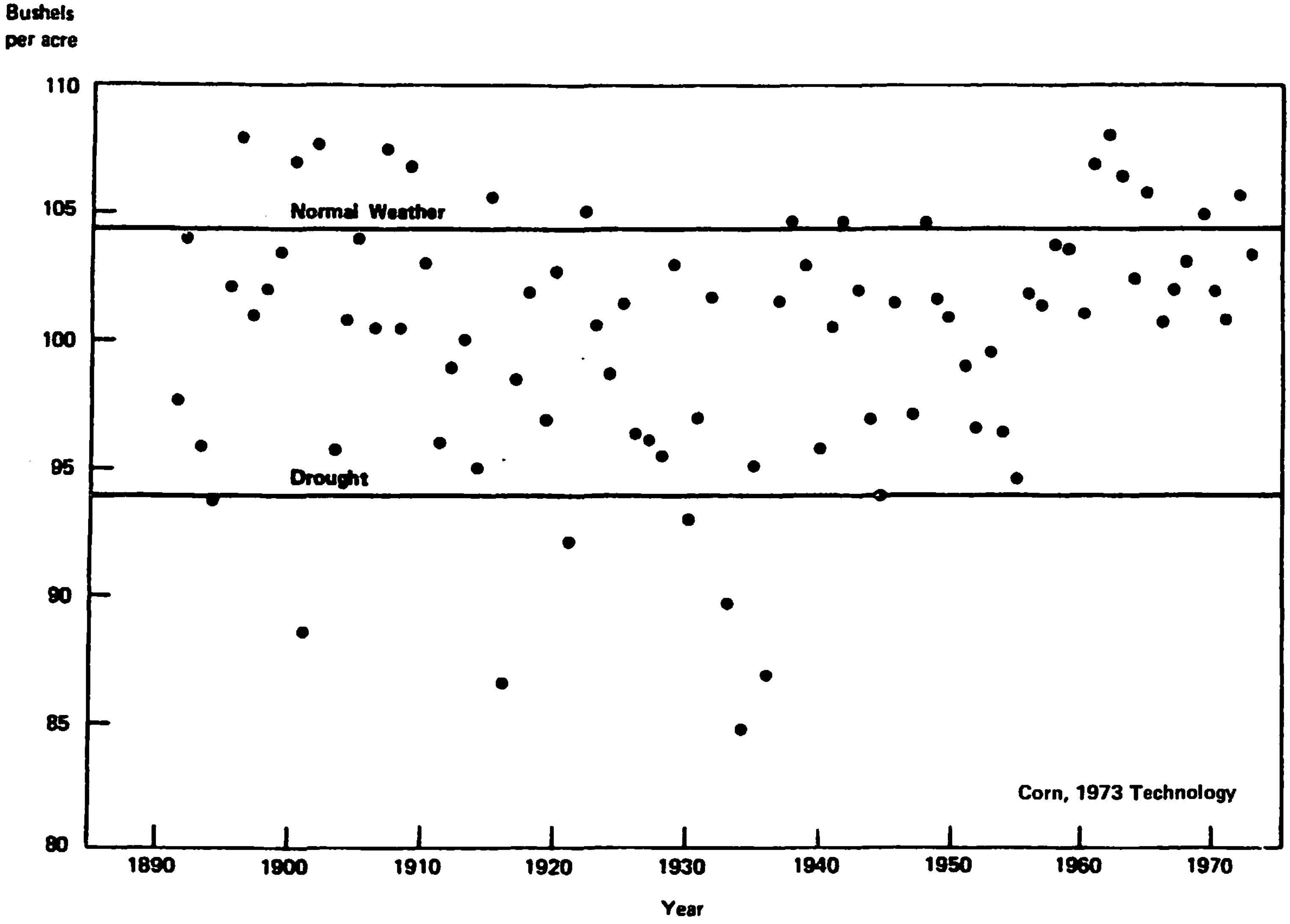

Fig. 12. Simulated mean annual yield of corn in 5 Corn Belt states given that 1973 technology (use of hybrid corn, fertilizers, etc.) had been available in each of the years. After McQuigg and Le Duc (5).

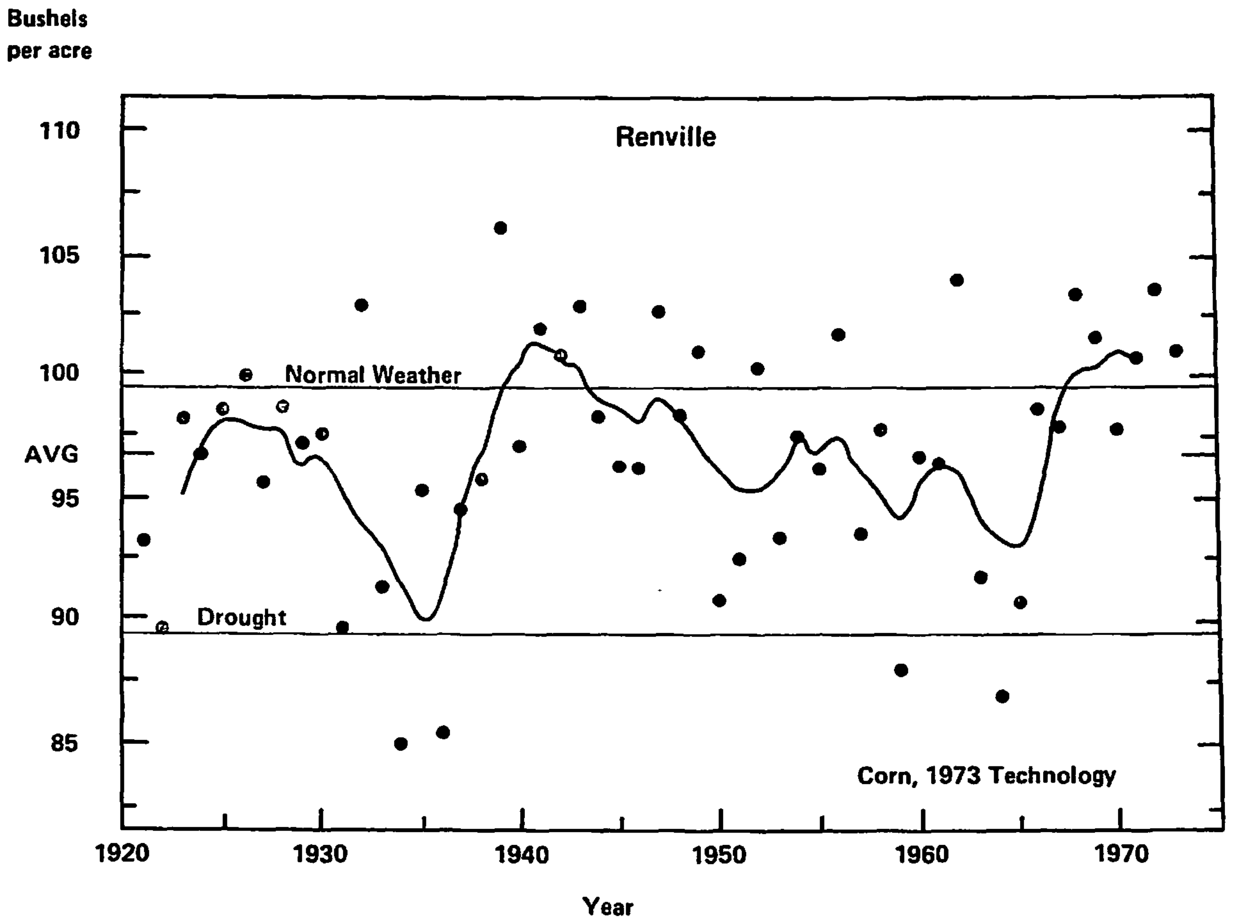

Fig. 13. Simulated mean annual yield of corn in Renville Co., Minn., given that 1973 technology (use of hybrid corn, fertilizers, etc.) had been available in each of the years. Dots represent the calculated annual yield and the curved line is the smoothed yield trend line. The straight line labeled "normal weather" is the yield expected with normal weather. A "drought" is defined as a yield that is less than 90% of the normal weather yield. After Enz (4).

As a result of this succession of apparently very favorable years for agriculture that occurred from about 1957-73, agriculture should now be prepared for a series of more normal years. That is, years in which the weather reverts to its apparently more characteristic greater variations that occurred previous to 1957. Perhaps the early frost of 1974 and the current drought are manifestations of this expected change.

c. Projections for the 1977 Season

Even though the drought may have bottomed out in 1976, this is not to be taken that 1977 will be necessarily a "good" year. Looking at the 1977 growing season from the distance of January, 1977, there are several factors working against the 1977 season: first, the unusual dryness of the soil at the end of August; second, the 1976 autumn recharge failed to materialize placing greater importance upon the spring recharge period; and finally, because many subsoils are so low in water, an almost ideal distribution of above normal rainfall will be required in order to compensate for the subsoil deficits.

It has already been explained why confidence can neither be placed in a meteorological forecast made several months in advance of a growing season nor in a climatological (probability) forecast for a specific period. Although the indications are for a better precipitation season in 1977 than in 1976, this remains highly qualitative when it comes to making management decisions in the 1977 spring. In light of this, data on crop yields, current soil water supplies, seasonal evapotranspiration requirements, and the effective rainfall under various precitation regimes were combined in order to make yield projections for the 1977 season.

These projections in the form of the percent of normal that corn and soybean yields and small grain yields are predicted to be for the 9 season combinations and 3 soil water values are shown in Tables 2 and 3, respectively. Table 4 has been prepared for small grains in the Red River basin where special condtions exist relative to soil drainage. The estimated soil water content at the beginning of spring is mapped in Fig. 14. These mapped values are to be used in conjunction with Table 2, 3, anf 4 in order to apply the yields to a particular locale. A number of assumptions have had to be made with respect to what is shown in these three tables. A major one is that the precipitation distribution is normal, since an abnormal distribution of the rain can, of course, ruin an otherwise good season. It should be understood, too, that as the soil water value increases the water itself becomes less a limiting factor. Other factors such as air temperature assume increasing importance. As a result, confidence in the projected yields decreases as the amount of water available to a crop increases. Another assumption is that the soil is well-drained or tiled.

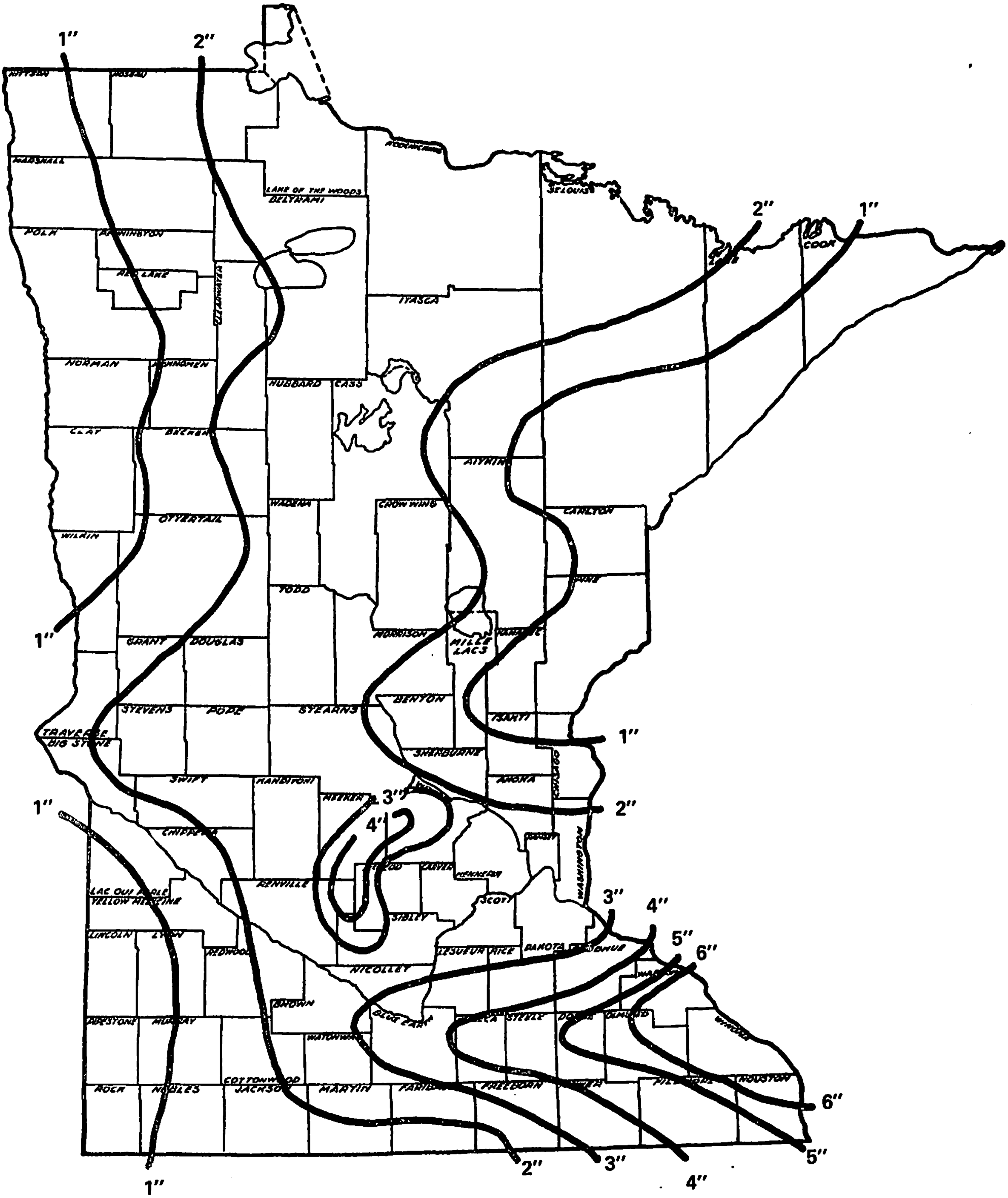

Fig. 14. The estimated inches of plant available water present in the soil at the beginning of spring, 1977.

Table 2. Estimated percent of the normal yield of corn and soybeans expected in 1977 with 9 season combinations and with 2, 4, and 6 inches of plant available water in the soil. (To be used in conjunction with Fig. 14).

Season Combinations		Plant Available Soil Water		
Spring	Summer	2 In.	4 In.	6 In.
Dry (a)	Dry	0 %	20%	40%
Dry (a)	Normal	40	60	80
Dry (a)	Wet	70	85	100 (c)
Normal	Dry	30	50	70
Normal	Normal	60	80	100
Normal	Wet	90+	100	100+ (c)
Wet (b)	Dry	40	60	80
Wet (b)	Normal	90+	90+	100
Wet (b)	Wet	90+	100 (c)	100+ (c)

(a) Assuming adequate seed germination in the dry spring.

(b) Assuming planting not delayed due to the wet spring.

(c) Surplus water could limit yields.

Table 3. Estimated percent of the normal yield of small grains expected in 1977 with 9 season combinations and with 2, 4, and 6 inches of plant available water in the soil.* (To be used in conjunction with Fig. 14).

Season Combinations		Plant Available Soil Water		
Spring	Summer	2 In.	4 In.	6 In.
Dry (a)	Dry	0 %	40%	60%
Dry (a)	Average	25	50	75
Dry (a)	Wet	40	70	90
Average	Dry	30	60	90
Average	Average	50	75	100
Average	Wet	60	90	100 (c)
Wet (b)	Dry	50	80	90
Wet (b)	Average	100	100	100 (c)
Wet (b)	Wet	100	100	100 (c)

* The cooperation of W. Fenster, L. Hanson and C. Simpkins is acknowledged.

a. Assuming adequate seed germination in a dry spring.

b. Assuming planting not delayed due to a wet spring.

c. Surplus water could limit yields.

Table 4. Estimated percent of the normal yield of small grains in the Red River basin for 9 season combinations.

Season Combination		Predicted Yield
Spring	Summer	
Dry	Dry	0 %
Dry	Average	35
Dry	Wet	50
Average	Dry	25
Average	Average	65
Average	Wet	100
Wet	Dry	25
Wet	Average	40
Wet	Wet	40

*The cooperation of C. Simpkins is acknowledged.

Table 2 shows that with 6 inches of stored soil water at the beginning of spring and average precipitation in both the spring and summer the predicted yield would be 100% of the normal yield for a given location. If, however, the same precipitation combination occurred with only 2 inches of stored soil water, a condition all too common in Minnesota as shown in Fig. 14, then the predicted yield would be only 60% of the normal for the same locality.

d. Special Considerations Related to the Dry Soils

There is a potential bright spot amidst the gloom that should be mentioned. The extremely dry soil conditions of 1976 may permit a greater income of water into the soil from that predicted based upon our measurements and experience which date from 1960. In previous years the frozen soil water has occupied much of the soil pore space and effectively blocked the entrance of meltwater. As a result the winter precipitation has been largely discounted as a source of recharge. This year perhaps 50% of the over-winter precipitation may enter the soil. However, with only about 3.5-4.0 inches of precipitation from Decmeber-March in a normal year the addition of 50% or about one inch of water to the soil does not constitute a major amount.

One manifestation of the very dry soils is the rapid temperature fluctuations and frequent freeze-thaw cycles observed during November and December, 1976. The low water content has greatly reduced the heat capacity of the soil without appreciably altering its thermal conductivity. The extreme dryness of the soil is further shown by the lack of a pause as the temperature goes above and below 32°F, indicating there is no phase change as normally occurs when water or ice are present. Fig. 15 shows how the combinations of a dry soil, shallow snow cover and cold air temperatures has affected the soil temperatures in early 1977 at St. Paul. It is noteworthy that the 32°F isotherm has already penetrated deeper in mid-January than the winter maximum that ordinarily is reached in early March (4).

It has been noted that only a very small gain or loss of heat is required to cause the temperature of a very dry soil to fluctuate widely. Thus, the presence of a persistent snow cover of only about 5 inches, which is sufficient to insulate the soil amost completely from the external environment, would permit a most unusual circumstance to occur in agricultural soils this year. That is, the heat escaping upwards from the lower soil depths may be capable of thawing the soils before the winter is over.

As demonstrated in Fig. 15 much lower than normal soil temperatures have already occurred. The damage that these temperatures may have upon perennial plants is uncertain. It seems obvious, however, that if an inadequate snow cover continues the damage to vegetation may indeed be serious.

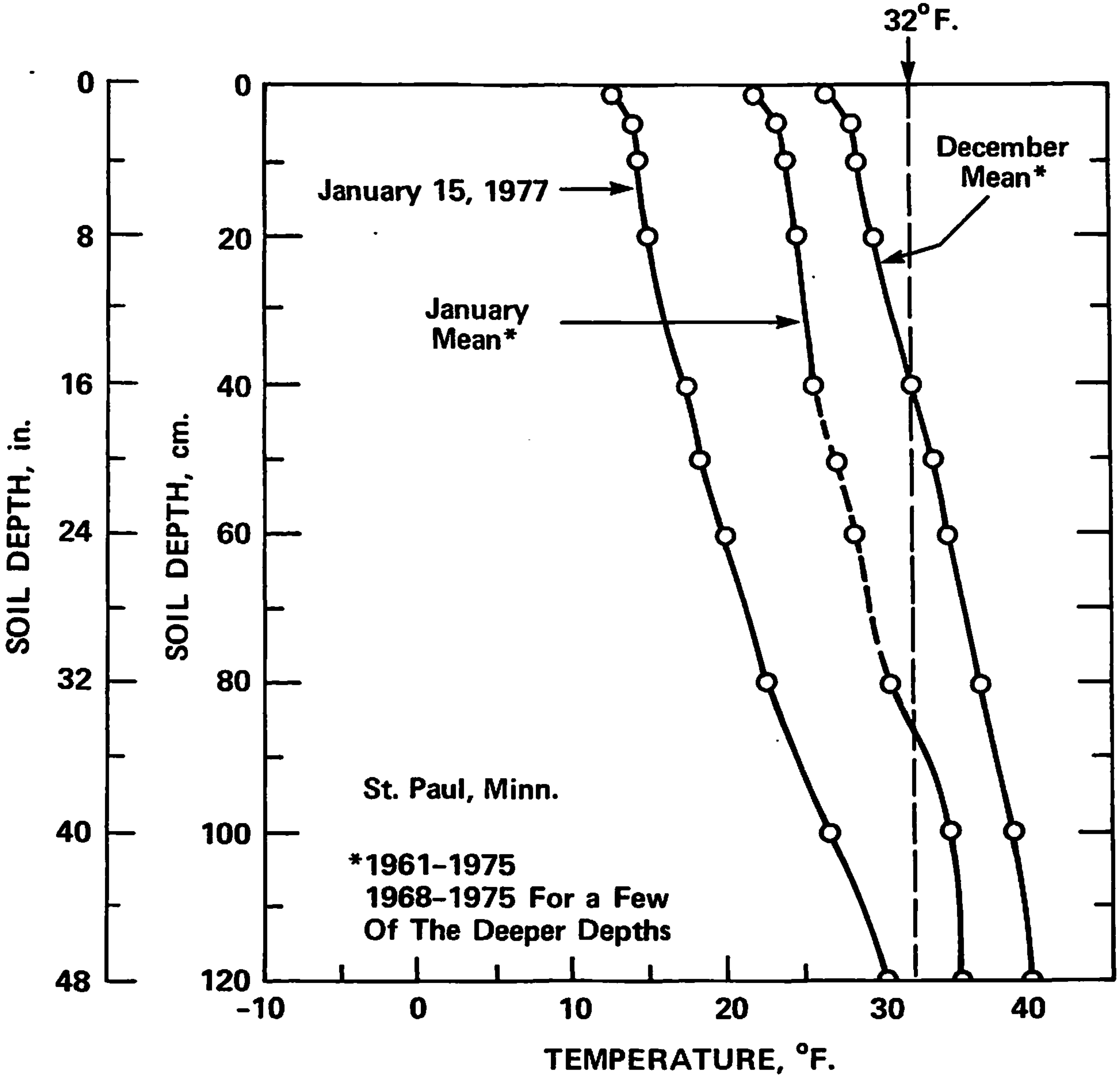

Fig. 15. The January 15, 1977, temperatures in a soil that is bare of vegetative cover at St. Paul, Mn, compared to the 1961-1975 mean soil temperatures in December and January.

III. The Possibility of Alleviating Drought

Cloud seeding (weather modification) in order to augment precipiatio precipitation can be effective only if the proper kind of clouds and adequate atmospheric moisture are present. The proper atmospheric conditions are seldom present during a drought, and therefore cloud seeding should not be considered as a means of appreciably increasing water supplies in periods of drought. General information on this subject may be found in "A View of Cloud Seeding" (2) with more detailed information in "Weather Modification: Where are We Now and Where Should We Be Going?"

(7).

Given the proper quantity and quality of underground and surface water resources, irrigation can be considered.

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NITROGEN TREATMENT'S RELATIONSHIP TO SOIL pH AND POTATO PRODUCTION

Becker - 1976

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

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

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

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

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

Thus far, only potato yields have been obtained, but ensuing years should provide information on the effect of nitrogen on controlling the soil pH and its possible effect on potato scab.

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

Treatment*	Norland	Norgold
	Cwt/A	Cwt/A
Check	146 a	180 a
Ammonium nitrate	319 b	398 bc
Urea	372 b	408 c
Ammonium sulfate	398 b	385 b
Trt. Sign.	**	**
BLSD (5%)	84	16
Rep.	ns	ns
C.V.	17.7	9.7

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

[1/] Efforts of Bob Schoper, Jerry Lensing and Glenn Titrud are gratefully acknowledged.

NITRIFICATION INHIBITORS AND SLOW RELEASE NITROGEN SOURCES FOR CORN PRODUCTION ON IRRIGATED SANDS

BECKER - 1976

G.L. Malzer and R.P. Schoper

A trial was established in 1976 at the Sand Plain Experimental farm at Becker, Minnesota to investigate the significance of nitrification inhibitors as well as slow release urea based nitrogen fertilizers for corn production under irrigation. The objectives were to compare urea applications with various methods of slower release to determine if greater efficiency can be made of fertilizer nitrogen under irrigation.

EXPERIMENTAL PROCEDURES

Six treatments were established in a randomized complete block design. These treatments included a control which received no nitrogen and five urea treatments. All urea treatments were spring applications (4/29/76) preplant and incorporated at 150 lbs N/A. The treatments included urea, urea + N-Serve (0.5 lb/A active ingredient) urea + Terrazole (0.5% by wt) urea formaldehyde and sulfur coated urea.

Soil tests were taken and potassium applied at the rate of 120 lbs K_2O/A broadcast and incorporated. Corn (Min-Hybrid 4201) was planted May 10 in 30" rows at a population of 30,700 plants/acre. Starter fertilizer was applied as 150 lbs/A of 0-25-25 at planting. Good weed control was accomplished with the use of a lasso (2 lbs/A-a.i.) atrazine (1 lb/A-a.i.) mixture (May 11). One inch of irrigation water was applied on May 13 and the normal irrigation sequence started on June 6. Water was then applied at approximately one week intervals through September 5 at rates varying between 3/4 - 2.0 inches/application. A total of 16.26 inches of irrigated water was applied during the season.

Tissue samples including the leaf opposite and below the ear at silking, silage samples (stover, cob and grain) and grain at harvest were analyzed for Kjeldahl nitrogen content. Silage dry matter yields were determined by harvesting 10' of row from each plot and separating it into stalk and ear and subsequent separation after drying to stalk cob and ear. Grain yields were taken by hand harvesting 20' of the center two rows from each plot.

RESULTS

The dry matter yields, N content, and N removal for the three silage components are presented in Table 1. Nitrogen application had no influence on dry matter production of stover but had significant influences with regard to the ear. There were no significant differences in the N content of the three silage components compared over treatments even between the control and any N treatment. Differences in N removal within the silage were accounted for because of increased production and not increased N content. There were no differences between the urea, urea + N-Serve, and urea + Terrazole. The control, urea formaldehyde, and sulfur coated urea were substantially lower.

The same relationship between treatments are found when we look at leaf N content and the grain parameters measured (Table 2). At 150 lb N/A urea formaldehyde and sulfur coated urea were inferior to urea alone or the urea-nitrification inhibitor treatments.

CONCLUSIONS

In many respects the CV's were quite high partially due to the hot dry weather during pollination and partially due to soil differences and other variables. Even considering this, nitrogen release from urea formaldehyde and sulfur coated urea did not appear to be adequate for corn production under irrigation. It would also appear that the 150 lb N/A application was too high in 1976 to exhibit any differences between uncoated urea and the treatments coated with nitrification inhibitors.

Table 1. Dry matter production, N content and total N removal by corn silage as influenced by 150 lbs N/A as urea treated with nitrification inhibitors or slow release urea nitrogen sources.

Treatment[1]	Dry Matter - Silage				N Content - Silage			N Removal - Silage			
	Stover	Cob	Grain	Total	Stover	Cob	Grain	Stover	Cob	Grain	Total
	T/A				%			lb/A			
Control	4.15	.26	.55	4.96	.46	.53	1.37	37.8	2.4	13.0	53.2
Urea	4.25	.69	2.40	7.34	.70	.44	1.45	59.3	6.0	68.7	134.0
Urea+N-Serve[2]	4.40	.65	2.89	7.93	.56	.48	1.39	50.5	6.2	79.9	136.6
Urea+Terrazole[3]	4.71	.64	2.24	7.58	.54	.48	1.45	50.6	6.1	63.2	119.8
Urea Formaldehyde	4.46	.43	1.71	6.60	.63	.39	1.26	55.9	3.3	41.3	100.6
Sulfur Coated Urea	4.31	.35	1.30	5.95	.54	.47	1.30	47.5	3.2	32.9	83.6
Significance	NS	**	**	**	NS	NS	NS	NS	**	**	**
BLSD (.05)	--	.18	.96	1.37	--	--	--	--	2.6	21.9	33.9
C.V.	9.9	24.7	34.7	13.3	21.7	22.3	14.4	27.9	35.7	30.3	21.8

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[1] All treatments received 150 lb N/A except the control.

[2] 0.5 lb/A N-Serve (active ingredient) coated onto urea.

[3] 0.5% Terrazole coating onto Urea.

Table 2. Leaf N and various corn grain parameters as influenced by 150 lbs N/A as urea treated with nitrification inhibitors or slow release urea nitrogen sources.

Treatment[1/]	Leaf N	Grain			
		Yield	Moisture	N	N Removal
	%	bu/A	%	%	lb N/A
Control	1.10	23.4	38	1.30	13.2
Urea	1.99	110.1	27	1.51	77.7
Urea+N-Serve[2/]	1.89	109.4	27	1.37	69.2
Urea+Terrazole[3/]	2.06	121.2	30	1.40	80.2
Urea Formaldehyde	1.51	56.4	32	1.38	36.2
Sulfur Coated Urea	1.49	61.9	31	1.31	38.2
Significance	**	**	**	NS	**
BLSD (.05)	.41	47.5	4	--	26.2
C.V.	13.5	38.8	9.6	10.6	34.0

[1/] All treatment received 150 lb N/A except the control.

[2/] 0.5 lb/A N-Serve (active ingredient) coated onto urea.

[3/] 0.5% Terrazole coating onto urea.

1976 WEATHER SUMMARY

Below normal precipitation for the second consecutive year highlights weather conversation about the 1976 weather at the Northwest Experiment Station. Total precipitation for the year was more than seven inches below normal, and for the growing season, April to September, it was six inches below normal.

January, March and June were the only months recording above normal precipitation, with the largest increase only 15% above normal in June. The precipitation for September was the smallest amount ever recorded in the 86-year history of the weather station. The new "all-time" September low of 0.24 inch was only 11% of the normal 2.26 inches. May and November were also very close to breaking the all-time low for their respective months. The precipitation of 0.04 inch in November was the third lowest ever recorded while May's precipitation of 0.38 inch was the fourth lowest in the history of the Northwest Experiment Station. For the 1976 growing season, the average precipitation per month was one inch below normal.

Total precipitation for the year was 13.48 inches which is 7.25 inches less than the 85-year average. Of this 13.48 inches, 10.88 inches fell as rain and the remaining 2.60 inches were received as 46.0 inches of snow. The moisture content of the snow for 1976 (0.057 in./1 in. snow) was less than the long time average of 0.077 in./1 in. of snow. Table 1 shows the weather summary data for 1976 including precipitation, mean temperature, and long-time averages.

The last spring frost occurred May 17 when the temperature dropped to 32°F. The first fall frost occurred on September 21 with a temperature of 31°F. The first killing frost came on the 23rd of September with a reading of 25°F. The frost-free period of 127 days during 1976 was only 21 days longer than average.

The temperatures at the station for 1976 were 1.5°F. warmer than average.

With the exception of March, the average monthly temperatures from January through September were above normal. October, November, and December also recorded below normal temperatures. February and August both ranked fourth as being the warmest February and August in the weather history at Crookston.

Six new "all-time" maximum daily temperature records were set in the month of August. For four consecutive days, August 18, 19, 20 and 21, the respective temperatures reached were 100, 100, 99 and 99°F. August 24 and 25 set the remaining two records with 97°F. readings. September 3, September 30 and October 4 also set new "all-time" daily maximum temperature records with their respective readings of 95, 86 and 83°F.

Three "all-time" minimum daily temperature records were also set in 1976. On the dates May 7, June 16 and December 30, the new record low temperatures were 18, 37 and -32°F. respectively.

Table 1. Weather Summary for 1976 with Averages for Precipitation and Mean Temperatures for 1890-1973.

	Precipitation, Inches					Mean Temperature ----degrees----	
	Snow Inches	Precip. Inches	Rain	Total	1890-1973	1976	1890-1973
Jan.	18.2	.95	.00	.95	.56	6.0	3.9
Feb.	8.4	.38	.00	.38	.54	19.8	8.2
Mar.	12.1	.97	.04	1.01	.85	20.6	23.0
Apr.	0.0	.00	.74	.74	1.53	47.0	41.4
May	0.0	.00	.38	.38	2.61	55.0	54.5
June	0.0	.00	4.18	4.18	3.61	68.3	64.5
July	0.0	.00	1.91	1.91	3.13	70.8	69.4
Aug.	0.0	.00	2.77	2.77	2.88	72.2	67.5
Sept.	0.0	.00	.24	.24	2.26	61.0	57.4
Oct.	T	T	.61	.61	1.39	40.9	45.4
Nov.	0.8	.03	.01	.04	.76	24.3	26.9
Dec.	6.5	.27	.00	.27	.61	5.7	11.5
TOTAL	46.0	2.60	10.88	13.48	20.73	41.0	39.5

NITROGEN RATE AND CARRIER COMPARISONS ON WHEAT

G. W. Wallingford and R. K. Severson

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

An experiment which compared the four nitrogen materials at three nitrogen rates was established at two locations in 1976. One location was on a coarse-textured soil located east of Thief River Falls and the other was on a fine-textured soil north of Stephen. The location at Stephen was lost due to the extreme dry weather which caused uneven germination and extremely poor plant populations. Soil test results are listed below for the Thief River Falls site.

SOIL TEST RESULTS

NO_3-N	P	K	OM	pH	Soil Type
104	22	140	H	7.1	Sandy loam

The experimental design used in 1975 was used again in 1976. Nitrogen rates of 30, 60 and 90 lbs N/A were used in a randomized complete block design with four replications. All materials were applied preplant and were incorporated after application. Plots were planted on April 28 and harvested for grain on August 5.

RESULTS

Table 2 contains the dry matter and grain yields harvested from the Thief River Falls location in 1976. There were no significant differences between any of the treatments. A relatively high nitrate content of the soil was sufficient to satisfy the nitrogen requirement of the crops through the growing season. According to the Minnesota soil test recommendations, no response is expected at a nitrate-N level of 104 lbs N/A and no response was found.

Table 2. Wheat dry matter (soft-dough stage) and grain yields as affected by nitrogen material and rate at Thief River Falls in 1976.

Material	N Rate	Yield	
		Dry Matter	Grain
	lbs/A	lbs/A	bu/A
Control	0	6241	63.9
Ammonium	30	6223	65.1
Nitrate	60	6007	57.6
(34-0-0)	90	6835	66.4
Urea	30	5980	63.2
(46-0-0)	60	6794	59.0
	90	5833	59.0
Urea-Ammonium	30	6302	65.8
Nitrate Solution	60	6234	67.9
(28-0-0)	90	6390	68.5
Anhydrous	30	5382	60.1
Ammonia	60	5946	58.1
(82-0-0)	90	6027	61.8
Significance		N.S.	N.S.
CV (%)		9.2	16.0

FALL VS. SPRING NITROGEN APPLICATIONS FOR WHEAT

G. W. Wallingford and R. K. Severson

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

A study was initiated in the fall of 1975 to compare fall vs. spring nitrogen applications, nitrogen carriers and rates of nitrogen on the yield of wheat. The study was located on the Northwest Experiment Station on a Wheatville loam soil. The soil test results are given below. A previous nitrate survey of the field showed the chosen location to be low in nitrate, but the sample taken in fall 1975 was high in nitrate.

SOIL TEST RESULTS

NO_3-N	P	K	OM	pH	Soil Type
134	20	150	H	7.9	Wheatville loam

Fall applications were made on October 22, 1975 and spring applications on April 19, 1976. Plots were planted on April 23 to Profit 75 and were harvested on August 13 for grain yield. Eighty pounds of phosphate and 120 lbs of K_2O were applied to all plots.

RESULTS

The grain yields are given in Table 3. The extremely dry conditions during the spring stunted the growth of the plants and caused early maturity. The plants were already heading by the middle of June when the only substantial rain of the season occurred. The rain did not come in time to allow the plants to recover and the resulting yields were very low.

The extremely low yields due to the drought and the initial high nitrate level in the soil prevented any treatment differences from occurring. The experiment is being continued in the same form for the 1977 season.

Table 3. Wheat grain yields in 1976 as affected by nitrogen material, rate, and time of application.

Material	N Rate	Yield	
		Fall	Spring
	lbs/A	bu/A	bu/A
Control	0	19.7	19.7
Ammonium	30	15.8	15.2
Nitrate	60	17.1	14.4
(34-0-0)	90	17.4	20.8
Urea	30	17.6	20.8
(46-0-0)	60	25.1	20.2
	90	20.9	15.0
Urea-Ammonium	30	20.4	16.7
Nitrate Solution	60	18.4	24.8
(28-0-0)	90	15.0	18.6
Anhydrous	30	20.7	18.7
Ammonia	60	18.1	18.6
(82-0-0)	90	15.2	21.3
Significance		N.S.	N.S.
CV (%)		27.2	27.2

PHOSPHORUS FERTILIZATION OF WHEAT IN THE RED RIVER VALLEY

G. W. Wallingford and C. A. Simkins

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

Three experimental locations were established in 1976 at Crookston, Shelly and Stephen. The location at Stephen was lost due to extremely poor germination resulting from the dry spring. The soil test results for the Crookston and Shelly locations are given below.

SOIL TEST RESULTS

	NO_3-N	P	K	OM	pH	Soil Type
Crookston	134	58	310	H	7.9	Wheatville loam
Shelly	137	38	600+	H	7.1	Fargo silty clay

A randomized complete block design with four replications and ten treatments was used. The ten treatments consisted of one control and three rates of phosphorus (20, 40 and 60 lbs P_2O_5/A) applied as triple superphosphate (0-44-0) with three banded and three broadcast treatments, and as ammoniated superphosphate (18-46-0) with three banded treatments only. The fertilizer was placed with the seed in the banded treatments while the broadcast treatments were applied preplant and incorporated.

Additional nitrogen was applied so that all plots received a total of 60 lbs N/A and 60 lbs of K_2O/A. The treatments were applied and the plots planted with 1.5 bu/A of Era wheat on April 22 at Crookston and on April 26 at Shelly.

RESULTS

The grain yields from the two locations are given in Table 4. There were no significant differences between any of the treatments at either location. There were also no visible growth differences between treatments any time during the season.

The spring of 1976 was early, dry and warm. Response of small grains to phosphorus applications are most likely in wet, cool springs. The springs of both 1975 and 1976 were not conducive, therefore, to phosphorus response. Several more years of data are needed so that the wheat response to phosphorus can be measured under different weather conditions.

Table 4. Wheat grain yield as affected by phosphorus rate and method of application at two locations in 1976.

Material[a]	Rate lbs P_2O_5/A	Method	Crookston Grain bu/A	Shelly Grain bu/A
Control	0	--	31.5	61.4
TSP	20	Banded	32.4	65.4
TSP	20	Bd'cst	33.1	63.8
ASP	20	Banded	28.6	64.8
TSP	40	Banded	30.9	60.9
TSP	40	Bd'cst	23.3	60.4
ASP	40	Banded	33.0	62.8
TSP	60	Banded	32.8	64.7
TSP	60	Bd'cst	29.8	63.0
ASP	60	Banded	32.7	62.0
Significance			N.S.	N.S.
CV (%)			17.8	7.5

[a] TSP = Triple Superphosphate (0-44-0)
ASP = Ammoniated Superphosphate (18-46-0)

CORN FERTILITY IN NORTHWESTERN MINNESOTA

G. W. Wallingford and R. K. Severson

The area of corn production in Minnesota is moving steadily northward. In 1975 there were 47,000 acres of corn grown in Polk, Norman and Mahnomen counties. Most corn in this area is grown on the coarse-textured soils east of the Red River Valley basin. Research on nitrogen, phosphorus and potassium fertility of corn has been very limited in this area.

Two experimental locations were established in 1976 in Norman county north and east of Ada. The soil test results and soil types of the two locations are listed below. The experimental design used in 1975 was followed again in 1976. The studies included a nitrogen rate study, a phosphorus rate and material study and a potassium rate study. A randomized complete block design with four replications was used. All fertilizer materials were applied preplant and incorporated. The nitrogen and potassium materials were urea and potassium chloride. The phosphorus rates were duplicated by using both triple superphosphate and a nitrogen-polyphosphate solution (10-34-0) as phosphorus materials. The fertilizer was applied on May 1 at the Berglind location and on May 3 at the Gill location. Planting was done within one week after fertilizer applications were made. At the Berglind farm, the same location was used in 1976 as was used in 1975 and the treatments were superimposed on the exact same plot area. The plots were hand harvested on September 28 at the Gill location and on September 30 at the Berglind location by harvesting two thirty-foot sections of each plot.

SOIL TEST RESULTS

	NO_3-N	P	K	OM	pH	Soil Type
Berglind (1975)	59	27	150	M	8.1	Ulen fine sandy loam
Gill	51	14	150	H	8.1	Ulen fine sandy loam

RESULTS

There were no significant differences due to treatment at either location in the phosphorus and potassium studies (Table 5). In the nitrogen study, maximum yields were obtained at the 100 lbs N/A rate.

The growing season in 1976 was unusually good for corn production from the standpoint of growing degree days. Although limited rainfall caused poor germination and erratic stands in the plots as well as many other fields in the area, the long growing season caused the yields to be higher than average. The lack of rainfall probably made the broadcast fertilizer applications positionally unavailable throughout most of the season because the soil surface remained dry and fertilizer incorporation was shallow. Phosphorus and potassium were probably affected the most by positional unavailability which could explain the lack of response to these nutrients even though soil tests and previous cropping history (corn) indicated a likely response.

Table 5. Corn yields as influenced by nitrogen, phosphorus and potassium at two locations in 1976.

N Rate lbs N/A	Yield bu/A		P Rate[a] lbs P_2O_5/A	Yield bu/A		K Rate lbs K_2O/A	Yield bu/A	
	Berglind	Gill		Berglind	Gill		Berglind	Gill
0	59.3	64.8	0	84.9	78.9	0	94.9	83.8
20	67.4	77.3	20 TSP	83.6	80.9	40	95.7	74.2
40	69.5	65.3	20 Poly	87.3	82.9	80	97.9	76.5
60	65.6	70.0	40 TSP	85.0	81.6	120	95.2	77.3
80	80.2	79.0	40 Poly	82.7	74.5	160	99.1	83.1
100	85.9	92.2	60 TSP	92.7	75.0			
			60 Poly	83.6	81.5			
			80 TSP	86.9	72.4			
			80 Poly	88.8	84.7			
Significance	**	*		N.S.	N.S.		N.S.	N.S.
BLSD (0.05)	14.2	16.1						
CV (%)	12.6	13.5		9.2	15.4		6.5	10.7

[a] TSP = Triple superphosphate (0-44-0), Poly = Polyphosphate (10-34-0)

WEST CENTRAL EXPERIMENT STATION - MORRIS

WEATHER SUMMARY - 1976

		Precipitation			Air Temperature			Soil (10 cm) Temperature	
Month	Period	1976	89-yr. av.	Dev. from av.	1976	89-yr. av.	Dev. from av.	1976	9-yr. av.
January	1-31	.98	.65	+ .33	7.1	8.3	- 1.2	13.6	21.8
February	1-29	.61	.66	- .05	23.2	12.7	+10.5	23.2	24.5
March	1-31	1.23	1.04	+ .19	26.0	26.8	- 0.8	29.0	29.2
April	1-10	.02	.58	- .56	45.4	38.1	+ 7.3	42.2	
	11-20	.33	.65	- .32	54.1	44.3	+ 9.8	49.8	
	21-30	.12	1.10	- .98	47.0	48.2	- 1.2	49.2	
Total or av.		.47	2.33	-1.86	48.9	43.6	+ 5.3	47.1	40.9
May	1-10	.05	.79	- .74	46.5	52.0	- 5.5	49.2	
	11-20	0	.99	- .99	58.4	55.6	+ 2.8	61.8	
	21-31	.34	1.23	- .89	61.0	60.0	+ 1.0	63.5	
Total or av.		.39	3.01	-2.62	55.5	56.0	- 0.5	58.4	55.8
June	1-10	.10	1.32	-1.22	72.8	63.1	+ 9.7	72.8	
	11-20	.24	1.20	- .96	67.2	66.5	+ 0.7	70.4	
	21-30	1.29	1.36	- .07	68.8	68.2	+ 0.6	71.0	
Total or av.		1.63	3.88	-2.25	69.6	66.0	+ 3.6	71.4	69.4
July	1-10	0	1.52	-1.52	72.9	69.9	+ 3.0	78.0	
	11-20	.25	1.07	- .82	72.2	71.4	+ 0.8	78.6	
	21-31	.82	1.03	- .21	74.3	71.5	+ 2.8	79.0	
Total or av.		1.07	3.61	-2.54	73.2	71.0	+ 2.2	78.6	76.7
August	1-10	.13	1.08	- .95	70.2	70.4	- 0.2	78.7	
	11-20	1.30	.89	+ .41	72.2	69.3	+ 2.9	74.0	
	21-31	.33	.98	- .65	74.4	66.9	+ 7.5	77.5	
Total or av.		1.76	2.95	-1.19	72.4	68.8	+ 3.6	76.8	74.4
September	1-30	.57	2.22	-1.65	58.9	59.1	- 0.2	63.4	61.5
October	1-31	.08	1.61	-1.53	40.4	47.5	- 7.1	44.8	48.0
November	1-30	.14	.94	- .80	23.3	29.9	- 6.6	28.3	33.8
December	1-31	.46	.68	- .22	9.2	15.6	- 6.4	15.4	24.3
April-August Growing Season		5.32	15.78	-10.46	64.0	61.2	+ 2.8	66.6	63.5
January-December Annual		9.39	23.58	-14.19	42.3	42.1	+ 0.2	45.9	46.8

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

West Central Experiment Station - Morris

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

The experiment initiated in 1970 was continued. Treatments and results in previous years are given in Soil Series 88, 89, 91, 95, and 97. Manure was applied in 1970 and 1971 only. Fertilizer has been applied to the fertilized checks each year. In 1975 and 1976 the comparison of Furadan vs. no Furadan was dropped and the no Furadan sub-plots were planted to soybeans.

