Research on Irrigation of Corn and Soybeans At Conesville and Ankeny, Iowa, 1951 to 1955

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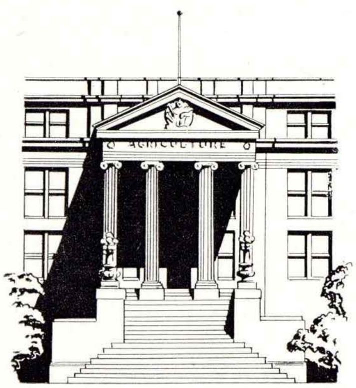

AGRICULTURAL AND HOME ECONOMICS EXPERIMENT STATION, IOWA STATE COLLEGE

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Research on Irrigation of Corn and Soybeans at Conesville and Ankeny, Iowa, 1951 to 1955[1]

BY G. O. SCHWAB, W. D. SHRADER, P. R. NIXON AND R. H. SHAW[2]

Irrigation in the humid and semihumid sections of the United States has increased manyfold since World War II. Before this, irrigation was confined principally to the more arid western states. Some of the reasons for the spread to more humid areas were the development of portable lightweight aluminum pipe and couplers, moderately high farm prices, occurrence of several drouthy seasons, increased use of fertilizers and development of better crop varieties. Drouths in various portions of the state in 1953, 1954, 1955 and 1956 have prompted many farmers to buy irrigation equipment. A 1953 survey in Iowa showed that only 55 farmers were irrigating about 3,600 acres. Twenty-two of these farmers were in Muscatine County where irrigation is used on vegetable crops. Two years later, in 1955, another survey indicated that 250 farmers were irrigating approximately 15,000 acres.

Indications are that irrigation will continue to increase, particularly along the Mississippi and Missouri rivers. Along the Missouri River there are about 600,000 acres of bottomland. Most of this area needs better surface drainage. Without too much additional cost, land which is surface drained can be shaped for surface irrigation. Because of good ground water supplies, this area has a high irrigation potential. These conditions also exist to a more limited extent along other major Iowa streams.

The purpose of this study was to determine the response of corn and soybeans to irrigation. The only known research on field crops in Iowa was a study reported by Davidson[3] on sewage irrigations at Ames. Corn yields were increased only 6 percent for the two years, 1907 and 1911. Several other crops were irrigated, but those giving the greatest response were barley, sugar beets and grasses. Considerable research on vegetable crops has been done at the Muscatine Island Field Station.[4]

The data to be discussed include the results of 2 years of irrigation research on corn on a medium-textured soil near Ankeny and the results of 5 years of work on sandy soil near Conesville. Soybean results were obtained for 3 years at Conesville only.

ANKENY FIELD STATION

The Ankeny Field Station is located about 5 miles north of Des Moines on land formerly occupied by the Des Moines Ordinance Plant. The irrigation experiment was conducted for 2 years—1954 and 1955. A diagram of the experimental design is given in fig. 1. Because

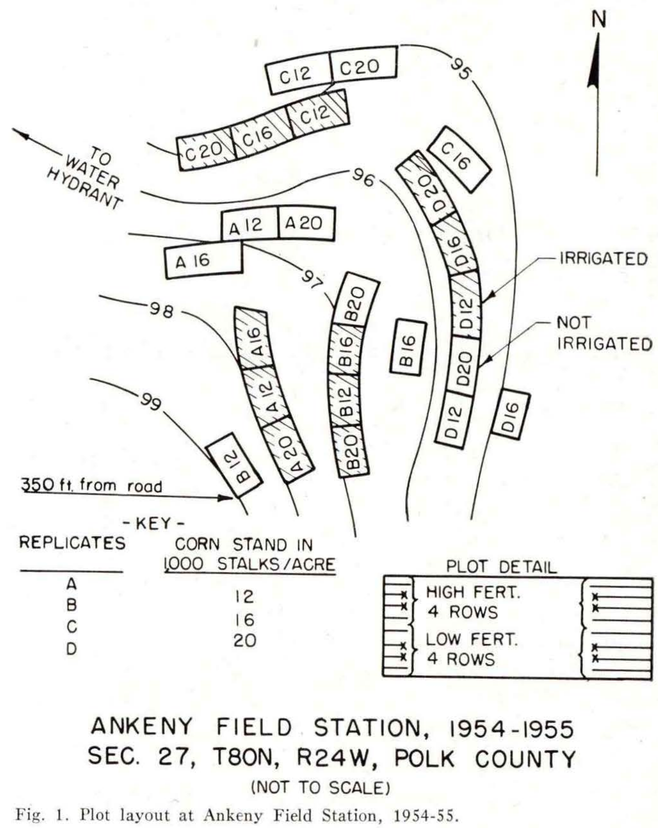

Fig. 1. Plot layout at Ankeny Field Station, 1954-55.

[1] Project 1247, Iowa Agricultural and Home Economics Experiment Station. The authors wish to acknowledge the assistance of M. W. Bittinger, R. K. Frevert, C. R. Weber, Frank Schaller, C. E. Beer, H. P. Johnson, Theodore Horner, W. F. Buchele, G. R. Peterson and T. L. Willrich.

This work was made possible through the cooperation and assistance of several agencies and commercial organizations. The Aluminum Company of America provided considerable financial assistance and supplied the aluminum pipe for the irrigation system. The Southeastern Iowa Experimental Association provided the land on which the experiments were conducted at Conesville. The Carver Pump Company at Muscatine and the Construction Machinery Company at Waterloo loaned pumps for the irrigation system. The Carver Pump Company also furnished couplers and fittings. The U. S. Department of Agriculture, Soil Conservation Service and Agricultural Research Service (Field Crops Branch) cooperated in portions of the study as well as the Iowa Cooperative Extension Service in Agriculture and Home Economics.

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[3] J. B. Davidson. Summary of 6 years of experimentation in sewage irrigation. (Iowa State College, unpublished research.) Department of Agricultural Engineering. April 1914.

[4] L. E. Petersen and E. T. Lana. Irrigation, fertilizer and cultural studies with sweet potatoes, muskmelons and watermelons on Buckner coarse sand. Trans. Iowa State Hort. Soc. 88:237-252. 1953.

better facilities became available near Ames, the Ankeny studies were discontinued.

SOIL CHARACTERISTICS

The experiment was located on Nicollet loam soil which is a deep, dark-colored, highly productive soil with a high water-holding capacity. Nicollet loam is one of the major soils in the Clarion-Webster soil area in north-central Iowa. It occurs on gentle slopes in a position between the sloping, well-drained Clarion soils and the level, poorly oxidized Webster soils.

The surface of the Nicollet loam is a very dark, grayish-brown, friable loam which grades at depths ranging from about 12 to 14 inches into a yellowish-brown, slightly mottled loam to clay loam subsoil. The subsoil grades into a calcareous loam glacial till parent material, usually within about 36 inches.

Nicollet loam is a highly productive soil and is used extensively for corn and soybean production. The water-holding capacity is high, averaging about 1.8 to 2 inches of available water per foot of soil. Both surface and internal drainage are moderately good.

SOIL TREATMENTS

In 1954 the plots received a blanket application of 125 pounds per acre of an 0-45-0 fertilizer. In 1955, 60 pounds per acre of both phosphorus (P_2O_5) and potash (K_2O) were applied. Aldrin was used in 1955 to control corn rootworm. In 1955 all plots received 60 pounds of nitrogen (N) per acre at planting time, and the high fertility plots received an additional 60 pounds when the corn was about 18 inches high.

The corn was planted on top of ridges made with a

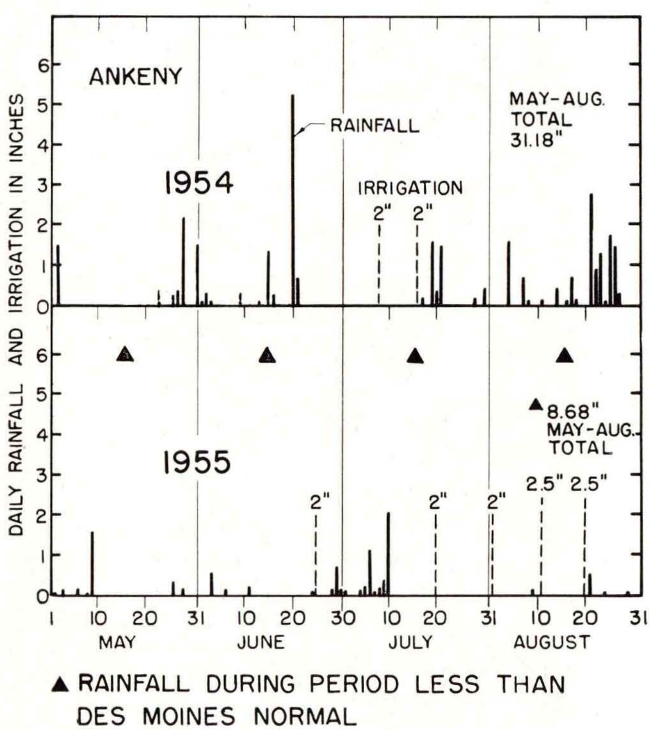


Fig. 2. Rainfall and irrigation at Ankeny Field Station for May through August 1954-55.

TABLE 1. OCCURRENCE OF HIGH TEMPERATURES AT ANKENY FIELD STATION.

Month	Number of days with indicated (or greater) maximum temperatures (°F.) 1954 90	1954 95	1954 100	1955 90	1955 95	1955 100
May	0	0	0	0	0	0
June	9	2	0	2	0	0
July	12	5	0	15	7	1
August	0	0	0	18	11	0
4-month total	21	7	0	35	18	1

modified moldboard plow. Weeds were controlled by pre-emergence spraying, by use of disk hillers and by hand weeding. In both years Iowa Hybrid 4298 was planted at a rate to obtain stands of about 26,000 stalks per acre and later thinned to the desired stands of from about 12,000 to 22,000 stalks per acre. Corn was planted in 1954 on May 14 and in 1955 on May 21.

Water obtained from the City of Des Moines was supplied to each furrow with a fire hose. Small dams were built in the furrow to hold the water on the plot. As shown in fig. 2, the plots were irrigated twice in 1954 (4 inches) and five times in 1955 (11 inches). The plots were irrigated when the soil moisture dropped to 60 percent of the total available to plants[5] in the top 3 feet. Both the direct and the electrical resistance (nylon blocks) methods were used to determine the time of irrigation.

CLIMATIC DATA

The amount and distribution of rainfall at Ankeny for 1954 and 1955 are shown in fig. 2. Rainfall for May, June, July and August and the total for the 4 months was above normal in 1954 and below normal in 1955. The normal 4-month total is 16.55 inches for Des Moines, and the normal annual rainfall is 30.74 inches. Despite the greater rainfall in 1954, there were two dry periods during the growing season. A 20-day period in May and a 25-day period from June 21 to July 16 were without rainfall. The total rainfall in 1955 for the 4-month period was about half of normal. Except for the first half of July, the season was very dry.

