Yield Response of Corn in a Planosol Soil to Subsurface Drainage With Variable Tile Spacings

by C. E. Beer, H. P. Johnson and W. D. Shrader

Department of Agricultural Engineering

Department of Agronomy

AGRICULTURAL AND HOME ECONOMICS EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology

Research Bulletin 540 . . . September 1965 . . . Ames, Iowa

CONTENTS

Yield Response of Corn in a Planosol Soil to Subsurface Drainage With Variable Tile Spacings[1]

by C. E. Beer, H. P. Johnson and W. D. Shrader[2]

The Edina soil series of southeastern Iowa and northern Missouri are soils of relatively flat topography and poor internal drainage. The need for research data on the feasibility of drainage (both surface and subsurface) on the Edina soils was recognized at the time experiments were begun on the Southern Iowa Experimental Farm, Davis County, Iowa. The yield response of corn to surface drainage by bedding was summarized and reported by Beer et al.[3] in 1961. Since initiation of the subsurface drainage experiment in 1949, data on crop-yield response to tile drainage have been collected. The purpose of this bulletin is to present the results of this study as related to the effects of tile drainage on crop yields, with the emphasis on corn, during the period of record. The nature of tile discharge during the growing seasons from 1951 to 1963 also is presented.

Soil Characteristics

The soil at the Southern Iowa Experimental Farm is Edina silt loam, an argipan planosol or claypan soil which developed from about 70 inches of weathered loess on level topography under a tall-grass, prairie vegetation.

The upper 7 to 9 inches of the soil is a brownish-gray, moderately friable silt loam with a weakly developed medium-granular structure. The subsurface or A_2 horizon is a gray "ashy" silt loam horizon with a weakly developed platy structure. At a depth of about 18 inches, the subsurface is underlaid by a dense, plastic, mottled gray and olive-brown clay subsoil. Although the transition from the "ashy" subsurface to the claypan subsoil is abrupt, the zone of maximum clay accumulation is usually at the 30-inch depth. Below this depth, the soil becomes slightly less plastic with increasing depth and grades into the weathered and leached silt loam parent material at a depth of about 50 inches.

The physical properties of the soil on the Southern Iowa Experimental Farm were reported in 1957 by Schwab et al.[4] Their results show that the aeration porosity varies from 11.6 percent in the surface 6 inches to 0.14 percent in the lower portion of the B horizon at a depth of about 4 feet. A mechanical analysis shows that a heavy soil stratum between 24 and 29 inches below the surface contains 54.6 percent clay, based on the United States Department of Agriculture classification.

Design and History of Experiment

The subsurface drainage experiment was originally designed as a randomized block experiment with three replicates of three tile spacings of 15, 30 and 60 feet. A cropping system of corn-oats-meadow[5] was begun in 1949 and continued until 1956. A layout is shown in part A of fig. 1. The experiment was modified in 1956 to include a greater variety of crops. The original three, 80-foot wide strips were reduced to 40 feet as shown in part B of fig. 1 to include the additional crops of continuous corn, continuous soybeans and permanent meadow. The modification of the experiment enabled accumulation of data for continuous corn—a practice being increasingly accepted by farmers. Modifying the experiment also permitted evaluation of the returns from commercial nitrogen applied to crops on tiled land.

The corn in the COM rotation received 100 pounds of starter fertilizer per acre. The analysis was 0-20-20, and the numbers refer to percentage N, P_2O_5 and K_2O, respectively. In elemental form, this represents 0, 8.8 and 16.6 pounds of N, P and K, respectively. The continuous corn received the same starter in addition to 100 pounds per acre of actual nitrogen.

Since 1956, the experiment has continued without further modification. The corn was sampled for yields by husking 2 rows, 60 feet long. Thus, each sample

[1] Project 1003 of the Iowa Agricultural and Home Economics Experiment Station.

[2] Acknowledgement of assistance is made to William Sutherland and Raymond Nicholson.

[3] C. E. Beer, H. T. David and W. D. Shrader. Response of corn yields in a planosol soil to surface drainage, cropping system and variable fertilizer treatments. Iowa Agr. and Home Econ. Exp. Sta. Res. Bul. 499. 1961.

[4] G. O. Schwab, D. Kirkham and H. P. Johnson. Effect of tile spacing on crop yield and water table level in a planosol soil. Soil Sci. Soc. Amer. Proc. 21:448-452. 1957.

[5] Corn, oats and meadow will be abbreviated to COM in further discussion. Likewise, rotation corn yields refer to the corn in the COM rotation.

C. E. BEER is associate professor and H. P. JOHNSON is professor of agricultural engineering; W. D. SHRADER is professor of agronomy.

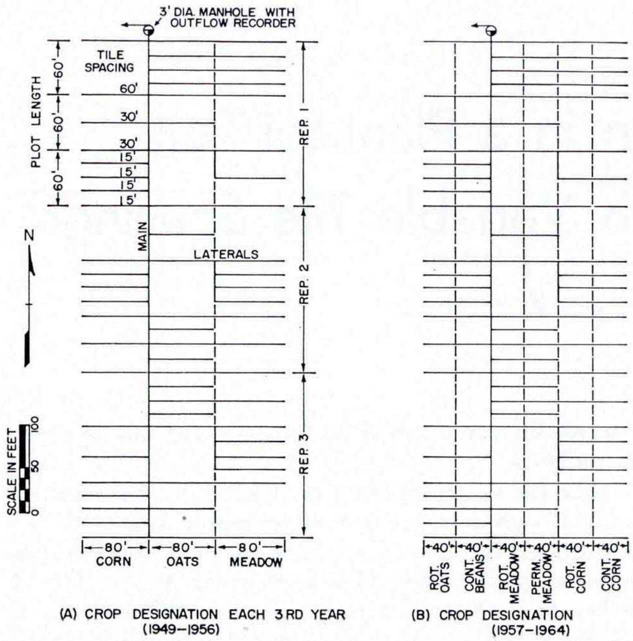

Fig. 1. Schematic of original and modified tile-spacing experiment, Southern Iowa Experimental Farm.

tended to integrate the effects of drainage between tile lines. Tillage, planting and harvesting operations were conducted on all treatments at the same time. Thus, any possible benefits related to earlier planting that the closer tile spacing may provide were not measured.

Corn yields on land without subsurface drainage were not available from this experiment. However, the level land plots with no tile described in the bulletin by Beer et al.[6] were on the same soil type and located within 300 feet of the tile-spacing experiment. The fertilizer treatment for the rotation corn was the same for both experiments; therefore, a reasonable measure of corn yield response for tile versus no tile was available for rotation corn. The fertilizer treatments for continuous corn were not the same in both experiments. Two fertilizer treatments (pounds per acre) for continuous corn on the level land plots with no tile were (a) 60 pounds N, 80 pounds P_2O_5 and 20 pounds K_2O and (b) 120 pounds N, 80 pounds P_2O_5 and 20 pounds K_2O. By interpolating, an estimate of corn yields on undrained land for 100 pounds N may be obtained. Thus, a comparison between yields for continuous corn with and without tile may be made at the 100-pound N level.

RESULTS

All individual plot yields of the crops are presented in the Appendix. The statistical analyses of the corn yield results were divided into three main categories:

(1) rotation corn for 1950 through 1964,
(2) continuous corn for 1957 through 1964, and
(3) combined continuous corn and rotation corn for 1957 through 1964.

