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.

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DROUGHT AND THE 1977 SEASON

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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).

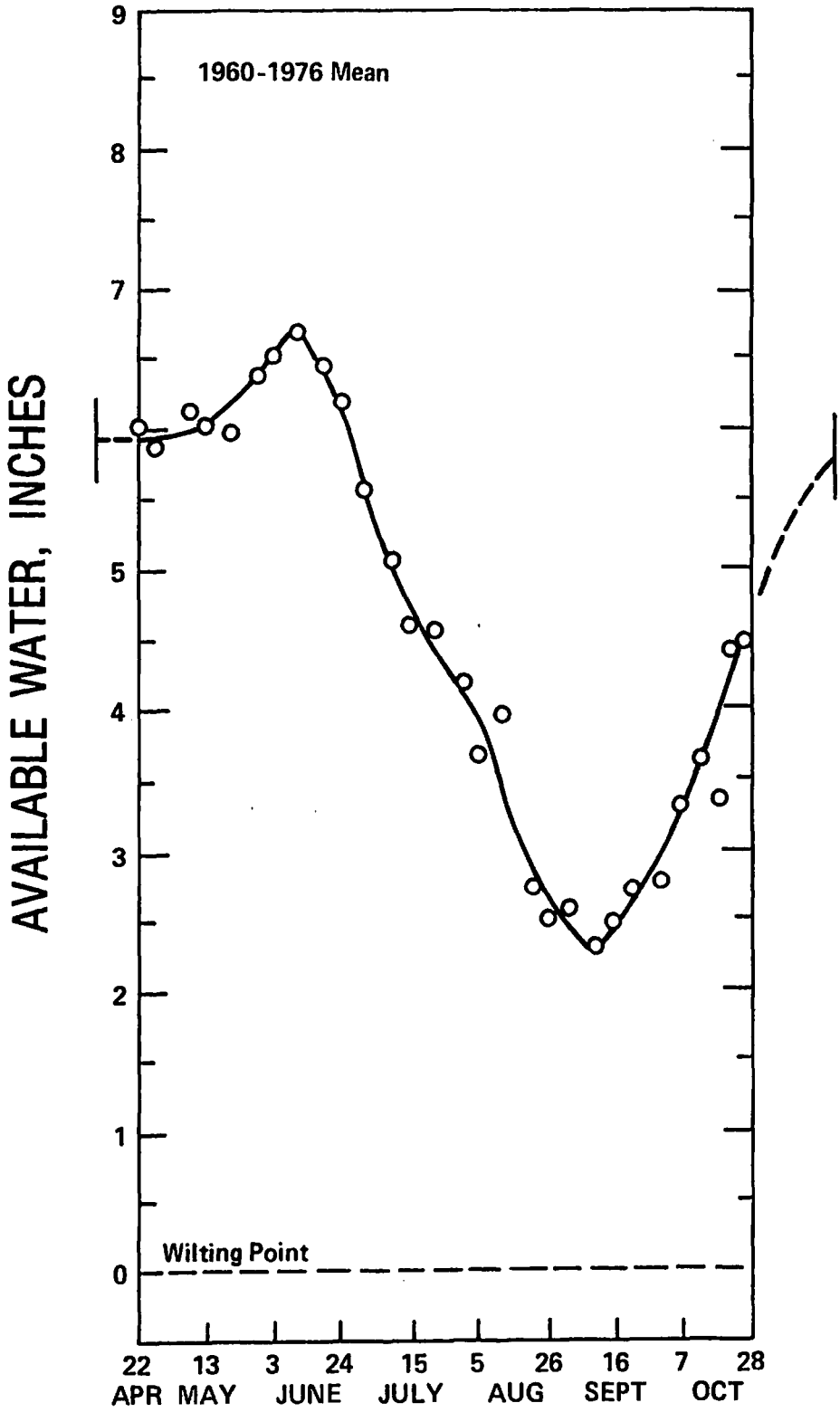


Fig. 1. The 1960-1976 mean total plant available soil water in a 5-foot column of soil under continuous corn at the Southwest Agricultural Experiment Station, Lamberton, between late April through October. The dashed lines represent assumed water contents, due to few soil samples, after the spring soil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

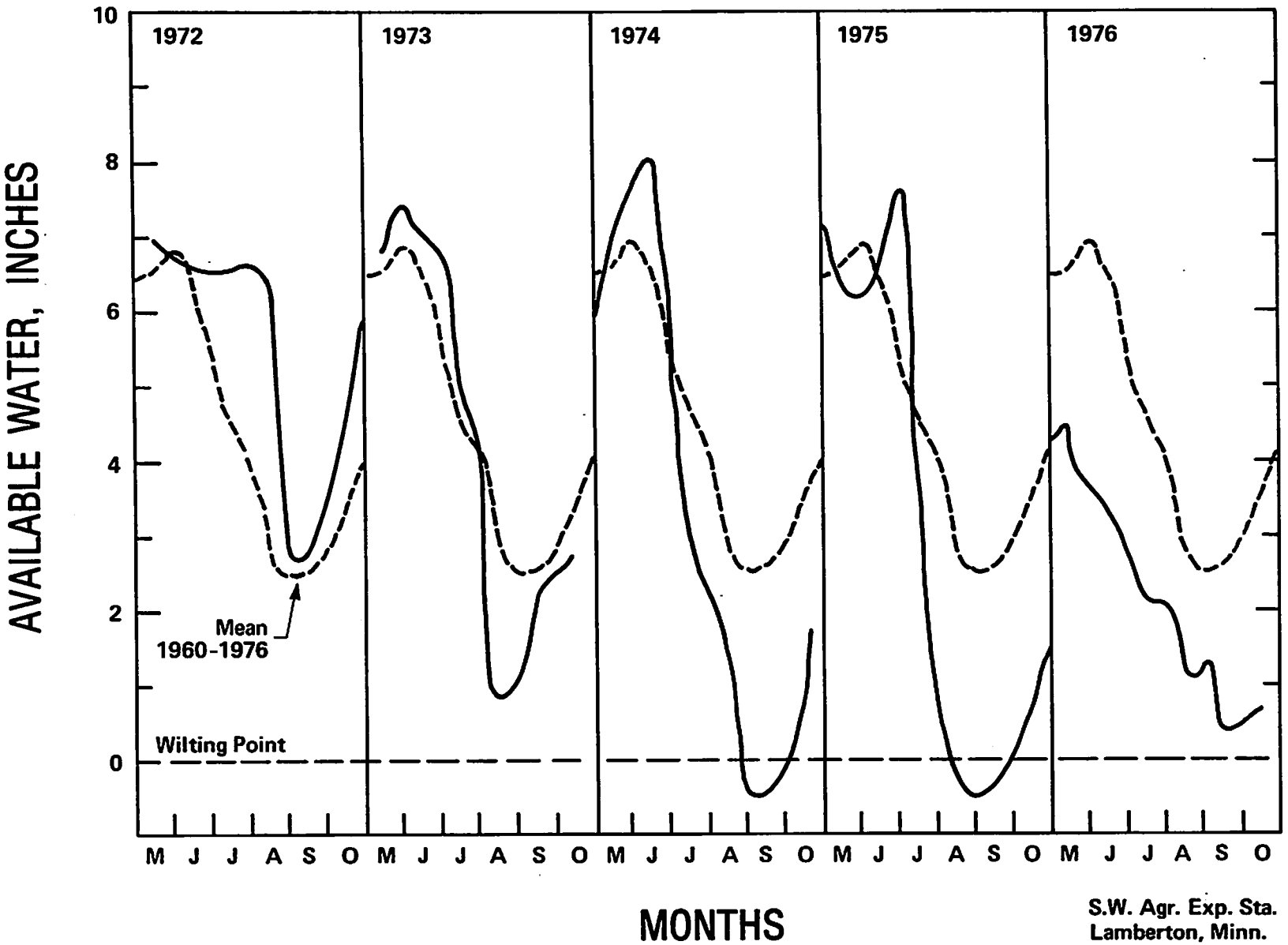


Fig. 2. The total plant available soil water in a 5-foot column of soil under continuous corn during two seasons of 100 bu./A. yield (1972 and 1973), two seasons of 60 bu./A. yield (1974 and 1975) and a season of about 25 bu./A. yield (1976) at the Southwest Agricultural Experiment Station, Lamberton.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

