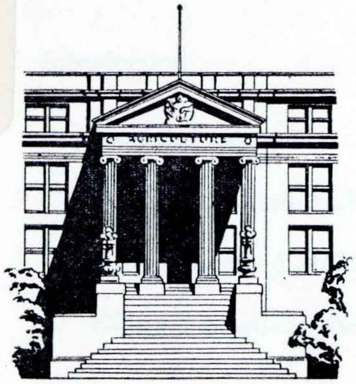

Interrelationships of Plant Population, Soil Moisture and Soil Fertility in Determining Corn Yields on Colo Clay Loam at Ames, Iowa

by C. E. Beer, W. D. Shrader and R. K. Schwanke

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CONTENTS

SUMMARY

This investigation included a 6-year study of the effects of irrigation, stand and fertility treatments on corn yields on a clay loam soil near Ames, Iowa. The data obtained from 1956 to 1961 indicated that variations in yields were caused by all three variables. Significant yield differences caused by irrigation treatments were greatest in 1956, 1959 and 1960. The highest mean irrigated yields averaged over stand and fertility treatments usually correlated best with the irrigation treatment where the soil moisture was maintained at or above 60 percent of the available moisture content (AMC). The greatest yield response to irrigation occurred in 1956, primarily because of the very dry conditions throughout the entire growing season. In 1956, each inch of water increased yield by 2.7 bushels per acre up to the 60-percent AMC level. Beyond this point, maintaining soil moisture at 90 percent or greater of field capacity reduced yield per increment of added water.

There was not a significant response to irrigation in 1957, 1958 and 1961, primarily because of ample soil moisture storage and good rainfall distribution at critical periods during the growing season.

Water-use efficiency, in terms of bushels corn produced per inch of soil moisture used, showed a high correlation with yield in most years. The unirrigated plots had the highest water-use efficiencies of up to 10 bushels per inch of water used.

When 60-percent AMC was set as the optimum moisture level, yields were reduced by nearly 2 bushels for every stress day above 10.9 days during a 40-day period before silking and a 40-day period after silking. This indicated that the soil moisture level is quite critical during the silking stage of the corn plant.

When yields were averaged over all irrigation levels, there was a positive response to increased stand levels at each fertility level in 4 years of the 6-year experiment. There were significant differences among stand levels in all years except 1956 and 1957. With adequate fertility and moisture, highest yields for most years were obtained between stands of 18,000 to 22,000 plants per acre.

Nitrogen fertilizers applied as a side-dressing produced significant differences in yield in 3 of the 6 years. Irrigation resulted in greater responses to N fertilizer than did no irrigation in most years. There was no consistent stand level that gave the best N fertilizer response. The largest mean yield responses to N of 10.1 and 13.7 bushels per acre were obtained in 1958 with 60 pounds N and in 1960 with 120 pounds N per acre, respectively. Because of high soil fertility on the experimental plots, N fertilizer did not significantly affect the water-use efficiency.

Interrelationships of Plant Population, Soil Moisture and Soil Fertility in Determining Corn Yields on Colo Clay at Ames, Iowa[1]

by C. E. Beer, W. D. Shrader and R. K. Schwanke[2]

Even though Iowa's normal growing season rainfall of about 20 inches is adequate on most Iowa soils, droughts during 1953 to 1956 in various areas of the state prompted many farmers to purchase and use irrigation equipment. Irrigated acreage in Iowa has increased from 3,600 acres in 1953 (55 farmers) to 80,000 acres in 1963 (500 farmers).[3] The potential acreage for irrigation in Iowa is quite large, especially along the Missouri River bottomlands.

The desire to maximize corn yields by providing optimum moisture, stand and fertility levels has created the need to quantify the effects of these treatments, both singularly as well as interactions. Consequently, with occasional below-normal rainfall and its poor distribution through the corn-growing season, researchers in various climatic regions of the United States have begun to study the effects of supplemental irrigation on high stand and fertility levels. Pumphrey and Harris (4) studied the effect of nitrogen (N) rates and irrigation in Nebraska. They observed that corn yields were markedly increased with irrigation and N applications of 40, 80 and 120 pounds N per acre at 10,000 plants per acre. In the experiment, the N was applied by side-dressing at an early stage of corn growth. In Georgia, Boswell et al. (2) found that yields were increased with 60, 120 and 240 pounds of N per acre when irrigation was used. They used population levels of 10-, 15- and 20-thousand plants per acre. At various experimental sites throughout the state, they obtained larger response with 120 pounds N plus irrigation than with 240 pounds of N plus irrigation. The only extensive irrigation research in Iowa was by Schwab et al. (5) and was not conducted until the early 1950's on Thurman loamy sand and Nicollet loam soils. They studied the effects of irrigation on corn yields at stand levels of 12-, 15- and 18-thousand plants per acre and N rate of 40, 80, 120 and 160 pounds per acre at one Iowa site. Yields were increased under irrigation with increasing stand and N levels. Over a 5-year period, corn yields increased by an average of 34.5 bushels per acre annually in response to irrigation. Optimum stand levels for maximum yields increased with each additional increment of irrigation and N.

Irrigation research in subhumid and humid areas has shown that the benefits from irrigating corn vary from year to year. This variance makes it vital that any beneficial irrigation research on corn be continued for a large number of years. Because of the small amount of available information on irrigation of corn in Iowa and because of the rapid increase in irrigation use on higher corn stands and higher fertility in Iowa, a 6-year study was begun in 1956 at Ames, Iowa. This experiment used irrigation, stand and fertility as variables. It was hoped that results of this investigation would provide data that could be used to partially answer some important corn-production questions in this area. This study, therefore, was designed primarily to investigate and to determine (a) the stand, fertility and water requirements for maximum corn yields and (b) the influence of moisture on corn production with irrigation use.

EXPERIMENTAL METHODS

Experimental Site and Design

The site for the irrigation experiment was on the Iowa State University experimental fields located between Beach Avenue and South Riverside Drive.

The soil on this site is a Colo clay loam, a minimal Humic Gley, formed from alluvial sediments. The first 9 to 12 inches of the soil profile are a dark brown clay loam, with a medium granular structure. The next 12 to 50 inches are a dark grayish-brown clay loam, with a fine blocky structure. Below 50 to 55 inches, the soil is yellowish-brown and of sandy texture. Sand or gravel is usually encountered at a depth from 5 to 6 feet.

Infiltration rates from various irrigation treatments on this soil were 1.3 inches per hour, with no evidence of restricting layers in the profile (1). The plant-available water-holding capacity totals 7.5 to 9 inches in the upper 5 feet (1).

Soil tests of Colo clay loam obtained in 1956 and 1957 indicated that the soil was high in organic matter, nitrifiable N, available P and available K. The surface soil was slightly acid with a pH of 6.3 to pH 6.6.

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[1] Project 1247 of the Iowa Agriculture and Home Economics Experiment Station.

[2] Associate Professor of Agricultural Engineering, Professor of Agronomy and former Graduate Assistant, respectively, Iowa State University.

[3] Ted L. Willrich, Ames, Iowa, Extension Agricultural Engineer. (Private communication.) 1965.

A corn-corn-oats-alfalfa cropping system was systematically planted on four 1.24-acre areas. Data presented in this study refer to the first-year corn yields that followed alfalfa meadow.

A split plot experimental design was used each year of the study. The whole plot treatment consisted of factorial combinations of irrigation levels and fertility levels. Each whole plot was divided equally into 3 stand levels. This design was replicated 3 times in each 1.24-acre area of first-year corn. A schematic of the 1956 treatments is shown in fig. 1.

