# Response of Corn Yields in a Planosol Soil to Surface Drainage, Cropping System and Variable Fertilizer Treatments

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# Response of Corn Yields in a Planosol Soil to Surface Drainage, Cropping System and Variable Fertilizer Treatments[1]

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The Edina soil series of southeastern Iowa and northern Missouri are areas of relatively flat topography and poor internal drainage. For these areas, where the topography and soils permit, surface drainage is the most practical method of removing excess water from the land. One method of surface drainage that has been used on the Edina soils is bedding, in which the field is divided into narrow-width plow lands with the deadfurrows running parallel to the prevailing land slope.

Little is known about the relative returns from investment in a bedding system in comparison with other surface or subsurface drainage methods. Bedding requires that some topsoil be moved to obtain the desired grade for drainage. The effect on crop yields of topsoil removal and movement in land-forming operations such as bedding, however, is not quantitatively understood. It is the general purpose of this bulletin to present and analyze 6 years of corn-yield data involving drainage (bedded versus level), cropping and fertilizer variables from a study on the Southern Iowa Experimental Farm near Bloomfield.

A surface drainage experiment was initiated on this farm in 1952 with the following objectives:

1. to compare corn yields from drained[2] plots with yields on plots which had been leveled,

2. to compare corn yields from different fertilizer treatments applied to the cropping systems of continuous corn and a corn-oats-meadow rotation[3] and

3. to study the interactions among drainage, fertilizer and cropping-system variables.

Sutherland *et al.*[4] have reported corn yield response to nitrogen on the level part of the same experiment reported here. The study reported here, however, concerns the effect of bedding as a method of surface drainage and the interactions with different fertilizer levels and cropping systems.

## SOIL CHARACTERISTICS

The soil on 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.

From 7 to 9 inches below the surface, 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 usually is not encountered above 30 inches. Below the 30-inch depth, the soil becomes slightly less plastic with increasing depth and grades at a depth of about 50 inches into the weathered and leached silt loam parent material.

The physical properties of the soil on the Southern Iowa Experimental Farm were reported by Schwab *et al.*[5] 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

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

[2] All further references to drained plots pertain to the bedded plots.

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

[4] W. M. Sutherland, W. D. Shrader and J. T. Pesek. Effect of legume residue nitrogen and inorganic nitrogen in corn production. Submitted for publication in Agronomy Journal.

[5] G. O. Schwab, Don 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.

of the B horizon. The B horizon is included between the depths of 1.5 and 4.0 feet below the surface. Since the aeration porosity is 1 percent or less below 2.5 feet, poor internal drainage is indicated. A mechanical analysis shows that the surface 6 inches contains 3.5 percent sand, 74.9 percent silt and 21.6 percent clay, whereas a heavy soil stratum between 24 and 29 inches below the surface contains 54.6 percent clay. The average hydraulic conductivity at the 3-foot depth, obtained from 34 observations using the auger hole method, was 0.0145 foot per day.

## DESIGN AND LAYOUT OF EXPERIMENT

A diagram of the experimental layout showing replicate I is given in fig. 1. The experiment is a form of the split-split-plot design, with drainage as the whole-plot treatment, rotation as the subplot treatment and fertilizer application as the sub-subplot treatment. It varies, however, from the standard design because of the arrangement of the fertilizer applications to the sub-subplots. Each whole plot is an area 100 feet wide by 200 feet long. Each subplot and sub-subplot, respectively, are areas of 20 feet by 200 feet and 20 feet by 50 feet. In the following discussion whole plots, subplots and sub-subplots will be called blocks, columns and plots, respectively.

**Drainage treatment.** Each block on which the drainage treatment was applied was replicated three times. Therefore, three blocks were leveled to remove depressions, and the remaining three blocks were bedded as shown in fig. 1. The beds were constructed with a bulldozer and have the channels for drainage at 100-foot spacing. The arrows indicate the grade in the channel and the drainage in the direction of the cultivated rows. Since the grade in the channel is perpendicular to the direction of cropping, the excess water flows to the outlet over different soil coverings. Each bed was subdivided into the upper and lower portions for sampling and analyzing purposes.

**Rotation treatment.** Each block was divided into five columns, 20 feet wide by 200 feet long, and was cropped according to the cropping plan shown in fig. 1. Each block consisted of five columns, three of which were randomly allocated to a COM rotation and two to continuous corn.

**Fertilizer treatment.** Each column was divided into plots 20 feet wide by 50 feet long on which were applied the various fertilizer treatments. The numbers in the center of the plots in fig. 1 indicate the fertilizer treatment which a particular plot received. The plots in the three rotation corn columns and one continuous corn column received fertilizer treatments 1 through 4, which were a factorial design of two levels of nitrogen and phosphorus. The remaining continuous corn column received fertilizer treatments 5 through 8, which were a geometric increase in nitrogen application with the phosphorus application held constant. Treatments 4 and 5 were the same, thus serving as a common treatment for measuring column differences.

## STATISTICAL ANALYSIS[6]

The statistical analysis is based on the average yields of corn over the 6-year period from 1954 through 1959. Although data were collected in 1952 and 1953, the 1954-59 period was chosen to exclude 2 years of corn yields from the COM rotation during the 1952-53 period (when no meadow preceded the corn) and to minimize effects from cropping in previous years.