I. Planting Information

Sixteen rows of each plot were planted to corn (var. Trojan TXS99) and eight rows to soybeans (var. Clay) on May 5, 1976. Furadan at 10 lbs./acre (1 lb./acre active ingredient) was applied to the corn. Starter fertilizer consisting of 154 lbs./acre of 8-33-17 was applied to both the corn and soybeans in the fertilized treatment. Nitrogen in the form of ammonium nitrate was applied to the fertilized plots to provide 110 lbs./acre of N on October 14, 1975. All plots were plowed on October 15, 1975. Lasso (2) + Bladex (2) were applied to the corn and Lasso (2) + Lorox (1) were applied to the soybeans. All materials were broadcast applied on May 6, 1976. The corn was sprayed with 2,4-D LV ester @ 1/2 lb./acre on June 8, 1976.

II. Soil Sampling and Analysis

A. 1975 measurements

The results of the analysis of the soil samples collected to a depth of 16 feet are given in Table 1. Other measurements not included in this report are Bray #1 P 1:10 and 1:50, Na, K, and electrical conductivity of the top 4 feet and Mn in the top foot only.

1. $(NO_3 + NO_2)$-N - All manure treatments had higher values than the two check treatments at all depths. There was substantial nitrogen movement to the 10-foot depth with all manures and to the 14-foot depth with the liquid beef manure.

2. Chloride - In most cases the chloride content of the soil in the manured treatments was higher than in the check treatments. Chloride had increased to the 16-foot depth with the two beef manures and to the 12-foot depth with the hog manure.

3. Chloride/$(NO_3 + NO_2)$-N Ratio - Below the 4-foot depth the ratio is generally constant indicating the chloride and the $(NO_3 + NO_2)$-N were moving thru the profile together and denitrification was not taking place.

B. 1976 measurements

The soils were sampled to a depth of 4 feet in the fall of 1976 but the results are not yet available.

Table 1. Effect of high rates of manure and commercial fertilizer five years (fall 1975) after application on the $(NO_3 + NO_2)$-N and Cl content of a Tara soil profile.

Depth	CK	FE	SB	LB	LH
			$(NO_3 + NO_2)$-N, ppm		
0-1'	4.9	7.8	24.7	25.7	13.2
1-2'	0.6	27.7	70.2	114.9	40.6
2-3'	1.8	31.4	101.8	160.0	105.1
3-4'	4.2	8.8	66.5	98.0	57.7
4-6'	6.7	4.2	41.1	68.8	42.1
6-8'	5.6	2.2	20.4	45.9	16.3
8-10'	2.8	2.0	10.0	34.1	9.4
10-12'	2.2	1.3	5.3	21.2	7.2
12-14'	1.9	1.3	4.7	13.9	4.9
14-16'	1.6	0.8	4.0	8.4	3.9
			Cl, ppm		
0-1'	1.5	6.5	8.2	8.4	8.8
1-2'	3.1	31.8	84.7	82.8	33.5
2-3'	8.5	31.1	152.6	160.0	79.7
3-4'	7.6	14.7	117.7	104.1	41.5
4-6'	5.3	6.8	106.8	75.0	25.6
6-8'	6.6	3.5	58.2	57.6	14.3
8-10'	5.6	12.7	26.1	42.1	10.8
10-12'	4.4	4.2	13.6	27.2	6.6
12-14'	4.6	4.5	10.3	17.2	4.8
14-16'	4.9	2.4	10.2	14.2	3.2
			$Cl^-/(NO_3 + NO_2)$-N Ratio		
0-1'	0.3	0.8	0.4	0.4	0.6
1-2'	4.7	1.2	1.6	2.6	1.0
2-3'	4.8	1.0	1.6	1.0	0.8
3-4'	1.8	1.7	2.0	1.1	0.7
4-6'	0.8	1.6	2.8	1.1	0.7
6-8'	1.2	1.6	2.9	1.3	0.9
8-10'	2.4	9.4	2.6	1.4	1.4
10-12'	2.1	3.3	2.8	1.4	1.0
12-14'	2.4	3.8	2.3	1.3	1.3
14-16'	3.2	3.1	3.1	2.4	0.9

III. Plant Tissue Analysis

Stands were very poor and plants stunted by the dry weather, but plant samples were taken as in previous years.

A. Early whole corn plants (Table 2)

The manure treatments were significantly higher in K and lower in Mg than the CK and FE treatments. The SB and LB treatments were lower than FE in Ca, Zn, and Mn. The LH treatment was significantly lower than SB and LB in K and higher in Zn. The LH treatment was higher than LB in Mn. The CK treatment was significantly lower than the manure treatments in P and K and higher in Ca and Mg.

B. Corn leaves at silking (Table 3)

The manure treatments were significantly higher than the FE treatment in K and lower in Mg. The CK treatment was significantly lower than all other treatments in N. The FE and LH treatments were significantly higher than all other treatments in Zn.

C. Soybean leaves at mid-bloom (Table 4)

The manure treatments were generally higher than the CK and FE treatments in P and K and lower in Ca, Mg, and Cu. The CK treatment was much higher than all other treatments in Cu.

IV. Field and Plant Measurements (Table 5)

Stands in all plots were very poor due to the dry conditions during the planting season. The plants that were left were severely stunted by the dry weather during the summer and were further damaged by a severe hail storm on the evening of August 10, 1976. Therefore, only a limited number of measurements were made.

A. Early plant height - All manures increased the early plant height as compared to the CK.

B. Early plant dry weight - The SB and LB treatments were significantly heavier than all other treatments. The FE and LH treatments were not different, but LH was heavier than CK.

C. Ear moisture at harvest - There were no significant differences.

D. Corn grain yield - The FE treatment was significantly higher yielding than all other treatments.

E. Soybean yield - There were no significant differences in yield.

Table 2. Summary of analysis of early corn plant samples[1] - 1976.

Treatment	P	K	Ca	Mg	Zn	Cu	Mn	B
	%				ppm			
CK	.38	1.81	.69	.70	39.8	8.8	98	7.4
FE	.43	2.93	.58	.62	57.0	7.9	104	8.3
SB	.45	3.98	.44	.37	36.3	6.6	82	7.6
LB	.50	4.08	.45	.38	35.4	6.6	76	8.5
LH	.46	3.54	.52	.42	53.3	7.8	92	8.2
Significance:	**	**	**	**	**	NS	**	NS
BLSD (.05)	.05	.35	.12	.09	10.9	-	13	-

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[1] Sampled June 16, 1976.

Table 3. Summary of analysis of corn leaves at silking - 1976.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
CK	2.22	.23	1.25	.78	.64	223	14.1	12.9	67	13.7
FE	2.60	.28	1.36	.86	.75	224	23.9	11.0	85	17.7
SB	2.61	.36	2.30	.86	.47	237	15.8	10.2	97	18.8
LB	2.62	.34	2.16	.81	.48	240	16.3	9.2	86	21.3
LH	2.74	.35	2.09	.85	.51	235	24.8	10.7	87	22.9
Significance:	**	+	*	NS	*	NS	*	+	NS	NS
BLSD (.05)	.20	-	.74	-	.15	-	7.0	-	-	-

Table 4. Summary of analysis of soybean leaves[1] - 1976.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
CK	4.41	.24	1.00	2.08	.88	310	40.4	8.5	80	49.3
FE	3.92	.23	.98	2.55	.90	349	54.9	5.8	100	49.4
SB	4.13	.28	1.44	2.67	.71	267	29.7	3.6	108	51.1
LB	4.33	.29	1.52	2.72	.73	343	39.6	4.4	108	51.1
LH	4.29	.27	1.49	2.65	.76	321	48.5	3.8	98	50.2
Significance:	NS	*	**	**	*	NS	NS	**	+	NS
BLSD (.05)	-	.04	.18	.29	.12	-	-	1.9	-	-

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[1] Sampled July 26, 1976.

Table 5. Summary of plant measurements - 1976.

Treatment	Early plant height inches	Early plants (10) Dry wt. grams	Corn Grain Ear moisture at harvest %	Corn Grain Yield @ 15.5% M. Bu/Ac	Soybean yield Bu/Ac
CK	19.6	36.5	39.0	15.0	8.6
FE	21.7	50.6	29.3	28.9	11.9
SB	23.9	70.7	27.6	13.3	7.3
LB	24.4	69.9	28.7	7.4	5.9
LH	22.3	54.7	25.6	18.1	6.1
Significance:	*	**	NS	*	NS
BLSD (.05)	2.8	17.2	-	13.4	-

THE RESIDUAL EFFECT OF RATES OF SOLID BEEF MANURE ON CORN GROWTH AND YIELD

West Central Experiment Station - Morris

S. D. Evans

The experiment which was initiated in 1971 was continued. Only one application of manure was made. Treatment descriptions and results in previous years are given in Soil Series 88, 91, 95, and 97.

I. Planting Information

The plots were planted to corn (var. Trojan TXS 99) on May 5, 1976. All plots were treated with Furadan at 10 lbs./acre (1 lb./acre active ingredient). Starter fertilizer consisting of 154 lbs./acre of 8-33-17 was applied to the fertilized plots only. Nitrogen in the form of ammonium nitrate was applied to the fertilized plots to provide 110 lbs./acre of N on October 14, 1975. All plots were plowed on October 15, 1976. Lasso (2) + Bladex (2) were applied broadcast on May 6. The corn was also sprayed with 2,4-D LV ester @ 1/2 lb./acre on June 8.

II. Plant Tissue Analysis

Stands were very poor and plants stunted by the dry weather, but plant samples were taken as in previous years.

A. Early whole plants (Table 1)

The only significant differences were in Ca and Mg. The highest rate of manure had lower contents than all other treatments. The Mg content of the plants from FE were higher than from all other treatments.

B. Leaf samples at silking (Table 2)

The only significant differences were at the 10% level with K and Mg. The K level increased and the Mg level decreased as manure was increased above the fertilized treatment.

III. Yield and Plant Measurements (Table 3)

Stands in all plots were very poor due to the dry conditions during the planting season. The plants that were left were severely stunted by the dry weather during the summer and were further damaged by a severe hail storm on the evening of August 10, 1976.

There were no significant differences in any of the measurements.

Table 1. Summary of analysis of early plant samples - 1976.[1]

Treatment	P	K	Ca	Mg	Zn	Cu	Mn	B
	%				ppm			
Fertilized	.40	2.82	.55	.66	49.8	7.4	80	7.5
Solid Beef @ 33 1/3 T/A	.44	3.10	.56	.55	46.0	7.0	89	6.8
Solid Beef @ 66 2/3 T/A	.42	3.30	.56	.55	35.8	7.6	90	6.8
Solid Beef @ 100 T/A	.43	3.64	.49	.45	31.3	7.6	86	7.0
Significance:	NS	+	**	**	NS	NS	NS	NS
LSD (.05)	-	-	.02	.07	-	-	-	-

[1] Two reps only.

Table 2. Summary of analysis of leaf samples at silking - 1976.[1]

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
Fertilized	2.46	.27	1.09	.98	.90	224	18.8	8.5	88	13.6
Solid Beef @ 33 1/3 T/A	2.38	.30	1.48	.85	.65	220	14.4	7.4	74	13.0
Solid Beef @ 66 2/3 T/A	2.46	.33	1.70	.86	.65	222	16.4	7.8	90	16.3
Solid Beef @ 100 T/A	2.48	.34	1.90	.91	.59	248	15.3	8.2	84	14.2
Significance:	NS	NS	+	NS	+	NS	NS	NS	NS	NS

[1] Two reps only.

Table 3. Summary of plant measurements - 1976.[1]

Treatment	Early plant height inches	Early plants (10) dry wt. grams	Corn Grain	
			Ear moisture at harvest %	Yield @ 15.5% M. Bu/A
Fertilized	25.6	71.0	26.8	32.8
Solid Beef @ 33 1/3 T/A	24.0	57.0	29.8	31.0
Solid Beef @ 66 2/3 T/A	23.9	61.8	30.2	22.0
Solid Beef @ 100 T/A	23.4	60.6	26.2	18.2
Significance:	NS	NS	NS	NS

[1] Two reps only.

MANURE RATE STUDY

West Central Experiment Station - Morris

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

Solid and liquid beef manures were applied and the effects were compared against check plots. Treatments and results from previous years are given in Soil Series 91, 95, and 97.

I. Manure Application and Analysis

Manure was applied for the fourth time in the fall of 1975. Samples were taken at the time of application and were analyzed by the Animal Waste Laboratory in the Department of Agricultural Engineering. The amounts are given in Table 1. The chemical analysis of each manure is given in Table 2. Using these figures, the amount of each nutrient applied to each manure treatment was calculated and is given in Table 3.

II. Planting Information

The plots were planted to Trojan TXS99 on May 5, 1976. Furadan was applied at 10 lbs./acre (1 lb./acre active ingredient) to one-half of each main plot and the other half was left untreated. Starter fertilizer (consisting of 154 lbs./acre of 8-33-17) was used only on the fertilized treatment. Nitrogen had been applied to the fertilized treatment in the fall prior to plowing at a rate to give 110 lbs./acre of N. Lasso (2) + Bladex (2) were applied broadcast on May 6. The corn was sprayed with 2,4-D LV ester on June 8.

III. Soil Sampling and Analysis

A. 1975 measurements

The results of some of the analysis are given in Table 4. Other measurements made on the upper 4 feet of soil were Bray #1 P 1:10 and 1:50, Na, K, and pH. These latter measurements are not included in this report.

1. $(NO_3 + NO_2)$-N - The fertilized treatment was higher than the check down to 4 feet. SB1 and LB1 treatments have levels similar to those in the fertilized treatment. The heavier manure treatments have high levels and there was some movement into the 4th and 5th foot.

2. Chloride - Increased manure applications resulted in higher chloride values. The only treatment with any substantial chloride movement below 5 feet was SB3.

3. Conductivity - The increases were associated with an increase in manure rates. There was an increase in chloride to the 4-foot depth with SB2 and SB3.

B. 1976 measurements

The soils were sampled to a depth of 4 feet in the fall of 1976 but the results are not yet available.

IV. Plant Sampling and Analysis

Stands were very poor and plants stunted by the dry weather, but plant samples were taken as in previous years.

A. Early whole plants (Table 5)

There were no significant differences due to treatment.

B. Corn leaves at silking (Table 6)

1. Nitrogen - There was a significant difference between the CK and all other treatments.
2. Phosphorus - The manure treatments were significantly higher than CK and FE. Increased manure rates caused slight increases in P content of the leaves.
3. Potassium - FE was significantly higher than CK and lower than all manure treatments in K.
4. Magnesium - In general the manure reduced the Mg content.
5. Zinc - All manure treatments were significantly higher in Zn than CK. The FE treatment was significantly higher than all SB treatments and LB1.
6. Manganese - The Mn content of the leaves increased with increasing manure applications.

V. Yield and Plant Measurements (Table 7)

Stands were very poor due to the dry conditions during the planting season. The plants that were left were severely stunted by the dry weather during the summer and were further damaged by a severe hail storm on the evening of August 10. Therefore, only a limited number of measurements were made.

A. Early plant height - The higher rates of manure (SB2, SB3, and LB3) were slightly smaller.

B. Early plant dry weight - There were no significant differences.

C. Ear moisture at harvest - There were no significant differences.

D. Grain yield - There were no significant differences. However, the manured treatments were slightly lower in yield.

Table 1. Actual amounts of manure applied in the fall of 1975.

Treatment	Dry Weight	Wet Weight
	- tons/acre -	
SB1	8.063	33.333
SB2	16.127	66.667
SB3	24.190	100.000
LB1	1.913	18.844
LB2	3.825	37.687
LB3	5.738	56.531

Table 2. Average* analysis of manure samples applied in the fall of 1975.

Measurement	Unit†	Type of Manure SB	Type of Manure LB
pH	-	6.3	7.4
Total solids	%	24.2	10.2
Electrical conductivity	mmhos/cm	1.88	3.67
Total Kjeldahl N	%	3.5	8.3
NH_4^+-N	%	2.1	5.3
Organic N	%	1.4	3.0
Phosphates (PO_4-P)	%	.72	1.31
Emission Spectrograph			
P	%	.86	1.55
K	%	2.15	2.76
Ca	%	1.39	1.89
Mg	%	.62	.76
Na	%	.67	1.02
Fe	ppm	2444	964
Al	ppm	2056	655
Mn	ppm	141	136
Zn	ppm	132	147
Cu	ppm	29	20
B	ppm	37	28

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* Values based on three samples each of SB and LB manure.

† Dry weight basis.

Table 3. Nutrients applied in 1975 for the 1976 crop year.

Element	SB1	SB2	SB3	LB1	LB2	LB3
			- lbs./acre -			
Total Kjeldahl N	564	1129	1693	318	635	952
NH_4-N	339	677	1016	203	405	608
Org-N	225	452	677	115	230	344
PO_4-P	116	232	348	50	100	150
P	139	277	416	59	119	178
K	347	693	1040	106	211	317
Ca	224	448	673	72	145	217
Mg	100	200	300	29	58	87
Na	108	216	324	39	78	117
Fe	39	79	118	3.7	7.4	11.1
Al	33	66	99	2.5	5.0	7.5
Mn	2.3	4.5	6.8	0.5	1.0	1.6
Zn	2.1	4.3	6.4	0.6	1.1	1.7
Cu	0.5	0.9	1.4	0.08	0.15	0.23
B	0.6	1.2	1.8	0.11	0.21	0.32

Table 4. Effect of two types of beef cattle manure and commercial fertilizer (fall 1975) on the $NO_3 + NO_2$)-N content, chloride content, and conductivity.

Depth	CK	FE	SB1	SB2	SB3	LB1	LB2	LB3
				($NO_3 + NO_2$)-N, ppm				
0-1'	6.5	6.9	19.3	68.8	85.7	17.5	30.6	57.9
1-2'	2.7	29.1	18.8	75.6	108.8	29.2	58.3	107.0
2-3'	5.4	38.1	19.6	56.4	76.2	15.7	44.2	69.4
3-4'	8.1	13.9	12.4	30.2	29.5	8.9	20.7	13.4
4-5'	8.7	9.0	9.6	11.2	21.0	8.9	14.7	8.0
5-6'	7.8	8.1	6.6	8.4	12.8	7.5	8.5	6.6
6-7'	6.0	6.0	4.7	6.6	9.8	6.3	5.9	6.4
7-8'	5.1	4.6	4.9	5.0	6.8	5.1	3.9	5.2
8-9'	4.3	3.3	3.3	3.7	5.2	3.8	3.9	4.5
9-10'	3.8	2.9	2.8	2.9	4.6	3.5	3.3	3.5
				Cl,ppm				
0-1'	5.7	15.2	9.8	42.6	53.0	9.5	13.8	16.6
1-2'	12.6	21.3	43.9	149.0	145.2	41.3	50.5	99.2
2-3'	13.0	20.1	35.2	137.8	116.1	23.0	49.1	76.1
3-4'	11.0	11.2	15.6	72.2	44.1	12.1	24.9	14.9
4-5'	11.7	12.5	10.5	18.8	30.0	12.3	18.3	8.0
5-6'	10.0	5.9	6.9	8.6	16.0	11.6	11.9	9.5
6-7'	8.1	5.3	7.0	6.9	11.2	9.3	7.9	6.2
7-8'	7.5	4.8	6.1	7.0	7.3	12.1	6.0	5.7
8-9'	6.7	5.2	5.5	4.8	5.3	8.7	6.8	6.6
9-10'	6.9	6.0	3.9	3.7	5.0	8.9	4.5	4.8
				Conductivity (mmhos/cm)				
0-1'	.153	.188	.276	.510	.557	.278	.302	.343
1-2'	.232	.293	.307	.590	.660	.331	.460	.613
2-3'	.240	.317	.320	.523	.527	.235	.433	.480
3-4'	.219	.215	.230	.363	.317	.195	.313	.215

Table 5. Summary of analysis of early plant samples - 1976.

Treatment	P	K	Ca	Mg	Zn	Cu	Mn	B
	%				ppm			
CK	.41	2.61	.60	.64	39.5	7.9	101	8.0
FE	.45	3.23	.65	.55	44.4	7.9	119	9.6
SB1	.45	3.71	.53	.45	42.0	7.9	108	8.4
SB2	.45	3.47	.69	.50	47.3	7.8	117	9.9
SB3	.53	3.43	.59	.52	45.6	6.9	113	10.4
LB1	.45	3.26	.62	.56	38.3	9.0	105	8.5
LB2	.45	3.15	.63	.54	38.4	8.1	107	8.4
LB3	.49	3.68	.56	.45	40.0	6.8	118	11.2
Significance:	NS	NS	NS	NS	NS	NS	NS	NS

Table 6. Summary of analysis of corn leaves at silking - 1976.

Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%					ppm				
CK	1.20	.26	1.13	.80	.75	222	15.1	8.7	64	13.3
FE	1.35	.25	1.48	.81	.67	212	23.7	9.8	89	17.6
SB1	1.39	.31	1.88	.78	.56	240	18.8	10.1	96	18.2
SB2	1.41	.32	1.93	.74	.46	217	19.2	8.3	122	20.5
SB3	1.48	.34	1.89	.74	.43	216	18.1	7.9	123	18.8
LB1	1.42	.32	1.71	.82	.63	217	19.5	11.0	100	17.7
LB2	1.40	.33	1.68	.82	.64	231	21.1	9.9	111	22.2
LB3	1.38	.36	1.94	.83	.57	245	22.1	10.2	147	25.4
Significance:	**	**	**	NS	+	NS	*	NS	**	NS
BLSD (.05)	0.11	.03	.26	-	-	-	2.9	-	16	-

Table 7. Summary of 1976 measurements.

Treatment	Early plant height inches	Early plant (10) dry wt. grams	Grain	
			Ear moisture at harvest %	Yield @ 15.5% M. Bu/Ac
CK	10.6	20.8	33.2	24.6
FE	10.0	20.0	33.7	25.8
SB1	10.8	26.4	30.3	16.8
SB2	7.4	13.7	36.6	13.6
SB3	8.1	16.6	31.5	22.4
LB1	9.6	19.2	33.2	19.2
LB2	10.0	23.6	32.3	19.9
LB3	8.9	19.9	26.9	14.6
Significance:	+	NS	NS	NS
+ Insecticide	N.M.[1]	N.M.	32.1	18.8
- Insecticide	N.M.	N.M.	32.3	20.5
Significance:			NS	NS
Interaction Significance:	N.M.	N.M.	NS	NS

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

Table 8. Plant measurements - 1976.

Main plot treatment	Insecticide	Grain Ear moisture at harvest %	Grain Yield @ 15.5% M. Bu/Ac
CK	W	33.7	25.6
	W/o	32.8	23.7
FE	W	36.5	25.1
	W/o	30.8	26.6
SB1	W	28.2	15.5
	W/o	32.4	18.1
SB2	W	34.7	11.4
	W/o	38.4	15.9
SB3	W	27.6	28.8
	W/o	35.4	15.9
LB1	W	36.1	15.7
	W/o	30.3	22.8
LB2	W	29.3	17.5
	W/o	35.3	22.2
LB3	W	31.0	10.7
	W/o	22.9	18.4

NITROGEN FERTILIZATION OF WHEAT

West Central Experiment Station - Morris

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

I. Plot Description and Planting Information

The experiment initiated in 1975 was continued on a new site. The soil type was again Doland silt loam. Soil test information in the fall of 1975 is given in Table 1.

Table 1. Soil test information for the 1976 plots.

Sample	pH	Organic matter	Phosphorus (lbs/Ac)	Potassium (lbs/Ac)	NO_3-N (lbs/Ac)
1	7.8	H	5*	220	29
2	8.0	H	8*	200	23

* 1:50 soil:solution ratio.

Prior to plowing in the fall of 1975, 100 lbs. of P_2O_5 and 100 lbs. of K_2O were broadcast. Samples were taken in each replicate to a 2-foot depth for NO_3-N. Results showed 70, 78, and 53 lbs. NO_3-N/acre in replicates 1, 2, and 3, respectively. The wheat was seeded on April 14 and the nitrogen was applied as topdressed ammonium nitrate on April 15.

The rates of nitrogen used were based on the average NO_3-N in the fall of 1975. The two tests averaged 26 lbs./acre so the recommended N application for a yield goal of over 60 bu./acre would be 120 lbs./acre. Rates of 90 and 150 lbs. N/acre in addition to a check were included.

II. Yield Results

The 1976 yields are given in Table 2.

Table 2. Effect of N rate and variety on yield of wheat at Morris, 1976.

	N Rate - lbs./Acre				
Variety	0	90	120	150	Average
			- Bu./Acre -		
Era	17.3	21.1	19.2	20.0	19.4
Olaf	13.8	17.1	19.6	18.1	17.2
Kitt	19.8	21.8	22.8	19.8	21.0
Waldron	20.3	19.4	23.6	20.1	20.8
Crosby	16.4	18.3	18.7	19.3	18.2
Botno	17.2	18.2	18.8	17.3	17.9
Average	17.5	19.3	20.5	19.1	

	Significance	BLSD (.05)
Varieties	NS	-
N Rates	*	1.8 Bu./Acre
Interaction	NS	-

The varieties were not significantly different. The 90-lb. and 120-lb. N rates were significantly different from the 0-lb. rate. Four of the six varieties reached maximum yield at the 120-lb. rate which was the recommended rate. Based on the spring NO_3-N test the recommended rate was 70 lb./acre. There was no interaction between varieties and N.

III. Protein Results

The protein percentages from the 1976 plots are given in Table 3. Varieties and N rates were both highly significant. Era had the lowest protein of the hard red spring wheat varieties, with Olaf being the highest. The percent protein increased up to the 120-lb. rate with all varieties and to the 150-lb. rate with Kitt, Waldron, and Botno. The interaction was not significant.

Table 3. Effect of N rate and variety on percent protein of wheat at Morris, 1976.

	N Rate - lbs./Acre				
Variety	0	90	120	150	Average
			- % Protein -		
Era	15.87	17.02	17.31	16.68	16.71
Olaf	18.34	18.86	19.15	18.63	18.73
Kitt	17.42	18.86	18.11	19.03	18.35
Waldron	16.85	17.65	18.28	18.86	17.92
Crosby	17.08	18.05	18.63	18.17	17.98
Botno	15.64	16.79	16.68	17.08	16.54
Average	16.86	17.87	18.03	18.07	

	Significance	BLSD (.05)
Varieties	**	.63%
N Rate	**	.32%
Interaction	NS	

IV. Bushel Weight

The test weight values are given in Table 4. There was a significant difference between varieties with Olaf, Kitt, and Waldron being significantly lower in test weight than Era, Crosby, and Botno. There was no significant effect of the N and the interaction was not significant.

Table 4. Effect of N rate and variety on test weight of wheat at Morris, 1976.

Variety	N Rate - lbs./Acre				
	0	90	120	150	Average
			- lbs./bu. -		
Era	65.9	66.0	65.9	66.2	66.0
Olaf	64.2	63.7	64.1	63.5	63.9
Kitt	63.9	63.1	63.6	63.7	63.6
Waldron	64.1	63.5	63.6	63.7	63.7
Crosby	65.8	65.6	65.7	65.4	65.6
Botno	65.4	64.9	65.2	64.7	65.0
Average	64.9	64.5	64.7	64.5	

	Significance	BLSD (.05)
Varieties	**	1.0 lb./Bu.
N Rate	NS	-
Interaction	NS	-

CONTINUOUS CORN SILAGE

West Central Experiment Station - Morris

Samuel D. Evans

I. Experimental Description

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

II. 1976 Operations

In 1976 the variety used was Trojan TXS99. Furadan was applied at 1 lb./acre (active ingredient) at planting on May 3. Lasso at 2 lbs./acre and Bladex at 2 lbs./acre were applied broadcast on May 4. Silage yields were taken on September 2 and grain yields on September 16. Yields were very low due to drouth and hail damage.

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

	1976 Yield	1966-76 Yield
A. On plots harvested as grain 1965-76:		
Low fertility (74 + 48 + 48)	2.35	5.44
High fertility (148 + 96 + 96)	1.61	5.84
B. On plots harvested as silage 1965-76:		
Low fertility (74 + 48 + 48)	2.81	5.27
High fertility (148 + 96 + 96)	2.52	5.68

IV. Grain Yields - Bushels/acre @ 15.5% moisture.

A. On plots harvested as grain 1965-76:	1976	1966-76
Low fertility (74 + 48 + 48)	28.68	86.50
High fertility (148 + 96 + 96)	14.78	91.12

V. Check Yields

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

	1976	1966-76 Average
Grain (0 + 0 + 0)	7.10 Bu/A	48.88 Bu/A
Silage (0 + 0 + 0)	1.65 tons/A	3.71 tons/A

VI. Discussion

A. In 1976 silage yields were reduced slightly by fertilization on areas that had been harvested either for grain or for silage for 11 years. There was also a slight reduction in yield where continuous silage was grown compared to continuous grain. Grain yields were lower under the high fertility conditions.

B. The 11-year average yields show essentially no difference between growing continuous grain and continuous corn silage.

SULFUR FERTILIZATION OF FIELD CROPS UNDER IRRIGATION AT PARK RAPIDS IN 1976

A.C. Caldwell and R.P. Schoper

Sulfur is an essential element for plant growth and is required in relatively large amounts by some crops such as alfalfa. Since there are extensive areas in Minnesota where sulfur deficiencies do occur, investigations on sulfur needs by crops in this state were conducted quite a few years ago, and then more recently by the Department of Soil Science.

In 1976, studies were continued both on and off the Park Rapids Experimental Field on a wide range of crops including alfalfa, potatoes, corn, wheat, barley and navy beans. The soil on which the studies were conducted is a Dorset sandy loam testing 7 and 2 ppm available S on the experimental field and the Monico farm, respectively.

ALFALFA

A trial started in 1974 was continued into 1976. It consisted of S rates of 25, 50 and 100 lbs/A applied as either elemental sulfur or gypsum in a single application at the initiation of the experiment. The results shown in Table 1 reflect a substantial increase in yield and S concentration in the plant tissue. It is interesting to note that even a modest application of S after 2 years is maintaining the S concentration within the alfalfa tissue well above the 0.25% critical level.

POTATOES

Russet Burbank potatoes were grown under irrigation at both the experimental field and the Monico farm. At both locations tuber yield and S concentration in the potato petioles were increased (Tables 2 and 3). In addition, analysis indicated that 100 lbs S/A could increase the %S in the tuber on the Monico farm from 0.126 to 0.157 and on the station with 50 lbs S/A from 0.128 to 0.163. This certainly suggests that applied S may be valuable in improving the nutritional value of potatoe tubers. Visually, the potatoes at the farm site were chlorotic and showed reduced vegetative growth, a further indication of an S deficiency situation.

CORN, SMALL GRAIN AND NAVY BEANS

Excellent yields of corn, wheat, barley and navy beans were obtained under irrigation at the experimental farm, however, no consistent yield increases due to the use of sulfur were noted. In all cases, as with alfalfa and potatoes, the application of sulfur significantly increased the S concentration in the plant tissue.

Table 1. Yield and S content of alfalfa tissue under irrigation at Park Rapids in 1975 and 1976.

Sulfur Treatment	1975 1st cutting T/A	1975 1st cutting %S	1975 2nd cutting T/A	1975 2nd cutting %S	1976 1st cutting T/A	1976 1st cutting %S	1976 2nd cutting T/A	1976 2nd cutting %S
0	1.2	.212	1.1	.176	1.2	.179	1.2	.188
25 (elem.)	1.5	.294	1.5	.258	1.6	.224	1.8	.240
25 (gypsum)	1.4	.325	1.5	.297	1.4	.246	1.7	.229
50 (elem.)	1.5	.326	1.6	.288	1.6	.259	2.0	.276
50 (gypsum)	1.3	.358	1.4	.361	1.6	.314	1.8	.293
100 (elem.)	1.6	.365	1.5	.385	1.7	.347	2.1	.364
100 (gypsum)	1.5	.393	1.5	.409	1.8	.351	2.0	.342

Table 2. Tuber yield and S content of potatoe petioles under irrigation at Park Rapids in 1976.

Sulfur Treatment	Yield cwt/A	Petiole %S
0	386	.331
25 (gypsum)	416	.385
25 (elemental)	420	.354
*25 (fortified gyp.)	410	.360
50 (gypsum)	407	.377
50 (elemental)	403	.373
*50 (fortified gyp.)	413	.388

* Fortified gypsum is a mixture containing approximately 2/3 gypsum and 1/3 elemental S.

Table 3. Tuber yield and S content of potatoe petioles under irrigation at the Monico farm in 1976.

Sulfur Treatment	Yield cwt/A	Petiole %S
0	372	.321
* 50 (gypsum)	440	.353
50 (elemental)	362	.351
*100 (gypsum)	401	.379
100 (elemental)	450	.363

* Due to the variable stand on portions of the experimental area gypsum and fortified gypsum treatments were averaged.

PESTICIDE INTERACTION PLOTS AT ROSEMOUNT

Russell S. Adams, Jr.

An experiment studying the effects of combinations of the insecticide Furadan, the herbicide Atrazine, and soil pH in continuous corn culture was established for the fourth year in 1976. Treatments included five residual lime treatments, Furadan at 0, 1/2 and 2 pounds per acre, Atrazine at 0, 2, 4 and 8 pounds per acre and their combinations. Each treatment was replicated four times. The plots have been managed so as to maximize both weed and corn rootworm infestation.

The 1976 season was extremely dry, as was 1974. Consequently the study is becoming something of a drought study. Severe drought effects occurred in 1976. The soil was so dry in early spring that neither the herbicide nor the insecticide were activated and pest control was ineffective. Weeds in the chemically treated plots contributed to reduced yields under the drought stress even though the plots were cultivated three times.

We previously reported evidence of an herbicidal effect of Furadan. This was particularly pronounced in 1976 and appeared to be selective. These effects are now reflected in the four year averages at the 0 and 2 pounds per acre Atrazine rate. Data are given in Tables 1 and 2.

Corn yields generally reflected chemical treatments, particularly in 1976. Yields in the no lime, no chemical treatments were lowest being 15 bushels per acre in 1976 and 47 bushels per acre for the four year acreage. In the high lime, high Atrazine, high Furadan treatments yields were highest being 67 bushels per acre in 1976 and averaging 95 bushels per acre over the four years.

Two changes in response became apparent in 1976. Data are given in Tables 3 and 4. In 1973 when lodging was compared with the untreated check the 2 pound per acre treatment of Furadan decreased lodging as soil pH increased. However, in 1976, and to a lesser extent in 1975, the high lime treatments showed little or no lodging control with 2 pounds per acre Furadan. These results could be due to a highly selective corn rootworm resistence, which seems unlikely, or to increasingly more rapid decay of Furadan in the high lime soils. Some difficulty with alleged Furadan resistance in corn rootworm has been reported. These observations indicate that the question needs more study.

Finally, in 1973, 1974 and 1975 broadleafed weeds made up 10% or less of the total weed population. Most of these were velvet leaf. In 1976 broadleafed weeds, again largely velvet leaf, made up about one-third of the population. Whether this is due to a toxin liberated by velvet leaf (which we have confirmed in laboratory studies), to the extremely dry season, to a greater competitive ability under drought stress of velvet leaf with giant foxtail, or merely to a cyclic fluctuation in velvet leaf populations remains to be determined.

Table 1. The amount of lodging, weed growth, and corn yields in Atrazine-Furadan --soil pH studies at Rosemount, Minnesota, 1976.

Rate of Furadan lbs/A, and lime status	Atrazine applied, lbs/A											
	None			2.0			4.0			8.0		
	Lodging %	Weeds Tons/A	Corn bu/A	Lodging %	Weeds Tons/A	Corn bu/A	Lodging %	Weeds Tons/A	Corn bu/A	Lodging %	Weeds Tons/A	Corn bu/A
No lime-somewhat (~ pH 5.4)												
Furadan 0 lbs/A	68	1.10	15	65	1.47	25	58	0.69	37	60	0.59	36
1/2	30	1.28	29	22	0.85	43	20	0.85	44	28	0.31	55
2	28	0.85	47	45	0.76	44	43	0.91	50	38	0.19	53
Moderate lime-slightly acid (~ pH 6.3)												
Furadan 0 lbs/A	50	1.29	34	45	1.26	33	50	0.48	49	60	0.30	48
1/2	65	0.84	34	42	1.21	34	22	0.95	58	40	0.48	55
2	50	0.82	44	10	0.96	44	18	0.55	50	25	0.59	46
Well limed-near neutral (~ pH 6.8)												
Furadan 0	52	1.08	32	58	1.17	26	40	0.49	44	42	0.21	62
1/2	37	0.57	51	42	0.86	43	53	1.06	46	45	0.17	56
2	48	0.32	35	50	0.54	44	40	0.32	60	30	0.29	56
Heavily limed-slightly Calcareous (~ pH 7.2)												
Furadan 0 lbs/A	72	0.98	22	62	0.83	45	40	0.50	66	45	0.12	58
1/2	48	1.02	45	68	0.49	45	42	0.20	69	32	0.09	70
2	52	0.92	36	72	0.54	51	62	0.28	67	58	0.09	67

Table 2. The amount of lodging, weed growth and corn yields in Atrazine-Furadan soil pH studies at Rosemount, Minnesota, 4 year average.

Atrazine applied, lbs/A

Rate of Furadan lbs/A, and lime status		None			2.0			4.0			8.0	
	Lodging %	Weeds Tons/A	Corn bu/A	Lodging %	Weeds Tons/A	Corn bu/A	Lodging %	Weeds Tons/A	Corn bu/A	Lodging %	Weeds Tons/A	Corn bu/A
No lime-somewhat acid (∼pH 5.4)												
Furadan 0 lbs/A	54	1.50	47	51	0.98	69	54	0.45	75	39	0.25	79
1/2	25	1.86	57	33	0.65	78	33	0.65	73	32	0.21	85
2	18	1.17	69	39	0.80	78	15	0.66	75	36	0.16	84
Moderate lime-slightly acid (∼pH 6.3)												
Furadan 0 lbs/A	43	1.89	61	51	0.70	67	42	0.33	80	52	0.08	86
1/2	46	1.33	55	36	0.66	76	26	0.54	89	40	0.20	83
2	24	1.61	65	22	0.88	75	16	0.31	83	21	0.22	86
Well limed-near neutral (∼pH 6.8)												
Furadan 0 lbs/A	48	1.28	55	36	0.83	70	45	0.24	79	44	0.10	91
1/2	40	1.25	72	34	0.87	71	37	0.48	84	48	0.09	90
2	25	1.00	67	20	0.74	87	27	0.40	92	25	.11	89
Heavily limed-slightly calcareous (∼pH 7.2)												
Furadan 0 lbs/A	61	1.48	56	58	0.34	79	52	0.17	82	50	0.05	80
1/2	36	1.36	73	42	0.42	84	38	0.16	89	38	0.05	93
2	40	0.84	75	43	0.35	83	30	0.18	90	38	0.02	95

Table 3. Lodging in the 2 lb/A Furadan treatments as a percentage of the untreated check. 100% would be lodging in cultivated check the same as in 2 lb/A Furadan treatment.

Lime Treatment	1973	1974	1975	1976
		% of check		
No lime-somewhat acid ∼pH 5.4	63	39	53	60
Moderate lime-slightly acid ∼pH 6.3	68	33	59	51
Well limed-near neutral ∼pH 6.8	26	50	68	88
Heavily limed-slightly calcareous ∼pH 7.2	25	57	112	111

Table 4. Ratio of Broadleaf weeds: grasses in cultivated checks. A number of 1.0 would mean equal dry weights of both.

Lime Treatment	1973	1974	1975	1976
No lime-somewhat acid ∼pH 5.4	0.109	0.025	0.092	0.275
Moderate lime-slightly acid ∼pH 6.3	0.027	0.043	0.052	0.448
Well limed-near neutral ∼pH 6.8	0.203	0.037	0.144	0.354
Heavily limed-slightly calcareous ∼pH 7.2	0.490	0.093	0.128	0.332

ALFALFA AND RED CLOVER POTASSIUM AND COPPER TRIALS

Staples, Minnesota - 1976

C. J. Overdahl, Melvin Wiens, R. Schoper and J. Lensing

POTASSIUM TREATMENT EFFECT (ALFALFA AND RED CLOVER)

Plots were established in July of 1970. Experiments on phosphorus, lime and sulfur were discontinued after 1974. No significant effect from these treatments were noted. Phosphorus and sulfur tested high in all of these trials. The soil pH was originally low, but it was determined that irrigation water had a calcium carbonate content of 280 ppm. This resulted in over 1,000 pounds of lime equivalent added annually. The check plots in 1974 had a pH of 7.1, making the lime experiment meaningless. Very high water rates were applied in 1976 (38 inches). The average pH in October was 7.8, indicating a potential problem.

POTASSIUM TREATMENTS ON RED CLOVER AND ALFALFA

	Annual treatments of K_2O in lbs/A and time of application						
	None	June 240	Oct. 240	June 120	Oct. 120	June 120 Oct. 120	Significance
			Yields Tons/Acre at 15% Moisture				
Alfalfa							
1972	3.4	3.6	3.8	3.5	3.4	3.6	ns
1973	4.0a	4.8bc	4.6bc	4.6bc	4.3ab	4.8c	5%
1974	5.1a	6.5b	6.4b	6.4b	6.3b	6.5b	5%
1975	5.1a	6.4bc	6.6c	6.1b	6.2b	6.4bc	1%
1976	4.5a	6.2c	6.1c	5.8b	5.6b	5.7b	1%
Red Clover							
1972	4.2	5.0	4.5	4.7	4.7	4.7	ns
1973	3.3	3.6	3.3	3.4	3.6	3.7	ns
1974*	-	-	-	-	-	-	
1975	5.0a	6.0b	5.8b	5.8b	5.6b	6.0b	5%
1976*	2.8a	3.2b	3.3b	3.2b	3.1b	3.2b	5%
				Soil Test K lbs/A			1976
Alfalfa							
1972	92	258	322	160	165	185	Avg. pH=7.8
1973	85	290	210	150	140	195	
1974	60	175	240	95	75	200	Avg. P=60
1975	48	178	160	75	63	135	
1976	40	210	145	68	68	128	
Red Clover							
1972	107	262	230	182	167	162	
1973	90	290	240	160	190	310	
1974	135	180	200	150	155	180	
1975	60	180	83	108	60	115	

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* red clover failed in 1974, was reseeded August 1, 1974 and a good stand was established for 1975. Red clover in 1976 was plowed and reseeded after two cuttings.

	Plant Analysis %K						
	None	June 240	Oct. 240	June 120	Oct. 120	June 120 Oct. 120	Significance
Alfalfa							
1972							
1st cut	2.05	2.76	2.89	2.20	2.74	2.65	
2nd cut	2.00	2.50	2.46	2.27	1.92	2.34	
3rd cut	2.52	3.44	3.08	2.94	2.85	3.18	
1973							
1st cut	1.74a	2.74b	2.88b	2.40b	2.45b	2.47b	5%
2nd cut	1.58a	2.76b	2.76b	2.48b	2.39b	2.65b	1%
3rd cut	1.64a	2.60b	2.57b	2.45b	2.17b	2.56b	5%
1974							
1st cut	1.37	3.08	3.59	2.17	2.32	3.21	
2nd cut	1.29	2.40	2.85	2.25	1.89	2.60	
3rd cut	1.11	2.18	2.48	2.08	1.62	2.36	
1975							
1st cut	1.24a	2.19c	2.67d	1.67b	2.15c	2.31c	1%
2nd cut	1.39a	2.74c	2.49bc	2.27b	1.93a	2.67c	1%
3rd cut	1.23a	2.60c	2.85c	2.15b	1.72a	2.45bc	1%
1976							
1st cut	1.24a	3.66f	3.26de	1.55b	2.38c	2.99d	5%
2nd cut	1.45a	2.98d	2.83d	2.68c	2.02b	2.90d	5%
3rd cut	1.49a	2.78cd	2.86d	2.26b	2.03b	2.68c	5%
Red Clover							
1972							
1st cut	2.14	3.05	2.83	3.02	2.61	3.04	
2nd cut	2.20	2.86	2.60	2.51	2.21	2.44	
3rd cut	2.65	3.54	2.98	3.32	2.87	2.98	
1973							
1st cut	1.76a	2.63b	2.65b	2.56b	2.42b	2.66b	5%
2nd cut	2.03a	2.84c	2.97c	2.65bc	2.48b	2.92c	1%
3rd cut	1.81a	3.00d	2.53c	2.40c	2.10b	2.66c	1%
1974							
none							
1975							
1st cut	1.55a	2.59d	2.33cd	2.01bc	1.87ab	2.45d	1%
2nd cut	1.69a	3.00c	2.18b	2.80c	2.05b	2.89c	1%
3rd cut	1.78a	3.12d	2.37b	2.68c	2.25b	2.87c	1%
1976							
1st cut	1.43	2.96	3.18	2.08	2.37	2.80	5%
2nd cut	1.70a	3.09c	2.67b	2.66b	2.47b	3.05c	5%

The potassium (K) experiment has provided useful data on differences between alfalfa and red clover K needs.

In 1976, the 240 pound potash treatments gave yields significantly higher than for the 120 pounds per acre for alfalfa, but not for red clover. There has been no significant difference in yield between October or June application. Each year plant analyses show higher K content from October treatments at the first cutting time. This is prior to the June K applications. K content in plants from the 120 pound rate, at time of the last cutting, is higher from June treatments. This is generally true for all years of the experiment. Check plots after the first year show plant K to be less than 2 percent in both alfalfa and red clover. Potassium soil tests are unusually low. The basic difference between alfalfa and red clover so far is the loss of red clover stand and the necessary reseeding of this crop every year. Alfalfa is still grown from the seeding of 1970.

COPPER OBSERVATIONS

	Lbs/acre of copper applied as copper sulfate		
	0	10	Sig. 5%
		Tons/Acre	
Alfalfa			
1972	0.52	0.60	3rd cutting only
1973	5.3	5.4	ns
1974	6.4	6.9	ns

In 1972 to 1974, copper treatments were made on a special area of alfalfa adjacent to the alfalfa-red clover site. There was a slightly higher yield from copper treatments, but this was not significant at the 5 percent level.