The results are presented by showing both the statistical analysis of variance and a graph of the average yields *for each category. Figure 2 shows the average yields* of the three replicates by years for both the 60-foot and 15-foot tile spacings on rotation corn. Several trends are evident from the graph. The year-to-year fluctuation of yields is quite pronounced and is independent of the tile spacing; i.e., the two curves representing yields for both tile spacings tend to remain parallel throughout the period of record. The 15-year averages for the 15-foot and 60-foot spacings are 99 bu./A. and 93 bu./A., respectively.

The trends shown in fig. 2 are further supported by an analysis of variance of the data. Table 1 shows that, when 15 years of data are analyzed as a group, the 6 bu./A. advantage associated with the 15-foot spacing is significant. There is no spacing-year interaction, as illustrated by the relative parallelism of the two curves. Since a different area of ground was planted to corn within the 3-year series of corn, oats and meadow, it was desirable to examine the portion of variance for replicates within series. Table 1 shows this to be negligible, which further justifies an analysis in which the data are pooled for the period of record, even though the corn is rotated on three different tracts of land within a 3-year period (series).

Figure 3 presents the average yearly yields for continuous corn. The pattern of the year-to-year variation is similar to that for rotation corn; i.e., a large year-to-year variation in yields, with the curves remaining relatively parallel. The 8-year average yields for the 15-foot and 60-foot spacings are 106 bu./A. and 102 bu./A., respectively.

The analysis of variance for continuous corn was made with a model in which years of record were considered as subplots of a split-plot arrangement. Table 2 shows that neither spacing nor its interaction with years is significant. The main effect of years is highly significant, as would be expected from the large year-to-year fluctuations shown in fig. 3.

The comparison between rotation and continuous corn is shown in fig. 4 in terms of the increase in yield

Table 1. Analysis of variance summary for tile spacing on rotation corn.

Source	d.f.	M.S.[a]
C—Year effect	14	7836.68**
A within S—Replicates within series	6	52.61
B—Tile spacings	2	385.52**
BC	28	48.09
Pooled error	84	38.49
Total	134	

[a] Double asterisks indicate statistical significance at the 0.01 level.

[6] Op. cit., p. 328-329.

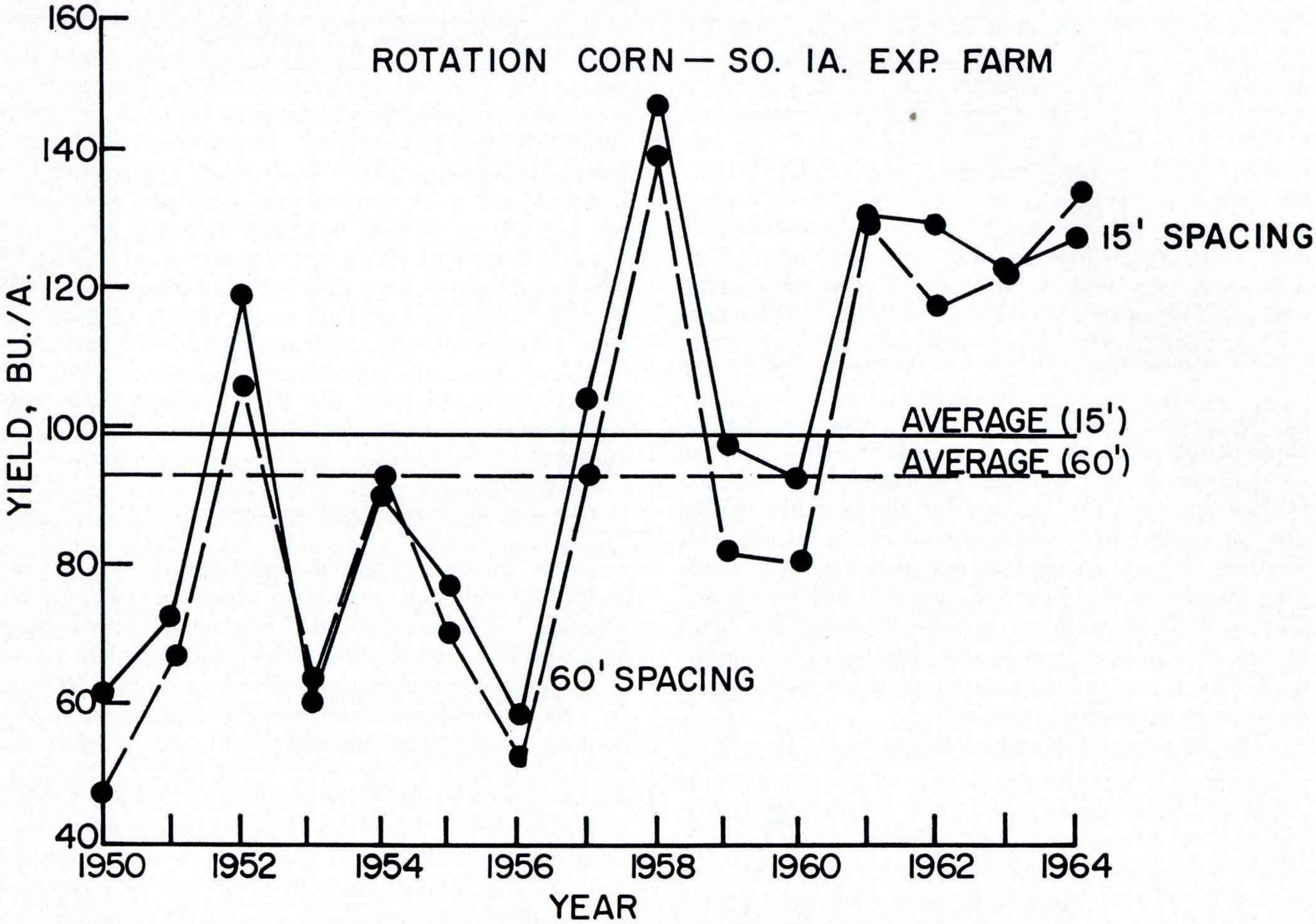

Fig. 2. Rotation corn yields on tile-spacing experiment, Southern Iowa Experimental Farm.