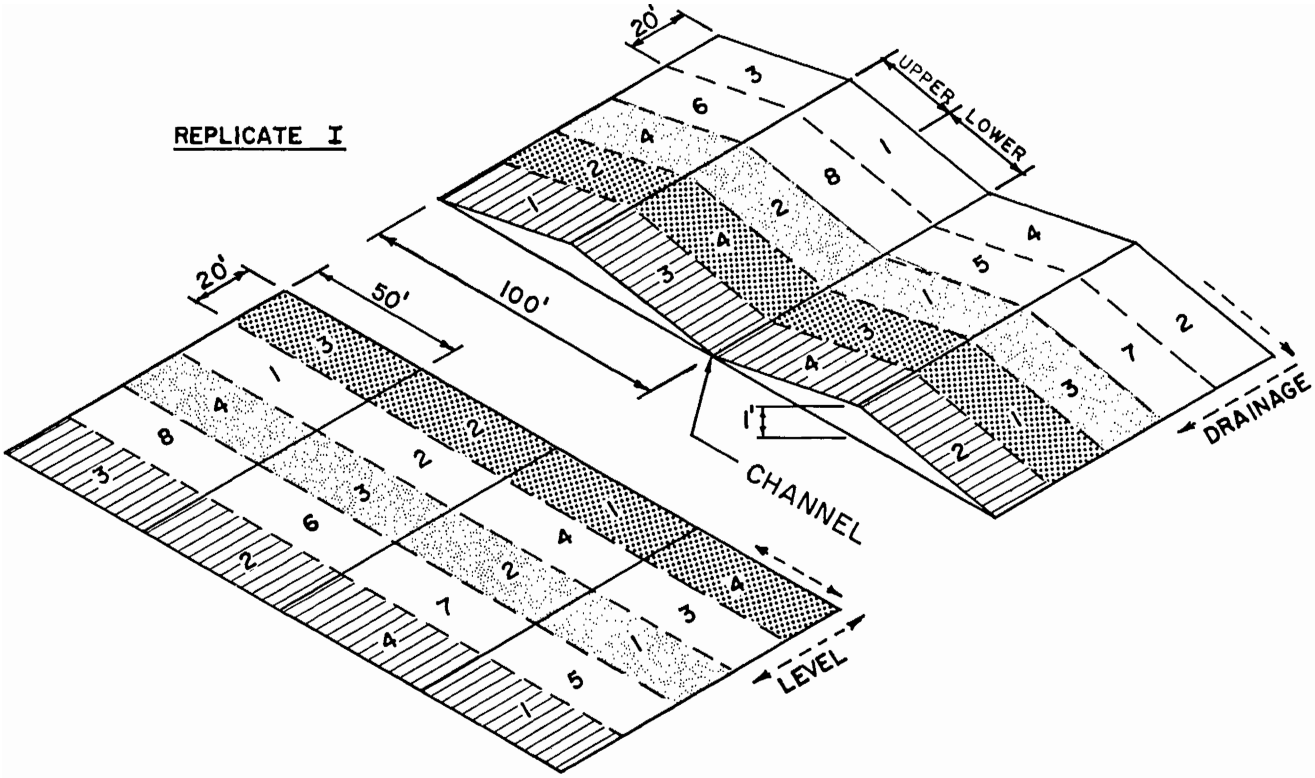
The analysis was performed in three major sections with two parts to each section (see tables 1, 2 and 3). Each section is described separately in the following paragraphs; where a main effect is repeated in a succeeding section, however, the symbol for the main effect remains the same. The symbols used for the main effects in the analyses are as follows: D = Drainage, Y = Year effect, F = Fertilizer, P = Drainage position, B = Cropping system, C = Column effect, Ph. = Phosphorus[7], N = Nitrogen and $T_i$ = $i^{th}$ fertilizer treatment. The analysis of each part was conducted according to its individual statistical model; the models, however, were established in such a way that the error structure would be comparable in each section. This is shown by the similarity of the interactions which are components of the error terms in each table.

Error is taken to signify the residual variation remaining after all of the variation attributable to factors under investigation is subtracted from the total variation among the data. Error is assumed to consist of three components. The first component measures the expected discrepancy among block yield averages for repeated, identical croppings of the same block during the same period of time. The second component measures the expected discrepancy among column yield averages within the same block for repeated, identical croppings of all of the columns of this block. Columns, rather than rows, are singled out here, in view of the column randomization used in the experiment. The third component measures the expected discrepancy among plot yields within the same column for repeated, identical croppings of all of the plots within a given column. These error components appear in the tables as errors I, II and III, respectively.

Therefore, because of the error structure assumed, each mean square corresponding to an interaction with replicates is treated as a nonrepeatable or random effect and, hence, estimates a component of error.

[6] The reader who is not interested in the statistical methods may omit this part and turn to the results.

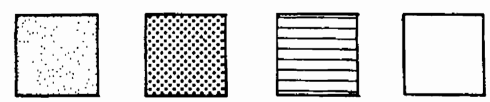
[7] The main effect for phosphorus is designated as Ph. to avoid confusion with the main effect for drainage position, P.




FERTILIZER TREATMENTS

| TREATMENT NUMBER | POUNDS OF N, $P_2O_5$ AND $K_2O$ APPLIED PER ACRE. CORN | OATS | CONT. CORN |
|---|---|---|---|
| 1 | 0+20+20 | 0+40+40 | 0+20+20 |
| 2 | 30+20+20 | 0+40+40 | 30+20+20 |
| 3 | 0+80+20 | 0+160+40 | 0+80+20 |
| 4 | 30+80+20 | 0+160+40 | 30+80+20 |
| 5 | ---- | ---- | 30+80+20 |
| 6 | ---- | ---- | 60+80+20 |
| 7 | ---- | ---- | 120+80+20 |
| 8 | ---- | ---- | 240+80+20 |

CROPPING PLAN



| | | | | |
|---|---|---|---|---|
| 1954 | O | M | C | C |
| 1955 | M | C | O | C |
| 1956 | C | O | M | C |
| 1957 | O | M | C | C |
| 1958 | M | C | O | C |
| 1959 | C | O | M | C |

NOTE: ALL CORN RECEIVES 100 LBS./A OF 0-20-20 IN THE ROW AT PLANTING TIME; REMAINDER IS BROADCAST AND PLOWED UNDER. THE MEADOW CROP DOES NOT RECEIVE A DIRECT APPLICATION OF FERTILIZER.