Irrigation, Stand and Fertility Treatments

The various irrigation, stand and fertility treatments used each year are presented in table 1. Five levels of irrigation treatment were incorporated in the experimental design. The wide variation in the precipitation received from year to year made it impossible to fulfill some of the treatments. The criteria used for water application was the available moisture content (AMC), where AMC equals the total inches of moisture at field capacity minus the inches of moisture in the soil at wilting point.

Cultural Practices and Measurements

The alfalfa crop that preceded the first year of corn was plowed in the fall. Corn was drill planted during the second or third week of May on 12- to 18-inch-high ridges in rows 40 inches apart. A well-adapted variety, AES 704, was planted each year. Plants were thinned to the desired stand level when the plants were 8 to 10 inches high. Starter fertilizer of 0-30-30[4] was applied each year, and all nitrogen fertilizer treatments were side-dressed applications of ammonium nitrate when the corn was 18 to 20 inches high. Furrow irrigation was practiced. Before 1961, each furrow was filled separately by using a large fire hose. In 1961, gated, light-weight aluminum pipe was used to irrigate 15 furrows simultaneously. The latter method reduced the labor and time required to irrigate.

Soil moisture was determined by a commercial neutron-scattering moisture meter, gravimetric samples and irrometer tensionmeters. All methods were used to determine AMC to a 5-foot depth in the soil profile of the plot with the highest stand and fertility levels.

Table 1. Irrigation, stand and fertility treatments used for 1956 to 1961.

Year	Irrigation level	Inches applied: Irrigation	Inches applied: Rain	Stand Plants/A.	Nitrogen Lbs./A.
1956	A—None	0.0	10.8	10,000	0
	B—Preseason[a]	6.3	10.8	14,000	40
	C—20% AMC[b]	11.9	10.8	18,000	80
	D—60% AMC	15.8	10.8		
	E—90% AMC	28.0	10.8		
1957	A—None	0.0	19.7	8,000	0
	B—Preseason	6.0	19.7	14,000	60
	C—20% AMC	0.0	19.7	20,000	
	D—60% AMC	12.4	19.7		
	E—90% AMC	34.4	19.7		
1958	ABC—None[c]	0.0	17.3	8,000	0
	D—60% AMC	5.1	17.3	15,000	60
	E—90% AMC	8.1	17.3	22,000	
1959	ABC—None	0.0	20.6	10,000	0
	D—60% AMC	13.4	20.6	15,000	60
	E—90% AMC	27.3	20.6	20,000	
1960	AC—None	0.0	16.2	10,000	0
	D—60% AMC	10.0	16.2	15,000	120
	E—90% AMC	20.0	16.2	20,000	
1961	AB—None	0.0	12.9	14,000	0
	D—60% AMC	2.0	12.9	18,000	60
				22,000	120

[a] Applied in April to bring moisture up to field capacity.

[b] Irrigated when the top 5 feet of soil was dried to 20 percent of available moisture-holding capacity (AMC). Available moisture equals the total inches of moisture at field capacity minus the inches of moisture at wilting point.

[c] From 1958 to 1961, none, preseason and (or) 20 percent AMC irrigation treatments were combined because soil moisture was high enough not to require the preseason and 20 percent AMC treatments. Consequently, unirrigated corn yields reported for these years are means of two or three plots instead of one.

To assure physiological maturity, 60 days elapsed after silking before the corn was hand harvested. The harvest plot consisted of two 35-foot center rows of each plot. All corn yields were calculated in bushels of shelled corn per acre on the basis of 15.5-percent moisture.

Rainfall, temperature and pan-evaporation measurements were made each year at the experimental site with standard U. S. Weather Bureau instruments. The inches of rainfall and the deviation from long-term normals for each year's growing season (May to August) are given in table 2. Records from the Iowa State University Agronomy Farm were used to compute the long-term normals. The Agronomy farm was located about 2 miles SW of the experimental site.

Table 2. Inches rainfall and departure from long-term normals (records from the Agronomy Farm, Ames, Iowa) during six growing seasons (May to August).

Month	1956 Actual	1956 Dep. from norm.	1957 Actual	1957 Dep. from norm.	1958 Actual	1958 Dep. from norm.	1959 Actual	1959 Dep. from norm.	1960 Actual	1960 Dep. from norm.	1961 Actual	1961 Dep. from norm.
May	3.95	−0.23	6.19	2.16	1.66	−2.37	8.08	4.05	7.82	3.79	1.32	−2.71
June	1.56	−2.78	6.50	0.99	4.29	−1.22	3.26	−2.25	2.70	−2.81	3.68	−1.83
July	1.61	−1.81	3.48	0.29	9.59	6.40	2.15	−1.04	2.74	−0.45	5.68	2.49
August	4.26	0.55	3.41	−0.51	1.79	−2.13	2.65	−1.27	5.56	1.46	2.22	−1.70
TOTAL	11.38	−4.27	19.58	2.93	17.33	0.68	16.14	−0.51	18.82	1.99	12.90	−3.75

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[4] Numbers refer to oxides of P_2O_5 and K_2O.