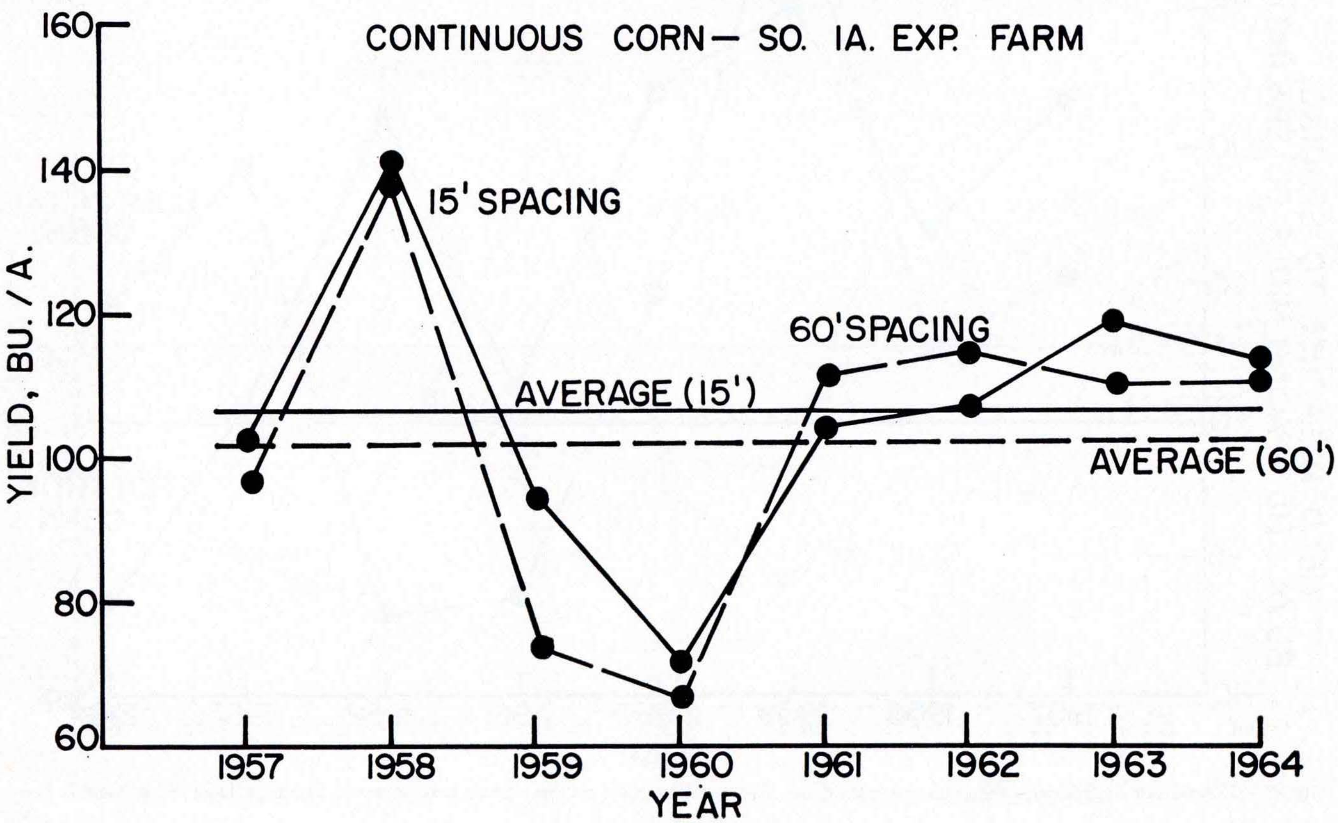

Fig. 3. Continuous corn yields on tile-spacing experiment, Southern Iowa Experimental Farm.

Table 2. Analysis of variance summary for tile spacings on continuous corn.

Source	d.f.	M.S.[a]	
A—Replicates	2	45.29	
B—Tile spacings	2	122.74	
AB—Error I	4	97.28	
C—Year effect	7	4437.56**	
BC	14	82.21	
AC } Error II	14	77.40	Pooled
ABC } Error II	28	43.31	54.67

[a] Double asterisks indicate statistical significance at the 0.01 level

of the 15-foot spacing over the 60-foot spacing. In three of the years, there was a negative effect; i.e., the yield of the 15-foot spacing was less than that of the 60-foot spacing. The reasons for the negative results are not evident from the operation of the experiment. Further, there is no obvious reason for the two cropping systems to give negative values in different years. The analysis of variance in table 3 shows the main effects of cropping system and spacing to be significant. This is because the rotation corn has shown more response to a closer tile spacing.

The crop-year interaction is shown by the divergence of the two curves in fig. 4 for the years 1962 and 1963. Although statistically significant there is no practical explanation for this interaction, and it may be a result of uncontrolled factors, such as plant stand or random and unmeasured disease or insect damage.

The legume-commercial nitrogen experiment on the Southern Iowa Experimental Farm was initiated in

Table 3. Analysis of variance summary for tile spacings for combined continuous and rotation corn.

Source	d.f.	M.S.[a]	
A—Replicates	2	52.47	
B—Tile spacings	2	374.82**	
E—Cropping system	1	4507.99**	
BE	2	15.27	
AB } Error I	4	43.09	
AE } Error I	2	12.67	Pooled
ABE } Error I	4	69.50	47.57
C—Year effect	7	8163.29**	
CE	7	242.50**	
BC	14	76.27	
BCE	14	56.01	
AC } Error II	14	58.39	
ACE } Error II	14	84.44	Pooled
ABC } Error II	28	37.97	51.82
ABCE } Error II	28	46.09	

[a] Double asterisks indicate statistical significance at the 0.01 level.

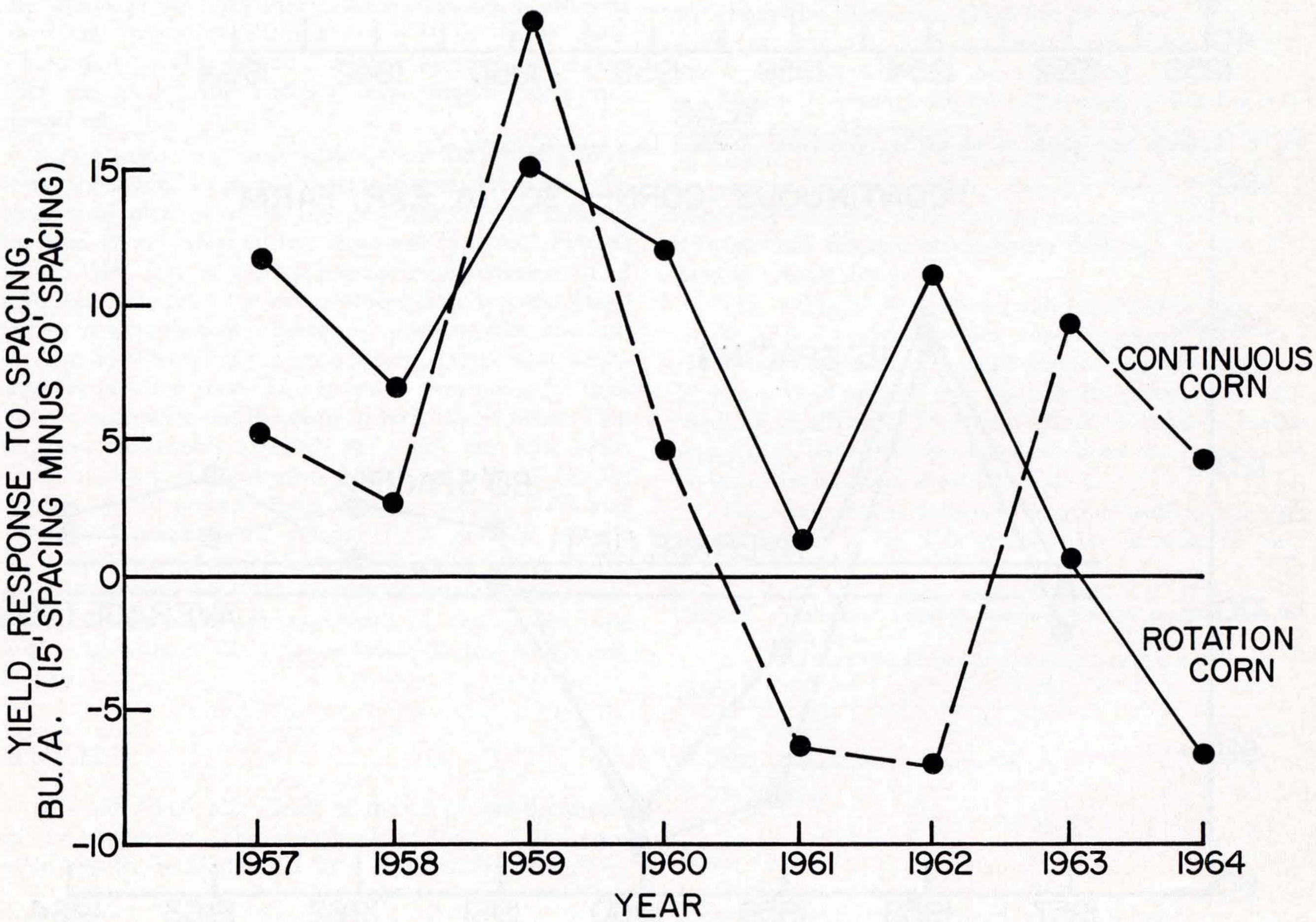

Fig. 4. Comparison of drainage response for continuous and rotation corn on the spacing experiment, Southern Iowa Experimental Farm.