In 1975 and 1976, two of the four replicates in the alfalfa-red clover trials had 10 pounds per acre of copper.

	Lbs. of copper applied as copper sulfate annually		
	0	10	Sig.
		Tons/Acre	
Alfalfa			
1975	5.8	6.1	ns
1976	5.5	5.8	10%
Red Clover			
1975	5.6	5.8	ns
1976	3.1	3.2	ns

				ppm Cu plant tissue			
Cuts	1	2	3	1	2	3	
Alfalfa							
1975	0.8	-	-	2.2	-	-	1%
1976	1.2	2.2	2.1	4.5	6.5	6.4	1%
Red Clover							
1975	4.5	-	-	4.3	-	-	ns
1976	3.5	3.7	-	6.7	8.6	-	1%

Added copper had a highly significant effect on copper content in both alfalfa and red clover tissue. Copper is always higher in red clover, particularly without added copper. There is no copper effect on yield with red clover, but there was an indication of some copper effect on alfalfa yield in 1976. Trials will be continued in 1977 with newly seeded red clover.

PLANT AND GRAIN YIELD AND NITROGEN CONTENT OF FERTILIZED CORN UNDER IRRIGATION (CMDIR STATION, STAPLES, MINNESOTA, 1976)

A.C. Caldwell, L. Goodroad, J. Gerwing, M. Wiens, H. Werner

An experiment was established on an Estherville loamy sand at the CMDIR Station at Staples, Minnesota, in the spring of 1974 to study the effects of time and rate of application of fertilizers on corn yield and to account for those essential nutrients and other elements added to soils by analysis of plant, soil, and materials applied. The results reported below are some observations from the third cropping year, 1976.

A 90-day hybrid was planted at 26,000 seeds per acre in middle May in 30-inch rows. Herbicides were used to control weeds. Irrigation water was applied as needed. Fertilizer treatments and rates are given in the following table. The nitrogen was not applied at one time but at 2 or 3 intervals up to tasseling time depending upon the rate required. For example, the 80 pound rate of nitrogen (treatment 2) was split into 18 (starter), 22 and 40 pound allotments of nitrogen; the 160 pound rate (treatments 4, 7, 8) was split into 18 (starter), 42, 50, and 50 pound allotments of nitrogen as urea. The soybean meal (treatment 9) was applied all at one time prior to planting. The treatments were replicated four times.

Total plant yield was obtained by sampling the corn when it had reached physiological maturity. Grain yield was determined on mature corn. Grain and plant tissue were analyzed for nitrogen.

Total plant yields increased with increasing nitrogen rates up to 240 pounds N/A (see accompanying table). An additional 150 pounds of K/A seemed to depress whole plant yields slightly. An additional 30 pounds P/A gave about the same yield as the basic application.

Grain yields increased with increasing nitrogen rates to 160 pounds N/A. Additional applications of P and K over the basic application had little effect on grain yields.

Pounds per acre of N in the tissue and grain show the amounts required to produce the dry matter and yields obtained. For example, treatment 4 (160 lbs N/A) gave maximum yield of 142 bu/A which contained 108 pounds of nitrogen.

Total Plant and Grain Yield and Nitrogen Content of Corn Under Irrigation (CMDIR, Staples, 1976)

Treatment Number	Fertilizer Treatments[1]			Total Plant Yield	Nitrogen in tissue		Grain Yield	Nitrogen in Grain	
	N	P	K						
	lbs/A			tons/A	%	lbs/A	bu/A	%	lbs/A
1	18	10	150	4.28	0.77	66	73	1.18	41
2	80	10	150	6.11	0.87	106	113	1.42	76
3	120	10	150	6.82	1.13	154	130	1.62	100
4	160	10	150	6.99	1.07	150	142	1.61	108
5	200	10	150	6.92	1.13	157	137	1.69	110
6	240	10	150	7.26	1.13	164	141	1.62	108
7	160	40	150	7.08	1.13	160	136	1.60	103
8	160	10	300	6.62	1.10	146	139	1.66	109
9	160	24	194	7.09	1.07	152	135	1.59	102

[1] All plots received 18, 10, and 56 lbs/A of N, P, and K, respectively, as starter along the row, plus an additional broadcast application of 94 lbs of K/A (as KCl). Treatment 7 got an extra 30 lbs P/A (as superphosphate), and treatment 8 an additional 150 lbs K/A (as KCl). The soybean meal application, treatment 9, contributed another 14 lbs P and 44 lbs K per acre. Sulfur was applied to all plots at 20 lbs S/A as gypsum.

NITROGEN TRIALS ON SPRING WHEAT UNDER IRRIGATION AT STAPLES IN 1976

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

As a continuation of a trial initiated in 1974, a time and rate of nitrogen experiment on wheat was conducted under irrigation on a sandy loam soil at Staples in 1976. In 1976, as in the previous two years, Kitt and Era were the two semi-dwarf wheat varities grown. A randomized complete block design was used with six nitrogen treatments, applied as ammonium nitrate, replicated four times.

Nitrogen Treatment	Time and Rate of Application
lbs N/A	lbs N/A
0	--
50	50 preplant
75	50 preplant, 25 early boot
100	50 preplant, 50 early boot
125	75 preplant, 50 early boot
175	75 preplant, 50 stooling, 50 early boot

In addition to the nitrogen treatments, 20 lbs. P_2O_5/A was applied with the seed and 60 lbs. K_2O/A was broadcast over the experimental area.

Grain yield for the two varieties was better than average ranging from 32-77 bu/A. (Table 1) as compared to a range of 19-62 bu/A. in 1974 and 11-26 bu/A. in 1975. This dramatic improvement in yield is probably due to not only an earlier seeding date, April 6 versus May 2 in 1975, but also to an improved irrigation schedule.

Forage yields for both varieties were collected at the soft dough stage to determine total dry matter yield, percent nitrogen and total nitrogen removal for the various rates of nitrogen. In addition, grain protein was measured following harvest. The results of these measurements are reported in Tables 2 and 3.

Table 1. Yield of Era and Kitt wheat as affected by nitrogen fertilizer rates under irrigation at Staples in 1976.

Fertilizer Treatments	Variety	
	Era	Kitt
lbs N/A	- - - - -Bu/A- -	- - - -
0	32	39
50	60	68
75	69	69
100	72	73
125	77	74
175	70	71
Significance	**	**
BLSD (.05)	7	7
CV, %	7.2	7.6

Table 2. The grain protein, dry matter yield, percent N in the tissue and total N removal by the forage for Era wheat as affected by nitrogen fertilizer at Staples in 1976.

Fertilizer Treatment	Grain Protein	Forage Yield	Forage N	Forage N Removed
lbs N/A	%	Tons/A	%	lbs/A
0	10.3	2.24	0.92	41
50	10.3	3.37	1.13	76
75	12.2	3.94	1.45	115
100	13.2	3.82	1.52	116
125	15.7	4.07	1.52	123
175	15.7	4.36	1.86	162
Significance	**	**	**	**
BLSD (.05)	0.6	0.31	0.24	21
CV, %	3.7	6.3	12.3	14.5

Table 3. The grain protein, dry matter yield, percent N in the tissue and total N removal by the forage for Kitt wheat as affected by nitrogen fertilizer at Staples in 1976.

Fertilizer Treatment	Grain Protein	Forage Yield	Forage N	Forage N Removed
lbs N/A	%	Tons/A	%	lbs/A
0	11.7	2.52	1.06	54
50	12.4	3.99	1.32	106
75	13.2	4.39	1.46	129
100	13.4	4.16	1.58	132
125	15.2	4.28	1.76	151
175	15.9	4.43	1.93	169
Significance	**	**	**	**
BLSD (.05)	1.3	0.36	0.37	32
CV, %	9.2	6.8	16.2	18.7

N RATE STUDIES OF IRRIGATED WHEAT AND OATS WITH AND WITHOUT LEGUME UNDERSEEDING, STAPLES, 1976

H. Meredith, M. Wiens, R. Schoper, J. Lensing
H. Werner and J. O. Jacobson

1976 was the second crop year of a study initiated in 1975 to:

a) determine optimum economic N rates for continuous cropping to oats and wheat

b) determine optimum economic N rates for continuous cropping to oats and wheat with red clover underseeding

c) determine optimum N rates for wheat following plowdown of an established stand of red clover.

Stout oats, Era wheat and Lakeland red clover represented the varieties of the respective crops. The experiment consists of a randomized complete block design with four replications and four N rates. Urea was used as the N source. N rates for oats were 0, 40, 80 and 120 pounds of N per acre. Wheat received 0, 60, 120 and 180 pounds of N per acre. N on the oats was applied at two intervals, one-half at seeding and the remaining N applied just prior to boot formation.

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

All plots received a broadcast application of 300 pounds K per acre in early April. Urea was broadcast and incorporated by harrowing prior to seeding. Seeding rate in pounds per acre was: wheat, 120; oats, 96; and red clover, 16.

Plots were moldboard plowed, disced, and harrowed in early April. Seeding was accomplished on April 7.

Table 1. Grain Yield from Irrigated Wheat, Staples, 1975 and 1976.

	1975			1976		
Lbs. N/Ac	Wheat[1/]	Wheat[2/]	Lbs.N/Ac	Wheat[1/]	Wheat[2/]	Wheat[3/]
0	7.3	5.0	0	24.3	53.0	59.1
40	18.0	13.0	60	53.0	58.3	70.0
80	21.3	16.5	120	66.4	55.2	69.2
120	24.0	17.0	180	68.0	56.7	66.7
Treatments	**	**		**	NS	*
BLSD (.05)	5.8	4.1		8.1	-	7.6
C.V.	21.1	20.8		10.2	12.6	6.8

1/ Chemical weed control

2/ Seeded with a red clover companion crop

3/ Seeded following plowdown of established stand of red clover and chemical weed control.

Table 2. Grain Yield from Irrigated Oats, Staples, 1975 and 1976.

	1975		1976	
Lbs N/Ac	Oats[1/]	Oats[2/]	Oats[1/]	Oats[2/]
0	24.0	24.0	54.4	85.7
40	35.8	44.8	84.0	87.7
80	40.8	51.8	100.9	90.2
120	34.8	41.0	111.2	93.2
Treatments	*	NS	**	NS
BLSD (.05)	4.3	--	28.5	--
C.V.	17.3	29.9	20.1	15.9

[1/] Chemical weed control

[2/] Seeded with a red clover companion crop

Table 3. Protein in Irrigated Wheat Grain, Staples, 1975 and 1976.

- - - - - - - - - - - - - - Percent Protein - - - - - - - - - - - - - - -						
1975			1976			
Lbs. N/Ac	Wheat[1/]	Wheat[2/]	Lbs. N/Ac	Wheat[1/]	Wheat[2/]	Wheat[3/]
0	12.4	12.3	0	12.1	12.1	12.5
40	11.8	11.1	60	12.9	11.2	13.7
80	13.0	12.4	120	15.2	13.2	15.2
120	15.7	13.4	180	15.4	15.6	15.3
Treatments	**	**		**	**	**
BLSD (.05)	.58	.44		1.4	1.5	1.0
C.V.	6.2	4.9		6.6	7.5	4.6

1/ Chemical weed control

2/ Seeded with red clover companion crop

3/ Seeded following plowdown of established stand of red clover and chemical weed control.

Table 4. Protein in Irrigated Oat Grain, Staples, 1975 and 1976.

	Percent Protein			
	1975		1976	
Lbs. N/Ac	Oats[1/]	Oats[2/]	Oats[1/]	Oats[2/]
0	14.4	11.9	14.3	13.0
40	13.6	12.0	14.9	13.5
80	15.1	12.4	16.5	15.1
120	15.7	14.0	16.5	15.6
Treatments	NS	NS	*	**
BLSD (.05)	--	--	1.8	1.4
C.V.	12.4	10.9	6.8	5.9

1/ Chemical weed control

2/ Seeded with red clover companion crop

Table 5. Approximate Nutrient Removal in Wheat and Oats Grain and Straw[1/]

	N	P_2O_5	K_2O
Wheat			
Grain/bu	1.2	.6	.4
Straw: 75 lbs/bu	.6	.2	1.0
Oats			
Grain/bu	.7	.25	.2
Straw: 50 lbs/bu	.3	.15	1.0

1/Source: Soil Fertility Notes, Univ. of Minn., No. 58, Sept. 1976

Table 6. Nutrient Removal From Intensively Irrigated Wheat Plots - Grain and Straw, Staples, 1976.

		Actual	Estimated[1/]		
		- - - - Lbs/A - - - -			
Lbs N/A	Yield Bu/A	N	N	P_2O_5	K_2O
0	24.3	47	44	19.4	34.0
60	53.0	87	102	42.4	65.7
120	66.4	120	128	53.1	82.3
180	68.0	142	139	54.4	84.3
0	59.0	87.6	106.2	47.2	73.2
60	70.0	114.8	126.0	56.0	86.8
120	69.2	125.6	124.5	55.3	85.8
180	66.7	133.6	120.0	53.3	82.7

1/ Based on Soil Fertility Notes, No. 58, Sept. 1976, University of Minnesota

Table 7. Nutrient Removal From Intensively Irrigated Oat Plots - Grain and Straw, Staples, 1976.

		Actual	Estimated[1/]		
		- - - - - - Lbs/A - - - -			
Lbs N/Ac	Yield Bu/A	N	N	P_2O_5	K_2O
0	54.4	43.2	54.4	21.8	65.3
40	84.0	74.3	84.0	33.6	100.8
80	100.9	114.0	100.9	40.3	121.1
120	111.2	127.8	111.2	44.5	133.4

1/ Based on Soil Fertility Notes, No. 58, Sept. 1976, Univ. of Minnesota

Table 8. Wheat Forage Yields under Intensive Irrigation, Staples, 1976 1/

Lbs N/Ac	Tons D.M./A	Percent Protein in forage	Lbs Protein per acre in forage	Lbs N per acre in forage
0	1.77	8.34	292.6	46.8
60	3.28	8.30	543.7	87.0
120	3.98	9.44	749.6	119.9
180	3.76	11.80	889.3	142.3
Treatments	**	**	**	**
BLSD (.05)	.38	1.64	102.1	17.4
C.V.	7.5	10.3	11.0	11.0

1/ Chemical weed control

Table 9. Wheat-Red Clover Forage Yields Under Intensive Irrigation, Staples, 1976 1/

Lbs N/Ac	Tons D.M./A	Percent Protein in forage	Lbs Protein per acre in forage	Lbs N per acre in forage
0	3.34	8.69	582.9	93.3
60	3.83	8.52	649.9	104.0
120	3.81	10.66	811.0	129.8
180	3.74	10.72	796.9	127.5
Treatments	NS	*	**	*
BLSD (.05)	-	1.64	169.1	27.1
C.V.	10.3	10.3	14.2	14.2

1/ Seeded with red clover companion crop

Table 10. Wheat Forage Yield under Intensive Irrigation, Staples, 1976[1].

Lbs N/Ac	Tons D.M./A	Percent Protein in forage	Lbs. Protein per acre in forage	Lbs. N per acre in forage
0	3.17	8.63	547.8	87.6
60	3.75	9.56	717.4	114.8
120	3.58	10.93	784.9	125.6
180	3.56	11.78	835.1	133.6
Treatments	NS	**	**	**
BLSD (.05)	-	1.13	103.2	19.0
C.V.	11.1	6.7	9.9	9.9

[1] Seeded following plowdown of established red clover and chemical weed control.

Table 11. Oat Forage Yield under Intensive Irrigation, Staples, 1976 [1].

Lbs N/Ac	Tons D.M./A	Percent Protein in forage	Lbs Protein per acre in forage	Lbs N per acre in forage
0	2.05	6.58	270.0	43.2
40	2.98	7.83	464.1	74.3
80	3.84	9.34	712.4	114.0
120	4.26	9.41	798.7	127.8
Treatments	**	**	**	**
BLSD (.05)	.78	1.25	118.9	20.4
C.V.	14.5	9.0	14.1	14.1

[1] Chemical weed control

Table 12. Oat-Red Clover Forage Yields under Intensive Irrigation, Staples, 1976 1/.

Lbs N/Ac	Tons D.M./A	Percent Protein in forage	Lbs Protein per acre in forage	Lbs N per acre in forage
0	3.30	7.95	527.3	84.4
40	3.58	8.02	569.2	91.1
80	3.89	9.94	769.4	123.1
120	4.09	9.69	792.9	126.9
Treatments	NS	*	**	**
BLSD (.05)	--	1.67	109.2	19.9
C.V.	9.8	11.1	11.2	11.2

1/ Seeded with red clover companion crop

Table 13. Oat, Straw, and Oat Grain-Straw Ratios under Intensive Irrigation, Staples, 1976 1/.

Lbs N/A	Lbs Straw per acre	Lbs Straw per Bu	Straw	Grain
			- - - - Percent - - - - -	
0	2360	43.4	58	42
40	3272	39.0	55	45
80	4451	44.1	58	42
120	4962	44.6	58	42
Ave.		42.8	57.2	42.8

1/ Chemical Weed Control

Table 14. Wheat Straw and Wheat Grain-Straw Ratios under Intensive Irrigation, Staples, 1976[1].

	1976			
Lbs N/Ac	Lbs Straw per acre	Lbs Straw per bu	Straw	Grain
			- - - Percent	- - - - -
0	3760	63.6	51.5	48.5
60	4340	62.0	50.8	49.2
120	4240	61.3	50.5	49.5
180	4380	65.7	52.2	47.8
Ave.		63.2	51.2	48.8

1/ Seeded following plowdown of established red clover and chemical weed control

Table 15. Wheat Straw and Wheat Grain-Ratios under Intensive Irrigation, Staples, 1976[1].

Lbs N/Ac	Lbs Straw per acre	Lbs Straw per bu	Straw	Grain
			- - - Percent	- - -
0	2060	84.8	58.6	41.4
60	3460	65.3	52.1	47.9
120	3740	56.3	48.4	51.6
180	4260	62.6	51.0	49.0
Ave.		67.2	52.5	47.5

1/ Chemical Weed Control

Table 16. Soil Test Results Following Two Years Intensive Irrigation, Staples, 1976.

Lbs N/A/Yr	pH1/	P1/	K1/
0	6.25	48	248
40	6.18	41	200
80	6.10	36	195
120	6.00	36	185

Irrigation 1975: 13.5 acre inches; rainfall 9.9 inches, in season.

Irrigation 1976: 25 acre inches; rainfall 7.3 inches in season.

Samples: August, 1976.

Crop: Wheat, 1975; oats, 1976.

1/ Average of four replications

Table 17. Soil pH following two years Intensive Irrigation, Staples, 1976.

Lbs N/Ac1/	April 76 Sampling2/	August 76 Sampling3/
0	5.89	6.32
60	5.91	6.18
120	5.85	6.15
180	5.79	6.05

1/ Received 0, 40, 80, 120 Lbs N/Ac in 1975.

2/ Average of eight replications

3/ Average of four replications.

Irrigation and rainfall data same as Table 19.

Table 18. Two-Inch Soil Temperature Maximums [1].

June

Days Over 75°F		Days Over 85°F		Days Over 95°F	
1975	1976	1975	1976	1975	1976
23	26	12	17	2	8

July

Days Over 75°F		Days Over 85°F		Days Over 95°F	
1975	1976	1975	1976	1975	1976
31	31	27	30	14	26

[1] Temperatures recorded under vegetation-free area.

Table 19. Rainfall, Irrigation and Pan Evaporation Data by Month for 1975 and 1976.

	1975			1976		
	Inches Rainfall	Inches Irrigation	Ave. Pan Evap/day	Inches Rainfall	Inches Irrigation	Ave. Pan Evap/day
April[1]	--	--	--	0.7	3.2	.14
May	1.6	3.6	.23	.3	7.9	.27
June	6.0	1.7	.24	5.0	6.6	.33
July	2.3	6.8	.33	1.3	6.4	.32
Total	9.9	12.1	24.5	7.2	24.1	29.5

Ratio $\frac{\text{Rainfall + Irrigation}}{\text{Pan Evaporation}}$: 1975: $\frac{22.0}{24.5} = 0.9$ 1976: $\frac{31.3}{29.5} = 1.1$

[1] Seeded May 2, 1975
Seeded April 7, 1976

Water Quality Studies - 1976

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

Water samples were analyzed several times during the irrigation season to gain a better understanding of water quality. Samples are from the Staples Irrigation Farm and adjacent area.

Table 1. Water Hardness from North well, Staples Irrigation Center, 1975 and 1976.

1975		1976		
Date	$mg/CaCO_3/L$[1]	Date	pH	$mg/CaCO_3/L$[1]
5/12 (1)	144	4/28[2]	8.1	216
5/12 (2)	148	4/28	8.6	118
5/24	167	5/29	7.8	206
6/24	169	6/10	8.7	68
7/24	188	7/8	8.3	136
8/2 (1)	159	7/17	8.1	146
8/2 (2)	153	7/17	8.9	133
9/24 (1)	242	8/10	8.3	99
9/24 (2)	240	9/6	8.2	151
Average	179			141[3]

[1] $CaCO_3$ equivalent based on total hardness

[2] Not pumped

[3] 32 Lbs. $CaCO_3$/A Inch water

Table 2. Water Analyses of North well, Staples Irrigation Center, 1976.

Date	Spec. Conductance 1/	SO_4-S	Cl	B
		- - - - - -	PPM	- - - - - -
4/28	241	2.3	4.6	--
4/28	279	--	4.8	.12
5/29	503	2.6	8.1	.15
6/10	87	< 2.0	1.3	.04
7/8	291	< 2.0	7.0	.06
7/17	369	2.9	8.9	.09
7/17	403	2.6	8.4	.07
8/10	200	4.5	1.4	.12
9/6	338	< 2.0	4.7	.06

1/ Micromhos/cm @25°C

Table 3. Water Hardness from Center well, Staples Irrigation Center 1975 and 1976.

1975		1976		
Date	mg/$CaCO_3$/L 1/	Date	pH	mg$CaCO_3$/L 1/
5/27	164	4/28	8.1 2/	175
6/24 (1)	148	4/28	8.7	136
6/24 (2)	132			
7/12 (1)	155			
7/12 (2)	182	5/15	8.2	172
8/2 (1)	157	7/3	8.0	--
8/2 (2)	141	7/7	8.2	113
		7/17	8.0	149
		7/27	7.9	133
		9/6	8.2	261

1/ $CaCO_3$ equivalent based on total hardness

2/ Not pumped

Table 4. Water Analyses of Center Well, Staples Irrigation Center, 1976.

Date	Spec.[1/] Conductance	SO_4-S	Cl	B
		- - - - - - - - PPM - - - - - - - -		
4/28 (1)	402	2.6	6.6	.06
4/28 (2)	337	3.1	6.8	.03
5/15	418	2.7	6.8	.04
7/3	187	--	1.1	--
7/7	304	3.0	6.2	.02
7/17	348	2.3	5.3	.49
7/27	137	--	.8	.12
9/6	565	<2.0	7.3	.09

[1/] Micromhos/cm @ 25°C

Table 5. Water Analyses of Farmer Wells in Staples Area, 1976.

Farmer Name	pH	S.C.[1/]	S	Cl	B	$CaCO_3$[2/] Equivalent
			- - - - PPM - - - - - - - - - -			
B. Cedar	7.9	371	6.1	4.6	.16	125
"	7.9	303	8.1	3.4	.15	97
S. Roth	8.0	325	4.8	4.3	.11	131
"	8.1	369	7.6	4.9	.07	149
"	8.1	347	6.4	4.4	.08	157
M. Roth	8.1	280	3.0	4.1	.05	131
"	8.2	392	4.5	3.4	.04	193
L. Wallace	8.2	361	3.3	2.4	.06	185
C.M. Wilkins	8.1	368	3.0	4.9	.05	165
Plagon (?)	8.2	216	5.9	8.0	--	341
B. Sommars	8.2	412	3.7	10.6	.04	175
H. Kramer	8.2	424	5.0	6.7	.07	203
C. Olson-Pond	8.2	435	4.0	22.3	.11	139
C.Olson-C. Pivot	8.2	351	5.1	8.7	.05	66

[1/] Specific Conductance, micromhos/cm @ 25°C

[2/] $CaCO_3$ equivalent based on total hardness

SOUTHERN EXPERIMENT STATION - WASECA
WEATHER DATA - 1976

Month	Period	Precipitation		Avg. Air Temp.		Growing Degree Days	
		1976	Normal	1976	Normal	1976	Normal
		inches		°F			
January	1-31	.35	.73	12.3	12.9		
February	1-28	.47	.96	26.6	17.5		
March	1-31	2.66	1.94	30.6	28.5		
April	1-30	1.79	2.48	49.8	45.6		
May	1-10	.01		49.6		69.5	
	11-20	.58		58.8		111.5	
	21-31	1.67		60.8		128.5	
	Total	2.26	3.86	56.5	57.7	309.5	323
June	1-10	.36		70.8		201.0	
	11-20	.76		67.6		174.0	
	21-30	1.43		66.4		163.5	
	Total	2.55	4.75	68.3	67.1	538.5	521
July	1-10	.00		71.4		208.0	
	11-20	1.24		73.2		217.5	
	21-31	1.41		73.5		253.0	
	Total	2.65	4.02	72.7	71.4	678.5	637
August	1-10	.87		66.3		163.5	
	11-20	.33		70.2		196.0	
	21-31	.20		72.0		236.5	
	Total	1.40	3.60	69.6	69.7	596.0	583
September	1-30	2.11	3.45	59.0	60.3	324.0	310
October	1-31	.89	1.89	42.8	50.3		44
November	1-30	.06	1.25	26.2	32.9		
December	1-31	.24	1.02	9.8	19.0		
Year	Jan-Dec	17.43	29.95	44.4	44.4	2446.0	2418
Growing Season	May-Sept	10.97	19.68	65.3	65.3	2446.0	2374

Notes:

1) Highest temp. on July 11 - 98°

2) Highest 24-hour precipitation on July 15 - 1.15"

3) Frost on September 28

4) Record low rainfall for growing season and for year

NITROGEN FERTILIZATION OF CORN

Waseca, 1976

G. W. Randall and W. E. Lueschen

To evaluate various sources of N fertilizer, an experiment involving four sources of N applied at two rates in both the fall and the spring was established at the Southern Experiment Station on a Cordova silty clay loam in 1971. The experimental design was a randomized complete-block, replicated four times.

Because P and K had not been applied since 1972, P and K (100 lb P_2O_5+150 lb K_2O/A) were broadcast and plowed under in the fall of 1975. Starter fertilizer was not used. Ammonium nitrate, urea and 28% N solution were fall-applied on 10/28/75 and plowed down immediately. Anhydrous ammonia was applied on 11/17/75. Ammonium nitrate, urea and UAN (urea-ammonium nitrate solution, 28% N) were spring-applied on 4/26/76 and disked in. The anhydrous ammonia was applied on 4/20/76. Fall and spring soil conditions were considered to be fair and excellent, respectively, for N application. Beginning in 1974, UAN was substituted for aqua ammonia (20% N) because of the unavailability of the latter material.

Corn (Pioneer 3780) was planted at 26,000 ppA in 30" rows on April 29. An insecticide (Counter at 1 lb/A) was applied at planting. Weeds were controlled with 3 lb/A of Lasso and 2½ lb/A of Bladex applied preemergence. Soil nitrate samples were taken to a depth of 2 feet from all 150-lb treatments on July 1. The leaf opposite and below the ear was sampled at silking and was submitted for Kjeldahl analysis. Yields were taken by combine harvesting the center two rows from each plot.

RESULTS

Only leaf and grain N (protein) were affected by the N treatments in 1976 (Table 1). Grain moisture, yield and N removal in the grain were not influenced in this dry year in which CV's were quite high.

In comparing N sources, leaf N was significantly lower with UAN (2.07%) than with either anhydrous ammonia, urea or ammonium nitrate (2.23, 2.17 and 2.20%, respectively). Grain N was significantly higher with anhydrous ammonia than with the other sources.

Significant increases in leaf and grain N, yield and N removal were associated with the 150-lb rate over the 75-lb N rate.

Denitrifying conditions did not exist at any time during this dry year. Therefore, time of N application had no effect on any of the parameters measured in 1976.

Table 1. Continuous corn parameters as influenced by source, rate and time of application of N at Waseca in 1976.

Treatment			Leaf	Grain			
Source	Rate	Time	N	Moisture	Yield	N	N Removal
	lb N/A		%	%	bu/A	%	lb N/A
Anhyd. Am.	75	F	2.20	18.8	62.7	1.88	55.4
"	75	S	2.13	19.8	70.4	1.86	61.2
"	150	F	2.39	19.5	66.4	1.94	60.2
"	150	S	2.18	18.7	78.2	1.88	69.5
Urea	75	F	2.01	18.7	61.0	1.74	49.8
"	75	S	2.04	19.1	63.6	1.84	54.3
"	150	F	2.24	20.5	65.6	1.80	55.5
"	150	S	2.38	18.6	72.5	1.84	63.1
Am. Nitrate	75	F	2.12	19.8	63.8	1.78	52.8
"	75	S	2.02	19.8	68.6	1.61	52.4
"	150	F	2.26	19.8	69.4	1.84	59.0
"	150	S	2.40	19.3	72.5	1.82	62.4
UAN[1/]	75	F	2.00	20.5	53.8	1.76	44.9
"	75	S	1.91	19.8	57.3	1.68	45.2
"	150	F	2.23	18.6	75.4	1.86	65.6
"	150	S	2.16	19.7	67.5	1.86	58.0
Significance:			**	NS	NS	*	NS
CV (%) :			4.8	6.0	21.3	6.1	20.0
BLSD (.05) :			.14			.20	
Individual Factors							
Source							
Anhydrous Am.			2.23	19.2	69.4	1.89	61.6
Urea			2.17	19.2	65.7	1.80	55.7
Am. Nitrate			2.20	19.6	68.6	1.76	56.6
UAN			2.07	19.6	63.5	1.79	53.4
Significance:			**	NS	NS	*	NS
BLSD (.05) :			.07			.08	
Rate							
75 lb N			2.05	19.5	62.6	1.77	52.0
150 lb N			2.28	19.3	70.9	1.86	61.7
Significance:			**	NS	*	**	**
Time							
Fall			2.18	19.5	64.7	1.82	55.4
Spring			2.15	19.3	68.8	1.80	58.2
Significance:			NS	NS	NS	NS	NS
Interaction							
Source X Rate			NS	NS	NS	NS	NS
Source X Time			*	NS	NS	NS	NS
Rate X Time			NS	NS	NS	NS	NS
Source X Rate X Time			+	+	NS	NS	NS

[1/] Urea-ammonium nitrate solution (28% N)

With the exception of the S x T interaction for leaf N, other interactions did not exist at the 95% probability level. Spring application of the dry materials (33 and 45%) resulted in increased leaf N over fall applications whereas the opposite was true for 28 and 82% N.

Soil NO_3-N analyses showed marked differences among the treatments (Table 2). Spring application resulted in NO_3-N levels being approximately double fall application, except for UAN. No reason can be given for the low values with spring-applied UAN, however, the same pattern occurred in 1975. Soil NO_3-N was equal from all four N sources when fall-applied.

Table 2. Effect of N source and time of application on soil NO_3-N on July 1, 1976.

Treatment[1/] Source	Time	NO_3-N (0-24") lb/A
Anhyd. Am.	F	98
"	S	216
Urea	F	98
"	S	139
Am. Nitrate	F	94
"	S	175
UAN	F	95
"	S	73

[1/] 150 lb N/A

FIVE-YEAR YIELD RESULTS

Yields show no significant differences among the treatments in 1972 and 1976 (Table 3). In both years spring rainfall (April-June) was below average (-2.55" in 1972 and -4.49" in 1976). Consequently, denitrifying conditions apparently did not exist. Rainfall from July thru September was above normal in 1972, resulting in excellent yields. In 1976 dry conditions continued throughout the summer and yields were quite low.

Yields were affected significantly in 1973, 1974 and 1975. Spring rainfall in each of these years totaled 3.20, 0.11 and 2.35 inches above normal, respectively. Fall applications of the ammonium forms of N resulted in yields equal to those from spring applications. The nitrate forms, however, provided a vastly different picture. Spring application of both UAN and ammonium nitrate were far superior to the fall applications. Average yields over that period show approximately a 15 bushel annual advantage for spring application. Equal yields were obtained from all N sources when applied in the spring at the 150-pound rate.

Table 3. Continuous corn yields as influenced by source, rate and time of application of N at Waseca in 1972-1976.

Treatment			Grain Yield						
Source	Rate	Time	1972	1973	1974	1975	1976	1972-76 Avg.	1974-76 Avg.
	lb N/A		bu/A						
Anhyd. Am.	75	F	144.8	145.4	103.3	52.1	62.7	101.7	72.7
(82%)	75	S	142.4	143.2	100.6	53.4	70.4	102.0	74.8
"	150	F	149.7	145.8	111.1	64.1	66.4	107.4	80.5
"	150	S	149.9	146.8	112.3	57.3	78.2	108.9	82.6
Urea	75	F	154.0	136.8	80.4	51.9	61.0	96.8	64.4
(45%)	75	S	160.1	126.8	95.1	52.8	63.6	99.7	70.5
"	150	F	151.9	145.3	112.9	71.7	65.6	109.5	83.4
"	150	S	150.0	144.3	113.0	69.8	72.5	109.9	85.1
Am. Nit.	75	F	153.7	122.7	75.6	34.8	63.8	90.1	58.1
(33%)	75	S	153.2	128.7	96.0	51.4	68.6	99.6	72.0
"	150	F	140.8	137.3	96.8	46.5	69.4	98.2	70.9
"	150	S	147.7	146.0	108.9	64.4	72.5	107.9	81.9
UAN	75	F	--	--	84.0	33.0	53.8	--	56.9
(28%)	75	S	--	--	103.0	51.3	57.3	--	70.5
"	150	F	--	--	103.7	47.8	75.4	--	75.6
"	150	S	--	--	113.0	60.9	67.5	--	80.5
	Significance:		NS	*	**	*	NS		
	CV (%)	:	6.0	7.3	9.3	25.4	21.3		
	BLSD (.05)	:		17.1	13.1	23.3			

CONCLUSION

The proper source and time of N application for greatest N efficiency is highly dependent on the moisture conditions during the early part of the growing season. In years of average to above average spring rainfall, it is apparent that denitrification conditions and subsequent losses of N exist in south-central Minnesota. Therefore, fall applications of nitrate forms (28 and 33%) should not be attempted. Fall application of ammonium forms of N after soil temperatures are below 50°F will minimize losses and improve fertilizer efficiency as well as yields. Equal efficiency among all sources was shown with spring application.

N-SERVE ON CORN

Waseca, 1976

G. W. Randall, G. L. Malzer and H. G. Johnson

Increasing the efficiency of fertilizer N has gained strong support within the last few years due to environmental concern, crop production economics and shortages of natural gas supplies for ammonia production. One of the methods to increase efficiency is to inhibit temporarily the nitrification reaction that converts NH_4^+ (a stable form) to NO_3^- (a mobile form). N-Serve (nitrapyrin), a nitrification inhibitor produced by Dow Chemical Co., is perhaps the most commonly available product at this time. The objective of this study was to evaluate the effect of fall and spring applications of N and N-Serve on soil N fractions and corn production in Southern Minnesota.

EXPERIMENTAL PROCEDURES

The experimental site consisted of a Webster clay loam which is tiled at a 75-foot spacing perpendicular to the plots. Spring wheat had been the previous crop.

Anhydrous ammonia with and without N-Serve was applied with a 6-row tool-bar applicator on September 25, October 25, 1975 and April 27, 1976. The application depth was 6 inches. Nitrogen rates were 90, 120 and 150 lb N/A. The design was a randomized, complete-block with four replications.

Following the October application the site was chisel plowed perpendicular to the plots. The area was field cultivated following the spring application and before planting (May 3). Corn (Dekalb XL-43A) was planted at 26,100 ppa with 140 lb 0-23-30/A applied as a starter. Weeds were controlled with a preemergence application of Lasso (3 qts) plus Bladex (2½ lb).

Soil samples were taken periodically (Table 2) in 0-1 and 1-2' increments from the 0 and 150 lb treatments. The 10/24/75 sampling consisted of taking three 2" cores from 5 to 7 inches to the side of the anhydrous band in each plot. Because the tillage operations obliterated the anhydrous tracks, 8 random cores were taken and composited per plot on the other dates. All replications were sampled.

The leaf opposite and below the ear was sampled at silking and analyzed for N. Barren stalk, lodging and stalk rot readings were taken just prior to harvest. Stalk rot was determined by splitting open 20 stalks per plot. The six internodes and the node above them starting at the soil line were evaluated individually. A scale from 0 (no rot) to 5 (all nodes and internodes severely rotted) was used.

Yields were taken by combine harvesting the center two rows from each plot with a modified JD 3300 combine. Moisture and grain protein were determined on subsamples of harvested grain.

RESULTS

Climatic conditions during the course of this experiment could be summarized as warm and dry (Table 1). Soil and air temperatures were above normal from 9/21 thru 11/10/75. These temperatures should have induced rapid nitrification; however, it was very dry during this period (0.35") and nitrification was probably curtailed somewhat. A total of 4.39" of rain fell in November, but most of it occurred after soil temperatures fell below 50°F.

Table 1. Weather data from late September 1975 thru July 1976 at Waseca.

Period	Avg. Air Temp.	Precip.	Avg. 4 & 8" Soil Temp.	1965-74 Avg. 4 & 8" Soil Temp.
	°F	in.	°F	
9/21 - 9/30/75	50.7	.14	58.1	55.3
10/1 - 10	54.9	.09	59.9	52.2
11 - 20	51.0	.00	58.9	46.4
21 - 31	46.0	.12	52.1	42.5
11/1 - 10	50.6	1.77	52.4	35.7
11 - 20	39.0	1.27	42.4	
21 - 30	19.4	1.35	35.8	
4/1 - 4/10/76	46.1	.16	40.8	
11 - 20	56.1	.98	51.3	
21 - 31	47.3	.65	49.5	
5/1 - 10	49.6	.01	52.8	
11 - 20	58.8	.58	59.6	
21 - 31	60.8	1.67	64.1	
6/1 - 10	70.8	.36	71.3	
11 - 20	67.6	.76	72.9	
21 - 30	66.4	1.43	71.3	
7/1 - 10	71.4	.00		
11 - 20	73.2	1.24		
21 - 31	73.5	1.41		

Dry conditions prevailed throughout the 1976 growing season. Consequently, conditions for large denitrification losses of N did not exist. Soil temperatures warmed above 50°F about May 1.

Soil NH_4-and NO_3-N values were quite inconsistent (Table 2). This may have been due primarily to the random sampling technique used. Samples taken from the top foot on 10/24 indicated that N-Serve was stabilizing the N applied one month earlier (9/25) as NH_4 (26.3 ppm compared to 12.3 ppm without N-Serve). By April 26 the NH_4-N values were almost identical, which would indicate that the early fall-applied ammonia had nitrified by this time. On the other hand, soil NO_3-N was lower with N-Serve indicating incomplete nitrification. Samples taken on May 20 and June 16 from this early fall treatment again show N stabilization with N-Serve (27.0 and 14.3 ppm with and 12.6 and 6.6 without N-Serve, respectively).

Table 2. Effect of N-Serve on soil NH_4-and NO_3-N at Waseca in 1976.

Treatment[1]				Sampling date			
Applc'n date	N-Serve	Depth	10/24/75	4/26/76	5/20/76	6/16/76	7/13/76
				NH_4-N (ppm)			
Check		0-1'	13.2	3.8	3.8	6.4	5.1
9/25/75	-	"	12.3	13.3	12.6	6.6	7.7
"	+	"	26.3	14.2	27.0	14.3	7.4
10/25/75	-	"		10.6	8.2	6.9	6.3
"	+	"		9.4	9.1	7.4	7.0
4/27/76	-	"			68.0	17.4	8.7
"	+	"			81.7	27.7	12.7
Check		1-2'	8.2	2.5	2.6		
9/25/76	-	"	10.2	3.1	2.6		
"	+	"	11.2	2.9	3.0		
10/25/76	-	"		3.1	3.0		
"	+	"		2.5	2.9		
4/27/76	-	"			2.9		
"	+	"			7.3		
				NO_3-N (ppm)			
Check		0-1'	7.0	9.0	11.6	7.1	2.6
9/25/75	-	"	11.0	40.7	60.2	37.3	27.8
"	+	"	9.2	26.7	48.4	48.4	15.5
10/25/75	-	"		30.9	44.8	48.3	14.5
"	+	"		20.6	38.6	33.0	8.9
4/27/76	-	"			28.7	65.0	48.9
"	+	"			34.3	53.0	30.1
Check		1-2'	1.0	3.9	4.0	4.5	2.2
9/25/75	-	"	1.4	13.0	14.8	12.5	8.8
"	+	"	1.0	10.2	11.3	13.6	11.2
10/25/75	-	"		9.0	6.9	8.3	9.8
"	+	"		6.2	6.3	8.3	3.4
4/27/76	-	"			4.1	7.5	3.6
"	+	"			5.0	6.1	5.6

[1] 150 lb N/A as anhydrous ammonia; 0.5 lb (ai) N-Serve/A

Soil N data from the October 25 application show little effect of N-Serve. No detectable differences can be seen in the NH_4-N data; whereas, soil NO_3-N was lower throughout the 1976 season with N-Serve.

Spring-applied ammonia with N-Serve resulted in consistently higher soil NH_4-N levels and lower soil NO_3-N in June and July than without N-Serve. This would indicate that with the dry conditions complete nitrification was delayed well into the growing season.

Samples taken from the 1-2' depth indicates very little movement of NH_4^+ or NO_3^- from the surface layer. No detectable differences between the N-Serve treatments can be found in samples from this depth.

The inconsistencies described above make accurate interpretation of the soil N data almost impossible. It points out the need for more detailed, spatial sampling at shorter time intervals in future studies.

Leaf and grain N, yield and moisture, were affected by the treatments in 1976 (Table 3). Leaf N was significantly increased by N-Serve. Application date and rate had no effect on leaf N. Grain N (protein) was increased significantly over the check by all the N treatments. Highest protein was associated with 150 lb N rate and the spring application. N-Serve did not influence protein. No explanation can be given for the lower values associated with the October 25 application.

Grain yield differences among the treatments were significant; however, the main effects of application date, rate and N-Serve were not significant. A date X rate interaction was shown and is partially attributed to the low yields with the 150-lb rate with N-Serve in April. Early growth of these plants was stunted and showed effects of ammonium toxicity. Plants on the 150-lb spring applied treatment without N-Serve did not show the toxicity effect. Grain moisture was reduced by the high N rates.

Table 3. Effect of N-Serve on corn production at Waseca in 1976.

Treatment			Leaf	Grain		
Date	Rate	N-Serve[1]	N	N	Moisture	Yield
	lb N/A			------%-------		bu/A
	Control		1.69	1.28	22.2	109.3
9/25/75	90	-	2.00	1.59	21.0	126.0
	"	+	2.27	1.61	20.3	112.9
	120	-	2.39	1.58	20.0	129.8
	"	+	2.34	1.58	20.4	135.9
	150	-	2.10	1.70	18.4	102.0
	"	+	2.42	1.63	19.3	128.4
10/25/75	90	-	2.02	1.52	21.1	127.0
	"	+	2.26	1.49	20.2	116.9
	120	-	2.08	1.59	19.8	114.4
	"	+	2.19	1.59	19.0	109.1
	150	-	2.26	1.53	19.4	127.2
	"	+	2.26	1.60	20.2	125.8
4/27/76	90	-	2.10	1.62	20.6	120.3
	"	+	2.53	1.54	19.8	127.4
	120	-	2.35	1.65	19.9	117.8
	"	+	2.34	1.61	20.4	140.0
	150	-	2.21	1.66	20.1	122.4
	"	+	2.20	1.70	19.2	107.8
	Signif:		+	**	**	*
	CV (%):		13.1	5.3	4.2	11.3
	BLSD(.10):		0.48	-	1.1	20.4
	(.05):			0.12	1.3	24.4

Individual Factors

	Leaf N	Grain N	Moisture	Yield
Date				
9/75	2.26	1.61	19.9	122.5
10/75	2.18	1.55	19.9	120.1
4/76	2.27	1.63	20.0	122.6
Signif:	NS	**	NS	NS
BLSD(.05):		0.05		
Rate				
90	2.20	1.56	20.5	121.7
120	2.28	1.60	19.9	124.5
150	2.24	1.63	19.4	118.9
Signif:	NS	**	**	NS
BLSD(.05):		0.05	0.5	
N-Serve				
-	2.17	1.60	20.0	120.8
+	2.31	1.59	19.8	122.7
Signif:	*	NS	NS	NS
Interactions				
Date X Rate	NS	NS	*	*
Date X N-Serve	NS	NS	NS	NS
Rate X N-Serve	NS	NS	+	NS
Date X Rate X N-Serve	NS	NS	NS	*
Signif (DxR) and (DxRxN-S): .05 =			0.9	15.3

[1] N-Serve applied at 0.5 lb ai/acre

Table 4. Effect of N-Serve on corn plant characteristics and plant population at Waseca in 1976.