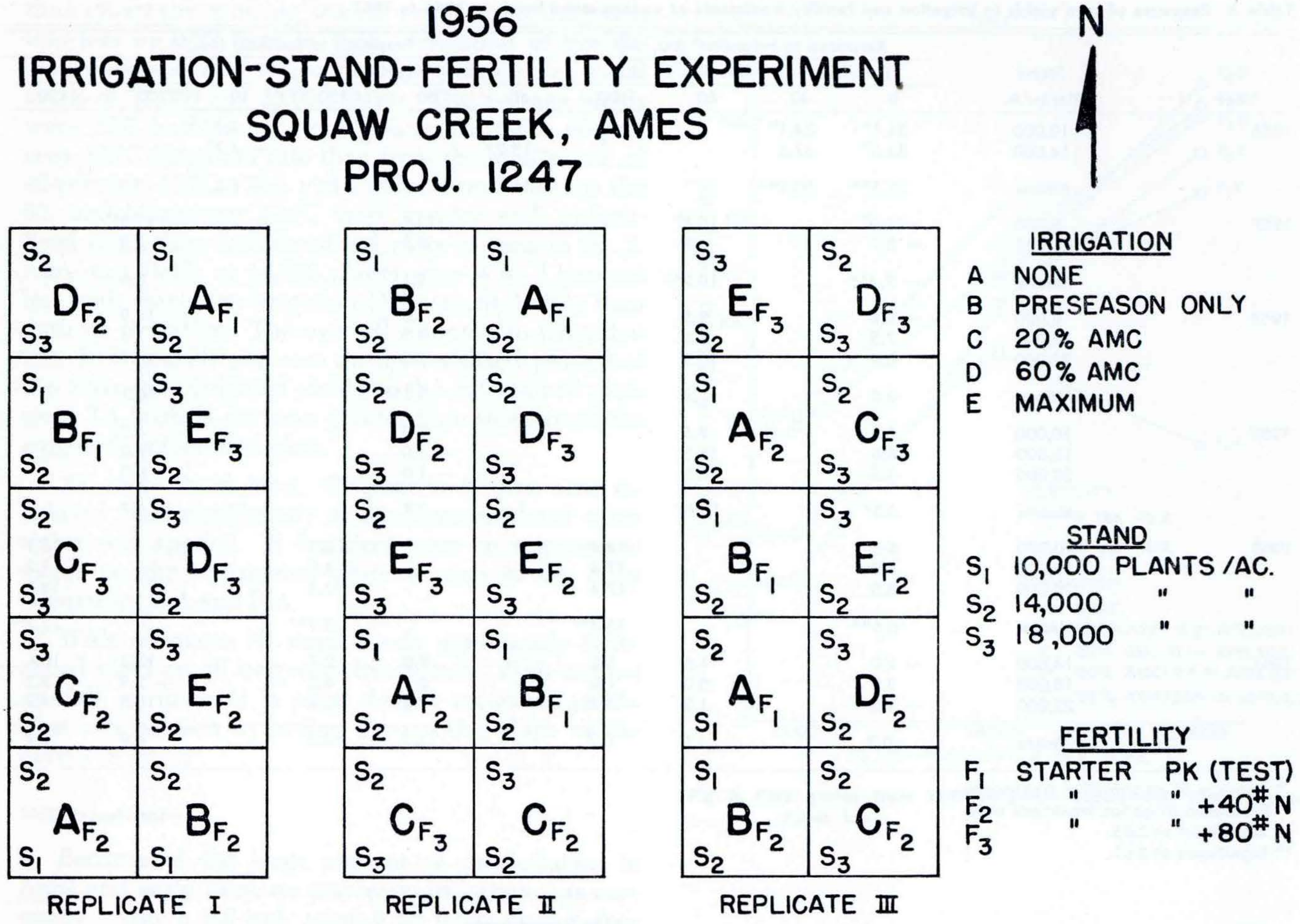

Fig. 1. Layout of irrigation experiment, Ames, Iowa.

RESULTS

Influence of Irrigation, Stand and Fertility on Corn Yields

The results of the irrigation experiment are shown and discussed for the combined 6-year period as well as for each year separately. Detailed corn-yield data for the average of all replicates for all 6 years are given in Appendix A.

Table 3 shows the positive (increase in corn yield) and negative (decrease in corn yield) responses to the experimental treatments. All responses are given in bushels of corn per acre. For example, in 1957 at a level of 14,000 plant population and 60 pounds of N per acre, the difference between the average yield of all irrigated plots and the unirrigated plots was a positive 4.8 bushels per acre.

During all years there was a positive response to irrigation at a level of 40 pounds or more of N per acre. The average response varied from a high of 50.9 bushels per acre in 1956 to a low of 0.7 bushels per acre in 1961. With no application of N, however, a negative response to irrigation was obtained for the year 1957 and for two stand levels in 1961.

The increase in corn yields from the application of N fertilizer was more consistent throughout the period on the irrigated plots than on the unirrigated. Table 3 shows that an average decrease in yield on unirrigated plots was obtained in 3 of the 6 years when 40 pounds or 60 pounds of N per acre were used. The basis for comparison was the plots where no N was applied. With irrigation, however, corn yields were generally increased from an average high of 13.8 bushels per acre in 1960 to a low of 5.9 bushels per acre in 1961. During the dry year of 1956, there was a negative response to N on both the irrigated and unirrigated plots.

In general there was a net increase in corn yields due to irrigation during the period 1956-1961. The response was usually greater at higher rates of N fertilization and at plant populations of 15,000 or more. The year-to-year climatic variation, however, influenced the magnitude of the response from the experimental treatments.

Table 3. Response of corn yields to irrigation and fertility treatments at various stand levels in 1956 to 1961.

Year	Stand Plants/A.	Response to irrigation[a] (bu./A.) Fertilizer treatments (lbs. N./A.) 0	40	60	120	Response to fertilizer (bu./A.) Without irrigation 40	60	120	With irrigation[a] 40	60	120
1956	10,000	31.1[b]	34.1[b]			−10.2			− 7.7[b]		
	14,000	34.0[b]	67.6			−13.2			− 4.7[b]		
	Means	32.5**	50.9**			−11.7			− 6.2		
1957	8,000	−11.0[b]		15.6[b]			−14.8			11.8[b]	
	14,000	− 3.7		4.8			− 3.3			5.3	
	Means	− 7.4**		10.2**			− 9.1			8.6	
1958	8,000	− 0.8		9.5			1.6			11.9	
	15,000	7.5		1.8			9.1			3.4	
	22,000	0.9		10.9			5.0			14.9	
	Means	2.5		7.4			5.2**			10.1**	
1959	10,000	3.5		7.5			0.0			4.0	
	15,000	8.5		16.5			− 1.0			7.0	
	20,000	6.5		16.5			− 1.0			9.0	
	Means	6.3*		13.5*			− 0.7			6.7	
1960	10,000	5.6			14.4			3.3			12.1
	15,000	6.2			17.4			4.0			15.2
	20,000	8.0			17.4			4.4			13.8
	Means	6.6**			16.4**			3.9**			13.7**
1961	14,000	− 2.7		1.6	5.2		9.0	2.7		13.3	10.6
	18,000	3.0		0.0	1.0		0.1	4.2		− 2.9	2.2
	22,000	− 1.8		1.3	− 3.7		7.2	6.8		10.3	4.9
	Means	0.3		1.0	0.7		5.4	4.6		6.9	5.9

[a] Average of all irrigation treatments.
[b] Preseason irrigation treatment only.
* Significant at 0.05.
** Significant at 0.01.

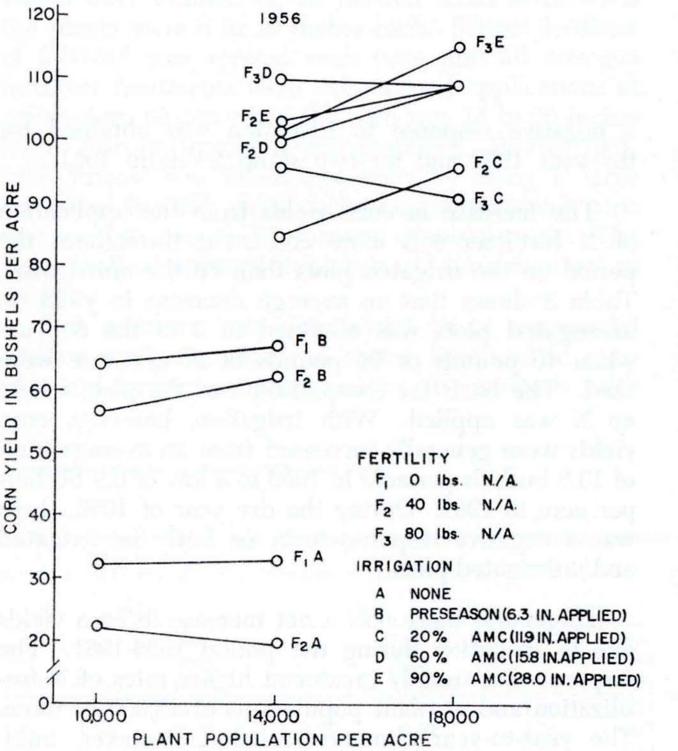

Fig. 2. Corn yields from 1956 irrigation experiment, Squaw Creek, Ames, Iowa.

1956 Experiment—

In 1956 the growing season rainfall was 4.27 inches below normal (table 2). Corn yields for the five irriration rates are shown in fig. 2. With 10,000 and 14,000 plants per acre, preseason irrigation of 6 inches increased yields by an average of 35.5 bushels per acre. This response emphasized the importance of an ample subsoil moisture reserve in a dry season. The preseason irrigation treatment constituted over half of the entire season's rainfall of 11.38 inches. Higher irrigation rates (20-, 60- and 90-percent AMC), as shown in fig. 2, gave additional yields of 30 to 40 bushels per acre over that of preseason. The effect of each irrigation treatment may be seen with 14,000 plants per acre and 40 pounds N per acre where 28.0 inches of water increased yields by 83.8 bushels per acre.

