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IRRIGATED CORN YIELDS IN THE NORTH CENTRAL REGION OF THE UNITED STATES

Agricultural Experiment Stations of Alaska, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin, and the U.S. Department of Agriculture cooperating.

IOWA AGRICULTURE AND HOME ECONOMICS
EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology
Ames, Iowa

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FOREWORD

In 1956 the Directors of the North Central Region authorized the establishment of the NCR-12 Committee under the title, "Irrigation and Drainage." Although the function of the Committee was to review regional research problems relating to the assigned subject matter, scientists whose primary interest was irrigation soon recognized the desirability of bringing together a summarization of a number of corn-irrigation experiments that had been and were being conducted in the 11 states representing the Corn Belt. Further consideration indicated the desirability of conducting experiments employing uniform irrigation trials in several states.

Subsequently, a plan was devised to conduct such trials in Iowa, Indiana, and Illinois for a 5-year period from 1959 through 1963. The objectives of these trials were to determine the effect of a range of soil and climatic conditions on yields of irrigated corn and to characterize the stand, moisture, and fertility conditions necessary for maximum irrigated corn yields in the North Central Region. The NCR-12 Committee served as the coordinating group for these trials. Although the work reported herein was supported by the individual states involved rather than from regional funds, it is believed to represent a truly regional approach to a problem of common interest that cuts across state lines.

James M. Beattie
Administrative Advisor

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CONTENTS

SUMMARY

This bulletin is a compilation of corn yields from irrigation experiments conducted in nine states of the North Central Region. The yield data reflect the influence of fertilizer level, plant population, and degree of soil moisture maintained. The data reported were obtained from 1949 through 1963. The raw data have been classified by treatment variables, and are listed in Appendix A under the headings:

a. Response of corn to irrigation
b. Response of corn to irrigation and plant population
c. Response of corn to irrigation and fertility
d. Response of corn to irrigation and cultural practices
e. Response of corn to irrigation and corn maturity type, and
f. Response of corn to irrigation, fertility, and plant population.

The bulk of the data did not lend itself to a rigorous statistical analysis. Broad grouping, however, indicated certain trends. With no irrigation, the medium stand level shows the highest average yield for soil types other than sandy. This trend holds for all fertilizer rates, with the highest average yield occurring with highest nitrogen. With sandy soil types and no irrigation, low plant populations produced highest yields at all fertilizer levels. With irrigation only at silking and tasseling, yields fluctuated with plant populations, but yields tended to increase with increased nitrogen in all soils. The same relationship between yield and variable population and nitrogen was found for the irrigation treatment when the soil was irrigated at 50% available moisture.

Uniform irrigation trials with standardized treatment variables were conducted by some states in the region. These uniform trials were made to determine the effect of a range of soil and climatic conditions on yields of irrigated corn, and to characterize the stand, moisture, and fertility conditions necessary for maximum irrigated corn yields in the North Central Region.

An analysis of variance showed that the main effects of irrigation, years, and the irrigation-state interaction were highly significant. Irrigation increased yields, but large variations in maximum irrigated yields occurred from year to year. The response to irrigation was greater in some states than in others.

IRRIGATED CORN YIELDS IN THE NORTH CENTRAL REGION OF THE UNITED STATES

by C.E. Beer and Dan Wiersma [1]

Corn is one of the principal crops of the 12 states composing the contiguous North Central Region of the United States. The "Corn Belt" includes all or parts of 11 of these states. It extends west to approximately the 25-inch rainfall line in eastern South Dakota, Nebraska, and Kansas, east to the Appalachian Mountains, and south to the Ohio River. It is by far the largest geographical area in the world in which corn is the primary economic crop.

Although the climate and the soils are generally very well suited for corn production, there are areas in the region where the amount and distribution of rainfall and soils with low moisture-holding characteristics frequently limit the yield. There has been considerable research in the past 20 years on the irrigation of corn. This bulletin is a compilation of experimental results from corn irrigation in the North Central Region.

Since fertility, population, and timing of irrigations are not the same at all locations, statistical analyses and interpretations will be limited. Several stations had uniform irrigation trials for 5 years. These trials are discussed in a special section.

DEVELOPMENT OF IRRIGATION IN THE NORTH CENTRAL REGION

Irrigation is the artificial application of water to land to promote better plant growth. The history of irrigation begins with the history of man. It was practiced by the natives of South America more than 1,000 years ago. Modern irrigation in the United States began when the Mormons settled in The Salt Lake Valley of Utah in 1847. In the arid West, irrigation is essential for the production of most crops.

Although irrigation has been more commonly associated with the West, it has been practiced in humid regions for many years. Literature dated in the 19th century is available about the irrigation of high-value crops in the eastern section of the United States.

The western border of the North Central Region, which includes the west half of North Dakota, South Dakota, Nebraska, and Kansas, is in the arid region, and irrigation has been steadily developing there since before 1900. It was not until after World War II, however, that general interest in irrigating field crops and pastures developed over the entire region. This interest was fostered by a relatively high level of farm income at the time, the occurrence of drought conditions for part of the growing season, the desire of farmers to find some means of reducing weather risk and uncertainty associated with crop production, and by the technological developments in automating sprinkler irrigation.

Basically, the problems involved with irrigation in the more humid eastern part of the region would be similar to those in the more arid western part. In the eastern section, however, seasonal precipitation usually provides most of the needed water, and irrigation timing needs to be coordinated with periods when rainfall is limited.

There are many problems involved in studying the feasibility of irrigation as an agricultural practice. They include: (i) response of a crop to irrigation, (ii) the effect of a drought at various physiological stages of the crop, (iii) when and how much to irrigate, (iv) management practices, such as fertility, plant population, choice of variety, and weed, insect, and disease control, and (v) investment of capital and labor that will provide the most economical net return.

CLIMATE AND SOILS OF THE CORN BELT

The uniqueness of the climate and soils of the region make it especially suitable for corn production. All the North Central Region, however, is not included in the Corn Belt. The unshaded section of the map (fig. 1) broadly outlines its boundaries. In the shaded sections, corn production primarily is limited by deficient rainfall to the west, a short growing season to the north, and the rough nature of the topography and high temperatures to the south and east.

Fig. 1. Location of the Corn Belt within the North Central Region

[1] Associate professor of agricultural engineering, Iowa State University, and professor of agronomy, Purdue University, respectively.

Cold-to-warm temperatures and semi-arid-to-humid continental climates are prevalent in the North Central Region. Winters are cold, and summers warm or hot. Climatic variations within the region are characterized in figs. 2 through 7.

The rainfall is least in the western section, with the greatest portion occurring during the spring and early summer. Seasonal differences are smaller in the humid, eastern area of the region. The relatively high rainfall during the spring and winter months in the eastern section assures recharge of the soil moisture, whereas the low winter rainfall in the western section decreases the probability of moisture recharge for the next growing season. In an analysis of a 50-year climatic record, Newman[1], shows seasonal rainfall variations with-

Fig. 2. Average annual temperatures (degrees Fahrenheit) in the North Central Region. [Redrawn from Soils of the North Central Region of the United States, Wis. Agr. Exp. Sta. Bul. 544 (North Central Regional Res. Pub. 76). 192 pp. 1960.]

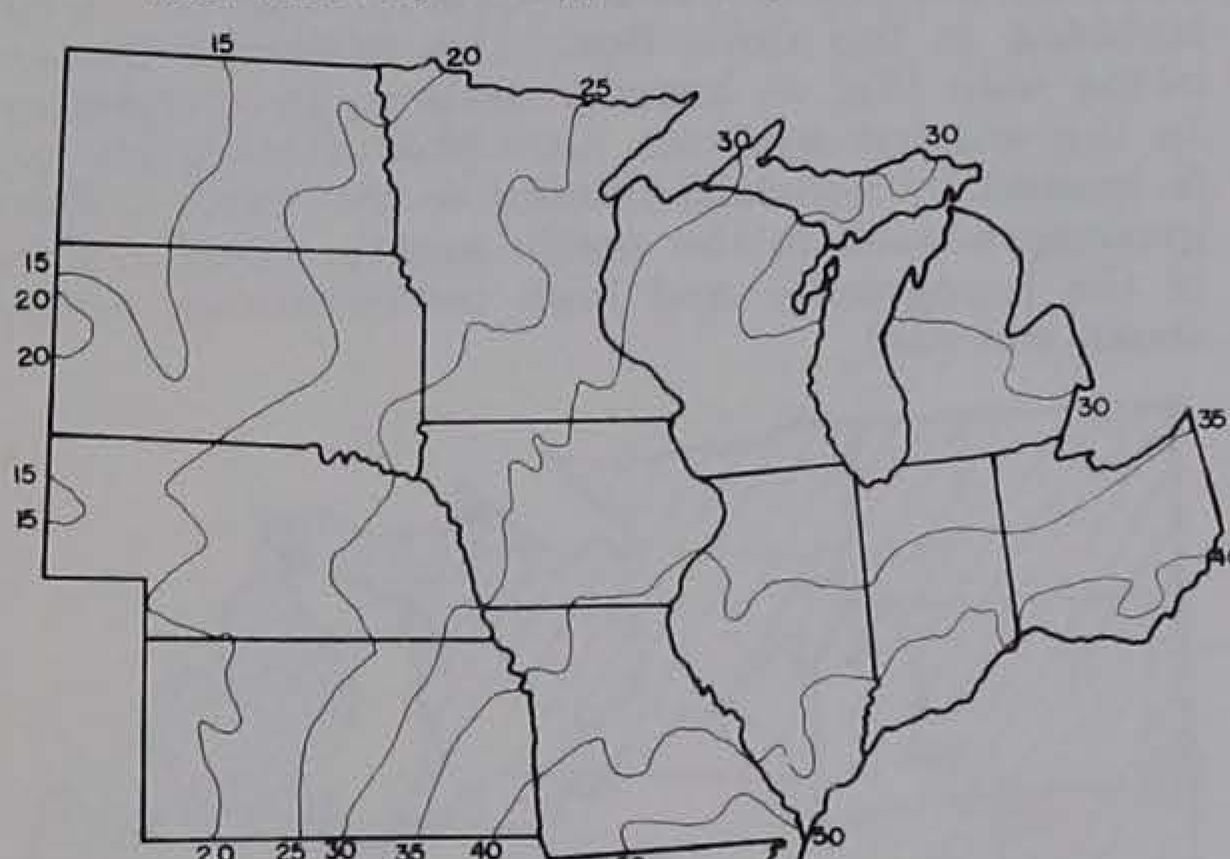

Fig. 3. Average annual precipitation (inches) in the North Central Region. [Redrawn from Soils of the North Central Region of the United States, Wis. Agr. Exp. Sta. Bul. 544 (North Central Regional Res. Pub. 76). 192 pp. 1960.]

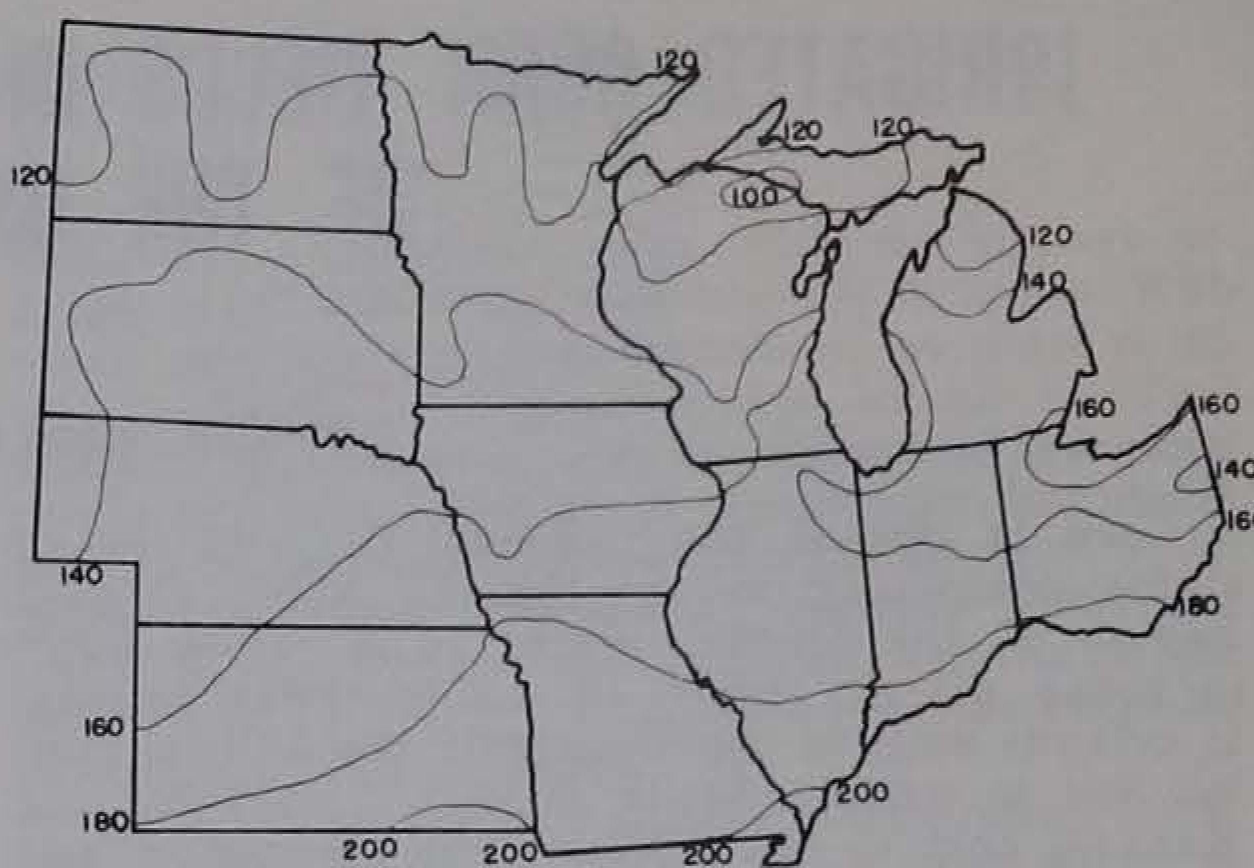

Fig. 4. Average length of frost-free days in the North Central Region. [Redrawn from Soils of the North Central Region of the United States, Wis. Agr. Exp. Sta. Bul. 544 (North Central Regional Res. Pub. 76). 192 pp. 1960.]