Treatment Date	 Rate	 N-Serve[1/]	Barren stalks	 Lodging	Stalk rot[2/] reading	 Pop'ln
	lb N/A		--------%--------			ppa X 1000
	Control		0.5	0.8	0.68	25.0
9/25/75	90	-	0.2	3.0	1.09	25.0
	"	+	0.0	4.6	1.20	26.3
	120	-	0.2	1.3		24.7
	"	+	0.0	1.8		24.5
	150	-	0.0	6.0		25.9
	"	+	0.8	4.0		25.2
10/25/75	90	-	0.0	3.5	0.87	25.1
	"	+	0.2	4.5	1.25	25.0
	120	-	0.2	5.8		26.2
	"	+	0.5	6.1		25.0
	150	-	0.5	4.6		25.3
	"	+	0.2	2.8		25.5
4/27/76	90	-	0.2	3.8	1.10	25.0
	"	+	0.2	2.4	1.27	25.8
	120	-	0.8	3.1		25.0
	"	+	0.2	2.0		25.0
	150	-	0.2	4.5		25.2
	"	+	0.2	6.8		25.7
	Signif:		NS	NS	NS	NS
	CV (%):		209.	75.	35.8	3.1

[1/] N-Serve applied at 0.5 lb ai/acre

[2/] 0 = no rot, 5 = severe rot in nodes and internodes

Barren stalks, lodging, stalk rot and final plant population were not affected by the treatments (Table 4). The incidence of stalk rot was very low especially on the check plots.

SUMMARY

Even though the soil N data was inconsistent it was apparent that N-Serve did inhibit nitrification under these conditions. Additional, spatial sampling would have been necessary to determine the length of the inhibitory effect.

In this dry year when denitrification conditions did not exist, N-Serve did not influence grain yield, protein or stalk rot.

NITRIFICATION INHIBITOR (TERRAZOLE) APPLICATION FOR CORN PRODUCTION IN SOUTHERN MINNESOTA

G. L. Malzer and G. W. Randall

Field experiments were conducted in 1975 and 1976 to investigate the potential of an experimental chemical (Terrazole - Registered trademark of the Olin corporation) for use as a nitrification inhibitor. The objectives were to measure the influence of different levels of terrazole at several nitrogen rates and acertain with the use of soil analysis, plant tissue analysis, and crop response (corn) the effectiveness of Terrazole as a nitrification inhibitor.

EXPERIMENTAL PROCEDURES

Thirteen treatments including a check, three rates of nitrogen (60, 120, and 180 #N/A as urea), and four levels of Terrazole (0, .25, .50) and 1.0% by weight of fertilizer) were applied in all combinations. The thirteen treatments were established in a randomized complete block design with five replications. Poor geographic position forced a shifting in the plot layout. Due to this, three replications had a previous cropping history of corn and two replications had a previous cropping history of soybeans. Considerable variation in crop growth was found in 1976 due to cropping history so data included in this report will make reference to both cropping histories as well as overall observations. The experimental area was on a recently tiled Nicollet loam on the Southern Experiment station at Waseca, MN.

All nitrogen fertilizer treatments were applied as spring applications of urea preplant and incorporated (4/25/76). Corn (Pioneer 3780) was planted on May 4 at a population of 26,000 ppa. Starter fertilizer was applied at the rate of 180 #/A of 0-23-30. Good weed control was accomplished with the use of preemergence applications of Lasso (3 lbs/A) and Atrazine (2 1/2 lbs/A). Insecticide was also applied as 1 lb. of Furadan/A.

Tissue samples including the leaf opposite and below the ear at silking, as well as silage samples were analyzed for Kjeldahl nitrogen content. Silage dry matter yields were determined by harvesting 10 ft. of row from each plot and grain yields determined by harvesting two 20 ft. rows. Measurements concerning various other growth parameters such as smut, barren stalks, and lodging were also recorded. The effectiveness of the nitrification inhibitor in slowing the nitrification reaction was evaluated by the analysis of soil samples for ammonium-N and nitrate-N at two different times during the season. Soil samples were taken from each plot on 8/10/76 (silking) and 10/18/76 (after harvest) to a depth of 24 inches. The samples were divided into increments 0-6" and 6-24" with all samples being analyzed for nitrate-N and the 0-6" sample being analyzed for ammonium-N.

RESULTS

The nitrogen content of the leaf opposite and below the ear at silking and the grain yields are presented in Table 1. Nitrogen rate significantly increased nitrogen content of the leaf under both previous cropping histories as well as overall. Nitrogen content in the leaves on the corn following corn area was substantially lower than on the corn following soybean area. The highest level (1.0%) of Terrazole did reduce the leaf nitrogen content on the corn following soybeans but had no influence on the corn following corn or overall.

Considerable grain yield differentials were observed on the corn following corn vs. the corn following soybeans. Across all treatments their was a 72 bu/A reduction in yield with corn following corn as compared to corn following soybeans. Most of this differential does not appear to be treatment related. Nitrogen rate regardless of cropping history had no influence on grain yield. The highest Terrazole level did significantly reduce yields on the corn following soybeans and this was also reflected overall.

Silage dry matter yields (Table 2) were also markedly affected by previous cropping history with dry matter yields averaging 2.3 T/A less on the corn following corn area. Aside from one treatment there was no influence due to nitrogen rate or Terrazole level. The silage nitrogen content was also not significantly influenced by treatments other than the control comparisons. Even with the substantial differences between the previous corn and soybean areas as far as yield and dry matter production there was very little difference in nitrogen content between silage treatments.

Other growth parameters such as smut, barren stalks, and lodging in most cases were not influenced by treatments. Here again previous crop did appear to have an influence.

Soil ammonium and soil nitrate concentrations (Table 4) in the surface 6 inches when collected on 8/10/76 were significantly influenced by the treatments. Increasing nitrogen rates significantly increased both ammonium and nitrate concentration in the surface 6 inches. Increasing Terrazole concentrations significantly increased soil ammonium concentration and at the same time significantly decreased the soil nitrate concentration within the same layer. Therefore, suggesting that the Terrazole was effective in inhibiting the nitrification reaction.

Soil ammonium and soil nitrate concentrations measured on 10/18/76 (Table 5) also detected significant influences due to the treatments. The inhibitor was still effective in delaying the nitrification reaction late into the season (6 months). The effectiveness of the inhibitor coupled with the dry weather experienced in 1976 might suggest that much of the ammonium nitrogen and possibly nitrate nitrogen was positionally unavailable to the plant rooting system.

Soil nitrate concentration in the 6-24 inch depth (Table 6) were low suggesting that the plants were effective in the removal of NO^{-3}-N from this depth. The interaction of nitrification inhibitors with dry soil and environmental conditions and its implications on nitrogen availability remain to be investigated.

Table 1. Leaf N content and corn grain yields (15.5% moisture) as influenced by rate of nitrogen application (urea) and nitrification inhibitor coating (Terrazole) following corn and soybeans.

Treatment N Rate	 Terrazole Coating	Leaf N f/soybeans	 f/corn	 overall	Grain Yield f/soybeans	 f/corn	 overall
lbs N/A	%		-% -			-bu/A-	
control		1.62	1.61	1.61	105.0	27.3	58.4
60	0	2.05	1.84	1.92	119.6	32.8	67.5
60	.25	2.08	1.79	1.91	94.6	29.9	55.8
60	.50	2.24	1.76	1.96	113.4	32.3	64.7
60	1.00	2.03	1.83	1.91	105.9	28.3	59.3
120	0	2.23	1.98	2.08	117.8	34.1	67.6
120	.25	2.18	1.95	2.04	118.4	28.7	64.6
120	.50	2.06	1.97	2.01	90.3	19.6	47.9
120	1.00	1.97	1.83	1.89	80.8	34.7	53.1
180	0	2.30	1.99	2.11	131.2	41.5	77.4
180	.25	2.25	2.04	2.13	102.5	45.7	68.4
180	.50	2.20	1.92	2.03	111.1	34.7	65.4
180	1.00	2.10	2.00	2.04	73.9	33.3	49.5
	Signif.	**	*	**	+	NS	NS
	BLSD (.05)	.23	.20	.14	30.8 (.10)	-	-
	C.V.	4.9	5.8	5.7	14.7	44.0	25.1

Factorial - Excludes checks

N Rate	60 #N/A	2.10	1.81	1.92	108.4	30.9	61.9
	120	2.11	1.93	2.00	101.8	29.3	58.3
	180	2.21	1.99	2.08	104.7	38.8	65.1
	Signif.	+	*	**	NS	NS	NS
	BLSD	0.21 (.10)	0.09	.07	-	-	-
Terrazole level	0%	2.19	1.93	2.04	122.9	36.2	70.8
	.25	2.17	1.93	2.03	105.1	34.8	62.9
	.50	2.17	1.89	2.00	104.9	28.9	59.3
	1.00	2.03	1.89	1.95	86.8	32.1	54.0
	Signif.	+	NS	NS	*	NS	*
	BLSD	0.12 (.10)	-	-	20.6	-	12.7
NXT	Signif.	NS	NS	NS	NS	NS	NS
	BLSD	-	-	-	-	-	-
	C.V.	4.8	5.7	5.4	15.0	44.3	25.7

Table 2. Silage yields and nitrogen content of silage as influenced by rate of nitrogen application (urea) and nitrification inhibitor coating (Terrazole) following corn and soybeans.

Treatment		Silage Yield			Silage N Content		
N Rate	Terrazole Coating	f/soybeans	f/corn	overall	f/soybeans	f/corn	overall
lbs N/A	%	----------Ton/A-----------			------------%-------------		
control		6.56	3.83	4.92	1.00	.69	.81
60	0	4.94	4.47	4.66	1.02	.97	.99
60	.25	6.30	4.33	5.12	.89	.95	.92
60	.50	6.98	4.19	5.31	.92	.92	.92
120	1.00	7.64	4.22	5.58	1.02	1.22	1.14
120	0	7.23	4.74	5.73	.92	1.07	1.01
120	.25	6.80	4.00	5.12	.97	1.05	1.02
120	.50	6.74	3.90	5.04	1.09	1.16	1.13
180	1.00	4.34	4.01	4.14	1.07	1.00	1.03
180	0	8.01	4.57	5.94	1.01	1.06	1.04
180	.25	7.29	4.70	5.73	1.09	1.10	1.10
180	.50	6.33	4.35	5.14	1.09	1.06	1.07
180	1.00	5.94	4.33	4.97	1.13	1.11	1.12
	Signif.	+	NS	+	NS	NS	**
	BLSD	2.41 (.10)	-	1.15 (.10)	-	-	0.21
	C.V.	14.6	12.1	15.6	13.7	20.1	17.3

Factional - Excludes Checks

N Rate	60 #N/A	6.46	4.30	5.17	.96	1.01	.99
	120	6.28	4.16	5.01	1.01	1.07	1.05
	180	6.89	4.49	5.45	1.08	1.08	1.08
	Signif.	NS	NS	NS	NS	NS	NS
	BLSD	-	-	-	-	-	-
Terrazole Level	0%	6.73	4.59	5.45	.98	1.03	1.01
	.25	6.79	4.34	5.32	.98	1.03	1.01
	.50	6.68	4.15	5.16	1.03	1.05	1.04
	1.00	5.97	4.19	4.90	1.07	1.11	1.09
	Signif.	NS	NS	NS	NS	NS	NS
	BLSD	-	-	-	-	-	-
NXT	Signif.	*	NS	*	NS	NS	NS
	BLSD	2.43	-	1.28	-	-	-
	C.V.	15.2	12.2	16.0	11.1	20.6	16.4

Table 3. Various growth parameters related to the rate of nitrogen application and nitrification inhibitor coating (Terrazole) following corn and soybeans.

Treatment		Smut			Barren stalks			
N Rate	Coating	f/soybeans	f/corn	overall	f/soybeans	f/corn	overall	Lodging
lbs N/A	%				%			
Control		4.6	20.4	15.5	1.7	5.0	4.1	0.2
60	0	8.0	28.9	20.6	0.5	4.9	3.2	0.4
60	.25	10.2	25.1	19.1	1.0	4.3	3.0	0.0
60	.50	1.4	25.9	16.1	1.4	5.2	3.7	0.6
60	1.00	2.8	27.3	17.5	2.8	4.6	3.9	0.4
120	0	5.4	26.0	17.8	0.5	6.9	4.4	0.2
120	.25	2.9	32.6	20.7	2.0	8.3	5.8	1.0
120	.50	14.5	32.5	25.3	3.4	7.6	5.9	0.2
120	1.00	17.5	29.6	27.2	0.0	6.4	5.1	0.8
180	0	3.5	33.6	21.6	1.0	7.9	4.9	0.6
180	.25	9.6	22.7	17.5	1.9	3.3	2.7	0.8
180	.50	7.5	24.4	17.6	1.0	5.4	3.6	0.6
180	1.00	17.2	26.2	22.6	2.0	4.5	3.5	0.4
	Signif.	NS	NS	NS	NS	NS	NS	NS
	BLSD (.05)	-	-	-	-	-	-	-
	C.V.	77.3	26.5	37.6	82.0	35.9	45.9	151.9

Factorial - Excludes Check

		Smut f/soybeans	Smut f/corn	Smut overall	Barren stalks f/soybeans	Barren stalks f/corn	Barren stalks overall	Lodging
N Rate	60 #N/A	5.7	26.8	18.3	1.6	4.8	3.5	0.4
	120	12.2	29.8	22.8	2.2	7.4	5.3	0.6
	180	9.5	26.7	19.8	1.4	5.3	3.7	0.6
	Signif.	NS	NS	NS	NS	*	**	NS
	BLSD (.05)	-	-	-	-	1.6	1.2	-
Terrazole	0%	5.7	29.5	20.0	0.5	6.6	4.2	.4
Level	.25	7.6	26.8	19.1	1.6	5.3	3.8	.6
	.50	7.8	27.6	19.7	2.1	6.1	4.5	.5
	1.00	15.3	27.2	22.4	2.5	5.3	4.2	.5
	Signif.	NS	NS	NS	NS	NS	NS	NS
	BLSD (.05)	-	-	-	-	-	-	-
N X T	Signif.	NS	NS	NS	NS	NS	NS	NS
	BLSD	-	-	-	-	-	-	-
	C.V.	76.5	58.7	38.3	85.0	36.3	46.3	14.8

Table 4. Influence of nitrogen rate and nitrification inhibitor concentration (Terrazole) on soil ammonium and soil nitrate concentration in the 0-6" depth taken 8/10/76

Treatment

N	Terrazole	Soil Ammonium 0-6"			Soil Nitrates 0-6"		
Rate	Coating	f/soybeans	f/corn	overall	f/soybean	f/corn	overall
lbs N/A	%	----------ppm------------			-----------ppm-----------		
control		6.9	6.9	6.9	5.4	4.2	4.7
60	0	9.0	9.2	9.1	20.5	14.6	16.9
60	.25	8.6	10.7	9.9	19.7	5.6	11.2
60	.50	13.2	13.8	13.6	14.5	5.5	9.1
60	1.00	10.7	11.1	10.9	9.4	3.5	5.8
120	0	9.8	15.2	13.0	24.9	46.2	37.7
120	.25	14.9	15.5	15.3	21.4	8.7	13.8
120	.50	12.0	21.9	17.9	14.3	8.5	10.8
120	1.00	20.5	21.0	20.8	9.8	5.8	7.4
180	0	13.8	7.8	10.2	54.4	63.1	59.6
180	.25	16.7	27.5	23.2	24.4	18.6	20.9
180	.50	22.1	34.1	29.3	14.1	15.8	15.1
180	1.00	49.5	47.4	48.2	21.0	8.6	13.5
	Signif.	*	+	**	**	**	**
	BLSD (.05)	22.7	25.3 (.10)	14.6	18.7	16.3	11.5
	C.V.	56.3	76.0	64.7	41.1	62.7	56.1

Factorial - Excludes Checks

N Rate	60 #N/A	10.4	11.2	10.9	16.0	7.3	10.8
	120	14.3	18.4	16.8	17.6	17.3	17.4
	180	25.5	29.2	27.7	28.4	26.5	27.3
	Signif.	*	*	**	*	**	**
	BLSD	10.6	8.9	7.1	9.5	8.6	6.0
Terrazole Level	0%	10.8	10.7	10.8	33.2	41.3	38.1
	.25	13.4	17.9	16.1	21.8	11.0	15.3
	.50	15.8	23.3	20.3	14.3	10.0	11.7
	1.00	26.9	26.5	26.6	13.4	5.9	8.9
	Signif.	+	NS	**	**	**	**
	BLSD	11.0 (.10)	-	8.8	10.6	9.5	6.8
NXT	Signif.	NS	NS	*	NS	*	**
	BLSD	-	-	18.0	-	11.8	13.8
	C.V.	56.2	75.4	64.4	40.2	62.2	55.1

Table 5. Influence of N Rate and nitrification inhibitor concentration (Terrazole) on soil ammonium and soil nitrate concentration in the 0-6" depth on 10/18/76

Treatment		Soil Ammonium 0-6"			Soil Nitrates 0-6"		
N Rate	Terrazole Coating	f/soybeans	f/corn	overall	f/soybeans	f/corn	overall
lbs N/A	%						
control		9.6	12.9	11.6	8.3	6.5	7.2
60	0	13.2	11.1	11.9	23.7	21.1	22.2
60	.25	12.5	12.5	12.5	14.6	13.5	13.9
60	.50	15.1	12.7	13.6	23.8	10.9	16.0
60	1.00	14.1	15.5	15.0	17.5	9.8	12.8
120	0	13.1	11.2	11.9	23.3	25.3	24.5
120	.25	13.0	18.2	16.1	35.7	20.6	26.6
120	.50	14.9	15.1	15.0	35.0	20.8	26.5
120	1.00	27.2	21.3	23.6	10.7	12.8	12.0
180	0	13.8	19.3	17.1	21.1	43.4	34.5
180	.25	31.5	18.5	23.7	50.8	23.6	34.5
180	.50	35.7	15.5	23.6	20.6	15.2	17.3
180	1.00	30.0	26.3	27.8	21.6	13.7	16.7
	Signif.	*	**	**	*	*	**
	BLSD (.05)	15.5	7.5	7.8	22.9	22.6	15.6
	C.V.	36.6	25.2	34.8	38.8	59.4	53.8

Factorial - Excludes Checks

		f/soybeans	f/corn	overall	f/soybeans	f/corn	overall
N Rate	60 #N/A	13.7	12.9	13.3	19.9	13.8	16.2
	120	17.0	16.4	16.7	26.2	19.9	22.4
	180	27.8	19.9	23.0	28.4	24.0	25.8
	Signif.	**	**	**	NS	NS	*
	BLSD	7.8	3.1	3.6	-	-	7.7
Terrazole Level	0%	13.4	13.9	13.7	22.7	29.9	27.0
	.25	19.0	16.4	17.4	33.7	19.2	25.0
	.50	21.9	14.4	17.4	26.4	15.6	20.0
	1.00	23.8	21.0	22.1	16.5	12.1	13.9
	Signif.	NS	**	**	+	*	*
	BLSD	-	3.7	4.5	11.1 (.10)	11.5	8.7
NXT	Signif.	NS	NS	NS	*	NS	NS
	BLSD	-	-	-	20.3	-	-
	C.V.	36.7	23.6	34.1	38.0	58.5	53.0

Table 6. Influence of N rate and nitrification inhibitor concentration (Terrazole) on soil nitrate concentration in the 6-24" depth on 8/10/76 and 10/18/76

Treatment		8/10/76			10/18/76		
N Rate	Terrazole Coating	Soil Nitrates 6-24" f/soybeans	f/corn	overall	Soil Nitrates 6-24" f/soybeans	f/corn	overall
lbs N/A	%	ppm			ppm		
Control		1.7	0.9	1.2	2.3	1.5	1.8
60	0	10.4	4.3	6.7	2.9	3.1	3.0
60	.25	3.7	3.0	3.3	3.2	2.4	2.7
60	.50	2.4	1.9	2.1	2.6	1.9	2.2
60	1.00	2.4	1.7	2.0	3.2	2.2	2.6
120	0	3.1	4.6	4.0	3.9	3.8	3.8
120	.25	11.9	3.0	6.6	3.3	3.5	3.4
120	.50	5.6	4.4	4.9	4.2	3.8	4.0
120	1.00	3.4	2.4	2.8	3.3	2.8	3.0
180	0	6.5	4.5	5.3	6.0	4.6	5.1
180	.25	13.8	4.0	7.9	5.4	3.1	4.0
180	.50	3.0	3.1	3.1	2.7	2.9	2.8
180	1.00	13.0	2.5	6.7	5.5	2.4	3.7
	Signif.	NS	*	NS	NS	**	**
	BLSD (.05)	-	2.5	-	-	1.3	1.3
	C.V.	86.0	40.8	83,2	34.0	24.3	30.0

Factorial - Excludes checks

N rate	60 #N/A	4.7	2.7	3.5	2.9	2.4	2.6
	120	6.0	3.6	4.6	3.7	3.5	3.5
	180	9.1	3.5	5.7	4.9	3.3	3.9
	Signif.	NS	NS	NS	*	**	**
	BLSD	-	-	-	1.5	0.6	0.6
Terrazole Level	0%	6.6	4.5	5.3	4.2	3.8	4.0
	.25	9.8	3.3	5.9	4.0	3.0	3.4
	.50	3.7	3.1	3.4	3.1	2.9	3.0
	1.00	6.3	2.2	3.8	4.0	2.5	3.1
	Signif.	NS	*	NS	NS	**	*
	BLSD	-	1.3	-	-	0.7	0.8
N X T	Signif.	NS	NS	NS	NS	NS	NS
	BLSD	-	-	-	-	-	-
	C.V.	84.0	39.8	81.3	34.5	24.1	29.5

FOLIAR FERTILIZATION OF CORN

Waseca, 1976

G. W. Randall and G. L. Malzer

Foliar fertilization has become a popular topic since the release of Iowa State data which showed up to a 45% yield increase in 1975 with foliar-applied NPKS to soybeans late in their growing season. The objective of this study was to determine if corn would respond to these NPKS materials when applied to the foliage late in the growing season.

EXPERIMENTAL PROCEDURES

Soil-applied fertilizer consisted of 150 lb N/A (anhydrous ammonia) in April, 1976 and 0+60+100 (lb N+P_2O_5+K_2O/A) broadcast and plowed down in October, 1975. Soybeans were the previous crop. Corn (Pioneer 3780) was planted on May 3 at 26000 ppa in 30" rows. Weeds were chemically controlled.

Foliar fertilizer with a N-P_2O_5-K_2O-S ratio of 10.1-5.0-2.5-0.4 was applied at a rate of 26 gal/acre (250 lb/A) with a High-Boy sprayer. Application rates totaled 25.2+12.5+6.2+1.0 lb N+P_2O_5+K_2O+S/A per application. Tween 80, a surfactant, was mixed with the solution at a 0.1% v/v rate. The three application dates were 8/13, 8/20 and 9/1. Four hours after the 8/13 application, 0.08" of rain fell. On 8/20 and again on 9/1 a double rate (52 gpa) was applied on a 4-row strip adjacent to the trial.

Yields were obtained from the six replicates by hand harvesting 40 feet of row from each plot. Moisture, test weight and nutrient analyses were determined on center-sections from the ears.

RESULTS

Grain yield, moisture and test weight were not affected by the foliar treatments (Table 1). The hot and dry conditions during late August and early September resulted in severe stress and early maturation of the corn. Perhaps this was the major factor limiting response. Yields were not taken from the 52 gpa treatment because it was not replicated.

Table 1. Influence of foliar-applied NPKS on corn production at Waseca in 1976.

Treatment		Grain		
Times	Dates	Moisture	Yield	Test Wt.
		%	bu/A	lb/bu
0	Check	23.3	131.2	55.2
1	8/13	22.3	135.9	54.7
2	8/13, 8/20	22.1	125.4	55.7
3	8/13, 8/20, 9/1	21.9	133.9	55.0
	Significance:	NS	NS	NS
	CV (%) :	12.1	7.5	1.8

Only slight burning of the leaf margins was noticed when applying this material at the 26 gpa rate. Moderate to severe burning of the leaf tissue was observed when the 52 gpa rate was used.

Although trends for P and K were positive, grain N, P, K, Mg, Fe and Zn concentrations were not affected by the foliar treatments (Table 2). N removal (% N in grain times grain yield/A) was not altered by the treatments. Protein levels were high for all treatments.

Table 2. Influence of foliar-applied NPKS on nutrient concentrations and N removal in corn grain at Waseca in 1976.

Treatment		Grain						N removal
Times	Dates	N	P	K	Mg	Fe	Zn	
		--------	%	---------		--ppm--		lb/bu
0	Check	1.79	.30	.35	.13	29	28	110.5
1	8/13	1.73	.31	.38	.14	29	29	111.4
2	8/13, 8/20	1.79	.32	.37	.14	26	28	106.0
3	8/13, 8/20, 9/1	1.78	.33	.39	.14	29	30	113.0
	Significance:	NS	NS	NS	NS	NS	NS	NS
	CV (%) :	4.0	11.5	9.1	7.2	9.3	8.5	8.9

NON-CONVENTIONAL SOIL ADDITIVES AND FERTILIZERS APPLIED TO CORN

Waseca, 1976

G. W. Randall

Fertilizer shortages and higher fertilizer prices over the last few years have brought a number of new "non-conventional" products onto the market. In many cases, they are sold as a replacement to conventional fertilizers and in some cases are even purported to be superior.

Research results from various universities throughout the U. S. generally show no benefit from many of these materials. Because of the numerous products, crops, soils and environmental conditions, only a few of these combinations have been tested. Therefore, the objective of this study was to evaluate three of these products in combination with NPK fertilizer on continuous corn grown in south-central Minnesota.

EXPERIMENTAL PROCEDURES

A randomized, complete-block experiment involving four replications and four treatments (Table 1) was established in the spring of 1975 on a Webster clay loam. Soil pH, P and K values were 5.8, 48 and 230, respectively. These P and K levels were considered to be high.

SOL-EZ, advertised as a material for compacted, wet, gumbo-like soils, and Medina, advertised as a soil activator, were applied to the soil surface with a bicycle sprayer in May 1975. Immediately following the application, the experimental area was disked and field cultivated. Pioneer 3780 corn was planted at 25,800 seeds/acre in both years. Starter fertilizer consisting of 150 lb 9-23-30/A was used. Anhydrous ammonia was applied at a rate of 180 lb N/A previous to planting. Weeds were chemically controlled with preemergence application of 3 lb Lasso + 2½ lb Bladex/A. Rootworms were controlled with 1 lb Furadan/A. Medina was applied to the soil surface again in 1976 at a rate of 1 gal/A on June 16.

Bayfolan, advertised as a foliar fertilizer, was applied to the corn foliage two times -- the 7th and 14th-leaf growth stages. Each time Bayfolan (9-6-5, $N+P_2O_5+K_2O$) was diluted at a rate of 2 qt/100 gal. water and applied at that rate/acre with a three-gallon, stainless steel, hand sprayer in 1976. Precipitation did not occur within 48 hours after application.

Tissue samples consisting of the leaf opposite and below the ear were taken at silking. Grain yields and moisture were determined by combine harvesting the two center rows from each plot. Grain samples along with the leaf samples were submitted for analysis by emission spectroscopy and Kjeldahl methods.

RESULTS AND DISCUSSION

The addition of Medina or SOL-EZ to the soil or Bayfolan to the corn foliage did not result in yields or grain moisture different from the NPK only treatment in either year (Table 1). In addition, these materials did not alter nutrient concentrations in either the leaf tissue or in the grain (Table 2). Protein levels in the grain were not affected.

CONCLUSION

Results from two consecutive years indicate no advantage for applying SOL-EZ, Medina or Bayfolan to improve corn yields over those from conventional NPK fertilizer on a Webster clay loam in south-central Minnesota.

Table 1. Effect of some non-conventional soil additives and fertilizers on corn yields at Waseca.

		Moisture		Yield	
Treatment[1/]	Rate	1975	1976	1975	1976
	/A	---- %	----	-- bu/A	---
NPK Only	--	22.4	21.7	99.5	116.0
NPK + SOL-EZ	2 oz.[2/]	21.5	21.6	99.4	108.8
NPK + Medina	1 gal.	21.8	21.2	97.2	116.9
NPK + Bayfolan	2 qt. + 2 qt.[3/]	22.3	21.7	99.9	106.8
	Significance:	NS	NS	NS	NS
	CV (%) :	2.8	2.4	10.9	13.2

[1/] All treatments received 190 + 32 + 42 lb $N+P_2O_5+K_2O$/A.

[2/] Residual from 1975 application.

[3/] Two applications on 6/16 and 7/5 at the 7 and 14-leaf stages, respectively.

Table 2. Influence of some non-conventional soil additives and fertilizers on the nutrient concentrations in corn leaves and grain at Waseca in 1976.

Treatment	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
					Leaf[1]					
NPK only	2.08	.22	1.85	.84	.70	180	56	38	10.6	9.1
NPK + SOL-EZ	2.07	.22	2.00	.84	.67	180	67	36	9.6	8.9
NPK + Medina	2.05	.21	1.96	.88	.68	167	66	41	11.6	8.0
NPK + Bayfolan	2.08	.20	1.81	.85	.67	152	54	37	9.4	9.0
Significance:	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
BLSD (.05) :									1.6	
CV (%) :	5.2	8.6	10.7	5.6	8.8	10.7	21.0	15.6	9.3	18.4
					Grain					
NPK only	1.76	.25	.32	[2]	.13	[2]	[2]	24.	[2]	[2]
NPK + SOL-EZ	1.74	.25	.34		.13			25.		
NPK + Medina	1.78	.28	.36		.14			27.		
NPK + Bayfolan	1.83	.25	.32		.13			25.		
Significance:	NS	NS	NS		NS			NS		
CV (%) :	3.5	10.3	8.0		10.1			9.4		

[1] Leaf opposite and below the ear at silking

[2] Below detection limits

CORN - SOYBEAN TILLAGE

Waseca, 1976

G. W. Randall

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

Fall primary tillage operations were conducted October 22, 1975. The spring primary tillage treatments were performed on April 16 and the secondary treatments on the date of planting.

Broadcast P and K (40+80 lb $P_2O_5+K_2O$/A) were applied in October, 1975. Nitrogen (150 lb N/A as ammonium nitrate) was broadcast on April 15 to the corn area.

Corn (Pioneer 3710) was planted at a rate of 25,000 ppA on April 30. A John Deere Max Emerge planter with 2" fluted coulters was used to plant the plots which did not receive primary tillage. For those plots which did receive primary tillage, the fluted coulters were removed. Starter fertilizer was not applied. Chemical weed control consisted of 3 lbs. Lasso/A and 2½ lbs. Bladex/A applied preemergence. Surface residue did not prevent cultivation in 1976, therefore, each treatment was cultivated once. Yields were obtained by combine harvesting two center rows from each plot.

Soybeans (Corsoy) were planted at a rate of 8.6 beans/foot of row on May 11. The planter and procedures used were the same as those described above for corn. Weeds were controlled with 3 lbs. Lasso/A and 2½ lbs. Amiben/A. All treatments received one cultivation. Yields were obtained by combine harvesting four center rows from each plot.

EXPERIMENTAL TREATMENTS

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

Table 1. Tillage treatments in the corn-soybean rotation tillage study at Waseca in 1976.

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

RESULTS: CORN

Differences in seedbed condition at planting were again noticed in 1976. The best seedbed resulted from either the fall chisel, field cultivate, spring disk or fall plow treatments. Here the soil was moist, firm, easy to work and provided a good seed-soil contact. Large clods were not present. Seedbed condition with the other primary tillage treatments ranked no tillage> spring chisel> spring moldboard plow. Large clods resulted from the latter treatment.

The aforementioned seedbed conditions had a pronounced influence on germination and subsequent seedling emergence and early growth as shown in Table 2. Emergence and early plant growth were slowest with the continuous spring moldboard and chisel plow treatments (no. 6 and 9). Rapid emergence and plant growth were obtained with the fall plow and fall chisel treatments (no. 2, 3 and 12).

Early plant growth differences were not significant (90 percent level) because of the high variability. This variability caused by uneven emergence under dry conditions is shown by the percent of small plants on June 14. Most uniform emergence occurred with fall moldboard or chisel plowing, fall field cultivating, spring disking or no tillage only when following soybeans. Emergence was most uneven with spring plowing or chiseling with up to 33% being delayed two leaf stages or more in growth.

Final population was lowest with the no tillage and spring moldboard plow treatments (Table 2). Lodging at harvest was minimal and was not affected by tillage treatment. Grain moisture was lowest when no tillage followed soybeans and was highest with spring moldboard plowing.

Table 2. Influence of tillage methods following soybeans on corn production at Waseca in 1976.

Tillage Treatment			Emergence	Early plant	Small[1]	Final	Lodging	Moisture at	Yield	
No.	Primary	Secondary	date	growth	plants	popl'n		harvest	1976	1974-76
			May	g/plant	%	x 1000	%	%	--- bu/A	----
1	NONE	NONE	20	7.0	17	20.0	0	22.4	112.7	104.5
2	Fall plow	f. cult.	17	8.0	8	23.9	.6	22.4	146.9	126.7
3	Fall chisel	" "	18	9.5	9	24.5	0	22.3	144.4	129.8
4	Spr. "	" "	20	6.6	24	23.6	0	21.8	130.5	118.1
5	Zero	Zero	19	6.8	14	23.1	.3	20.8	143.3	128.4
6	Spr. plow	f. cult.	22	6.2	33	21.9	.6	23.8	125.8	113.1
7	Fall chisel	" "	18	7.2	12	24.7	.5	21.6	138.2	121.7
8	Zero	Zero	20	8.0	13	22.0	0	21.4	125.7	120.0
9	Spr. chisel	disk	22	6.0	29	22.7	.6	22.5	130.5	119.0
10	Spr. disk	"	19	7.6	11	23.5	0	21.0	139.5	129.5
11	Fall f. cult.	f. cult.	18	7.1	10	24.0	.2	22.6	148.6	129.8
12	Fall plow	" "	18	9.2	11	23.7	.8	22.6	140.9	126.8
	Significance:[2]			ns	**	**	ns	**	**	
	BLSD (.05) :				7	0.8		1.4	21.2	
	CV (%) :			24.1	31.2	2.7	204.	4.1	9.4	

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[1] Percentage of plants that were delayed two leaf stages or more in growth from the average on June 14.

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

Yields (Table 2) for 1976 were reduced significantly by the continuous no tillage, spring moldboard and spring chisel plow treatments (no. 1, 6 and 9) and by the spring chisel-fall plow system (no. 4). Highest yields were obtained with the fall field cultivate-fall chisel, fall chisel-fall plow, fall plow-fall disk and the continuous fall plow systems (no. 11, 3, 12 and 2). Yields from the two systems without primary tillage following soybeans (no. 5 and 8) were above average when following moldboard plowing of corn but below average when following chiseling of corn; a pattern similar to 1974. These yield differences indicate the importance of a seedbed with adequate moisture in the seed contact zone following planting. In a year characterized by dry conditions immediately following planting, primary tillage systems that tended to dry the soil or leave a cloddy seedbed resulted in poorest yields; while those systems with minimum tillage (spring disk, fall field cultivate, fall chisel and zero tillage) provided excellent yields. Yield was not correlated with early plant growth, however (r = +.032).

Highest three-year yield averages were found with the continuous fall plow and spring disk systems and the fall chisel-fall plow, zero-fall plow, fall field cultivate-fall chisel and fall plow-fall disk systems (no. 2, 10, 3, 5, 11 and 12). Lowest yields resulted from continuous no tillage and spring plow systems. Primary reasons thought to contribute to these lower yields were lack of good weed control (perennial grasses) and poor seedbed with the former treatment and only a poor seedbed with the latter treatment.

Leaf samples taken at the silking stage show significant effects of the tillage treatments on plant K, Ca and Mg (Table 3). Plant K was highest following either continuous fall or spring moldboard plowing or the fall chisel-fall plow system. The very low K level with the no tillage-fall plow treatment (no. 5) is not explainable; especially since this treatment has resulted in higher K levels in previous years. The interaction between K and both Ca and Mg was very evident. Other nutrients were not affected by the tillage treatments but were considered to be adequate for optimum plant growth.

Table 3. Influence of tillage methods following soybeans on nutrient concentrations in the corn earleaf at Waseca in 1976.

Treatment			Nutrient								
No.	Primary	Secondary	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			%				ppm				
1	NONE	NONE	.31	1.78	.80	.52	420	65	36	8.2	16
2	Fall plow	f. cult.	.30	2.01	.67	.46	385	59	30	7.0	15
3	Fall chisel	" "	.32	2.09	.68	.43	375	55	30	7.4	15
4	Spr. "	" "	.32	1.76	.82	.56	410	68	29	8.4	17
5	Zero	Zero	.32	1.40	.84	.59	400	71	32	7.4	15
6	Spr. plow	f. cult.	.30	2.06	.66	.44	355	65	32	7.9	15
7	Fall chisel	" "	.31	1.71	.79	.57	380	59	28	7.8	14
8	Zero	Zero	.30	1.55	.83	.61	375	63	31	8.0	15
9	Spr. chisel	disk	.31	1.49	.85	.67	390	70	30	8.0	16
10	Spr. disk	"	.31	1.63	.75	.54	405	55	32	7.4	14
11	Fall f. cult.	f. cult.	.30	1.62	.74	.54	365	58	31	6.8	14
12	Fall plow	" "	.31	1.84	.73	.45	390	63	34	7.2	15
		Significance:	NS	**	*	**	NS	NS	NS	+	NS
		BLSD (.05) :		.38	.15	.14					
		CV (%) :	6.3	13.7	11.2	16.3	11.8	19.3	12.5	9.3	10.0

Average 4-inch soil temperatures were obtained via thermocouples from three continuous tillage systems: fall plow, fall chisel and no tillage. Temperatures were read daily over a seven-week period (Table 4).

Table 4. Average soil temperature at 4 inches and surface residue accumulation as influenced by three continuous tillage methods for a corn-soybean rotation at Waseca in 1976.

	CORN following Soybeans			SOYBEANS following Corn		
Period	Fall plow f. cult.	Fall chisel f. cult.	No tillage	Fall plow f. cult.	Fall chisel f. cult.	No tillage
	°F					
5/1 - 7	52.8	52.2	53.1			
5/8 -14	59.2	58.7	59.3			
5/15-21	61.7	60.9	61.7	62.8	61.8	59.5
5/22-28	64.6	63.9	64.9	65.1	64.0	62.0
5/29-6/4	68.5	68.2	68.6	68.0	67.1	65.8
6/5 -11	76.2	75.5	76.6	76.5	75.6	74.0
6/12-18				72.4	71.7	70.7
Average	63.5	62.9	63.7	69.4	68.6	66.9
	Tons Dry Matter/A					
	Trace	Trace	Trace	Trace	1.2	4.0

Soil temperature differences averaged less than 0.9° difference among the tillage treatments for corn. This small difference would be expected with only trace amounts of soybean residue on the surface.

For soybeans, the soil temperature differences among the treatments were significantly larger. Temperature of the chiseled and no tillage areas averaged 0.8°F and 2.5°F cooler, respectively, over the seven-week period than with moldboard plowing. This would be expected due to the accumulation of corn residues on the soil surface. These residues averaged trace, 1.2 and 4.0 tons DM/A for the plow, chisel and no tillage treatments, respectively. Even though these residue accumulations were significant and soil temperatures were cooler, early soybean plant growth differences were not visually noticed among these three treatments.

RESULTS: SOYBEANS

Emergence date was delayed from 4 to 6 days with the spring chisel and spring plow treatments (Table 5). Earliest emergence occurred with the fall moldboard plow and fall disk treatments. The seedbed conditions were very similar to those discussed in the corn section and were undoubtedly responsible for the emergence differences. Soybean plant population was not affected by the tillage treatments.

Table 5. Influence of tillage methods following corn on soybean production at Waseca in 1976.

Treatment			Emergence		Early [1] plant	Yield	
No.	Primary	Secondary	date	Popl'n	growth	1976	1973-76
			May	beans/ft	g/plant	----bu/A----	
1	NONE	NONE	25	8.0		29.2	36.1
2	Fall plow	f. cult.	24	8.6		41.5	43.0
3	" "	" "	24	8.6		43.0	44.4
4	" "	" "	25	8.6		40.7	42.3
5	" "	" "	24	8.6		42.4	43.0
6	Spr. plow	disk & f. cult.	30	7.7		44.1	42.7
7	Fall chisel	disk	25	8.0		36.7	41.0
8	" "	"	26	8.4		38.0	41.9
9	Spr. chisel	"	28	8.1		36.2	41.3
10	Spr. disk	"	25	8.4		40.8	42.6
11	Fall chisel	f. cult.	26	8.6		39.1	42.7
12	Fall disk	disk	24	8.8		40.4	42.6
		Significance:		ns		**	
		BLSD (.05) :				3.8	
		CV (%) :		6.1		6.9	

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[1] Early plant growth samples were not taken in 1976 because of Banvel drift which caused early growth irregularities.

Soybean yields were highest with spring and fall moldboard plowing and spring and fall disking of the corn stalks (Table 5). Intermediate yields were obtained with the fall and spring chisel systems. The continuous no tillage treatment resulted in significantly lower yields than all other treatments. This was due primarily to poor weed control, especially perennial weeds and grasses. The preemergence herbicides apparently were deactivated or intercepted by the surface residues so that grass control was minimal. Volunteer corn was not a problem in any of the tillage treatments in 1975.

Four-year yield average from the continuous no tillage treatment was significantly lower than the average yields from all other treatments. Again, this was primarily due to lack of weed control. No yield differences were observed among the other 11 treatments.

Nutrient concentrations in the uppermost, fully mature trifoliate leaf sampled at the early bloom stage generally were not affected by the tillage treatments (Table 6). However, K concentrations were affected significantly and were generally higher with the moldboard plow systems (no. 2, 3, 4 and 6) and were lowest with those systems that provided very little incorporation (chiseling, disking and no tillage).

Table 6. Influence of tillage methods following corn on nutrient concentrations in the soybean leaf at early bloom stage at Waseca in 1976.

Treatment			Nutrient								
No.	Primary	Secondary	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			-------- %			---------	--------ppm				--------
1	NONE	NONE	.41	2.03	1.38	.54	200	45	40	8	48
2	Fall plow	f. cult.	.39	2.36	1.29	.49	205	44	42	8	47
3	" "	" "	.40	2.30	1.33	.50	210	42	42	8	46
4	" "	" "	.39	2.22	1.38	.51	230	45	42	7	48
5	" "	" "	.39	2.17	1.36	.51	225	48	42	8	46
6	Spr. plow	f. cult/disk	.40	2.39	1.37	.52	200	44	40	7	42
7	Fall chisel	disk	.40	2.18	1.40	.53	210	44	41	8	48
8	" "	"	.41	2.06	1.46	.56	220	48	42	8	47
9	Spr. chisel	"	.40	1.98	1.32	.54	205	42	40	7	45
10	Spr. disk	"	.40	1.97	1.47	.58	215	44	42	9	45
11	Fall chisel	f. cult.	.40	2.14	1.43	.56	215	48	42	8	48
12	Fall disk	disk	.40	2.00	1.40	.54	206	44	43	8	44
	Significance:		NS	**	NS	NS	NS	NS	NS	NS	
	BLSD (.05) :			.22							
	CV (%) :		5.	7.	8.	8.	8.	10.	5.	10.	8.

Soil moisture (gravimetric basis) was determined in 1-foot increments to a depth of four feet from four of the continuous tillage systems on April 15, 1976 (Table 7). Significant differences among the treatments were found following both soybeans and corn. After both crops soil moisture was highest with no tillage. Fall chiseling resulted in lowest moisture following soybeans; whereas, fall moldboard plowing showed the least moisture after corn. The spring disk treatments had not been done yet on April 15; consequently, soil moisture levels were similar to no tillage. Soil moisture following soybeans ranged from 1.3 to 4.0% higher than following corn.

Table 7. Soil moisture on April 15, 1976, at Waseca as influenced by tillage following soybeans and corn.

Depth	No tillage(1)	Fall plow(2)	Fall chisel(7)	Spr. disk(10)
	% H_2O			
feet		following soybeans in 1975		
0-1	36.4	33.8	33.3	33.1
1-2	30.7	31.2	29.3	31.0
2-3	29.4	25.7	25.0	28.2
3-4	28.9	26.5	24.5	29.4
Avg.	31.3	29.3	28.0	30.4

Signif: Tillage = * BLSD(.05)= 2.1 CV = 9.2
Depth = ** " = 1.8

Depth	No tillage(1)	Fall plow(2)	Fall chisel(7)	Spr. disk(10)
		following corn in 1975		
0-1	34.0	31.2	31.1	32.4
1-2	28.3	26.0	26.7	27.1
2-3	24.7	22.6	25.0	25.2
3-4	22.8	21.4	24.0	24.5
Avg.	27.5	25.3	26.7	27.3

Signif: Tillage = + BLSD(.10)= 1.5 CV = 6.5
Depth = ** BLSD(.05)= 1.1

CONSERVATION TILLAGE STUDY

Waseca, 1976

G. W. Randall and J. B. Swan

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

EXPERIMENTAL PROCEDURES

To evaluate some of these conservation tillage practices on continuous corn an experiment was established in 1975 on a Webster clay loam at the Southern Experiment Station. Five tillage treatments (Table 1) were replicated four times. Each plot was 20' wide by 125' long. Tile lines spaced 75' apart lie perpendicular to the rows within all plots.

Ridges were built along the corn rows for the till-plant (Ridge) treatment by cultivation in June, 1975. After harvest the stalks were chopped and the moldboard and chisel plow operations were performed in early November. On May 3 the moldboard and chisel plow plots were field cultivated once.

Corn (Pioneer 3780) was planted at a rate of 26,000 ppA on May 3. A John Deere planter equipped with 2" fluted coulters was used for the no-tillage treatment. The fluted coulters were removed for the plow and chisel treatments. A Buffalo till planter was used for the till-plant treatments.

Broadcast P and K were applied at a rate of 0+40+80 (lb $N+P_2O_5+K_2O/A$) in October, 1975. Nitrogen (175 lb N/A as ammonium nitrate) was broadcast on April 15. Starter fertilizer (13+32+42 lb $N+P_2O_5+K_2O/A$) and an insecticide (1 lb Furadan/A) were applied to all plots at planting. Chemical weed control consisted of 3 lb Lasso and 2½ lb atrazine/A applied preemergence. Weed control was excellent in all treatments. Treatments 2, 3 and 4 were cultivated in mid-June, 1976. Yields were taken by combine harvesting four rows from each plot.