Fig. 1. Surface drainage-rotation-fertilizer experiment, Southern Iowa Experimental Farm.

## SECTION I; SURFACE DRAINAGE VERSUS LEVEL

The objective of this analysis was to investigate the effects of surface drainage for each of the two cropping systems (COM and continuous corn). The statistical model for Section I (see table 1) contains effects for **replicates, drainage, fertilizer application, column effect** for continuous corn and **year effect** for COM rotation, and all **interactions** except those with replicates which appear in the three error components associated with between blocks, between columns and within columns. It should be pointed out that the column and year effects arise from the design of the experiment. A particular group of fertilizer treatments (treatments 1 through 4 or treatments 5 through 8) are thus identified with a given column for continuous corn. The year effect arises from the fact that corn is rotated each year among the remaining three columns. The expected mean square values were calculated for all main effects and interactions with the resulting error structure and analysis as shown in table 1. The tables are arranged so that any item is tested by the first error term encountered below the listed item. For example, in table 1 items A and D are tested with Error I, and items Y and DY, with Error II.

In the continuous corn analysis, the fertilizer effect (F) with 3 degrees of freedom represents a grouping of fertilizer treatments which in itself would not provide a good measure of the effect of fertilizer applications. For example, one column always contains fertilizer treatments 1 through 4, while the other column contains treatments 5 through 8. Thus, the main effect F by itself would represent a grouping of fertilizer treatments 1 and 5, 2 and 6, etc. This would naturally be expected to be highly significant. Therefore, a further division of the 12 degrees of freedom represented by F, FC, DF and CDF was necessary to examine more closely the fertilizer effects and the drainage-fertilizer interaction within columns. The division as presented permits the investigation of the main effects of nitrogen (N), phosphorus (Ph.) and nitrogen-phosphorus interaction (NPh.) in treatments 1 through 4 and the investigation of linear, quadratic and cubic nitrogen in fertilizer treatments 5 through 8. The nitrogen effects appear in two forms in table 1. The form with the numeral subscript followed by subscripts 1a, 2a and 3a, respectively, represents the linear, quadratic and the cubic components of the yield response to nitrogen when yield is plotted against an arithmetic scale of nitrogen application rate. Those with the numeral subscript only, represent the linear, quadratic and cubic components of the yield response when yield is plotted against the logarithm of the nitrogen application rate. The differences observed between the two forms of nitrogen effects support the fact that yield is essentially a linear function of the logarithm of the amount of nitrogen applied.

The error structure is the same for both parts; for the continuous corn, however, Error III (13.89) is slightly larger than Error II (10.86). This would not be expected because of less variation within columns than between columns. The fact that the two errors are about equal in size can be explained in part by the positions of the continuous corn columns in all of the blocks. In four of the six blocks, the randomization placed the continuous corn columns side by side which would tend to reduce the magnitude of Error II.

## SECTION II; UPPER DRAINAGE POSITION VERSUS LOWER DRAINAGE POSITION

The objective of this analysis was to investigate any differences in corn yields between the upper and lower portions of the bedded plots which could result from extremes in amounts of precipitation or excessive removal of topsoil during construction of the bed. The models for this section (see table 2) are identical to those in Section I except that the drainage-position effect (P) replaces the drainage effect (D). Thus, only the data from the bedded plots are used in this analysis. Since disturbance of the topsoil is inevitable in the construction of beds, it is also desirable to investigate any interactions of fertilizer with drainage position. The 8 degrees of freedom associated with P, CP, FP and CFP for continuous corn are subdivided in the following two ways:

1. The effect of drainage position is investigated within each of the eight fertilizer treatments ($T_1$, $T_2$, etc.).

2. The interactions of the fertility components with position within columns is given as an alternate division.

## SECTION III; ROTATION CORN VERSUS CONTINUOUS CORN FOR DRAINAGE POSITION AND LEVEL VERSUS SURFACE DRAINED

This analysis differs from the previous two in that it permits a direct contrast between the two cropping systems (COM and continuous corn) and the associated main effects and interactions for fertilizer treatments 1 through 4 only. In this analysis, the continuous corn data was divided into three, 2-year periods to correspond with the COM rotation. For example, one column was corn in rotation in 1954 and 1957 (see fig. 1). Therefore, the corresponding year's data were used from the continuous corn column to provide an equal comparison with respect to time. This gives rise to the main effect Y with 2 degrees of freedom.