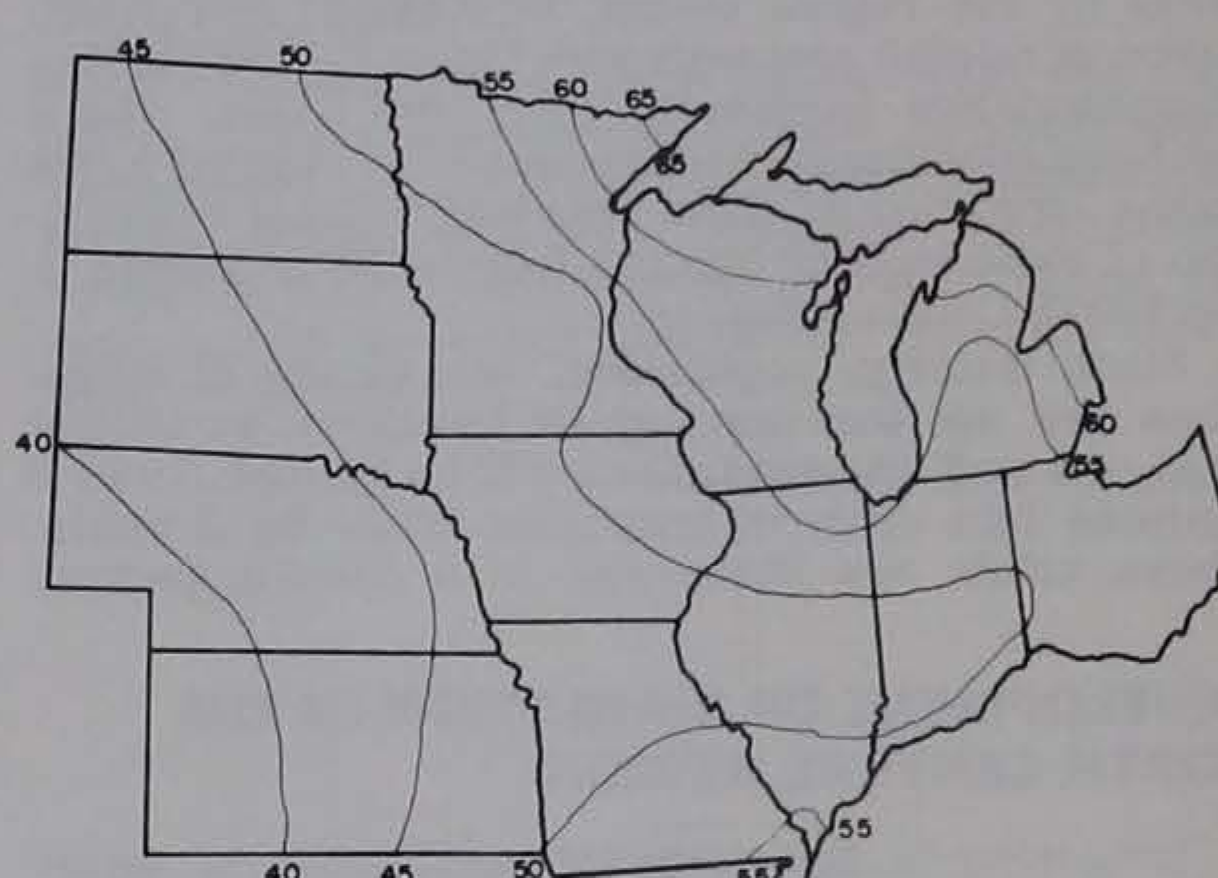

Fig. 5. Average relative humidity (percent) in the North Central Region. [Redrawn from Soils of the North Central Region of the United States, Wis. Agr. Exp. Sta. Bul. 544 (North Central Regional Res. Pub. 76). 192 pp. 1960.]

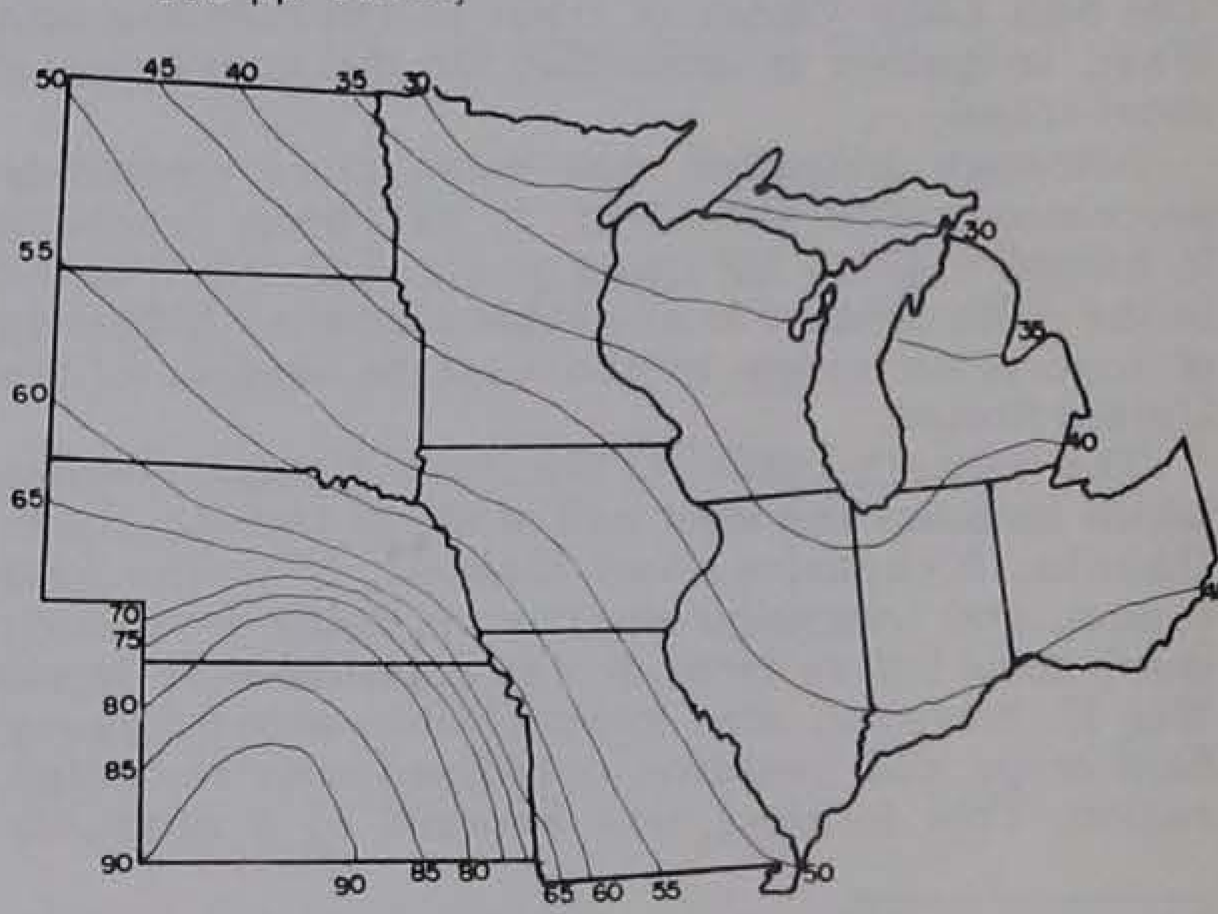

Fig. 6. Average annual class A pan evaporation (inches) in the North Central Region

[1] James E. Newman. Summer rainfall patterns in the Corn Belt. Proc. 15th Annu. Hybrid Corn Ind. Res. Conf. pp. 104-115. 1960.

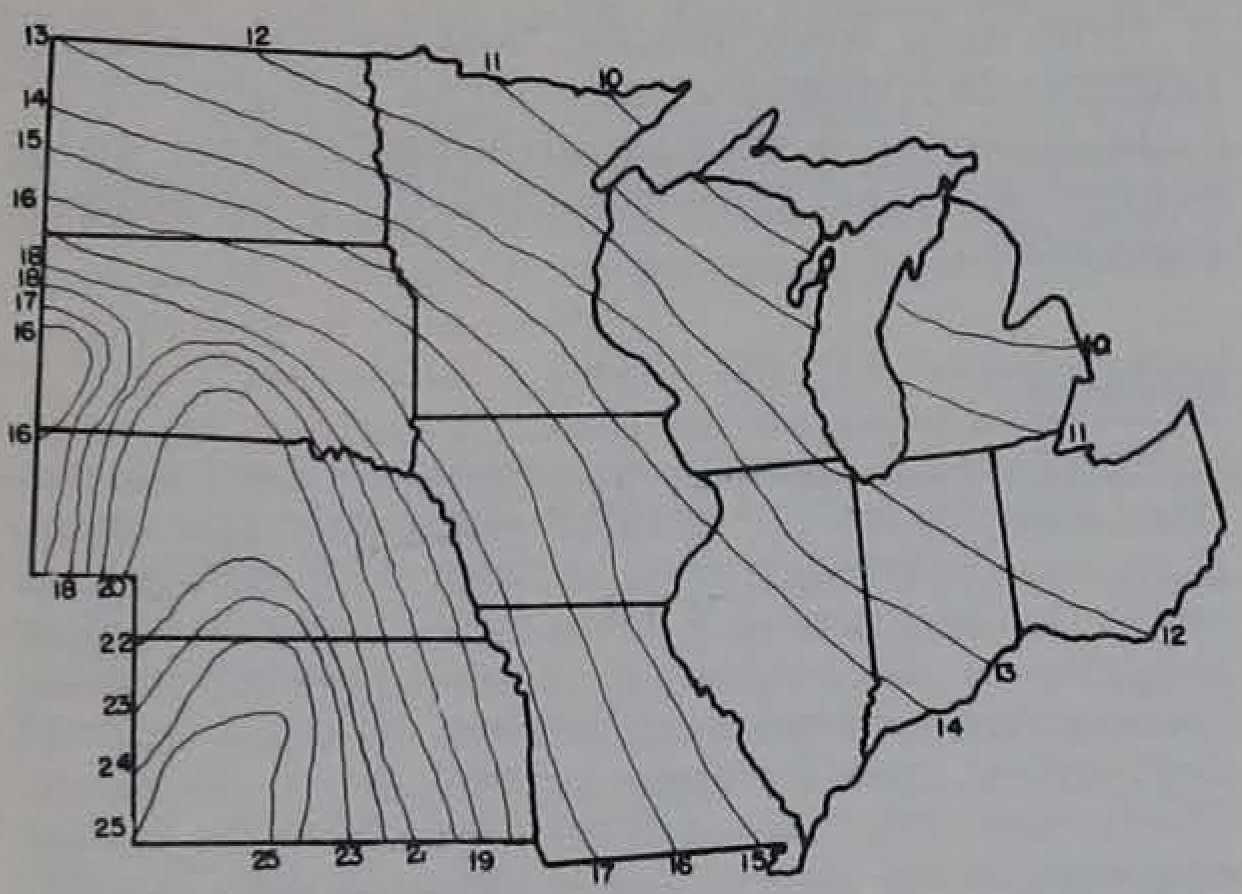

Fig. 7. Average class A pan evaporation (inches) for July and August in the North Central Region

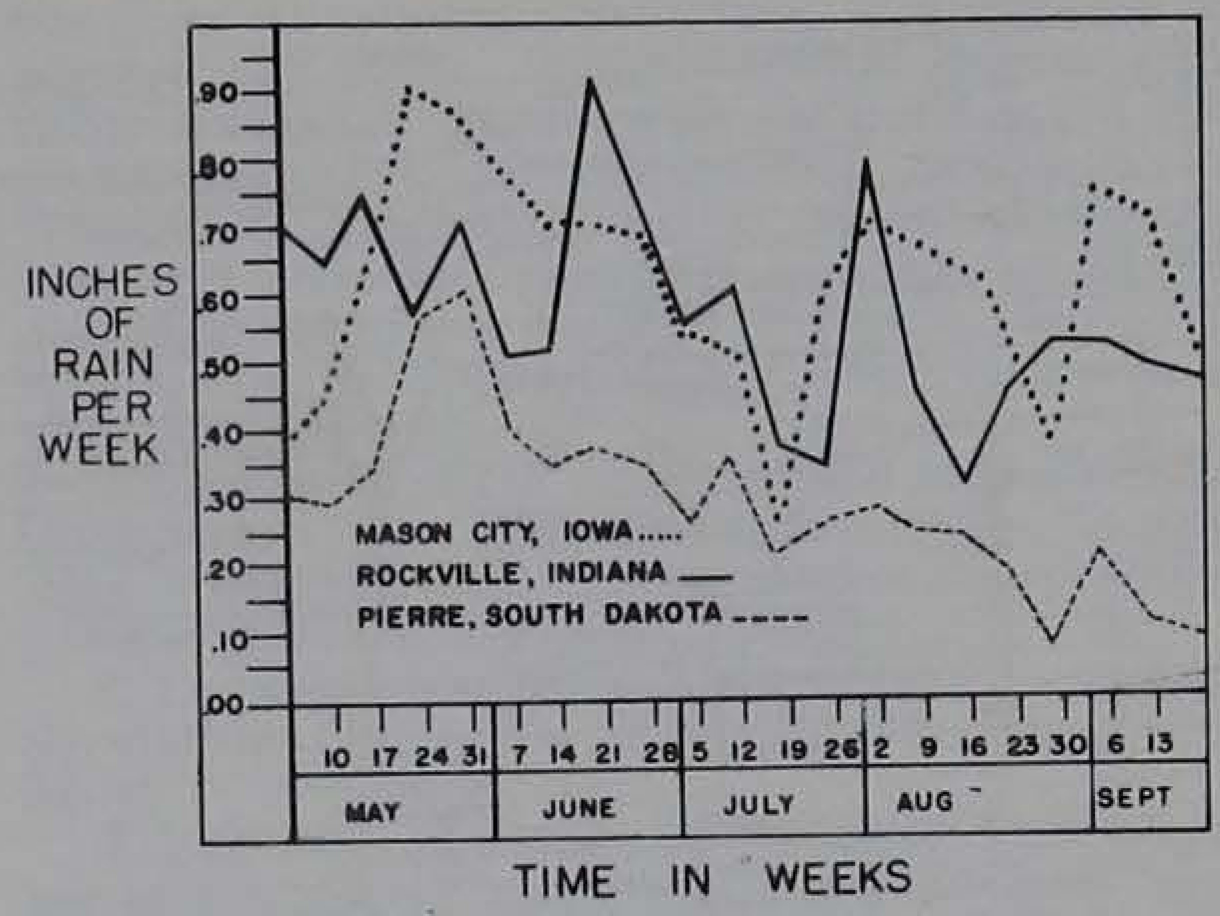

Fig. 8. The seasonal distribution of the fifty percent probability level of precipitation across the North Central Region. [Redrawn from James E. Newman. Summer rainfall patterns in the Corn Belt. Proc. 15th Annual Hybrid Corn Industry Research Conf. pp. 104-115. 1960.]

in the North Central Region. The rainfall characteristics (fig. 8) include a single late-spring maximum at Pierre, S.D.; a late-spring maximum, followed by secondary maxima in August and early September, at Mason City, Iowa; and a late-spring maximum, followed by a secondary maximum in early August, at Rockville, Ind. Fig. 9 shows the geographic distribution of the spring and summer maxima. These unique patterns of warm-season rainfall contribute to the adaptation of corn to the area, but periods of below normal rainfall may result in a soil moisture deficiency when irrigation may be feasible.