The lack of significant response to N with and without irrigation, as noted by the position of the curves in fig. 2, may be due to high soil fertility. One cannot say that stands increased yields because of the incomplete split, split-plot design used in this experiment. As shown in fig. 2, however, the highest yields were obtained from the highest stand levels.

1957 Experiment—

With 19.58 inches of rainfall and good distribution throughout the growing season, response to irrigation was less in 1957 than in 1956. Irrigation at the 60-percent AMC level was optimum at the higher stand levels of 14,000 and 20,000 plants. The average yields were 12.5 bushels per acre greater from the 60-percent AMC irrigation rate than from the higher rate of 90-percent AMC. The yield differences between the 60- and 90-percent AMC were greater with unfertilized plots than with fertilized plots as seen in fig. 3. Also, the yields at 14,000 plants were 4 to 7 percent less with maximum irrigation (90-percent AMC) than with no irrigation. The over-all response to irrigation was 10.2 bushels per acre on the fertilized plots, but the average unirrigated yields on the unfertilized plots were 7.4 bushels per acre greater than those from the irrigated, unfertilized plots.

At each stand level, 60 pounds N per acre increased yield significantly at the 5-percent level when water was applied. N fertilizer gave no response to yields on the unirrigated plots as seen in fig. 3 by comparing F_1A and F_2A.

With adequate N, stand levels significantly influenced yield on all irrigation treatments. With normal rainfall, an increase in plant density increased yields. This can be seen by noting the positive slope of the curves in fig. 3.

1958 Experiment—

Because of the large amount of precipitation in April and early May, no preseason irrigation was necessary. Also, a 6.6-inch rainfall 20 to 40 days before silking and a 3.32-inch rain after silking caused the soil to remain at greater than 20-percent AMC for the entire growing season. Consequently, the mean corn yields were calculated for three unirrigated treatments and are presented in fig. 4 along with the mean yields for irrigation at 60- and 90-percent AMC.

Response to irrigation for unfertilized and fertilized plots as shown in fig. 4 was not significant. This may be attributed to the 0.86-inch above-normal rainfall during the growing season. As in 1957, yields were depressed with maximum irrigation (90-percent AMC) on unfertilized plots at 15,000 to 22,000 plants per acre, but yields were increased on fertilized plots.

An analysis of variance indicated the main effects of plant population and fertilizer rate were significant at the 1-percent level. As shown in fig. 4, all F_2 points plot above the F_1 points, and calculations show that the average response to N fertilizer was doubled with irrigation. The influence of stand on yield followed a quadratic function (fig. 4) and increased yields by 43.7 bushels per acre over the low stand of 8,000 plants per acre. Response curves in fig. 4 indicate that the optimum stand level with 60 pounds N per acre and 90-percent AMC was not obtained in this particular year.

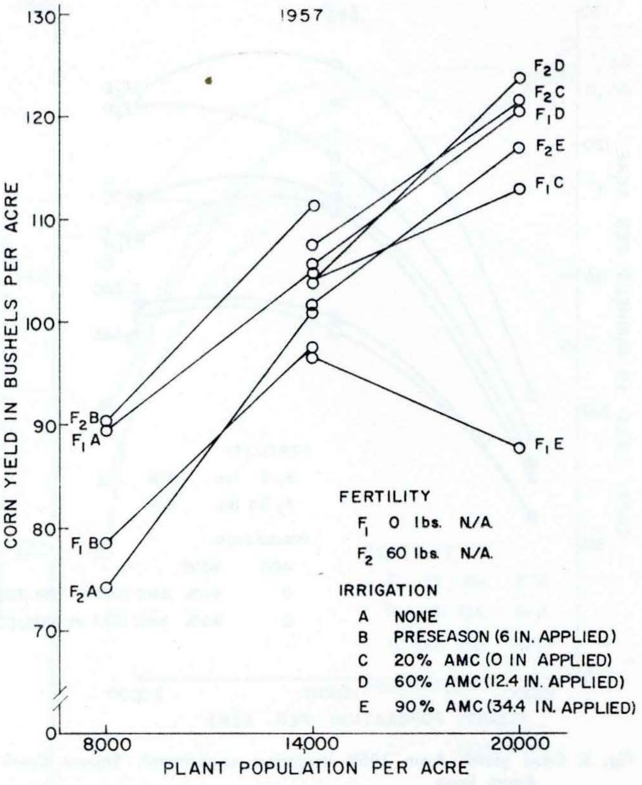

Fig. 3. Corn yields from 1957 irrigation experiment, Squaw Creek, Ames, Iowa.

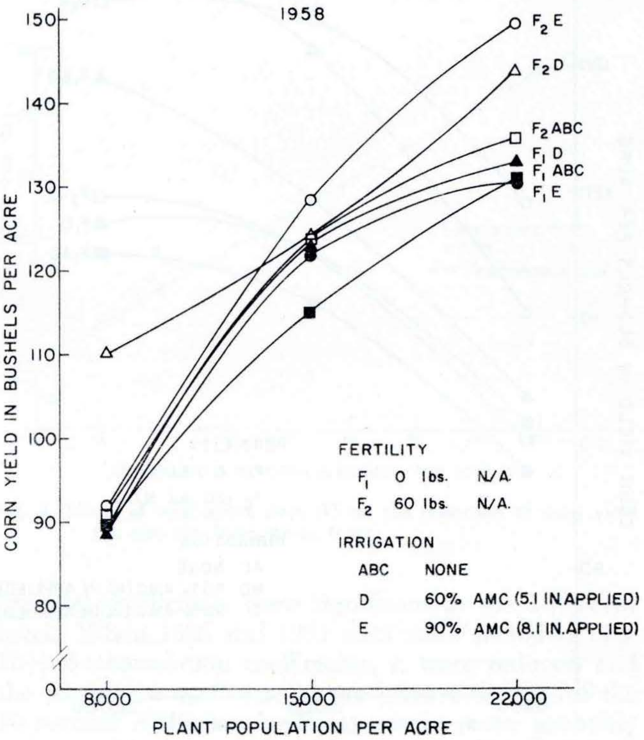

Fig. 4. Corn yields from 1958 irrigation experiment, Squaw Creek, Ames, Iowa.

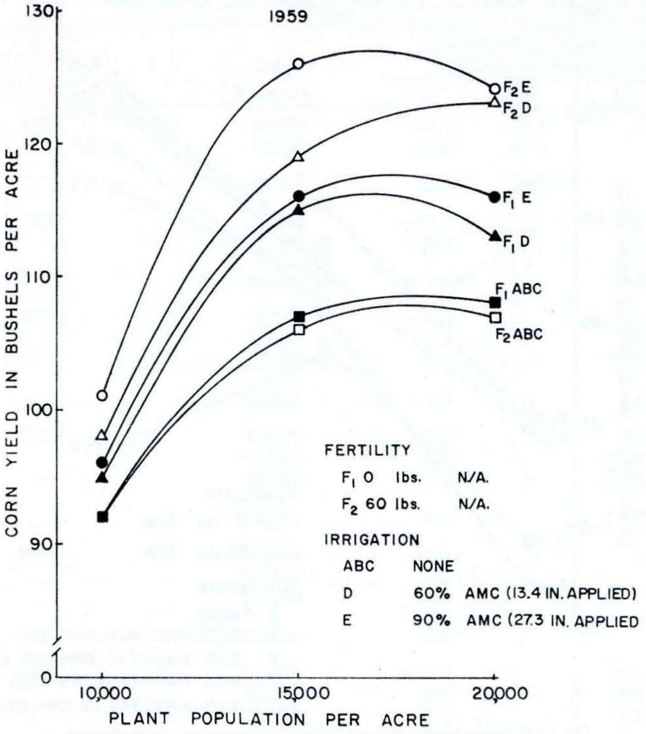

Fig. 5. Corn yields from 1959 irrigation experiment, Squaw Creek, Ames, Iowa.