RESULTS

Significant differences in final population and yield were found among the five treatments (Table 1). Due primarily to a shallow planting depth (1¼-1½"), the till planted plots had about 20 percent fewer plants than those plots planted with the John Deere Max-Emerge planter. Following planting a rainfall event greater than 0.27" did not occur for 25 days. This allowed some of the more shallow seeds as well as those that were not pressed as firmly by the Buffalo till planter press wheel to dry out shortly after they began to germinate. This 20% population reduction illustrates how important proper seeding depth and seed-soil contact is in obtaining good stands.

Table 1. Influence of tillage methods on continuous corn production at Waseca in 1976.

Treatment	Lodging	Barren stalks	Final popl'n	Grain		1975-76 Avg. Yield
				Moist.	Yield	
	%	%	x 1000	%	-----bu/A-----	
No tillage (Fluted Coult.)	0.9	1.1	21.7	14.8	76.3	74.6
Fall plow, f. cult.	1.4	1.6	23.3	15.8	93.3	95.6
Fall chisel, "	1.1	1.0	23.3	15.5	82.0	75.7
Till plant (Ridge)	1.2	1.0	17.5	16.0	92.6	98.7
" " (No Ridge)	0.9	0.2	18.2	14.8	92.0	101.4
Significance:	NS	NS	**	NS	*	
BLSD (.05) :			1.9		14.7	
CV (%) :	139.	85.	6.3	5.6	9.8	

Yields in 1976 were similar to those obtained in 1975. Lowest yields resulted from the no tillage and fall chisel treatments. At harvest, kernel depth was considerably less from these treatments. Perhaps a disking before field cultivation of the fall chisel treatment would improve the performance of this treatment. We can speculate on this based on data obtained in another continuous corn tillage study from 1970-74. Yields among the fall moldboard plow, till plant (ridge) and till plant (no ridge) treatments were highest and were not significantly different from each other. Lodging, barren stalks and grain moisture were not affected by the tillage treatments. With the exception of late-May and a short period in late-June soil moisture was inadequate throughout the season. In a year of adequate moisture with normal or below normal spring temperatures, results between the till plant ridge vs no ridge treatments would be expected to favor the ridged treatment, which exposes a raised strip of bare soil for earlier warming and drying. On the poorly drained, heavy Webster and associated soils of south-central Minnesota, where cold, wet soil conditions prevail in the spring, ridging would be recommended when the till plant system is used.

Emergence date was only slightly affected by tillage (Table 2). Earliest emergence occurred with the moldboard plow and chisel treatments while the till planted corn without a ridge was latest. Small plant growth differences were not statistically significant because of the variability. A significant correlation between small plant growth and grain yield was not found (r=-.283).

Table 2. Influence of tillage methods for continuous corn on emergence, small plant growth and surface residue accumulation at Waseca in 1976.

Treatment	Emergence date	Small plant growth	Surface residue
	May	g/plant	T DM/A
No tillage (Fluted Coult.)	19	8.7	3.3
Fall plow, f. cult.	18	8.6	Trace
Fall chisel, "	18	8.2	1.6
Till plant (Ridge)	19	8.6	1.7
Till plant (No Ridge)	20	6.2	1.7
Significance:		NS	
CV (%) :		22.9	

Surface residue from the preceding corn crop showed an accumulation of approximately 3 tons dry matter per acre after planting with the no tillage system (Table 2). Chiseling and till planting incorporated approximately 50 of the residue.

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

Table 3. Soil temperature (4" average) as influenced by tillage practices at Waseca in 1976.

	Preplant			Post Plant					
Tillage Treatment	4/13 -16	4/17 -23	4/24 -30	5/8 -14	5/15 -21	5/22 -28	5/29 -6/4	6/5 -11	6/12 -18
					°F				
No Tillage	51.8	50.6	49.5	57.9	60.7	63.5	67.2	74.7	70.4
Fall Plow	55.2	52.1	52.1	59.4	62.5	65.3	68.3	76.3	71.2
Fall Chisel				58.0	61.1	63.8	67.4	74.6	70.4
Till Plant (R)	53.6	51.0	50.5	58.6	62.2	64.8	68.3	75.8	71.3
Till Plant (NR)				57.3	60.4	63.2	67.0	74.5	70.2

After planting soil temperatures continued to remain highest with moldboard plowing. However, temperatures in the till planted plots equalled temperatures in the moldboard plots within two weeks. Fall chiseling, till planting without a ridge and no tillage showed very consistent, slightly cooler temperatures for the six-week period following planting.

Soil moisture samples were taken in one-foot increments from all plots on April 15, 1976, before any spring tillage. Slight differences in percent water on a gravimetric basis were shown among the treatments (Table 4). Soil moisture was highest with the fall plow treatment and lowest with the till plant, no ridge treatment. A possible explanation for this difference could lie in the fact that the greatest yields occurred from the till plant (NR) system in 1975. As a result less soil moisture was left as indicated by the lower moisture contents, especially at the 2-3 and 3-4 foot depths. Run-off of fall precipitation was not observed on any plots.

Table 4. Soil moisture on April 15, 1976, at Waseca as influenced by tillage practice.

	Tillage Treatment					
	No	Fall	Fall	Till Plant		
Depth	tillage	plow	chisel	ridge	no ridge	Avg.
feet	%					
0-1	33.4	34.0	32.1	32.4	32.8	33.0
1-2	27.8	28.6	26.9	27.5	26.4	27.5
2-3	28.0	28.8	27.0	26.6	25.6	27.2
3-4	29.8	29.8	27.9	29.4	26.6	28.7
Avg.	29.7	30.3	28.4	28.9	27.8	

Significance:	(Tillage)	+
	(Depth)	**
	(Tillage x Depth IA)	NS
BLSD(.10):	(Tillage)	1.6
CV(%):		7.2

Soil moisture samples were not taken after planting, but one could assume that larger amounts of moisture were lost with secondary tillage on the plow and chisel treatments than with the till plant or no tillage systems. As a result soil moisture differences among the five treatments may have been very small following planting.

Earleaf samples were taken at silking stage. Nutrient concentrations generally were not affected by the tillage systems and were considered sufficient for optimum plant growth (Table 5). Even though K was not influenced statistically, a trend toward lower plant K with the till plant systems was evident and resulted in slightly higher Mg concentrations (90% level).

Table 5. Influence of tillage methods for continuous corn on the nutrient concentrations in the earleaf at Waseca in 1976.

Treatment			Nutrient									
No	Primary	Secondary	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			%					ppm				
1	No Tillage	(Fluted Coulter)	2.43	.27	2.32	.92	.46	158	46	33	6.6	12
2	Fall Plow,	f. cult.	2.59	.26	2.36	.90	.40	156	55	35	7.2	10
3	Fall Chisel,	"	2.55	.27	2.34	.91	.42	152	55	34	6.9	12
4	Till Plant	(Ridge)	2.58	.28	2.19	.99	.50	158	47	29	6.6	11
5	Till Plant	(No Ridge)	2.59	.26	2.20	.93	.50	145	53	33	7.4	11
		Significance:	NS	NS	NS	NS	+	NS	NS	NS	NS	+
		BLSD (.10) :					.08					1.7
		CV (%) :	5.	12.	10.	7.	11.	8.	16.	24.	15.	11.

RIDGE CULTIVATION IN SOYBEANS

Waseca, 1976

G. W. Randall

In the past few years interest has increased dramatically in till-plant systems for corn. On the heavy, poorly drained soils it is quite desirable to have ridges prepared in the row the previous year so that corn can be planted on these ridges. The advantages of the ridges are early spring warming and drying to facilitate early planting. In continuous corn these ridges can be prepared easily at cultivation. The purpose of this study was to determine the effect of building ridges at cultivation on the production of soybeans.

EXPERIMENTAL PROCEDURES

Hodgson soybeans were planted in 30-inch rows on a Nicollet clay loam on May 12. Weed control with Treflan plus Amiben was excellent. In each of the three replications 8 rows were ridged and 8 rows were not ridged nor cultivated. The ridges were prepared with a Buffalo disk-hilling cultivator on July 6. Since weed control was excellent the only purpose of the cultivation was to build the ridges. Four rows from each plot were combined harvested with a JD 3300 combine.

RESULTS

Soybean production was affected significantly by the ridging treatment (Table 1). Plant height above the soil was reduced somewhat because the soil ridge was built up around the stem. This resulted in the lowest pod being only 2.5 inches from the soil surface compared to 4 inches without ridging. Yield was reduced by 3.0 bu/A with ridging and could be accounted largely by the increase in harvest loss.

Table 1. Effect of ridging on soybean production at Waseca in 1976.

Treatment	Plant height	Pod[1/] height	Yield	Harvest loss
	-----inches-----		------bu/A------	
No ridge	29	4.0	36.7	1.8
Ridge	26	2.5	33.7	3.9
Significance:	+	*	+	NS
CV (%) :	3.8	9.7	2.8	37.4

[1/] Distance from ground to lowest pod.

SUMMARY

These data indicate that ridging of soybeans in preparation for corn the following year would not be recommended. Soybean yield loss due to low pod height and harvest loss could be substantial. If ridging is needed, it should be attempted after harvest.

N-SERVE ON SOYBEANS

Waseca, 1976

G. W. Randall

Results from past years reported by Ham and Randall in the bluebook have shown soybean yield increases with spring N fertilization. Generally, the response has been with urea, an ammonium form of N. The objective of this study was to evaluate N-Serve applied with anhydrous ammonia in early summer on soybean production. The hypothesis was that because spring-applied urea was beneficial perhaps early summer applied NH_3 either with or without an inhibitor may also be beneficial.

EXPERIMENTAL PROCEDURES

Hodgson soybeans were planted in 30" rows on a Webster clay loam on May 15. On July 6, 100 lb N/A as anhydrous ammonia was applied with N-Serve at rates of 0 and 0.5 lb/A. The six-row plots were replicated four times. Four center rows were combine harvested to determine yields.

RESULTS

Neither plant height at maturity nor seed yield were influenced by the N or N-Serve (Table 1). The plants were short and the yields somewhat limited, primarily because of the dry conditions during the year.

Table 1. Effect of early summer applied N and N-Serve on soybean production at Waseca in 1976.

Treatment		Plant height	Seed yield
N rate	N-Serve rate		
--------lb/A---------		inches	bu/A
0	0	28	37.4
100	0	27	37.4
100	0.5	28	37.2
Significance:		NS	NS
CV (%)	:	3.5	3.9

NITROGEN FERTILIZATION OF SPRING WHEAT IN SOUTH-CENTRAL MINNESOTA

Waseca, 1976

G. W. Randall and W. E. Lueschen

Experiments were established at the Southern Experiment Station to determine the nitrogen (N) needs of spring wheat following two crops -- corn and soybeans grown in 1975. The soil types were a Webster clay loam and a LeSueur clay loam following corn and soybeans, respectively. Treatments of 0, 25, 50, 75 and 100 lb N/A were replicated four times at each site. Nitrogen was applied as ammonium nitrate and disked in on April 8. Two semidwarf varieties, Era and Kitt, were planted on April 9. A seeding rate of 100 lb/A was used with both varieties. Broadleaf weeds were controlled with Bromoxynil + MPCA (¼ + ¼ lb/A) applied on May 20. Yields were taken by harvesting a 10 x 50-foot area from each plot with a JD 3300 combine modified with expanded augers and an electronic weigh-cell system.

Soil samples (0-6") were taken prior to treatment application from each rep. Soil P and K averaged 39 and 260 lb/A following corn and 69 and 410 lb/A following soybeans, respectively. Fertilizer P and K (0+35+45 lb N+P_2O_5+K_2O/A) was applied prior to N application. Soils from the check plots were sampled in 0-12", 0-24" and 0-36" cores on April 9 and May 28 and NO_3-N analyses were conducted. At the late boot stage, leaf samples were taken for total N analyses. Grain samples were taken at harvest and analyzed for protein.

RESULTS AND DISCUSSION

Regardless of the previous crop wheat yields were not affected by N fertilization in 1976 (Tables 1 and 2). Perhaps this was due partly to the dry conditions between planting and harvest. In addition, leaf analyses indicated more than adequate amounts of N in the tissue when no fertilizer N was added. Era outyielded Kitt in both trials, however, the difference wasn't significant when the previous crop was soybeans.

Although protein levels in the wheat were high without fertilizer N, they were increased significantly by N fertilizer in both trials. At least 50 lb N/A was needed to optimize the protein level when following soybeans with slightly more N needed when following corn. However, all protein levels were above the discount level (14%) except Era without N following corn. Kitt contained 1.1 - 1.2% more protein than Era.

Table 1. Influence of N on yield, protein, N removal and leaf N of spring wheat following corn.

N rate	Yield		Protein		N removal		Leaf N	
	Era	Kitt	Era	Kitt	Era	Kitt	Era	Kitt
lb/A	bu/A		%		lb N/A		%	
0	49.9	44.0	14.5	15.6	63.0	60.2	4.43	4.54
25	54.6	47.4	14.8	15.9	70.6	65.7	4.53	4.52
50	54.7	47.0	15.5	17.0	74.1	69.8	4.51	4.60
75	56.4	45.0	16.1	16.8	79.1	65.9	4.58	4.63
100	54.0	43.6	16.4	18.1	77.4	69.0	4.68	4.43
Variety Avg.	53.9	45.4	15.5	16.7	72.8	66.1	4.55	4.55
N Avg.								
0	47.0		15.1		61.6		4.48	
25	51.0		15.4		68.2		4.53	
50	50.9		16.3		72.0		4.56	
75	50.7		16.4		72.5		4.60	
100	48.8		17.2		73.2		4.56	
Significance:								
Variety	**		**		*		NS	
N rate	NS		**		**		NS	
VxN IA	NS		NS		NS		NS	
BLSD(N).05:	--		0.8		6.2		--	
CV (%):	7.4		5.8		8.5		3.4	

Nitrogen (protein) removal following both corn and soybeans was increased significantly with 25 and 50 lb N/A, respectively. Era following corn removed more N because of its higher yield. No difference existed between the two varieties when following soybeans.

Efficiency of the fertilizer N, obtained by subtracting the N removed by the check from that removed by the fertilized wheat and then dividing this difference by the amount of N applied, was very low in both trials. Highest efficiency was only 26 and 18% following corn and soybeans, respectively. Efficiency ranged from 5 to 14% at the 75 and 100 lb rates and was lower when the preceding crop was soybeans rather than corn.

Table 2. Influence of N on yield, protein, N removal and leaf N of spring wheat following soybeans.

	Yield		Protein		N removal		Leaf N	
N rate	Era	Kitt	Era	Kitt	Era	Kitt	Era	Kitt
lb/A	bu/A		%		lb N/A		%	
0	74.4	71.3	13.9	15.6	90.3	97.3	4.34	4.65
25	73.1	69.5	14.4	15.2	91.7	92.0	4.54	4.85
50	77.3	73.6	15.2	16.0	102.8	102.8	4.71	4.84
75	73.9	70.0	15.2	16.0	98.0	97.8	4.68	4.91
100	76.6	69.4	15.4	16.6	103.2	99.9	4.79	4.82
Variety Avg.	75.1	70.8	14.8	15.9	97.2	98.0	4.61	4.81
N Avg.								
0	72.8		14.8		93.8		4.49	
25	71.3		14.8		91.8		4.70	
50	75.5		15.6		102.8		4.77	
75	72.0		15.6		97.9		4.79	
100	73.0		16.0		101.6		4.80	
Significance:								
Variety	NS		+		NS		NS	
N rate	NS		**		**		+	
VxN IA	NS		NS		NS		NS	
BLSD(N).05:	--		0.8		5.2		--	
CV (%):	4.4		4.8		5.2		5.2	

Nitrogen in the leaf tissue at the boot stage was not increased by fertilizer N when following corn and only increased at the 90% level when following soybeans. Varietal difference did not exist. Leaf N concentrations were considered sufficient for optimum yields.

Interactions between variety and N rate were not found for any of the above parameters.

Data from the two trials can't be compared on an absolute basis. However, on a relative basis wheat following soybeans yielded greater, had a lower protein content and showed higher N removal than wheat following corn.

Results from the nitrate soil tests obtained prior to treatment application showed NO_3-N values of 55 and 62 lb/A following corn and soybeans, respectively. Basing N recommendations for western Minnesota on these values would have resulted in a recommendation of 70 lb N/A; considerably higher than the optimum rate in 1976.

Samples taken on April 9 indicate large amounts of NO_3-N in the 0-36" profile (Table 3). In fact, almost 50% of the NO_3-N following soybeans was in the 24-36" layer. This may help explain the lack of response to fertilizer N in this dry year with deeper root penetration. It also points to a problem when samples for NO_3-N analyses and N recommendations are limited to only 0-24" cores.

Table 3. Soil nitrates as influenced by sampling date and past crop.

Sampling depth	April 9 Following Corn	April 9 Following Soybeans	May 28 Following Corn	May 28 Following Soybeans
inches	---------lb NO_3-N in depth sampled---------			
0 - 12	24(5.9)[1/]	46(11.4)	6(1.6)	13(3.2)
0 - 24	55(6.9)	62(7.7)	20(2.4)	34(4.3)
0 - 36	81(6.7)	118(9.8)	56(4.6)	73(6.1)
12 - 24[2/]	31	16	14	21
24 - 36	26	56	36	39

[1/] ppm NO_3-N in profile

[2/] by difference

Soil nitrate levels on May 28 indicate plant removal of NO_3-N throughout the 0-36" profile with substantial removal from the upper two feet. Between May 28 and harvest (early August) one could expect substantial NO_3-N removal below two feet (perhaps to a depth of five feet) especially in a dry year.

LIME PLOTS, WASECA 1976[1]

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

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

CORN

Dolomitic limestone was applied to the continuous corn experiment in spring of 1971. The experiment was relimed in spring of 1975 because the soil pH had not been increased to 6.5, considered to be optimum for crop production on mineral soils. All corn plots received the following cultural practices in 1976:

Fertilizer: 183+82+112 lb/acre of plant nutrients, expressed as N, P_2O_5, K_2O;

Herbicide: Broadcast 3 lb Lasso and 2.5 lb Bladex per acre;

Insecticide: Furadan, 1 lb/A;

Tillage: Moldboard plow in fall;

Pioneer 3780 corn was planted on April 24. Plant population: 24,200 plants/acre. Plots were harvested on October 12.

Extremely dry weather conditions resulted in low corn yield (Table 1). Liming had no effect on the yield or moisture content of corn. Dolomitic limestone treatments of 5 tons per acre and more increased magnesium concentration of 6th leaf from 0.41 to 0.47%, but, also decreased zinc concentration from 50 to 38 ppm, and manganese from 102 to 53 ppm. However, even the lowest concentrations of these two micro-elements fall in the "sufficient" range.

SOYBEANS

The liming experiment with continuous soybeans was established in spring of 1972 and was relimed at the end of 1975 growing season (Nov.17). Soybean plots received the following cultural treatments in 1976:

Fertilizer: 0+50+100 broadcast, November 1975;

Herbicide: 1 qt. Treflan and 5 qts. Amiben;

Tillage: Moldboard plowed, November 1975, after applying lime.

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

Wells soybean variety was planted on May 12 in 30-inch rows. Plant population: 8.5 plants/ft. Plots were harvested on September 23.

Liming had no effect on soybean yield (Table 3). However, the concentration of microelements copper, manganese and boron was decreased by the application of 2.5 tons/acre and more of limestone. Relatively low concentration (6.8 ppm) of copper in trifoliate leaves was found in tissue from check plots. Liming resulted in further decrease of copper concentration in soybean tissue. The concentration of Mn and B, however, were within the limits of the "sufficient" range.

ALFALFA

The liming experiments with alfalfa was established in spring of 1972. Vernal alfalfa was grown for four years. Roundup, a non-selective herbicide, was applied at 1/2 gal/acre in August 1972 to kill quackgrass, perennial weeds and alfalfa. Plot area was plowed in August. Dolomitic limestone was applied on November 17, 1975 and disked in on April 20, 1976. Eptam herbicide was applied at 3 lb/acre rate and Agate alfalfa variety was seeded on April 20 at 16 lb/acre. No fertilizer was applied at establishment. Alfalfa was harvested at mid-bloom stage, on July 12 and August 30.

Relatively low alfalfa yields were harvested in both cuttings (Table 5). Liming had no effect on the yield. The only effect of liming in 1976 was a decrease of zinc concentration of tissue of first cutting alfalfa from 40 ppm to 36 ppm. Copper concentration in alfalfa tissue ranged from 5 to 7 ppm, considered a "deficient" level. Liming had no effect on Cu concentration in tissue.

SUMMARY AND CONCLUSIONS

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

In 1976, crop yields were relatively low due to drought. But in previous years relatively high yields of all three crops have been produced with good cultural practices and proper fertilization. However, liming has not affected crop yields (Table 7).

Concentration of some microelements in plant tissue was reduced by lime applications. This is to be expected, considering the effect of higher soil pH on the availability of manganese and zinc. However, even the highest lime rates did not decrease the concentration of these elements to such extent so as to cause deficiencies.

Since crop yields have been increased by liming in other areas of Minnesota, the lack of response at Waseca, is rather puzzling. It could be due to the relatively shallow depth (3 feet) at which free carbonates occur. Another possibility is that certain benefits of liming are eliminated by the use of fertilizers in these experiments. Liming, for example, is known to increase P and N availability.

Table 1. Yield and moisture content of corn grain, Waseca lime plots, 1976.

Rate of lime tons/acre	Yield bu/acre	Moisture %
0	66[1]	19.3
2.5	71	18.9
5.0	59	19.1
7.5	71	19.0
10.0	62	19.2
Significance	NS	NS
CV, %	15.1	3.8

[1] Average of 6 replications

Table 2. Chemical composition of 6th corn leaf at tasseling, Waseca lime plots, 1976.

Rate of Lime	P	K	Ca	Mg	Al	Fe	Zn	Cu	Mn	B
tons/acre	------% in dry matter--------				---------------ppm in dry matter---------------					
0	0.27	2.10	0.83	0.41a	75	164	50cd	6	102c	17
2.5	0.28	2.15	0.83	0.44b	73	163	46c	5	66b	16
5.0	0.28	2.15	0.85	0.47c	69	167	38b	5	53a	16
7.5	0.27	2.13	0.84	0.48c	67	168	37b	5	51a	15
10.0	0.28	2.04	0.84	0.48c	68	181	32a	5	48a	15
Significance	NS	NS	NS	**	NS	NS	**	NS	**	NS
BLSD (0.05)	-	-	-	0.02	-	-	4	-	8	-
CV, %	7.3	8.3	9.4	6.7	25.0	19.1	16.7	18.6	22.6	19.2

Table 3. Yield soybeans, Waseca lime plots, 1976.

Rate of Lime, tons/acre	Yield, bu/acre
0	32[1]
2.5	30
5.0	29
7.5	31
10.0	33
Significance	NS
CV, %	13.9

[1] Average of 6 replications

Table 4. Chemical composition of soybean trifoliate leaves, Waseca lime plots, 1976.

Rate of Lime	P	K	Ca	Mg	Al	Fe	Zn	Cu	Mn	B
tons/acre	--------% in dry matter------				---------------ppm in dry matter---------------					
0	0.41	2.21	1.12	0.41	92	200	63	6.8c	64c	63b
2.5	0.41	2.29	1.11	0.41	89	194	61	6.1b	50ab	59a
5.0	0.40	2.17	1.13	0.41	83	193	60	6.3bc	51b	59a
7.5	0.41	2.23	1.16	0.43	82	201	58	5.9b	48ab	59a
10.0	0.41	2.15	1.13	0.43	92	202	59	5.2a	46a	58a
Significance	NS	NS	NS	NS	NS	NS	NS	*	**	*
BLSD (0.05)	-	-	-	-	-	-	-	0.5	4	2
CV, %	4.2	6.1	5.4	4.3	16.7	7.0	6.8	12.8	12.2	3.8

Table 5. Yield of alfalfa, Waseca lime plots, 1976.

Rate of lime tons/acre	Hay Yield First Cutting	Hay Yield Second Cutting	Hay Yield Total
	---tons/acre---		
0	1.1[1]	1.0	2.1
2.5	1.1	1.1	2.2
5.0	1.1	1.0	2.1
7.5	1.1	1.1	2.2
10.0	1.1	1.0	2.1
Significance	NS	NS	NS
CV, %	6.2	20.8	12.3

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[1] Average of 6 replications

Table 6. Chemical composition of alfalfa, Waseca lime plots, 1976.

Rate of Lime	P	K	Ca	Mg	Al	Fe	Zn	Cu	Mn	B
tons/acre	-----% in dry matter-------				--------------ppm in dry matter---------------					
					FIRST CUTTING					
0	0.24	1.67	1.93	0.41	882	1078	40b	6	77	50
2.5	0.25	1.58	1.81	0.43	844	1054	36a	7	60	44
5.0	0.25	1.54	1.80	0.42	858	1057	35a	5	57	44
7.5	0.25	1.53	1.81	0.42	830	1034	35a	5	56	43
10.0	0.25	1.56	1.79	0.42	809	1016	34a	6	62	43
Significance	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
BLSD (0.05)	-	-	-	-	-	-	2	-	-	-
CV, %	4.7	11.0	6.4	7.3	20.0	19.4	7.6	31.6	17.6	7.2
					SECOND CUTTING					
0	0.23	1.73	1.37	0.32	700	800	33	6	51	35
2.5	0.23	1.66	1.29	0.35	679	765	29	5	40	31
5.0	0.23	1.58	1.22	0.32	647	713	28	5	36	30
7.5	0.24	1.56	1.28	0.35	674	759	30	5	33	29
10.0	0.23	1.68	1.22	0.32	556	636	31	5	34	28
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV, %	5.8	10.9	15.9	12.5	30.4	29.1	8.7	10.4	30.9	15.7

Table 7. Effect of liming on yields of continuous corn, soybeans and alfalfa, Waseca lime plots.

Rate of Lime tons/acre	Yield Average Corn 1971-1976	 Soybeans 1972-1976	 Alfalfa 1973-1976
	--------- bu/acre	----------	--tons/acre--
0	119	41	3.7
2.5	114	40	3.8
5.0	112	39	3.7
7.5	117	41	3.8
10.0	116	41	3.8
Significance	NS	NS	NS

HIGH PHOSPHORUS AND POTASSIUM RATES FOR CONTINUOUS CORN

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

EXPERIMENTAL PROCEDURES

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

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

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

Treatment numbers 2, 3, 4, 5, 6, 7, 8 were broadcast on cornstalks and plowed down at all locations in the fall of 1975. Phosphorus was applied as CSP (0-46-0) and K as muriate of potash (0-0-60). Starter fertilizer was not used.

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

Table 2. Experimental procedures for the high P and K rate study on continuous corn at the three branch stations in 1976.

Variable	Lamberton	Morris	Waseca
Planting date	4/27	5/6	4/29
Row spacing	30"	30"	30"
Population	23,000	23,000	26,000
Hybrid	Pioneer 3780	DeKalb XL12	Pioneer 3780
Nitrogen rate	100# N	110# N	200# N
Herbicide	2½# Sutan/A +1.5# Bladex(Bdct)	2# Lasso + 2# Bladex/A (Bdct)	3# Lasso + 2.5# Bladex/A (Bdct)
Insecticide	1# Furadan/A	1# Furadan/A	1# Counter/A
Harvest date	10/21	9/22	10/13

RESULTS AND DISCUSSION

Soil samples were taken at the end of the 1976 growing season. After three years of application soil test P was affected significantly by the P treatments at Morris and Waseca (Table 3). Soil test P was more than doubled by the P treatments at Lamberton, however, due to extreme variability these differences were not significant. Soil test K was significantly influenced by the K treatments at Lamberton and Morris for the first time since initiation of the experiment. No differences were noted at Waseca. Soil pH was not influenced by the treatments at any of the locations.

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

Treatment No.	Treatment Description [2/]	pH La	pH Mo	pH Wa	P La	P M_{10}	P M_{50}	P Wa	K La	K Mo	K Wa
	lb $P_2O_5+K_2O$/A				lb/A						
1	0 + 0	5.7	7.5	6.0	36	14	44	29	170	370	230
2	0 + 100	5.6	7.6	5.8	30	17	64	29	245	450	260
3	50 + 100	6.2	7.4	5.6	65	32	90	38	255	415	270
4	100 + 100	5.7	7.6	5.8	49	44	108	51	250	400	275
5	0 + 100	5.9	7.5	5.9	41	28	80	34	235	420	260
6	100 + 0	5.6	7.6	6.0	65	54	131	43	210	360	270
7	100 + 50	5.5	7.6	5.9	59	42	114	40	230	390	250
8	100 + 0	5.9	7.5	5.9	53	43	102	42	210	385	260
9	0 + 0	5.9	7.5	5.9	51	31	86	34	250	390	250
10	0 + 0	5.7	7.6	6.1	38	20	70	32	205	370	270
Significance:[3/]		NS	-	NS	NS	**	**	**	**	**	NS
BLSD (.05)	:		-			11	18	7	25	40	
CV (%)	:	6	-	3	38	25	15	13	9	6	11

[1/] Samples were taken in October before the 1976 treatments were applied.

[2/] Rates applied in fall of 1975 for 1976 crop.

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

Approximately 5-6 weeks after planting, ten plants randomly selected from each plot were measured, harvested, dried and weighed to determine early plant growth. Early plant growth (weight and height) was increased significantly by the P treatments at Morris (Table 4). Early weight at Waseca was affected but the contribution of either P or K to this effect was not easily distinguishable. Neither height nor weight differences were found at Lamberton.

Table 4. Early plant growth characteristics as influenced by high P and K rates at the three experimental sites in 1976.

Treatment		Weight			Height		
No.	Description	La	Mo	Wa	La	Mo	Wa
	lb $P_2O_5+K_2O/A$	g/dry plant			----inches-----		
1	0 + 0	11.0	3.4	10.5	29	18	33
2	0 + 100	10.6	3.5	9.6	29	19	32
3	50 + 100	11.4	4.3	11.4	29	21	34
4	100 + 100	8.8	5.0	11.2	30	22	36
5	0 + 100	10.6	4.7	10.9	29	21	34
6	100 + 0	11.4	4.3	11.3	30	20	32
7	100 + 50	11.5	4.2	13.4	30	20	34
8	100 + 0	10.6	5.0	12.8	29	22	33
9	0 + 0	8.7	3.8	11.2	29	20	32
10	0 + 0	10.9	4.0	10.4	28	20	33
	Significance:	NS	*	*	NS	**	NS
	BLSD (.05) :		1.2	2.6		2	
	CV (%) :	18	16	13	5	6	5

Nutrient concentrations in the small whole plants were significantly affected by the P and K treatments (Table 5). The K treatments resulted in increased K levels and decreased Mg levels at all locations and decreased Ca at Morris. In addition, plant P levels were increased by the P treatments at Morris with concomitant decreases in plant Zn. This interaction was not found at the other locations.

The K treatments resulted in increased K concentrations in the leaf samples with corresponding decreases in Ca and Mg at all locations (Table 6). Leaf P was increased by the P treatments only at Morris. However, significant decreases in leaf Zn were associated with P additions at all locations. Concentrations of nutrients in the leaf tissue were considered to be adequate at all locations.

Table 5. Effect of high P and K rates on the nutrient concentrations in the small whole plants at the three experimental sites in 1976.

Treatment No.	Treatment Description	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb P_2O_5+K_2O/A	--------	%	--------		-------	ppm	-------		
					Lamberton					
1	0 + 0	.36	3.36	.60	.66	475	72	51	6	8
2	0 + 100	.38	4.72	.54	.51	510	80	45	9	9
3	50 + 100	.38	4.15	.61	.58	460	70	40	9	9
4	100 + 100	.38	4.63	.54	.57	500	66	40	8	8
5	0 + 100	.37	4.28	.57	.63	455	72	44	7	8
6	100 + 0	.38	3.69	.53	.64	465	73	47	7	8
7	100 + 50	.36	4.20	.58	.54	415	80	46	7	8
8	100 + 0	.35	3.57	.57	.71	480	63	40	7	8
9	0 + 0	.34	3.84	.63	.63	445	69	38	7	7
10	0 + 0	.35	3.96	.58	.56	470	73	44	7	9
	Significance:	NS	**	NS	**	NS	NS	NS	NS	NS
	BLSD (.05) :		.45		.13					
	CV (%) :	8	8	13	11	18	14	16	14	14
					Morris					
1	0 + 0	.40	3.18	.61	.83	325	73	56	11	9
2	0 + 100	.40	4.12	.51	.66	315	72	56	11	9
3	50 + 100	.43	3.84	.53	.65	345	68	45	11	8
4	100 + 100	.44	3.92	.49	.62	320	70	40	10	8
5	0 + 100	.44	3.68	.52	.71	330	72	49	10	8
6	100 + 0	.44	2.81	.65	.88	310	69	40	11	9
7	100 + 50	.42	3.55	.56	.68	315	70	39	10	9
8	100 + 0	.44	2.99	.61	.82	330	68	42	11	9
9	0 + 0	.42	2.86	.59	.86	340	72	45	11	9
10	0 + 0	.43	3.25	.56	.75	315	71	51	11	8
	Significance:	*	*	**	**	NS	NS	**	NS	NS
	BLSD (.05) :	.03	.40	.05	.07			5		
	CV (%) :	3	8	7	7	11	7	8	13	8
					Waseca					
1	0 + 0	.35	2.72	.66	.44	240	83	49	9	9
2	0 + 100	.39	3.70	.58	.37	270	74	52	8	9
3	50 + 100	.41	3.54	.58	.36	270	80	46	9	9
4	100 + 100	.34	2.73	.55	.32	220	68	39	6	8
5	0 + 100	.37	2.69	.63	.39	270	82	49	8	10
6	100 + 0	.38	2.76	.73	.53	260	74	43	9	9
7	100 + 50	.48	3.72	.80	.51	240	105	57	10	12
8	100 + 0	.38	2.88	.75	.52	280	82	45	9	10
9	0 + 0	.39	2.89	.73	.50	300	98	51	10	11
10	0 + 0	.39	3.07	.64	.41	270	77	49	9	9
	Significance:	NS	*	NS	*	NS	NS	NS	NS	NS
	BLSD (.05) :		.92		.14					
	CV (%) :	20	18	20	20	20	26	23	29	30

Table 6. Effect of high P and K rates on the nutrient concentrations in the corn leaf at the three experimental sites in 1976. 1/

Treatment No.	Treatment Description	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb P_2O_5+K_2O/A	--------	%	--------		-------		ppm	-------	
					Lamberton					
1	0 + 0	.26	1.53	.87	.78	280	66	36	8	23
2	0 + 100	.27	2.15	.75	.56	270	63	35	7	26
3	50 + 100	.27	2.14	.77	.60	265	56	26	7	24
4	100 + 100	.28	2.18	.75	.56	280	60	28	7	23
5	0 + 100	.27	1.99	.81	.65	275	65	29	6	25
6	100 + 0	.27	1.63	.92	.75	300	63	27	7	22
7	100 + 50	.28	2.06	.78	.64	285	71	30	7	25
8	100 + 0	.27	1.72	.90	.75	265	66	21	7	24
9	0 + 0	.27	1.79	.92	.69	260	65	29	7	25
10	0 + 0	.27	1.89	.80	.68	290	61	31	6	26
	Significance:	NS	**	**	**	NS	NS	*	NS	NS
	BLSD (.05) :		.24	.09	.10			9		
	CV (%) :	7	9	7	10	6	17	18	17	10
					Morris					
1	0 + 0	.22	1.40	.72	.87	300	66	33	10	16
2	0 + 100	.22	1.79	.68	.73	285	66	34	9	20
3	50 + 100	.27	1.92	.83	.82	315	68	25	8	21
4	100 + 100	.27	1.79	.79	.82	320	79	23	9	21
5	0 + 100	.25	1.68	.75	.85	300	70	29	9	19
6	100 + 0	.27	1.31	.88	1.00	315	80	20	10	20
7	100 + 50	.26	1.63	.83	.84	310	83	22	10	20
8	100 + 0	.26	1.44	.92	.94	315	66	22	9	19
9	0 + 0	.26	1.29	.83	1.04	315	79	25	9	19
10	0 + 0	.24	1.51	.79	.89	305	72	27	10	18
	Significance:	**	**	**	**	NS	+	**	NS	NS
	BLSD (.05) :	.03	.29	.12	.15			5		
	CV (%) :	8	6	9	11	9	12	15	10	13
					Waseca					
1	0 + 0	.28	1.85	.96	.58	170	78	41	8	13
2	0 + 100	.27	2.13	.88	.51	155	64	38	7	14
3	50 + 100	.27	2.14	.87	.50	155	65	36	7	13
4	100 + 100	.29	2.15	.93	.53	170	66	30	6	14
5	0 + 100	.28	2.23	.91	.55	170	61	34	7	12
6	100 + 0	.29	1.82	.99	.60	165	75	28	6	13
7	100 + 50	.27	1.92	.94	.54	170	61	32	7	13
8	100 + 0	.27	1.82	.96	.57	165	67	32	6	13
9	0 + 0	.28	1.86	.95	.58	165	67	34	7	14
10	0 + 0	.27	2.04	.94	.57	165	64	36	7	12
	Significance:	NS	**	*	**	NS	NS	**	NS	NS
	BLSD (.05) :		.18	.09	.05			7		
	CV (%) :	6	6	6	6	7	13	13	12	7

1/ Leaf opposite and below the ear at silking.

Silage and grain yields and grain moisture (an indication of maturity at harvest) are given in Table 7. Significant differences (95%) in silage yields were not found at Lamberton or Waseca. Grain yield at Waseca was affected significantly with an apparent response to potassium. This was true even though soil test K was not influenced by fertilizer K. No reason can be given for the low yield obtained with treatment 4, however. The P treatments did not appear to effect the yield. Yields from both Lamberton and Morris were extremely low due to the lack of rainfall and inadequate subsoil moisture. Consequently, yield differences were not obtained. Grain moisture was affected slightly at Waseca but a relationship to P and K treatments was not evident.

Table 7. Corn yields and moisture at harvest as influenced by high P and K rates in Minnesota in 1976.

Treatment		Silage yield			Grain yield			Grain moisture		
No.	Description	La	Mo	Wa	La	Mo	Wa	La	Mo	Wa
	lb P_2O_5+K_2O/A		T DM/A			------bu/A-------			------%-------	
1	0 + 0	1.8	1/	5.9	16.7	29.0	74.7	2/	27.8	21.5
2	0 + 100	1.4		5.7	8.9	23.4	97.9		29.4	21.9
3	50 + 100	1.5		5.9	16.8	26.4	101.9		24.4	23.0
4	100 + 100	1.4		5.3	15.2	35.8	86.4		22.9	21.0
5	0 + 100	1.2		6.1	14.3	31.0	105.5		25.2	21.4
6	100 + 0	1.8		6.2	15.1	33.4	93.7		21.0	21.1
7	100 + 50	1.6		6.0	17.5	33.6	118.0		23.8	20.0
8	100 + 0	1.6		6.2	11.6	24.3	98.6		22.8	21.6
9	0 + 0	1.2		5.6	12.6	32.6	98.5		24.5	19.8
10	0 + 0	1.4		5.7	11.2	30.6	91.7		24.8	19.2
Significance:		NS		NS	NS	NS	*		NS	+
BLSD (.05) :							24.8			
CV (%) :		26		13	39	28	15		16	7

1/ Yield not taken due to variable plant stands.

2/ Moisture not determined.

NITROGEN NEEDS FOR CORN AND ACCUMULATION OF NITRATES IN PROFILE, 1970 to 1976

W. E. Fenster and C. J. Overdahl

In the fall of 1969, nitrogen experiments were established with continuous corn on highly productive land to determine what rates of nitrogen would result in highest economic yields with a minimum of nitrate movement through the soil profile.

Two adjacent nitrogen experiments, one on continuous corn and one established to continuous corn on a virgin soil, were established in Martin County. The continuous corn experiment was established in the fall of 1969 and the one on the virgin soil was established one year later.

In 1976, drought conditions lowered yields and caused increased variation. As in previous years, the continuous corn area continued to respond to nitrogen, while the virgin area did not respond. Yield, tissue test and soil nitrate values for these experiments are given in tables 1, 2 and 3.

Table 1. Martin County corn yields as influenced by nitrogen treatments (8 replications).

N (lbs/A) annually	Yield (bu/A)													
	Continuous corn plots							Virgin plots						
	1970	1971	1972	1973	1974	1975	1976	1971	1972	1973	1974	1975	1976
0	120a	130a[1]	68[2]	112a	100a	77a	60a	179a	103	157	151	112	98
50	128ab	142b	78	115ab	126b	96ab	79b	190bc	107	151	155	128	104
100	140c	151b	68	136c	135bc	109ab	92b	187bc	88	149	157	118	99
150	132bc	144b	76	132bc	142c	100ab	80b	183b	103	150	154	120	109
200	131abc	147b	69	121abc	145c	117b	78ab	194c	96	145	153	126	103
400	135bc	153b	64	121abc	147c	132bc	89b	190bc	103	142	154	120	98
Sig.	5%	5%	ns	5%	5%	5%	5%	5%	ns	ns	ns	ns	ns

[1] Where letters differ for each experiment, yields are statistically different.

[2] A meaningful statistical analysis could not be run in 1972 because of severe hail damage.

All plots received a basic treatment of 0+150+200+20 Zn. The soil is classified as Nicollet silty clay loam.

Table 2. Percentage nitrogen in tissue* as related to nitrogen application on corn in Martin County.

N (lbs/A)	% Nitrogen in Tissue											
	Continuous Corn						Virgin plots					
	1971	1972	1973	1974	1975	1976	1971	1972	1973	1974	1975	1976
0	2.5	2.4	2.0	2.1	1.7	1.6	2.8	2.9	2.6	2.4	2.4	1.9
50	2.7	2.9	2.3	2.4	2.2	2.1	2.7	2.8	2.5	3.0	2.4	2.4
100	2.6	2.8	2.4	2.8	2.4	2.4	2.8	2.8	2.7	3.0	2.5	2.3
150	2.9	2.7	2.4	3.0	2.7	2.3	2.8	2.8	2.7	3.1	2.8	2.4
200	2.9	2.9	2.6	3.1	2.8	2.6	2.8	2.9	2.8	3.0	2.8	2.3
400	2.9	2.7	2.6	3.3	2.9	2.6	2.9	2.8	3.0	3.1	2.7	2.5
Date sampled	7/21	7/28	7/25	7/22	7/21	7/21	7/21	7/28	7/25	7/22	7/21	7/21

* sixth leaf at tasseling

Additional Observations

The average yield of all treated plots in bu/acre between the originally virgin plots above the long time continuously cultivated plots were:

1971	1972	1973	1974	1975	1976
41	29	26	21	16	22

It appears that the differences are narrowing somewhat each year.

Table 3a. Nitrate-nitrogen (ppm) in soil profile on long time continuous corn - Martin County - Thate Farm, 1976.

Soil Depth (ft.)	Treatment - lbs. of N per acre applied annually					
	0	50	100	150	200	400
0-1	6	7	14	23	47	78
1-2	3	2	10	6	12	37
2-3	2	3	8	17	19	41
3-4	3	6	14	14	27	27
4-5	5	9	10	14	17	22
5-6	6	11	9	14	20	21

Table 3b. Amount of nitrate-nitrogen (ppm) in the soil profile on virgin plots - Martin County - Thate Farm, 1976.

Soil Depth (ft.)	Treatment - lbs. of N per acre applied annually					
	0	50	100	150	200	400
0-1	7	12	24	35	44	123
1-2	2	4	10	9	17	36
2-3	4	6	28	18	12	11
3-4	9	10	18	23	19	74
4-5	8	6	12	17	13	24
5-6	10	6	11	15	13	27

PASTURE FERTILIZATION TRIALS, GOODHUE COUNTY - 1976

C. J. Overdahl

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

Close evaluation of botanical composition has not been made as yet, but the Flueger farm has mostly bromegrass, with some legume remaining from a previous improvement. The Bryan pasture appears to have a predominance of bluegrass, resulting in short growth during July and a clipping at this time could not be made.

Data in the following tables are intended as a progress report only. Conclusions cannot be made on this one year's evidence.

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

N +	P_2O_5 +	K_2O	Bryan* lbs/A	N response over check	Protein lbs/A
0	40	40	1642	-	229
30	40	40	2248	606	328
60	40	40	2685	1043	378
90	40	40	3775	2133	642
120	40	40	4054**	2412	680

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

N +	P_2O_5 +	K_2O	Flueger* lbs/A	N response over check	Protein lbs/A
0	40	40	3646	-	440
30	40	40	4789	1143	660
60	40	40	5301	1655	843
90	40	40	7110**	3464	1250
120	40	40	6767	3121	1210

* 3 cuttings at Bryan's and 4 at Flueger's.
** best rate.

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Table 2. The P and K effect on pasture yield (lbs/A dry matter) - Goodhue County, 1976.

	Cuttings				
Bryan Farm					
P Effect	1	2	3	4	Total
90 (3)* + 0 + 40	255	1583	-	732	2570
90 (3) + 40 + 40	361	1677	-	970	3008
significance	ns	ns		ns	ns
K Effect					
90 (3)* + 40 + 0	392	1633	-	895	2920
90 (3) + 40 + 40	361	1677	-	970	3008
significance	ns	ns		ns	ns
Flueger Farm					
P Effect					
120 (4)* + 0 + 40	1071	3224	708	1832	6835
120 (4) + 40 + 40	1540	3449	985	1950	7924
significance	ns	ns	ns	ns	ns
K Effect					
120 (4)* + 40 + 0	1067	2930	824	1724	6545
120 (4) + 40 + 40	1540	3449	985	1950	7924
significance	ns	ns	ns	ns	ns

* number of 30 lb. applications of nitrogen.