There is a wide variation in the soils of the region because of the soil formation factors of climate, parent material, topography, vegetation, and time. Some of the region has been glaciated, and some has not. A detailed description of the soils in the region has been published in Wisconsin Agricultural Experiment Station Bulletin 544 (North Central Regional Research Publication 76) "Soils of the North Central Region of the United States."

As rainfall decreases, irrigation becomes increasingly important for corn production. All organic soils with fairly level topography and good internal drainage are potentially irrigable for corn production. In the North Central Region, however, salinity and alkalinity also are problems. In the more humid sections, soil moisture-holding capacity may determine the feasibility for corn irrigation. In the humid sections, corn responds to irrigation only on the most droughty soils. Other soils have sufficient moisture-holding capacity to supply crop needs during periods of rainfall deficiencies.

In the low-rainfall areas where irrigation is most needed, water supply and water quality are important problems. The salt content and sodium percentage of water determines its suitability for irrigation. In the eastern section of the region there is, in general, an adequate supply of good-quality water.

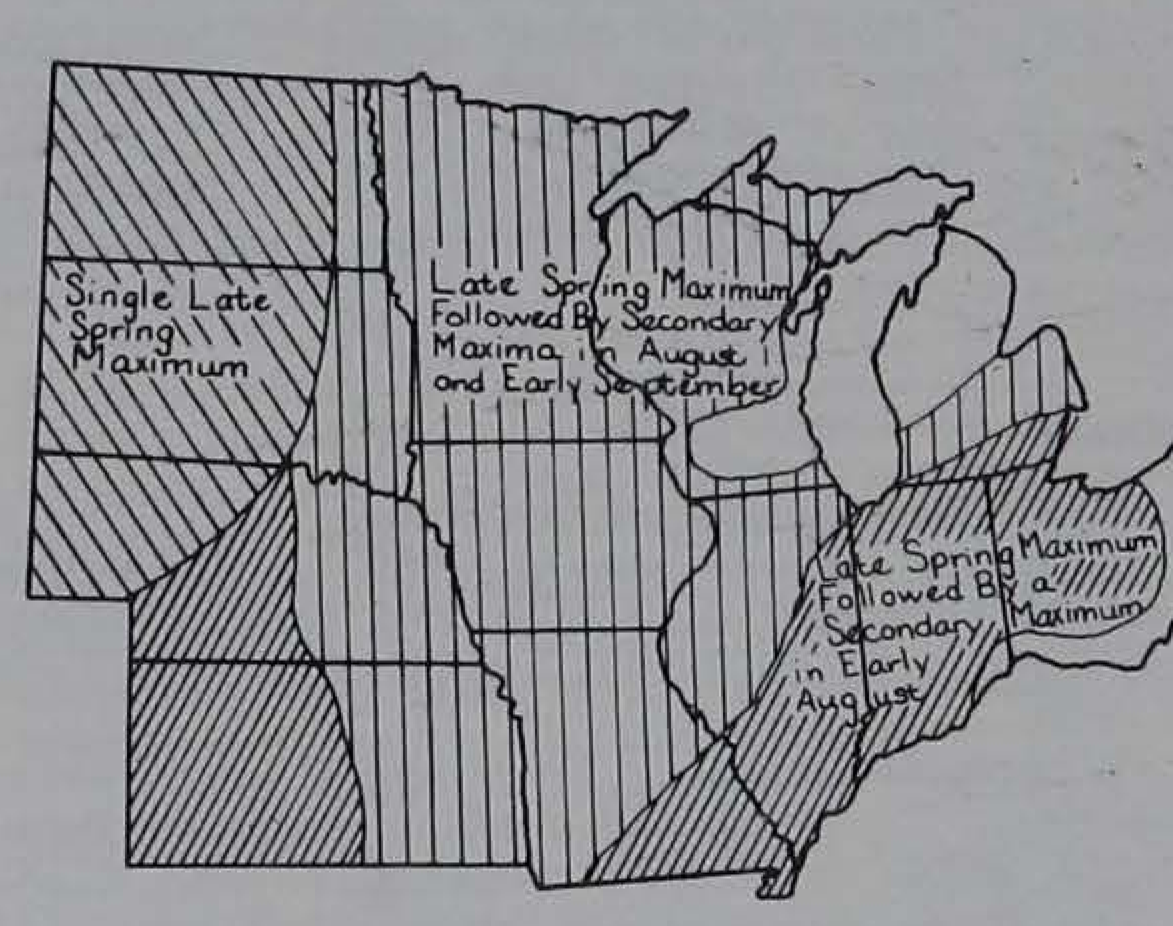

Fig. 9. Geographic distribution of the North Central States warm season rainfall patterns. [Redrawn from James E. Newman. Summer rainfall patterns in the Corn Belt. Proc. 15th Annual Hybrid Corn Industry Research Conf. pp. 104-115. 1960.]

IRRIGATION RESEARCH BY STATES

Many of the states in the North Central Region conducted research on irrigated corn from 1945 to 1965. Experiments were designed for specific objectives within each state. As a result, no uniform treatment variables or levels of individual treatments were planned on a regional basis. In 1958, however, several states conducted uniform irrigation trials. These uniform trials will be discussed in a separate section.

The location and identification of the experimental sites are shown in fig. 10, and data from each location are given in tables A-1 through A-6, Appendix A. Table B-1, Appendix B, describes the soils at each site.

Fig. 10. Names and locations of sites of irrigation research, North Central Region

The state irrigation research, except for the uniform trials, will be presented in two forms. (1) Each state prepared a short narrative describing the objectives and results of the research and submitted corn yield data obtained from the research plots. Limited statistical analyses and interpretation of the results are presented after the state narratives. (2) Tables A-1 through A-6, Appendix A, contain the yield data and levels of treatment variables.

Illinois

Two 5-acre tracts of Grantsburg silt loam, a Gray-Brown Podzolic intergrading to Red-Yellow Podzolic (fragipan) soil with two fertility levels and three moisture levels, were studied from 1955 to 1958.

Ranges of fertilizer treatments used were: NH_4NO_3, 74-153 lb./A; double superphosphate, 24-114 lb./A; potassium chloride, 57-203 lb./A.

The three soil-moisture levels used were: (1) "O," natural rainfall; (2) "M," medium—two 2-inch water applications (2 inches of water were applied when the corn was in the early tassel stage, and 2 inches more were applied 10-14 days later); and (3) "H," high—rainfall, plus enough irrigation water so that the total averaged 2 inches per week from the 7th through the 12th week after corn planting. The three soil-moisture levels were maintained each year except 1958. During 1958, unusually heavy rains occurred in July (12.83 inches); thus, it was not necessary to irrigate.

Over the 4-year period, fertilizer was as effective as irrigation in yield response, showing that a high state of fertility is an important factor in efficient water use. During the 4-year period, the fertilized unirrigated plots yielded from 87 bu/A to 128 bu/A. The best irrigated yields on the fertilized plots ranged from 107 bu/A to 132 bu/A. The average 4-year response due to irrigation alone on well-fertilized land was 23 bu/A, and the 4-year average increase for both fertilizer and irrigation was 48 bu/A. The average response due to fertilizer alone in the absence of irrigation was 27 bu/A. If 1958 data were omitted, however, the average response to fertilizer would only be 10 bu/A.

In general 4 inches of supplemental water applied at tassel time produced the most economical yields.

Indiana

The Indiana climate is suitable for corn production, with its annual rainfall averaging well above that required to produce a crop. With rare exceptions, the soil profile is filled to its moisture-holding capacity at the beginning of each growing season. During the corn-growing season of June through September, the average rainfall is 14-15 inches. There are intervals within this 4-month period, however, when the rainfall is normally low; in many years, this interval may be long enough to cause a moisture stress within the corn plant. Analysis of rainfall over several years indicates that this interval occurs in mid-to-late July, coinciding with the tasseling and silking of corn. This is a critical time for optimum yield.

Irrigation experiments were begun in Indiana in 1947 on some silt loam soils in the central portion of the state. From the results of these early experiments, it was concluded that the value of irrigation on the finer textured and more poorly drained soils was questionable because there was very little yield response and, in some instances, a decrease.

Four years of research (1948, 1952, 1953, 1955) on the Purdue Sand Experimental Field indicated that, with adequate fertilization and proper plant populations, corn with irrigation yielded from 120 to 145 bu/A. This was on a Chelsea sandy loam that, with no irrigation, yielded from 45 to 60 bu/A. In extremely dry years, this soil produced essentially no yield.

Experiments testing the interaction of population and irrigation (1947, 1948, 1953, 1954, 1955, 1956, 1957) indicated that, to get maximum yield with irrigation, it was necessary to have from 17,000 to 20,000 plants per acre. On the sandy soils with no irrigation, maximum yields usually were attained at less than 10,000 plants per acre. Experiments studying the effects of nitrogen showed that, on a very droughty soil with high irrigation, 200-250 lb./A of fertilizer were required to achieve maximum yield; 150 lb./A seemed, however, to give the greatest return per unit of input.

An unsolved problem remains for the very sandy soils. Yields have never exceeded 150 bu/A on experimental plots, and field crops seldom exceed 120 bu/A. These yields were obtained only with optimum fertilization and seeding rate. On the loamy soils with irrigation, yields of 175-200 bu/A have been attained.

Iowa

Irrigation research was begun in Iowa in 1951 and continued through 1963. The main objective of the research was to determine yield response from variable stand levels, fertilizer treatments, and levels of irrigation. The main crop grown on the irrigated plots was corn, but limited data were secured on soybeans.

The research has been centered in two areas: on sandy soils near Conesville in eastern Iowa and on silt loam soils in central Iowa. Average annual precipitation ranges from 35 inches in eastern Iowa to 31 inches in central Iowa.

The treatments selected for the experimental plots have varied throughout the period of record, but the range is sufficient to bracket the management practices necessary for optimum corn yields on irrigated land. Ranges of treatments used were: actual nitrogen, 0-240 lb./A; plant population, 7,000-23,000 plants per acre; irrigation treatment, no irrigation to maintaining 90% AMC (available moisture capacity); and plant variety, limited testing of inbreds and single crosses.

The studies were conducted on the sandy soils for 5 years. The average response to irrigation during this period was 34 bu/A. The optimum plant population was 15,000-16,000 plants per acre. Maximum corn yields under irrigation were not extremely high, averaging slightly over 100 bu/A. Maximum yields on plots not irrigated varied from 39 to 95 bu/A. With irrigation and fertilization, however, maximum yearly corn yields varied as much as 25% over the 5-year period.

In 1956, the irrigation research was moved to Ames, Iowa, on a silt loam soil. The average yield difference between the best irrigated and unirrigated plots during the 8-year period, 1956-63, was 22 bu/A. The greatest contribution to the averaged response occurred during one adverse year. The optimum plant population for the irrigated treatments was 18,000-20,000 plants per acre. The average irrigated yield was 135 bu/A, with a 20% variation during the period.

Kansas

An irrigation test on corn grown for both grain and forage was begun in north-central Kansas in 1954 and continued through 1957. The influence of time and amount of water applied during the production of grain and forage was studied. Based on the results, the following recommendations for irrigated corn were made:

1. Pre-irrigate unless the soil reservoir is near field capacity at plant time.
2. Irrigate just before the corn tassels.
3. Maintain a moderate soil-moisture level in the root zone for plant use from tassel to soft-dough stages. This requires a soil-moisture level about 50% of available in the root zone.
4. Fill the entire root zone at each irrigation. Soil sampling has shown that the effective root zone for corn at the Concordia Field is 4 ft.

A moisture-spacing-fertility study with corn was begun in 1960 with two moisture levels, three plant populations, (14,000, 17,000, and 20,000 plants per acre), and six fertility treatments. Six additional studies of irrigated plant populations were completed in the 1966 and 1967 growing season with eight commercially available corn hybrids. Plant populations ranged from 12,000 to 28,000 plants per acre. Locations, populations, and hybrids all affected corn yields. In three central Kansas locations, maximum yields were obtained at 24,000 plants per acre. In western Kansas, yields increased at populations up to 20,000 plants per acre and remained relatively constant at 24,000 plants per acre, but declined at 28,000 plants per acre. From these experiments, the following conclusions were drawn:

1. Maximum yields were obtained at higher populations in central Kansas than in western Kansas. Also, changes in yield with population changes were greater in central Kansas.
2. Lodging increased significantly with increasing population. No consistent hybrid differences were found.
3. Maturity as measured by days from planting to 50% silking was not affected by either location or population.