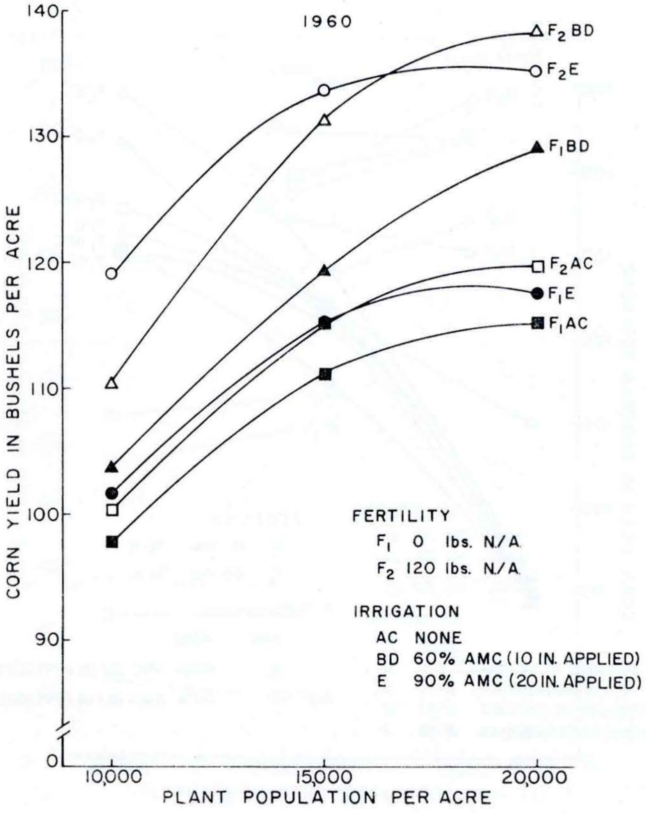

Fig. 6. Corn yields from 1960 irrigation experiment, Squaw Creek, Ames, Iowa.

1959 Experiment—

Preseason and 20-percent AMC irrigation treatments were not necessary because of good seasonal rainfall distribution. Therefore, mean yields for these two treatments were used for unirrigated plot yields. Even though the annual rainfall was above normal, the precipitation during May through August (growing season) was 0.51 inches below normal. That this small deficit contributed to a highly significant difference between irrigation treatments emphasizes the importance of proper distribution of moisture during the growing season. As shown in fig. 5, little benefit was obtained from the additional 14 inches of the 90-percent AMC level except at the higher N level. This is shown by the relative position of the F_2D curve.

As in 1958, a plot of corn yield versus stand followed a quadratic function as stand levels increased from 10,000 to 20,000 plants per acre, fig. 5. The slope of the curves indicate that optimum yields would be obtained for most N and irrigation treatments at about 18,000 plants per acre.

Irrigation was needed for a positive response to fertilizer. Sixty pounds N per acre gave a 6.7-bushel-per-acre response with irrigation. Fig. 5 indicates that fertility may have limited yields at the higher stand and irrigation levels.

1960 Experiment—

No 20-percent AMC irrigation treatment was used because rainfall kept the soil moisture above this level during the growing season.

In 1960 the main effects of irrigation, stand and fertility were all significant at the 1-percent level. When averaged over all stand and fertility levels, the 60-percent AMC treatment increased yields by 12.4 bushels per acre over the unirrigated treatment. Nitrogen fertilizer at 120 pounds per acre nearly tripled the response to irrigation. This is shown in fig. 6 by comparing the difference (F_2E minus F_2AC) with (F_1E minus F_1AC). As in 1957 and 1958, all yields on the unfertilized 90-percent AMC plots were less than those on the unfertilized 60-percent AMC plots. This is evidence that saturated soil conditions may be detrimental to corn yields and that yields may be increased with the application of high rates of N fertilizer. The rainfall during the growing season was 1.99 inches above normal; however, the below-normal amount of precipitation before silking and during June and July probably was responsible for the significant response to irrigation. Average yields for 10,000, 15,000 and 20,000 plants were 105, 120 and 125 bushels per acre, respectively.

1961 Experiment—

Only two irrigation rates were investigated because of previous experimental information, even distribution of precipitation throughout the growing season and a good soil moisture reserve at planting time.

Irrigation gave no significant difference in corn yields as seen in fig. 7. Nitrogen fertilizer did not affect the response to irrigation. As shown in fig. 7, the response to 60 and 120 pounds N per acre was essentially the same, with and without irrigation. The average yield was from 5 to 6 bushels per acre more than the yields from the unfertilized plots.

Significant yield differences were attributed to stand levels. The curvilinear response in yields at the three stand levels can be seen in fig. 7. This response was more obvious for no fertilizer and 120 pounds N per acre treatments than for the 60 pounds N application. These inconsistent results suggest that the soil fertility was perhaps very high for all plots and indicate that the planting rate was the major factor influencing yields. In general, the optimum stand level seemed to be 20,000 plants per acre for most treatments.

Influence of Moisture on Yield

Results of irrigation effects on corn yield indicate that the optimum soil moisture condition on Colo clay loam for years with near-normal rainfall is at or near the 60-percent AMC level.

To determine the effect of below-optimum soil moisture of 60-percent AMC on corn yields, soil moisture stress days were determined during an 80-day period—40 days before silking to 40 days after silking—on plots kept below 60-percent AMC. A soil moisture stress day was defined as a day when the soil moisture level in the rooting zone was below 60-percent AMC. Fig. 8 shows the influence of the number of stress days for the 80-day period on the amount of yield reduction from yields obtained at the 60-percent AMC level. In the analysis, the intercept of 10.9 stress days indicates yield reductions would begin after this number of days. The importance of stress days on yields has been shown by Dale (3). The number of stress days was highly correlated with yield depression from optimum soil moisture conditions.

Another important aspect of irrigation in a humid climate is the efficient use of water by a crop. Water-use efficiency, as determined and used by Viets (6), is equal to yield (Y) divided by evapotranspiration (ET). To find the water-use efficiency for this study, total growing-season rainfall, table 2, was added to the inches of irrigation water applied at the 60- and 90-percent AMC levels. This figure represents the total water use for each year's growing season, assuming that the soil moisture was above the 90-percent AMC level at the beginning and end of the season and that no deep seepage occurred. Fig. 9 shows that the highest water-use efficiency for the 4 years was on the unirrigated plots. As irrigation water was applied, there was less efficient use of water. The best correlation coefficient was with 60-percent AMC. All regression coefficients were significant at the 1-percent level. When 1958 and 1961 data were included (fig. 10), the correlation coefficients, r, were reduced and the regression coefficients were greater except for the 60-percent AMC level. These results were probably caused by higher yields with less rainfall and less irrigation water used in 1958 and 1961.