Table 3. The effect of split applications of nitrogen on pasture yield (lbs/A dry matter) - Goodhue County, 1976.

	Cuttings				
N + P_2O_5 + K_2O	1	2	3	4	Total
Bryan Farm					
60 + 40 + 40	423	1154	-	608	2185
60 (1,3)* +40 + 40	199	872	-	724	1795
significance	ns	ns		ns	ns
120 + 40 + 40	1516	1786	-	752	4054
120 (1,3)+ 40 + 40	758	1314	-	1011	3038
significance	1%	ns		ns	5%
Flueger Farm					
60 + 40 + 40	1679	2432	504	686	5301
60 (1,3) 40 40	753	2273	603	569	4197
significance	.1%	ns	ns	ns	1%
120 + 40 + 40	2176	2962	515	1114	6767
120 (1,3)+ 40 + 40	1414	2512	879	1353	6158
120 (1,2,3,4)40+ 40	1540	3449	985	1950	7924
significance	ns	1%	ns	5%	ns

	Bryan	Flueger
Soil test P 0 - 6"	21 high	15 medium
Soil test K 0 - 6"	303 very high	241 high
Soil pH 0 - 6"	6.0	6.2

* application code:

1- early spring
2- following 1st cut
3- following 2nd cut
4- following 3rd cut

INFLUENCE OF NITROGEN RATE AND TIMING OF APPLICATION ON THE PRODUCTION AND QUALITY OF FORAGE GRASSES ON ORGANIC SOILS

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

In 1975 three experiments were established on organic soils in Roseau County, Minnesota to evaluate the significance of timing and rate of nitrogen application on the production and quality of three grass species.

Three rates of nitrogen 0, 150, and 300 #/acre were applied as NH_4NO_3 to existing stands of orchardgrass, quackgrass, and reed canarygrass. The three grass experiments were separated, but were all contained within the same area of organic soil and were within reasonable proximity to each other. The 150 and 300 # N/A treatments were applied in four different manners: 1) the entire amount in one early spring application, 2) applied in two equal amounts one in early spring and the second after the first clipping, 3) applied in three equal portions including early application and after the first and second clipping, and 4) as four equal amounts applied early spring and then after the first, second and third clippings.

The experiments were set up to evaluate two management programs, a hay management with a two clipping sequence and pasture management with a four clipping sequence. Only the information obtained from the four clipping program will be included in this report. Clippings in 1976 were taken on June 1, June 28, August 2, and September 8. On these dates, all plots were cut back to about a 7 cm height.

Initial soil tests were taken, and to insure that P and K were not limiting all nitrogen treatments received 100 #/A of P_2O_5 and 100 #/A of K_2O applied as an early spring application. Two additional treatments were also included, a "true check" containing no N, P, and K and the high rate of nitrogen applied in four split applications with no phosphorus or potassium within the experimental areas.

Treatments were evaluated by determining dry matter production at each clipping (Table 1). Samples from each plot were obtained at harvest and analyzed for crude protein-Kjeldahl nitrogen (Table 2). These values allowed the calculation of total N removal (Table 3). Samples are also being analyzed for acid detergent fiber but results are not available at this time.

GENERAL RESULTS

Orchardgrass - Significant dry matter increases were found even at the higher rate of N application (300 #/A). Splitting of nitrogen application had no influence on total dry matter production. Splitting of N applications did significantly influence distribution of dry matter production and protein content between clippings. Applications of 150 #N/A when applied early had no influence on dry matter production on the third and fourth clipping. The 300 #N/A treatment did result in a dry matter increase on the fourth clipping. Protein contents at each clipping were directly related to the amount and time of nitrogen application. Protein content in general for orchardgrass was lower than either quackgrass or reed canarygrass.

Quackgrass - Dry matter production of quackgrass in general followed the same trends as orchardgrass. Total yields were higher for quackgrass than orchardgrass and also had much higher crude protein contents. Quackgrass appeared to be much more efficient in obtaining nitrogen from the soil as can be seen in Table 3. When no nitrogen was applied, the quackgrass check plots utilized twice as much nitrogen from the soil than did either orchardgrass or reed canarygrass. This resulted in a much higher N uptake than either of the other grasses.

Reed canarygrass - Yield responses were similar to those of quackgrass with total production being very similar. Crude protein contents were higher for the reed canarygrass treatments than for orchardgrass resulting in larger amounts of total N being removed by reed canarygrass. Nitrogen removal by the three grass species at 300 #N/A was lowest for orchardgrass followed by reed canarygrass and was highest for quackgrass.

Table 1. Dry matter production of orchardgrass, quackgrass, and reed canarygrass as influenced by rate and time of nitrogen application (organic soil - Roseau County, Minnesota - 1976).

N applied (#/A)	Clipping 1	Clipping 2	Clipping 3	Clipping 4	Total
Orchardgrass					
	lbs DM/A				
0	273	1794	508	304	2879
150 (1-150)	1037	2591	554	633	4815
150 (2-75)	787	3047	617	698	5149
150 (3-50)	649	2520	838	902	4909
150 (4-38)	658	2228	801	1135	4822
300 (1-300)	673	2925	1019	1388	6005
300 (2-150)	654	2783	955	1495	5887
300 (3-100)	800	2635	868	1542	5845
300 (4-75)	668	2652	846	1374	5540
+ 0	297	1281	421	308	2307
+300 (4-75)	372	1752	716	939	3778
Signif.	**	**	**	**	**
BLSD (.05)	180	456	239	300	671
CV, %	21.4	14.1	22.3	23.2	10.1
Quackgrass					
	lbs DM/A				
0	1213	2454	733	670	5070
150 (1-150)	1958	2615	831	1119	6523
150 (2-75)	1725	2844	894	1113	6576
150 (3-50)	1564	2901	941	990	6396
150 (4-38)	1413	2496	1027	1358	6294
300 (1-300)	2228	2521	1130	1458	7337
300 (2-150)	2217	2725	1032	1385	7359
300 (3-100)	1996	2389	1038	1498	6921
300 (4-75)	1903	2648	913	1480	6944
+ 0	966	2087	636	776	4465
+300 (4-75)	1027	2201	593	1184	5001
Signif.	**	**	**	**	**
BLSD (.05)	369	528	303	241	606
CV, %	16.4	12.3	21.5	15.0	7.3
Reed Canarygrass					
	lbs DM/A				
0	484	1932	688	285	3389
150 (1-150)	1361	2948	855	349	5513
150 (2-75)	1000	3120	1074	447	5641
150 (3-50)	775	3298	1552	515	6140
150 (4-38)	706	2772	1417	955	5850
300 (1-300)	2242	2699	1455	543	6939
300 (2-150)	1801	3087	1367	716	6971
300 (3-100)	1087	3346	1737	764	6934
300 (4-75)	992	3300	1575	963	6830
+ 0	332	1571	701	258	2862
+300 (4-75)	518	2578	1271	713	5080
Signif.	**	**	**	**	**
BLSD (.05)	501	663	417	393	1207
CV, %	20.0	9.7	13.7	7.1	8.7

+ No phosphorus and potassium applied.

Table 2. Crude protein content (%) of orchardgrass, quackgrass, and reed canarygrass as influenced by rate and time of nitrogen application (organic soil - Roseau County, Minnesota - 1976).

N applied (#/A)	Clipping 1	Clipping 2	Clipping 3	Clipping 4
		Orchardgrass		
0	20.4	11.4	14.0	16.8
150 (1-150)	27.3	17.0	18.1	16.7
150 (2-75)	25.8	19.6	17.8	16.4
150 (3-50)	24.8	17.5	22.1	16.7
150 (4-38)	27.7	17.4	20.4	20.5
300 (1-300)	34.7	20.9	24.1	22.1
300 (2-150)	27.6	23.1	24.2	22.0
300 (3-100)	25.9	20.7	21.7	22.5
300 (4-75)	24.9	21.3	24.1	24.3
+ 0	20.8	12.6	15.0	16.8
+300 (4-75	28.7	21.3	24.6	23.9
Signif.	**	**	**	**
BLSD (.05)	7.0	2.6	3.9	1.4
CV, %	16.6	10.5	13.5	5.4
		Quackgrass		
0	22.2	17.9	18.8	19.7
150 (1-150)	27.6	20.4	24.2	21.5
150 (2-75)	25.8	22.4	24.7	24.4
150 (3-50)	23.5	21.5	25.5	22.2
150 (4-38)	25.5	21.5	23.3	23.3
300 (1-300)	30.4	23.3	26.5	26.6
300 (2-150)	29.0	23.8	24.7	26.6
300 (3-100)	27.3	22.9	25.5	26.9
300 (4-75)	28.3	23.5	26.4	26.6
+ 0	26.3	17.5	19.8	20.3
+300 (4-75)	28.0	21.3	28.5	25.8
Signif.	**	**	**	**
BLSD (.05)	2.5	1.5	3.2	2.4
CV, %	6.3	5.2	9.3	7.4
		Reed Canarygrass		
0	21.7	14.6	17.9	19.7
150 (1-150)	26.0	16.3	17.7	20.4
150 (2-75)	23.6	17.1	17.8	20.1
150 (3-50)	21.6	16.6	20.2	22.4
150 (4-38)	18.0	16.0	18.1	22.8
300 (1-300)	31.7	21.1	21.3	25.3
300 (2-150)	26.7	22.4	23.9	25.1
300 (3-100)	23.8	20.0	24.5	24.8
300 (4-75)	22.4	17.5	22.6	24.6
+ 0	21.8	14.5	16.0	20.4
+300 (4-75)	23.5	18.5	22.9	26.3
Signif.	**	**	**	**
BLSD (.05)	5.0	2.3	2.6	3.6
CV, %	8.6	5.4	5.2	6.4

+ No phosphorus and potassium applied.

Table 3. Total pounds of nitrogen removed by orchardgrass, quackgrass, and reed canarygrass as influenced by rate and time of nitrogen application (organic soil - Roseau County, Minnesota - 1976).

Orchardgrass

N applied (#/A)	Clipping 1	Clipping 2	Clipping 3	Clipping 4	Total
0	9	33	12	8	62
150 (1-150)	46	69	16	17	148
150 (2-75)	33	96	18	18	165
150 (3-50)	26	70	29	24	149
150 (4-38)	29	61	26	37	153
300 (1-300)	37	98	39	49	223
300 (2-150)	29	102	37	53	221
300 (3-100)	33	88	30	55	206
300 (4-75)	25	91	32	53	201
+ 0	10	26	10	8	54
+300 (4-75)	18	59	28	35	140
Signif.	**	**	**	**	**
BLSD (.05)	11	15	10	9	27
CV, %	30.2	15.4	28.2	21.7	13.2
Quackgrass					
0	43	71	22	21	157
150 (1-150)	87	85	32	39	243
150 (2-75)	71	102	35	45	253
150 (3-50)	59	100	38	36	233
150 (4-38)	58	85	38	51	232
300 (1-300)	108	94	48	62	312
300 (2-150)	103	103	40	59	305
300 (3-100)	86	87	42	64	279
300 (4-75)	86	99	38	63	286
+ 0	40	58	20	26	144
+300 (4-75)	46	75	27	49	197
Signif.	**	**	**	**	**
BLSD (.05)	16	16	10	11	24
CV, %	16.8	12.7	20.2	17.1	7.7
Reed Canarygrass					
0	17	45	19	9	90
150 (1-150)	57	77	24	11	169
150 (2-75)	38	86	30	14	168
150 (3-50)	27	87	50	19	183
150 (4-38)	20	71	41	35	167
300 (1-300)	114	92	49	22	277
300 (2-150)	76	110	52	29	267
300 (3-100)	41	107	68	30	247
300 (4-75)	18	93	57	37	205
+ 0	12	36	18	8	74
+300 (4-75)	19	76	47	30	172
Signif.	**	**	**	**	**
BLSD (.05)	15	24	8	16	34
CV, %	24.0	12.0	12.6	28.8	12.0

+ No phosphorus and potassium applied.

FERTILIZATION OF GRASS PASTURES
Crookston, Minnesota - 1976

R. P. Schoper, C. A. Simkins, J. Lensing
R. K. Severson, G. W. Wallingford

This was the third and final year of the experiment described initially in the 1975 Blue Book. The same location with the same fertilizer treatments were used again in 1976. The full 20' x 20' plot area was used for pasture management simulation in 1976. The plots were clipped on June 10 and July 20 when the plants were approximately 8 to 10 inches high. Due to lack of rain, there was little plant growth after the July 20 clipping date. Due to the extremely dry spring, the earliest clipping date did not produce the highest yields as it did in 1975 and 1976. A rain in the middle of June provided the moisture to allow substantial growth in early summer which was reflected in the July 20 clipping. After July 20 there was little plant growth due to the continued drought.

Table 6. Dry matter yields of grass as influenced by clipping date and fertilizer treatment in 1976.

Treatment $N-P_2O_5-K_2O$ lbs/A	Dry Matter Yields lbs/A June 10	July 20	Total
0-0-0	125	477	602
0-60-0	321	1936	2257
0-0-60	125	541	666
0-60-60	450	2796	3246
30-60-60	426	2553	2979
60-60-60*	662	4046	4708
90-60-60*	662	4647	5309
120-60-60*	642	4717	5359
150-60-60*	560	5380	5940
150-0-0*	219	2532	2751
Significance	**	**	**
BLSD (.05)	212	807	805
CV (%)	36.1	20.7	18.2

* Plots received 30 lbs N/A of the nitrogen after the first cutting

GRASS SEED PRODUCTION AS INFLUENCED BY FERTILIZATION

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High production costs, and concern for energy conservation and environmental quality make correct fertilizer use important. Therefore, it is most important that information on efficient use of commercial fertilizer is available. Past research has supplied information on nutrient requirements of grasses, on soil fertility and on rates and time of fertilizer application. But as new materials or new varieties become available or as new problems arise, additional investigations are needed.

Research during 1976 consisted of (a) nitrogen source comparison, (b) nitrogen rate study on peat, and (c) copper study with Kentucky bluegrass on peat. Eight experiments with timothy and Kentucky bluegrass were conducted on growers' fields in Roseau and Lake of the Woods counties. Fertilizer effects were determined by yield measurements and plant analysis of grass tissue.

A. WEATHER CONDITIONS DURING 1975/76 GROWING SEASON

Comments on weather conditions are based on measurements of U.S. Weather Station at Roseau, observations and soil temperature determinations at the Magnusson farm at Roseau (table 1, fig. 1). August and September of 1975 were cool and relatively dry, with about 2 inches rainfall below normal. During October about 1.5 inch of rainfall was measured, about normal for the area. However, during an eight day period, from October 2 to 9, air temperature ranged from 67 to 78°F. Such high temperature may have affected N transformations in the nitrogen source experiments. November also was very dry and with the air temperature measuring about 3.5 degrees above normal. The area received about normal snowfall. April was warm with less than normal precipitation. May was very dry, with nearly 2 inches less rainfall than normal. During June 5.8 inches of rain were measured, but most of it fell during a six day period, from 6/7-6/13. Generally, during the period from August '75 to July '76, nearly 4 inches less precipitation than normal were received at Roseau while the average air temperature was about normal. Weather data of previous growing seasons indicate that during good seed production seasons (1964/65 and 1973/74) nearly 22 inches of precipitation are received at Roseau. Only 17 inches of precipitation were measured at Roseau during 1975/76 growing season. Rainfall in the area may have been spotty with some production fields receiving more rainfall than others.

Soil temperature (under sod at 3-inch depth) during May ranged from 45 to 55°F. Maximum soil temperature rose to 76-78° during first half of June. During the second half of June and during July, maximum temperature ranged from 71 to 76° while minimum temperature measured from 60 to 65°F.

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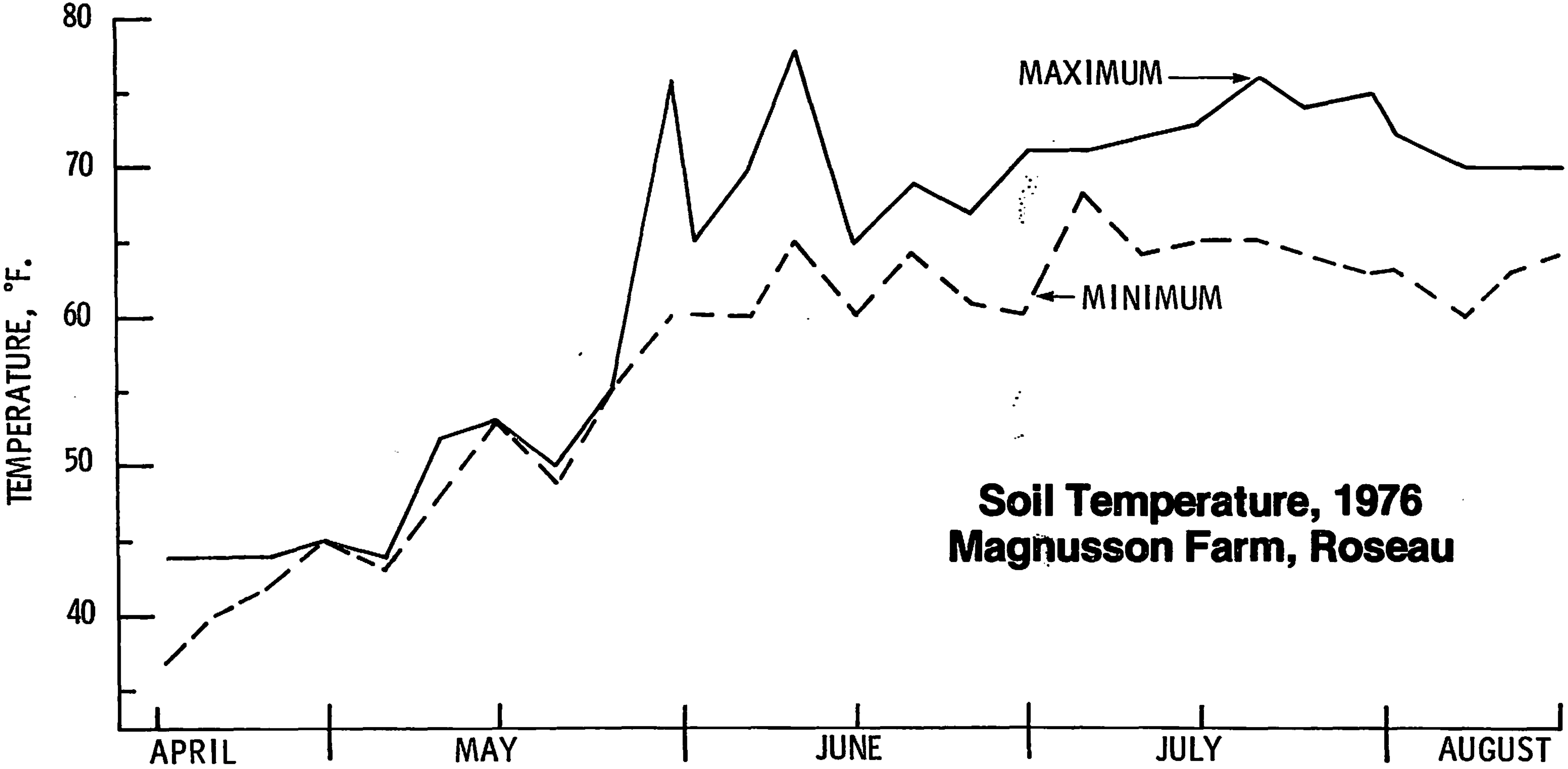

Soil Temperature, 1976
Magnusson Farm, Roseau

Table 1. Precipitation and Temperature Data for the 1975/76 Growing Season as Measured at Roseau Weather Station (KRWB Radio)*

Period	Precipitation (Inches) Total	Precipitation (Inches) Departure From Normal	Air Temperature (°F) Average	Air Temperature (°F) Departure From Normal	GDD T_b = 40°F
1975 Aug.	1.75	-1.47	61.1	-3.8	654
Sep.	1.79	-0.82	49.8	-4.8	294
Oct.	1.49	0.27	45.1	0.6	158
1975 Nov. to 1976 Apr.	4.30	-0.32	19.1	2.3	84
1976 May	0.54	-1.91	52.6	0.7	391
June	5.82	2.40	64.1	2.3	723
July	1.52	-1.93	64.8	-2.4	769
Total	17.21	-3.78			3073
Average			37.7	0.5	
Normal (1941-70)	20.99		37.2		3329

* Calculated from Climatological Data, Minnesota, Vol. 81 and 82, 1975 and 1976. U.S. Dept. of Commerce.

B. NITROGEN SOURCE COMPARISON

One of the most recent trends in fertilizer industry is the shift towards production of urea. In the grass seed producing area, urea has almost completely replaced ammonium phosphate and ammonium nitrate as source of nitrogen. This shift has occurred mainly because it's cheaper, easier and less hazardous to produce urea than other dry N fertilizers. For example, nitric acid, a highly corrosive material that must meet rigid pollution control standards, is required to produce ammonium nitrate. Also transportation and storage of ammonium nitrate is severely limited because of strict regulations.

As with any new material, questions have been raised about the effectiveness of urea as a N source for grass seed production. Growers also are concerned about possible N losses from urea when applied to soils under grass sod.

Research conducted elsewhere has shown that, in alkaline or calcareous soils, urea eventually is changed to ammonia gas (NH_3) which can escape into atmosphere when left on the soil surface. Urea losses can be cut down on cultivated land by incorporation into the soil. This, of course, is impossible with sod crops. Fortunately, moisture and low temperature greatly reduce urea losses. These losses can be minimized by applying urea when soil temperature is 50°F or below and when there is moisture from dew or rain that can wash urea into the soil. Such conditions normally exist around mid-October or May 1st - the usual dates for fertilizing grass seed production fields in NW Minnesota.

In a field experiment conducted in 1973 with Park Kentucky bluegrass on Helmstetter Bros. farm, urea was equally effective to ammonium nitrate as a N source. Both fertilizers were applied at rates to supply 40 or 100 lb/acre of N. Treatments were made on September 15 and April 25. Bluegrass seed yield and N concentration in grass tissue were affected to the same degree by ammonium nitrate and urea.

In fall of 1975, three field experiments were established on growers' fields. The soils contained 20-40 lb/acre of nitrate-N in the top two feet, considered to be relatively low (table 2). Nitrate-N concentration, in the main root zone (0-3 inches), was less than 3.4 pp2m. The timothy fields had fine textured silty clay loams and the bluegrass field had a sandy loam soil (table 3). The soils were calcareous with pH values near 8.

Table 2. Amount of Nitrate-N in the Soil Collected From 0-3, 3-6 and 6-24 Inch Depth on September 30, 1975

Location	Soil Texture	Sampling depth, inches			Total[1] NO_3-N in 0-24"
		0-3	3-6	6-24	
		NO_3-N pp2m			Lbs/A
Helmstetter Bros. Park K. bluegrass	Sandy loam	2.6	2.6	15.0	20
L. Knochenmus Kampe II timothy	Silty clay loam	3.0	3.0	33.6	40
D. Hedlund Timfor timothy	Silty clay loam	3.3	3.8	13.8	21
G. Kveen Park K. bluegrass	Peat	1.3	0.5	3.0	5
G. Kveen Newport K. bluegrass	Peat	0.5	0.5	3.0	4

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[1] By addition

Table 3. Soil Test Results of Samples Collected from 0-3, 3-6 and 6-24 Inch Depths on September 30, 1975

Location	Sampling depth, inches	Texture	pH	Extractable P pp2m	Exchangeable K pp2m
Helmstetter Bros.	0-3	SL	8.0	14	80
Park K. bluegrass	3-6	SL	8.2	20[1]	50
	6-24	LS	8.2	7[1]	30
L. Knochenmus	0-3	SICL	7.8	47[1]	310
Kampe II timothy	3-6	SIL	8.0	13[1]	100
	6-24	SIL	8.3	3[1]	60
D. Hedlund	0-3	SICL	8.0	19	250
Timfor timothy	3-6	SICL	8.1	11[1]	200
	6-24	SICL	8.5	2[1]	140
G. Kveen	0-3	P	7.7	14	140
Park K. bluegrass	3-6	P	7.3	4	40
	6-24	P	7.0	4	20
G. Kveen	0-3	P	7.2	22	50
Newport K. bluegrass	3-6	P	6.4	3	10
	6-24	P	6.3	3	10

[1] Bray P-1, 1:50 soil/solution ratio as reported to customer

Both nitrogen fertilizers were applied at rates of 50 and 100 lb of N per acre, either on September 30 or April 20. All plots received a 0+40+40 treatment. Fertilizer materials were applied with a 3-foot Gandy spreader.

Kampe II timothy yielded about 300 to 450 pounds of seed per acre (table 4). Sixty six pounds more seed were produced with ammonium nitrate than with urea. Optimum yield was produced with 100 lb/acre of nitrogen and spring fertilization was somewhat superior to fall. Ammonium nitrate treatments as well as the higher N rate and spring applications resulted in higher N concentration of tissue than other variables of this experiment.

Timfor timothy yield was not affected by the application of either N source when used at 100 lb per acre rate (table 5). The N100 treatments resulted in significantly higher N% of tissue than the check (N0).

Park Kentucky bluegrass yield (table 6) on sandy loam was relatively low, ranging from 200 to 250 pounds per acre. This probably was caused by draughty conditions. Fertilization with urea resulted in 37 pounds less seed per acre and a lower N concentration of tissue than obtained with comparable ammonium nitrate treatments. The rate or date of application had no effect on seed yield but the higher rate and spring treatments resulted in higher N concentration of tissue.

Table 4. Effects of Nitrogen Source, Rate and Time of Application on Seed Yield and N Concentration in Tissue of Kampe II Timothy. Louis Knochenmus Farm, Roseau County - 1976

Treatment	Seed yield lbs/acre	N percent in dry matter
(a) Source		
Urea	335 a	2.79 a
Ammonium nitrate	401 b	3.15 b
Significance	**	**
BLSD (0.05)	38	0.16
(b) Rate		
50 lbs/acre N	297 a	2.63 a
100 lbs/acre N	438 b	3.31 b
Significance	**	**
BLSD (0.05)	50	0.21
(c) Date		
Sept. 30	334 a	2.70 a
April 20	402 b	3.24 b
Significance	*	**
BLSD (0.05)	56	0.12
(d) Interaction		
Sept. 30 x 50 lbs/acre N	261	2.40 a
x 100 lbs/acre N	406	3.00 c
April 20 x 50 lbs/acre N	333	2.86 b
x 100 lbs/acre N	471	3.62 d
Significance	NS	*
BLSD (0.05)		0.09

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

Symbols indicating significance: NS - non significant; * - significant at 5% level; ** - highly significant at 1% level.

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

Table 5. Effects of Nitrogen Source and Time of Application on Seed Yield and N Concentration of Timfor Timothy on a Silt Loam Soil, 1973 Seeding. Dell Hedlund Farm, Roseau County - 1976

Treatment	Seed yield lbs/acre	N percent in dry matter
Check	418	3.10 a
<u>Sept. 30</u>		
Urea	421	3.92 c
Ammonium nitrate	417	3.84 bc
<u>April 20</u>		
Urea	517	3.57 b
Ammonium nitrate	475	3.69 bc
Significance	NS	**
BLSD (0.05)		0.33

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

All plots received 0+40+40 lbs/acre of P_2O_5 and K_2O. Urea and ammonium nitrate were applied at the rate of 100 lbs/acre of N.

Table 6. Effects of Nitrogen Source, Rate and Time of Application on Seed Yield and N Concentration in Tissue of Park Kentucky Bluegrass. Helmstetter Bros. Farm, Lake of the Woods County - 1976

Treatment	Seed yield lbs/acre	N percent in dry matter
(a) Source		
Urea	207 a	2.40 a
Ammonium nitrate	244 b	2.75 b
Significance	*	**
BLSD (0.05)	33	0.16
(b) Rate		
50 lbs/acre N	212	2.33 a
100 lbs/acre N	239	2.82 b
Significance	NS	**
BLSD (0.05)		0.08
(c) Date		
Sept. 30	241	2.40 a
April 20	210	2.75 b
Significance	NS	**
BLSD (0.05)		0.12
(d) Interaction		
Sept. 30 x 50 lbs/acre N	233	2.22 a
x 100 lbs/acre N	249	2.58 c
April 20 x 50 lbs/acre N	191	2.44 b
x 100 lbs/acre N	229	3.06 d
Significance	NS	*
BLSD (0.05)		0.12

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

All plots received 0+40+40

C. FERTILIZER RATE STUDIES ON PEAT

In field experiments and growers' fields during 1960's, nitrogen rates of 20 to 30 pounds per acre often caused severe lodging of bluegrass on peat. Consequently, recommendations to growers called for an application of 10-15 lb/acre N. On the other hand, in experiments conducted during 1974 and '75, maximum seed yields were produced with 40-80 lb/acre of nitrogen.

A field experiment with Park Kentucky bluegrass on peat was established in fall of 1975 to further investigate effectiveness of different N rates. Four nitrogen rates were used: 0, 20, 40, 80 lb/acre and the treatments were replicated four times. All plots received uniform 0+40+40 lb/acre phosphate and potash treatment. Twenty pounds of N were sufficient to produce optimum yield of 459 lb/acre (table 7). The 40-80 lb/acre N treatments, however, increased the nitrogen concentration of tissue.

Newport Kentucky bluegrass, in another experiment, produced relatively low seed yield (140-189 lb/acre), probably due to poor burn (table 8). Nitrogen concentration of tissue was increased by the use of the two highest nitrogen rates.

D. COPPER STUDY ON PEAT

The importance of copper fertilization in seed production of Kentucky bluegrass was investigated in three field experiments during 1976. Copper sulfate and copper chelate were dissolved in water and sprayed to 10 x 20 ft. plots on April 20. The treatments were replicated 6 times.

Copper concentration in tissue of Park and Newport varieties was relatively low, 2-4 ppm, while the Arista showed 31 ppm Cu concentration (table 9). Apparently the Arista field had been fertilized previously with copper. Copper concentration in the grass tissue was increased only by application of the sulfate form of copper. The seed yield of grass was not affected by fertilization with copper (table 10).

The lack of Kentucky bluegrass response to copper application is not surprising. Among several experiments conducted with grasses on peat during 1968-71, the seed yield was increased by copper application only in one trial. However, copper treatments, either the sulfate or chelate forms, have been effective in raising the copper concentration of grass tissue from 1-3 ppm to 6-10 ppm, considered to be sufficient. The concentration of over 200 ppm Cu, resulting from copper sulfate application, obtained in two experiments in 1976 is extremely high. It may be somewhat related to adverse weather conditions during growing season.

Table 7. Effect of Fertilization on the Seed Yield and N Concentration in Tissue of Park Kentucky Bluegrass on Peat, Gus Kveen Farm, Roseau County - 1976

Treatment[1)] N P_2O_5 K_2O lbs/acre	Seed yield lbs/acre	N percent in dry matter
Check	384 a	2.57 ab
0 + 40 + 40	354 a	2.36 a
20 + 40 + 40	459 bc	2.51 a
40 + 40 + 40	411 ab	2.77 ab
80 + 40 + 40	502 c	2.98 b
Significance	**	*
BLSD (0.05)	73	0.44

1)Fertilizer treatments were made on September 30, 1975.

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

Table 8. Effect of Fertilization on the Seed Yield and N Concentration in Tissue of Newport Kentucky Bluegrass on Peat, 1971 Seeding. Gus Kveen Farm, Roseau County - 1976

Treatment[1)] N P_2O_5 K_2O lbs/acre	Seed yield lbs/acre	N percent in dry matter
Check	156	3.38 a
0 + 40 + 40	162	3.42 a
20 + 40 + 40	140	3.45 a
40 + 40 + 40	162	3.72 b
80 + 40 + 40	189	3.87 b
Significance	NS	**
BLSD (0.05)		0.17

1)Fertilizer treatments were made on September 30, 1975.

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

Table 9. Copper Concentration of Kentucky Bluegrass Tissue on Peat as affected by Fertilization with Copper, Roseau County - 1976

Copper Treatment	Cooperator and variety G. Kveen Park	 G. Kveen Newport	 Habstritt Arista
	Cu, ppm in dry matter		
None	2 a	4 a	31 a
50 lb/A Copper sulfate	17 b	217 b	202 b
2 lb/A Copper chelate	5 a	5 a	21 a
4 lb/A Copper chelate	6 a	16 a	48 a
Significance	**	**	**
BLSD (0.05)	4	152	56

Table 10. Effect of Copper Applications on the Seed Yield of Kentucky Bluegrass on Peat, Roseau County - 1976

Copper Treatment[1]	Cooperator and variety G. Kveen Park	 G. Kveen Newport	 Habstritt Arista
	Yield of seed, lbs/acre		
None	509[2]	179	259
50 lbs/A Copper sulfate	523	196	264
2 lbs/A Copper chelate	564	188	261
4 lbs/A Copper chelate	547	200	243
Significance	NS	NS	NS
C.V. %	13	20	30

[1] Copper treatments were made on April 20, 1976.

[2] Average of 6 replications

SUMMARY AND CONCLUSIONS

Eight field experiments with Kentucky bluegrass and timothy were conducted on growers' fields in northwestern Minnesota. The main objective of these investigations was to determine the effects of urea and ammonium nitrate applications, nitrogen rate, and fertilization with copper on plant tissue and seed yield of grasses.

Weather conditions during 1975/76 growing season were less than optimum. Nearly 4 inches of precipitation below normal were recorded at Roseau from August '75 to July '76. Relatively high air temperature, during October and November, may have affected nitrogen transformations in the N source experiments.

Fertilization with ammonium nitrate resulted in slightly higher seed yield and N concentration of tissue than from urea.

Optimum seed yield of Park Kentucky bluegrass on peat was produced with 20 pounds per acre of nitrogen.

Fertilization with copper had no effect on the seed yield of Kentucky bluegrass on peat.

Acknowledgments

Grateful acknowledgments are made to the following cooperators and University personnel for their valuable assistance during 1976 in obtaining the information pertaining to grass seed production:

Messrs. Everett and George Helmstetter, Lake of the Woods county; Louis Knochenmus, Dell Hedlund, Habstritt Bros., Gustav Kveen, Roseau county; Dr. Laddie Elling, Messrs. Robert Schoper, Jerome Lensing, Tim Wagar, Mike O'Leary, Rick Quade, Donn Vellekson, University of Minnesota.

NAVY BEAN TRIALS - 1976

J.N. Lensing and G.E. Ham

Field experiments were established at Becker and Rosemount Experiment Stations to study the effect of nitrogen rates on yield of two varieties of navy beans. The two varieties used were Seafarer and Sanilac navy beans. The nitrogen source was urea. A randomized complete block design, replicated four times was used with each plot split with navy bean varieties.

Nitrogen fertilizer significantly increased bean yields with both varieties at Rosemount (Table 1), with highest yields at 120 lbs N/A. At Becker Seafarer beans increased from 1747 - 2264 lbs/A with highest yield at 90 lbs N/A. Sanilac beans increased from 1554 - 1933 lbs/A with highest yield at 60 lbs N/A.

Table 1. Yield of navy beans as affected by various rates of nitrogen.

Nitrogen Rate	Yields (lbs/A)			
	Rosemount		Becker	
lbs N/A applied	Seafarer	Sanilac	Seafarer	Sanilac
0	3115	3058	1747	1554
30	3227	3182	1788	1842
60	3434	3191	2046	1933
90	3748	3386	2264	1872
120	3847	3530	2009	1858
Significance	**	**	NS	NS
BLSD (.05)	210	253	--	--

POTATO TILLAGE,[1]

Grand Forks, 1976

G.R. Blake
Professor, Department of Soil Science
University of Minnesota

Tillage System 2/	Total Weight lbs/A	Clods Removed lbs/A 3/	Culls Removed lbs/A	Net Weight cwt/A
Fall plowed	15018	678	26.0	143.1
Ditto	13425	283	36.2	131.1
Average				138.1
No fall tillage	14830	66	27.9	147.4
Ditto	14807	291	32.0	144.8
Average				146.1

1/ Harvested about two acres for each tillage treatment in two truckloads from each. No difference found in potato specific gravity.

2/ Spring and summer tillage, fertilizer, spraying and vine killing were the same on both treatments. Prior to planting this consisted of field cultivating, marking rows, application of 20-20-12 and 30 lbs. of 10-G Thimet. Cultivations were blind with Lilliston and dragged with Melroe drag June 1 and 2; cultivated with Lilliston on June 17 and July 7. Sprayed 4 times plus vine killer.

3/ Weights approximate.

SOYBEAN NITROGEN FERTILIZER STUDIES

G.E. Ham and G.W. Randall

Ammonium nitrate and urea were compared at Waseca at the rate of 50 and 100 pounds N per acre when applied in the fall and spring. In addition, urea at the rate of 200 pounds N was applied in the fall. Fall applied-N was plowed-down and spring applied N was applied to the surface and disked in before planting. Corsoy and Hodgson varieties were planted on May 12th. Seed yields are shown in Table 1. Yields were lower than normal due to the extremely dry weather during the 1976 growing season. The seed yield of both varieties was increased significantly by the 200 pound rate of nitrogen. In addition, the seed yield of Hodgson was increased by the 100 pound rate of nitrogen as urea and ammonium nitrate with spring or fall application.

Several soybean genotypes were compared to common varieties for their response to 200 pounds of nitrogen per acre as urea. Planting was done on May 13 in 15-inch rows. The seed yield of 16 genotypes was increased significantly (Table 2). The other seven genotypes showed yield increases which were not significant. In no case did the fertilized yield less than the control. One genotype was destroyed by herbicide damage.

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

Fertilizer Treatment	Corsoy 15" rows	Corsoy 30" rows	Hodgson 15" rows	Hodgson 30"rows
lbs N/acre	bu/acre			
Control	33	34	33	34
50 urea, fall applied	34	35	35	36
50 urea, spring applied	34	37	37	37
100 urea, fall applied	35	35	37*	38*
100 urea, spring applied	33	34	37*	38*
200 urea, fall applied	37*	39*	40*	41*
50 amm. nitrate, fall applied	33	34	38*	36
50 amm. nitrate, spring applied	33	33	35	37
100 amm. nitrate, fall applied	33	36	38*	39*
100 amm. nitrate, spring applied	33	34	38*	38*

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* Seed yield is significantly greater than the unfertilized control of the same variety and same row spacing.

Table 2. Effect of nitrogen fertilizer on soybean seed yield at Waseca.

Soybean Genotype**	Fertilizer N (urea) applied		Nitrogen Response
	0	200 lb N/A	
	bu/acre		
Corsoy	32	34	2
Hodgson	31	39*	8
Hark	29	35*	6
Grande	29	36*	7
M-67-68	33	37	4
M-68-48	31	37*	6
M-68-49	32	35	3
M-68-284	30	34	4
M-69-36	32	39*	7
Dt-2	25	32*	7
L-2	27	35*	8
12-055	29	38*	9
12-131	31	38*	7
A73D28	33	37	4
12-286	30	33	3
A73D8	31	37*	6
A73D22	31	38*	7
A74-102011	31	39*	8
A74-201006	31	39*	8
13-803	29	34*	5
13-825	29	38*	7
13-1030	30	35*	5
13-1035	27	34*	7

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* Seed yield of fertilizer nitrogen treatment greater than control.

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

SOYBEAN YIELD IMPROVEMENT WITH FOLIAR FERTILIZER

W.D. Poole[1], G.E. Ham[1] and G.W. Randall[2]

The recent soybean yield increases of 23 bushels per acre reported from foliar fertilization of soybeans has greatly increased interest in the subject. Dr. John Hanway of Iowa State University increased Corsoy soybean seed yields from 53 to 76 bushels per acre in tests in 1975.

Foliar fertilization is not a substitute for a good soil fertility program of soil applied fertilizers. Rather, foliar fertilization is in addition to soil applied fertilizers with other top management factors (narrow rows, high-yielding varieties, etc.). If all other factors are optimum, foliar fertilization can result in increased yields.

The time of application is important and the best time to apply foliar fertilizers to soybean leaves is between the time when the top pods start filling and when about half of the leaves have turned yellow. Generally, 2-4 foliar fertilizer applications at least a week apart give the best results. One large application would probably "burn" the leaves severely and reduce the yield response to foliar fertilization.

According to previous Iowa State University research the suggested rate of application for an acre of soybeans is about 25 pounds of nitrogen, 3 pounds of phosphorus (6 pounds of P_2O_5), 7.5 pounds of potassium (9 pounds of K_2O) and 1.5 pounds of sulfur in 20 gallons of solution. Urea supplies the nitrogen; some potassium and the sulfur comes from potassium sulfate; and the phosphate and additional potassium comes from potassium polyphosphate. All four nutrients (nitrogen, phosphorus, potassium and sulfur) must be in the solution. Omitting any one of the nutrients decreases the yield response. Using other sources of nutrients (commercially available liquid fertilizers) in the quantities mentioned above may "burn" the leaves and reduce yields.

In University of Minnesota studies in 1976 the lack of rainfall depressed all yields at Waseca while the plots at Rosemount were irrigated (Table 1). Soybean seed yields were not increased significantly by any foliar fertilizer treatment. The materials used in the Iowa State University studies (treatments A, B and C) were compared to conventional fertilizers (10-34-0 plus urea or 28% nitrogen solution and potassium sulfate in treatments D and E). The conventional fertilizers decreased

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yields and increased leaf burn significantly when UAN was used as the N source. This indicates the importance of using the proper source of nutrients.

The conventional fertilizers were included because they are cheaper and more readily available than the potassium polyphosphate. The benlate was included since it had increased soybean yields in Illinois studies under conditions where pod and stem blight existed. Boron was included to determine the influence it may have on soybean seed yield.

In another study at Rosemount in 1976, the seed yield of Evans variety soybeans was increased significantly (from 56 to 65 bushels per acre) by the treatment with the same materials used by Iowa State University. Adding phosphorus, potassium and sulfur from the same sources and changing the nitrogen source (calcium nitrate, ammonium sulfate or ammonium chloride) reduced yields very severely due to leaf burning. Adding nitrogen only as urea as a foliar or soil treatment did not increase yields.

Table 1. Influence of foliar fertilization on 1976 soybean seed yields in Minnesota.

	Waseca		Rosemount	
Treatment*	Corsoy	Hodgson	Evans	Hodgson
	bu/acre			
Control	25	28	47	50
Surfactant only	25	28	47	48
NPKS (3-4)[a]	26	27	46	49
NPKS (2-4)[b]	28	28	45	47
NPKS (1-4)[c]	26	28	45	48
10-34-0 + NKS[cd]	29	29	42	44
10-34-0 + NKS[ce]	23	26	38	43
NPKS (1-4)[f]	24	26	48	46
Benlate[g]	27	27	47	48
Benlate + NPKS (1-4)	27	29	47	49
Boron[h]	28	30	48	50
Boron + NPKS (1-4)	28	27	45	50

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* 22.3 - 2.1 - 6.4 - 1.5 pounds NPKS/application in 26 gallons solution containing 0.1% tween 80 as surfactant.

[a] applied twice

[b] applied three times

[c] applied four times

[d] 10-34-0 + potassium sulfate + urea

[e] 10-34-0 + 28% N solution (UAN) + potassium sulfate)

[f] same as c except nitrogen supplied as ammonium thiosulfate

[g] applied at the rate of 1.0 pounds per acre

[h] applied at the rate of 0.4 pounds per acre

Table 2. Influence of foliar and soil fertilization on Evans soybean yields in 1976 at Rosemount, Minnesota.

Treatment	Seed Yield - bushels/acre
Control	56
Surfactant only[c]	57
NPKS foliar[a]	65
Urea only - foliar[b]	58
Urea only - soil	57
Calcium nitrate foliar[a]	44
Ammonium sulfate foliar[a]	43
Ammonium chloride foliar[a]	34

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[a] Four applications of 18 - 1.7 - 5.2 - 1.2 pounds NPKS/application in 26 gallons solution containing 0.1% Tween 80 as surfactant.

[b] Four applications of 18 pounds N/application in 26 gallons solution containing 0.1% Tween 80 as surfactant.

[c] Four applications of 26 gallons solution containing 0.1% Tween 80.

REPORT ON SOYBEAN INOCULATION TRIALS

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

Humus inoculants containing Rhizobium japonicum were applied to soybean seeds within 24 hours of planting and granular inoculants were applied with the seed at planting. All plots including the controls were hand planted into furrows opened with the planter and after planting the furrows were closed with a hand operated covering device. Emergence and germination of the plots were as good as the machine planted border rows. Plots were 16 feet long and 4 rows wide with a 15-inch row spacing. Weed control was excellent during the season. Rainfall was much less than normal and the drought during the pod-filling period was very severe. As a result, yields were about one-half of the normal yields obtained at Waseca. Also, the yield differential between the nodulating and the nonnodulating isoline was only 1.3 bu/acre which represents the yield contributed by nodulation.

Soybean seed yields were not increased significantly with inoculation with commercial humus or granular inoculants containing large numbers of Rhizobium japonicum (Table 1). Humus inoculants contained 4.9×10^5 to 1.3×10^8 rhizobia/gm inoculant and the granular inoculants contained 2.3×10^4 to 1.1×10^8/gm inoculant. Nodules are being serotyped to determine the recovery of added rhizobia.

Table 1. Influence of inoculating soybeans with Rhizobium japonicum on 1976 seed yields at Waseca, Minnesota.