Minnesota

The major portion of the corn-producing land in Minnesota is located in the southern part of the state, where fine-textured (usually silt loam) soils predominate. Since these soils are moderately high in natural fertility, have high water-holding capacities, and normally receive from 15 to 20 inches of rainfall during the growing season, irrigation of field corn on such soils usually is not considered economically feasible.

Field corn is grown, however, on thousands of acres of sandy soils in central Minnesota. Satisfactory yields are difficult to obtain in this area because of the low water-holding capacity of the soil and the consequent crop damage from drought. The irrigation of field corn grown on such sandy soils, coupled with the maintenance of a high fertility level and other good cultural practices, can greatly increase the net income per acre.

Irrigated field-corn research in Minnesota has been confined largely to the sandy soil areas. Data obtained at various locations and during different years indicate that irrigation alone will not produce satisfactory yields on such soils. High levels of fertility and high plant populations must be combined with irrigation to provide maximum returns.

Plant populations of 10,000-26,000 plants per acre have been used. The highest yield (157 bu/A) was obtained at Elk River (1949) with a population of 20,000 plants per acre on a Cass sandy loam soil.

A high fertility level was maintained by applying 100 lb./A of 5-20-20 as a starter application, with 200 lb./A of elemental nitrogen applied on three later occasions (part side-dressed and the rest through the irrigation water).

At Holloway in 1963, plant population levels up to 26,300 plants per acre on a Sioux sandy loam (underlain with gravel) were studied. The populations of 26,000 plants per acre, however, showed slightly lower yields as compared with those obtained with populations of 20,200 plants per acre. Maximum fertilizer application on the Holloway plots was 350 lb./A of 10-30-10, plus 80 lb./A of elemental nitrogen applied as a side dressing.

Nebraska

Consumptive use of water by corn was studied at the North Platte Experiment Station near North Platte, Nebr., from 1959 to 1964. The work was done on a Bridgeport very fine sandy loam in an area that receives 21 inches of rainfall annually.

Early, medium-, and full-season corn varieties were tested under different levels of irrigation. Treatments ranged from a full profile at planting and no irrigation, to a system holding the soil-moisture tension at 24-inch depth less than 70-centibars tension. All plots were wetted to field capacity to a 6-ft. depth on May 1. The plots received from 10.7 to 31.1 inches of water during the growing season from irrigation and precipitation.

The medium-season corn yielded slightly more than the early or full-season varieties. Corn yields ranged from 55 to 136 bu/A. The highest yields were obtained on plots kept at low-moisture tension, and the lowest yields were obtained on unirrigated plots. Severe hail damage occurred in 1962, and the plots were not harvested for yield comparisons. Thus, no data are presented for the 1962 crop year.

Yield data are presented for the effect of irrigation with the best fertility level and plant population. Ranges of treatments used were: actual nitrogen, 158-193 lb./A; plant populations, 15,200-17,120 plants per acre.

Yields of corn varieties available at the time of the study did not increase with increase in plant population above 16,000. The highest corn yields were obtained when the soil-moisture tension at the 24-inch depth was held above 70 centibars. Treatments receiving higher total amounts of irrigation water did not produce a higher yield than the plots held at a low soil-moisture tension.

The recommended practice for corn production is to apply 180-15-0 fertilizer, establish 17,000 plants per acre, and irrigate to keep soil-moisture tension above 70 centibars at the 24-inch depth.

North Dakota

The consumptive use of water by corn was studied at the Deep River Development Farm near Upham, N.D., from 1953 to 1957. The research was done on a Gardena loam, in an area that receives about 15 inches of rainfall annually. In a corn, potato, barley, and alfalfa crop rotation, corn had a seasonal consumptive use of 17.5 inches during a 4-year period. The average daily water use, based on weekly samplings, varied from a peak of 0.22 inch per day in July to a minimum of 0.12 in September. The average period of consumptive use for corn at this location was 113 days.

In a 6-year experiment at Sidney, Mont., and Mandan, N.D., corn forage and grain yields, under dryland conditions, were highly correlated with total available moisture. After total available water exceeded 6 inches, yields were linearly related to the sum of soil moisture at planting and precipitation. The relationships were influenced little by population (ranging from 5,000 to 20,000 plants per acre) and nitrogen fertilization.

At the Carrington Irrigation Branch Station, corn yielded 75.2 bu/A when irrigated and 38.2 bu/A under dryland conditions over a 3-year period from 1962-64. Cool temperatures later in the 1965 growing season were unfavorable for the production of corn at the Carrington Station. The irregularity of summer temperatures in this climatic zone causes a range of irrigated corn yields from below 45 to over 125 bu/A.

Experiments were conducted at Upham during the growing seasons of 1956-57 to study the effects of two soil-moisture levels, two plant densities, and several rates of nitrogen fertilization on the evapotranspiration rate and yield of corn. Neither nitrogen fertilizer nor plant density influenced yield in the unirrigated treatment. In the irrigated treatment, corn yields were higher with nitrogen fertilization than without at plant densities of 14,000 and 23,000 plants per acre. With no fertilization, however, the yields of both plant populations were quite similar. At the higher fertilizer levels with irrigation, yields were higher with 23,000 plants per acre than with 14,000 plants per acre.

Neither nitrogen fertilizer nor plant density appreciably affected the evapotranspiration rate, but evapotranspiration was considerably greater for the irrigated plots than for the unirrigated plots. More yield per inch of water used was obtained on the dryland plots than on the irrigated plots, except where the high population rate was used with a fertility level of 120 lb./A of nitrogen.

A study of the effect of nitrogen and phosphorous fertilization on yield and nutrient composition of corn plants grown under irrigation was made at the Upham farm by using the hybrid, Nodak 301, from 1953 through 1957. The yields were highly correlated with the nitrogen percentages in the corn leaves at nitrogen rates up to 80 lb./A.

South Dakota

Corn irrigation research in South Dakota since 1949 has investigated the variables of water application and fertility level. The cropping system between 1949 and 1955 used corn in a 4-year rotation with wheat and alfalfa at two fertility levels. Results from irrigation research in South Dakota have shown that corn needs adequate moisture from the beginning of tasseling to the completion of pollination, a period critical in the life of the corn plant. A study at the South Dakota Agricultural Engineering Farm in 1961 showed that yields were not increased from full-season irrigation of corn over those where irrigation was terminated 2 weeks after tasseling.

A fertility study with corn under uniform irrigated conditions was conducted at Redfield, S.D., in 1961. An application of 240 lb./A of nitrogen was optimum, giving a corn yield of 97 bu/A.

Wisconsin

Research on corn irrigation at the experiment stations at Hancock and Spooner, Wis., was conducted to determine the relative importance of three interrelated factors: moisture, soil fertility, and plant population.

The soil types are a light Plainfield sand at Hancock and a Pence loamy fine sand at Spooner. The average annual rainfall in these areas is sufficient to produce good corn crops on heavy soil, but low yield and occasional crop failure is expected on light soil because of low fertility and low water-holding capacity.

Irrigation alone has resulted in only modest yield increases; likewise, the application of fertilizer without irrigation has resulted in some increase in production, with considerable variation from year to year, depending on the frequency and intensity of rainfall. Increased plant population alone showed little or no yield increase.

A combination of high fertility and sufficient irrigation produced consistently large yield increases. Proper fertility with irrigation and an increase in plant population produced much higher corn yields.

It seems that, with proper irrigation, fertility, and plant population, yields of 130 to 150 bu/A of corn are possible on soil that normally produces 35 to 40 bu/A without irrigation. In the research work, the maximum yield was 130 bu/A at Hancock, and 153 bu/A at Spooner.

For research purposes, three levels of moisture were maintained during the growing season. The low level involved no additional application of water beyond the natural rainfall. Moderate irrigation was in the crop-saving range. Water was applied when needed, based either on plant observation or on the length of period without rain. With full irrigation, there was always adequate available water in the entire root zone.

Through many years of experience, the conventional fertility level has been established to effectively utilize the normal rainfall on the soils at Hancock and Spooner. Higher fertility levels should be maintained to utilize water supplied by supplemental irrigation.

Plant population and rate of fertilizer application are under direct control of the operator. With supplemental irrigation also under the control of the operator, it is possible to plan for and usually achieve a desired production. With normal rainfall and no irrigation, there is little chance to consistently attain high production through increases in fertility, higher plant population, or a combination of the two.

Analysis and Discussion

In response to a letter sent to members of the NCR-12 committee, irrigation research data were received from North Dakota, Nebraska, Iowa, Missouri, Wisconsin, Illinois, Indiana, and Michigan on experiments conducted from 1950 through 1960.

The research data received was divided into two categories, according to type of information given. The data for 1959 and 1960 were more detailed and gave corn yields on an individual plot basis; the data for the years before 1959, however, were average yields that could be divided into five irrigation levels for three stand levels in each of three fertilizer levels.

The data for 1950 through 1958 were not suitable for rigorous statistical analysis, although a summary of the information relative to the different treatments in each of two general soil classes, (a) sand soils with more than 70% sand and (b) loams, is presented in table 1. Cautious interpretation is necessary, however, because:

Table 1. North Central Region corn yield data, bu/A, 1950 through 1958[a]

			Low Nitrogen			Med. Nitrogen			High Nitrogen		
	Soil Group		Low Stand	Med. Stand	High Stand	Low Stand	Med. Stand	High Stand	Low Stand	Med. Stand	High Stand
No irrigation	Loam	Av. yield	53.5	70.1	48.5	60.0	77.8	60.9	66.7	83.2	81.7
		No. samples	9	12	7	12	14	6	11	15	9
		Std. dev.	24.3	28.2	21.7	31.1	33.5	22.6	37.6	35.7	28.1
No irrigation	Sand	Av. yield	62.3	57.3	32.4	69.3	59.8	35.8	64.2	55.1	38.5
		No. samples	4	7	3	4	5	4	4	9	4
		Std. dev.	31.1	34.3	42.1	23.0	34.2	36.9	29.8	32.3	36.4
Irrigation at silking and tasseling	Loam	Av. yield	52.6	77.7	52.9	84.4	75.7	99.2	97.7	122.0	110.0
		No. samples	3	5	3	3	2	3	3	7	3
		Std. dev.	25.6	31.5	32.9	27.0	14.9	19.8	11.4	20.5	2.9
Irrigation at silking and tasseling	Sand	Av. yield	52.7	51.6	7.7	66.0	64.5	85.7	88.0	80.6	80.3
		No. samples	2	2	1	2	2	3	3	5	2
		Std. dev.	42.1	52.7		30.8	41.6	57.8	33.4	37.7	68.1
Maintaining 50% available in upper ½ of root zone	Loam	Av. yield	57.3	88.6	77.3	88.3	107.4	113.1	86.9	113.8	114.4
		No. samples	6	10	8	8	11	8	9	13	12
		Std. dev.	27.7	30.1	39.8	26.8	23.8	16.0	27.7	26.3	22.5
Maintaining 50% available in upper ½ of root zone	Sand	Av. yield	75.0	72.5	65.2	103.1	96.2	90.8	109.1	95.5	109.9
		No. samples	4	3	2	4	5	4	3	7	7
		Std. dev.	24.6	38.1	66.8	8.6	24.7	30.8	1.1	23.2	27.2

[a]Low, medium, and high classes for nitrogen and stand include: low nitrogen (0-40 lb./A), medium nitrogen (40-100 lb./A), high nitrogen (100-300 lb./A), Low stand (8,000-12,000 plants/A), medium stand (12,000-16,000 plants/A), high stand (16,000-25,000 plants/A).

1. Not all average yield figures are based on the same number of samples; all states did not include all treatment combinations.

2. The years of data for a given treatment combination may be different from the years of data for other treatment combinations; thus, effects of year-to-year variations are different for different treatment combinations.

3. Some yield values are from only one state since others did not have the treatment combination.

Thus, table 1 reflects only general trends in the yields for the treatment combinations. With no irrigation, the medium stand level gave the highest yields for the loam soils at all three fertilizer levels, with the highest average yield occurring with the high nitrogen level. Samples are fewer for the unirrigated sand soils, but the low plant population shows a slightly higher yield for all three fertilizer levels. The effect of fertilizer is not established.

The rest of table 1 shows yields for two irrigation treatments. With irrigation only at silking and tasseling, the yields fluctuate among stand levels, but table 1 shows a general increase in yield with increasing nitrogen in both the sand and loam soils. A similar result was found for the water treatment of irrigating when the soil moisture reached 50 percent AMC. Usually, the highest yields occur for high stands in the loam soils and for low stands in the sand soils.

The standard deviations show the ranges of individual yields for a given combination (table 1). Generally, the standard deviation is large relative to the size of the mean. Within a water treatment, the standard deviation is usually higher for sand than for loam soils.

Soil-moisture changes were included in the 1959 and 1960 data; thus, the total moisture use could be computed for three states. Table 2 gives the best estimate available from the data for the moisture use in the respective states. It was not possible to determine if any moisture was lost to deep seepage because of soil moisture exceeding the field capacity. It is quite probable that some soil moisture was lost to seepage in the Iowa plots in May 1959. The soil moisture was near field capacity at planting time on May 15, and with no vegetation, some of the 5.80 inches of rainfall for the remainder of May was not used by the corn crop. A similar situation existed in August 1959 in the Illinois plots when a 5.5-inch rain fell 3 days after a 2.0-inch irrigation. Therefore, the total water use would tend to be less than that given in table 2. The time at which the soil was sampled in relation to the planting date also was not the same in all states.

In general, table 2 shows more yield per inch of water used on the irrigated plots than on plots not irrigated. An exception is the Illinois data, where the total rainfall nearly equaled the consumptive use. Table 2 also shows that Nebraska has a higher yield per inch of water used than either Iowa or Illinois. Part of the explanation is that the corn had grown a month before sampling began; also, there was less opportunity for direct evaporation from the soil with less frequent rainfall. Any differences of corn yield per inch of water used associated with climatic factors could be confounded with variety of corn since different varieties were used in the states.

UNIFORM REGIONAL IRRIGATION TRIALS

Because of the wide range of treatment variables in the results reported in the previous section, the NCR-12 Committee set forth suggested guidelines to equalize the experimental variables on a regional basis. The objectives were: (a) To determine the effect of a range of soil and climatic conditions on yields of irrigated corn in the North Central Region and (b) To characterize the stand, moisture, and fertility conditions necessary for maximum irrigated-corn yields in the North Central Region.