# RESULTS

The summary of the statistical analysis is shown in tables 1 through 3, and the average corn yields for the 6-year period are given in tables 4, 5, 6 and 7. In the statistical summary tables, the double and single asterisk are used to denote signi-

TABLE. 1 ANALYSIS OF VARIANCE SUMMARY FOR SURFACE DRAINAGE VERSUS LEVEL FOR COM ROTATION AND CONTINUOUS CORN

**Rotation corn**

| Source | d.f. | | M.S. | Pooled |
|---|---|---|---|---|
| A—Replicates | 2 | | 76.84 | |
| D—Drainage | 1 | | 92.25 | |
| AD—Error I | 2 | | 155.25 | |
| Y—Year Effect | 2 | | 2039.70** | |
| DY | 2 | | 65.75 | |
| AY (Error II) | 4 | | 141.62 | 103.04 |
| ADY (Error II) | 4 | | 64.46 | |
| F—Fertilizer | 3 | | 225.75** | |
| N | | 1 | 610.75** | |
| Ph. | | 1 | 53.91 | |
| NPh. | | 1 | 12.58 | |
| FY | 6 | | 74.70* | |
| DF | 3 | | 17.76 | |
| DFY | 6 | | 32.38 | |
| AF (Error III) | 6 | | 17.01 | 23.81 |
| ADF (Error III) | 6 | | 31.90 | |
| AFY (Error III) | 12 | | 26.22 | |
| ADFY (Error III) | 12 | | 20.76 | |
| Total | 71 | | | |

**Continuous corn**

| Source | (m.s.) | d.f. | Source | M.S. | Pooled |
|---|---|---|---|---|---|
| A—Replicates | | 2 | | 147.62 | |
| D—Drainage | | 1 | | 914.38* | |
| AD—Error I | | 2 | | 15.71 | |
| C—Column Effect | | 1 | | 14011.75** | |
| DC | | 1 | | 536.67** | |
| AC (Error II) | | 2 | | 14.83 | 10.86 |
| ADC (Error II) | | 2 | | 6.89 | |
| F within C | | | | (m.s.) | |
| N | 1605.57** | 1 | N/Ph.$_1$ | 875.52** | |
| Ph. | 13.65 | 1 | N/Ph.$_2$ | 733.20** | |
| NPh. | 3.15 | 1 | Ph. | 13.65 | |
| $N_{1a}$ | 4205.67** | 1 | $N_1$ | 5054.41** | |
| $N_{2a}$ | 1062.37** | 1 | $N_2$ | 108.38* | |
| $N_{3a}$ | 0.03 | 1 | $N_3$ | 105.28* | |
| DF within C | | | | | |
| DxN | | 1 | | 0.63 | |
| DxPh. | | 1 | | 22.23 | |
| DxNPh. | | 1 | | 20.72 | |
| Dx$N_1$ | | 1 | | 12.89 | |
| Dx$N_2$ | | 1 | | 31.30 | |
| Dx$N_3$ | | 1 | | 2.92 | |
| AF (Error III) | | 6 | | 15.37 | 13.89 |
| ADF (Error III) | | 6 | | 15.62 | |
| ACF (Error III) | | 6 | | 11.04 | |
| ACDF (Error III) | | 6 | | 13.53 | |
| Total | | 47 | | | |

TABLE 2. ANALYSIS OF VARIANCE SUMMARY FOR UPPER DRAINAGE POSITION VERSUS LOWER DRAINAGE POSITION FOR COM ROTATION AND CONTINUOUS CORN

**Rotation corn**

| Source | d.f. | | M.S. | Pooled |
|---|---|---|---|---|
| A—Replicates | 2 | | 311.70 | |
| Y—Year Effect | 2 | | 1693.95* | |
| AY—Error I | 4 | | 104.26 | |
| F—Fertilizer | 3 | | 306.81** | |
| N | | 1 | 891.12** | |
| Ph. | | 1 | 3.51 | |
| NPh. | | 1 | 25.80 | |
| FY | 6 | | 123.44* | |
| AF (Error II) | 6 | | 37.06 | 42.68 |
| AFY (Error II) | 12 | | 45.49 | |
| P—Drainage Pos. | 1 | | 8439.17** | |
| PY | 2 | | 2832.93** | |
| FP | 3 | | 5.52 | |
| FPY | 6 | | 16.68 | |
| AP (Error III) | 2 | | 15.80 | 12.55 |
| APY (Error III) | 4 | | 13.37 | |
| AFP (Error III) | 6 | | 7.60 | |
| AFPY (Error III) | 12 | | 14.21 | |
| Total | 71 | | | |

**Continuous corn**

| Source | (m.s.) | d.f. | Source | M.S. | Pooled |
|---|---|---|---|---|---|
| A—Replicates | | 2 | | 121.49* | |
| C—Column Effect | | 1 | | 9020.08** | |
| AC—Error I | | 2 | | 19.50 | |
| F within C | | | | | |
| N | | 1 | | 1520.04** | |
| Ph. | | 1 | | 66.00 | |
| NPh. | | 1 | | 5.61 | |
| $N_{1a}$ | | 1 | | 4689.39** | |
| $N_{2a}$ | | 1 | | 733.29** | |
| $N_{3a}$ | | 1 | | 2.50 | |
| AF (Error II) | | 6 | | 28.13 | 30.76 |
| ACF (Error II) | | 6 | | 33.38 | |
| P within C & F | | | | (m.s.) | |
| $P/T_1$ | 723.80** | 1 | P—Drain. Pos. | 6288.34** | |
| $P/T_2$ | 1356.00** | 1 | PC | 1.69 | |
| $P/T_3$ | 349.61** | 1 | Nx$P/C_1$ | 129.74** | |
| $P/T_4$ | 995.88** | 1 | Ph.x$P/C_1$ | 45.38 | |
| $P/T_5$ | 965.20** | 1 | NPh.x$P/C_1$ | 2.16 | |
| $P/T_6$ | 475.80** | 1 | $N_{1a}$x$P/C_2$ | 329.89** | |
| $P/T_7$ | 873.63** | 1 | $N_{2a}$x$P/C_2$ | 41.41 | |
| $P/T_8$ | 126.96** | 1 | $N_{3a}$x$P/C_2$ | 28.29 | |
| AP (Error III) | | 2 | | 6.94 | 10.59 |
| ACP (Error III) | | 2 | | 16.92 | |
| AFP (Error III) | | 6 | | 6.36 | |
| ACFP (Error III) | | 6 | | 14.10 | |
| Total | | 47 | | | |