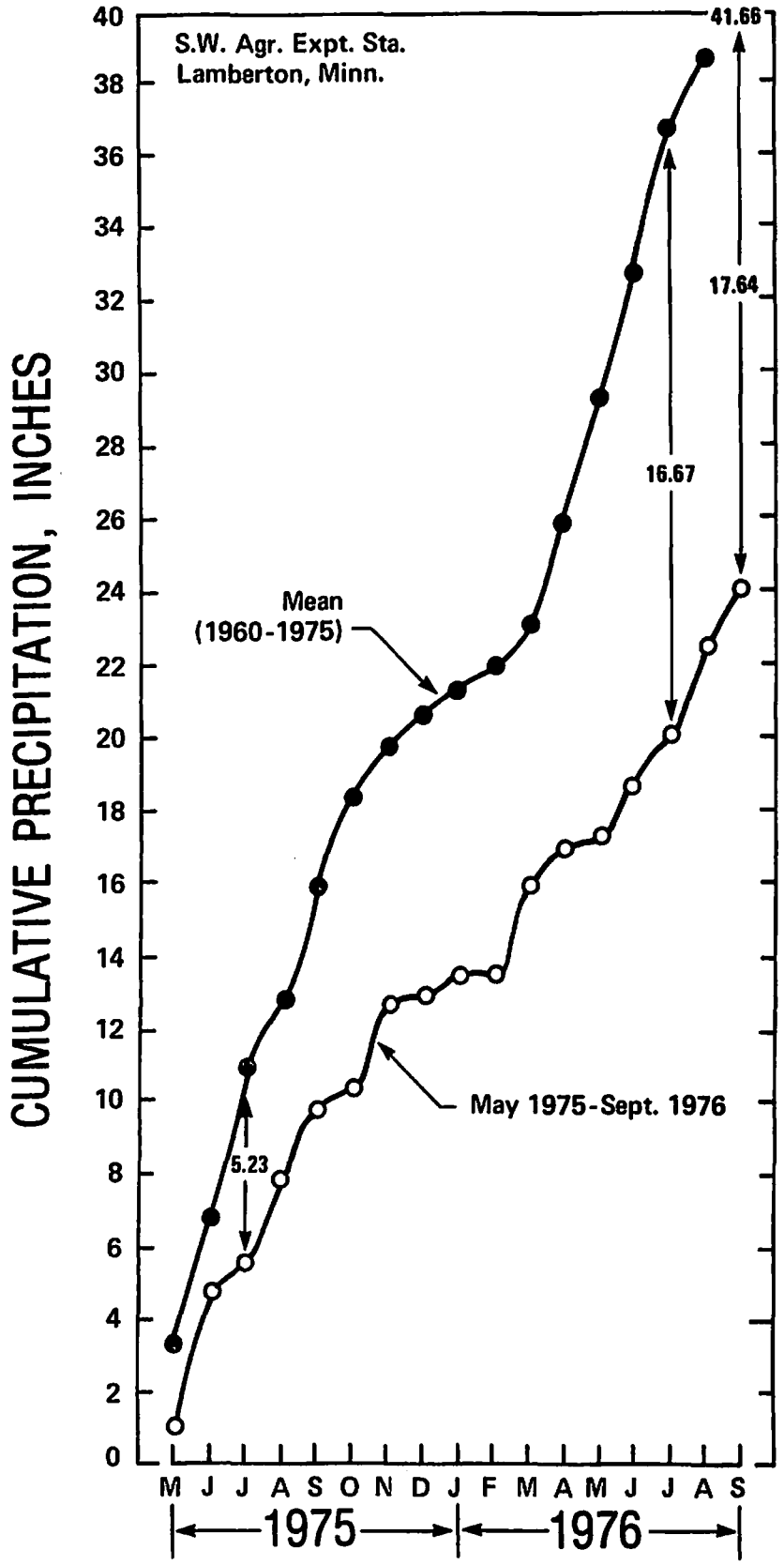


Fig. 3. The cumulative May, 1975--September, 1976, precipitation compared to the 1960-1975 cumulative mean at the Southwest Agricultural Experiment Station, Lamberton.

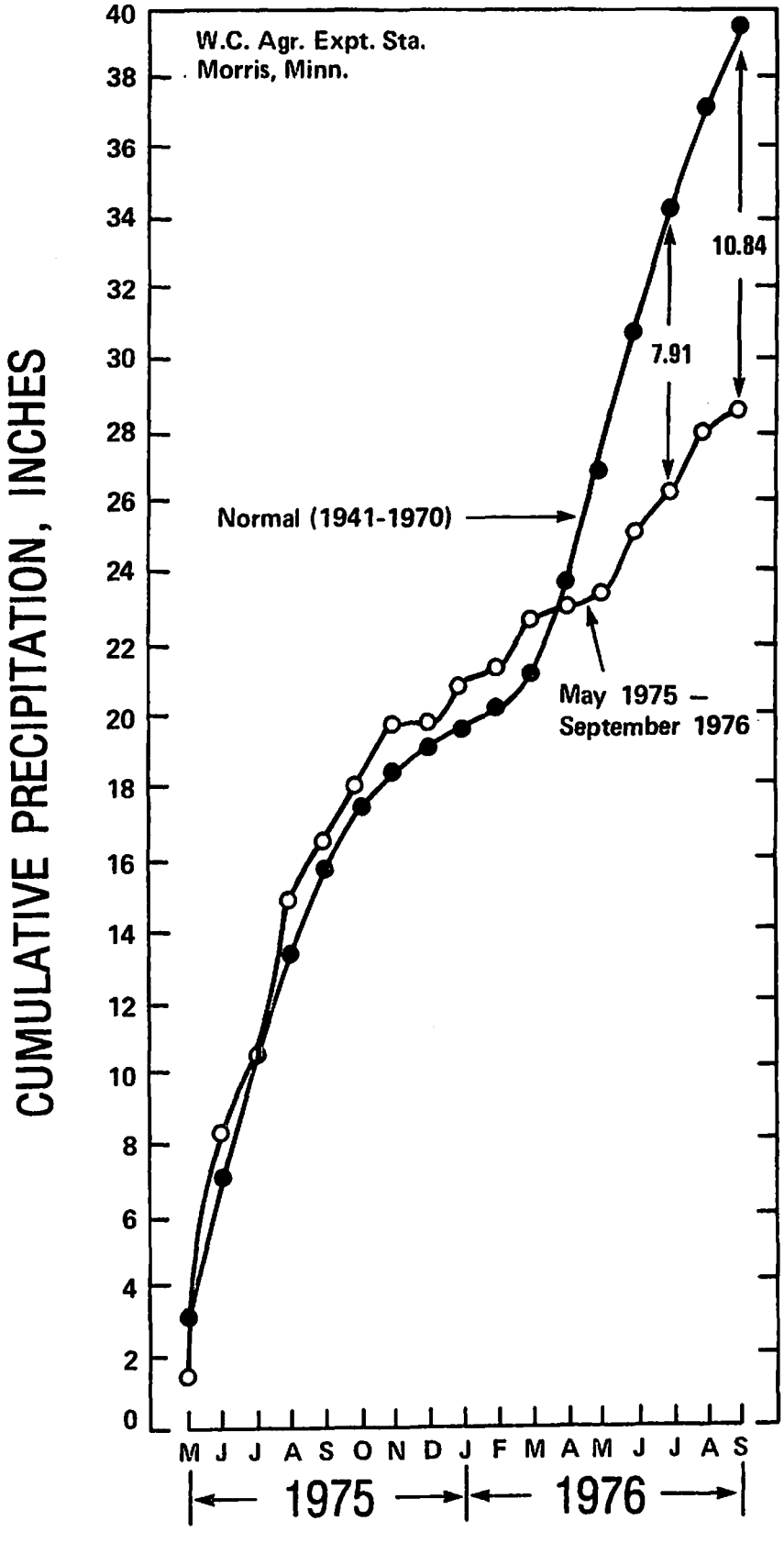


Fig. 4. The cumulative May, 1975--September, 1976, precipitation compared to the 1941-1970 cumulative normal at the West Central Agricultural Experiment Station, Morris.