As shown in table 1, the number of days with temperatures over 90° F. was considerably greater in 1955 than in 1954. This difference resulted primarily from the high temperatures in August 1955, which was a month of practically no rainfall.

RESULTS

Detailed records of stand and yield are given in table A-1 of the Appendix. The results discussed here deal primarily with average values.

Corn, 1954. Irrigation resulted in a significant yield increase on the fertilized plots but not on the unfertilized. The response to nitrogen was significant at the 99-percent level. There was also a significant increase in yields at high stand levels on the fertilized plots but not on the unfertilized. The increase in yield with increasing stand, as shown in fig. 3 and table 2, is confined to the unirrigated fertilized plot. The lack of response with increasing stand on the irrigated and fertilized plots can perhaps be explained by the fact that rains in August

[5] Water "available to plants" is the water held in the root zone in the soil between field capacity (estimated from the moisture equivalent) and wilting point (estimated from water held in the soil at 15 atmospheres tension).

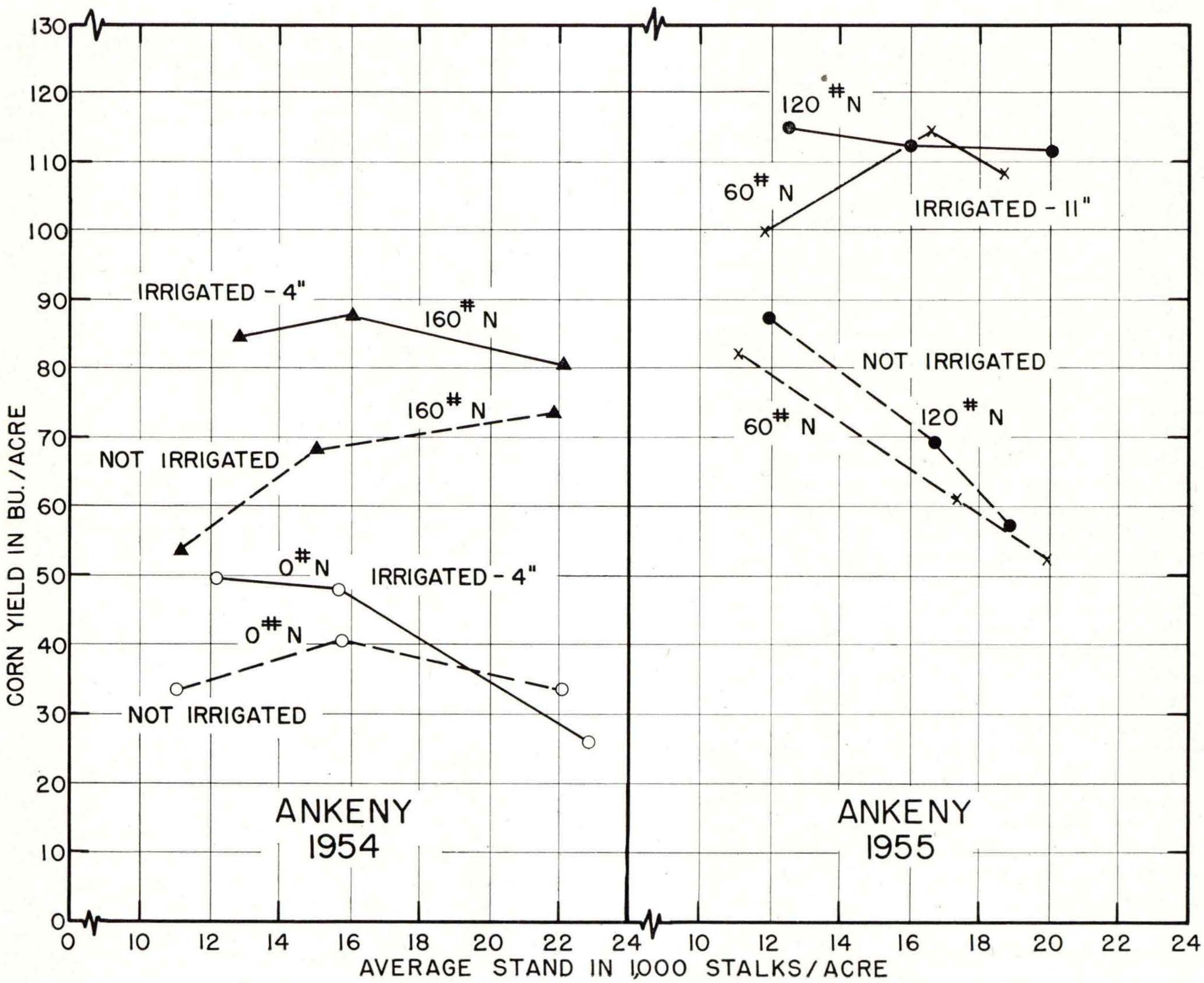


Fig. 3. Effect of stand, irrigation and fertility treatments on corn yields at Ankeny Field Station, 1954-55.

(see fig. 2) resulted in possible damage by excess moisture from water ponding in the contour furrows. Corn yields were depressed on the unfertilized irrigated plots at higher stand levels. This depression in yield indicates a severe nitrogen deficiency, a condition that would be accentuated by too much water. Responses to different treatments are summarized in table 3.

Without adequate nitrogen, irrigation did not result in a significant yield increase. Where nitrogen was supplied, irrigation resulted in an increase of 19.3 bushels per acre. Even without irrigation there was an increase of 29.2 bushels per acre as a result of using nitrogen. On the irrigated plots, the fertilized corn had an average yield of 43.1 bushels per acre more than the unfertilized corn.

TABLE 2. EFFECT OF IRRIGATION, STAND AND FERTILITY TREATMENTS ON CORN YIELDS AT ANKENY, IOWA, IN 1954.

	Corn yield (bu./acre)			
	Not irrigated		Irrigated	
Stand*	No fertilizer	160 lbs. N/acre	No fertilizer	160 lbs. N/acre
12,000	33.6	53.7	49.5	84.5
15,500	40.5	68.1	48.0	87.8
22,000	33.4	73.3	26.0	80.6
Average all stands	34.8	65.0	41.2	84.3

*Approximate number of stalks per acre.

As shown in fig. 2, rainfall was adequate except for the first part of July. The second irrigation on July 16 was followed in a few days by 2.6 inches of rain, which made the second irrigation much less effective than the first irrigation on July 8. Despite this condition, yields were increased 19.3 bushels per acre.

Corn, 1955. Since rainfall was below normal during the growing season in 1955 (see fig. 2), response to irrigation was much greater than in 1954. Average yields for different treatments are given in tables 4 and 5 and fig. 3. An analysis of variance indicated a significant difference at the 99-percent level among the stands and between irrigated and nonirrigated plots. Fertility treatment differences were significant at the 95-percent level. The

TABLE 3. CORN YIELD INCREASES AT ANKENY, FROM IRRIGATION AND NITROGEN FERTILIZER FOR 1954 (AVERAGE OF ALL STANDS).

Response to irrigation	
a. No nitrogen	5.4 bu./acre
b. 160 lbs. nitrogen per acre	19.3 bu./acre
Response to 160 lbs. nitrogen per acre	
a. No irrigation	29.2 bu./acre
b. Irrigated	43.1 bu./acre

TABLE 4. EFFECT OF IRRIGATION, STAND AND FERTILITY TREATMENTS ON CORN YIELDS AT ANKENY, 1955.

	Corn yield (bu./acre)			
	Not irrigated		Irrigated	
Stand*	60 lbs. N/acre	120 lbs. N/acre	60 lbs. N/acre	120 lbs. N/acre
12,000	82.1	87.2	99.5	114.8
16,600	60.9	69.1	114.5	112.7
19,600	52.3	57.4	108.1	111.5
Average all stands	65.1	71.2	107.4	113.0

*Approximate number of stalks per acre.

TABLE 5. CORN YIELD INCREASES AT ANKENY, FROM IRRIGATION AND NITROGEN FERTILIZER FOR 1955 (AVERAGE OF ALL STANDS).

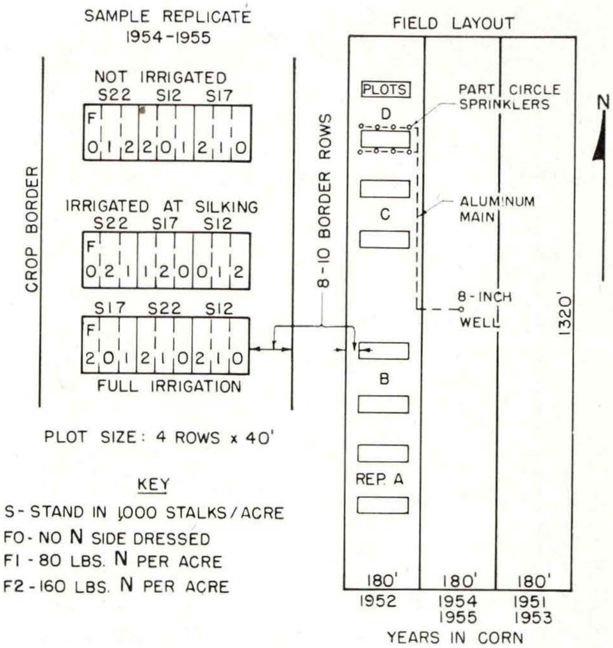
Response to irrigation	
a. 60 lbs. N per acre	42.3 bu./acre
b. 120 lbs. N per acre	41.8 bu./acre
Response to 120 lbs. N over 60 lbs. per acre	
a. No irrigation	6.1 bu./acre
b. Irrigated	5.6 bu./acre

interaction between stand and irrigation treatments was also significant at the 99-percent level. As shown in fig. 3, the highest average yields on both the irrigated and nonirrigated plots at the lowest stand level were obtained with 120 pounds of nitrogen per acre. At this stand level, where 120 pounds of nitrogen per acre were used, the advantage due to irrigation was 27.6 bushels per acre, and these differences increased with an increase in stand. The depressed yields with higher stand levels on the nonirrigated plots accounted for the greater yield differences between irrigated and nonirrigated plots at higher stand levels. Responses to different treatments are summarized in table 5.

Because of different climatic conditions and fertility levels in 1954 and 1955, a comparison of the yields is hard to interpret. In 1954 the data are for second-year corn and, in 1955, for third-year corn. The yields on the nonirrigated plots at the high fertility level increased with stand in 1954 and decreased in 1955. The seasonal rainfall and temperatures for the 2 years varied considerably from the normal.