1952. The plots were levelled with a land plane. No subsurface drainage was provided. Both rotation corn and continuous corn were grown on these plots; thus this experiment provides a basis for comparison between corn yields on land with tile drainage and land without tile drainage. Since the tile-spacing and the legume-commercial nitrogen experiments were not designed jointly, no rigorous statistical analysis is directly applicable. The yearly average yields from both experiments are plotted for rotation corn in fig. 5 and, for continuous corn, in fig. 6. As indicated previously, the commercial fertilizer application for the rotation corn was the same in both experiments. However, the continuous corn yield for 100 lbs. per A of nitrogen on the undrained area was obtained by linearly interpolating between the yields resulting from actual applications of 60 and 120 lbs. per A. of nitrogen. A corn-yield versus nitrogen response curve previously developed for these conditions shows that a straight-line interpolation would give a conservative yield estimate.

The general comparisons between the yields for tiled plots and undrained plots show that little response is obtained with continuous corn, whereas an average increase of 13 bu./A. is obtained with the rotation corn.

As is shown in table A-4 of the Appendix, hay yields have been greater on the tiled area than on the area without tile in 8 years of the 10-year period, 1954 through 1963. First-cutting hay yields averaged 1.56 tons per acre on the undrained (level) land as compared with 1.91 tons per acre for the 60-foot tile spacing.

While no specific measurements were made, observations indicated that there was a higher proportion of legumes in the hay removed from the tile-drained plots than in the hay removed from the plots without tile.

Since there was a greater yield of better-quality hay on the tile-drained land, it appears reasonable to assume that more nitrogen was furnished by the meadow to the corn crop that followed on the tiled land than to the corn on the land without tile. A portion of the 13-bushel difference in corn yield probably resulted from differences in nitrogen availability on the two sites.

Observations indicated that the poor meadow yield on the undrained plots resulted from frost heaving of the legumes. Frost heaving was less severe on the tile-drained plots, particularly near the tile. Therefore, through increased nitrogen fixation on the drained plots, drainage probably was directly or indirectly responsible for most of the 13-bushel difference in corn yield.

Oat yields have also been greater each year and have averaged 16 bu./A. more on the tiled plots than on the plots without tile. As with the other crops, it is impossible to determine how much of this yield difference has resulted from drainage differences, how much is due to differences inherent in the two sites and how much may be a residual effect of differences in nitrogen associated with different amounts and kinds of meadow. Oat yields have been consistently and appreciably greater on the tiled plots than on the neighboring undrained area. It is likely that a portion of this difference, directly or indirectly, resulted from drainage differences on the two areas.

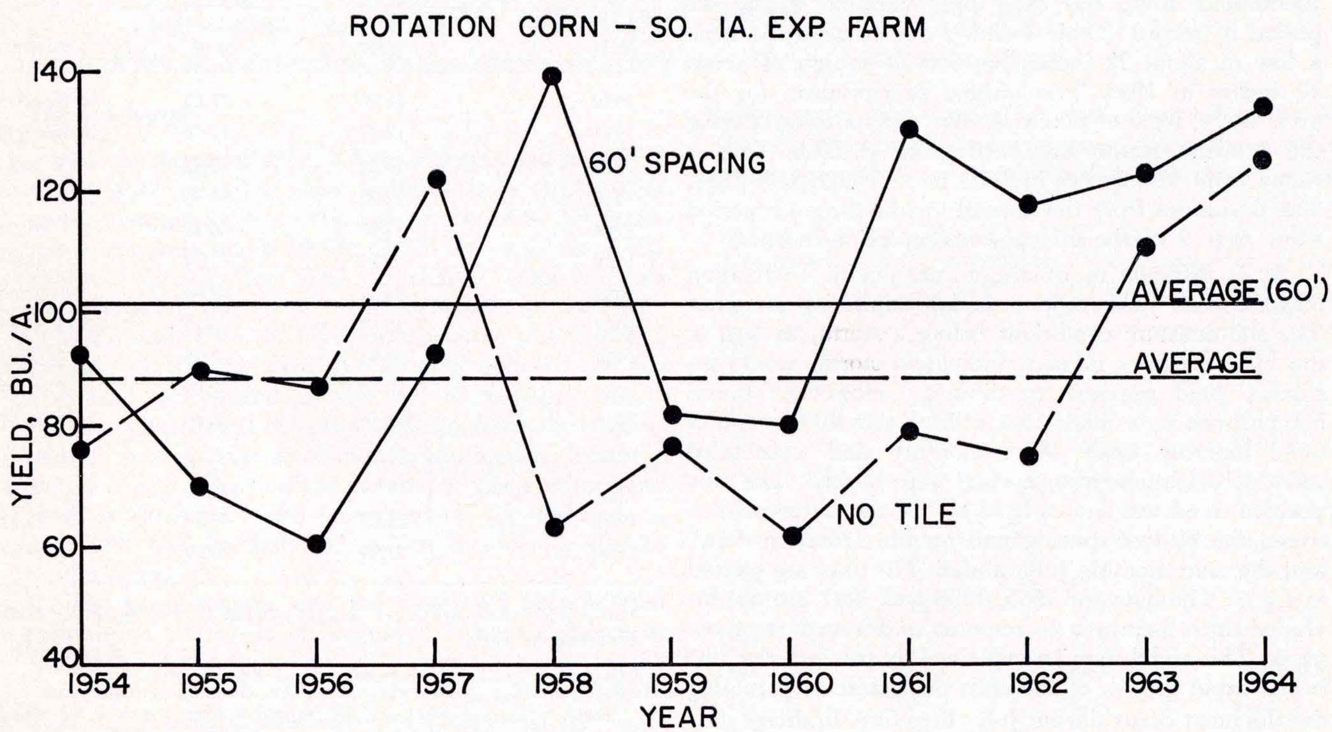

Fig. 5. Comparison of yields from 60-foot spacing with no tile for rotation corn, Southern Iowa Experimental Farm.