Data were received from Iowa, Indiana, and Illinois for the 5-year period 1959-63. The lack of uniformity in the uniform regional experiments and the absence of data from several states seriously affects any conclusions that might be applicable on a regional basis. The plant populations on both irrigated and unirrigated plots varied from state to state as well as within a given state during the 5-year period. As shown in table 3, the irrigated plots represent populations of 16,000-20,000 plants. The unirrigated plots represent populations of 10,000-20,000. Further inspection of the data showed that the yields used in the analysis in most

Table 2. Total seasonal use of moisture by corn in Iowa, Nebraska, and Illinois

		Unirrigated			Irrigated		
		Precip.[a] (in.)	Water used[b] (in.)	Yield[c] (bu/in. water)	Precip.[a] (in.)	Water used[b] (in.)	Yield[c] (bu/in. water)
1959	Iowa	20.6	28.00	3.8	20.6	30.00	4.1
	Ill.	21.5	22.16	3.8	21.5	24.62	3.4
	Neb.[d]	10.3	18.94	5.2	10.3	22.23	6.0
1960	Iowa	16.1	23.00	5.2	16.1	28.00	5.0
	Neb.[d]	4.7	18.07	3.4	8.1	24.72	5.4

[a] Precipitation column includes the amount of rainfall during the period the moisture balance was made.
[b] Total water used by corn plants during period of moisture sampling; assumes no water lost to deep seepage.
[c] Yield of corn obtained per inch of water used.
[d] Sampling in Nebraska began 1 month after planting; in Iowa and Illinois, sampling began at planting time.

Table 3. Plot corn yields used in uniform analyses [a]

Treatment	Year	I Iowa	I Ind.	I Ill.	II Iowa	II Ind.	II Ill.	III Iowa	III Ind.	III Ill.
		Replicate								
Irrigated	1959	120.9	112.4	75.8	126.0	119.3	79.7	121.5	113.8	83.9
	1960	147.1	134.0	148.6	139.6	139.0	146.7	133.6	144.0	144.4
	1961	141.5	115.0	107.0	148.3	115.0	132.0	140.2	117.0	109.0
	1962	126.4	115.0	148.3	129.3	127.0	152.2	142.8	106.0	169.3
	1963	136.4	149.0	180.9	122.7	158.0	188.3	128.1	143.0	169.7
Unirrigated	1959	94.6	36.1	77.9	90.3	31.5	76.6	92.9	35.5	86.0
	1960	103.7	102.0	98.1	100.9	97.0	102.6	98.7	100.0	90.6
	1961	147.7	106.0	134.0	141.9	101.0	129.0	145.8	101.0	121.0
	1962	123.1	79.0	97.1	119.0	68.0	88.1	121.5	74.0	89.5
	1963	132.6	102.0	170.4	116.2	99.0	157.3	135.2	104.0	157.3

[a]Constant fertility. Highest N treatment. Plant population is variable from state to state and from year to year; range is from 16,000 to 20,000 for irrigated data. Unirrigated data represents, in most instances, the optimum yield for the particular year.

instances (22 of 30) represented the optimum (highest) for a treatment in a given state for a given year. Therefore, little significance may be placed on stand other than giving optimum yield for a particular year.

The level of nitrogen fertilizer application has fluctuated somewhat within the three states during the 5-year period. A more significant variation is the change in varieties used. There is little doubt that the record high yields obtained in 1963 in Illinois and Indiana were due to the change in corn variety. Table 4 shows the pattern of application and variety used in the three states.

Graphic Analysis

Both a graphic representation and an analysis of variance were made for the 5 years of data from Iowa, Indiana, and Illinois. The average yields reported for irrigated plots and unirrigated plots are shown in figs. 11 and 12. There is considerable

Table 4. Rates of nitrogen and varieties used in irrigation trials

State	Year	Nitrogen, lb.	Variety
Iowa	1959	60	Ia. 704
Indiana	1959	150	Ind. 605
Illinois	1959	150	Ill. 1996
Iowa	1960	120	Ia. 704
Indiana	1960	211	WF9X OH07
Illinois	1960	(100-300)	Ill. 1996
Iowa	1961	120	Ia. 704
Indiana	1961	161	G-76
Illinois	1961	150	Ill. 1996
Iowa	1962	120	Ia. 704
Indiana	1962	166	G-76
Illinois	1962	217	Ill. 1996
Iowa	1963	120	Ia. 704
Indiana	1963	160	S 412 Sx
Illinois	1963	184	P-G-Sx 29

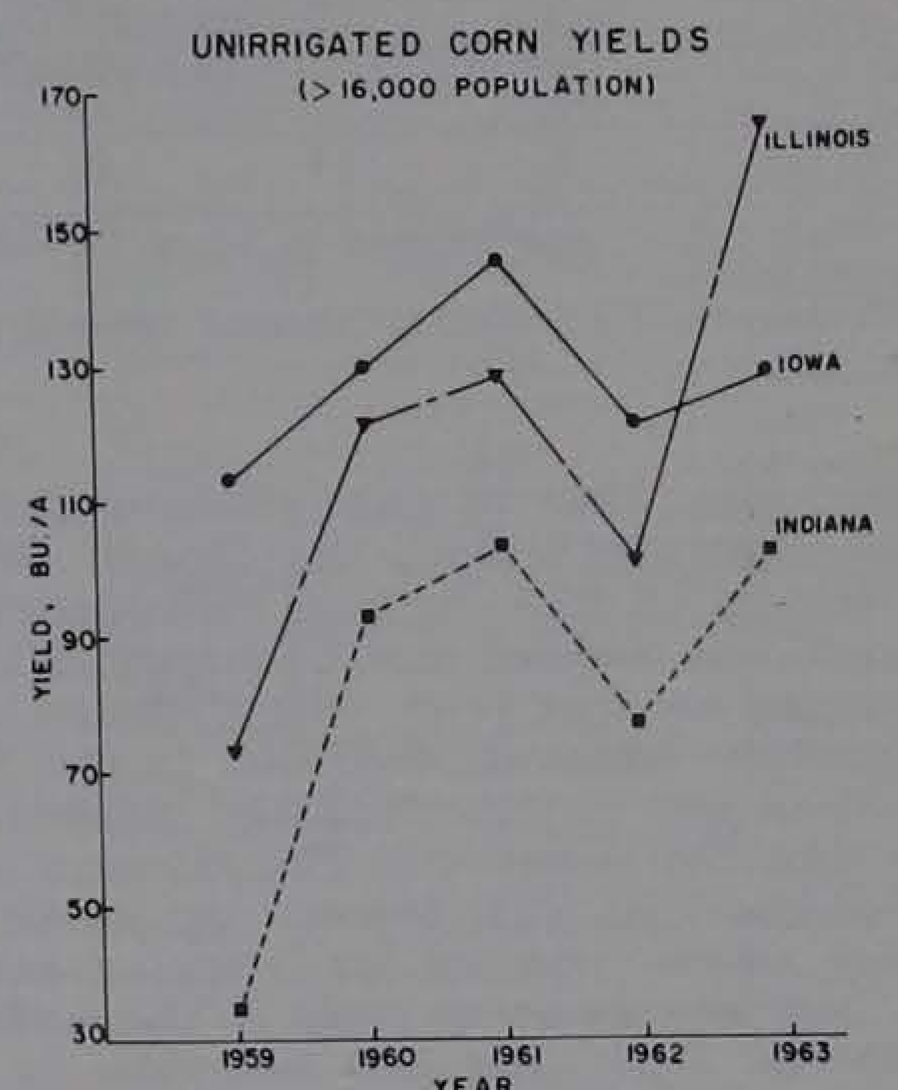

Fig. 11. Unirrigated corn yields from uniform irrigation trials, North Central Region

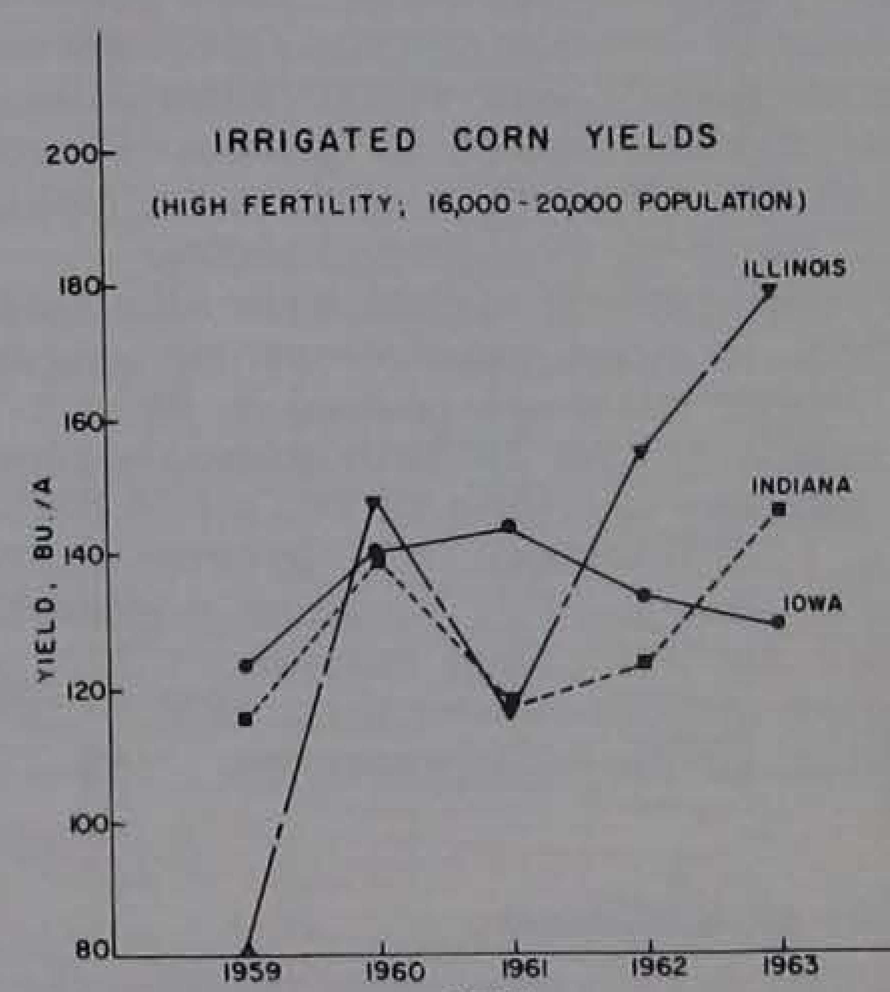

Fig. 12. Irrigated corn yields from uniform irrigation trials, North Central Region

Table 5. Yearly responses to irrigation and year-to-year variations in maximum yields from irrigated and unirrigated (check) plots

Year	Iowa			Ind.			Ill.		
	Response to irr., bu	Yearly[a] diff. irr, bu	Yearly[b] diff. check, bu	Response to irr., bu	Yearly[a] diff. irr, bu	Yearly[b] diff. check, bu	Response to irr., bu	Yearly[a] diff. irr, bu	Yearly[b] diff. check, bu
1959	10			80			1		
		17	17		20	62		60	36
1960	10			38			25		
		9	21		22	3		19	9
1961	−2			13			3		
		16	27		7	26		29	26
1962	8			46			52		
		12	6		22	25		33	65
1963	13			43			19		
5 yr. av.	8	13	18	44	18	29	20	35	34

[a] These values were obtained by taking the difference in maximum irrigated yields on two successive years; e.g., 1959 and 1960, 1960 and 1961.

[b] The values were obtained by taking the difference in maximum unirrigated yields on two successive years.

variation from year to year within a given state. For the unirrigated plots, the dips in the curves seem associated with moisture deficiencies as evidenced by the number and frequency of irrigation applications for that year. With optimum moisture and fertility, however, variation in the irrigated yields from year to year should be reduced. Fig. 12 shows that this is not true. The extent of response to irrigation and year-to-year variations in the optimum yields reported for irrigated and unirrigated plots are shown in table 5. The 5-year average figures show that the response in Indiana has been greatest because the plots are on a sandy soil. A rather surprising effect is shown in the average yearly fluctuations. They show that the application of optimum moisture does not materially reduce the year-to-year variation in maximum yields over unirrigated, except in Indiana. Therefore, climatic effects other than moisture shortage have an effect on yields on irrigated plots.

A limited amount of data were available to show the effect of plant populations on irrigated corn yields. These data are plotted in fig. 13. There is considerable scatter for both states, but by averaging within the brackets of 10,000-14,000, 14,000-16,000, 16,000-18,000, and greater than 18,000 plants, it was possible to show a general trend, indicated by the points enclosed within squares. The peaks of both curves show that 18,000 plants is optimum for the data presented.

Analysis of Variance

An analysis of variance was made on the 5 years of data. The purpose of the analysis was to secure information on the effect of location on yield response to irrigation. There were several problems involved in making a conventional statistical analysis:

1. The same experimental design was not used in all states; therefore, there was no certainty that all treatment effects were estimated with the same precision in all states. This problem was minimized by the use of the half-normal plot to investigate the validity of an assumed model and error structure for the analysis.