SOUTHEASTERN IOWA EXPERIMENTAL FARM, CONESVILLE

Irrigation experiments were conducted at Conesville for a 5-year period, 1951-55, on corn and for a 3-year period, 1952-54, on soybeans. The irrigation studies were conducted near Conesville on a 40-acre tract of sandy



SOUTHEASTERN IOWA EXPERIMENTAL FARM, CONESVILLE
SW 1/4, SW 1/4, SEC. 8, T76N, R4W, MUSCATINE COUNTY

Fig. 4. Plot layout at Southeastern Iowa Experimental Farm, Conesville, for irrigation of corn.

soil owned and operated by the Southeastern Iowa Experimental Association.

Irrigation research was started in 1950 to measure the effect of additional water on these field crops. Because of operational difficulties, the yield trends on the different replications for 1950 were not consistent and are not included in this report.

SOIL CHARACTERISTICS

The soils in the experimental plots are representative of relatively large areas of sandy soils throughout eastern Iowa. Thurman loamy sand is the principal soil type on the farm. Surface textures range from loamy sand to sand. Below depths of 1 to 2 feet, textures are sands

TABLE 6. SUMMARY OF TREATMENTS AT SOUTHEASTERN IOWA EXPERIMENTAL FARM, CONESVILLE.

Year	Irrigation treatments for corn (inches applied)	Corn stand, stalks per acre (approximate)	Corn fertility treatments (lbs. N per acre)	Uniform fertility treatment for corn (lbs./acre) N	P	K	Irrigation treatments for soybeans (inches applied)
1951	None Irrigated—10	V. Low—6,900 Med.—13,300	None V. Low—40 Low—80 Med.—120	0	40	40	
1952	None Irrigated—6.5	Low—10,000 Med.—13,400 M. High—16,600	M. Low—60 Med.—120 High—180	5	120	120	None Irrigated—4.5
1953	None Irrigated—7.5	Low—11,100 Med.—14,200 High—18,000 V. High—21,000	None Low—80 M. High—160 V. High—240	5	80 and 10 tons manure	140	None Irrigated—7.5
1954	None Silking time only—3 Irrigated—9	Low—11,000 M. High—16,000	None Low—80 M. High—160	5	80	140	None Irrigated—9
1955	None Silking time only—4 Irrigated—11	Med.—12,000 M. High—16,700 V. High—23,000	None Low—80 M. High—160	0	80	140	

except that lenses or bands of heavier texture may occur, usually at depths ranging from 4 to 7 feet. The surface soil is grayish-brown, the subsoil, yellowish-brown. Drainage and aeration are very good. Infiltration rate is very rapid and may exceed an inch per hour. The moisture equivalent is about 6 percent, and wilting point is about 1.5 to 2 percent. The soil can, therefore, hold only about ½ inch of water per foot in a form available for plant use. Wind erosion is a serious problem on these soils, especially when the soil surface is not covered by vegetation. These soils are low in all major nutrients.

PROCEDURE AND LAYOUT

The experimental area at Conesville consisted of three crop strips each having one crop of a 3-year rotation of corn, oats and alfalfa. The field layout and a sample replicate of the plots are shown in fig. 4. The plots were surrounded on all sides by at least 8 to 10 rows of corn. In 1952, 1954 and 1955 each block was subdivided for stand, and the stand subplot was then split for different fertility levels. In 1951, 1952 and 1953, two levels of irrigation were studied. In 1954 and 1955, a third irrigation treatment—irrigation at silking time only—was added. There were four replications of each treatment in all years except 1951 when two replications were used. In 1953 the stand and fertility treatments were completely randomized in each plot. Since the treatments varied from year to year, they are summarized in table 6 for clarity.

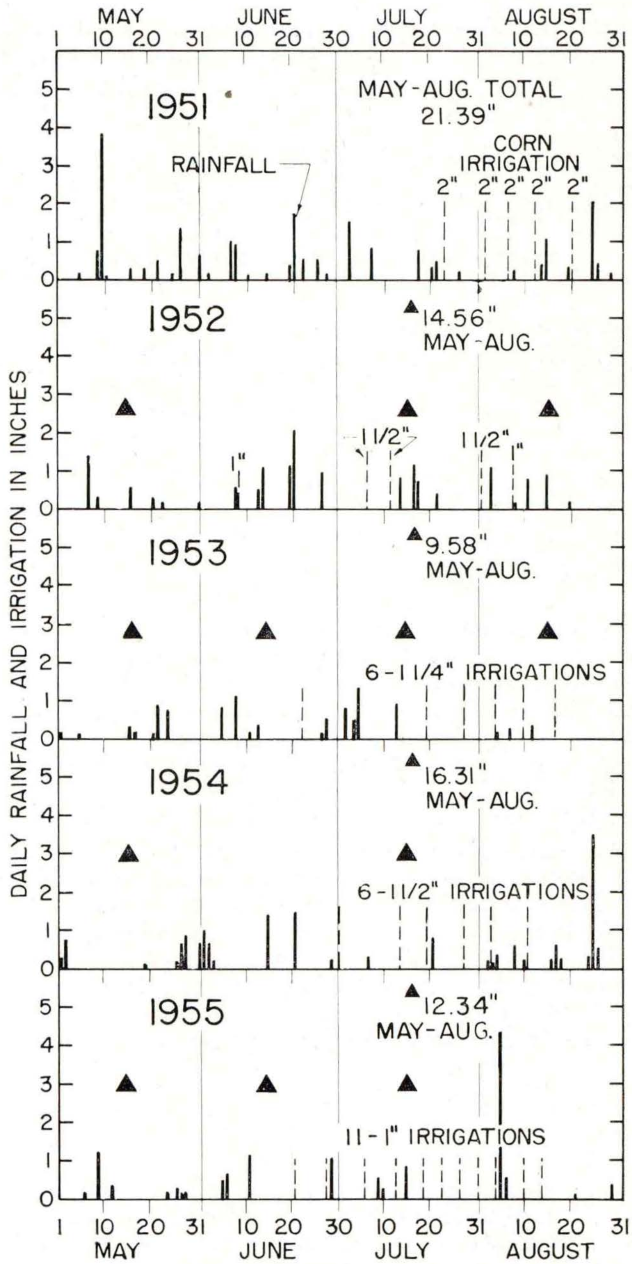
Soybean plots were located near the corn plots. Sprinkler lines were placed across the rows. In 1952 only the variety Adams (4 replications) was grown, but in 1953 and 1954 Adams, Hawkeye, Lincoln and Clark varieties (6 replications) were included. In 1953 and 1954 two replicates were located in each of three irrigated and three unirrigated blocks.

A 24-inch, gravel-packed well with an 8-inch casing was installed on the farm in July 1951. In the test drilling operation, coarse gray sand was found from 11 to 35 feet and blue clay at depths from 35 to 42 feet. The bottom of the 5-foot screen was placed at a depth of 36.8 feet. Normally, the water table is 8 to 12 feet below the surface. At the time of installation, the well was test pumped at 60 gallons per minute with a drawdown of 3.7 feet from a static water level of 8 feet. The yield from the well gradually increased until the summer of 1954 when it dropped to 55 gallons per minute with a 15-foot drawdown. The water had 0.7 parts per million of iron, 3.3 grains of hardness per gallon and a pH of 6.5. In 1954 the water for the soybean plots was pumped from 1½-inch diameter well points.

The corn plots were irrigated with part-circle sprinklers located on the plot borders as shown in fig. 4. In later years moving of the lateral lines was reduced by mounting the sprinkler head on a 6-foot portable tripod. A 50-foot garden hose connected to the tripod and to the aluminum lateral pipe permitted the sprinklers to be moved from one side of the plot to the other without moving the lateral. The soybean plots were irrigated with regular sprinklers in 1952 and with a 2-inch diameter perforated pipe in 1953 and 1954.

CLIMATIC DATA

The amount and distribution of rainfall at the Southeastern Iowa Experimental Farm for 1951 through 1955 are shown in fig. 5. The normal rainfall for May, June, July and August at Columbus Junction is 3.96, 4.84, 3.72 and 4.01 inches, respectively. The normal total for the 4 months is 16.53, and the normal annual precipitation is 34.69 inches.



▲ RAINFALL DURING PERIOD LESS THAN COLUMBUS JUNCTION NORMAL

Fig. 5. Rainfall and irrigation at Southeastern Iowa Experimental Farm for May through August, 1951-55.

The solid triangles in fig. 5 located next to the May-August totals indicate that the 4-month total was below normal. The triangles located at the middle of each month indicate monthly rainfall below normal. The monthly and 4-month totals were all above normal in 1951 and all below normal in 1953. In all years except 1951 the 4-month totals were below normal. In 1952

TABLE 7. OCCURRENCE OF HIGH TEMPERATURES AT SOUTHEASTERN IOWA EXPERIMENTAL FARM (DATA FOR COLUMBUS JUNCTION).

	Number of days with indicated (or greater) maximum temperature (°F.)														
	1951			1952			1953			1954			1955		
Month	90	95	100	90	95	100	90	95	100	90	95	100	90	95	100
May	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0
June	0	0	0	11	3	0	8	3	0	13	3	0	0	0	0
July	2	0	0	13	1	0	12	2	0	12	6	0	21	10	6
August	3	1	0	3	0	0	12	9	2	3	0	0	17	11	2
4-month total	5	1	0	29	4	0	35	14	2	28	9	0	38	21	8

TABLE 8. EFFECT OF IRRIGATION, STAND AND FERTILITY TREATMENTS ON CORN YIELDS AT CONESVILLE, 1951.

		Corn yield in bu./acre				
		Not irrigated*		Irrigated		
Stand, in stalks per acre (approximate)	Fertility treatment (lbs. N/acre)	Average yields	Increase due to N	Average yields	Increase due to N	Increase due to irrigation
6,930	0	32.5	—	25.0	—	—7.5
	40	56.3	23.8	33.8	8.8	—22.5
	80	46.0	13.5	47.0	22.0	1.0
	120	47.7	15.2	47.9	22.9	1.2
					Average	—7.0
13,340	0	36.1	—	19.9	—	—16.2
	40	56.8	20.7	49.4	29.5	—7.4
	80	76.1	40.0	72.3	52.4	—3.8
	120	85.0	48.9	75.6	55.7	—9.4
					Average	—9.2

*Results for one replicate only.

June was the only month with above-normal rainfall, and in 1955 only August had above-normal rainfall. The 1954 growing season was the nearest to normal; May and July were below normal, but June and August were above. During the 4-month interval in all 5 years there were three periods of 20 days or more with less than 0.2 inch of rainfall. These occurred in July 1953, May 1954 and July 1955.