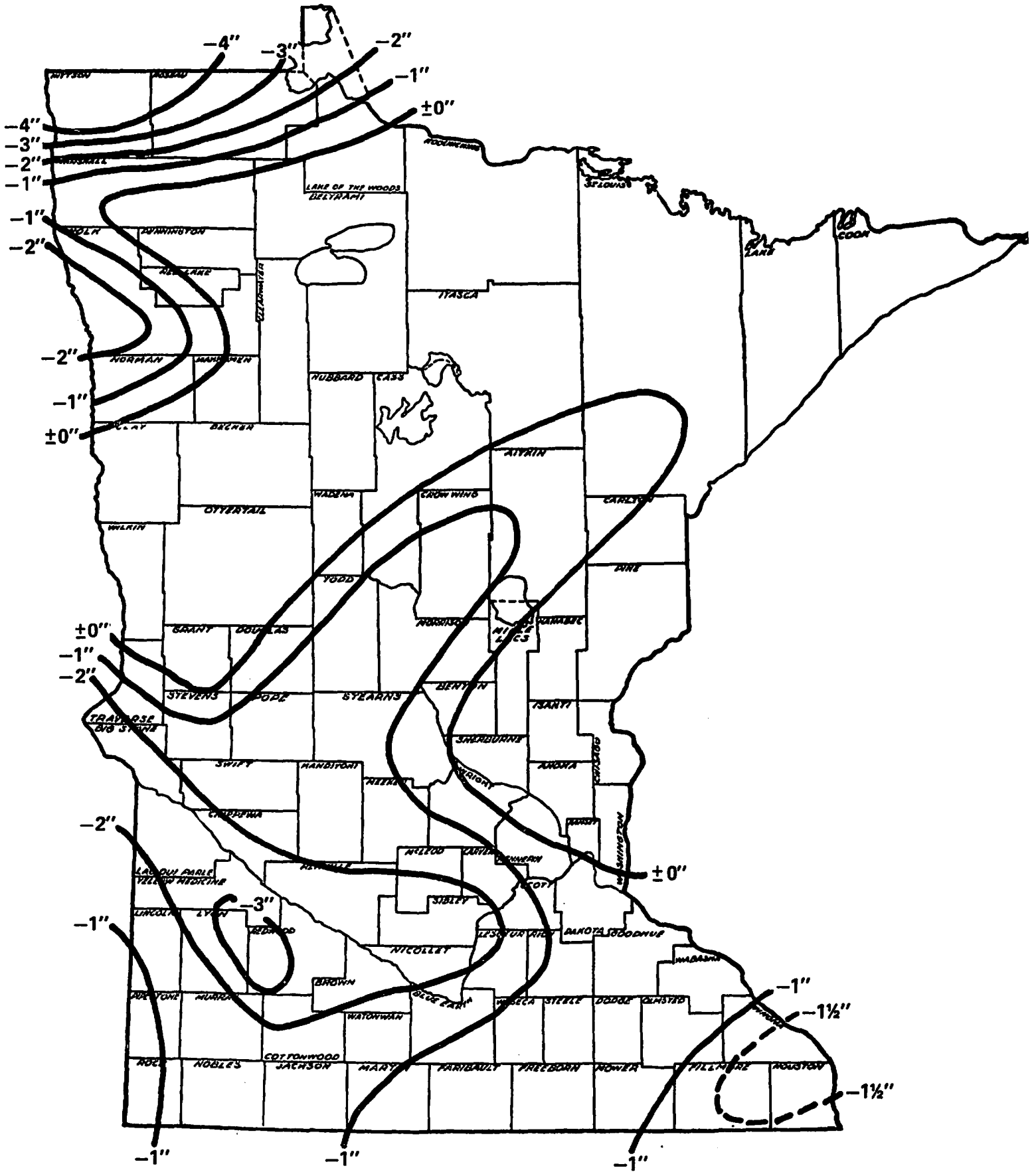


Fig. 5. The estimated departure of the soil water from the mean at the end of the September-November, 1975, soil water recharge period.

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.

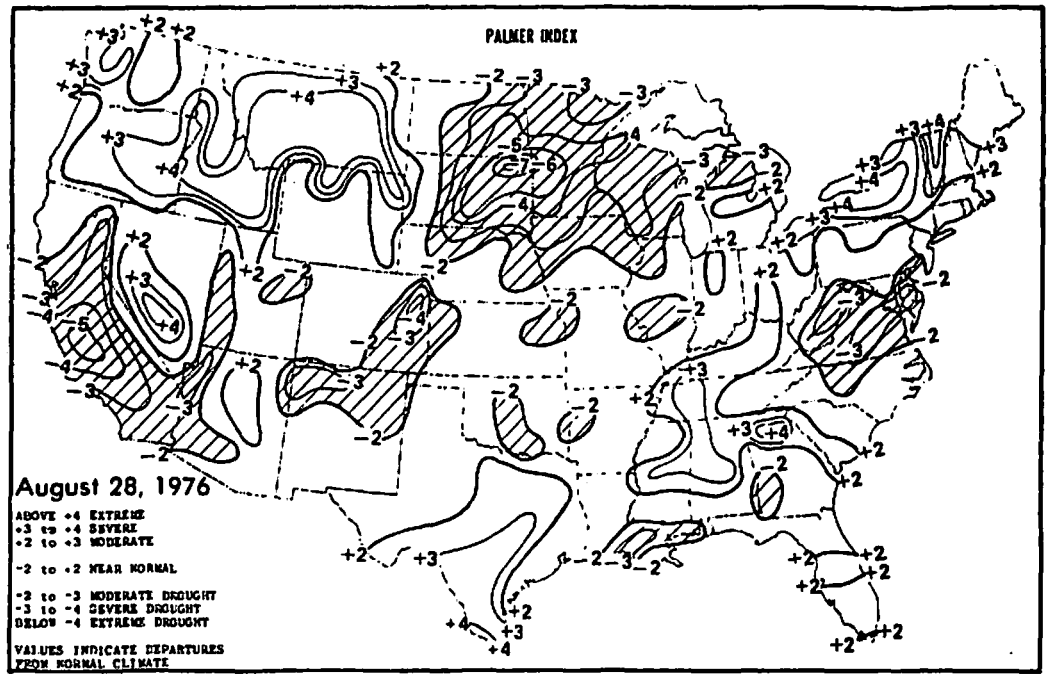
The corn yields in Redwood and Cottonwood counties for 1972-1976 permit an assessment to be made of the two growing season sources of water: precipitation and stored soil water. With adequate supplies of both in 1972 and 1973 yields were about 100 bushels per acre; with only stored soil water in adequate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



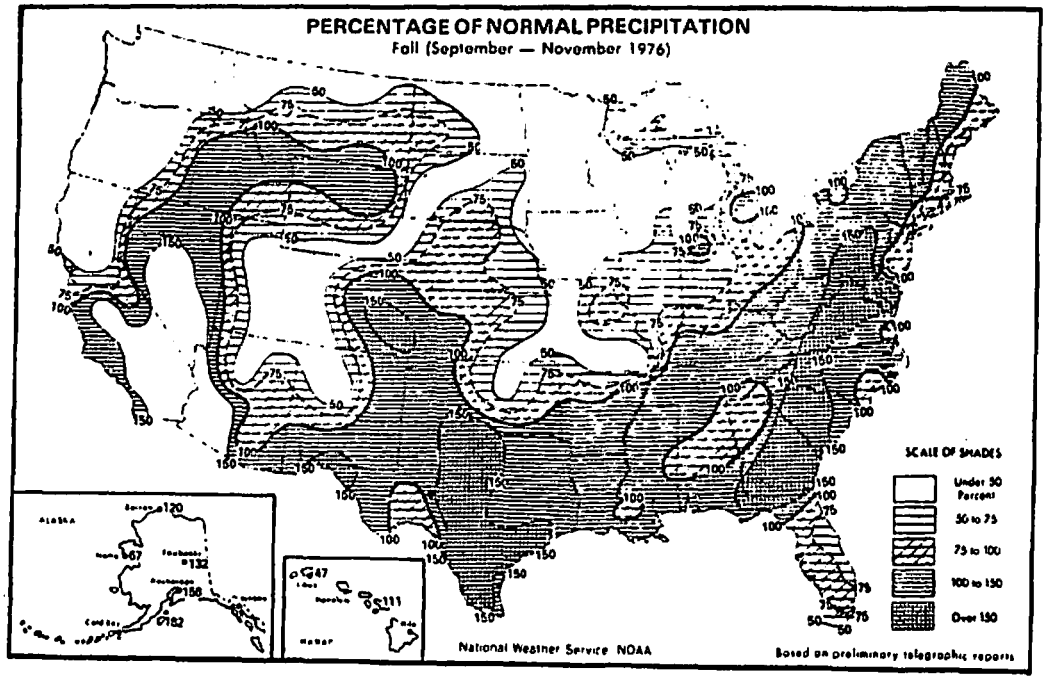


Fig. 6. The lower picture is the percent of the normal September-November precipitation received in the United States in 1976. Note how the area receiving 50% or less of normal coincides with the areal extent of the 1976 drought in the North-Central region (upper picture) at the end of August. The figures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