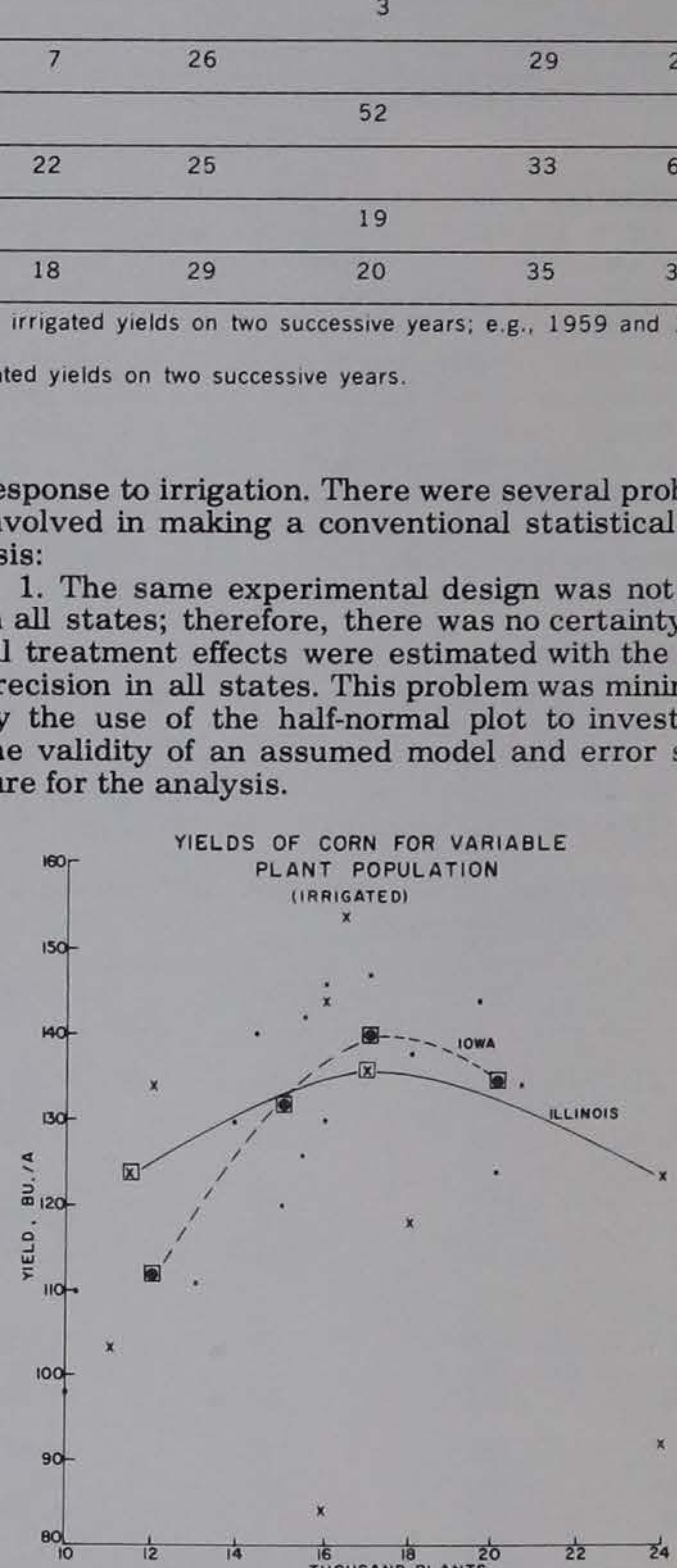

Fig. 13. Relationships of irrigated corn yields and plant population

2. The number of replicates was not the same in all the experiments in the states. Three was the minimum; therefore, the first three replicate values were arbitrarily used in all states.

3. To obtain the desired treatment contrasts, it was necessary to bracket the stand level and assume it to be a uniform treatment in the analysis.

Two different analyses included the same treatment comparisons, but in the log analysis, the logarithms of the data were used. Thus, in the latter instance, a proportional or percentage response is measured, whereas in the conventional analysis, an absolute additive effect of treatment between states is measured.

An abbreviated portion of the analysis of variance is shown in table 6. The error term given in table 6 is valid for testing A, B, AC, AC_1, and AC_2. The major information shown by the AOV is that there is a great variation from year to year (also see fig. 12). Further, the state-irrigation interaction is significant all the way through, showing that the absolute, as well as the percentage, response to irrigation is different from state to state (also see table 5).

Table 6. Analysis of variance

Treatment	df.	M.S. (Conventional)	M.S. (Logs)
A Irrigation	1	18,533**	0.01979
B Year	4	6,983**	0.1381**
C State	2	4,240	0.0940
C_1 Ia. vs. Ind. and Ill.	1	2,734	0.0790
C_2 Ind. vs. Ill.	1	5,746	0.1090
AC	2	1,815**	0.0592**
AC_1	1	1,809*	0.0431*
AC_2	1	1,822*	0.0753**
Error	52	261	0.0063

**Significant at 0.01 level.
*Significant at 0.05 level.

APPENDIX A
Corn yield data from North Central Region

Table A-1. Response of corn to irrigation.

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
Indiana, Sand Field, 1952	19.5	72.8	200-82-166	19,000	None	0	0	65
					Irrigated	6	8	120
Indiana, Sand Field, 1954	15.4	72.4	200-82-208	10,000	None	0	0	83
				20,000	Irrigated	4	4	130
Iowa, Beach Ave., 1963	17.3	72.6	120-0-0	13,500	None	0	0	131.1
					Irrigated-silking	1	5.15	126.6
					60% available	2	4.77	129.8
Michigan, Forbush Farm, 1955	--	--	--	15,000	None	0	0	80
					Irrigated	--	--	102
Michigan, Morgan Farm, 1955	--	--	--	17,000	None	0	0	90
					Irrigated	--	--	104
Missouri, South Farms, 1948	17.4	76.3	--	17,000	None	0	0	95.3
					Irrigated	1	3.3	136.7
Missouri, South Farms, 1955	13.6	75.0	--	15,000	None	0	0	79
					Irrigated	3	9.8	126
					Irrigated	4	10.5	154
Minnesota, Elk River, 1949	15.4	72.3	25-9-17	10,000	None	0	0	70
					Max. tension 0.8 ATM	2	3	79
					Above 50% available	3	6	79
South Dakota, Agr. Eng. Farm, 1961	18.5	68.6	--	19,000	None	0	0	75
					Irrigated 2 weeks after tasseling	5	--	109
					Irrigated all season	8	--	106
Wisconsin, Hancock Experiment Station, 1954-58	--	--	--	--	None	0	0	48.0
					Moderate irrigation	2	3.5	102.2
					Full irrigation	5	7.9	126.9

[a] May 1 through Sept. 30
[b] June, July, August
[c] Actual N-P-K

Table A-2. Response of corn to irrigation and population.

Location and year	Precip. [a] in.	Av. [b] temp.	Fertilizer [c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Yield bu/A
Indiana,	16.2	74.6	236-143-291	11,000	None	0	0	108
Mitchell Farms,				15,000				105
1947				22,500				81
				15,000	Wilting	1	1	112
				22,500	0-6″			106
				30,000	depth			80
Indiana,	20.9	.73.3	273-143-291	11,000	None	0	0	56
Poultry Farm,				15,000				54
1947				22,500				31
				15,000	Irrigated	3	1	60
				22,500				61
				30,000				52
				15,000	Irrigated	3	2½	83
				22,500				78
				30,000				76
Indiana,	20.9	75.2	280-212-431	12,000	None	0	0	140
Mitchell Farms,				17,000				147
1948				22,000				130
				12,000	Wilting	3	2.25	147
				17,000	0-6″			142
				22,000	depth			126
				12,000	pF 3.4	6	5.80	141
				17,000	0-6″			155
				22,000	depth			152
Indiana,	19.6	71.0	308-125-255	4,000	pF 3.4	0	0	47
Sand Field,				8,000	0-6″			59
1948				12,000	depth			58
				12,000	Irrigated	5	5.88	117
				17,000				130
				22,000				125
Indiana,	15.1	75.2	--	18,000	None	0	0	87
Farmer's Field,				21,500				81
1954								
				18,000	50% above	4	8.0	129
				21,500	available			143
Indiana,	18.4	--	--	15,000	None	0	0	12
Jone's Farm,				20,000				10
1955				25,000				7

Table A-2 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
				15,000	Soil moisture	3	11.4	106
				20,000	in upper 2 ft.			88
				25,000	dropped to			77
					30% available			
				15,000	Soil moisture	6	17.3	111
				20,000	dropped to			115
				25,000	about 85%			105
					of available			
Iowa, Beach Ave., 1962	14.5	70.6	120-0-0	10,200	None	0	0	109
				15,500				122
				20,500				125
				10,200	60% avail-	2	11.0	110
				15,500	able			126
				20,500				133
Michigan, Forbush Farm, 1953	--	--	--	12,700	None	0	0	42
				15,600				37
				12,700	Irrigated	--	--	81
				15,600				78
Michigan, Morgan Farm, 1954	--	--	--	11,700	None	0	0	109
				15,600				121
				11,700	Irrigated	--	--	112
				15,600				135
Michigan, Forbush Farm, 1954	--	--	--	11,700	None	0	0	60
				15,600				69
				11,700	Irrigated	--	--	98
				15,600				103
Michigan, Morgan Farm, 1956	--	--	--	13,100	None	0	0	78
				17,400				100
				13,100	Irrigated	--	--	90
				17,400				108
Michigan, Forbush Farm, 1956	--	--	--	11,800	None	0	0	109
				15,700				132
				11,800	Irrigated	--	--	118
				15,700				140

Table A-2 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
Missouri, South Farms, 1952	12.7	78.4	--	10,000[d]	None	0	0	75.4
				12,000[e]				73.6
				10,000[d]	Irrigated	3	3.75	98.9
				12,000[e]				101.14
Missouri, Campbell, 1953	7.5	81.2	--	10,000	None	0	0	40.0
				18,000				34.2
				18,000	Irrigated	3	5.52	76.9*
				18,000	Irrigated	2	4.02	60.7
Missouri, South Farms, 1956	20.9	75.1	--	12,600	None	0	0	117.5
				16,700				121.3
				18,500	Irrigated at 2" deficit	4	10.4	145.3**
				17,400	Irrigated at 4" deficit	1	4	140.2**
				17,700	Irrigated at 2" deficit from tasseling to dent.	2	4.5	142.3**
Missouri, South Farms, 1957	14.0	76.0	--	12,000	None	0	0	62.0
				17,000				51.0
				17,000	Irrigated	3	8.0	103.0**

[a] May 1 through Sept. 30
[b] June, July, August
[c] Actual N-P-K
[d] Continuous corn
[e] Rotation corn

* Significant at 5% level
** Significant at 1% level

Table A-3. Response of corn to irrigation and fertility.

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
Illinois, Dixon Springs, 1955	10.9	75.6	Residue only	12,700	None	0	0	85
			113-114-203					94
			Residue only		2" at tasseling & 2" 2 weeks later	2	4	116
			113-114-203					123
			Residue only		2" weekly from 7th through 12th week	4	6.33	116
			113-114-203					128

Table A-3 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
Illinois, Dixon Springs, 1956	10.5	76.3	Residue only	15,000	None	0	0	83
			153-80-93					90
			Residue only		2" at tasseling & 2" 2 weeks later	2	4	102
			153-80-93					122
			Residue only		2" weekly from 7th through 12th week	3	5.27	112
			153-80-93					132
Illinois, Dixon Springs, 1957	9.5	75.5	Residue only	15,500	None	0	0	71
			74-56-133					87
			Residue only		2" at tasseling & 2" 2 weeks later	2	4	76
			74-56-133					107
			Residue only		2" weekly from 7th through 12th week	4	8.04	70
			74-56-133					106
Illinois, Dixon Springs, 1958	21.7	74.4	Residue only	16,500	None	0	0	53
			128-24-57					128
			Residue only		None (high rainfall)	0	0	51
			128-24-57					125
			Residue only		None (high rainfall)	0	0	60
			128-24-57					125
Indiana, Sand Field, 1953	17.1	--	100-130-250	24,000	None	0	0	31
			200-130-250					35
			100-130-250		Irrigated	3	5	57
			200-130-250					78
			300-130-250					82
			100-130-250		Irrigated	8	8	70
			200-130-250					125
			300-130-250					144
Iowa, S.E. Iowa Exp. Farm, 1953	14.6	73.2	60-50-100	16,000	None	0	0	80.7
			120-50-100					85.2
			180-50-100					86.1
			60-50-100		50% available	5	6.5	112.4
			120-50-100					122.1
			180-50-100					130.8
Iowa, S.E. Iowa Exp. Farm, 1954	9.6	74.5	5-33-116	11,000	None	0	0	50.7
			85-33-116					63.8
			5-33-116		50% available	6	7.5	91.6
			85-33-116					108.3

Table A-3 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli- cations	In.	Yield bu/A
			85-33-116	14,000	None	0	0	60.7
			165-33-116					52.8
			245-33-116					47.1
			85-33-116		50% available	6	7.5	107.9
			165-33-116					106.9
			245-33-116					113.7
Iowa, Beach Ave., 1956	10.8	73.9	0-8-17	14,000	None	0	0	32.9
			40-8-17					29.7
			0-8-17		Pre-season (to field capacity)	1	6.3	66.9
			40-8-17					62.2
			40-8-17		20% available	2	11.9	95.3
			40-8-17		60% available	5	15.8	99.3
			40-8-17		90% available	12	28.0	103.5
Iowa, Beach Ave., 1957	19.7	70.3	0-8-17	14,000	None	0	0	104.6
			60-8-17					101.3
			0-8-17		Pre-season (to field capacity)	1	6	97.1
			60-8-17					111.3
			0-8-17		20% available	0	0	104.3
			60-8-17					107.4
			0-8-17		60% available	3	12.42	105.5
			60-8-17					104.3
			0-8-17		90% available	10	34.40	96.5
			60-8-17					101.7
Missouri, South Farm, 1954	11.6	79.6	125-0-0	14,000	None	0	0	.4
			245-0-0					.8
			125-0-0		Irrigated at 2" deficit	3	8.43	69.0
			245-0-0					82.0
			125-0-0		Irrigated at 3" deficit	2	7.05	75.1
			245-0-0					75.0
Minnesota, Elk River, 1949	15.41	72.3	5-8-17	20,000	None	0	0	70.5
			25-8-17		Above 50% available	3	6	108
			65-8-17					124
			205-8-17					157

Table A-3 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
Minnesota, Elk River, 1950	11.33	67.3	5-8-17	15,000	None	0	0	33
			25-8-17		Above 50% available	3	6	66
			65-8-17					80
			205-8-17					83
Minnesota, Halloway, 1963	11.8	70.1	0-0-0	13,000	None	0	0	45.5
			25-26-21		Above 50% available	4	5.5	89.0
			77-34-23					92.3
			87-34-23					100.1
			97-32-23					112.0
			115-43-29					106.1
			120-49-33					108.0
South Dakota, Redfield, 1949-55 av.	11.4	70.0	None	--	None	0	0	32
			30-0-0					92
			0-0-0		Irrigated	--	--	35
			60-0-0					97
South Dakota, Yankton, 1956	7.92	75.9	Low N	--	None	0	0	65.9
			Medium N					89.5
			High N					94.0
			Low N		Irrigated at tasseling	--	5	83.7
			Medium N					102.5
			High N					108.0
			Low N		Irrigated at silking	--	25	84.6
			Medium N					117.4
			High N					115.5
			Low N		Above 40% available	--	30	100.7
			Medium N					97.5
			High N					119.5
Wisconsin, Hancock, 1949-57 av.	14.05	--	conventional	--	None	0	0	45
			2x conventional					48
			3x conventional					46
			2x conventional		Moderate	2	2.4	71
			3x conventional					75
			4x conventional					70
			3x conventional		Full	4	8.1	96
			4x conventional					101
			5x conventional					104

[a] May 1 through Sept. 30
[b] June, July, August
[c] Actual N-P-K

Table A-4. Response of corn to irrigation and corn maturity type.