The number of days with temperatures of 90° F. or more during the 4-month growing season is given in table 7. The year with the highest temperatures was 1955 while 1951 was lowest. In 1955 there were 21 days with temperatures over 95° F. as compared with 1953, the next lowest year, which had 14 days. Except for a hot August in 1953, the years 1952, 1953 and 1954 were not greatly different in the number of hot days.

RESULTS

Corn

Crop yields and stands for individual plots for 1951 through 1955 are given in table A-2 of the Appendix. The results obtained are summarized in tables 8 to 11 and fig. 5.

1951. As shown in table 8, there was no response to irrigation in 1951. The season was cool and wet with only 5 days in the 4-month growing season with temperatures over 90° F. Three of these days were the last 3 days in August. Corn stands were quite low, and nutrients may have been limiting. Rainfall was also well distributed and above normal, indicating little need for irrigation for the treatments studied. Five 2-inch applications were given the irrigated plots, but these resulted in no increases in yields. Corn yields ranged from 18.3 to 85 bushels per acre. Because extreme soil variations within one replication obscured the treatment effects, only the other replicate of the nonirrigated plots was harvested, and a statistical analysis for irrigation could not be made. However, an analysis of all the plots showed that yield differences due to nitrogen and stand were significant at the 99-percent level and the 95-percent level, respectively. Yield response to nitrogen was somewhat greater at the higher stand than at the lower stand level.

Typical ear size with irrigation for the two stand levels and for 0 and 80 pounds of nitrogen per acre are shown in fig. 6. With 80 pounds of nitrogen, increasing the stand reduced ear size slightly; while with no added nitrogen, the ear size was greatly reduced at the higher stand level.

1952. The average yields for different stands and fertility levels for 1952 through 1955 are shown in fig. 7. In 1952 rainfall in May, July and August was somewhat below normal, but it was fairly well distributed throughout the season. Temperatures were moderate with only 4 days over 95° F.

As shown in fig. 7, corn yields from the nonirrigated plots were above average and ranged from 80.7 to 95.4 bushels per acre. On the nonirrigated plots, stand and fertility treatments did not have much effect on yield. Stands containing 13,000 to 14,000 stalks per acre pro-

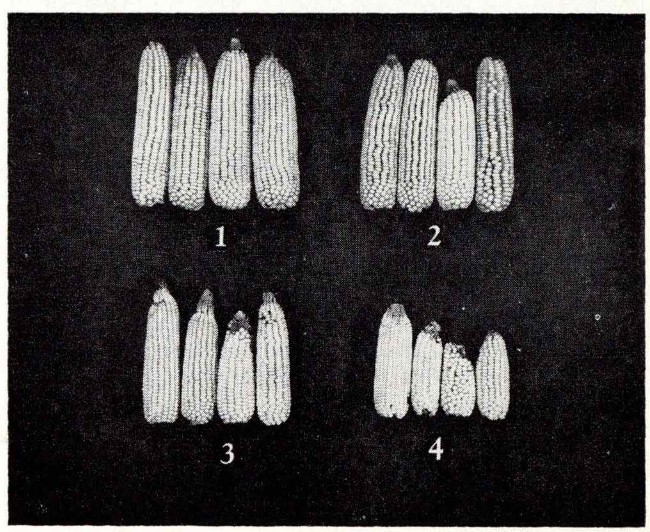


Fig. 6. Ear size for different stand and fertility treatments with irrigation at Conesville, 1951. (1) Stand, 6,930—80 lbs. N/acre; (2) stand, 13,340—80 lbs. N/acre; (3) stand, 6,930—no N; (4) stand, 13,340—no N.

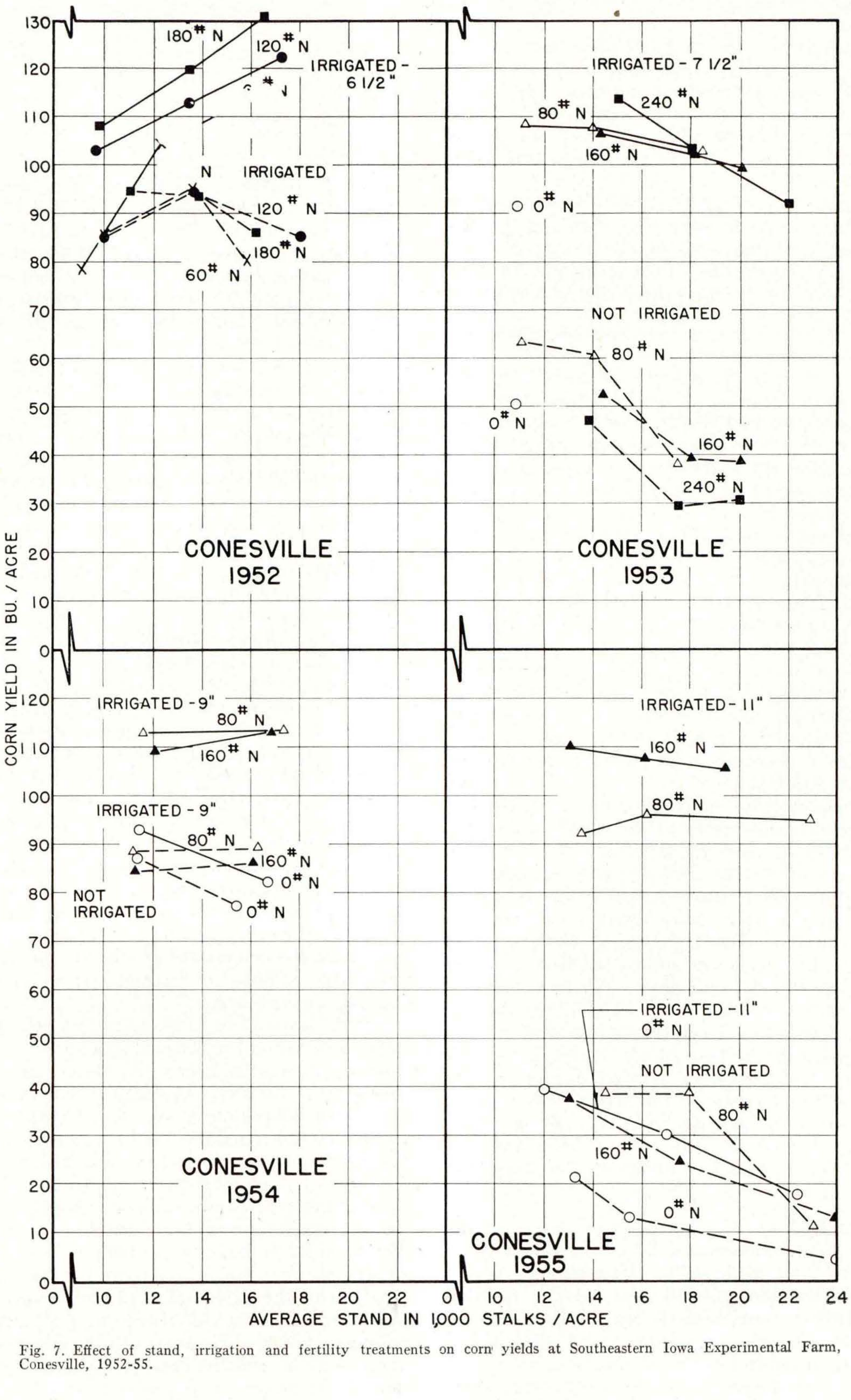


Fig. 7. Effect of stand, irrigation and fertility treatments on corn yields at Southeastern Iowa Experimental Farm, Conesville, 1952-55.

duced the highest yields. Except at the highest stand level, varying the fertilizer rate from 60 to 180 pounds of nitrogen per acre did not have much effect on corn yield.

Yields were higher on the irrigated plots than on nonirrigated plots at all fertility and stand levels except for the low stand with 60 pounds of nitrogen. Yields increased with stand within the range available for all fertility levels. Maximum yield increase from irrigation was about 45 bushels per acre for 180 pounds of nitrogen at the high stand level.

The average ear weight for all fertility levels from the lowest to the highest stands were 0.61, 0.49 and 0.35 for the nonirrigated plots compared with 0.71, 0.61 and 0.51 pounds for the irrigated plots. Differences due to stand and irrigation were larger than those due to fertility.

1953. Rainfall for 1953 from May through August was about 7 inches below normal. August was particularly dry with only 0.7 inch of rainfall. Temperatures were high, with 35 days above 90° F. and 14 days above 95° F. An extremely hot and windy period occurred from Aug. 24 to Sept. 4. Since water was not applied to the irrigated plots after Aug. 17 because of a pump failure, yields from these plots probably are lower than if irrigation had been continued.

Nonirrigated yields varied from 29.8 to 63.8 bushels per acre and, in general, decreased with an increase in stand at all fertility levels. The percentage of barren stalks increased from 6 percent at the low stand to 47.1 percent at the highest stand level. One plot in replicate A of the highest stand had 98-percent barren stalks. Some of the nonirrigated plots in replicate A received the greatest wind damage because they were located on the south end of the field. However, some plots in all replicates had wind damage. If replicate A is omitted from the treatment averages, high stand yields are not reduced as much as shown in fig. 7.

The irrigated plot yields were considerably higher than those on the nonirrigated plots at all fertility and stand levels. The irrigated plot yields varied from 91.6 to 113.7 bushels per acre. The lack of yield response with increased stand may have resulted from lack of irrigation after Aug. 17 and/or from more limiting soil moisture at the higher stand levels. The lack of response from nitrogen is probably due to a uniform application of 10 tons per acre of manure to all plots. The percentage of barren stalks, although much lower than in the nonirrigated plots, varied from 2.7 percent for the lowest stand to 14.1 percent for the highest stand. Many of the irrigated plots also had considerable wind damage. Some of this damage occurred early in the season from blowing sand. Maximum yield increase due to irrigation at the 160 pounds of nitrogen per acre fertility level was 62.7 bushels per acre at a stand of about 18,000 stalks per acre.

1954. Rainfall from May through August and the number of days with temperatures 90° F. or over in 1954 were nearly the same as in 1952. However, in August 1954 about 6 inches more rain fell than in 1952. Rainfall was low and temperatures high during the first 3 weeks in July, but it was adequate from about silking and tasseling time until the end of the season.

As in 1952, corn yields from the nonirrigated plots were above average and ranged from 77.4 to 89.3 bushels per acre. Leaves on the nonirrigated corn, especially on plots with high stand levels, rolled badly during the hot, dry period in July. The height and color of the plants were also noticeably affected. When the temperatures moderated and the rainfall became sufficient in the first week of August, the nonirrigated corn regained its vigor. The corn was planted late enough that the pollination period missed the hot dry weather.

TABLE 9. EFFECT OF IRRIGATION, STAND AND FERTILITY TREATMENTS ON CORN YIELDS AT CONESVILLE, 1954.