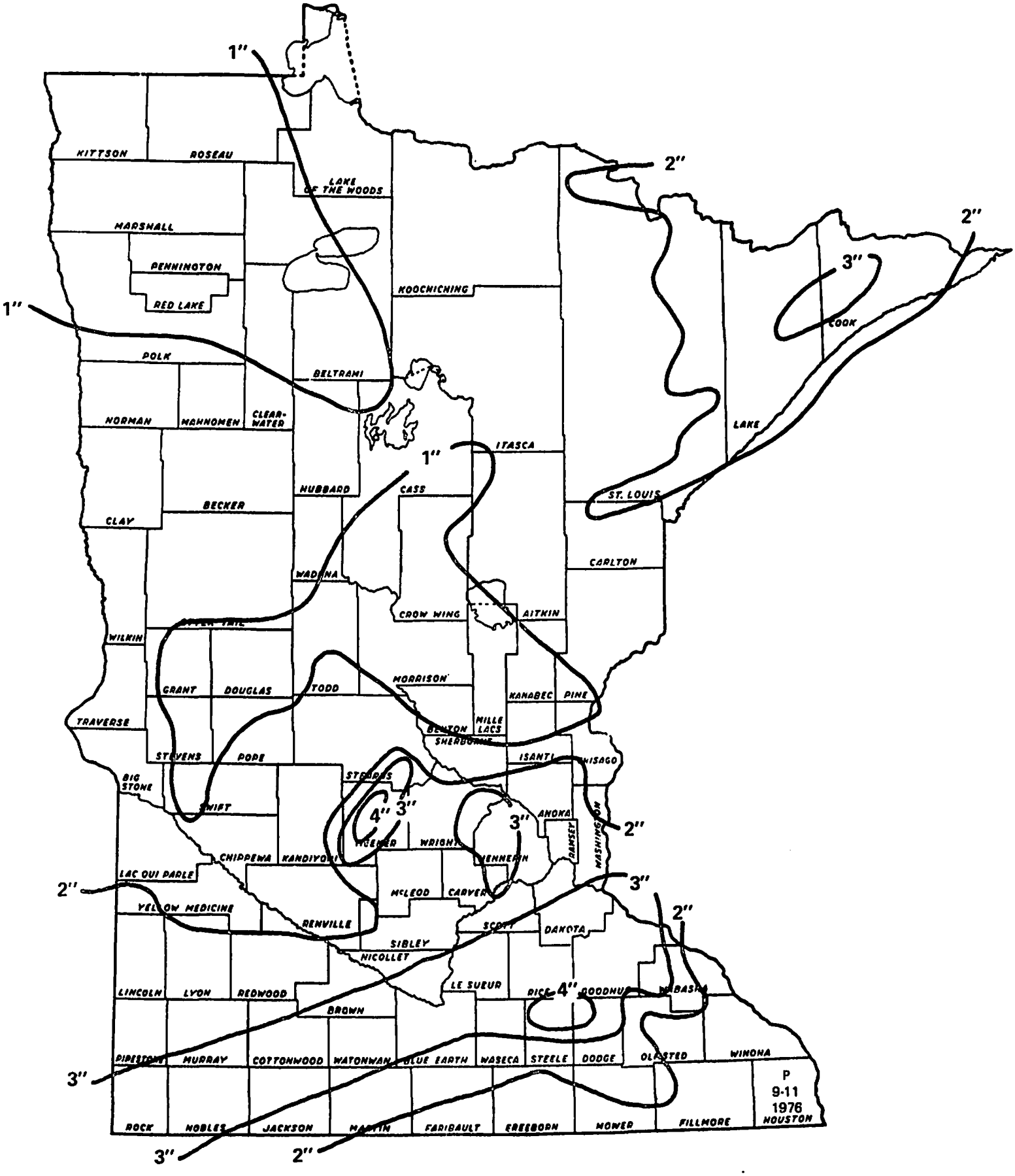


Fig. 7. Total precipitation for the period September-November, 1976.

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

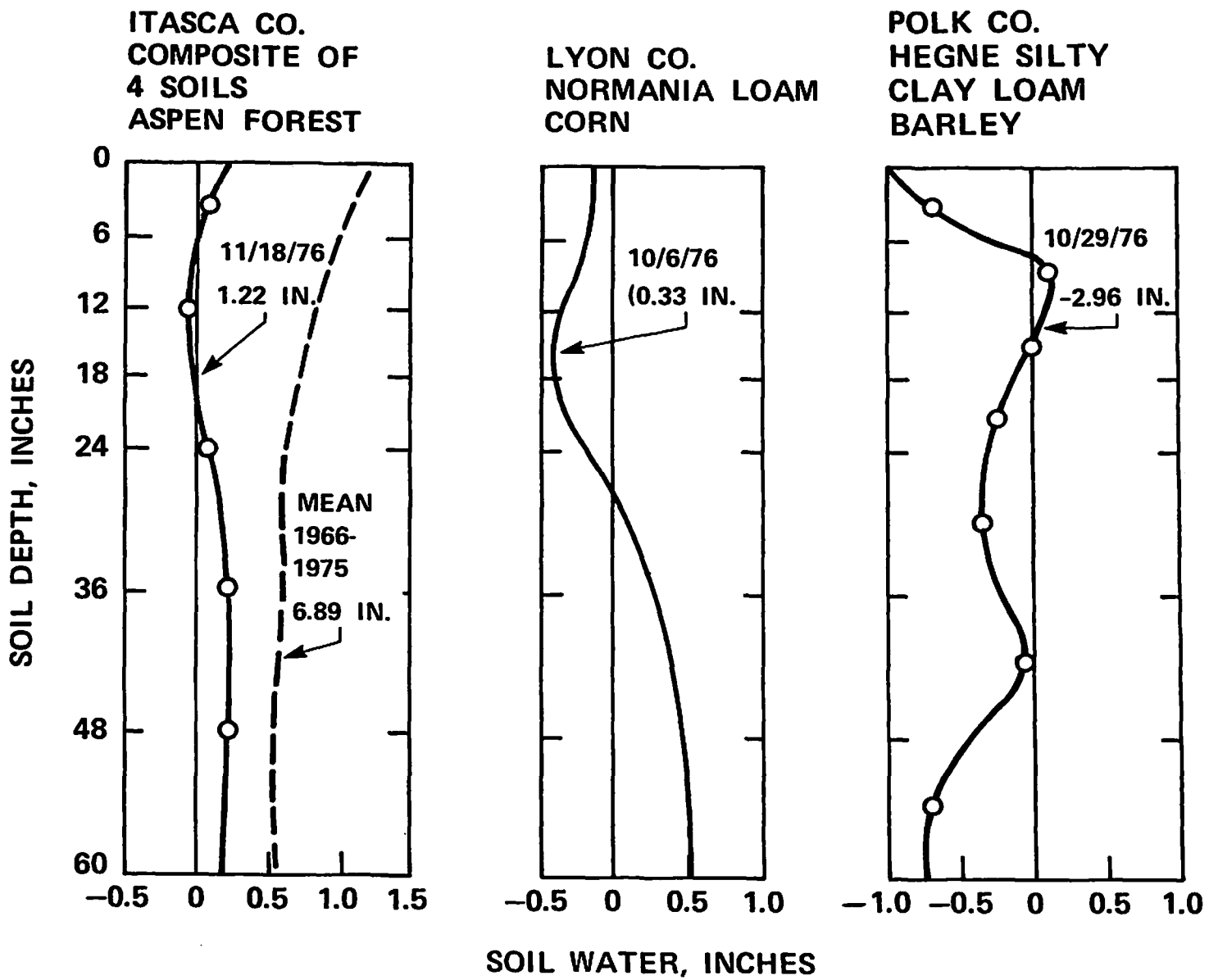


Fig. 8. Plant-available soil water profiles at nine locations in Minnesota, fall, 1976.