TABLE 3. ANALYSIS OF VARIANCE SUMMARY FOR UPPER AND LOWER POSITION AND SURFACE DRAINAGE AND LEVEL FOR ROTATION VERSUS CONTINUOUS CORN

Rotation versus continuous corn

Upper and lower position

| Source | d.f. | M.S. |
|---|---|---|
| A—Replicates | 2 | 319.30 |
| B—Cropping System | 1 | 71,217.82** |
| AB | 2 | 116.65 |
| AY Error I | 4 | 89.28 Pooled |
| ABY | 4 | 50.80 79.36 |
| Y—Year Effect | 2 | 903.07** |
| F—Fertilizer | 3 | 1,645.39** |
| BY | 2 | 846.62** |
| BF | 3 | 290.77** |
| FY | 6 | 72.30 |
| BFY | 6 | 55.89 |
| AF | 6 | 3.87 |
| AFY Error II | 12 | 33.56 Pooled |
| ABF | 6 | 56.33 40.78 |
| ABFY | 12 | 58.70 |
| P—Drainage Pos. | 1 | 18,265.52** |
| PY | 2 | 2,608.38** |
| FP | 3 | 64.43** |
| BP | 1 | 27.39 |
| BPY | 2 | 700.85** |
| BFP | 3 | 102.90** |
| FPY | 6 | 28.32* |
| BFPY | 6 | 9.58 |
| AP | 2 | 38.31 |
| ABP | 2 | 15.55 |
| APY | 4 | 7.70 |
| AFP | 6 | 6.90 Pooled |
| ABPY Error III | 4 | 11.25 10.89 |
| ABFP | 6 | 4.55 |
| AFPY | 12 | 11.27 |
| ABFPY | 12 | 11.28 |
| Total | 143 | |

Surface drainage and level

| Source | d.f. | M.S. |
|---|---|---|
| A—Replicates | 2 | 186.15 |
| D—Drainage | 1 | 0.27 |
| AD—Error I | 2 | 18.16 |
| B—Cropping System | 1 | 64,613.40** |
| Y—Year Effect | 2 | 2,015.17 |
| BD | 1 | 170.52 |
| DY | 2 | 389.60* |
| BY | 2 | 745.03** |
| BDY | 2 | 69.42 |
| AB | 2 | 174.32 |
| AY | 4 | 156.66 |
| ABD | 2 | 178.91 Pooled |
| ADY Error II | 4 | 99.06 107.18 |
| ABY | 4 | 81.76 |
| ABDY | 4 | 21.84 |
| F—Fertilizer | 3 | 1,481.24** |
| DF | 3 | 45.65 |
| BF | 3 | 374.82** |
| FY | 6 | 21.18 |
| BDF | 3 | 15.45 |
| DFY | 6 | 21.68 |
| BFY | 6 | 63.84* |
| BDFY | 6 | 19.61 |
| AF | 6 | 30.26 |
| ADF | 6 | 21.61 |
| ABF | 6 | 12.19 |
| AFY | 12 | 29.50 Pooled |
| ABDF Error III | 6 | 44.99 23.94 |
| ADFY | 12 | 10.95 |
| ABFY | 12 | 22.08 |
| ABDFY | 12 | 26.57 |
| Total | 143 | |

TABLE 4. SIX-YEAR AVERAGE CORN YIELDS, BU./A. FOR SURFACE DRAINED AND LEVEL PLOTS; CONTINUOUS CORN

| Fertilizer treatment | Surface drained | | | | Level | | | |
|---|---|---|---|---|---|---|---|---|
| | Replicate | | | | Replicate | | | |
| | I | II | III | Total | I | II | III | Total |
| 1 | 39.1 | 45.0 | 40.0 | 124.1 | 38.2 | 38.2 | 41.5 | 117.9 |
| 2 | 55.7 | 57.6 | 55.5 | 168.8 | 53.7 | 66.3 | 55.7 | 175.7 |
| 3 | 33.8 | 38.3 | 38.3 | 110.4 | 39.1 | 48.6 | 39.2 | 126.9 |
| 4 | 49.8 | 55.2 | 56.9 | 161.9 | 48.3 | 63.4 | 57.5 | 169.2 |
| | | | | 565.2 | | | | 589.7 |
| 5 | 46.8 | 53.0 | 64.3 | 164.1 | 67.5 | 67.8 | 70.4 | 205.7 |
| 6 | 65.1 | 70.4 | 62.9 | 198.4 | 77.1 | 89.5 | 85.7 | 252.3 |
| 7 | 79.0 | 88.6 | 86.2 | 253.8 | 100.7 | 104.4 | 103.4 | 308.5 |
| 8 | 91.6 | 90.0 | 97.1 | 278.7 | 103.6 | 106.7 | 103.2 | 313.5 |
| | | | | 895.0 | | | | 1,080.0 |
| | | | | 1,460.2 | | | | 1,669.7 |

ficance at the 1-percent and 5-percent levels, respectively. Significance, as used in the following discussion, indicates that the probability of obtaining as large or larger tabulated F value is either 5-percent or 1-percent if, in fact, there had been no difference between the effects which were tested. The usual concept of interaction is used; namely, if interaction is significant, the effects are not additive and are not independent of one another.