	Corn yield bu./acre					
	Low stand—Approximately 11,000 stalks/acre			High stand—Approximately 16,000 stalks/acre		
Irrigation treatment	No nitrogen	80 lbs. N/acre	160 lbs. N/acre	No nitrogen	80 lbs. N/acre	160 lbs. N/acre
No irrigation	87.4	88.4	84.6	77.4	89.3	86.4
Irrigated at silking only	82.5	87.8	86.2	88.9	94.0	85.2
Irrigated for entire season	93.1	113.0	109.2	82.4	113.7	113.1

Corn yields from the plots irrigated with two 1½-inch applications on Aug. 3 and 11 during the silking period were nearly the same as those from the nonirrigated plots. The average yields are shown in table 9.

Except for the plots with no nitrogen, the yields from plots with full-season irrigation were considerably higher than from the nonirrigated plots at both stand levels. The irrigated plot yields varied from 82.4 to 113.7 bushels per acre as shown in table 9.

A statistical analysis of the data indicates a significant difference among irrigation treatments at the 95-percent level and among the fertility treatments at the 99-percent level. The difference between stands was not significant.

The data in table 9 indicate that, without irrigation, there was essentially no response to added nitrogen. Without nitrogen there was only a very small increase in yield from irrigation. However, when both 80 pounds per acre of nitrogen and full-season irrigation were combined, a yield increase of 25.6 to 36.3 bushels per acre resulted. Essentially all of the nitrogen response was obtained with the first 80 pounds per acre.

Silking dates were taken on irrigated and nonirrigated plots having low and high fertility treatments, and the results are reported in fig. 8. Irrigated corn silked about 2 days ahead of corn that received no irrigation. On the irrigated corn the amount of nitrogen made no appreciable difference on date of silking. On the nonirrigated corn the addition of nitrogen speeded up silking an average of half a day.

1955. Rainfall in May, June and July was below normal. The rainfall in August was poorly distributed since one storm of 4.25 inches was more than the normal for the month. In July and August there were 38 days with maximum temperatures over 90° F., 21 over 95° F. and 8 over 100° F., making 1955 the hottest year of the five. Three major drouth periods occurred during the year: 17 days in June, 20 days in July and 22 days in August. The number of days with high temperatures was somewhat greater than in 1953, but rainfall for the 4-month period was 2.76 inches more than in 1953.

Average corn yields are shown in table 10. A statistical analysis of the data indicated that irrigation, stand and fertilizer treatment differences were all significant at the 99-percent level. The analysis also showed that irrigation increased the effectiveness of nitrogen fertilizer. Yields on all the nonirrigated plots and on the irrigated plots with no nitrogen decreased with increasing stand. With

TABLE 10. EFFECT OF IRRIGATION, STAND AND FERTILITY TREATMENTS ON CORN YIELDS AT CONESVILLE, 1955.

Irrigation treatment	Corn yield (bushels per acre): 13,037 stalks per acre, No nitrogen	13,037 stalks per acre, 80 lbs. N/acre	13,037 stalks per acre, 160 lbs. N/acre	16,727 stalks per acre, No nitrogen	16,727 stalks per acre, 80 lbs. N/acre	16,727 stalks per acre, 160 lbs. N/acre	23,060 stalks per acre, No nitrogen	23,060 stalks per acre, 80 lbs. N/acre	23,060 stalks per acre, 160 lbs. N/acre
No irrigation	21.6	38.5	37.4	13.2	38.8	24.6	4.2	11.3	13.4
Irrigated at silking	23.0	44.2	55.6	14.3	35.1	28.6	7.7	19.0	32.2
Irrigated for season	39.3	92.0	110.2	30.4	96.1	107.8	18.0	95.0	105.7

80 and 160 pounds of nitrogen per acre, high stand had little or no effect on the yields of the irrigated plot. Yields on the nonirrigated plots were, in general, lower than in 1953, but yields on the irrigated plots with high fertility were about the same.

Irrigation at silking time compared with no irrigation resulted in average increases in yield of 8.5 bushels per acre for the two highest fertility treatments at all stand levels, but only 2 bushels per acre with no nitrogen. On the plots irrigated at silking time, 4 inches of water were applied in 1-inch increments on July 31 and Aug. 4, 10 and 14.

A record of the silking dates for different irrigation and fertility treatments with a stand of 13,000 stalks per acre is shown in fig. 8. Full-season irrigation speeded up silking as much as 2 to 3 days, while 160 pounds of nitrogen per acre advanced silking as much as 6 days.

Comparison of Corn Yields at Conesville (1952 through 1955). A summary of the response of corn to irrigation and nitrogen for the years 1952-55 at Conesville is shown

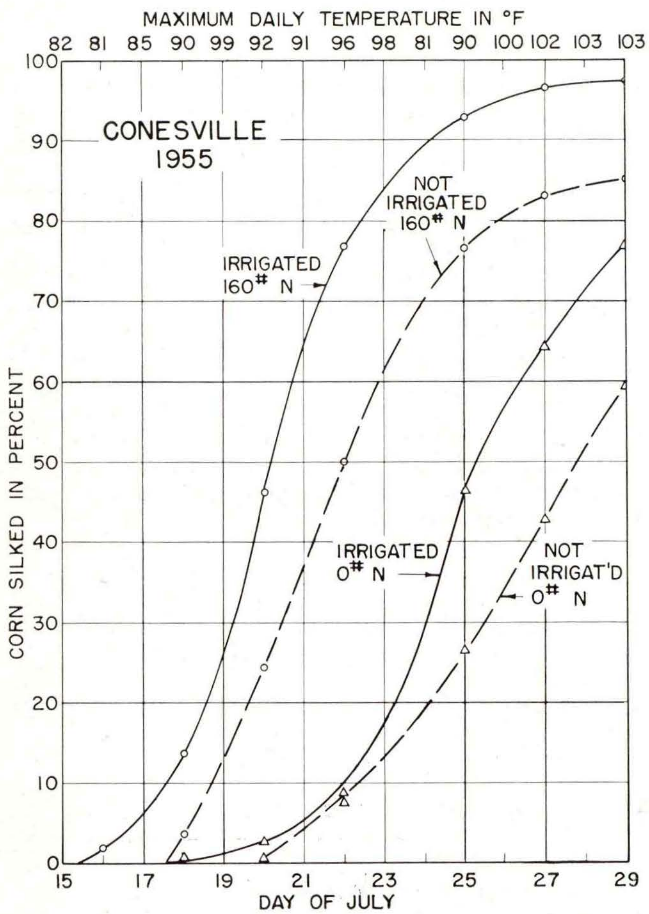


Fig. 8. Effect of irrigation and nitrogen (13,000 stalks per acre) on corn silking dates at Conesville, 1955.

in table 11. Because of reasons previously discussed, the yields for 1951 are not included in the averages.

In most cases studied, as is shown in fig. 7, yields were depressed on the nonirrigated plots as stand levels were increased. Yields were not depressed by increasing the stand levels on the irrigated plots. Thus there was a tendency for the yield differences between irrigated and nonirrigated plots to be greater at the higher stand level. To obtain a measure of the effect of irrigation on corn yields it is necessary to compare maximum yields on irrigated plots at one stand level with the highest yields obtained without irrigation, usually at a lower stand level. This comparison is made in table 16.

The effect of irrigation at different nitrogen levels varies from year to year partly because of differences in initial fertility level. As was previously mentioned, the addition of manure in 1953 supplied nitrogen to all plots and reduced the need for and response to nitrogen.

The yield response to nitrogen on the irrigated plots is shown in table 11 for 80 and 160 pounds of nitrogen per acre. In 1953 and 1954 the 160-pound rate gave no increase in yield over the 80-pound nitrogen rate, but in 1955 the average increase was about 13 bushels per acre for the additional 80 pounds of nitrogen.

Effect of Climate on Corn Yields at Conesville. Maximum corn yields from 1952 to 1955 varied as much as 20 percent even with irrigation and fertilization. There are many factors which may affect yield, but climate appears to be one of the more important. Although, as previously discussed, rainfall and the number of days with high temperatures appear to be important in determining yields, a more direct means of determining moisture stress in the plant is desirable. To make such an evaluation, a balance of the plant available water in

TABLE 11. CORN YIELD RESPONSE TO IRRIGATION AND FERTILITY TREATMENTS AT VARIOUS STAND LEVELS AT CONESVILLE, 1952-55.

Year	Stand in 1,000 stalks per acre	Response to irrigation in bu./acre*: Nitrogen application in lbs./acre None	40	80	120	160	Response to N with irrigation (N in lbs./acre) 80	160
1952	12	—	—	14	19	20	—	—
	15	—	—	25	25	31	—	—
	18	—	—	49	38	49	—	—
1953	12	43	44	45	47	47	17	18
	15	—	—	52	53	55	—	—
	18	—	—	68	65	63	—	—
1954	12	6	15	24	24	24	21	17
	15	7	16	24	25	26	27	26
	18	8	17	24	25	27	34	34
1955	12	13	32	51	61	70	50	71
	15	19	37	55	66	77	60	74
	18	17	37	57	70	82	68	78
	21	14	43	73	79	86	74	83
Average†	12	10‡	23‡	34	38	40	29§	35§
	15	13‡	27‡	39	43	48	44‡	50‡
	18	13‡	27‡	46	50	55	51‡	56‡

* Yield increases are only approximate since they are interpolated from stand-yield curves (see fig. 7).
† Data for 1951 not included in averages. All unmarked averages are for 1952 through 1955.
‡ Averages for 1954 and 1955 only.
§ Averages for 1953, 1954 and 1955 only.