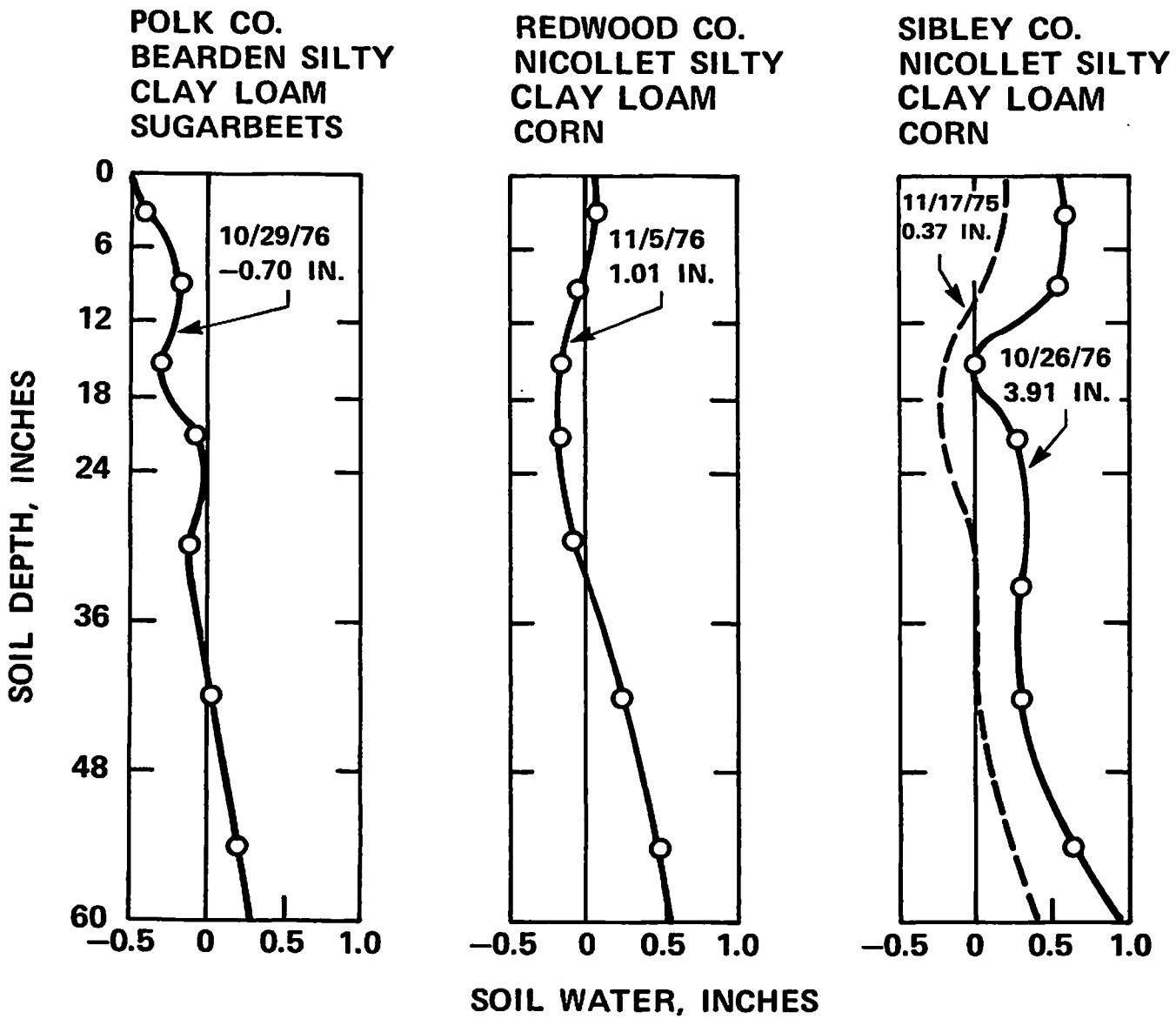


Fig. 8. (Continued).

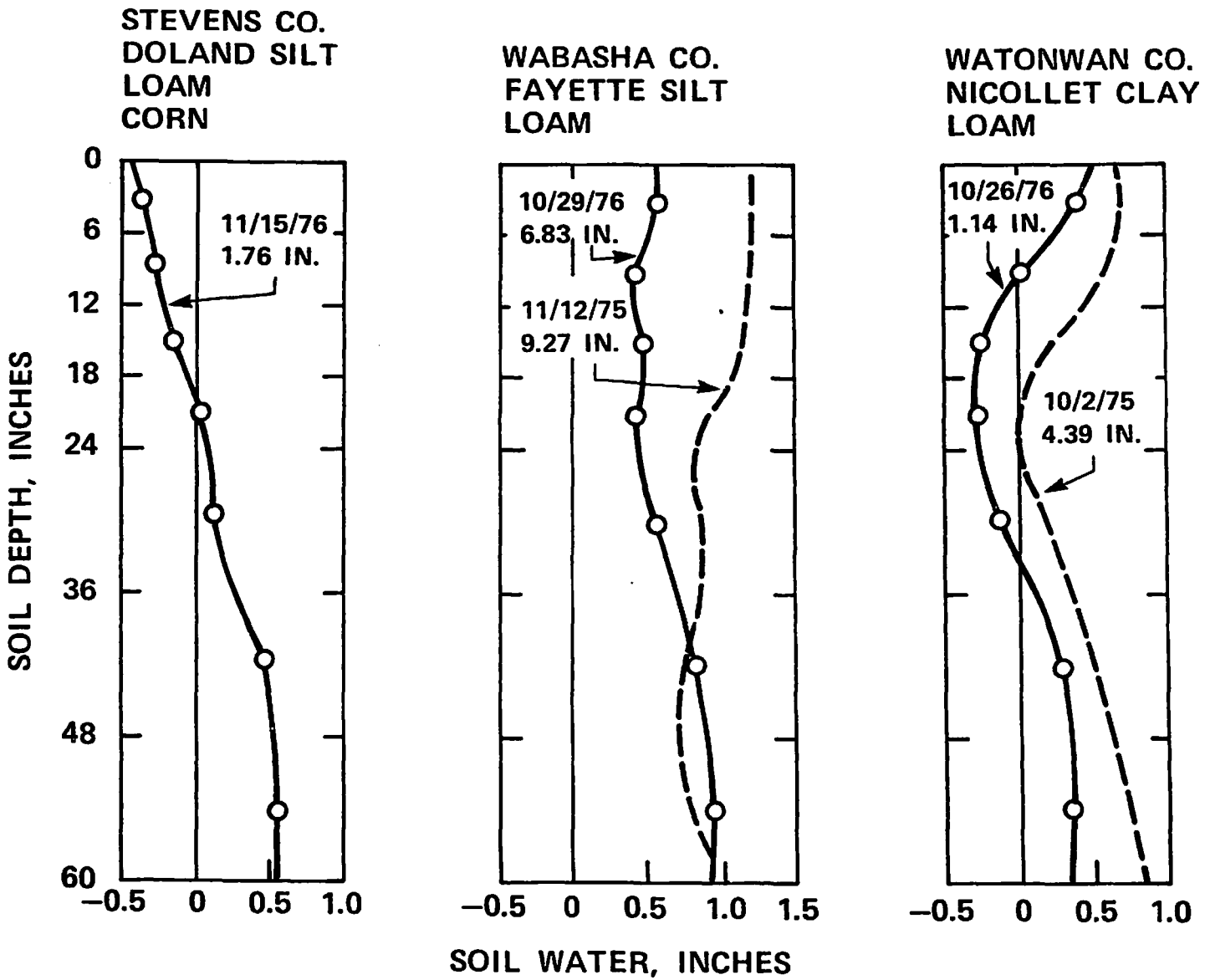


Fig. 8. (Continued).

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.

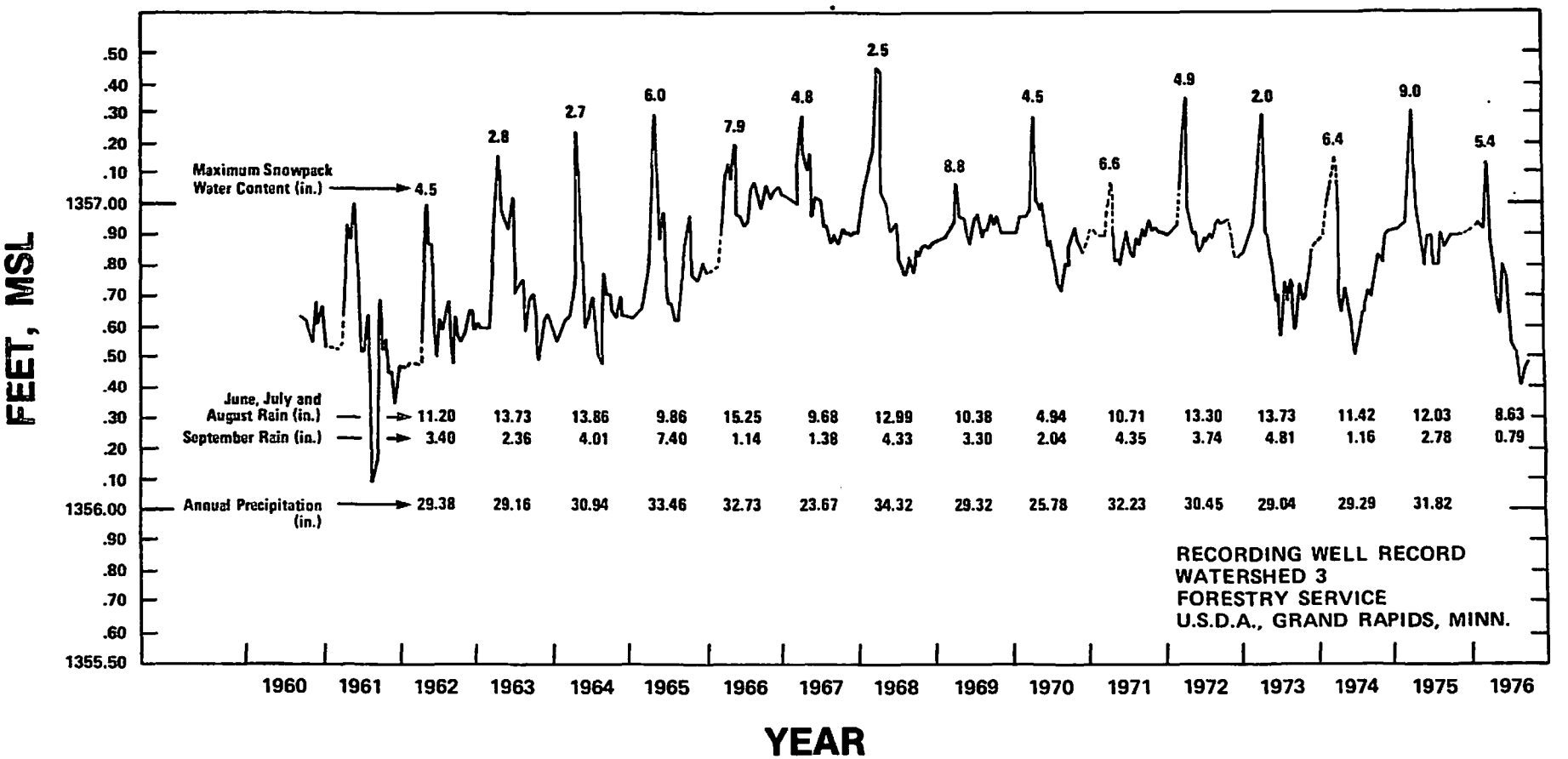


Fig. 9. Recording well record at Grand Rapids, 1960-1976.