DRAINAGE; SURFACE DRAINED VERSUS LEVEL

The increase in corn yield resulting from surface drainage by bedding is negligible for the rotation corn. This follows from table 1 in which the mean square for drainage (92.25) is smaller than

TABLE 5. SIX-YEAR AVERAGE CORN YIELDS, BU./A. FOR SURFACE DRAINED AND LEVEL PLOTS; ROTATION CORN

| Years | Fertilizer treatment | Surface drained Replicate I | II | III | Total | Level Replicate I | II | III | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1954 & 1957 | 1 | 99.2 | 102.1 | 96.0 | 297.3 | 95.6 | 94.4 | 107.8 | 297.8 |
| | 2 | 94.2 | 105.6 | 105.1 | 304.9 | 101.5 | 96.8 | 100.6 | 298.9 |
| | 3 | 93.3 | 106.6 | 98.3 | 298.2 | 99.4 | 94.1 | 110.6 | 304.1 |
| | 4 | 100.4 | 108.3 | 95.6 | 304.3 | 100.3 | 100.9 | 110.7 | 311.9 |
| | | | | | 1,204.7 | | | | 1,212.7 |
| 1955 & 1958 | 1 | 85.6 | 89.7 | 92.2 | 267.5 | 77.5 | 76.3 | 75.8 | 229.6 |
| | 2 | 97.9 | 98.0 | 87.3 | 283.2 | 98.5 | 97.0 | 69.4 | 264.9 |
| | 3 | 87.6 | 87.2 | 65.3 | 240.1 | 87.3 | 82.5 | 74.5 | 244.3 |
| | 4 | 103.9 | 104.5 | 90.5 | 298.9 | 93.3 | 93.9 | 92.9 | 280.1 |
| | | | | | 1,089.7 | | | | 1,018.9 |
| 1956 & 1959 | 1 | 76.2 | 77.7 | 77.5 | 231.4 | 87.6 | 82.2 | 76.3 | 246.1 |
| | 2 | 82.7 | 93.0 | 85.1 | 260.8 | 87.4 | 76.0 | 82.5 | 245.9 |
| | 3 | 81.2 | 86.9 | 83.0 | 251.1 | 91.5 | 76.2 | 78.3 | 246.0 |
| | 4 | 85.1 | 87.9 | 87.5 | 260.5 | 88.3 | 80.8 | 80.0 | 249.1 |
| | | | | | 1,003.8 | | | | 987.1 |
| | | | | | 3,298.2 | | | | 3,218.7 |

TABLE 6. SIX-YEAR AVERAGE CORN YIELDS, BU./A. FOR UPPER AND LOWER DRAINAGE POSITIONS ON SURFACE DRAINED PLOTS; CONTINUOUS CORN

| Fertilizer treatment | Upper Replicate I | II | III | Total | Lower Replicate I | II | III | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | 48.6 | 57.8 | 50.6 | 157.0 | 29.5 | 32.2 | 29.4 | 91.1 |
| 2 | 69.3 | 73.7 | 71.0 | 214.0 | 42.1 | 41.6 | 40.1 | 123.8 |
| 3 | 39.6 | 47.6 | 46.9 | 134.1 | 29.6 | 29.1 | 29.6 | 88.3 |
| 4 | 62.1 | 67.9 | 70.5 | 200.5 | 37.5 | 42.4 | 43.3 | 123.2 |
| | | | | 705.6 | | | | 426.4 |
| 5 | 56.3 | 67.2 | 78.6 | 202.1 | 37.2 | 38.8 | 50.0 | 126.0 |
| 6 | 82.2 | 86.6 | 76.6 | 245.4 | 48.0 | 54.2 | 49.1 | 151.3 |
| 7 | 95.9 | 98.3 | 95.9 | 290.1 | 62.1 | 79.0 | 76.6 | 217.7 |
| 8 | 96.2 | 96.8 | 99.5 | 292.5 | 87.0 | 83.3 | 94.6 | 264.9 |
| | | | | 1,030.1 | | | | 759.9 |
| | | | | 1,735.7 | | | | 1,186.3 |

TABLE 7. SIX-YEAR AVERAGE CORN YIELDS, BU./A. FOR UPPER AND LOWER DRAINAGE POSITIONS ON SURFACE DRAINED PLOTS; ROTATION CORN

| Years | Fertilizer treatment | Upper Replicate I | II | III | Total | Lower Replicate I | II | III | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1954 & 1957 | 1 | 107.3 | 116.8 | 114.2 | 338.3 | 63.9 | 62.4 | 70.1 | 196.4 |
| | 2 | 124.7 | 118.2 | 116.4 | 359.3 | 71.1 | 77.7 | 58.2 | 207.0 |
| | 3 | 105.9 | 111.3 | 88.4 | 305.6 | 69.3 | 63.1 | 42.1 | 174.5 |
| | 4 | 124.5 | 124.8 | 116.0 | 365.3 | 83.2 | 84.1 | 64.8 | 232.1 |
| | | | | | 1,368.5 | | | | 810.0 |
| 1955 & 1958 | 1 | 107.2 | 107.3 | 104.5 | 319.0 | 91.1 | 96.8 | 87.5 | 275.4 |
| | 2 | 101.7 | 109.1 | 108.6 | 319.4 | 86.5 | 102.1 | 101.5 | 290.1 |
| | 3 | 99.8 | 111.3 | 107.1 | 318.2 | 87.0 | 101.7 | 89.6 | 278.3 |
| | 4 | 106.1 | 113.7 | 99.8 | 319.6 | 94.7 | 102.9 | 91.3 | 288.9 |
| | | | | | 1,276.2 | | | | 1,132.7 |
| 1956 & 1959 | 1 | 76.9 | 81.3 | 84.2 | 242.4 | 75.5 | 74.2 | 70.8 | 220.5 |
| | 2 | 82.0 | 94.8 | 86.7 | 263.5 | 83.4 | 91.2 | 83.4 | 258.0 |
| | 3 | 84.7 | 92.1 | 87.9 | 264.7 | 77.6 | 81.6 | 78.1 | 237.3 |
| | 4 | 88.7 | 92.9 | 90.2 | 271.8 | 81.5 | 82.8 | 84.8 | 249.1 |
| | | | | | 1,042.4 | | | | 964.9 |
| | | | | | 3,687.1 | | | | 2,907.6 |