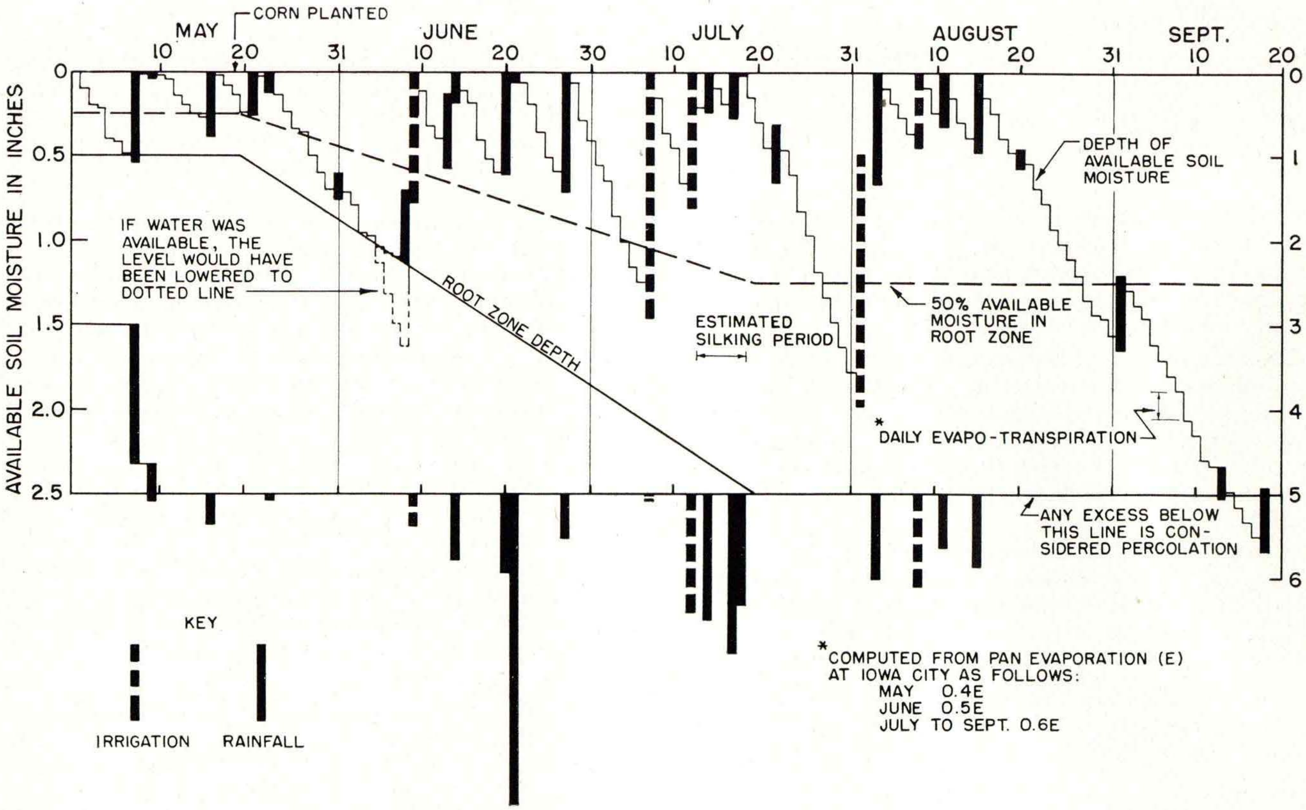


Fig. 9. Estimated water balance at Conesville for 1952.

the soil was determined. The soil-water balance presented here should be considered as a pilot study only, but it does show considerable promise.

The soil-water balance for the irrigated plots in 1952 is illustrated in fig. 9. To obtain some measure of the effect of radiation, wind, atmospheric humidity (factors which were not measured at Conesville) and temperature on water loss, evapo-transpiration was estimated from class A evaporation pan data recorded at Iowa City—the nearest station with such data. Class A evaporation pans are uncovered pans with a diameter of 48 inches. Pan evaporation was multiplied by 0.4 for May, 0.5 for June and 0.6 for July through September to obtain estimated daily rates of evapo-transpiration. Evapo-transpiration is the water lost by evaporation from the soil surface and transpiration from the plants. Penman[6] has estimated evaporation from bluegrass as 0.6 to 0.8 that of open-pan evaporation. The pan correction factor varied from month to month because of a changing root zone depth from which water could be extracted and because of the changing area of crop surface. As long as any water was present in the root zone, evapo-transpiration proceeded at this rate. When the moisture in the root zone was zero, no water loss was assumed.

The root zone depth was taken as 1 foot up to planting time, then increased linearly to 5 feet by July 20, where it remained constant. Available moisture-holding capacity of the soil was estimated at 0.5 inch per foot.

On May 1 of each year the soil moisture content was assumed to be 1.5 inches in the top 3 feet. All rainfall and irrigation water was assumed to enter the soil, and the excess above the water-holding capacity of the root zone was lost as deep seepage or percolation. Shortly after May 1 each year enough rain fell to fill the 5-foot profile to its moisture-holding capacity.

The period of study was from May 1 to 50 days after the silking period. Evapo-transpiration losses were estimated for each day during that period. When all soil moisture was depleted from the root zone depth, evapo-transpiration was assumed to be zero until more surface water was added.

A dry day was arbitrarily defined as one in which 50 percent or less of the available moisture was present in the root zone. This 50-percent moisture level is commonly taken as the time to start irrigation. In 1951 Pettis[7] used a dry day method of estimating yield, but he used a constant rate of evaporation for given periods. In the present study the dry days during the growing season were weighted as shown in table 12.

The number of dry days was doubled when the available soil moisture was depleted to the root zone depth or below. The weighted number of dry days for each period for the 4 years is given in table 13.

A comparison of various climatic factors with corn yields is shown in fig. 10. Data for a stand level of 14,000

[6] Penman, H. L. Natural evaporation from open water, bare soil and grass. Proc. Royal Soc. London. Series A, 195. 1948.

[7] Reported in: Cunningham, Glenn. Are little "dry" days the real corn robbers? Iowa Farm and Home Register, Page 3-5H, Dec. 2, 1951.

TABLE 12. WEIGHTING FACTORS USED FOR DRY DAY DETERMINATION.

Period	Weight
1. Planting to 30 days after planting	0.5
2. 30 days after planting to 5 days before silking	1.0
3. 5 days before to 5 days after silking period	2.0
4. 5 days after to 30 days after silking period	1.0
5. 30 days after to 50 days after silking period	0.5

TABLE 13. WEIGHTED NUMBER OF DRY DAYS

Period	1952	1953	1954	1955
1	5	6	7	12
2	3	4	3	3
3	0	2	0	0
4	4	7	0	9
5	5	10	8	17
Total	17	29	18	41

to 16,000 stalks per acre with nitrogen fertilizer, but not over 160 pounds of nitrogen, were used. Irrigated corn yields were inversely related to the weighted number of dry days, although the relationship was not as good as for high temperatures.

Yields were also compared with May through August rainfall and with the number of days above 90° (fig. 10b). The relative ranking in order of decreasing yields is 1952, 1954, 1953 and 1955. This is the same ranking as the number of days above 90° F. but is different from the rainfall ranking. One would expect that under a proper irrigation program high temperatures should be related closely to yield if other factors, including water, are properly controlled.

Nonirrigated yields showed a much wider fluctuation from year to year. The number of dry days was closely related to nonirrigated yields except in 1955 when the highest number of days above 90° F. occurred (fig. 11c).

The yield reduction and increase in dry days from the irrigated to the nonirrigated plots are shown in table 14. The greater reduction in yield for each dry day in 1955 may have been because of the more frequent occurrence of days above 90° F.

Although this method of estimating dry days must be

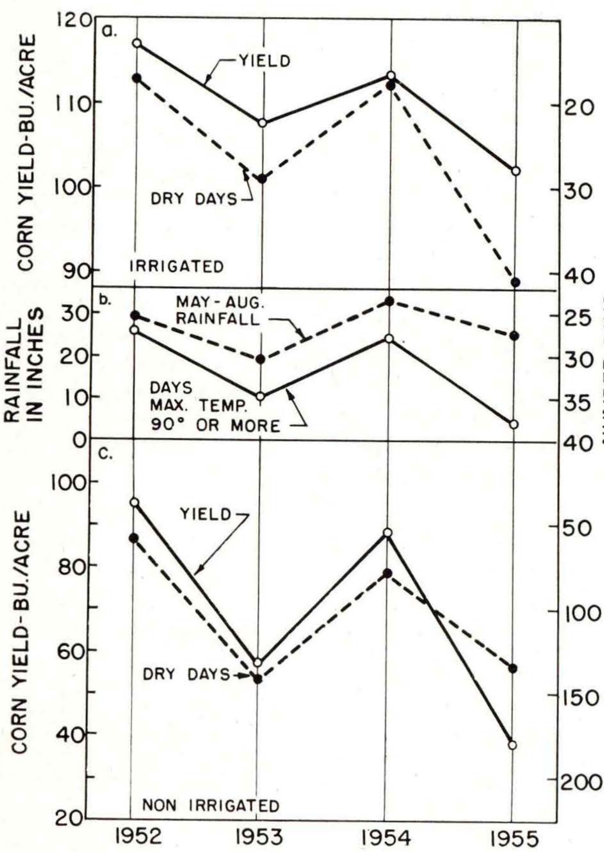


Fig. 10. Comparison of climate with corn yields at Conesville for 1952-55.

TABLE 14. COMPARISON OF YIELD DIFFERENCES AND NUMBER OF DRY DAYS FOR IRRIGATED AND NONIRRIGATED PLOTS AT CONESVILLE.

Year	Irrigated-nonirrigated yield difference (bu./acre)	Difference in dry days Nonirrigated-irrigated	Yield decrease (bu./acre) per dry day increase
1952	22	42	0.52
1953	51	112	0.46
1954	25	60	0.42
1955	64	94	0.68
Average			0.52

considered as only preliminary, it is believed that the results do give a measure of the yield reduction which occurs in sandy soils because of shortages of water.

Soybeans

Soybean yield summaries for 1952 through 1954 are given in table 15. A summary of the irrigation treatments is given in table 6.

1952. Preliminary studies on soybeans were started in 1952 by irrigating two strips each 40 by 150 feet in a soybean field. Thus, the plots were all planted at the same rate, and no fertilizer was applied. They were irrigated with three 1½-inch applications on July 7, July 12 and Aug. 1.

The irrigated strips were apparent by the increased height and fullness of the plants during much of the growing season. Eight 2-row plots each 13.1 feet long were harvested. The average yield of the nonirrigated plots was 29.3 bushels per acre compared with 42.9 bushels per acre for the irrigated plots. The increase due to irrigation was 13.6 bushels per acre.

1953 and 1954. In 1953 and 1954 four soybean varieties with time of maturation ranging from the early maturing Hawkeye to the late maturing Clark were planted with six replications. The plot size was one row, 16 feet long. Total irrigation applied was 7½ inches in 1953 and 9 inches in 1954. The last irrigation in 1953 was Aug. 17 and, in 1954, Aug. 12.

Average yield, protein content and oil content for 1953 and 1954 are shown in table 15. The early maturing varieties, Hawkeye and Adams, responded better to irrigation than did Lincoln and Clark. This difference may be due partly to discontinuance of irrigation in the middle of August. A statistical analysis of the yields showed a significant difference due to irrigation and to varieties at the 99-percent level in both years. The average increase for all varieties was 6.4 bushels per acre. In 1953 the low yields were probably due to the long period of high temperatures which appeared to adversely affect yields of soybeans even when irrigated.

Irrigated soybeans had slightly lower oil content and slightly higher protein content than beans grown without irrigation. Differences in protein content between irrigated and nonirrigated soybeans for all varieties were less in 1954 than in 1953.