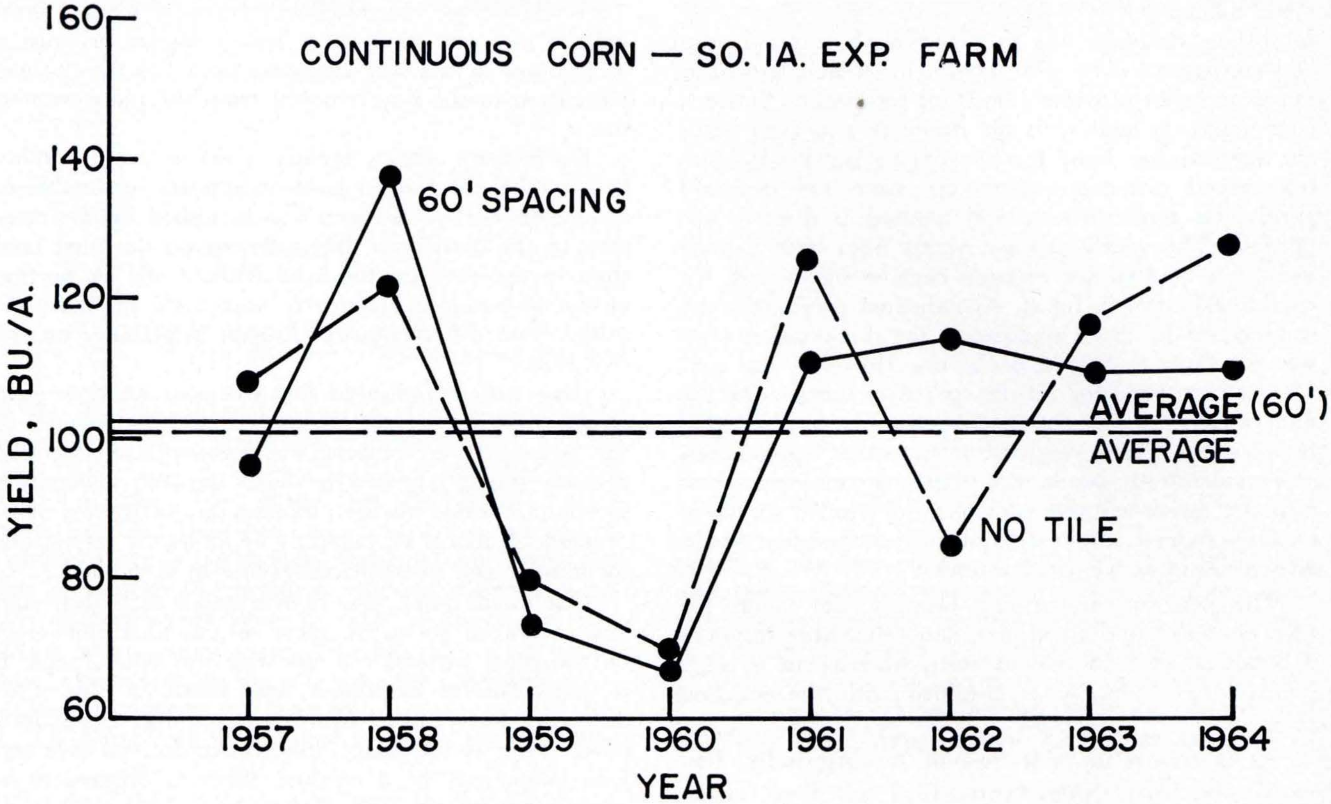

Fig. 6. Comparison of yields from 60-foot spacing with that estimated for no tile on continuous corn, Southern Iowa Experimental Farm.

Rainfall Characteristics

The average annual precipitation measured at Bloomfield, Iowa, has been quite variable during the period of record. Table 4 shows the range to be from a low of about 22 inches in 1956 to a high of about 42 inches in 1959. The normal precipitation for the area is 34 inches. Likewise, the precipitation during the growing season has been quite variable, with a range from 12.5 inches in 1953 to 35.9 inches in 1959. The deviations from the normal for the 6-month period show that 9 of the 15 values were below normal.

It is difficult to obtain a meaningful correlation between corn yield response and precipitation amounts. The soil-moisture conditions before a storm, as well as the characteristics of each individual storm, would influence yield response to drainage. However, several comparisons were made that utilized monthly or cumulated monthly totals. Also, monthly and cumulated monthly deviations from normal were plotted. The only positive trend was shown by a plot of the difference between the 60-foot spacing and no tile (rotation corn) and the total monthly July rainfall. The data are plotted in fig. 7. The data for 1955, 1956 and 1957 are not included since there was no response to drainage for those years. This trend may be explained by the fact that the initial rapid growth of the corn plant and deep rooting development occur during July; therefore, drainage may be most crucial during this period.

Table 4. Rainfall depths at Southern Iowa Experimental Farm.

Year	Depth, inches		
	April through Sept.[a]	Deviation from norm[b]	Yearly[c]
1950	25.90	+2.63	Incomplete
1951	18.27	+2.34	Incomplete
1952	15.25	−0.42	E 34.44
1953	12.52	−10.75	E 27.23
1954	22.59	−0.68	36.04
1955	19.53	−3.74	28.66
1956	14.87	−8.40	E 21.80
1957	20.64	−2.19	E 34.42
1958	30.90	+7.90	E 35.01
1959	35.90	+13.10	E 41.83
1960	27.30	+4.50	E 36.91
1961	23.10	+0.30	E 41.66
1962	18.19	−5.00	30.35
1963	15.58	−7.61	25.33
1964	22.89	−0.29	29.84

[a] Six-month totals are from gauge located at the Southern Iowa Experimental Farm.

[b] Deviations are for the 6-month period, April-Sept.

[c] Yearly totals are from the Bloomfield station located 7-8 miles from the Experimental Farm. The "E" indicates that some part of the year's record was estimated.

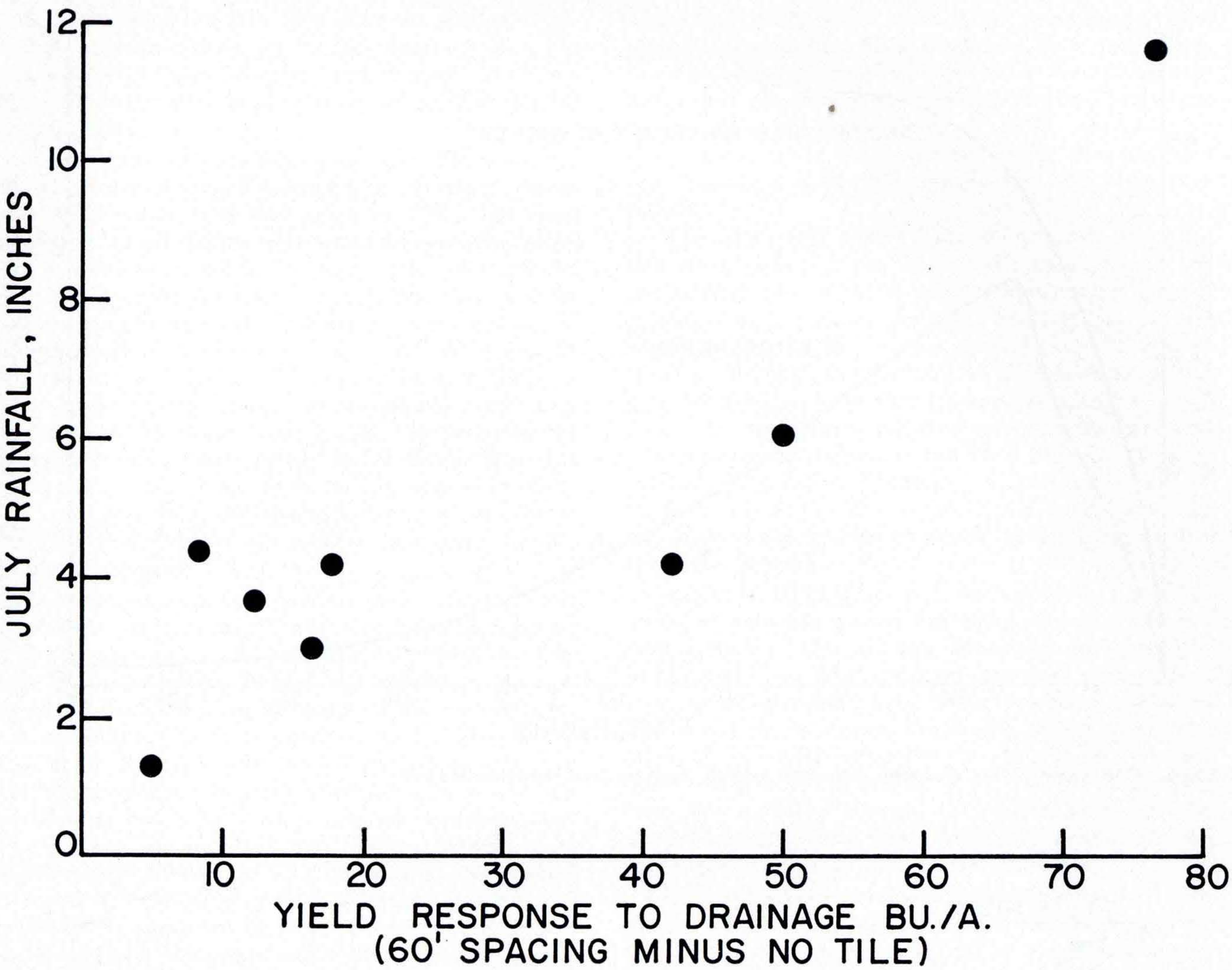

Fig. 7. Effect of July rainfall on drainage response for rotation corn, Southern Iowa Experimental Farm.