Error I (155.25), and also from table 5 in which the yields, when summed over all variables except drainage effect (level versus surface drained), show a difference of approximately 80 in 3,300 (3,298.2 minus 3,218.7). In the continuous corn analysis, however, the main effect for drainage was significant at the 5-percent level. The significance arises from a depression in the corn yields on the drained plots. The 6-year averages for the level and drained plots may be computed from table 4 as 69.5 and 60.7 bushels per acre, respectively.[8] This represents a depression of about 13 percent. Table 4 also shows that the major difference between the two averages arises

[8] 1,669.7/24 = 69.5; 1,460.2/24 = 60.7.

in the columns containing fertilizer treatments 5 through 8 (totals of 565.2 versus 589.7 as compared with 895.0 versus 1,080.0). This relationship between columns is further shown by the significance of CD interaction (536.67) for continuous corn in table 1.

Several soil and management factors combine to create a changed environment for growing plants in the bottom of the bed. The two main factors are:

1. The removal of topsoil during the construction of the bed tends to lower the aeration porosity and affects the soil structure of the remaining topsoil. The actual depth of disturbance was not measured; the idealized cross section, however, shows that the topsoil would be removed to a minimum depth of 0.5 foot (see fig. 1).

2. Tillage operations are performed with conventional farm machinery at right angles to the channel grade and tend to create obstructions to the flow of the excess water. This causes ponded conditions to occur in the lower part of the bed; these conditions are alleviated to some extent by using hand equipment to remove the ridges created by the tillage machinery. Thus, drainage was poorer on a portion of the "drained" than on the "undrained" plots. The results indicate a failure of the method of drainage employed, rather than a negative response to improved drainage.

Information is inadequate to explain the difference in response to drainage on rotation corn as compared with continuous corn. The size of the mean square for the drainage-cropping system interaction (BD) in table 3 (although not significant) indicates that the inclusion of meadow and oats in the rotation is more instrumental in offsetting the changed environment than is continuous corn. From the regressions presented in fig. 2, it is apparent that more nitrogen was required on the bedded than on the level continuous corn to achieve comparable yields. It is also apparent that yields of rotation corn were limited by the amount of nitrogen available. At the yield level of the unfertilized rotation corn, which was essentially the same on both bedded and level land, the rotation was equivalent to 140 pounds of nitrogen on the bedded continuous corn as compared with 70 pounds of nitrogen on the level continuous corn plots. It is possible that more nitrogen was produced by the meadow on the bedded than on the level plots but no definite proof exists.

## DRAINAGE POSITION; UPPER VERSUS LOWER

The differences in yields between the upper and lower portions of the bed are affected not only by the changed environment in the lower portion but also by the climatological factors and the level of fertilizer application. Table 2 shows the drainage position ($P = 8{,}439.17$) and the year-drainage position interaction ($PY = 2{,}832.93$) for rotation corn to be significant at the 1-percent level. From table 7, the average yield values may be computed as 102.5 bushels per acre and 81.0 bushels per acre, respectively, for the upper and lower drainage positions on rotation corn.[9] The PY interaction results from the following factors:

1. Since the grade in the channel is at right angles to the columns, the resistance to the flow of water, as influenced by the cover in the channel, is different each year.

2. The amount and intensity of precipitation and its time of occurrence in relation to the age of the corn influences the yield differences for the drainage positions.

It should be pointed out that the actual geometry of the beds after cropping differs somewhat from the cross section given in fig. 1. The channel has become wider and affects a larger portion of the area represented by the lower drainage position than that represented by the V-notch in fig. 1. Thus, it would be possible for the collection of water in the bottom of the bed to increase the yields in dry years and to reduce yields in wet years. The yield data show that corn yields were higher on the upper positions of the beds in 1957, 1958 and 1959, lower in 1956 and approximately the same on both positions in 1954 and 1955. The monthly distribution of precipitation as measured at the experimental area cannot be correlated with the highest yield occurring on the upper or lower position in any one year, except possibly for 1956. The entire 1956 season was generally dry, but high intensity showers occurred during which there was some runoff from the higher to the lower positions of the beds.

Although the lower position is more affected by the topsoil removal, the interaction between fertilizer and drainage position is not significant for the rotation corn. This is due to the comparatively low fertilizer application rates for rotation corn.

The effects of drainage position were similar for continuous corn (table 6). The average yield of 72.3 bushels per acre obtained from plots in the upper drainage position is significantly higher than an average yield of 49.4 bushels per acre[10] obtained for the lower position.

The use of eight fertilizer treatments in the continuous corn permits a better evaluation of the effect of higher nitrogen application rates to offset the changed environment in the lower drainage position. To study the 8 degrees of freedom associated with P within C and F, the 8 single degrees of freedom are shown in two forms in table 2. The first division shows the effect of drainage position within each individual fertilizer treatment. The result shows that, within each fertilizer treatment, there is a significant difference (1-percent level) between the upper and lower position. The result of this analysis, however, does not present information relative to the magnitude of the

[9] $3{,}687.1/36 = 102.5$; $2{,}907.6/36 = 81.0$.