DISCUSSION

Although the number of years of irrigation data is limited, the results appear to represent a wide range of climatic conditions. The two soils represent extremes in water-holding capacity. Therefore, interpolation of irrigation results on soils of intermediate texture may be

TABLE 15. SOYBEAN YIELDS AT SOUTHEASTERN IOWA EXPERIMENTAL FARM, CONESVILLE, 1952-54.

		Yield in bu. per acre				Not irrigated		Irrigated	
Variety	Year	Not irrigated	Irrigated	Increase due to irrigation	Average increase	Percent protein*	Percent oil*	Percent protein*	Percent oil*
Hawkeye	1953	10.8	14.2	3.4		43.3	19.1	46.2	18.0
	1954	20.2	32.9	12.7	8.1	39.0	22.7	40.6	24.1
Adams	1952	29.3	42.9	13.6		—	—	—	—
	1953	12.8	15.8	3.0	8.7	40.3	21.6	43.4	20.1
	1954	21.9	31.5	9.6		40.6	22.5	40.2	22.5
Lincoln	1953	8.8	9.0	0.2		43.5	19.0	45.2	17.2
	1954	28.5	36.6	8.1	4.2	40.3	22.8	40.0	22.4
Clark	1953	8.4	8.1	—0.3	3.8	44.8	17.4	47.8	15.1
	1954	32.0	39.9	7.9		41.0	22.9	40.4	22.5
Average all varieties		19.2	25.7	6.4		41.6	21.0	43.0	20.2

* Chemical analysis by staff of U. S. Regional Soybean Laboratory, Urbana, Illinois.

made with considerable confidence. Maximum response should normally be expected from sandy soils since they have the lowest water-holding capacity and cannot carry the crop through a drouth period as well as a medium- or fine-textured soil.

The results at Ankeny with corn planted on ridges may raise the question as to the applicability of these results to surface-planted corn. Yields at Ames, with ridge-planted corn on Clarion-Webster soil, averaged 4.5 bushels per acre less than surface-planted corn. These yields are for 1952-54 and were reported by Buchele, Collins and Lovely.[8] One of the major advantages of ridge-planting on sloping land is the saving in soil and water. Because of reduced erosion, the long-time effects may diminish the reduction in yields. Also the response to irrigation is likely to be less on ridge-planted corn because of greater moisture conservation and less need for additional water.

Although the data presented on the effect of climate on corn yields show considerable merit, the relative importance of rainfall and high temperatures could not be evaluated. Soil moisture deficiency should logically be a better measure of crop yields than rainfall. The water balance procedure was developed only for 4 years of data at Conesville and should be considered as a preliminary study. Further modification and checking are necessary before it can be used extensively. Continuous soil moisture records and long-time yields are needed for this purpose. Such records would provide a basis for establishing the recurrence of moisture deficiency and make possible better estimates of long-time responses to irrigation. This information along with unit costs and crop prices would facilitate the economic evaluation of irrigation.

Although actual yields of soybeans were not increased as much as those of corn, the percentage increase for the early varieties was as much as 40 to 50 percent for the 3 years. The yield response (Hawkeye and Adams) due to irrigation in 1952 and 1954, years of near-normal rainfall (May through August), was three to four times greater than in 1953. The lack of response in 1953 may have been caused by the hot, dry period after the last irrigation on Aug. 17. Continued irrigation later in the season might have increased the response to irrigation in all 3 years, particularly for the late-maturing varieties. Soybean response to irrigation should be interpreted with caution since data were obtained only on sandy soil and for a period of only 3 years.

[8] W. F. Buchele, E. V. Collins and W. G. Lovely. Ridge farming for soil and water control. Agr. Eng. 36:324-329, 331. 1955.

SUMMARY AND CONCLUSIONS

This study includes the results of 2 years of irrigation on corn at the Ankeny Field Station (1954-55), 5 years of irrigation on corn at the Southeastern Iowa Experimental Farm near Conesville (1951-55) and 3 years of irrigation on soybeans at Conesville (1952-54). The Nicollet loam soil at Ankeny has a high water-holding capacity while the soil at Conesville is Thurman loamy sand with a low water-holding capacity.

A comparison of the best nonirrigated corn yields with the best irrigated yields is shown in table 16. At Conesville the average response to irrigation for the 5-year period was 34.3 bushels per acre, while at Ankeny it was 21.1 bushels per acre. At Conesville moderate yields and lack of response to irrigation in 1951 probably were due to a cool, wet season, low stands and a possible shortage of some plant nutrients. A summary of the response to irrigation and nitrogen at different stands is given in table 11 for Conesville. Figure 7 shows the average yields for the years 1952 through 1955. A comparison of the yields for given stand and fertility levels at Ankeny is given in tables 2 to 5 and fig. 3.

TABLE 16. COMPARISON OF THE BEST NONIRRIGATED CORN YIELDS WITH THE BEST IRRIGATED YIELDS FROM EXPERIMENTAL PLOTS, 1951-55.

	Best nonirrigated			Best irrigated			Difference due to irrigation		
Year	Stand plants/acre	N lbs./acre	Yield bu./acre	Stand plants/acre	N lbs./acre	Yield bu./acre	N lbs./acre	Yield bu./acre	Irrigation amount inches
				Conesville					
1951	13,300	120	85.0	13,300	120	75.6	0	-9.4	10.0
1952	13,600	60	95.4	16,600	180	130.8	120	35.4	6.5
1953	11,100	80	63.8	14,500	240	113.7	160	49.9	7.5
1954	16,000	80	89.3	16,000	80	113.7	0	24.4	9.0
1955	18,000	80	38.8	13,100	160	110.2	80	71.4	11.0
Average			74.5			108.8		34.3	8.8
				Ankeny					
1954	21,900	160	73.3	16,100	160	87.8	0	14.5	4.0
1955	12,000	120	87.2	12,300	120	114.8	0	27.6	11.0
Average			80.2			101.3		21.1	7.5

The data indicate that for maximum yields on irrigated land higher stand and fertility levels are needed than on nonirrigated land.

It should be noted that maximum corn yields under irrigation were not extremely high, averaging only slightly over 100 bushels per acre. The cause of this relatively low ceiling on corn yields under irrigation is not clearly understood at present. Maximum nonirrigated yields varied from 39 to 95 bushels on the Conesville farm, but, even with irrigation and fertilization, maximum corn yields varied as much as 25 percent over the 5-year period. To explain these yield fluctuations and to better understand the causes of the relatively low top yields, various climatic studies were made. These studies indicate that the total rainfall from May through August is not a good indication of yields without irrigation.

The number of days with temperatures of 90° F. or above during this 4-month period appeared to be closely related to yield for both irrigated and nonirrigated corn. For 1952 through 1955 at Conesville, a soil moisture balance was computed each year by using pan evaporation records to estimate evapo-transpiration. When the soil moisture was depleted to 50 percent or less of that available in the root zone, the day was called a "dry day." The number of dry days throughout the growing season gave a good indication of irrigated and nonirrigated corn yields. These calculations, while too limited to permit definite conclusions, indicate that corn yields even on the irrigated plots are affected by climatic conditions. The correlation between yields under irrigation and number of days with temperatures of 90° F. or above, however, indicates that yields may be limited by high temperatures regardless of the soil moisture supply.

The response of corn to irrigation in both 1954 and 1955 at Ankeny should be noted. In 1954 rainfall was above normal for the entire season, but, even under these conditions of abnormal rainfall on a soil that has a high water-holding capacity, it was possible to increase yields slightly with irrigation.

Response of corn to irrigation was studied on both high and low water-holding capacity soils under rainfall conditions that ranged from 58 percent to 110 percent of normal. It therefore appears that the findings, limited as they are, can be used with some confidence in predicting the probable response of corn to irrigation in Iowa.

It appears probable that some increase in corn yields can be expected in most well-drained soils in most years. The magnitude of the response will be greater on sandy soils than on medium to heavy textured soils.

At Conesville the average yield increase for soybeans due to irrigation was 8.1 and 8.7 bushels per acre for Hawkeye and Adams varieties, respectively. Compared with the yields from nonirrigated plots this is an increase of about 40-50 percent. The irrigated soybeans averaged 4 percent lower in oil and 3.3 percent higher in protein than the nonirrigated soybeans.

APPENDIX

TABLE A-1. CORN YIELDS AT ANKENY FIELD STATION WITH SELECTED STANDS IN STALKS PER ACRE AND YIELDS IN BUSHELS PER ACRE.

Nitrogen lbs./acre	Replicate A		Replicate B		Replicate C		Replicate D		Average	
	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Not irrigated 1954 (2nd year corn)										
0	9,541	35.5	11,616	27.8	12,031	26.3	10,994	45.0	11,045	33.6
160	7,882	44.4	10,371	29.4	12,031	58.6	14,520	82.3	11,201	53.7
0	17,216	40.5	16,179	49.5	16,387	20.0	13,482	52.0	15,816	40.5
160	14,105	74.0	17,216	86.7	15,764	34.5	13,275	77.2	15,090	68.1
0	18,876	44.6	24,891	25.9	22,402	20.5	22,195	42.5	22,091	33.4
160	17,216	67.3	23,024	70.4	21,572	80.8	25,721	74.8	21,883	73.3
Irrigated 1954 (2nd year corn)										
0	10,371	45.2	12,238	48.7	13,482	48.8	12,860	55.4	12,237	49.5
160	12,031	86.2	13,275	83.0	12,446	85.4	13,690	83.5	12,860	84.5
0	16,387	55.4	14,520	50.2	16,179	34.8	15,764	51.5	15,712	48.0
160	16,387	92.1	17,216	89.5	15,972	91.6	14,727	78.1	16,075	87.8
0	22,817	26.7	21,365	22.4	21,780	21.2	25,721	33.9	22,921	26.0
160	21,780	82.4	16,386	74.6	20,950	91.6	21,572	73.8	20,172	80.6
Not irrigated 1955 (3rd year corn)										
60	11,979	85.9	12,197	74.4	10,672	88.1	11,761	80.1	11,652	82.1
120	12,632	77.6	12,415	94.8	11,108	89.5	11,761	86.8	11,972	87.2
60	16,335	62.0	18,295	79.8	16,335	51.5	17,860	50.3	17,206	60.9
120	16,771	56.7	16,988	88.5	16,553	71.6	16,771	59.4	16,771	69.1
60	23,305	59.1	19,384	58.6	17,206	54.7	19,384	36.9	19,820	52.3
120	19,602	58.3	19,384	68.5	16,771	57.6	19,602	45.2	18,840	57.4
Irrigated 1955 (3rd year corn)										
60	11,761	108.4	11,543	102.7	11,761	95.4	12,197	91.5	11,816	99.5
120	12,415	115.2	11,979	100.0	12,197	123.7	12,415	120.2	12,252	114.8
60	15,246	120.2	17,424	117.3	18.077	116.6	15,682	103.9	16,607	114.5
120	14,593	123.2	18,513	110.7	16,335	104.2	14,810	112.7	16,063	112.7
60	20,473	119.3	20,473	108.2	17,424	112.1	16,335	93.0	18,676	108.1
120	20,691	129.9	22,651	121.7	18,949	90.6	19,602	103.8	20,473	111.5

TABLE A-2. CORN YIELDS AT SOUTHEASTERN IOWA EXPERIMENTAL FARM, CONESVILLE, WITH SELECTED STANDS IN STALKS PER ACRE AND YIELDS IN BUSHELS PER ACRE.