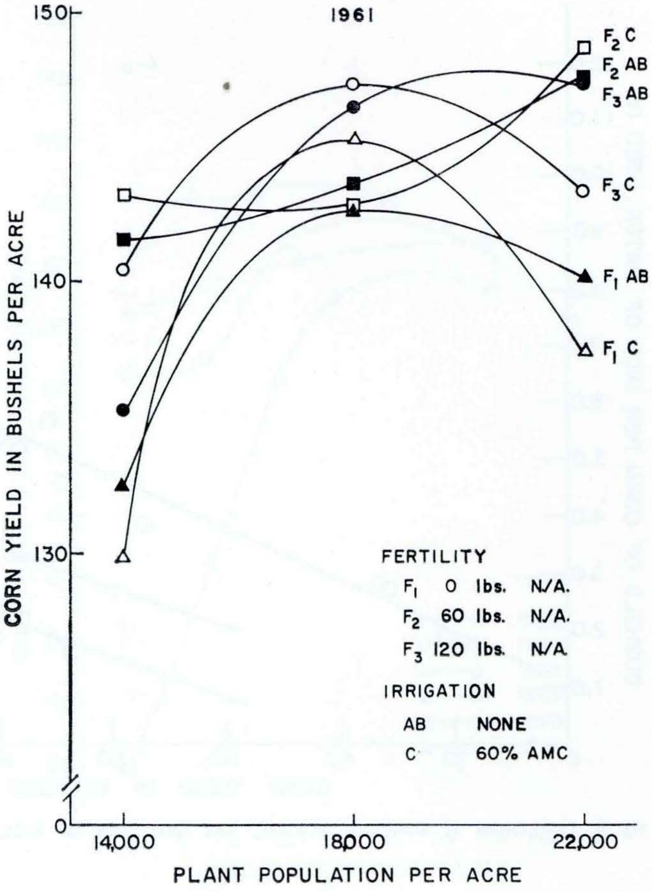

Fig. 7. Corn yields from 1961 irrigation experiment, Squaw Creek, Ames, Iowa.

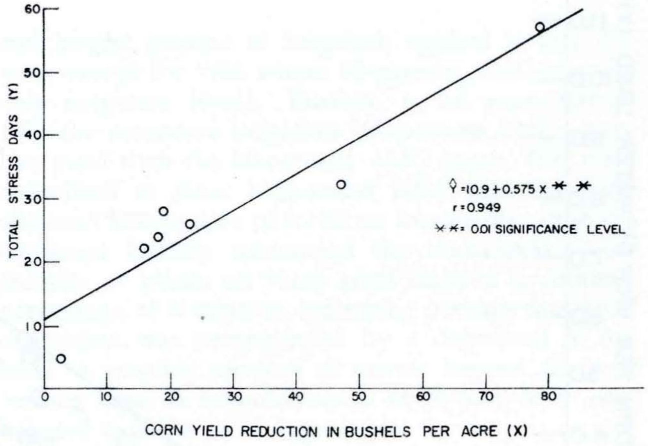

Fig. 8. Effect of total stress days (Y) on the reduction of corn yield (X), silty clay loam, Ames, Iowa.

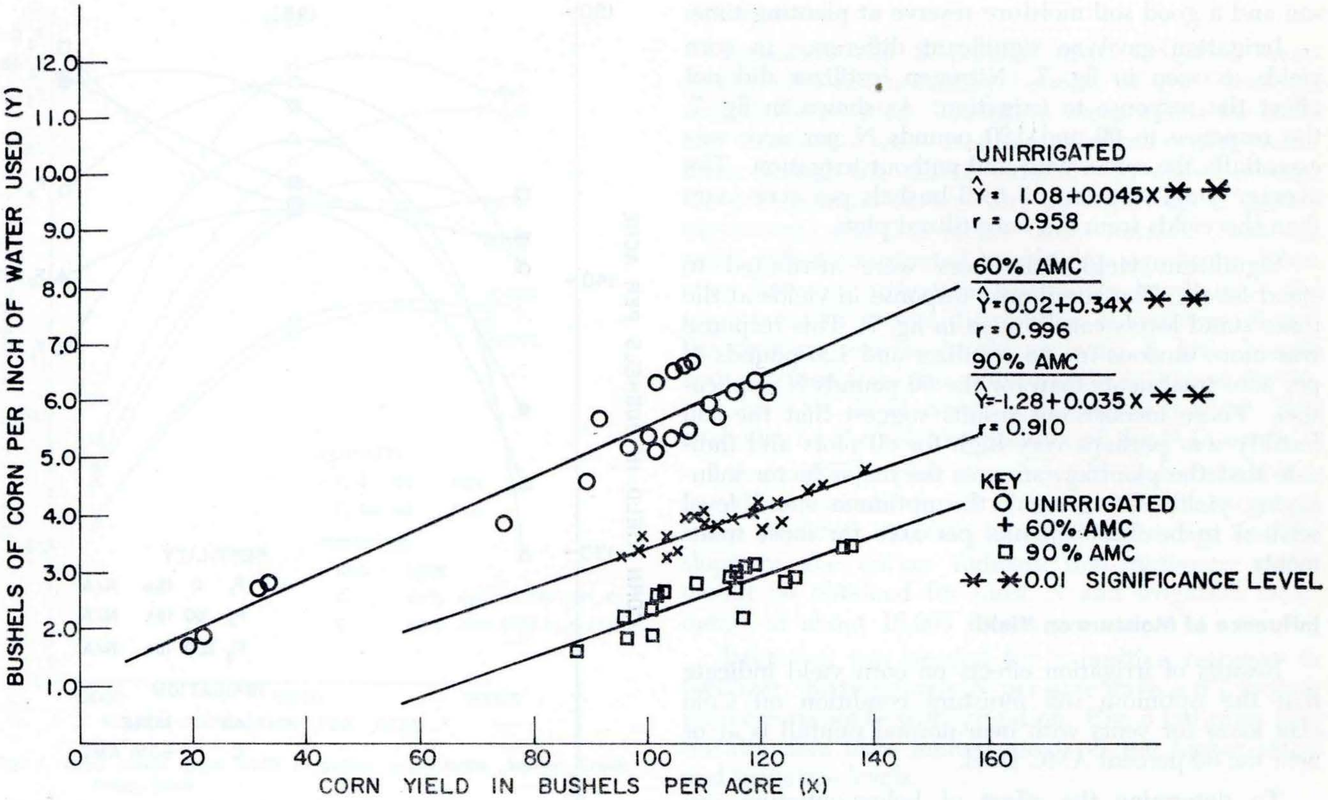

Fig. 9. Comparison of water-use efficiency and corn yield for 1956, 1957, 1959 and 1960 irrigation experiments, Squaw Creek, Ames, Iowa.