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Maturity type	Yield bu/A
Nebraska, North Platte Exp. Sta., 1959	14.68	73.9	158-15-0	17,120	None	0	0	Early	96.5
					Irrigated[d]	2	7.1	Early	128.1
					Irrigated	3	10.9	Early	134.4
					Irrigated	2	4.7	Early	128.4
					Irrigated	3	10.1	Early	133.2
					None	0	0	Medium	97.6
					Irrigated	2	7.1	Medium	133.1
					Irrigated	3	10.9	Medium	136.3
					Irrigated	2	4.7	Medium	132.1
					Irrigated	3	10.1	Medium	132.6
					None	0	0	Full seas.	93.7
					Irrigated	2	7.1	Full seas.	122.7
					Irrigated	3	10.9	Full seas.	126.3
					Irrigated	2	4.7	Full seas.	123.6
					Irrigated	3	10.1	Full seas.	128.3
Nebraska, North Platte Exp. Sta., 1960	10.67	71.8	193-15-0	16,100	None	0	0	Early	58.7
					Irrigated	3	8.9	Early	123.5
					Irrigated	3	12.8	Early	124.0
					Irrigated	3	6.5	Early	113.0
					Irrigated	4	11.2	Early	127.4
					None	0	0	Medium	60.7
					Irrigated	3	8	Medium	124.4
					Irrigated	3	12.8	Medium	134.2
					Irrigated	3	6.5	Medium	112.8
					Irrigated	4	11.2	Medium	134.5
					None	0	0	Full seas.	61.1
					Irrigated	3	8.9	Full seas.	126.8
					Irrigated	3	12.8	Full seas.	128.9
					Irrigated	3	6.5	Full seas.	115.9
					Irrigated	4	11.2	Full seas.	128.9
Nebraska, North Platte Exp. Sta., 1961	10.88	73.0	188-34-0	15,500	None	0	0	Early	67.3
					Irrigated	3	16.2	Early	130.3
					Irrigated	3	19.2	Early	135.5
					Irrigated	3	12.5	Early	132.0
					Irrigated	4	20.3	Early	136.1
					None	0	0	Medium	73.2
					Irrigated	3	16.2	Medium	131.1
					Irrigated	3	19.2	Medium	126.8
					Irrigated	3	12.5	Medium	130.9
					Irrigated	4	20.3	Medium	132.2
					None	0	0	Full seas.	55.1
					Irrigated	3	16.2	Full seas.	130.0
					Irrigated	3	19.2	Full seas.	128.9
					Irrigated	3	12.5	Full seas.	130.2
					Irrigated	4	20.3		126.7

[a] May 1 through Sept. 30
[b] June, July, August
[c] Actual N-P-K
[d] Irrigation treatments all at low tension, 70 centibars at 24 inches.

Table A-5. Response of corn irrigation and cultural practices.

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Cultural practice	Yield bu/A
Nebraska, North Platte Exp. Sta., 1963	14.27	74.7	65-18-0	15,200	None	0	0	Nebraska[d] Till	65
					Low tension 60-70 centi-bars at 24"	3	9.6		124
					Fill root zone at tasseling	1	6		112
					None	0	0	Conven-[c] tional Plant	43
					Low tension 60-70 centi-bars at 24"	3	9.6		115
					Fill root zone at tasseling	1	6		81
Nebraska, North Platte Exp. Sta., 1964	12.58	71.3	180-0-0	15,800	None	0	0	Nebraska[d] Till	62
					Low tension 60-70 centi-bars at 24"	3	11.7		111
					Fill root zone at tasseling	1	5.8		90
					None	0	0	Conven-[c] tional Plant	34
					Low tension 60-70 centi-bars at 24"	3	11.7		82
					Fill root zone at tasseling	1	5.8	Conven-[c] tional Plant	67
Missouri, South Farm, 1949	14.52	77.3	--	9,500	None	0	0	Contin-uous	95
				9,300				Rotation	103
				13,600	Irrigated	2	2	Contin-uous	106
				9,300		3	3	Rotation	152
Missouri, South Farm, 1950	12.43	72.3	--	12,500	None	0	0	Contin-uous	78
								Rotation	76
					Irrigated	2	4.89	Rotation	97
						2	3.82	Continuous	73

Table A-5 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Cultural practice	Yield bu/A
Missouri, South Farm, 1953	14.12	79.0	--	14,000	None	0	0	Contin-uous	68.6
				16,000				Rotation	51.3
				14,000	Irrigated	1	2	Contin-uous	84.6
				16,000		1	1.83	Rotation	79.0
Missouri, South Farm, 1959	10.85	76.6	175# N, P, & K to soil test	15,000	None	0	0	Conven-tional plow	94.1
								Strip-till	92.0
					Irrigated	6	11.8	Conven-tional plow	148.1
								Strip-till	159.3
Missouri, South Farm, 1960	11.47	74.7	--	15,000	None	0	0	Plowed	133
								Subtilled	129
					Irrigated	2	4.42	Plowed	144
						2	4.98	Subtilled	146
Missouri, South Farm, 1962	8.99	75.4	--	15,000	None	0	0	Plowed	100.7
								Subtilled	100.6
					Irrigated	3	7.64	Plowed	138.0
								Subtilled	133.9
Missouri, South Farm, 1963	15.33	75.5	--	15,000	None	0	0	Plowed	120.3
								Subtilled	123.9
					Irrigated	3	6.23	Plowed	138.6
								Subtilled	148.7
Missouri, South Farm, 1964	12.13	75.0	--	15,000	None	0	0	Plowed	92.8
								Subtilled	88.9
					Irrigated	2	3.50	Plowed	114.8
								Subtilled	106.2

[a] May 1 through Sept. 30
[b] June, July, August
[c] Actual N-P-K
[d] Cut stalks but no tillage before planting. Planted in old ridge.
[e] Seedbed preparation included plowing.

Table A-6. Response of corn to irrigation, fertility, and population.

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli- cations	Irrigation In.	Yield bu/A
Indiana, Sand Field, 1953	17.1	72.6	100-130-250	9,000	None	0	0	32
			150-130-250					35
			200-130-250					33
			100-130-250	12,000				33
			150-130-250					40
			200-130-250					37
			100-130-250	18,000				35
			150-130-250					39
			200-130-250					38
			100-130-250	24,000				31
			150-130-250					40
			200-130-250					35
			100-130-250	9,000	Irrigated when moisture depleted top 2.0 ft.	3	5.0	65
			200-130-250					68
			300-130-250					75
			100-130-250	12,000				81
			200-130-250					93
			300-130-250					92
			100-130-250	18,000				79
			200-130-250					98
			300-130-250					99
			100-130-250	24,000				57
			200-130-250					78
			300-130-250					82
			100-130-250	9,000	Irrigated when moisture depleted top 4″	8	8	70
			200-130-250					78
			300-130-250					85
			100-130-250	12,000				81
			200-130-250					102
			300-130-250					100
			100-130-250	18,000				96
			200-130-250					117
			300-130-250					125
			100-130-250	24,000				70
			200-130-250					125
			300-130-250					144
Indiana, Jones Farm, 1956	21.0	72.9	None	13,000	None	0	0	80
			80-60-150					92
			160-60-150					95
			240-60-150					88
			320-60-150					102

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Yield bu/A
			None	17,000				85
			80-60-150					90
			160-60-150					97
			240-60-150					98
			320-60-150					102
			None	21,000				67
			80-60-150					74
			160-60-150					78
			240-60-150					75
			320-60-150					91
			None	25,000				60
			80-60-150					69
			160-60-150					81
			240-60-150					82
			320-60-150					95
			None	13,000	Irrigated at 40% AMC top 2.0 ft.	3	7.0	86
			80-60-150					112
			160-60-150					112
			240-60-150					114
			320-60-150					119
			None	17,000				95
			80-60-150					120
			160-60-150					122
			240-60-150					131
			320-60-150					135
			None	19,000				85
			80-60-150					125
			160-60-150					121
			240-60-150					137
			320-60-150					137
			None	21,000				74
			80-60-150					128
			160-60-150					115
			240-60-150					134
			320-60-150					137
			None	25,000				99
			80-60-150					118
			160-60-150					117
			240-60-150					116
			320-60-150					115
			None	13,000	Irrigated at 75% AMC top 2.0 ft.	4	8.4	92
			80-60-150					128
			160-60-150					129
			240-60-150					133
			320-60-150					138

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
			None	17,000				86
			80-60-150					134
			160-60-150					127
			240-60-150					127
			320-60-150					145
			None	25,000				104
			80-60-150					110
			160-60-150					123
			240-60-150					126
			320-60-150					132
Indiana, Sand Field, 1957	22.14	71.3	None	10,000	None	0	0	40
			50-42-100					58
			100-42-100					74
			150-42-100					90
			200-42-100					90
			250-42-100					95
			300-42-100					95
			350-42-100					92
			None	15,000				12
			50-42-100					72
			100-42-100					90
			150-42-100					90
			200-42-100					85
			250-42-100					80
			300-42-100					80
			350-42-100					100
			None	20,000				22
			50-42-100					76
			100-42-100					100
			150-42-100					90
			200-42-100					90
			250-42-100					80
			300-42-100					80
			350-42-100					80
			None	25,000				22
			50-42-100					44
			100-42-100					56
			150-42-100					80
			200-42-100					80
			250-42-100					80
			300-42-100					75
			350-42-100					70
			None	10,000	Irrigated	1	3.45	26
			50-42-100					84
			100-42-100					106
			150-42-100					110
			200-42-100					114
			250-42-100					105
			300-42-100					105
			350-42-100					105

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Yield bu/A
			None	15,000				42
			50-42-100					64
			100-42-100					100
			150-42-100					120
			200-42-100					120
			250-42-100					120
			300-42-100					120
			350-42-100					120
			None	20,000				30
			50-42-100					50
			100-42-100					110
			150-42-100					130
			200-42-100					120
			250-42-100					120
			300-42-100					120
			350-42-100					120
			None	25,000				10
			50-42-100					70
			100-42-100					140
			150-42-100					120
			200-42-100					110
			250-42-100					110
			300-42-100					110
			350-42-100					110
			None	10,000	Irrigated	3	5.67	20
			50-42-100					100
			100-42-100					120
			150-42-100					110
			200-42-100					110
			250-42-100					110
			300-42-100					110
			350-42-100					110
			None	15,000				44
			50-42-100					53
			100-42-100					120
			150-42-100					142
			200-42-100					144
			250-42-100					140
			300-42-100					140
			350-42-100					140
			None	20,000				42
			50-42-100					86
			100-42-100					130
			150-42-100					160
			200-42-100					150
			250-42-100					150
			300-42-100					150
			350-42-100					150

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Yield bu/A
			None	25,000				10
			50-42-100					90
			100-42-100					123
			150-42-100					142
			200-42-100					163
			250-42-100					130
			300-42-100					130
			350-42-100					130
			None	10,000	Irrigated	4	3.83	50
			50-42-100					84
			100-42-100					102
			150-42-100					112
			200-42-100					120
			250-42-100					120
			300-42-100					120
			350-42-100					120
			None	15,000				15
			50-42-100					100
			100-42-100					112
			150-42-100					125
			200-42-100					133
			250-42-100					135
			300-42-100					135
			350-42-100					135
			None	20,000				20
			50-42-100					90
			100-42-100					130
			150-42-100					135
			200-42-100					140
			250-42-100					142
			300-42-100					145
			350-42-100					145
			None	25,000				15
			50-42-100					55
			100-42-100					125
			150-42-100					140
			200-42-100					140
			250-42-100					140
			300-42-100					130
			350-42-100					130
Iowa, S.E. Iowa Exp. Farm, 1954	16.31	74.2	5-33-116	11,000	None	0	0	87.4
			85-33-116					88.4
			165-33-116					84.4
			5-33-116		Irrigated at silking	2	3.0	82.5
			85-33-116					87.8
			165-33-116					86.2

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
			5-33-116		Irrigated at 50% available	6	9.0	93.1
			85-33-116					113.0
			165-33-116					109.2
			5-33-116	16,000	None	0	0	77.4
			85-33-116					89.3
			165-33-116					86.4
			5-33-116		Irrigated at silking	2	3.0	88.9
			85-33-116					94.0
			165-33-116					85.2
			5-33-116		Irrigated at 50% available	6	9.0	82.4
			85-33-116					113.7
			165-33-116					113.1
Iowa, S.E. Iowa Exp. Farm, 1951	21.39	69.8	0-16-33	6,930	None	0	0	32.5
			40-16-33					56.3
			80-16-33					46.0
			120-16-33					47.7
			0-16-33		Irrigated at 50% available	5	10	25.0
			40-16-33					33.8
			80-16-33					47.0
			120-16-33					47.9
			0-16-33	13,340	None	0	0	36.1
			40-16-33					56.8
			80-16-33					76.1
			120-16-33					85.0
			0-16-33		Irrigated at 50% available	5	10	19.9
			40-16-33					49.4
			80-16-33					72.3
			120-16-33					75.6
Iowa, Ankeny Field Station, 1954	31.18	74.3	0-23-0	12,000	None	0	0	33.6
			160-23-0					53.7
			0-23-0		Irrigated at 50% available	2	4	53.7
			160-23-0					84.5
			0-23-0	15,500	None	0	0	40.5
			160-23-0					68.1
			0-23-0		Irrigated at 50% available	2	4	68.1
			160-23-0					87.8
			0-23-0	22,000	None	0	0	33.4
			160-23-0					73.3
			0-23-0		Irrigated at 50% available	2	4	73.3
			160-23-0					80.6

Table A-6 (cont'd).