Inoculant Treatment	Seed Yield bu/acre
Control	30.8
Ag Labs - humus - seed coated	29.0
Ag Labs - granular - soil - 5 lbs/acre	29.6
Ag Labs - granular - soil - 20 lbs/acre	28.4
Kalo - humus - seed coated	26.1
Kalo - granular - soil - 5 lbs/acre	30.0
Kalo - granular - soil - 20 lbs/acre	27.1
Nitragin - humus - seed coated	27.5
Nitragin - granular - soil - 5 lbs/acre	30.0
Nitragin - granular - soil - 20 lbs/acre	26.9
Nitragin - granular - soil - 40 lbs/acre	27.6
Olin - humus - seed coated	31.3
Olin - granular - soil - 5 lbs/acre	28.6
Olin - granular - soil - 20 lbs/acre	30.2
Research Seeds - humus - seed coated	28.2
Research Seeds - granular - 5 lbs/acre	28.6
Research Seeds - granular - 20 lbs/acre	28.1
Research Seeds - granular - 40 lbs/acre	28.6
University of Minnesota - SM31 granular - soil - 5 lbs/acre	28.5
University of Minnesota - SM31 granular - soil - 40 lbs/acre	27.2
University of Minnesota - SM35 granular - soil - 5 lbs/acre	27.2
University of Minnesota - SM35 granular - soil - 40 lbs/acre	27.7
University of Minnesota - USDA110 humus - seed coated	27.2
University of Minnesota - USDA110 granular - 20 lbs/acre	30.1
University of Minnesota - USDA110 granular - 40 lbs/acre	26.3
University of Minnesota - USDA142 humus - seed coated	29.2
University of Minnesota - USDA142 granular - 20 lbs/acre	29.8
University of Minnesota - USDA142 granular - 40 lbs/acre	29.0
Nodulating isoline	27.4
Nonnodulating isoline	23.9

EVALUATION OF MAJOR NUTRIENT NEEDS OF SUGARBEETS IN WEST-CENTRAL MINNESOTA

W. E. Fenster and O. M. Gunderson

The main objective of this study is to determine the nitrogen needs of sugarbeets to the extent that recoverable sugar per acre can be increased and, hopefully, maximized in West-Central Minnesota. Unfortunately, 1976 was an extremely dry year and, as a result, the drought-stress on the sugarbeets masked nearly all of the fertilizer nitrogen treatments applied. Phosphorus and potassium experiments are also being conducted to ascertain what levels of these nutrients are needed for optimum sugar production.

Experimental procedure: Five locations were selected in West-Central Minnesota for the nitrogen correlation-calibration study. The sites represent the soil types on which most of the sugarbeets are grown. There was one nitrogen experiment in each of Traverse, Swift, and Chippewa counties and two in Renville County. The soils were Roliss Sicl in Traverse, Bearden Sicl in Swift, Tara sil in Chippewa, and Perella sil and Nicollet Sicl in Renville. One phosphorus and one potassium experiment was also established in Chippewa County on a Tara sil soil. Soil analyses were run on all experimental sites and fertilizers were added where necessary to insure adequate levels of nutrients.

A 5 x 5 Latin Square design was employed on all experiments. In addition, a starter-no starter split plot design was superimposed over the Latin Square in the phosphorus experiment.

Plant tissue analyses were run on young-mature petioles sampled at selected dates to check nitrate-nitrogen levels. Emission Spectrographic analyses were also run to ascertain nutrient levels in the plant tissue.

All plots were harvested with a one-row lifter and transported to North Dakota State University where the sugarbeets were immediately processed through the tare laboratory and the brei shipped to Rocky Ford for sodium, potassium, amino nitrogen and conductivity tests.

Statistical analyses were run on all data using a BLSD test.

Nitrogen investigation: Five soil profiles were taken to a depth of 5 ft. at each of the five locations. Depths of 0-6", 6-12", 12-24", 24-36", 36-48" and 48-60" were each analyzed for nitrate-nitrogen. These increments were each tested in an attempt to correlate depth and amount of nitrate with yield. Two of the five nitrogen trials, however, were affected by drought to the extent that they were abandoned and no yields were taken. The results from the remaining three trials are shown in tables 1-8. Based on the nitrate-nitrogen levels in the top two feet of soil at the start of the 1976 growing season (table 1), root yield increases would normally have been expected as a result of applying fertilizer nitrogen. Due to the extreme drought, however, no meaningful statistical differences in yields, percentage sugar, amino nitrogen, and recoverable sugar were noted as a result of increasing rates of fertilizer nitrogen (tables 2-4). This was also apparent in the nitrate levels of the petioles which generally were not significantly different as a result of nitrogen applications (tables 5-7). It is obvious from table 8, however, that the nitrate soil tests did reflect the increased nitrogen applications at the end of the season.

Table 1. Nitrate-nitrogen levels at the experimental locations prior to planting in 1976.

Depth (in.)	Davison Farm (Traverse Co.)	W. Schwitters Farm (Chippewa Co.)	Frieberg Farm (Renville Co.)
	lbs. NO_3-N/A(1)		
0 - 6	32	17	11
6 - 12	24	19	18
12 - 24	30	43	22
24 - 36	30	51	15
36 - 48	23	26	15
48 - 60	15	12	22
Total	154	168	103

(1) All figures are an average of 5 soil probes.

Table 2. Effect of varying rates of fertilizer nitrogen on sugarbeet root yields, percentage sugar, amino nitrogen, impurity index and recoverable sugar on the Earl Davison farm in Traverse County, Minnesota, 1976.

Nitrogen(1) Treatment lbs/A	Roots T/A	Sugar %	Amino Nitrogen ppm	Impurity Index	Recoverable Sugar T/A
0	6.6	17.6	1165	1049	0.972
50	7.3	17.9	1174	1053	1.095
100	6.9	17.4	1091	1013	1.015
150	7.0	17.3	1139	1053	1.013
200	6.1	17.4	1137	1084	0.893
Sig.	ns	*	ns	ns	ns
BLSD (.05)		-			
(.10)		.4			

(1) 5x5 Latin square design.

Table 3. Effect of varying rates of fertilizer nitrogen on sugarbeet root yield, percentage sugar, amino nitrogen, impurity index and recoverable sugar on the Wayne Schwitters farm in Chippewa County, Minnesota, 1976.

Nitrogen(1) Treatment lbs/A	Roots T/A	Sugar %	Amino Nitrogen ppm	Impurity Index	Recoverable Sugar T/A
0	12.8	17.8	488	549	2.074
50	12.6	17.4	552	582	1.999
100	13.9	17.3	506	572	2.194
150	11.6	17.5	550	576	1.851
200	13.1	17.6	637	649	2.082
Sig.	**	ns	*	ns	ns
BLSD (.05)	1.6		91		

(1) 5x5 Latin square design.

Table 4. Effect of varying rates of fertilizer nitrogen on sugarbeet root yield, percentage sugar, amino nitrogen, impurity index and recoverable sugar on the Pete Frieberg farm in Renville County, Minnesota, 1976.

Nitrogen[(1)] Treatment lbs/A	Roots T/A	Sugar %	Amino Nitrogen ppm	Impurity Index	Recoverable Sugar T/A
0	18.7	16.3	427	735	2.607
50	19.4	16.6	433	735	2.866
100	20.5	16.5	479	739	3.020
150	18.8	16.5	514	793	2.724
200	18.2	16.6	530	810	2.666
Sig.	ns	ns	ns	ns	**
BLSD (.05)					.145

(1) 5x5 Latin square design.

Table 5. Effect of varying rates of fertilizer nitrogen on nitrate-nitrogen content of young-mature sugarbeet petioles taken at selected times on the Earl Davison farm located in Traverse County, Minnesota, 1976.

Nitrogen(1) Treatment lbs/A	Sampling Date				
	July 19 ppm	August 2 ppm	August 16 ppm	August 30 ppm	September 13 ppm
0	7794	1605	2964	1941	1636
50	8750	2085	3502	1876	1918
100	8635	2270	3250	1712	1664
150	8343	2359	3167	1653	1900
200	10334	2573	3811	1987	2010
Sig.	ns	ns	ns	ns	ns
BLSD (.05)					

(1) 5 x 5 Latin square design.

Table 6. Effect of varying rates of fertilizer nitrogen on nitrate-nitrogen content of young-mature sugarbeet petioles taken at selected times on the Wayne Schwitters farm located in Chippewa County, Minnesota, 1976.

Nitrogen(1) Treatment lbs/A	Sampling Date				
	July 19 ppm	August 2 ppm	August 16 ppm	August 30 ppm	September 13 ppm
0	4604	1605	1696	1353	782
50	5573	2085	2087	1786	837
100	5947	2270	2090	1533	677
150	4986	2359	2172	1868	974
200	8292	2573	2426	2355	1215
Sig.	ns	ns	ns	ns	ns
BLSD (.05)					

(1) 5 x 5 Latin square design.

Table 7. Effect of varying rates of fertilizer nitrogen on nitrate-nitrogen content of young-mature sugarbeet petioles taken at selected times on the Pete Frieberg farm located in Renville County, Minnesota, 1976.

Nitrogen(1) Treatment lbs/A	Sampling Date July 19 ppm	August 2 ppm	August 16 ppm	August 30 ppm	September 13 ppm
0	3370	2491	2282	1628	1268
50	3902	2451	2713	1741	1279
100	4119	3171	2746	1861	1378
150	4881	4289	4004	2531	1780
200	4143	3874	3800	2345	1648
Sig.	ns	ns	*	ns	ns
BLSD (.05)			1368		

(1) 5 x 5 Latin square design.

Table 8. Effect of varying rates of fertilizer nitrogen on soil nitrate-nitrogen levels taken to a depth of two feet after sugarbeet harvest, 1976.

Nitrogen(1) Treatment lbs/A	Nitrate-Nitrogen (0-24") Davison Farm Traverse Co. lbs/A	Nitrate-Nitrogen (0-24") Schwitters Farm Chippewa Co. lbs/A	Nitrate-Nitrogen (0-24") Frieberg Farm Renville Co. lbs/A
0	78	94	67
50	115	77	70
100	105	118	90
150	172	146	127
200	208	159	150
Sig.	*	ns	**
BLSD (.05)	101		34

(1) 5 x 5 Latin square design.

Phosphorus and Potassium Investigations

Five rates of phosphorus ranging from 0 to 100 lbs/acre phosphate were broadcast and each of the plots was then split to compare a 7-21-7 starter fertilizer applied at a rate of 5 gal/acre. Again, as with the nitrogen results, the extremely dry weather conditions played a major role in the experimental results. No significant differences in growth or yield criteria were realized as a result of the phosphorus treatments (table 9). It is interesting to note that the percentage phosphorus in the petiole (table 9) is very low, even where the higher rates of phosphate were applied. This would indicate that the sugarbeets probably were not taking up appreciable amounts of nutrients from the extremely dry plow layer, but rather from the subsoil which is characteristically low in available phosphorus.

The results of the potassium trial are given in table 10. Only two replicates out of five were harvestable as a result of poor stands due to the drought. No meaningful growth or yield differences were noted as a result of the potassium treatments.

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Special recognition should also be given to Robert Schoper and Jerome Lensing in the Soil Science Department, University of Minnesota, for their untiring efforts and attention to needed details on this project. Appreciation is also extended to Tim Wagar, Mike O'Leary and Richard Quade for their many hours of field work.

Table 9. Effect of varying rates of broadcast phosphorus and starter fertilizers on sugarbeet percentage of phosphorus in petiole, root yields, percentage sugar, impurity index and recoverable sugar on the Wayne Schwitters farm in Chippewa County, Minnesota, 1976.

Phosphorus Treatment(1) lbs/A P_2O_5	Starter Applied(2)	Phosphorus Petiole %	Roots T/A	Sugar %	Impurity Index	Recoverable Sugar T/A
0	yes	.12	14.1	17.2	630	2.17
0	no	.12	14.2	17.4	588	2.55
25	yes	.12	16.2	17.4	613	2.39
25	no	.14	12.4	17.4	589	2.69
50	yes	.12	15.1	17.5	573	2.40
50	no	.12	15.1	17.3	597	2.22
75	yes	.13	17.0	17.1	648	2.67
75	no	.12	13.2	17.7	609	2.43
100	yes	.12	15.0	17.7	557	2.15
100	no	.14	13.9	17.4	564	2.19
Sig.		ns	ns	ns	ns	ns
BLSD (.05)						

(1) 5 x 5 Latin square design with a starter - no starter superimposed in a split plot configuration.

(2) All starter plots received 5 gal/A of 7-21-7.

Table 10. Effect of varying rates of fertilizer potassium on sugarbeet root yield, percentage sugar, amino nitrogen, impurity index and recoverable sugar on the Wayne Schwitters farm in Chippewa County, Minnesota, 1976.

Potassium Treatment(1) lbs/A K_2O	Potassium (brei) ppm	Sodium (brei) ppm	Roots T/A	Sugar %	Impurity Index	Recoverable Sugar T/A
0	1775	170	13.4	17.2	647	1.975
100	1510	150	13.2	18.5	498	2.254
200	1663	215	14.1	17.3	650	2.179
300	1980	168	12.7	17.4	685	1.971
400	1923	155	13.1	17.0	668	1.993
Sig.	ns	ns	ns	*	*	ns
BLSD (.05)				-	-	
(.10)				.7	91	

(1) 2 replicates.

WILD RICE FERTILIZATION RESEARCH - 1976

A PROGRESS REPORT
January 3, 1977

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Research was continued during 1976 on fertilization, nutrient requirement and water quality. Nitrogen rate studies were conducted on mineral soil at Grand Rapids with two varieties in second production year, and with three varieties in first production year. Three fertilization experiments were established on peat with a 2nd year stand in Aitkin county to study NPK rates and to explore effectiveness of foliar fertilization. A strip-trial on peat with potassium was conducted in Clearwater county. Plant samples were collected and analyzed to learn more about nutrient requirement of the plant. Soil temperature, redox potential and quality of paddy water were monitored during growing season to obtain information on the environment in which wild rice grows.

A. NITROGEN RATE AND VARIETY STUDIES ON MINERAL SOIL

Two experiments were conducted on mineral soil at the North Central Experiment Station, Grand Rapids. Experiment 1 was established in spring of 1976 with three varieties: early maturing K2 and M3 and the late maturing "Johnson". Experiment 2 had been established in spring of 1975 with K2 and "Johnson" varieties and was in second production year.

FIRST YEAR STAND

The experimental paddy was in fallow during 1975 and was fumigated with methyl bromide in fall 1975. Four rates of nitrogen were used: 0, 20, 40, 80 lb/acre. Urea (46-0-0) was applied with a 3-foot Gandy spreader on April 28 and incorporated into the soil by rototilling. Phosphorus and potassium were not applied because high availability of these nutrient elements was indicated by soil tests (4/8/76: pH 5.8; P 88; K 245). Three varieties, the early maturing K2 and M3 and late maturing "Johnson" wild rice were grown. Each variety occupied a 48 x 72 ft. area. Varieties were separated by 10 foot wide alleys. "Johnson" variety was placed between the two earlier maturing varieties to minimize cross-pollination. Individual plots were 12 x 12 ft. Each N treatment was replicated 6 times. Wild rice was seeded on April 28 and rototilled into the soil. Water level in the paddy was maintained at about 8-12 inches. Plant population in this experiment was 5-7 plants per square foot. Malathion (1.5 lb/A) was sprayed on May 28 to control midge. Copper sulfate (15 lb/A) was applied to control algae. Dithane and malathion were used to control disease and rice worm. Although the paddy had been covered with netting, blackbirds caused grain losses in some areas. Ten plants were selected at random from each plot at jointing and 5 plants per plot at late flowering for weight measurements and plant analysis. A 4 x 4 ft. square area from each plot was hand-harvested for yield determination. The K2 and M3 varieties were harvested on August 24 and the "Johnson" on September 1.

Wild rice responded well to nitrogen treatments and exhibited height and color differences, particularly at jointing and boot stages. Plants in NO plots were short, light green in color with yellow lower leaves. Plants in N40 and N80 plots were taller and had dark green color. At flowering, plants lodged in the N80 plots.

Yield of grain was not affected by different rates of nitrogen (table 1). Nitrogen concentration in second leaf at jointing of the K2 variety was increased from 3.56% in plants from NO treatment to 4.55% in those from N80 plots (table 2). Nitrogen concentration and uptake in different plant parts are given in tables 3 and 4. These values were affected by N rates in a few instances.

Table 1. Effect of nitrogen application on the yield of three wild rice varieties - 1976,
Grand Rapids, 1st year stand.

Variety	N rate, lb/Acre				Average (variety)
	0	20	40	80	
	Grain yield, lb/Acre				
K2	808[1)]	901	1046	862	904
M3	996	1052	932	766	937
"Johnson"	741	839	782	817	795
Average (rate)	848	931	920	815	

[1)] 7% moisture; 76% ave. Grain recovery
Significance NS (not significant)

Table 2. Effect of Nitrogen application on N concentration in 2nd leaf at jointing,
Grand Rapids - 1976, 1st year stand.

Variety	N Rate, lb/Acre				Significance
	0	20	40	80	
	N% in Dry Matter				
K2	3.56[1)]	3.75	3.76	4.55	+
M3	3.56	3.60	3.95	3.91	NS
"Johnson"	3.04	3.82	3.00	3.75	NS

[1)] Average of 20 plants
+ = Significance at the 10% level.

Table 3. Effect of Nitrogen application on N concentration of different plant parts at late flowering.
Grand Rapids - 1976, 1st year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves
		N% in Dry Matter		
K2	0	1.41[1)]	0.60	1.90
	20	1.63	0.76	1.75
	40	1.47	0.62	2.08
	80	1.96	0.76	2.17
Significance		+	NS	NS
M3	0	1.59	0.72	2.03
	20	1.59	0.70	2.24
	40	1.62	0.76	2.38
	80	1.61	0.74	2.44
Significance		NS	NS	NS
"Johnson"	0	1.50	0.67	1.85
	20	1.51	0.71	1.92
	40	1.40	0.59	1.77
	80	1.58	0.75	1.88
Significance		NS	NS	NS

[1)] Average of 10 plants.

Table 4. Effect of Nitrogen application on total uptake of N by wild rice at late flowering.
Grand Rapids - 1976, 1st year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves	Total
		N in milligrams per plant			
K2	0	43[1]	60	56	158
	20	59	88	71	218
	40	54	90	94	237
	80	64	88	101	253
Significance		NS	NS	NS	NS
M3	0	63	86	82	230
	20	59	98	101	258
	40	45	74	103	221
	80	64	109	142	315
Significance		NS	NS	*	NS
"Johnson"	0	63	124	106	294
	20	64	122	119	305
	40	71	134	144	348
	80	88	159	145	392
Significance		NS	*	*	NS

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[1] Average of 10 plants.
NS = Not Significant; * = Significant at the 5% level.

SECOND YEAR STAND

The nitrogen rate-variety experiment, established in spring of 1975 was continued. Three rates of nitrogen were used: 0, 40, 80 lb/acre. Urea was applied on April 28 and incorporated into the soil. Straw was disked and rototilled into the soil. A split-plot design was used in this experiment with the varieties, K2 and "Johnson", as main plots and N rates as sub-plots. Individual plots were 10 ft. wide and 12 ft. long. Nitrogen treatments were replicated 6 times with 3-foot wide alleys separating replications. Water level and pest control measures were the same as used in 1st year paddy.

Redox potential (Eh) of flooded paddy soil was determined by placing platinum electrodes into the root zone. Following readings were obtained during the season:

Date	Eh, millivolts
5/21	+ 190
6/02	- 100
7/16	- 190
7/22	- 190
8/04	- 200
8/12	- 205.

During June - August Eh ranged from -100 to -205 mv indicating a strongly reduced condition in the mineral soil.

The stand was not thinned and plant population was 8 - 9 plants per square foot. At jointing and boot stages striking differences in plant height and color were observed. Plants in N0 plots were shorter and lighter in color than those in plots receiving N80 treatment; plants in N40 plots were intermediate in color and height. In August, heavy lodging occurred in the plots receiving 80 lb/acre of N.

Grain yields (at 7% moisture) varied from 659 to 1231 pounds per acre (Table 5). The earlier maturing K2 outyielded the "Johnson" variety by nearly 330 lb/acre. Yield of wild rice was not affected significantly by the rate of nitrogen. It appeared, however, that the 80 pound N rate had a more adverse effect on the "Johnson" variety, probably due to greater vegetative growth (Table 7) and more severe lodging than on the K2 yield. Nitrogen concentration in second leaf at jointing was increased from 3.27 to 3.88 % by the application of 40 lb N/acre (Table 6). At late flowering, a single plant contained from 294 - 367 milligrams of N. Fertilization, generally had little or no effect on N concentration of different plant parts (Table 8) or the N uptake by wild rice at this stage of plant development.

Table 5. Effect of Nitrogen application on the yield of two wild rice varieties.
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate, lb/Acre		
	0	40	80
	Grain Yield, lb/Acre		
K2	989[1]	1101	1231
"Johnson"	787	892	659

[1] 7% moisture; Ave. Grain Recovery 79%

(a)

Variety	Grain Yield, lb/Acre
K2	1107
"Johnson"	779
Significance	*
Blsd (.05)	263

(b)

N Rate, lb/Acre	
0	888
40	997
80	945
Significance	NS

Table 6. Effect of Nitrogen application on N concentration in 2nd leaf of two varieties at jointing,
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate, lb/Acre			Average (Variety)
	0	40	80	
	N % in Dry Matter			
K2	3.24[1]	4.11	3.71	3.69
"Johnson"	3.30	3.65	3.96	3.63
Average (Rate)	3.27	3.88	3.84	

[1] Average of 60 plants
Significance *
BLSD (0.05) 0.44

Table 7. Effect of Nitrogen application on plant weight of two varieties at jointing.
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate 0	40	80	Average (Variety)
	Dry Matter, grams per plant			
K2	3.87[1]	3.42	3.73	3.67
"Johnson"	3.75	3.47	4.25	3.82
Average (Rate)	3.81	3.45	3.99	

[1] Average of 60 plants.
Significance (Rate) *
BLSD (0.05) 0.53

Table 8. Effect of Nitrogen application on N concentration of different plant parts at late flowering,
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves
		N % in Dry Matter		
K2	0	1.71[1]	1.00	2.39
	40	1.98	0.93	2.56
	80	1.74	0.88	2.44
"Johnson"	0	1.88	0.95	2.30
	40	1.88	1.04	2.50
	80	1.72	0.91	2.46
Significance		+	NS	NS

[1] Average of 30 plants.

Table 9. Effect of Nitrogen application on total uptake of N by wild rice at late flowering,
Grand Rapids - 1976, 2nd year stand.

Variety	N Rate lb/Acre	Panicles	Stems	Leaves	Total
		N in milligrams per plant			
K2	0	69[1]	121	104	294
	40	76	113	121	310
	80	80	140	144	364
"Johnson"	0	79	139	109	327
	40	82	152	133	367
	80	58	114	122	294

[1] Average of 30 plants.
Significance NS.

B. FERTILIZATION STUDIES ON PEAT

Since the great majority of paddies in Minnesota are on organic soils it is important that soil fertility and fertilization problems are investigated on organic soils. In the past our effort in the soil fertility area has been handicapped by the lack of an experimental site on peat. In fall of 1975 a suitable area of nearly 2 acres in size was located in one of Kosbau Bros. paddies in Aitkin county. A good first year stand of K2 variety was present. Soil samples were collected and depth of peat was measured in October of 1975. Soil characteristics for areas eventually occupied by experiments are given in Table 10.

Experiments were staked out and fertilizer materials were applied by hand on April 3. Fertilizer was not incorporated into the soil. Within a week the area was flooded. Rice was thinned once by airboat on May 26 when plants were in floating leaf-aerial leaf stage. Copper sulfate (20 lb/A) was applied on June 30 to control algae. Plant population, at early tillering stage, was 3 - 4 plants per square foot. Redox potential (Eh) on June 22 was -227 mv. indicating a strongly reduced condition. Paddy was sprayed with chemicals to control blight and rice worm, Helminthosporium was not evident, there was no lodging and no damage caused either by rice worm or blackbirds. By July 14 the paddy had been drained. Experimental areas were harvested on August 18. A 4 x 4 ft. area was hand-harvested from each plot for yield measurement.

Table 10. Depth of peat and soil test values of experimental areas Kosbau Bros., Aitkin County.

Area	Depth of Peat Inches	Soil test results for 0-6 inch depth		
		pH	Extractable P pp2m	Exchangeable K pp2m
Foliar Fertilization 175-225 ft.	7-8	4.6	17	40
NK Experiment 250-350 ft.	8-11	4.6	14	50
NP Experiment 400-500 ft.	18-21-11	4.4	7-15	60

NP RATE TRIAL

The NP experiment was located in an area within the paddy were the peat layer was thickest, ranging from 18-21 inches on north side and decreasing to 11 inches on south side (table 10). Water depth in this portion of paddy was greatest and wild rice yielded more than in the two other experimental areas. Extractable P was 7-15 pp2m indicating low to medium phosphorus level. Three nitrogen rates were used: 0, 40, 80 lb/acre with urea as N source. Concentrated superphosphate (0-46-0) was used to supply phosphorus at three rates: 0, 40, 80 lb P_2O_5/acre. All plots received 60 lb K_2O/acre. Fertilizer treatments were replicated 6 times. Size of individual plot was 12 x 12 ft.

Wild rice yield (table 11) ranged from 1110 to 1171 pounds per acre. Nitrogen and phosphorus treatments had no effect on the grain yield.

Nitrogen concentration in 2nd leaf at jointing ranged from 3.44-4.05% and was increased by application of N in combination of 40 lb P_2O_5 per acre. Total N uptake by the plant at jointing ranged from 82-114 mgm per plant and was increased significantly either by the N80 treatment alone or by N40 treatment in combination with phosphorus. Phosphorus concentration in 2nd leaf at jointing ranged from 0.52-0.58% P but was not affected by applications of either element. Total phosphorus uptake by the plant was not related to fertilizer treatments. A plant, on the average, had taken up 22 mgm P by jointing and 88 mgm by late flowering.

No visual differences in plants related to P treatments were observed during growing season. At the boot to heading-out stages plants in the N0 treatment plots were slightly shorter and lighter in color than those receiving N application.

Table 11. Effect of nitrogen and phosphorus application on grain yield of wild rice 1976,
Kosbau Bros., Aitkin County.

P rate P_2O_5, lb/acre	N rate, lb/acre 0	40	80	Ave.
	Grain yield, lb/acre			
0	1059[1]	1061	1171	1097
40	1098	1064	1132	1098
80	1030	1084	1110	1075
Ave.	1062	1070	1138	

[1] 7% moisture; 79% Ave. Grain recovery
Significance NS

NK RATE TRIAL

Exchangeable potassium in the plot area ranged from 30-70 pp2m considered to be a relatively low level. Depth of peat ranged from 8-11 inches. Nitrogen treatments consisted of 0, 40, 120 lb N/acre. Potassium was applied at rates of 0, 60 and 200 lb K_2O per acre. Urea and muriate of potash (0-0-60) were the fertilizer materials used in this experiment. All plots received 40 lb P_2O_5/acre. Fertilizer was applied by hand on April 3 but was not incorporated into the soil.

Plants, at jointing and boot stages, showed striking response to nitrogen treatments. Plants in NO treatment plots exhibited typical nitrogen deficiency symptoms: plants were slightly shorter and lighter in color than those observed in plots receiving N applications. Lower leaves were yellow with dead tissue at tips; some of these leaves had yellow margins (slightly resembling the marginal scorch observed in K deficient corn leaves). Response of wild rice to K treatments was not detected by visual observation.

Yield of wild rice, in this experiment ranged from 737 to 931 lb/acre (table 12). Nitrogen,applied at a rate of 120 lb/acre, increased the grain yield by 133 pounds per acre. On the other hand, potassium treatments (60 and 200 lb K_2O/acre) had no effect on the yield.

Weight and several chemical characteristics of plants collected at jointing and late flowering were affected by NK treatments. Most effective, however, appeared to be nitrogen treatments, particularly when applied at the high rate (120 lb/acre).

Dry matter at jointing ranged from 4 to 5 grams per plant and the increase was mainly due to N. At late flowering, an average plant weighed from 18 to 26 grams and the increase again was related mainly to N treatments.

At jointing, N concentration of the 2nd leaf was increased from 3.33% to 4.17% by the application of 120 lb N/acre (table 13). Average potassium concentration in 2nd leaf at jointing was 3.80% (table 14). Application of 60 lb K_2O/acre in combination with 40 lb N/acre increased concentration in 2nd leaf from 3.65 to 4.10%.

Total N uptake by wild rice was increased by the use of high rate of N. At jointing, a plant had taken up 100 to 160 milligrams of N. The same relationship between N uptake and nitrogen rate was found at late flowering (table 15). On the average, 237 grams of N had been taken up by wild rice. Total N uptake by plant was increased from 199 to 313 milligrams by the use of 120 lb N/acre.

Total K uptake by the plant also showed significant increases. However, such increases in K uptake resulted more from the increased dry matter production caused by N application than from K treatments. An average plant contained 125 grams of K at jointing and 237 grams at late flowering.

Table 12. Effect of nitrogen and potassium application on grain yield of wild rice - 1976,
Kosbau Bros.

K rate K_2O, lb/acre	N rate, lb/acre			
	0	40	120	Ave.
	Grain yield*, lb/acre			
0	778	801	909	829
60	737	827	931	832
200	795	811	869	825
Ave.	770	813	903	

* 7% moisture; 79 ave. grain recovery
Significance +
BLSD (0.10) 133

Table 13. Effect of NK application on N concentration in 2nd leaf at jointing,
Kosbau Bros. - 1976.

K rate K_2O, lb/acre	N rate, lb/acre 0	 40	 120	Average (K rate)
	N% in dry matter			
0	3.47[1]	3.49	3.33	3.43
60	3.34	3.43	4.12	3.63
200	3.28	3.65	4.17	3.87
Average (N rate)	3.36	3.52	3.87	

[1] Average of 60 plants
Significance *
BLSD (0.05) 0.70

Table 14. Effect of NK application on K concentration in 2nd leaf at jointing,
Kosbau Bros. - 1976.

K rate K_2O, lb/acre	N rate, lb/acre 0	 40	 120	Average (K rate)
	K% in dry matter			
0	3.49[1]	3.65	3.83	3.66
60	3.77	4.10	3.83	3.90
200	3.79	3.95	3.81	3.85
Average (N rate)	3.68	3.90	3.82	

[1] Average of 60 plants
Significance +
BLSD (0.10) 0.37

Table 15. Effect of NK application on N uptake by wild rice at late flowering,
Kosbau Bros. - 1976.

K rate K_2O, lb/acre	N rate, lb/acre 0	 40	 120	Average (K rate)
	N in milligrams per plant			
0	207[1)]	190	294	230
60	204	205	324	244
200	187	203	322	237
Average (N rate)	199	199	313	

1) Average of 30 plants
Signiicance *
BLSD (0.05) 85

FOLIAR FERTILIZATION

Growers' interest was aroused by the publicity given, last winter, to work by Dr. John Hanway at Iowa State University (J. J. Hanway, Foliar Fertilization of Soybeans, 28th Annual Fertilizer & Ag. Chemicals Dealers Conference, Des Moines, Iowa, 1976). Yields, on some fields, had been increased by 10 to 20 bushels per acre by applying a specially formulated fertilizer solution on foliage during the seed-filling period. The keys to the new technique appeared to be time of application and the ratio of specific nutrients of the solution. Understanding what happens within the soybean plant during its development was helpful in this research.

During the seed filling period, sugars produced in the leaves are moved to the seeds. This normal occurrence shortchanges the root's food supply, then (a) root growth slows down or stops, (b) nodules die, hence a reduced nitrogen supply, (c) nutrient uptake from the soil is reduced, and (d) loss of leaf nutrients as they nourish the seed causes a decline in photosynthesis (sugar manufacture) and further bean growth stops.

Supplying the depleted leaves with the right ratio of nutrients at this strategic time is expected to stop the decline of the soybean plant and can increase yield because it will prevent leaf nutrient depletion and keep leaves and roots active longer. But, excess amounts of fertilizer on the leaves can injure, or "burn" the leaves. So to increase seed yield by use of foliar fertilization, it is essential that the proper kinds and amounts of fertilizer solutions be sprayed on the plants at the proper times.

Numerous soybean leaf spraying trials were conducted in the Midwest during 1976. In some instances yields were increased slightly by foliar fertilization but there were many cases where serious "leaf burn" reduced yields resulting from foliar spraying related either to drought or too high application rate. "Wait and see" is the advice on foliar fertilization of soybeans that most researchers give.

Hanway (Foliar Fertilization of Soybeans, talk given at Soils, Fertilizer and Agricultural Pesticides Shortcourse, Minneapolis, Minn. 12/15/76) feels that there still is much to be learned before foliar fertilization should be generally recommended for farmers. But, he suggests that, because of the potential and the successes that have been obtained research should be continued. Research is needed to determine: (1) The most effective time and rate of application; (2) Forms of nutrients that are effective; (3) The most effective adjuvants; (4) Factors that result in leaf burn; (5) The effects of dew, urease, etc.; (6) Factors that limit yield increase.

Hanway has emphasized that foliar fertilization is in addition to, not a substitute for, for other good crop production and soil fertilization practices. To be successful, foliar treatment should supply all four elements, N. P, K and S, at about the same ratio as found in grain. Spray applications should be made at 2 to 4 times during the seed-filling period and each application should not exceed 20 to 25 lb N/acre.

FORMULATION

An objective of foliar fertilization is to supply four major nutrient elements at a ratio as closely as possible to that found in the seed. The concentrations of NPKS in wild rice grain are:

Nutrient	Green rice	Dehulled rice
	% in dry matter	
N	2.04	2.39
P	0.42	0.44
K	0.40	0.30
S	0.15	

So the desired ratio of the four elements, on elemental basis, is 6: 1: 1: 0.58, or on oxide basis 6: 2.3: 1.2: 0.58. Note: with the available fertilizer materials, the actual formulation was 6 - 2.3 - 3.7 - 0.58. It contained 3 times more K than desired. A fertilizer solution, having this formulation and applied at a rate of 250 pounds per acre (26.4 gallons/acre, since the material has specific weight of 9.4 lb per gallon) would give: 15+6+9+1.3S pounds per acre of plant nutrients at each spraying. Table 16 shows the formulation, materials used and the cost of foliar fertilization.

Table 16. Formulation for a 6-2,3-3.7-0.5S fertilizer solution

Material	Pounds per ton	Cost per pound	Cost per ton	Nutrient element	lb per ton	%
Urea (46-0-0)	260	6¢	$15.60	N	120	6
Potassium polyphosphate (0-26-25)	177	12.4	21.95	P_2O_5	46	2.3
				K_2O	44	3.7
Potassium sulfate (0-0-50-17S)	58	6.4	3.71	K_2O	29	
				S	10	0.5
Water	1505					

Total	2000*	$41.26
Add dealer service charge (25%)		10.32
Approximate cost to grower		$51.58

At 250 lb/acre: 0.125 tons x $51.58	$6.45/acre
Aerial application ($3.00 + 26.4 gal. x 25¢)	9.60/acre
Total cost per application	$16.05/acre
2 applications	$32.10
3 applications	$48.15

*Plus Tween 80 surfactant (adjuvant)

Potassium polyphosphate was supplied by the TVA, and Dr. Harvey Meredith (TVA) provided necessary information for calculating formulation and costs. Soil application of 40+40+60 lb/acre of N, P_2O_5 and K_2O, at 1976 prices, would cost $18.20 per acre.

In spring of 1976, a foliar fertilization trial was established with 2nd year stand of K2 variety on peat, Kosbau Bros. paddies, Aitkin county in an area adjoining the NK and NP experiments. Depth of peat was 7-8 inches. Soil test results (Table 10) indicated medium extractable P and low exchangeable K levels. Soil applications of fertilizer (40+40+60) were made by hand on April 3 but fertilizer materials were not incorporated into the soil. The paddy was flooded on April 4. Rice was thinned once with an airboat at floating leaf-aerial leaf stage. At 2nd aerial leaf stage the plant population was 4 plants per square foot. To control algae, 20 lbs per acre of copper sulfate were applied at boot stage. Pesticides were applied to control Helminthosporium and rice worm. Fertilizer solution was sprayed on 12 x 12 ft. plots with an electric cordless garden sprayer at a rate of 400 milliliters per plot. Foliar applications were made on the following dates:

1st spraying, 6/30 - at boot stage,
2nd spraying, 7/20 - mid-flowering,
3rd spraying, 8/06 - early grain formation.

No "leaf burn" damage was observed in this trial. Plots were harvested on August 18. Two 4 x 4 ft. areas were hand harvested from each plot. One replication, however, was not harvested because of extremely poor stand and growth due to low water level and weeds.

Table 17. Effect of foliar and soil application of fertilizer on the grain yield of wild rice - 1976, Kosbau Bros., Aitkin County.

Foliar Application					Soil Application		
Number	Total plant nutrients applied lbs/Acre				None	40+40+60	Average (Foliar)
	N	P_2O_5	K_2O	S			
					Grain yield[1], lb/acre		
None	None				658[2]	717	688
1x	15 +	6 +	9 +	1.3	---	734	734
2x	30 +	12 +	18 +	2.6	---	867	867
3x	45 +	18 +	27 +	3.9	781	791	786
Average (soil)					720	777	

[1] 7% moisture; [2] Ave. of 3 replications; Significance NS; C.V. % 16.7

Wild rice yield was increased slightly by foliar fertilization (table 17). The most effective treatment consisted of soil application (40+40+60) and two foliar applications (30+12+18+2.5S) made at boot and early grain formation.

Foliar fertilization of wild rice is not a recommended practice at the present time. With the varieties and production know-how that are available today, nutrient requirements of the plant can be satisfied effectively and economically by conventional soil applications of NPK and N topdressing. But there is potential that should be explored by continued investigation of this new practice. First, the positive trends of wild rice yield obtained in the 1976 trial look promising. Secondly, growers already are applying pesticides and topdress-N by airplane or helicopter. So there is a possibility of combining these operations, thus, making foliar fertilization more economical than it is today.

C. POTASSIUM RATE TRIAL

The role of potassium in wild rice production is subject to frequent inquiry. The possibility that losses caused by lodging or disease may be lessened, as in other crops, by the application of K is most intriguing to growers. Some growers have experimented with different K rates but the results have been inconclusive. In our own experiments, moderately high rates of potassium (200 lb/acre K_2O) have not produced any striking results. In 1974 on peat, plots receiving 200 lb/acre K_2O combined with 0-40 lb/acre N, had healthier plants and less lodging than plots receiving 0 or 40 lb/acre K_2O treatments. This, however, was not true for the 120+40+200 treatment. Since it is possible that rather large amounts of K are required for the nutrient to become beneficial to the crop, it was decided to include in this study some exceptionally high rates. Two trials were established on growers paddies. The cooperators applied fertilizer in 40-60 ft. wide strips in fall of 1974. In 1976 one of these trials was discontinued. The remaining trial was located in paddy No. 2W owned by the Clearwater Rice, Inc. in Clearwater county. The paddy had a good stand of "Johnson" wild rice (1972 seeding). Muriate of potash (0-0-60) was applied in 40x516 ft. strips in fall of 1974 and then rototilled into the soil. A basic application of 35+12+7 was made by airplane on June 29, 1976. Paddy was treated with insecticide against rice worm but Dithane was not used. The stand was thinned with an airboat. There was very little lodging in the paddy and infection with Helminthosporium was not serious. The yield was determined by harvesting two 4 x 4 square areas from each strip.

Grain yield was variable and did not appear to be affected by fertilization with potassium (table 18). At jointing stage, dry matter weight, K% of 2nd leaf and total K uptake by plant were not affected by K treatments (table 19, 20, 22). At the late flowering stage, however, the extremely high rates of potassium, made in fall of 1974, appeared to result in slight increases of total plant weight (table 19), K concentration in stems and leaves (table 21) and total K uptake by the plant (table 22).

Table 23 shows K test results of samples collected from the fertilizer strips (0-6 inch depth) at the end of 1975 and 1976 growing seasons. Exchangeable potassium in the root zone was increased only slightly by the application of 840-1260 lb K_2O/acre. Generally, in this trial, high to extremely high rates of potassium fertilizer had little or no effect on disease resistance, lodging and yield.

Table 18. Residual effect of K application on grain yield of wild rice on peat,
1976 - Clearwater Rice, Inc.

Treatment (1) K_2O, lb/acre	Grain Yield lb/Acre
0	720 (2)
42	633
210	543
420	768
630	867
840	753
1050	1032
1260	771

---

1) All strips received a basic treatment of 35+12+7 applied by plane on June 29.

2) 7% Moisture.

Table 19. Effect of K application on dry matter of wild rice,
1976 - Clearwater Rice, Inc.

Strip No.	Treatment K_2O, lb/Acre	Dry matter At jointing	Dry matter At late flower
		Grams per plant	Grams per plant
1	0	9 (1)	25 (2)
2	42	11	22
3	210	13	24
4	420	12	23
5	630	6	23
6	840	9	25
7	1050	13	33
8	1260	8	31

---

1) Average of 10 plants; 2) Average of 5 plants

Table 20. Effect of K application on K concentration of wild rice tissue at jointing stage - 1976. Clearwater Rice, Inc.

Strip No.	Treatment K_2O, lb/Acre	2nd leaf	Whole plant
		K% in dry matter	
1	0	3.45[1]	5.00[1]
2	42	3.79	3.90
3	210	3.97	4.63
4	420	3.37	4.87
5	630	4.29	5.12
6	840	3.97	5.21
7	1050	3.81	4.88
8	1260	3.73	5.96

[1] Average of 10 plants

Table 21. Effect of K application on K concentration of wild rice tissue at late flowering - 1976. Clearwater Rice, Inc.

Strip No.	Treatment	Stems	Leaves	Flower parts
			K% in dry matter	
1	0	3.36[1]	2.58	1.47
2	42	3.98	2.84	1.38
3	210	4.15	2.51	1.21
4	420	3.41	2.63	1.44
5	630	4.62	3.52	1.54
6	840	4.81	3.39	1.53
7	1050	4.86	3.18	1.86
8	1260	5.02	3.46	1.73

[1] Average of 5 plants

Table 22. Effect of K application on K uptake by wild rice, 1976 - Clearwater Rice, Inc.

Strip No.	Treatment K_2O, lb/Acre	Stage of development: Jointing	Stage of development: Late flowering
		— K uptake, milligrams per plant —	
1	0	425[1]	728[2]
2	42	440	738
3	210	615	796
4	420	549	665
5	630	324	908
6	840	487	998
7	1050	630	1268
8	1260	486	1274

[1] Average of 10 plants

[2] Average of 5 plants

Table 23. Effect of K application to peat on soil test levels, Clearwater Rice, Inc.

Treatment* K_2O, lb/Acre	Sampling date: 9/11/75	Sampling date: 8/31/76
	Exchangeable K, pp2m	
0	60	50
42	50	50
210	30	40
420	30	50
630	50	70
840	110	60
1050	100	90
1260	110	70

* Applied as 0-0-60 in fall 1974 and rototilled into the soil.

D. WEATHER AND PLANT DEVELOPMENT

The growing season of 1976 was an unusally warm and dry one. When compared to the normal (for a period 1931-60) all months from April through August in 1976 were warmer and consequently had a greater number of Growing-Degree-Days (see table 24 and Fig. 1). This warmer weather, coupled with increased solar radiation, allowed wild rice growth and development to advance about 2 weeks ahead of the usual pattern. Air temperature data for the Aitkin and Clearwater (Fosston) areas were taken at the nearest available weather station. These data may differ somewhat from actual temperature conditions in the peat bog area (bogs are usually cooler than upland areas) but they are indicative of the same "warmer than normal" trend.

The temperature and GDD data indicate that April, 1976 was much warmer than usual and started the growing season early. Upon seedling emergence, in mid-May, development was consistently ahead of the usual schedule. When compared to 1974, which had very close to normal temperature, 1976 wild rice development stages were always advanced by 2 weeks or more. The jointing stage occurred in mid-June rather than in mid-July and final harvest was in early September rather than mid-September (see Fig. 2). Regardless of planting date, however, the actual number of days from the floating leaf stage to maturity is rather constant and, at Grand Rapids, may vary from 90 to 110 days.

This early plant development during 1976 was also aided by increased solar radiation. Cloud cover was reduced and consequently radiation was increased by approximately 20%.

All of these factors leading to advanced plant development were beneficial in that they reduced the amount of late season cool weather and eliminated chances of frost injury.

Table 24. Average air temperature as measured at three U.S. weather stations.1)

Station, Year			Month			5 Month Average	GDD T_b=40
	April	May	June	July	August		
	average air temperature, °F						
Fosston, Polk Co.							
Normal2)	41.0	54.6	63.6	69.4	67.5	59.2	2954.5
1974	41.0	50.5	63.4	71.6	62.8	57.9	2743.9
1975	34.8	55.7	61.9	70.5	64.6	57.5	2851.8
1976	46.6	54.9	66.8	68.8	70.9	61.6	3314.6
Grand Rapids, N.C. School							
Normal	39.9	52.7	62.0	67.4	65.1	57.4	2681.2
1974	41.6	49.4	62.7	70.7	62.8	57.4	2669.5
1975	34.7	57.0	62.2	71.5	65.2	58.1	2950.7
1976	47.1	54.4	66.1	68.2	67.4	60.6	3166.0
Aitkin							
1974	42.9	49.8	63.1	71.1	63.3	58.0	2770.2
1975	39.0M	59.4M	64.4M	72.1	66.2M	60.2	3140.7
1976	47.5	54.8	66.8	69.3M	68.1	61.3	3267.2

1) Source: Climatological Data, Minnesota, Vol. 80, 81, 82 (1974-76), U.S. Dept. of Commerce.

2) Normals for the period 1931-60.

3) M = less than 10 days record missing.