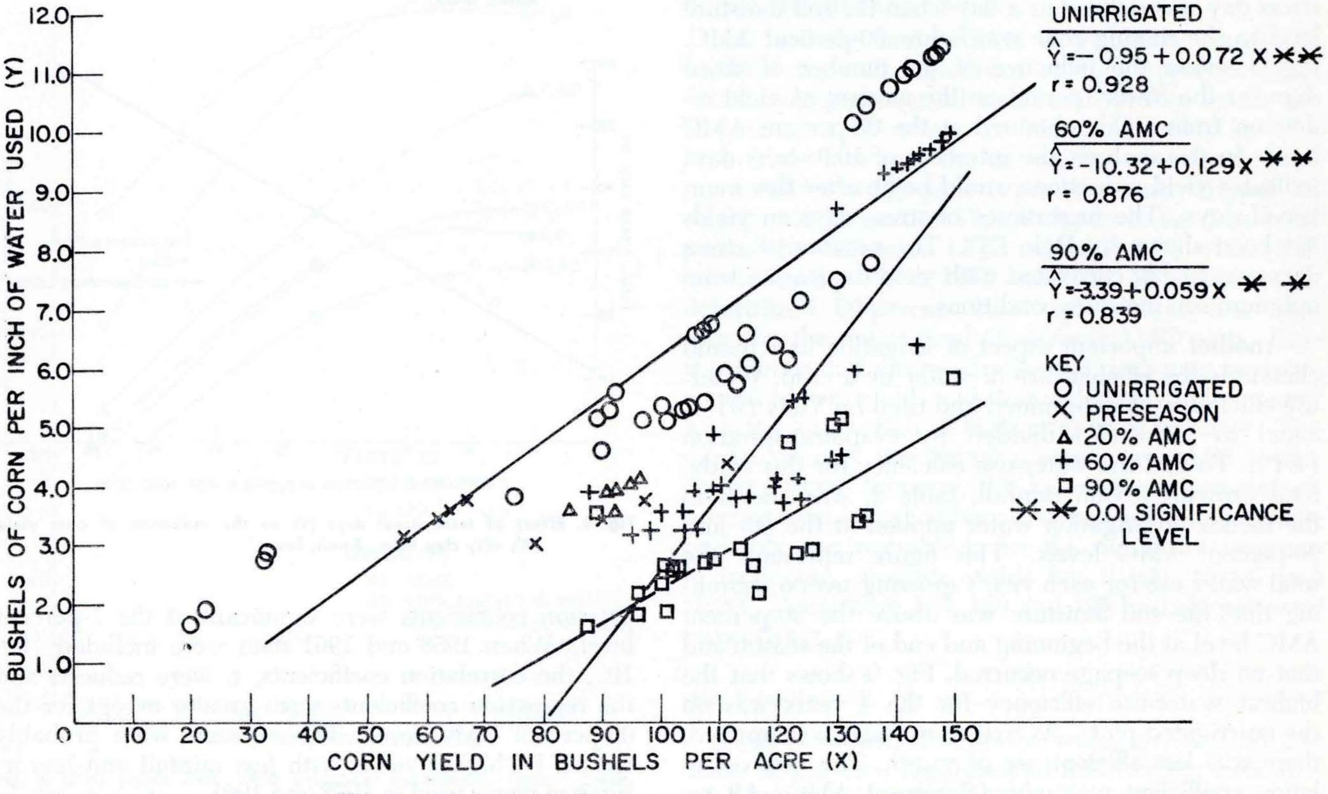

Fig. 10. Comparison of water-use efficiency and corn yield for 6-year period, 1956-61, Ames, Iowa.

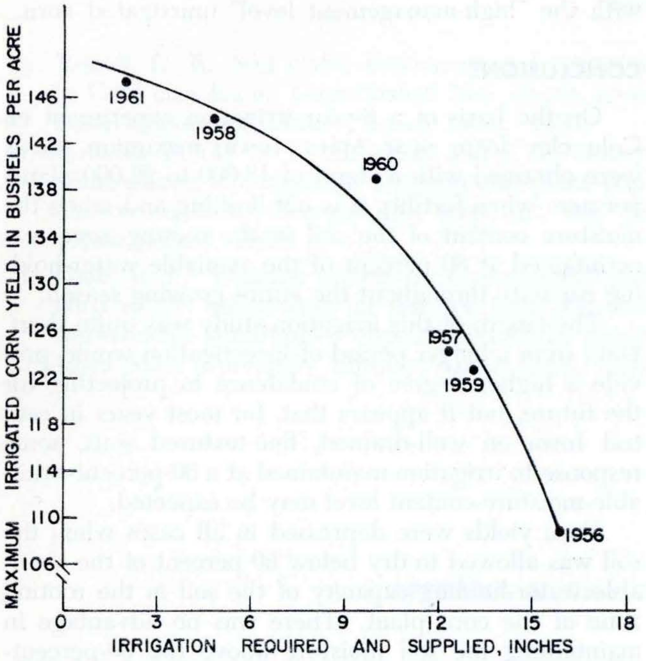

Fig. 11. Relationships between the amount of water required and supplied to maintain soil moisture above 60 percent of the available water-holding capacity and maximum corn yields obtained on Colo silty clay loam, Ames, Iowa.

Effect of Irrigation as Rainfall on Maximum Yields

In examining the yield data for each year, there is considerable variation in maximum corn yields obtained from year to year. This is quite evident in the data presented in fig. 11. In this figure, the maximum corn yield obtained with high stand, high fertility and 60-percent-AMC irrigation is plotted against the quantity of irrigation water applied. The more irrigation water that was required to maintain soil moisture above 60-percent AMC, the lower are the yields obtained under irrigation. The highest yield of 147 bushels of corn per acre was obtained in 1961, when only 2 inches of irrigation water were applied. The lowest yield of 109 bushels per acre was obtained in 1956, when 16 inches of irrigation water were required.

Although slight differences in stand and in fertility levels make comparisons between years subject to some question, the extremely good agreement between irrigation water and yield reductions indicates that there are climatic limitations that cannot be completely removed through irrigation. As indicated by Schwab et al. (5), extremely high temperatures during July are probably among the more important of the climatic factors that adversely affect yields even when there is ample moisture in the soil.

Fig. 12 shows the influence of inches of irrigation on corn yields for each year. These curves show that the 60-percent AMC level gave the best yields in 5 of the 6 years (60-percent AMC points are those for second largest amount of irrigation applied in any one year, except for 1961 where 60-percent AMC was the only irrigation level). Further, in all years except 1959 the maximum irrigation (90-percent AMC) gave less yield than the 60-percent AMC level. The yield reductions at these high-water rates were normally obtained irrespective of fertilizer treatments, although increased fertility minimized the depression. Leaf analysis of plants on these plots showed a reduced percentage of N content, indicating perhaps that yield depression was accompanied by a depressed N uptake. A possible removal of nitrate beyond the root feeding zone or immobilization of N may have contributed to these yield depressions.

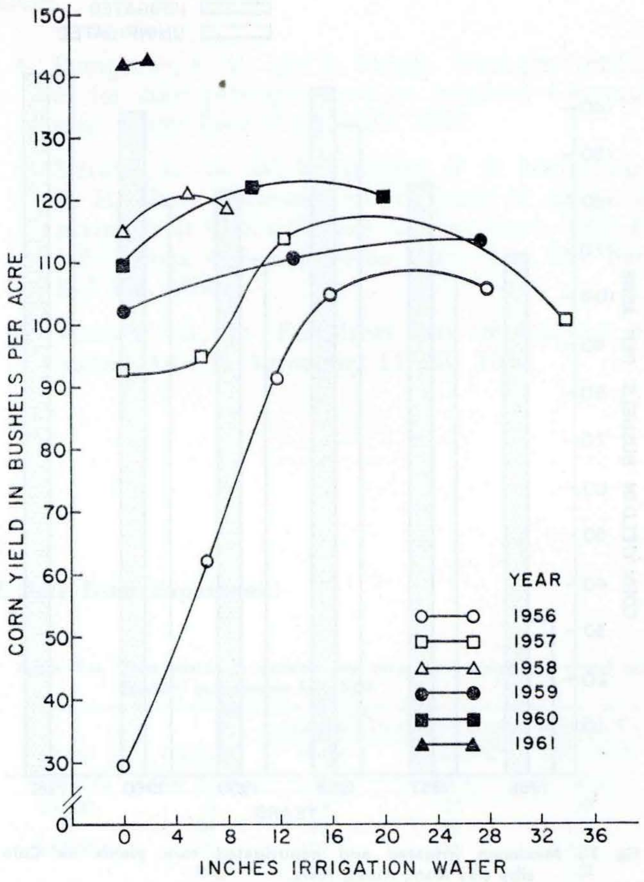

Fig. 12. Relationship of irrigation water applied and yield for the years 1956-61, Colo silty clay loam, Ames, Iowa.