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

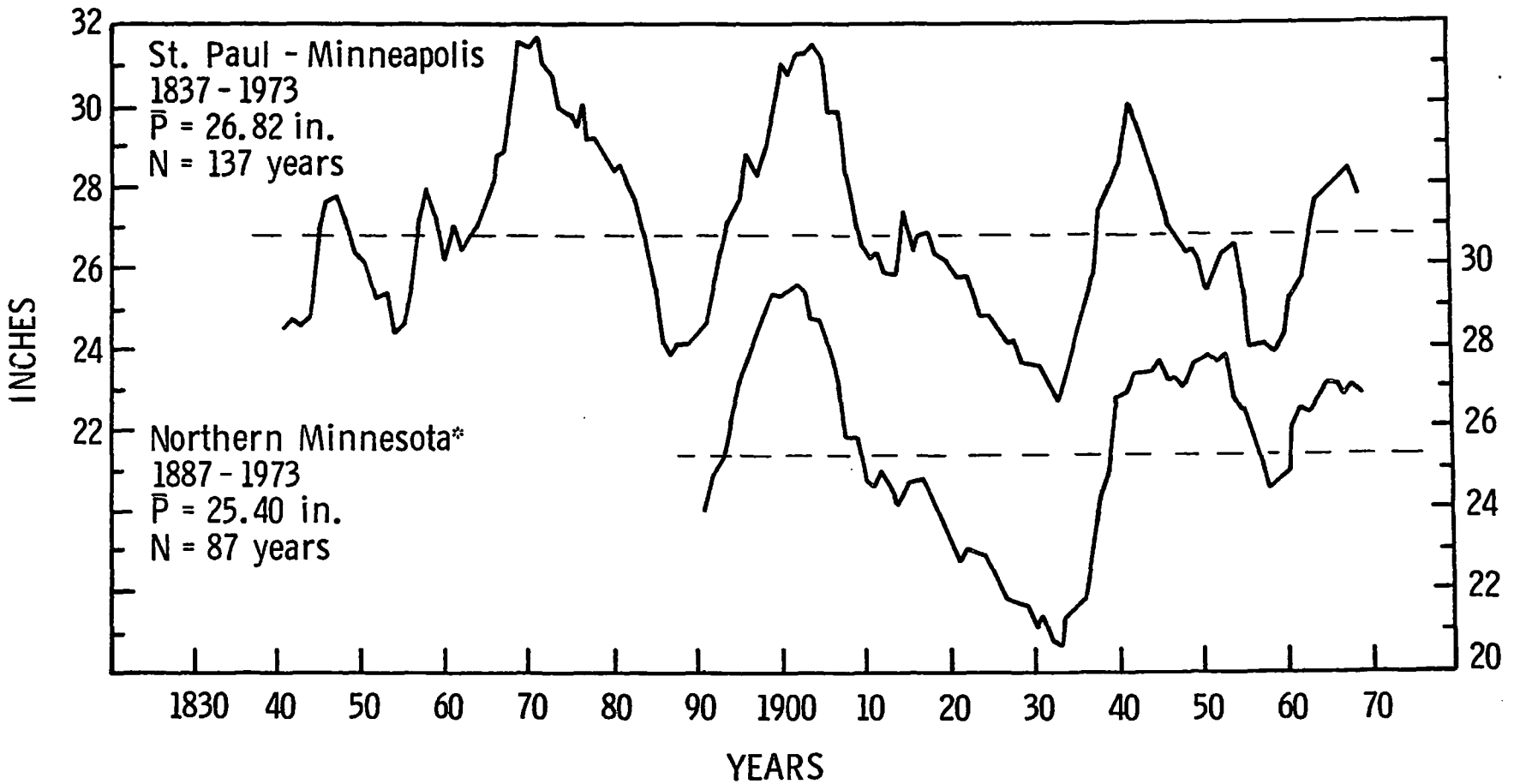


Fig. 10. The upper curve is the same data shown in Figure 3 but smoothed with the normal curve smoothing function of length $2\sigma = 9$ years. This procedure serves to reduce the "noise" of the year to year variation and permit trends to be observed. The lower curve is the smoothed average of five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

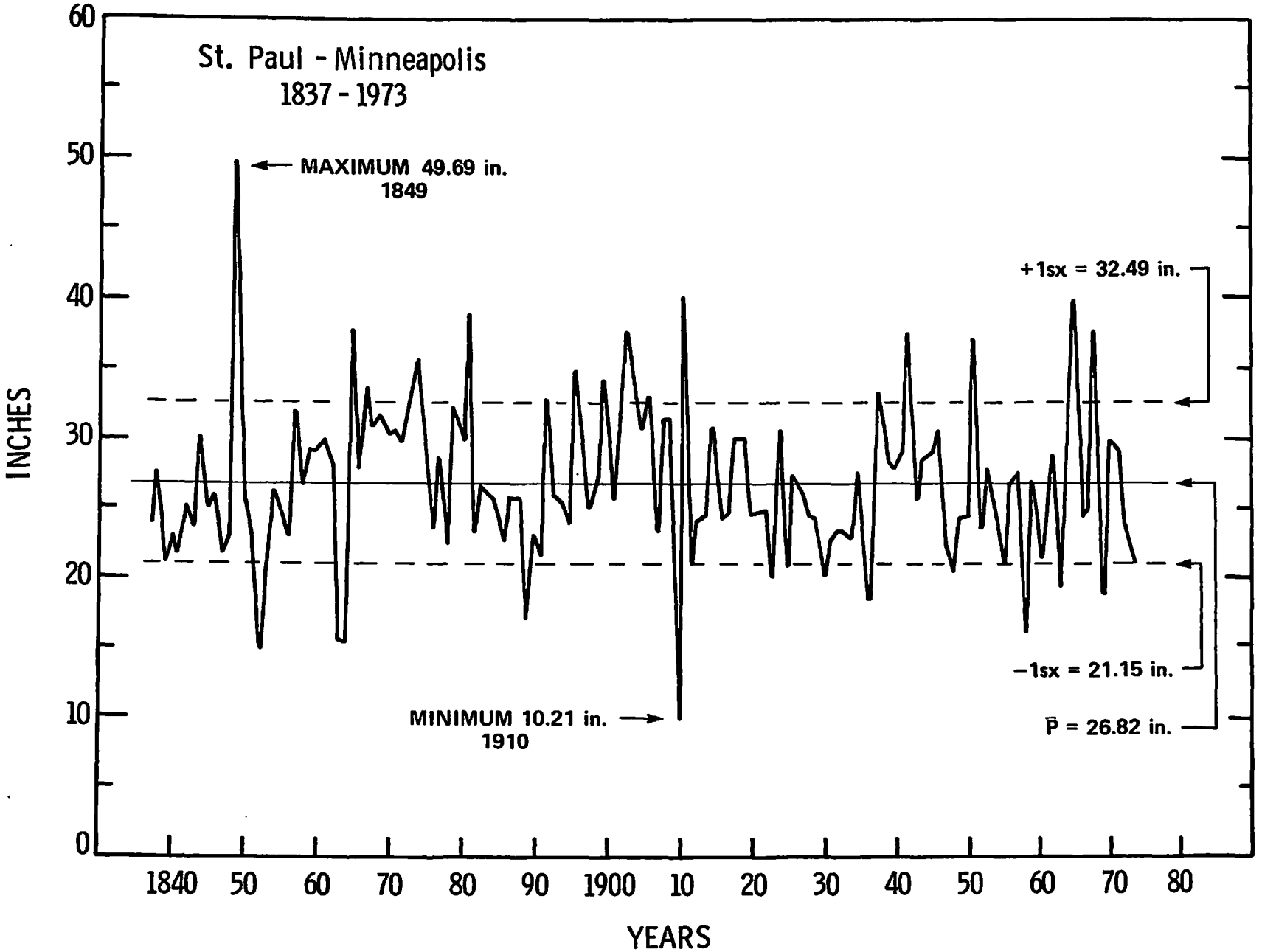


Fig. 11. Total annual precipitation received at St. Paul-Minneapolis from 1837-1973. The data are from combined records of Fort Snelling, St. Paul, Minneapolis, and the Minneapolis-St. Paul International Airport. The mean for the 137 years is 26.82 inches, and the mean plus and minus one standard deviation 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.