Fig. 1. CUMULATIVE GROWING DEGREE DAYS, GRAND RAPIDS

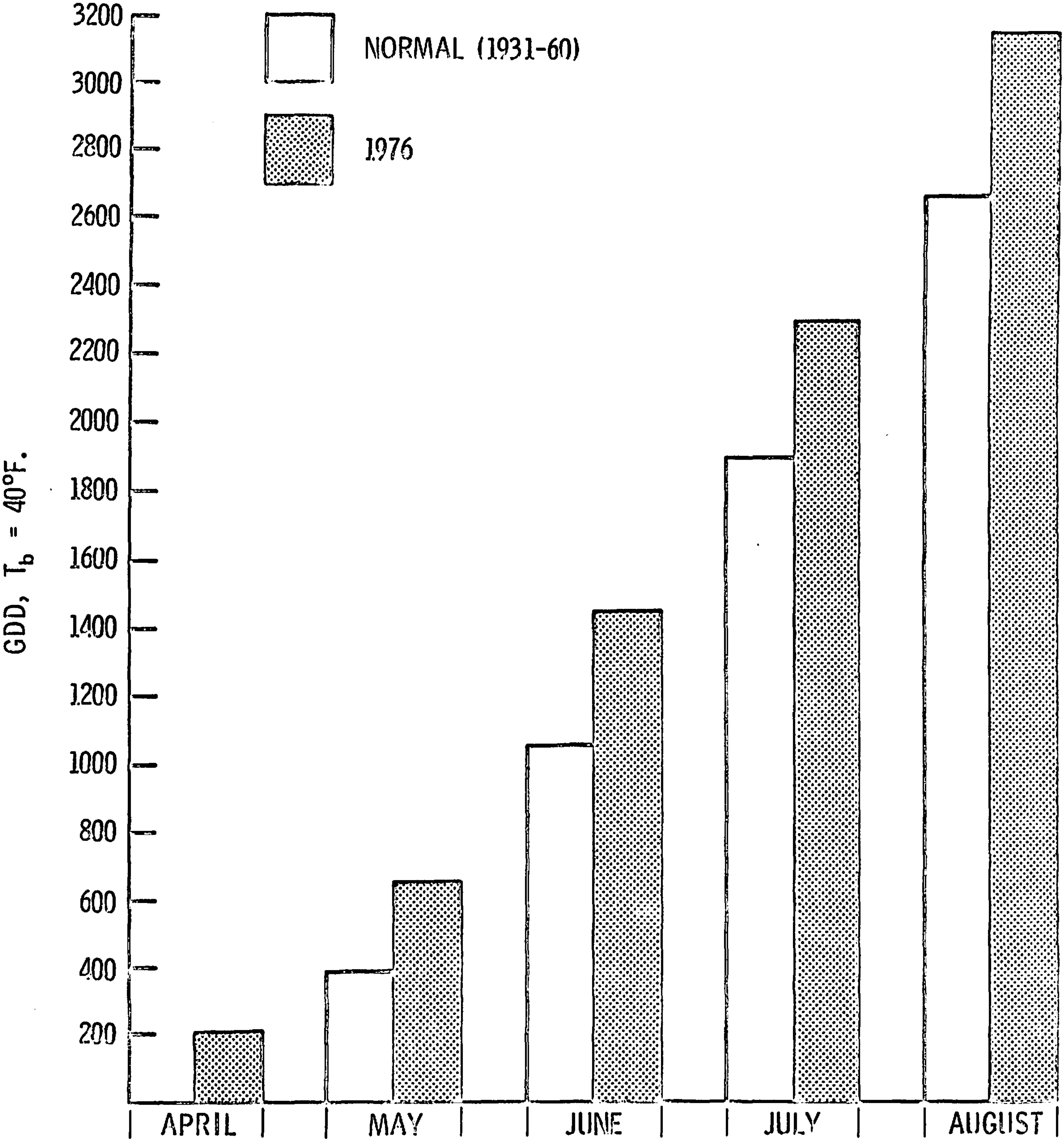


Fig. 2. DEVELOPMENT OF WILD RICE AT GRAND RAPIDS - 1974, 1975, 1976
JOHNSON VARIETY

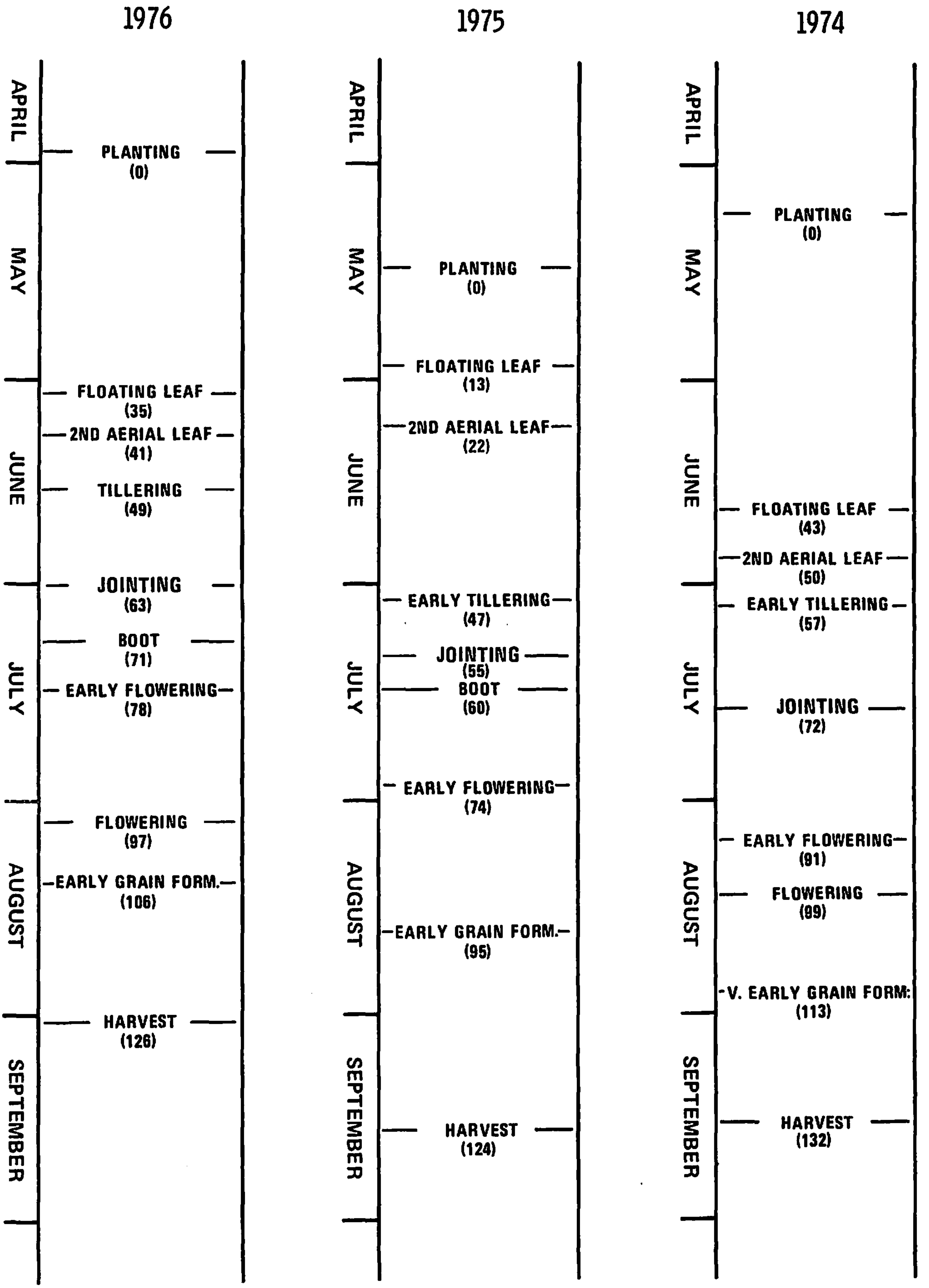
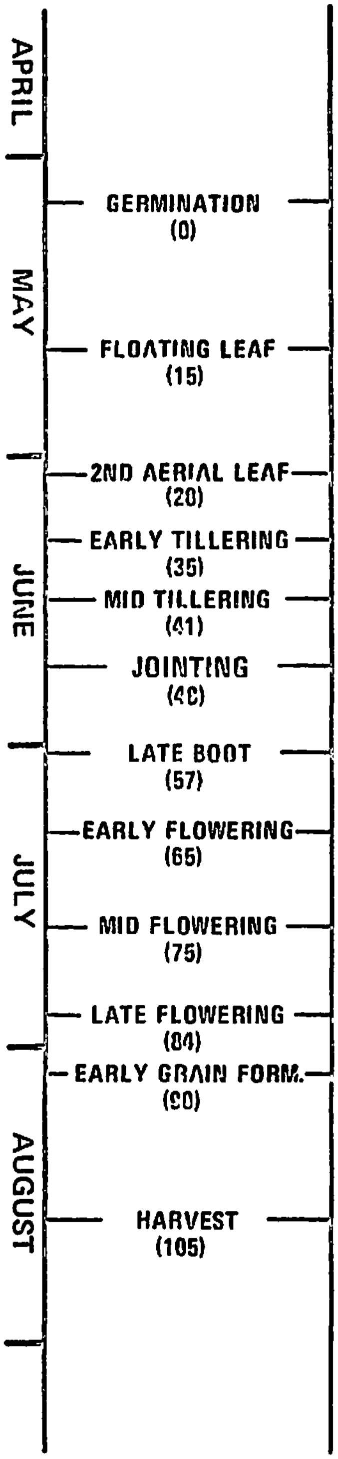


Fig. 3.
WILD RICE DEVELOPMENT
KOSBAU BROS. AITKIN CO.; 1976
K2 VARIETY
(April 3, 1976 - frost @ 3" depth)



TEMPERATURE MEASUREMENTS - 1976

Soil temperatures were taken during the growing season at Grand Rapids and at a commercial grower's paddy in Aitkin county. Air and water temperatures were also measured at the Aitkin county site. The soil temperature at Grand Rapids was measured by a stainless steel probe, inserted horizontally at about the 6 inch depth and connected to a thermometer measuring maximum, minimum and current soil temperatures (in °F.). This thermometer was read and reset daily. The soil, air and water temperatures at the Aitkin county site were measured by a 3 point, automatic sensing and recording thermograph (Weathermaster Corp. #T603). One probe was inserted into the soil at a 6 inch depth, one probe was placed in the water horizontally at a depth 6 inches from the water surface, and one probe was placed 3 feet above the water surface. Selected data for the two sites are reported at 5 day intervals (see Fig. 4-6).

The soil temperature for the Grand Rapids mineral soil (Fig. 4) was found to fluctuate much more than in the peat soil at the Aitkin county site (Fig. 5). The mineral soil temperature often varied by as much as 10°F in a single day, whereas the peat soil never varied by more than 3°F in a single day. However, both soils followed the same general heating and cooling trends. Both soils reached their maximum temperatures during the second week of June with the mineral soil reaching a high of 79°F and the peat soil reaching 70°F. After reaching these peaks both soils fluctuated within 60° and 70°F until harvest, with the peat soil being slightly cooler than the mineral soil.

The air and water temperatures at the Aitkin county site (Fig. 6) showed much greater fluctuations than the soil temperature. The water temperature closely followed the daily air temperature fluctuations. The mean water temperature was always slightly higher than the mean air temperature. The soil temperature was much more stable than air and water temperatures and stayed within the 60° and 70° range after it had reached its maximum.

Fig. 4. SOIL TEMPERATURE, 1976, GRAND RAPIDS - SOILS PADDY

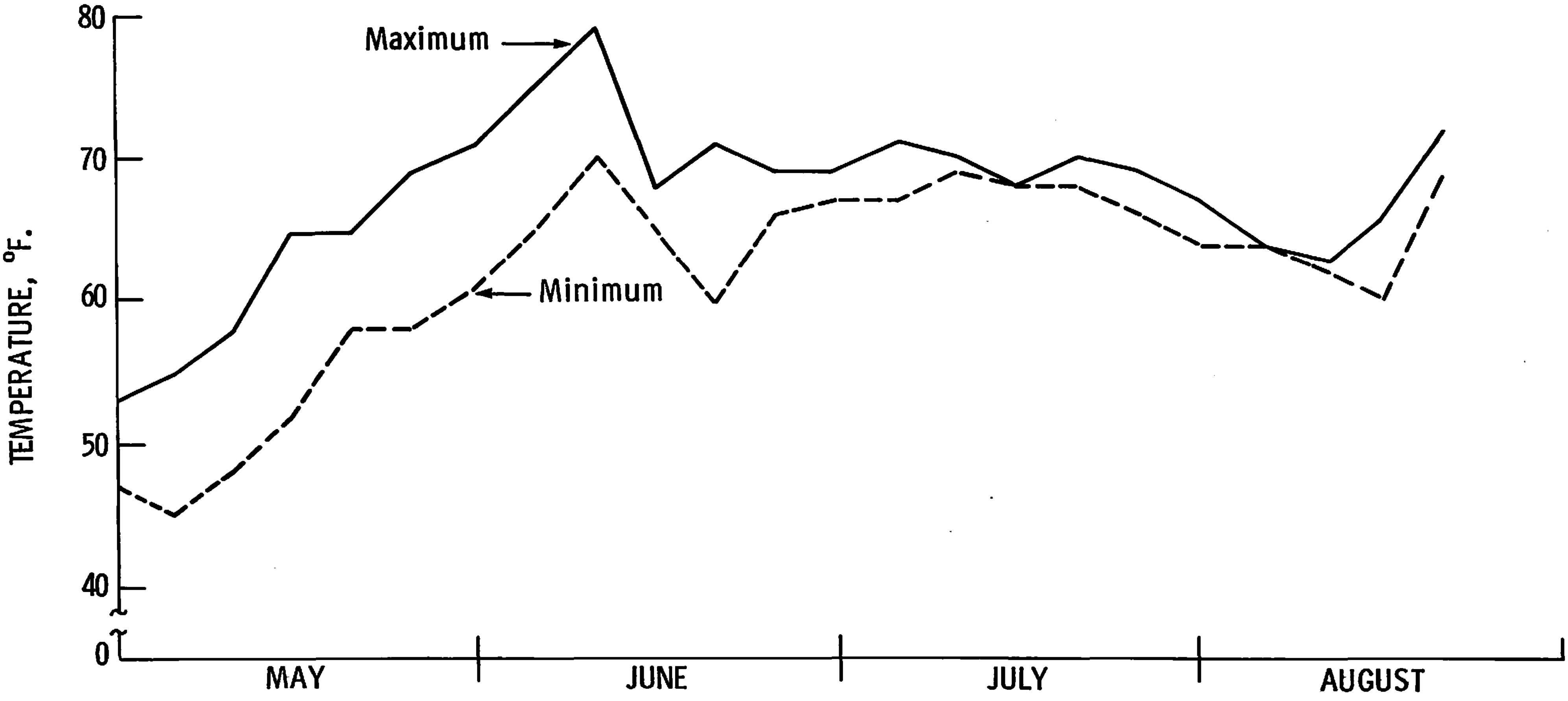


Fig. 5. SOIL TEMPERATURE, 1976, KOSBAU BROS., AITKIN COUNTY

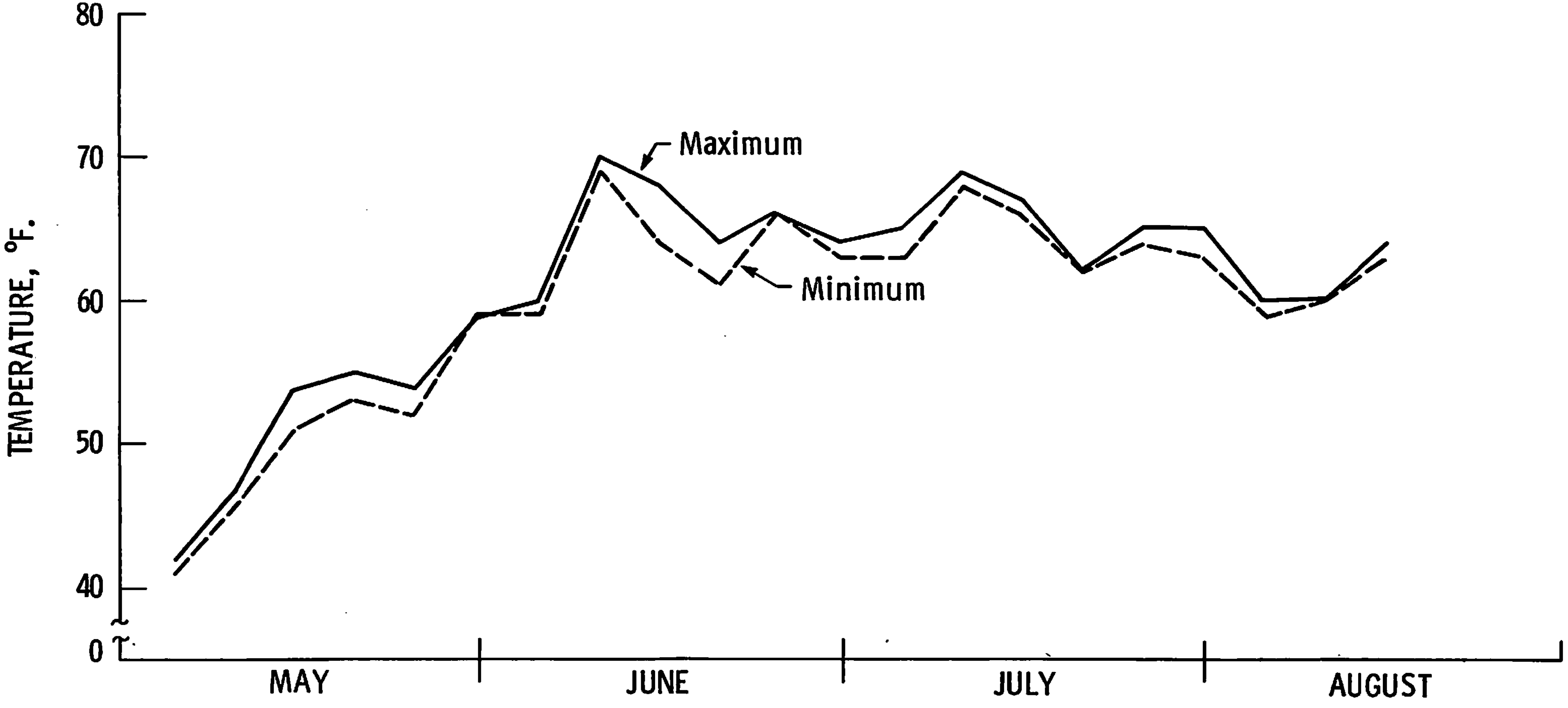
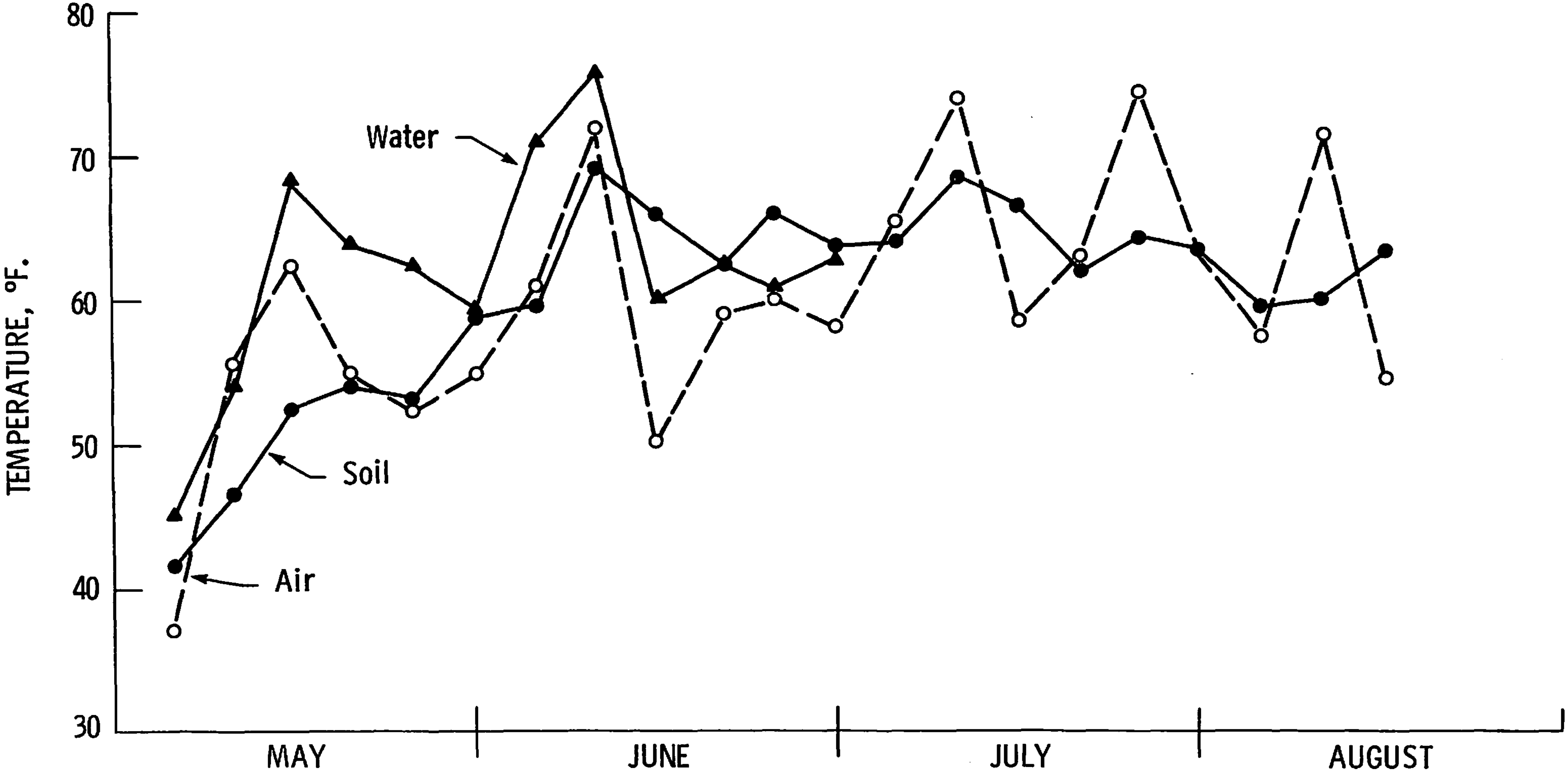


Fig. 6. MEAN AIR, WATER, SOIL TEMPERATURES, KOSBAU BROS., 1976



E. CHEMICAL CHARACTERISTICS OF PADDY WATER

The quality of paddy water is of interest to the grower as well as to state and federal agencies. The grower may be concerned, for example, with the concentration of sulfate in the water. Plant response to fertilization also may be related to nutrient levels found in the water. Public control agencies may want to know the levels of nitrogen and phosphorus present in the water when it is released during draining of paddies.

Water samples were collected from four paddies during 1976 growing season. Two of the paddies located on the Grand Rapids Experiment Station were used for nitrogen rate studies on mineral soil. Source of water is the Prairie River. The third sampling site was a paddy on peat in Aitkin county in which 3 fertilization trials were conducted. Paddies, at this location, derived water from the Little Willow River via a diversion ditch. Water passed through two other production paddies before entering the research paddy. Water level in the paddy dropped from June 15 on due to evaporation and by July 14 the remaining water had been drained off. The fourth paddy on peat in Clearwater county was the site of a potassium rate strip-trial. Water from Clearwater River reaches this paddy via Ruffy Brook. Chemical determinations were made by the Research Analytical Laboratory, University of Minnesota. Information on sampling dates and the chemical composition of water are given in table 25.

The alkalinity of water is its capacity to neutralize acid. The results, in this report, indicate alkalinity obtained by titration with a combination of indicators having an endpoint of pH 5.0. In most natural waters, the alkalinity is practically all produced by dissolved carbonate and bicarbonate ions. Some organic acids also may contribute to titratable alkalinity. The values for alkalinity follow closely to those of hardness. Water samples from the Kosbau paddy showed the lowest alkalinity levels and those from Clearwater the highest with the Grand Rapids paddy water having intermediate values.

The hardness is calculated by mutiplying Ca and Mg concentrations by factors, adding up and is expressed as $CaCO_3$, mg/liter. Water from Clearwater paddy is very hard with values ranging from 201 to 364. Water in Grand Rapids paddies is moderately hard (53-98 mg/L) while the Kosbau paddy has soft water with hardness values ranging from 26 to 62.

Chemical characteristics of water from 1st and 2nd year paddies at Grand Rapids were nearly the same. Total N, generally, did not exceed the 2 ppm level and total P concentration ranged from 0.13 to less than 0.01 ppm. Potassium concentration during most of the growing season was less than 2 ppm. Water contained less than 2 ppm sulfate-S or less than 6 ppm of sulfate (SO_4).

Water from paddy on peat located in Aitkin county, contained about 1.9 ppm total N and 0.73 ppm P at the end of April. Levels of these two chemical elements in water increased as the season progressed due to evaporation and release from the soil. Maximum levels of 4.97 ppm of total N and 2.75 ppm P were reached during June. Potassium levels also were exceptionally high in the water of this paddy. However, the water did not contain appreciable amounts of sulfate.

Water from the paddy on peat in Clearwater county contained 1.88 to 3.55 ppm total N, but the total P concentration was less than 0.7 ppm. May sampling showed 12.1 ppm K but by August the concentration had decreased to 3.3 ppm. Sulfate level in samples from this paddy varied considerably. The highest concentration of 13.6 ppm sulfate-S was measured on May 11, equivalent to 40 ppm of sulfate (SO_4).

ACKNOWLEDGMENTS

Grateful acknowledgments are made to following cooperators and University personnel for their valuable assistance during 1976 in obtaining information reported here: Messrs. Franklin and Harold Kosbau, Aitkin county; Messrs. Donald Barron and Ray Skoe, Clearwater Rice, Inc.; Dr. Wm. Matalamaki and the Staff, North Central Experiment Station, Grand Rapids; Drs. E. A. Oelke and M. F. Kernkamp, Messrs. Owney Koski and Henry Schumer, University of Minnesota; CENEX Co-op Oil Association, Gully.

Table 25. Chemical composition of water collected from wild rice paddies during the 1976 growing season.

Sample No.	Sampling Date	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Grand Rapids, 1st year paddy												
3.	4/28	50	58	.76	.20	.27	.61	< .01*	< 2.0#	16.5	4.0	1.5
9.	5/21	69	75	1.00	.10	< .01	.08	.02	< 2.0	20.6	5.8	2.0
15.	6/3	78	81	.53	.07	.07	.05	.01	< 2.0	22.5	6.1	2.3
17.	6/9	84	87	1.07	.19	< .01	.08	< .01	< 2.0	24.5	6.3	2.1
24.	6/16	68	73	.73	.10	.05	.05	< .01	< 2.0	20.6	5.3	1.6
28.	6/22	70	73	.58	.04	< .01	.02	< .01	< 2.0	20.0	5.6	1.5
32.	6/30	46	53	.90	.07	< .01	.04	< .01	< 2.0	15.1	3.6	.4
35.	7/8	73	81	1.61	.19	< .01	.13	.05	< 2.0	22.7	5.8	1.4
39.	7/15	78	76	1.60	.21	< .01	.16	.04	< 2.0	20.9	5.7	1.3
43.	7/22	79	77	1.99	.18	< .01	.21	.02	< 2.0	21.4	5.8	1.4
47.	7/27	83	80	1.33	.08	.01	.12	.03	< 2.0	22.7	5.6	1.8
49.	8/3	91	87	1.48	.33	< .01	.10	.04	< 2.0	24.0	6.5	1.5
53.	8/12	104	98	1.70	.26	< .01	.06	.01	< 2.0	25.8	8.1	2.0
Location: Grand Rapids, 2nd year paddy												
4.	4/28	50	57	.84	.10	.19	.37	< .01	< 2.0	16.3	4.0	1.6
10.	5/21	72	77	.96	.07	< .01	.06	.01	< 2.0	21.7	5.6	1.8
16.	6/3	86	86	.62	.08	< .01	.06	.01	< 2.0	24.1	6.2	2.7
18.	6.9	84	81	1.09	.22	< .01	.14	.03	< 2.0	22.1	6.3	2.2
23.	6/16	65	71	.73	.14	.05	.06	< .01	< 2.0	19.7	5.3	1.4
27.	6/22	72	71	1.31	.06	< .01	.13	.13	< 2.0	19.6	5.3	1.4
31.	6/30	48	55	1.00	.08	< .01	.06	.01	< 2.0	15.9	3.8	< .1
36.	7/8	66	75	.93	.07	< .01	.03	.01	< 2.0	21.7	5.0	1.1
40.	7/15	78	72	1.46	.13	< .01	.10	.02	< 2.0	20.1	5.2	2.1
44.	7/22	73	65	2.12	.11	< .01	.17	.05	< 2.0	18.4	4.7	2.6
48.	7/27	71	67	.88	.07	< .01	.06	.02	< 2.0	19.6	4.5	2.0
50.	8/3	78	72	1.77	.32	< .01	.18	.13	< 2.0	20.2	5.2	4.2
54.	8/12	93	81	1.10	.29	< .01	.13	.13	< 2.0	23.3	5.6	6.0

* < = less than; # 2.0 ppm sulfate-S x 3 = 6.0 ppm sulfate (SO_4).

Table 25. Chemical composition of water collected from wild rice paddies during the 1976 growing season (continued).

Sample No.	Sampling Date	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Ammonium N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm
Location: Kosbau Bros., Aitkin County												
5.	4/29	32	47	1.90	.20	< .01*	.73	.35	< 2.0#	12.3	3.9	15.7
11.	5/20	48	62	1.53	.30	< .01	1.04	1.01	< 2.0	15.6	5.5	17.9
14.	6/2	38	53	4.97	.58	< .01	1.63	1.63	< 2.0	13.0	4.9	21.4
20.	6/9	25	48	2.59	.63	.01	2.75	2.75	< 2.0	9.9	5.7	28.5
22.	6/15	10	28	4.32	.61	< .01	2.31	1.97	< 2.0	4.1	4.2	19.7
26.	6/22	13	26	4.45	.38	< .01	1.45	1.22	< 2.0	2.3	4.8	11.2
30.	6/30	18	29	2.78	.31	< .01	1.08	.86	< 2.0	4.0	4.7	6.6
38.*	7/14	50	52	3.45	.29	< .01	.35	.22	< 2.0	11.4	5.8	5.0
Location: Clearwater Rice, Inc., West 2 paddy												
7.	5/11	192	206	2.05	.08	< .01	.12	.03	13.6	55.1	16.5	12.1
33.	7/8	175	201	1.88	.12	< .01	.67	.63	< 2.0	44.5	21.9	9.6
52.	8/11	333	364	3.55	1.55	< .01	.65	.43	9.1	95.2	30.6	3.3

* < = less than; # 2.0 ppm sulfate-S x 3 = 6.0 ppm sulfate (SO_4).

SOIL WATER RECHARGE EXPERIMENT USING DRAINAGE WATER

Lowell Hanson and Dennis Linden

There were indications in the fall of 1975 that subsoil moisture conditions in south central and southwest Minnesota were quite dry and that without above normal rainfall, drought conditions would develop over wide areas in the 1976 crop season. Since ground water resources are generally inadequate for irrigation in this part of the state, the possibility of using drainage water from ditches was considered. A preliminary study of the use of spring drainage water as a soil water recharge source was conducted.

Arrangements were made with a farmer cooperator, Mr. Archie Forsberg, in Sibley County, for an experiment on corn. The site selected was on an area of Nicollet clay loam of 0-3% slope located near State Highway 19 just west of County Road 53. The water was pumped out of Judicial Ditch No. 2 about 300 feet west of the plot area. The total plot area was 1/2 acre and consisted of six plots, each 90.7 x 40 feet. Three treatments and two replications were used.

Initial Soil Water

A Nicollet soil about one half mile west was sampled (Nov. 17, 1974) and had only 0.37 inches of water in the 60 inch profile. However, a detailed sampling of the experiment site in the spring of 1975 showed that water recharge had occurred during the winter and early spring. Moisture samples were collected the week of April 12 and indicated that the soil contained about 70 percent of field capacity, or 7.6 inches of available water based on the moisture holding characteristics of the SCS sample site previously referred to.

Treatments

The three treatments consisted of two water application methods and a check. One of the application methods was a series of 20 inch deep by 4 inch wide trenches spaced 12 feet apart. The trenches were filled with corn cobs, sphagnum peat moss and surface soil. The purpose of this treatment was to test the feasibility of getting water directly into the subsoil, which was somewhat drier than the surface soil. The second water application method consisted of a sprinkler application at a rate of 50 gallons per minute (.63 inches/hr.) on an area of 7280 square feet. Water applications were made the week of April 21 after fertilizer application rates of 150+50+50 per acre. Corn was planted on May 3 and no additional water was applied. The amount of water applied for both methods of application was 3 inches.

Results

The growing season weather was extremely hot and dry in south central and southwest Minnesota. Baker[1] reported that the precipitation departure from normal was -9 to -10 inches in Sibley County from April through August, 1976.

The corn was severely damaged by drought. Yields were increased on the water treatment plots, however, the differences were not significant at the 90 percent probability level.

Corn Yield Response to Spring Water Treatments

Treatment	Yields, Bu/Ac
Check (Rain and no additional water)	30.5
Sprinkler, 3" (Rain + 3")	52.3
Trench, 3" (Rain + 3")	48.1

F 1.74 N.S.

Conclusions

In retrospect, it would have been desirable to have added additional water later in the season. Water was available through early June but pumping equipment was not available.

This additional water would have increased yields substantially. The concept of using water stored from fall and spring runoff or from early drainage flow directly from ditches appears to have merit. Dr. Wallace Nelson at Lamberton plans further work on this concept in 1977.

Appreciation is expressed to Ed Clapp, ARS, for making pump and lines available, and to Curt Klint, Tom Malterer, Archie Forsberg and John Peterson for assisting in the experiment.

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[1] Baker, Donald G. and Earl L. Kuehnast. 1977. The 1976 Drought in Minnesota. Soil Series 68. Soil Science Department. University of Minnesota.

ESTIMATES OF EVAPOTRANSPIRATION

George R. Blake

The following pages show a summary of evapotranspiration estimates based on formulae of Penman and Thornthwaite, net radiation, pan evaporation and measurements of plant water use at Lamberton.

Table 1 compiled by James Swan and Donald Baker shows a summary of some of these values and a judgemental estimate of potential evapotranspiration.

Table 2 is an estimate by George Blake of evapotranspiration at Minneapolis-St. Paul adapted specifically for grass cover. The Et corrections are as judgemental estimates of open water to grass vegetation using both Penman estimates made for England and the ratios for corn at Lamberton.

Figure 1 shows the Minneapolis-St. Paul precipitation and the Et estimates from Table 2.

Table 3 is reworked from Table 2.

Table 1. Monthly ET and PET Estimates and ET Measurements for the Seven County Metropolitan Area (MSP).

	1 PET Mpls. Penman	2 Mpls. PET Thornthwaite	3 R_N St. Paul	4 61-67 Lamberton ET Meas. Corn		5=6x7 ET Est. Mpls. Plan X Factor	6 Factor= Lamb. ET Lamb. Pan	7 St. Paul Pan	8 PET Lamb. Thornthwaite	9 Range of Est.	10 PET Best Est. Adapted
				Mo. Avg.	Mo. Max.						
Jan.	.15										.15
Feb.	.48										.48
Mar.	1.18										1.18
Apr.	2.58	1.25	2.70	.90	1.50	.72	.38	1.90	1.01	1.25-2.58	1.70
May	3.66	3.19	4.30	3.41	4.34	2.46	.43	5.74	3.05	3.19-3.66	3.50
June	4.47	4.87	4.80	5.10	7.20	4.99	.60	8.31	5.03	4.47-5.00	4.90
July	4.96	5.55	5.27	4.96	6.51	6.41	.75	8.55	6.63	4.96-5.55	5.50
Aug.	4.00	4.81	4.03	4.03	4.96	4.40	.66	6.59	4.68	4.00-4.81	4.60
Sept.	2.58	3.07	2.10	2.40	3.60	2.01	.46	4.37	2.81	2.10-3.07	2.50
Oct.	1.43	1.53	0.62	0.31	0.93	0.22	.22	1.04	1.71	1.43-1.53	1.40
Nov.	.48										.48
Dec.	.15										.15
Total	26.12	24.27									26.54
Source	Tech. Bull. 235 Agr. Drought	Baker letter	72 Blue-Book Soils	68 Bluebook-Soils			71 Bluebook	Baker	67 Blue-Book		

Table 2. Estimate of Evapotranspiration for Grass Cover.

	Et[1] Monthly	Et Corr.[2]	Et Corrected	Et Corr. Begin 1/2 Mo. Period	Et 1/2 Mo. Period	Ppt.[3] Begin 1/2 Mo. Period	Ppt. 1/2 Mo. Period	Ppt. Minus Et 1/2 Mo. Period
January	0.15	0.4	0.08					
February	0.48	0.4	0.28					
March	1.18	0.5	0.84					
April 1-15	2.58	0.6	2.21	1.50	0.93	1.67	0.88	- .05
April 15-30				2.21	1.30	1.85	1.12	- .18
May 1-15	3.66	0.7	3.66	3.00	1.66	2.62	1.45	- .21
May 15-31				3.66	1.96	3.19	1.75	- .21
June 1-15	4.47	0.75	4.79	4.2	2.25	3.80	1.95	- .30
June 15-30				4.79	2.52	4.00	1.93	- .59
July 1-15	4.96	0.8	5.67	5.4	2.77	3.70	1.74	-1.03
July 15-31				5.67	2.74	3.27	1.63	-1.11
August 1-15	4.0	0.8	4.57	5.3	2.47	3.25	1.61	- .86
August 15-31				4.57	2.02	3.18	1.53	- .49
Sept. 1-15	2.58	0.7	2.58	3.5	1.51	2.92	1.34	- .17
Sept. 15-30				2.58	1.11	2.43	1.06	- .05
Oct. 1-15	1.43	0.6	1.23	1.85	0.77	1.80	0.85	+ .08
Oct. 15-31				1.23		1.59		
November	0.48	0.4	0.28					
December	0.15	0.4	0.28					

[1] Blake, G.R., E.R. Allred, et al. Tech. Bull. 235. 1960. Agric. Drought and Moisture Excesses in Minnesota.

[2] Takes into account Penman's factors plus those by Baker, D.G. Bluebook, March 1971, p. 11.

[3] Baker, D.G., et al. Tech. Bull. 254. 1967. Climate of Minnesota. Part V. Precipitation, Facts, Normals, Extremes. Values in this column are on monthly basis. Monthly precipitation at beginning of April 1-15 period plus monthly precipitation at beginning of April 11-30 period divided by 4 gives the ppt for 1/2 month period shown in next column.

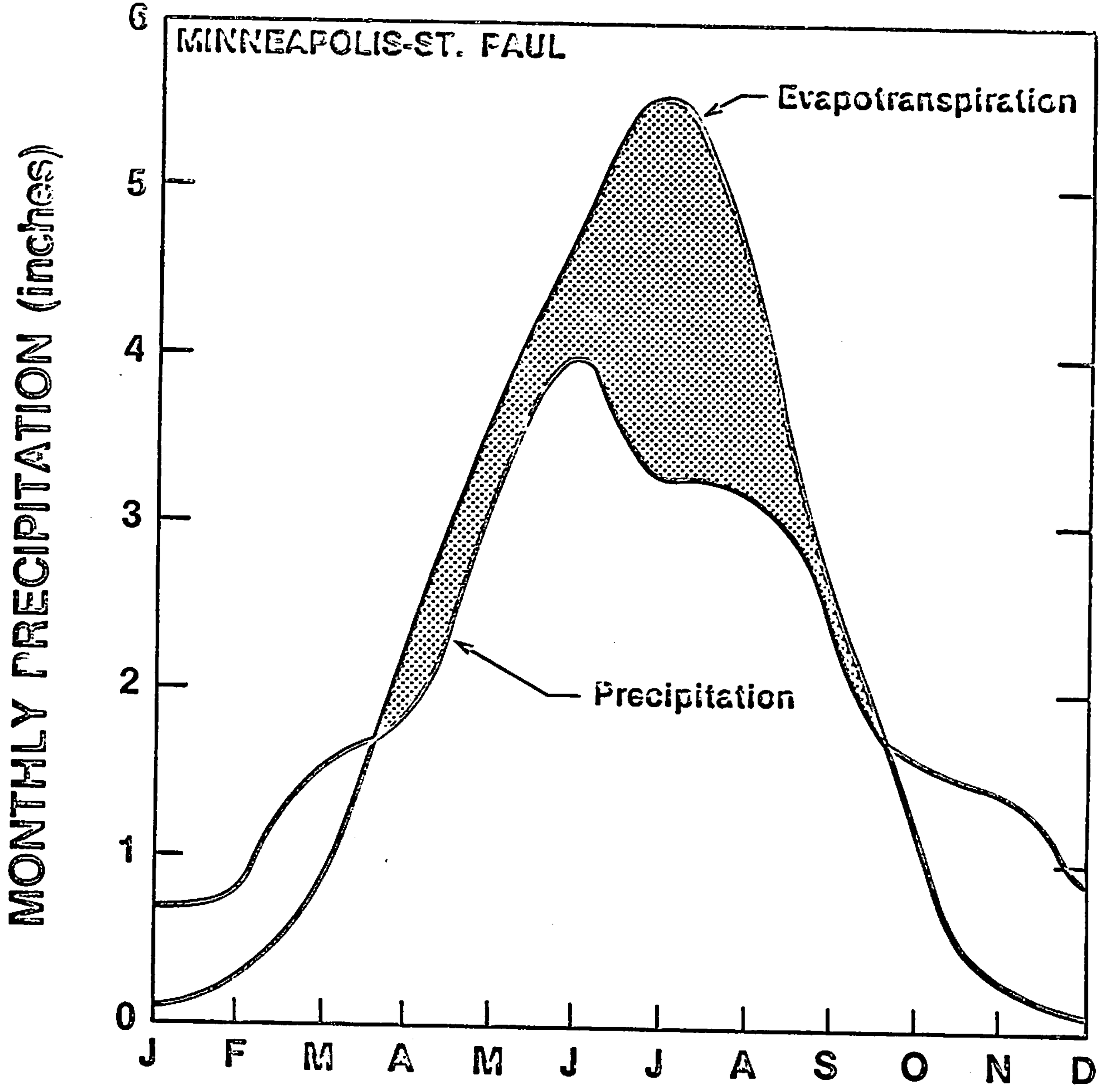
MINNEAPOLIS-ST. PAUL
Evapotranspiration
Precipitation
MONTHLY PRECIPITATION (inches)
0
1
2
3
4
5
6
J
F
M
A
M
J
J
A
S
O
N
D

Table 3. Supplemental Irrigation of Turf

Twin Cities Area

G. R. Blake

Period	Evapo-Transpiration Inches	Normal Rainfall Inches	Supplemental Water Needed Inches
April 1 to 15	0.9	0.9	0
April 15 to 30	1.3	1.1	0.2
May 1 to 15	1.7	1.4	0.3
May 15 to 30	2.0	1.7	0.3
June 1 to 15	2.2	1.9	0.3
June 15 to 30	2.5	1.9	0.6
July 1 to 15	2.8	1.7	1.1
July 15 to 31	2.7	1.6	1.1
August 1 to 15	2.5	1.6	0.9
August 15 to 31	2.0	1.5	0.5
September 1 to 15	1.5	1.3	0.2
September 15 to 30	1.1	1.1	0
October 1 to 15	0.8	0.8	0

EFFECT OF WEX ON CROP YIELDS*

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The product Wex is a soil additive which is supposed to increase crop yields. Since Wex is not a fertilizer, it is supposed to achieve this by releasing additional amounts of nutrients from the soil and enhance fertilizer efficiency.

With this in mind, experiments were conducted using the soil additive on corn, soybeans and wheat at the Waseca, Lamberton, and Morris Experiment Stations.

Experimental Procedure

Randomized complete block designs were used with six replicates and three treatments at Waseca and Morris and five replicates and three treatments at Lamberton. The treatments consisted of a check, and 8 and 16 oz. of Wex per acre at all locations. The Wex treatments were incorporated with the soil at Lamberton and surface applied at Waseca and Morris. There was a fourth treatment used on the corn experiment at Waseca which was another surfactant, Hydro-wet, applied at 16 oz./A and used for comparison purposes with Wex. The experiments were established on Webster clay loam at Waseca, Nicollet silty clay loam at Lamberton, and Forman clay loam at Morris. In all cases, adequate N, P and K treatments were applied and good weed and insect control were maintained.

Results and Discussion

The yield data for wheat, soybeans, and corn are presented in tables 1-3. There were no significant yield differences among treatments for any of the crops at any of the locations. Yield data are not reported for corn and soybeans at Morris because of crop failure due to drouth.

Table 1. Effect of varying levels of Wex on Era wheat yields in 1976.

Wex Treatment fl. oz/A	Waseca	Lamberton	Morris
		yield (bu/A)	
0	55	25	25
8	54	25	26
16	53	26	26
Sig. (.05)	ns	ns	ns

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[*] Laboratory analyses were paid for by the Conklin Co.

Table 2. Effect of varying levels of Wex on soybean yields in 1976.

Wex Treatment fl. oz/A	Waseca	Lamberton
	yield (bu/A)	
0	36	17
8	37	16
16	37	17
Sig. (.05)	ns	ns

Table 3. Effect of varying levels of Wex on corn yields in 1976.

Treatment		Waseca[1/]	Lamberton
Material	Fluid oz/A	yield (bu/A)	
Control		77	23
Wex	8	70	22
Wex	16	71	25
Hydro-wet	16	77	--

[1/] Moderate rootworm damage was noted at this site.

Various other criteria were also used to help determine if Wex improved plant growth. These included stand counts, early plant growth, silage yields on corn, lodging, whole plant weight, percentage of essential nutrients in the plant at various stages of growth, and percent protein in the wheat grain. In all cases, there were no meaningful significant differences in any of the criteria examined. Soil moistures were also taken post harvest and no differences were noted between treatments.

Based on the data collected in 1976, it would appear that Wex does not improve crop yields. It should be remembered, however, that this conclusion is based on one year's research and that 1976 was a very droughty year.