Effect of Irrigation on Maximum Yields and on Yield Variation

Fig. 13 compares the highest yields obtained from the unirrigated and irrigated plots in any one year. These yields, therefore, were not necessarily the result of the same stand, fertility and irrigation levels in all years. With limited data on irrigation response, fig. 13 does provide a measure for evaluating the yields that

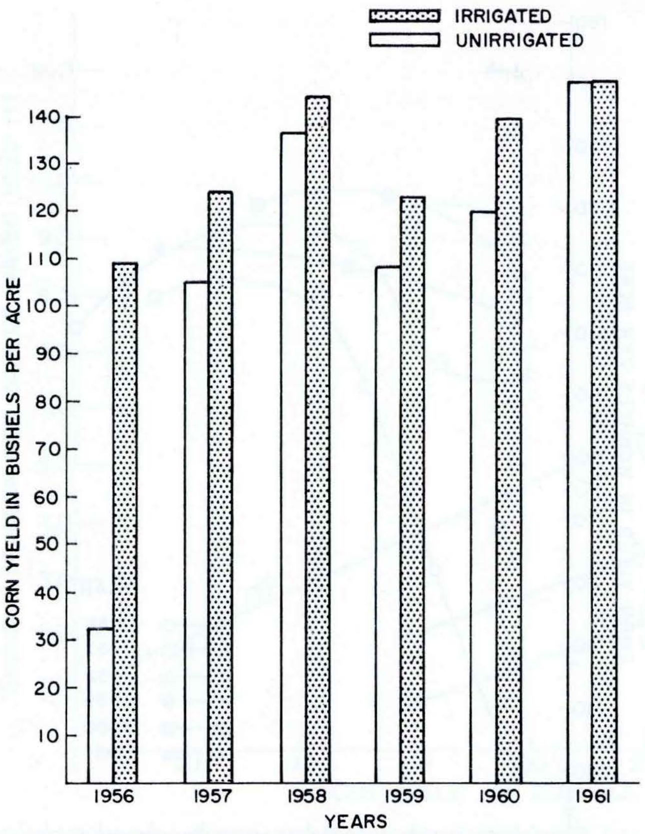

Fig. 13. Maximum irrigated and nonirrigated corn yields on Colo silty clay loam, Ames, Iowa.

a good manager could expect with and without irrigation.

Without irrigation, the highest yields obtained averaged 108 bushels per acre and ranged from 33 to 147 bushels per acre.

With irrigation, yields averaged 131 bushels per acre and ranged from 109 bushels to 147 bushels per acre. Thus, without irrigation, there was a range in yields of 114 bushels per acre, but under irrigation, this range was reduced to 38 bushels.

Average corn yields for the 6-year period were 23 bushels per acre higher under irrigation as compared with the "high-management level" unirrigated corn.

CONCLUSIONS

On the basis of a 6-year irrigation experiment on Colo clay loam near Ames, Iowa, maximum yields were obtained with a stand of 18,000 to 22,000 plants per acre when fertility was not limiting and when the moisture content of the soil in the rooting zone was maintained at 60 percent of the available water-holding capacity throughout the entire growing season.

The length of this irrigation study was quite short. Data from a longer period of investigation would provide a higher degree of confidence in projecting for the future, but it appears that, for most years in central Iowa on well-drained, fine-textured soils, some response to irrigation maintained at a 60-percent-available-moisture-content level may be expected.

Corn yields were depressed in all cases when the soil was allowed to dry below 60 percent of the available water-holding capacity of the soil in the rooting zone of the corn plant. There was no advantage in maintaining the soil moisture above the 60-percent-available level.

Even with optimum stand, fertility and irrigation levels, yields varied from year to year. Climatic conditions may explain much of this variability.

Yields were increased with 40, 60, 80 and 120 pounds of N per acre primarily when soil moisture was held at 60-percent-available-moisture content and when stand levels were above 15,000 and 20,000 plants per acre.

One of the most intriguing possibilities emerging from this study concerns the use of irrigation in central Iowa. Even though the period of this investigation was short, results show that irrigation, with high soil fertility, will increase yields most years even when above-normal growing-season moisture is present. One would expect responses to become more frequent in dryer and warmer areas of the state. Results of this study suggest the need for continued investigations dealing with the interrelationships of irrigation, fertility and stand levels under varying types of soil for maximum corn production.

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APPENDIX A: Corn Yield Data from Experiment

Table A-1. Corn yields in bushels per acre from irrigation, stand and fertility experiment for 1956.

		Irrigation Treatments (Inches applied/A.)				
Stand	Fertilizer	None	Pre-season	20% AMC	60% AMC	90% AMC
Plants/A.	Lbs. N./A.	0.3	6.3	11.9	15.8	28.0
10,000	0	32.3	63.9			
	40	22.1	56.2			
14,000	0	32.9	66.9			
	40	19.7	62.2	84.3	99.3	103.5
	80			95.5	109.5	101.5
18,000	40			95.3	109.5	108.8
	80			90.9	108.9	114.6
	Means	26.8	62.3	91.5	106.8	107.1

Table A-2. Corn yields in bushels per acre from irrigation, stand and fertility experiment for 1957.

		Irrigation Treatments (Inches applied/A.)				
Stand	Fertilizer	None	Pre-season	20% AMC	60% AMC	90% AMC
Plants/A.	Lbs. N./A.	0	6.0	0	12.4	34.4
8,000	0	89.6	78.6			
	60	74.8	90.4			
14,000	0	104.6	97.4	104.3	105.5	96.5
	60	101.3	111.3	107.4	104.3	101.7
20,000	0			112.8	120.6	87.6
	60			121.3	123.7	117.1
	Means	92.6	94.4	111.5	113.5	100.7

Table A-3. Corn yields in bushels per acre from irrigation, stand and fertility experiment for 1958.

		Irrigation Treatments (Inches applied/A.)		
Stand	Fertilizer	None	60% AMC	90% AMC
Plants/A.	Lbs. N./A.	0	5.1	8.1
8,000	0	89.8	88.8	89.2
	60	91.4	109.6	92.1
15,000	0	115.0	123.2	121.8
	60	124.1	122.9	128.9
22,000	0	130.7	132.9	130.6
	60	135.7	143.7	149.6
	Means	114.5	120.2	118.7

Table A-4. Corn yields in bushels per acre from irrigation, stand and fertility experiment for 1959.

		Irrigation Treatments (Inches applied/A.)		
Stand	Fertilizer	None	60% AMC	90% AMC
Plants/A.	Lbs. N./A.	0	13.4	27.3
10,000	0	92	95	96
	60	92	98	101
15,000	0	107	115	116
	60	106	119	126
20,000	0	108	113	116
	60	107	123	124
	Means	102.0	110.5	113.2

Table A-5. Corn yields in bushels per acre from irrigation, stand and fertility experiment for 1960.

		Irrigation Treatments (Inches applied/A.)		
Stand	Fertilizer	None	60% AMC	90% AMC
Plants/A.	Lbs. N./A.	0	10.0	20.0
10,000	0	97.2	103.8	101.7
	120	100.5	110.6	119.1
15,000	0	111.2	119.5	115.3
	120	115.2	131.4	133.7
20,000	0	115.2	129.1	117.3
	120	119.6	138.6	135.3
	Means	109.8	122.16	120.40

Table A-6. Corn yields in bushels per acre from irrigation, stand and fertility experiment for 1961.

		Irrigation Treatments (Inches applied/A.)	
Stand	Fertilizer	None	60% AMC
Plants/A.	Lbs. N./A.	0	2
14,000	0	132.6	129.9
	60	141.6	143.2
	120	135.3	140.5
18,000	0	142.3	145.3
	60	142.4	142.4
	120	146.5	147.5
22,000	0	140.2	138.4
	60	147.4	148.7
	120	147.0	143.3
	Means	141.7	142.1