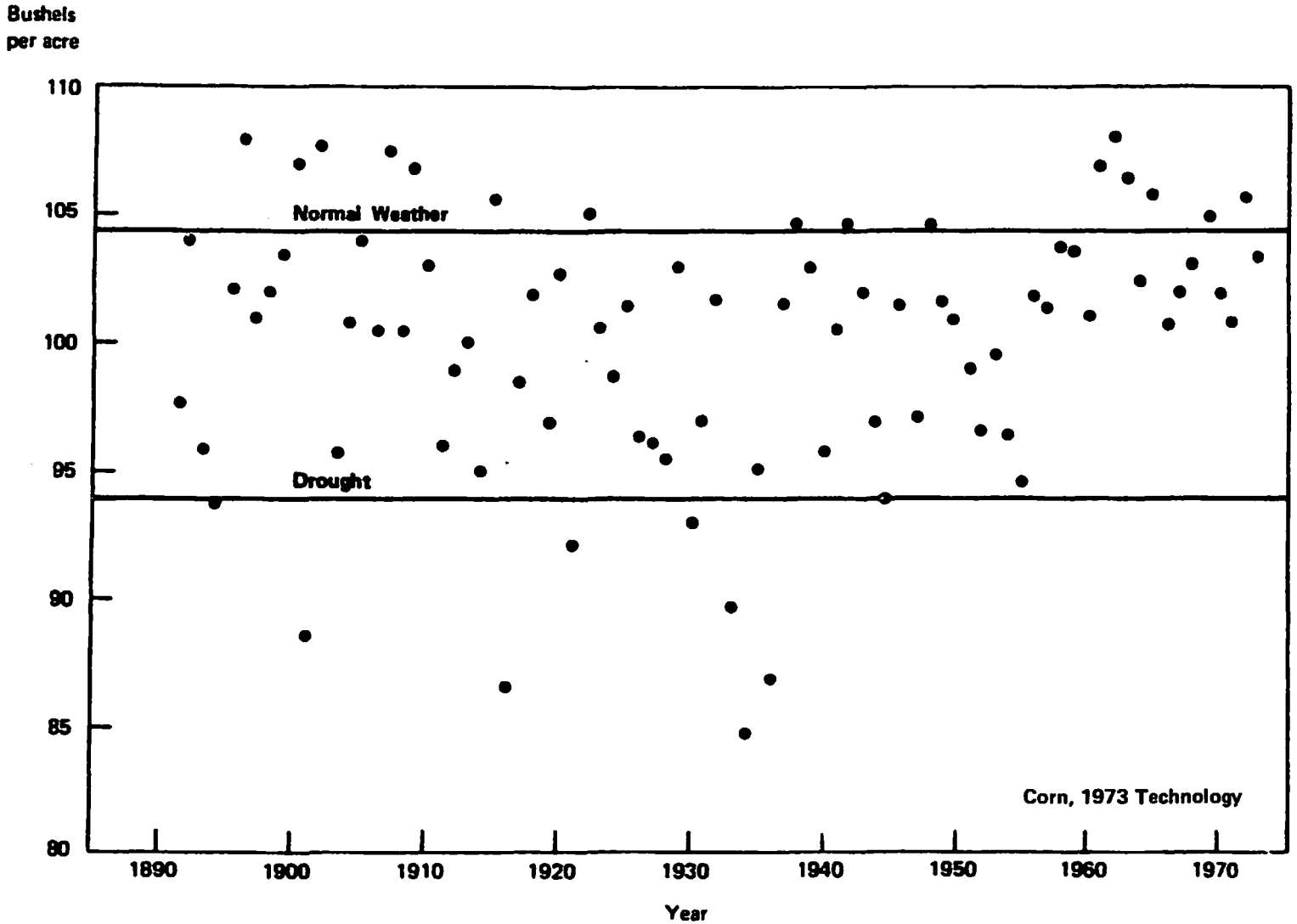


Fig. 12. Simulated mean annual yield of corn in 5 Corn Belt states given that 1973 technology (use of hybrid corn, fertilizers, etc.) had been available in each of the years. AfterMcQuigg and Le Duc (5).

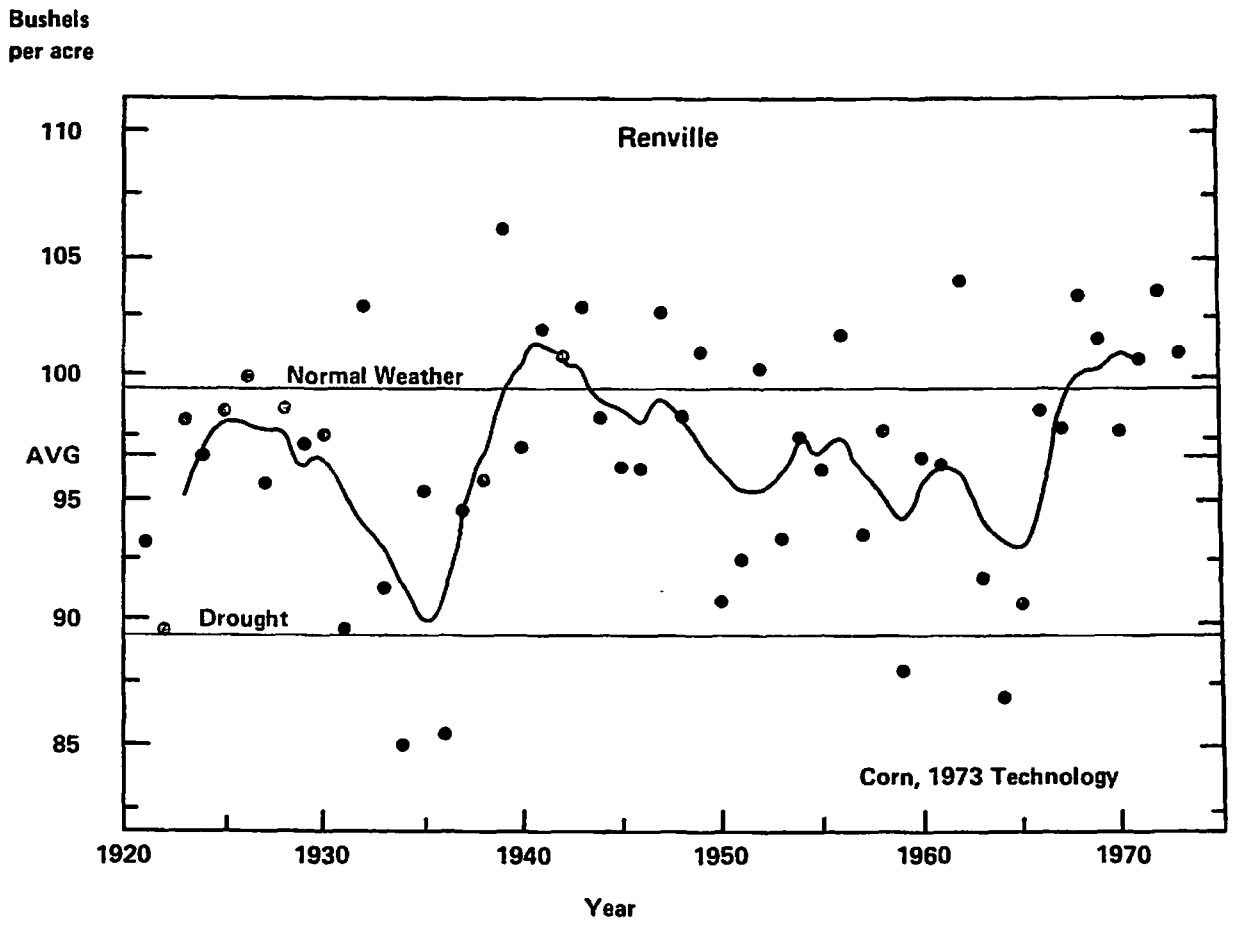


Fig. 13. Simulated mean annual yield of corn in Renville Co., Minn., given that 1973 technology (use of hybrid corn, fertilizers, etc.) had been available in each of the years. Dots represent the calculated annual yield and the curved line is the smoothed yield trend line. The straight line labeled "normal 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.