Tile Discharge

In the spring of 1951, a V-notch weir and an FW-1 water level recorder were installed in a 3-foot diameter manhole at the north edge of the plots. All drainage water collected in all tile within the experiment discharged through the weir. Discharge measurements were recorded during the growing season for the years 1951 through 1963. In 1956, no discharge was recorded because of the low rainfall. Detailed data on the tile discharge is presented in table A-5 of the Appendix.

The total depth of water drained from the experimental area and the maximum instantaneous discharge for each year are presented in table 5. The volumes and rates of discharge were computed on the basis of an area 280 feet by 580 feet, which includes a 20-foot border area.

The tile discharge and the associated accumulated rainfall for the storm of August 5, 1959, are shown in fig. 8. When the soil was moist, as in this case, the tile discharge increased very shortly after rainfall began. Very high rates of discharge were observed for short times during and immediately after rainfall occurred, while water was ponded in small depressions on the surface. Maximum discharge rates much above design drainage coefficients were recorded. However, the high

Table 5. Tile discharge during growing season.

	Total discharge	Maximum discharge rate	
Year	Inches	Inches/day	Date
1951	2.76	2.13	June 24
1952	1.65	1.48	June 20
1953	1.28	1.87	March 29
1954	0.95	1.78	Oct. 10
1955	0.22	0.36	May 12
1956	No discharge	....	......
1957	0.11	0.55	May 13
1958	3.14	3.54	July 28
1959	6.25	1.87	Aug. 5
1960	4.72	2.19	July 10
1961	1.42	0.97	April 25
1962	0.46	0.87	June 3
1963	0.03	0.11	May 15

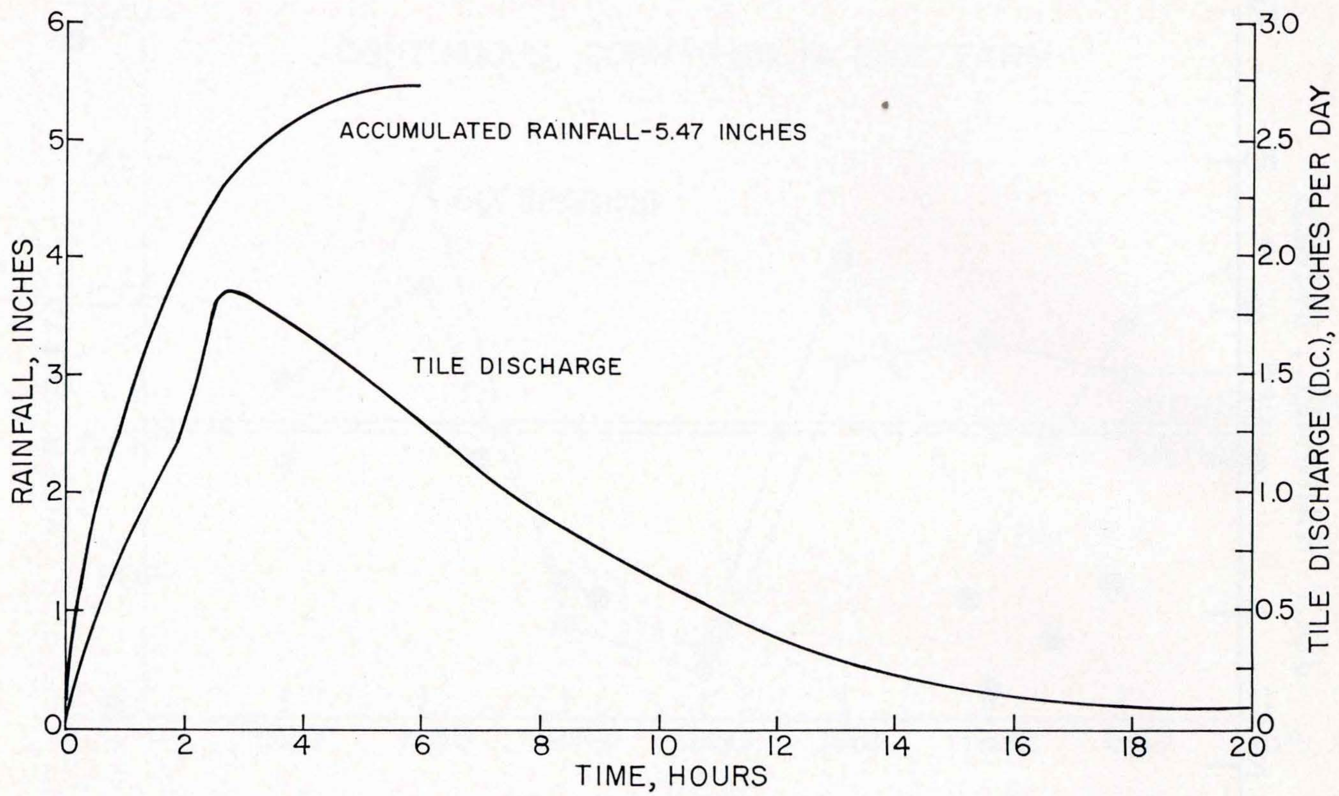

Fig. 8. Comparison of tile discharge and storm rainfall, Southern Iowa Experimental Farm.