Nitrogen lbs./acre	Replicate A		Replicate B		Replicate C		Replicate D		Average	
	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Not irrigated (1951)										
0	6,970	32.5							6,970	32.5
40	7,405	56.3							7,405	56.3
80	7,623	46.0							7,623	46.0
120	6,098	47.2							6,098	47.2
0	13,286	36.1							13,286	36.1
40	13,286	56.8							13,286	56.8
80	13,286	76.1							13,286	76.1
120	13,286	85.0							13,286	85.0
Irrigated (1951)										
0	6,752	24.8	6,316	25.2					6,534	25.0
40	6,752	32.2	6,752	35.4					6,752	33.8
80	6,316	46.0	6,752	48.0					6,534	47.0
120	6,534	51.0	7,187	44.7					6,861	47.9
0	11,543	21.4	13,504	18.3					12,524	19.9
40	14,593	57.6	14,157	41.1					14,375	49.4
80	13,504	78.5	13,721	66.0					13,613	72.3
120	12,414	76.6	13,286	74.6					12,350	75.6
Not irrigated (1952)										
60	10,454	90.0	9,801	82.7	8,930	84.6	10,890	85.9	10,019	85.8
120	12,415	95.1	9,148	79.8	9,801	87.8	8,712	78.5	10,019	85.3
180	13,286	106.8	10,454	94.8	10,672	88.4	10,019	89.0	11,108	94.8
60	14,375	91.9	12,850	98.3	13,939	112.3	13,286	79.2	13,612	95.4
120	15,028	89.0	13,068	97.9	13,504	103.7	13,286	86.5	13,722	94.3
180	13,286	91.6	15,899	106.5	13,286	90.6	13,068	87.1	13,885	94.0
60	15,028	81.4	13,939	74.4	17,206	81.7	16,988	85.2	15,790	80.7
120	18,513	91.9	16,988	80.8	17,424	78.5	19,384	89.4	18,077	85.2
180	16,771	92.9	15,899	74.4	16,335	94.4	15,899	82.7	16,224	86.1
Irrigated (1952)										
60	8,712	79.8	10,237	102.4	9,148	60.4	8,494	72.8	9,148	78.8
120	7,841	86.8	10,019	109.1	10,454	103.7	10,672	114.2	9,746	103.4
180	9,147	99.9	9,148	104.6	10,672	113.8	10,454	113.5	9,855	108.0
60	12,632	121.2	11,326	98.6	13,068	89.7	12,197	109.4	12,306	104.7
120	13,286	110.0	13,721	93.5	13,939	118.0	13,068	130.7	13,504	113.0
180	14,375	119.3	14,593	122.7	11,979	112.6	13,286	125.9	13,548	120.1
60	13,286	77.9	16,553	136.4	16,335	118.6	15,899	116.4	15,518	112.4
120	16,117	98.3	18,295	132.6	17,424	122.1	17,642	135.5	17,370	122.1
180	16,117	122.4	17,206	132.3	16,335	135.5	16,771	133.2	16,606	130.8
Not irrigated (1953)										
0	10,237	39.3	11,543	52.5	10,454	50.5	11,326	60.6	10,890	50.7
80	11,326	60.3	11,108	60.3	11,545	67.7	10,454	66.7	11,108	63.8
80	13,721	52.3	13,939	68.2	13,939	58.3	14,593	63.9	14,048	60.7
160	14,157	69.5	13,939	38.4	15,246	56.9	14,375	46.3	14,429	52.8
240	15,682	21.9	13,286	42.2	12,850	61.6	13,939	62.5	13,939	47.1
80	18,077	25.4	16,553	29.8	17,642	40.0	17,860	57.7	17,533	38.2
160	15,246	15.4	17,424	45.6	19,820	45.0	19,602	52.0	18,023	39.5
240	17,424	5.7	18,077	56.6	16,335	32.7	18,077	56.9	17,478	29.8
160	21,344	0.3	20,691	60.6	20,691	44.4	20,691	50.4	20,854	38.9
240	19,602	1.0	21,998	33.8	20,038	37.4	20,691	51.6	20,582	30.9
Irrigated (1953)										
0	10,672	99.0	11,543	85.2	10,454	96.2	10,454	85.8	10,781	91.6
80	13,068	120.1	10,890	106.4	11,108	104.5	10,019	102.1	11,271	108.3
80	14,593	118.5	14,375	102.7	13,504	95.2	13,504	115.1	13,994	107.9
160	14,810	129.3	14,810	121.5	13,504	65.1	14,157	111.8	14,320	106.9
240	14,157	123.9	14,593	129.0	14,464	111.8	13,939	90.1	14,538	113.7
80	19,166	118.2	16,771	71.3	19,166	106.7	18,731	115.4	18,459	102.9
160	17,206	103.5	18,295	82.4	18,949	99.4	18,513	123.4	18,241	102.2
240	18,513	117.2	17,206	74.2	18,731	116.5	18,077	104.8	18,132	103.2
160	20,255	127.1	18,295	64.3	20,691	119.4	21,344	86.9	20,146	99.4
240	21,998	100.9	22,651	95.5	23,087	70.7	20,473	100.9	22,052	92.0
Not irrigated (1954)										
0	12,197	81.3	11,543	96.4	10,454	80.8	11,325	91.2	11,380	87.4
80	11,107	97.9	12,414	88.7	12,197	83.1	9,148	84.1	11,217	88.4
160	11,979	93.3	11,979	78.3	10,237	82.4	10,890	84.5	11,271	84.6
0	15,464	94.2	16,335	88.5	13,721	68.2	16,335	78.6	15,464	77.4
80	15,682	85.0	16,117	104.6	16,117	85.4	17,424	82.4	16,335	89.3
160	14,810	82.3	15,464	98.8	16,553	75.2	17,424	89.4	16,063	86.4
Irrigated at silking time only (1954)										
0	10,672	74.1	11,326	99.6	9,365	72.8	11,543	83.4	10,727	82.5
80	10,019	100.2	11,326	84.4	10,890	79.4	9,801	87.3	10,509	87.8
160	10,237	92.5	10,890	89.3	11,326	77.3	10,890	85.6	10,836	86.2
0	15,028	101.2	15,682	68.2	13,068	79.4	15,899	106.8	14,919	88.9
80	16,335	118.8	16,988	83.6	16,988	84.7	16,553	89.0	16,716	94.0
160	13,721	101.6	15,682	78.0	16,335	78.7	15,028	82.7	15,192	85.2
Full season irrigation (1954)										
0	11,979	102.6	10,672	85.8	11,543	81.1	11,979	103.1	11,543	93.9
80	11,543	119.4	11,593	105.1	11,761	112.4	11,761	115.2	11,652	113.0
160	12,632	120.8	11,979	101.8	11,543	101.9	12,197	112.4	12,088	109.2
0	17,860	125.3	15,899	35.7	16,988	76.1	16,335	92.7	16,770	82.4
80	17,642	124.0	16,988	109.3	17,206	99.2	17,642	122.3	17,369	113.7
160	16,553	121.9	16,553	109.0	17,206	84.1	16,988	137.6	16,825	113.1

TABLE A-2 (Continued)

Nitrogen lbs./acre	Replicate A		Replicate B		Replicate C		Replicate D		Average	
	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand	Yield
Not irrigated (1955)										
0	13,068	29.3	14,810	12.4	12,850	18.9	12,632	25.9	13,340	21.6
80	16,117	43.0	14,810	33.5	14,810	15.3	12,197	62.2	14,484	38.5
160	12,632	51.4	14,374	35.2	13,068	21.5	12,197	41.5	13,068	37.4
0	8,712	11.3	20,037	13.5	15,898	20.7	17,420	7.3	15,518	13.2
80	17,859	38.0	18,513	60.3	17,637	38.0	17,855	19.1	17,966	38.8
160	19,602	28.8	16,335	39.7	18,289	19.6	16,116	10.5	17,586	24.6
0	25,047	2.7	24,829	10.0	23,305	1.8	22,638	2.1	23,955	4.2
80	23,958	6.5	21,126	29.5	26,572	0.3	20,464	8.9	23,040	11.3
160	25,918	24.5	23,740	19.1	22,203	1.7	23,522	8.2	23,846	13.4
Irrigated at silking time only (1955)										
0	11,543	19.4	14,810	28.8	13,068	16.0	12,415	28.0	12,959	23.0
80	11,979	47.8	13,939	50.5	14,810	31.9	11,326	46.4	13,014	44.2
160	11,108	61.6	13,285	52.2	13,068	35.1	13,721	73.3	12,796	55.6
0	19,602	13.9	17,206	17.7	15,246	12.8	14,810	12.9	16,716	14.3
80	16,988	50.2	18,077	39.3	18,077	24.2	16,985	26.6	17,532	35.1
160	13,285	45.9	13,285	24.6	18,941	21.9	17,637	22.2	15,787	28.6
0	22,869	8.9	28,532	2.3	23,305	14.5	25,047	5.1	24,938	7.7
80	18,949	50.3	26,136	4.1	25,047	13.5	22,638	8.3	23,192	19.0
160	21,562	57.4	27,225	18.9	23,740	42.1	22,855	10.7	23,846	32.3
Full season irrigation (1955)										
0	10,672	49.6	12,414	35.8	13,285	31.0	11,979	40.9	12,088	39.3
80	12,850	102.3	13,286	94.1	11,979	84.0	11,979	87.6	12,524	92.0
160	12,632	112.4	12,850	135.4	13,285	92.3	13,504	100.7	13,068	110.2
0	15,028	33.3	18,730	27.1	18,289	26.0	16,550	35.2	17,149	30.4
80	15,899	123.2	14,810	78.1	15,028	91.3	18,941	91.8	16,170	96.1
160	15,463	111.1	17,859	132.7	17,420	92.9	13,721	94.4	16,116	107.8
0	19,602	30.6	25,482	9.5	19,594	13.9	24,829	18.0	22,377	18.0
80	25,047	118.4	23,304	68.8	15,680	108.8	27,878	83.9	22,909	95.0
160	20,473	117.3	22,433	92.4	16,116	111.5	18,507	101.6	19,382	105.7