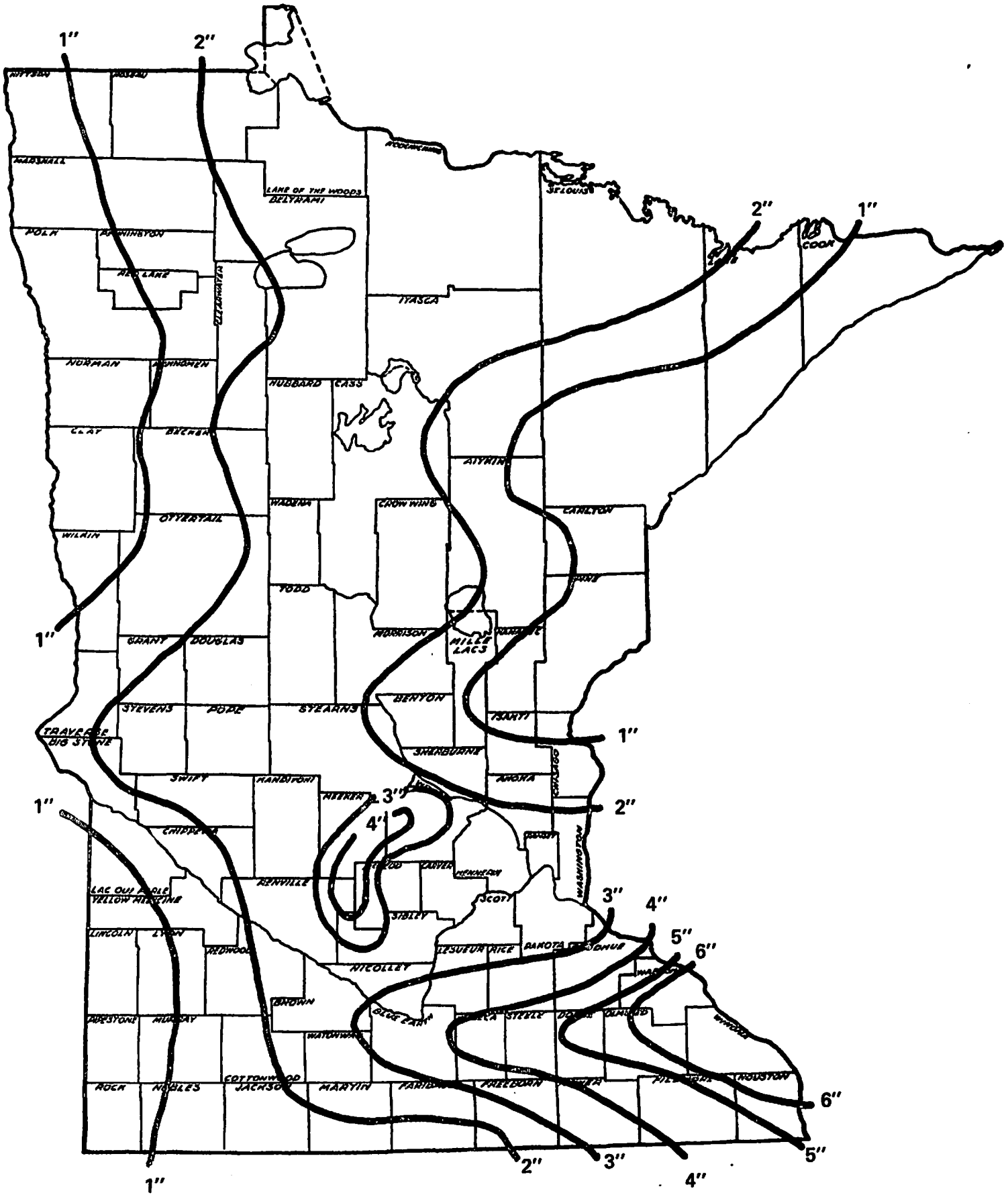


Fig. 14. The estimated inches of plant available water present in the soil at the beginning of spring, 1977.

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 Spring	Summer	Plant Available Soil Water 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 Spring	Summer	Predicted Yield
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.

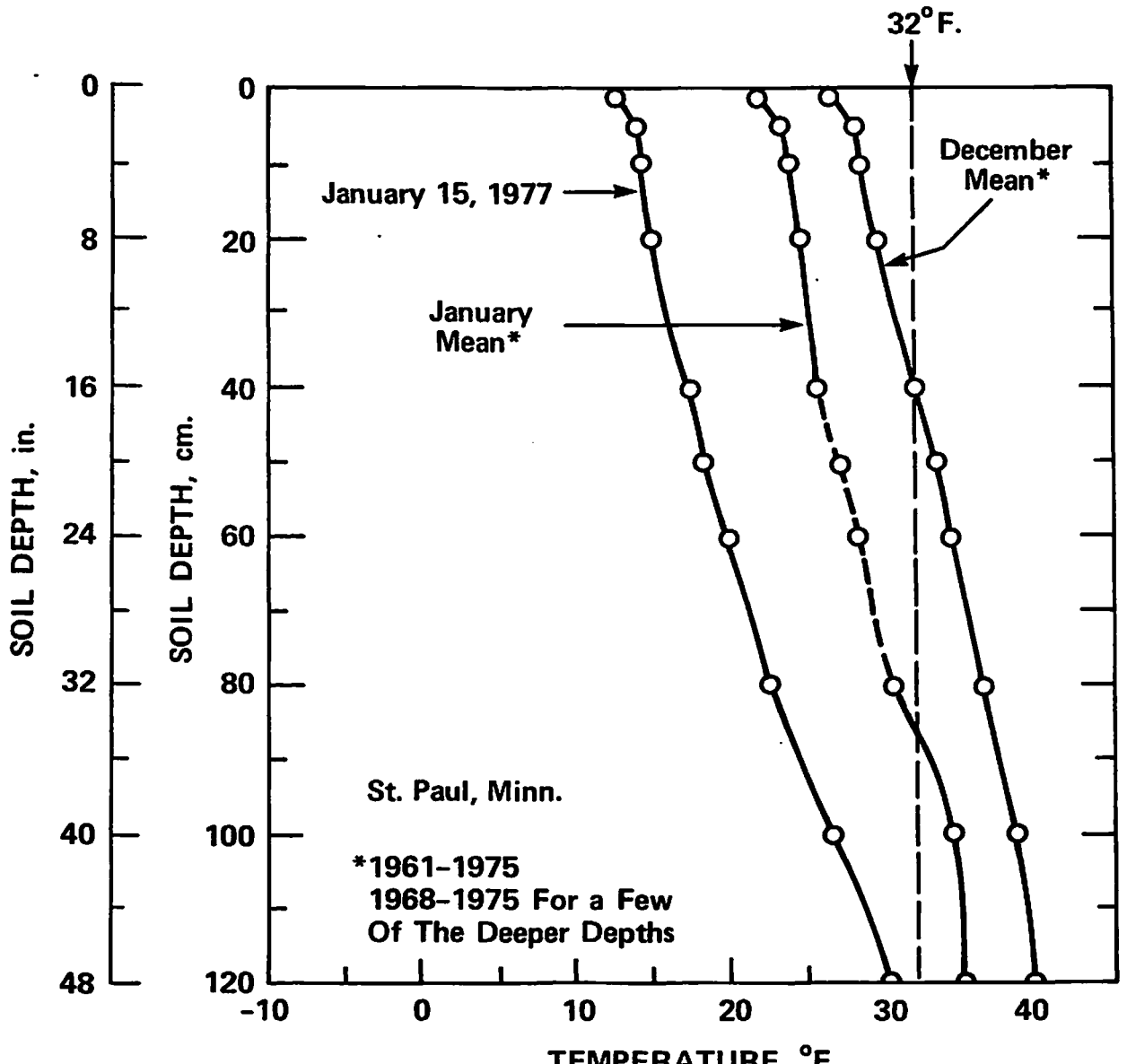


Fig. 15. The January 15, 1977, temperatures in a soil that is bare of vegetative cover at St. Paul, Mn, compared to the 1961-1975 mean soil temperatures in December and January.

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.

IV. Literature Cited

1. Baker, D.G., Boelter, D., Evans, S., Nelson, W.W., and Wallingford, G.W. The hydrology of soil water. M.S. in preparation. Soil Sci. Dept., U. Minn., St. Paul.

2. Baker, D.G. 1976. A view of cloud seeding. Minn. Agr. Ext. Service Folder 330. U. Minn. Agr. Ext. Service, St. Paul.

3. Baker, D.G. 1971. Snow cover and winter soil temperatures at St. Paul, Minnesota. Water Resources Res. Bull. 37. Water Resources Res. Center, U. of Minn.

4. Enz, J.W. 1976. The influence of induced rainfall on corn and soybean yields in Minnesota. Ph.D. Dissertation. Soil Sci. Dept., U. Minn., St. Paul.

5. McFarland, R. 1976. Public baths, privies "in" things up north. St. Paul Pioneer Press. Jan. 7.

6. McQuigg, J. and S. Le Duc. 1973. The influence of weather and climate on United States grain yields - bumper crops or droughts. EDS-NOAA, U.S. Dept. of Commerce.

7. Sax, R.I., S.A. Chagnon, L.O. Grant, W.F. Hitchsfield, P.V. Hobbs, A.M. Kahan, and J. Simpson. 1975. Weather modification: Where are we now and where should we be going? An editorial overview. Jour. App. Meteor. 14(5):652-672.

8. Skaggs, R.K. 1976. Personal communication. Geography Dept., U. Minn., Minneapolis.

9. U.S. Department of Commerce and U.S. Department of Agriculture. 1976. Weekly Weather and Crop Bulletin. Vol. 63, Nos. 18, 22, 27, 31, 35, 40 and 50. N.O.A.A., Dept. Commerce, Washington D.C.

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

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.