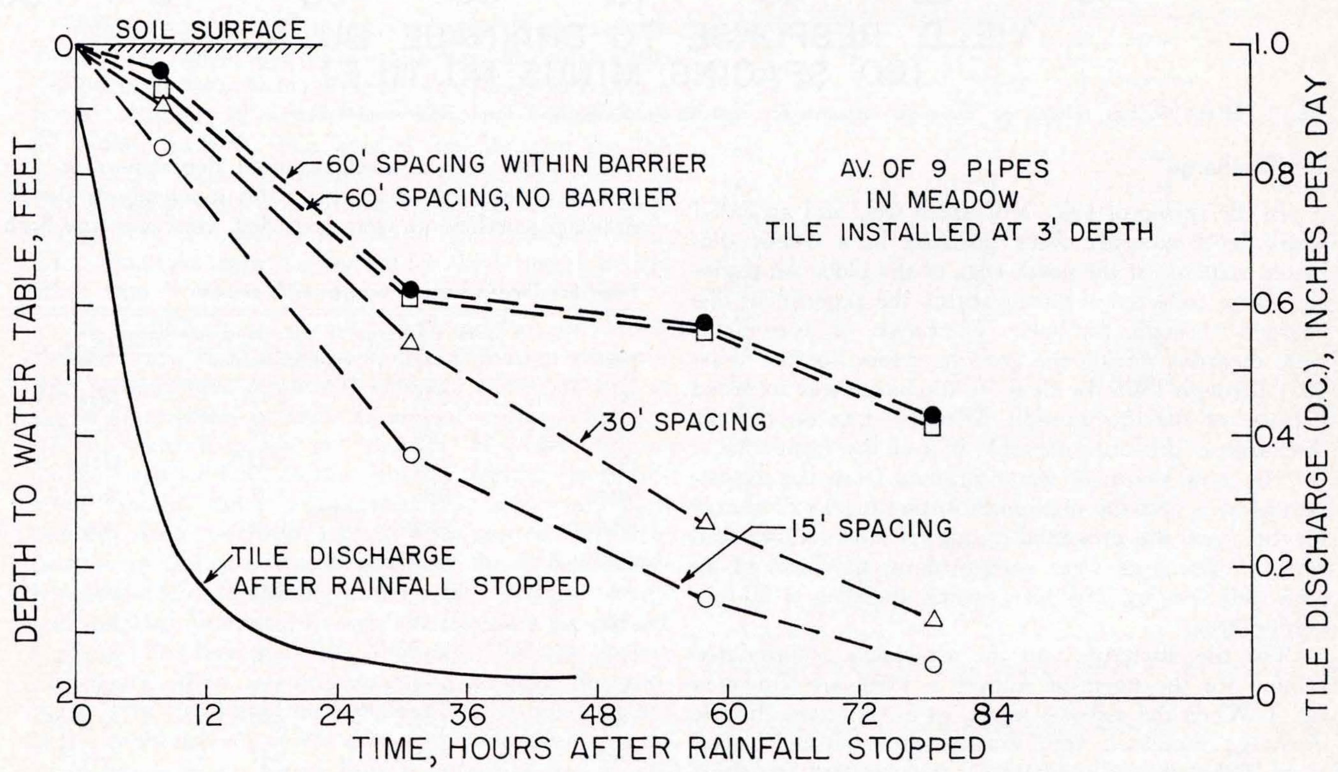

Fig. 9. Comparison of water table drawdown on different tile spacings and within metal barrier, Southern Iowa Experimental Farm.

rates of discharge were of very short duration, the discharge ordinarily dropping to less than 0.1 inch per day within 18 hours after rainfall stopped. Thus, tile removed little water after surface water had run off or infiltrated.

Water table levels midway between tile were observed after heavy rainfall during the growing seasons of 1949 through 1954 and again in 1959. The most consistant measurements were secured in meadow plots; the measurements made in corn plots were erratic, probably because of tillage effects and because the 3/8-inch perforated water table pipe could not be installed until after the corn emerged. As shown by Schwab, et. al.[7], water table measurements, taken in years when several pipes were installed between lines to determine the water table shape, revealed that the drawdown surface was nearly flat. For example, the water table level 5 feet from the tile was only about 0.3 foot lower than the level 15 feet from the tile at any time in the drawdown sequence for either the 30- or 60-foot spacing.

In 1956, sheet metal barriers were placed 3 feet deep to enclose a rectangular area within each replicate of the 60-foot spacing within permanent meadow. The area, about 10 feet by 20 feet, was located in the center of the plot. The long dimension of the enclosed area was oriented in the same direction as the long dimension of the plot. The top edge of the barrier was even with the soil surface. In 1959, water table levels were observed after heavy rains within the enclosed area midway between the tile lines, and midway between lines on three replicates of the 15-, 30- and 60-foot spacing in rotation meadow. Figure 9 presents the measured rate of fall of the water table, after the storm of August 6, 1959. Each point represents the average of nine-pipe readings (three pipes in each of three replicates).

Apparently, little lateral flow occured within the more permeable surface soil, since the rate of fall of the water table within the isolated area was essentially the same as that outside the barrier. Seven hours after rainfall stopped, the water table was 0.14, 0.18 and 0.32 feet below the surface for the 60-, 30- and 15-foot spacings, respectively. At the same time, the tile discharge rate had dropped to 0.27 inch per day. About 0.1 inch of water was discharged from the tile system between the time from 7 hours to 31 hours after rainfall stopped. Thus, tile discharge accounted for a small percentage (drainable pore space about 8 percent) of the total water table drop during this time.

SUMMARY AND CONCLUSIONS

Tile spacing experiments have been conducted on the Southern Iowa Experimental Farm since 1950. The criterion for measuring drainage response has been the yields of corn on field plots where the area sampled was approximately 0.01 acre. These experiments were intended to represent field conditions. It is recognized, however, that these field experiments do not exactly duplicate field conditions. Since all plots were planted and harvested at the same time, no credit was given to the drained plots for potential earlier planting and crop salvage in case of extremely wet harvesting conditions.

The corn yield results have shown that, for rotation corn, yields for the 15-foot tile spacing have, on the average, been 6 bu./A. greater than for the 60-foot spacing. For continuous corn, the average increase has been 4 bu./A. for the 15-foot spacing over the 60-foot spacing. Although the precision of the experiments has been adequate to show that 6 bu./A. is statistically significant in the case of rotation corn, the economics of quadrupling the amount of tile for a 6-bu./A. increase would not be sound. Therefore, in the Edina soils of southern Iowa, the data support the conclusion that the 60-foot tile spacing is nearly as effective as any closer tile spacing.

A general comparison was made between the yields on the 60-foot tile spacing and plots where no tile had been installed. The average advantage for the tiled plots was 13 bu./A. on rotation corn and an estimated 1-bu./A. advantage on tiled plots for continuous corn. The results are consistant in showing that tile drainage in the Edina soils influences the corn yields in a rotation corn cropping system more than in continuous corn. The source of nitrogen for rotation corn was the plowed-under legume crop, while the source for the continuous corn was commercial nitrogen.

Hay yields have averaged about 0.4 ton per acre greater on the tiled plots than on the plots without tile. The amount of nitrogen fixed by a legume meadow crop is proportional to the amount of meadow growth. Therefore, it is probable that the tiled rotation plots had a more adequate nitrogen supply than did the plots without tile. Thus, the difference in corn yields was, at least in part, due to a fertility difference which was indirectly an effect of drainage.

While the comparison of results on tiled and untiled areas cannot be subjected to statistical proof, the slight difference obtained justifies the following observations:

1. While removal of surface water is essential for the farming of the claypan soils of southern Iowa, many of the advantages of drainage are realized through surface drainage.

2. Tiling furnishes a convenient method of disposing of excess water, but the costs are greater than can probably be justified for ordinary field crops.

Tile discharge measured from the entire drainage system from 1951 to 1963 revealed that large quantities of water are removed through tile. A maximum of 6.25 inches was recorded for the growing season of 1959 when rainfall was 13.1 inches greater than normal for the months April through September. No discharge was recorded in 1956. Maximum discharge rates were high, but of short duration unless rainfall continued. While

[7] Op. cit. pp. 450-451.

peak discharge rates of over 2 inches per day were commonly recorded, the discharge rates fell to about 0.1 inch per day 18 hours after rainfall stopped. Records indicate that only about 0.3 to 0.4 inch of water was withdrawn from the 3-foot profile in the first 2 days after rainfall stopped. Tile was effective in removing excess water during rainfall and that portion of rainfall stored in surface depressions near tile lines after rainfall. However, little water was withdrawn from the soil profile. Thus, tile aided in drying the soil surface and provided some aeration, largely in the top 6 inches. During the growing season evaporation and transpiration were probably more effective in lowering the water table than tile.

In wet springs and falls, the soil is more stable over and near the tile. The improved trafficability of the Edina soil for harvest and planting operations that may be credited to tile is limited to about 10 feet on each side of the tile. This situation improves slowly, largely because of evaporation from the surface.

APPENDIX

Table A-1. Plot yields, bu./A., of rotation corn for period of record.