Location and year	Precip. [a] in.	Av. [b] temp.	Fertilizer [c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Yield bu/A
Iowa, S.E. Iowa Exp. Farm, 1955	12.34	74.0	0-33-116	13,000	None	0	0	21.6
			80-33-116					38.5
			160-33-116					37.4
			0-33-116		Irrigated at silking	4	4	23.0
			80-33-116					44.2
			160-33-116					55.6
			0-33-116		Irrigated at 50% available	11	11	39.3
			80-33-116					92.0
			160-33-116					110.2
			0-33-116	16,700	None	0	0	13.2
			80-33-116					38.8
			160-33-116					24.6
			0-33-116		Irrigated at silking	4	4	14.3
			80-33-116					35.1
			160-33-116					28.6
			0-33-116		Irrigated at 50% available	11	11	30.4
			80-33-116					96.1
			160-33-116					107.8
			0-33-116	23,000	None	0	0	4.2
			80-33-116					11.3
			160-33-116					13.4
			0-33-116		Irrigated at silking	4	4	7.7
			80-33-116					19.0
			160-33-116					32.2
			0-33-116		Irrigated at 50% available	11	11	18.0
			80-33-116					95.0
			160-33-116					105.7
Iowa, Ankeny Field Station, 1955	8.68	74	60-25-80	12,000	None	0	0	82.1
			120-25-80					87.2
			60-25-80		Irrigated at 50% available	5	11	99.5
			120-25-80					114.8
			60-25-80	16,500	None	0	0	60.9
			120-25-80					69.1
			60-25-80		Irrigated at 50% available	5	11	114.5
			120-25-80					112.7
			60-25-80	19,500	None	0	0	52.3
			120-25-80					57.4
			60-25-80		Irrigated at 50% available	5	11	108.1
			120-25-80					111.5

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
Iowa, Beach Ave., 1958	17.3	69.3	0-12-25	8,000	None	0	0	108.5
			60-12-25					91.0
			0-12-25		Irrigated[d]			89.3
			60-12-25					91.5
			0-12-25		Irrigated at[e] 20% available			88.4
			60-12-25					95.1
			0-12-25		Irrigated at 60% available	1	5.1	88.8
			60-12-25					109.6
			0-12-25		Irrigated at 90% available	2	8.1	89.2
			60-12-25					92.1
			0-12-25	15,000	None	0	0	104.3
			60-12-25					123.1
			0-12-25		Irrigated[d]			116.5
			60-12-25					119.9
			0-12-25		Irrigated at[e] 20% available			111.0
			60-12-25					129.5
			0-12-25		Irrigated at 60% available	1	5.1	123.2
			60-12-25					122.9
			0-12-25		Irrigated at 90% available	2	8.1	121.8
			60-12-25					128.9
			0-12-25	22,000	None	0	0	136.3
			60-12-25					140.7
			0-12-25		Irrigated[d]			132.1
			60-12-25					135.5
			0-12-25		Irrigated at[e] 20% available			127.1
			60-12-25					130.9
			0-12-25		Irrigated at 60% available			132.9
			60-12-25					143.7
Iowa, Beach Ave., 1959	20.6	72.9	0-12-25	10,000	None	0	0	92.0
			60-12-25					92.0
			0-12-25		Irrigated at 60% available	3	13.4	95.0
			60-12-25					98.0
			0-12-25		Irrigated at 90% available	9	27.3	96.0
			60-12-25					101.0
			0-12-25	15,000	None	0	0	107.0
			60-12-25					106.0

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
			0-12-25 60-12-25		Irrigated at 60% available	3	13.4	115.0 119.0
			0-12-25 60-12-25		Irrigated at 90% available	9	27.3	116.0 126.0
			0-12-25 60-12-25	20,000	None	0	0	108 107
			0-12-25 60-12-25		Irrigated at 60% available	3	13.4	113 123
			0-12-25 60-12-25		Irrigated at 90% available	9	27.3	116 124
Iowa, Beach Ave., 1960	16.2	70.9	0-12-25 120-12-25	12,000	None	0	0	97.7 100.5
			0-12-25 120-12-25		Irrigated at 60% available	1	5.0	103.8 110.6
			0-12-25 120-12-25		Irrigated at 90% available	5	17.0	101.7 119.1
			0-12-25 120-12-25	15,000	None	0	0	111.2 115.2
			0-12-25 120-12-25		Irrigated at 60% available	1	5.0	119.5 131.4
			0-12-25 120-12-25		Irrigated at 90% available	5	17.0	115.3 133.7
			0-12-25 120-12-25	18,000	None	0	0	115.2 119.6
			0-12-25 120-12-25		Irrigated at 60% available	1	5.0	129.1 138.6
			0-12-25 120-12-25		Irrigated at 90% available	5	17.0	117.3 135.3
Iowa, Beach Ave., 1961	12.9	71.0	0-12-25 60-12-25 120-12-25	15,000	None	0	0	132.5 141.7 135.2
			0-12-25 60-12-25 120-12-25		Irrigated at 60% available	1	5.0	130.2 143.2 140.5
			0-12-25 60-12-25 120-12-25	18,200	None	0	0	142.2 143.6 146.2

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
			0-12-25		Irrigated at 60% available	1	5.0	145.4
			60-12-25					142.4
			120-12-25					147.5
			0-12-25	20,600	None	0	0	140.1
			60-12-25					147.4
			120-12-25					146.9
			0-12-25		Irrigated at 60% available	1	5.0	138.4
			60-12-25					148.7
			120-12-25					143.3
Kansas, North Central Kansas Exp. Fields, 1960	20.15	74.7	None	14,000	Irrigated	2	12	52
			80-0-0					136
			80-41-0					104
			160-41-0					127
			240-0-0					141
			240-41-0					140
			None		Irrigated	3	18	34
			80-0-0					147
			80-41-0					126
			160-41-0					142
			240-0-0					134
			240-41-0					147
			None	17,000	Irrigated	2	12	34
			80-0-0					116
			80-41-0					130
			160-41-0					128
			240-0-0					154
			240-41-0					147
			None		Irrigated	3	18	22
			80-0-0					154
			80-41-0					123
			160-41-0					142
			240-0-0					134
			240-41-0					156
			None	20,000	Irrigated	2	12	70
			80-0-0					130
			80-41-0					117
			160-41-0					117
			240-0-0					148
			240-41-0					149
			None		Irrigated	3	18	40
			80-0-0					133
			80-41-0					110
			160-41-0					158
			240-0-0					148
			240-41-0					154

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Yield bu/A
Kansas, North Central Kansas Exp. Fields, 1962	22.51	74.7	None	14,000	Irrigated	2	12	51
			80-0-0					139
			80-41-0					126
			160-41-0					134
			240-0-0					141
			240-41-0					150
			None		Irrigated	3	18	70
			80-0-0					149
			80-41-0					137
			160-41-0					139
			240-0-0					127
			240-41-0					147
			None	17,000	Irrigated	2	12	44
			80-0-0					128
			80-41-0					142
			160-41-0					141
			240-0-0					159
			240-41-0					156
			None		Irrigated	3	18	67
			80-0-0					159
			80-41-0					145
			160-41-0					155
			240-0-0					136
			240-41-0					161
			None	20,000	Irrigated	2	12	64
			80-0-0					133
			80-41-0					133
			160-41-0					148
			240-0-0					156
			240-41-0					154
			None		Irrigated	3	18	62
			80-0-0					157
			80-41-0					143
			160-41-0					160
			240-0-0					148
			240-41-0					167
Kansas, North Central Kansas Exp. Fields, 1963	18.28	80.0	None	14,000	Irrigated	3	21	59
			80-0-0					120
			80-41-0					114
			160-41-0					125
			240-0-0					135
			240-41-0					132
			None		Irrigated	5	31	66
			80-0-0					126
			80-41-0					121
			160-41-0					129
			240-0-0					125
			240-41-0					136

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	In.	Yield bu/A
			None	17,000	Irrigated	3	21	49
			80-0-0					123
			80-41-0					124
			160-41-0					129
			240-0-0					141
			240-41-0					134
			None		Irrigated	5	31	66
			80-0-0					135
			80-41-0					122
			160-41-0					139
			240-0-0					133
			240-41-0					128
			None	20,000	Irrigated	3	21	70
			80-0-0					132
			80-41-0					126
			160-41-0					135
			240-0-0					127
			240-41-0					134
			None		Irrigated	5	31	58
			80-0-0					134
			80-41-0					131
			160-41-0					136
			240-0-0					133
			240-41-0					132
Michigan, Morgan Farm, 1953	--	--	None	12,700	None	0	0	90
			40-0-0					83
			None		Irrigated	--	--	111
			40-0-0					112
			None	15,600	None	0	0	88
			40-0-0					96
			None		Irrigated	--	--	122
			40-0-0					126
North Dakota, Deep River Dev. Farm, 1956	9.92	65.2	None	14,000	None	0	0	40
			30-0-0					37
			60-0-0					34
			120-0-0					38
			None		Irrigated	5	--	33
			0-60-0					42
			120-0-0					52
			None	23,000	None	0	0	35
			60-0-0					36
			120-0-0					31

Table A-6 (cont'd).

Location and year	Precip.[a] in.	Av.[b] temp.	Fertilizer[c] lb./A	Plants per acre	Treatment	Irrigation Appli-cations	Irrigation In.	Yield bu/A
			None		Irrigated	5	--	26
			60-0-0					49
			120-0-0					67
			180-0-0					64
North Dakota, Deep River Dev. Farm, 1957	9.84	65.5	None	10,000	None	0	0	50
			30-0-0					40
			60-0-0					44
			120-0-0					51
			None		Irrigated	5	--	59
			60-0-0					66
			120-0-0					72
			None	20,000	None	0	0	44
			60-0-0					40
			120-0-0					44
			None		Irrigated	5	--	65
			60-0-0					84
			120-0-0					95
			180-0-0					96

[a] May 1 through Sept. 30
[b] June, July, August
[c] Actual N-P-K
[d] Preseason to field capacity
[e] Due to rainfall, soil did not reach 20% AMC

APPENDIX B

Soils of irrigated corn experiments in the North Central Region

Table B-1. Soils of Irrigated Corn Experiments in the North Central Region.

		Location			Moisture Characteristics Depth of 4 ft.		
State	Name of Station	County	Post Office	Soil Series & Type	Field Capacity Inches	Wilting Point Inches	Available Inches
Illinois	Dixon Springs	Pope	Robbs	Grantsburg silt loam	--	--	9.4
Indiana	Sand Experimental Field	Marshall	Culver	Chelsea sand	5.0	1.3	3.7
	Mitchell Farms	Tipton	Tipton	Brookston silt loam	15.8	6.5	9.3
	Jones Farm	Sullivan	Merom	Fox sandy loam	8.0	3.8	4.2
	Poultry Farm	Tippecanoe	Lafayette	Fox loam	9.3	3.9	5.4
	Farmer's Field	Carrol	Camden	Fox loam	9.6	4.3	5.3
Iowa	Beach Ave. Farm	Story	Ames	Colo silty clay loam	--	--	8.0
	Ankeny Field Station	Polk	Ankeny	Nicollet loam	--	--	8.0
	Southeastern Iowa Exp. Farm	Muscatine	Conesville	Buckner Thurman loamy sand	--	--	2.0
Kansas	North Central Kansas Exp. Field	Cloud	Concordia	Crete silt loam	--	--	--
Michigan	Kelsey Morgan Farm		Eaton Rapids	Fox sandy loam	--	--	--
	Gardner Forbush Farm		Mendon	Warsaw loamy sand	--	--	--
Minnesota	Holloway	Swift		Sioux sandy loam (Gravel at 18")	--	--	2.6
	Elk River	Sherburne		Cass sandy loam	--	--	6.0
	Rosemont	Dakota		Waukegan silt loam	--	--	10.5
Missouri	Elsberry	Lincoln	Elsberry	Wabash	--	--	--
	South Farms	Boone	Columbia	Mexico silt loam	--	--	6.4
	McCredie	Callaway	McCredie	Putnam silt loam	--	--	--
	McBaine Campbell			Dexter sand	--	--	1.7
Nebraska	North Platte Exp. Station	Lincoln	North Platte	Bridgeport silt loam	--	--	--
	Nebraska Exp. Station	Lancaster	Lincoln				
	Box Butte Exp. Farm	Box Butte	Alliance		--	--	7.2

Table B-1 (cont'd).

State	Name of Station	Location		Soil Series & Type	Moisture Characteristics Depth of 4 ft.		
		County	Post Office		Field Capacity Inches	Wilting Point Inches	Available Inches
North Dakota	North Dakota Exp. Station	Cass	Fargo	Fargo silty clay	--	--	--
	Carrington Irrigation Branch Sta.	Foster	Carrington	Heimdal loam			
	Northern Great Plains Field Station	Morton	Mandan	Oahe-Williams	--	--	--
	Deep River Development Farm	McHenry	Upham	Gardena loam	--	--	5.4
Ohio	None						
South Dakota	Ag. Engr. Farm	Brookings	Brookings				
	Yankton	Yankton	Yankton	Sandy loamy sand	--	--	--
	Redfield Farm	Spink	Redfield	Beota silt loam	--	--	--
	U.S. Experiment Farm	Butte	Newell	Vale sandy loam Pierre Clay	--	--	--
Wisconsin	Spooner Experimental Station	Washburn	Spooner	Omega, Warman Scandia	--	--	--
	Hancock Experimental Station	Waushara	Hancock	Plainfield	--	--	--

APPENDIX C

Compilation of References on Irrigated Corn Research Conducted in Illinois, Indiana, Iowa, Kansas, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin

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