	Tile spacings											
	15 ft.				30 ft.				60 ft.			
Year	Rep I	Rep II	Rep III	Av.	Rep I	Rep II	Rep III	Av.	Rep I	Rep II	Rep III	Av.
1950	55.0	69.3	59.6	61.3	50.6	62.1	57.4	56.7	50.8	46.5	43.0	46.8
1951	84.3	65.3	67.8	72.5	81.3	73.9	65.8	73.8	77.4	66.0	56.9	66.6
1952	123.3	117.9	115.5	118.9	121.5	113.2	120.1	118.3	115.5	107.3	107.9	110.2
1953	60.8	60.9	57.8	59.8	69.4	65.6	63.3	66.1	63.9	62.3	61.6	62.6
1954	84.2	89.4	94.2	89.2	98.8	96.2	95.9	96.9	98.7	91.3	89.6	93.2
1955	77.3	70.3	82.5	76.7	74.4	74.6	66.3	71.8	63.0	70.3	75.4	69.6
1956	51.9	55.4	66.4	57.9	48.0	46.4	55.8	50.1	52.0	47.6	56.0	51.9
1957	103.6	96.3	113.1	104.3	100.9	100.5	95.4	98.9	90.7	83.4	103.5	92.5
1958	145.7	146.1	144.9	145.8	148.1	136.6	146.3	143.7	141.0	151.2	124.6	138.9
1959	97.2	106.2	88.3	97.2	95.9	94.0	83.4	91.1	84.3	79.1	82.5	82.0
1960	100.6	89.7	87.2	92.5	81.5	85.0	81.2	82.6	82.9	84.0	74.4	80.4
1961	127.7	128.7	137.1	131.2	120.1	128.7	142.0	130.3	123.8	130.5	135.8	130.0
1962	129.7	124.8	131.9	128.8	123.4	120.2	122.9	122.2	121.8	116.1	114.9	117.6
1963	128.5	116.0	125.1	123.2	121.0	123.3	121.5	121.9	124.0	122.0	121.5	122.5
1964	130.5	127.0	124.8	127.4	125.3	112.3	134.0	123.9	124.5	136.0	141.5	134.0

Table A-2. Plot yields, bu./A., of continuous corn for period of record.

	Tile spacings											
	15 ft.				30 ft.				60 ft.			
Year	Rep I	Rep II	Rep III	Av.	Rep I	Rep II	Rep III	Av.	Rep I	Rep II	Rep III	Av.
1957	104.0	101.4	100.3	101.9	87.6	102.4	93.0	94.3	91.7	107.8	90.2	96.6
1958	152.6	136.9	132.7	140.7	147.0	144.1	130.3	140.5	140.0	130.8	142.9	137.9
1959	89.8	87.4	105.8	94.3	76.2	86.4	74.3	79.0	75.6	58.6	86.4	73.5
1960	69.5	69.8	75.0	71.4	61.5	59.8	59.9	60.4	65.7	62.7	71.5	66.6
1961	112.2	94.3	106.3	104.3	113.4	112.6	107.1	111.0	109.8	108.2	113.4	110.5
1962	95.8	111.6	114.7	107.4	120.6	111.3	105.3	112.4	110.6	111.3	121.3	114.4
1963	115.2	124.1	116.3	118.5	109.0	112.3	109.5	110.3	110.2	108.5	108.7	109.1
1964	109.5	105.5	125.0	113.3	116.0	111.6	122.5	116.7	94.5	113.0	119.7	109.1

Table A-3. Plot yields, bu./A., of corn on land without tile drainage.

	Rotation corn[a]				Continuous corn: 60 lb. nitrogen[b]				Continuous corn: 120 lb. nitrogen[c]			
Year	Rep I	Rep II	Rep III	Av.	Rep I	Rep II	Rep III	Av.	Rep I	Rep II	Rep III	Av.
1954	76.5	70.4	81.6	76.2	59.6	73.2	79.4	70.7	82.9	83.7	88.2	84.9
1955	90.0	91.7	87.8	89.8	87.9	83.4	97.2	89.5	102.8	110.4	108.0	107.1
1956	93.0	93.4	73.7	86.7	87.7	82.3	85.4	85.1	89.7	87.0	92.1	89.6
1957	114.7	118.4	134.0	122.3	91.5	115.1	107.1	104.6	102.4	110.7	117.1	110.1
1958	64.9	60.8	63.8	63.2	75.8	114.2	85.8	91.9	143.8	142.4	121.8	136.0
1959	80.3	71.0	78.9	76.7	60.2	68.8	59.5	62.8	82.5	92.0	93.1	89.2
1960	60.4	63.8	60.6	61.6	44.9	59.7	62.9	55.8	62.3	82.8	86.1	77.1
1961	82.9	82.2	73.2	79.4	119.5	101.7	109.2	110.1	136.4	130.1	134.6	133.7
1962	77.4	66.7	80.7	74.9	57.5	56.5	61.4	58.5	95.5	104.6	91.7	97.3
1963	114.3	116.5	101.1	110.6	108.8	99.8	100.9	103.2	116.2	122.8	135.6	124.9
1964	128.4	124.6	122.7	125.2	106.8	92.5	84.9	94.7	152.2	144.9	135.5	144.2

[a] Rotation corn received the same fertilizer application as rotation corn in the tile spacing experiment.

[b] Complete fertilizer application was 60 lb. N, 80 lb. P_2O_5 and 20 lb. K_2O.

[c] Complete fertilizer application was 120 lb. N, 80 lb. P_2O_5 and 20 lb. K_2O.

Table A-4. Plot yields of oats and hay on land with and without tile drainage.

	Oats bu./A.				Hay (1st cutting only) tons/A.			
	Rep. I	Rep. II	Rep. III	Av.	Rep. I	Rep. II	Rep. III	Av.
Not tiled								
1954	46.6	51.4	51.5	49.8	1.55	1.69	1.03	1.42
1955	44.4	43.0	44.4	43.9	2.17	1.81	2.10	2.03
1956	22.4	18.3	22.8	21.2	0.61	0.66	0.75	0.67
1957	56.1	52.0	53.1	53.7	1.65	1.95	1.99	1.86
1958	68.0	71.4	85.2	74.9	2.18	2.53	2.19	2.30
1959	0.0	0.0	0.0	0.0	1.85	2.00	2.22	2.02
1960	7.9	6.1	18.2	10.7	1.27	...	0.54	0.91
1961	37.7	41.1	39.0	39.3	1.53	0.78	1.54	1.28
1962	25.9	18.7	26.6	23.7	1.35	1.50	1.00	1.28
1963	47.1	32.2	55.6	45.0	1.56	1.98	2.03	1.86
Av.				36.2				1.56
Tiled (60-ft. tile spacing)								
1954	57.4	44.6	57.0	53.0	1.42	1.38	1.31	1.37
1955	86.3	87.7	95.5	89.8	2.26	2.22	2.40	2.29
1956	23.8	23.9	25.0	24.2	0.69	0.50	0.61	0.60
1957	64.7	77.4	70.6	70.9	2.17	2.37	2.23	2.26
1958	90.0	89.5	96.6	92.0	2.87	2.70	3.03	2.87
1959	18.6	20.3	20.1	19.7	2.26	2.34	1.69	2.10
1960	13.1	13.2	18.3	14.9	2.56	2.13	2.42	2.37
1961	45.7	43.1	38.7	42.5	1.71	1.53	1.29	1.51
1962	54.4	56.8	66.5	59.2	1.74	1.67	1.58	1.66
1963	63.4	57.0	62.0	60.8	2.02	1.99	2.12	2.04
Av.				52.7				1.91