[10] $1{,}735.7/24 = 72.3$; $1{,}186.3/24 = 49.4$.

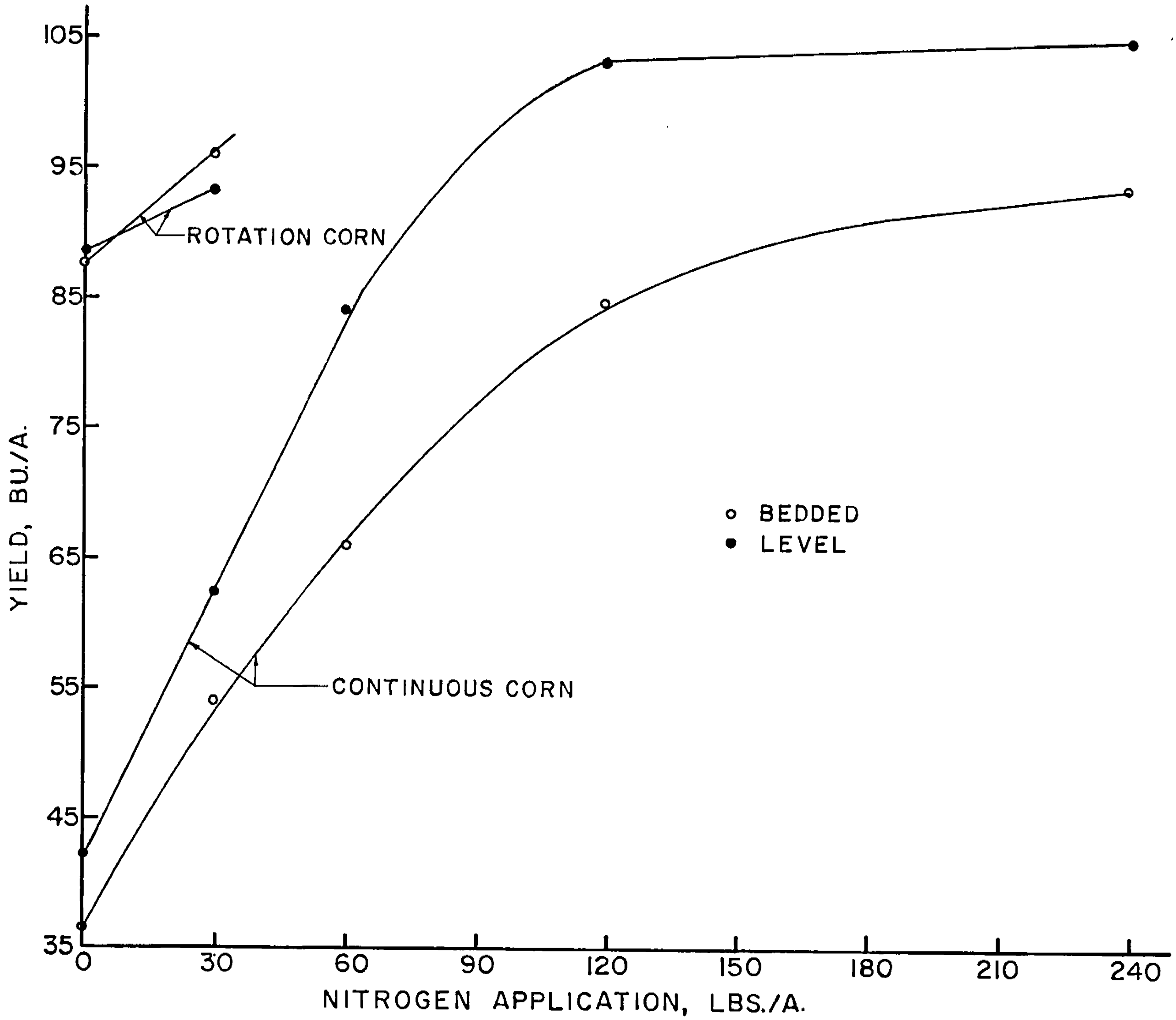



Fig. 2. Six-year average corn yields for bedded and level plots.

difference between the upper and lower yields as higher levels of nitrogen are applied. The other division which includes the interaction of linear nitrogen with position within column 2 ($N_{1a} \times P/C_2 = 329.89$) shows this interaction to be significant at the 1-percent level. As a result, it is known that the slope of a straight line which shows the yield response to level of nitrogen application is significantly different for the upper and lower drainage positions. For a quantitative evalution of the difference, table 6 shows the difference in the totals for treatments 6 and 7, and 7 and 8. Average yields (rounded to the nearest bushel) with 60, 120 and 240 pounds of nitrogen are 82, 97 and 98 bushels per acre, respectively, on the upper position of the beds as compared with 50, 73 and 88 bushels per acre on the lower position.[11] Therefore, the yield increase from 120 to 240 pounds of nitrogen was 14 bushels more on the lower than on the upper positions.[12] This indicates that the higher nitrogen application rate was instrumental in offsetting the changed environment in the lower drainage position.

## DRAINAGE; EFFECT OF NITROGEN LEVEL ON YIELD

The results of the linear, quadratic and cubic nitrogen analyses are nearly the same for the bedded plots as the analyses which pooled the data from both the bedded and level plots. This conclusion follows by noting that the percent reduction in total sum of squares due to the linear and quadratic nitrogen effect is nearly the same for both cases (compare the sum of $N_{1a} + N_{2a}$ to the sum of

[11] $245.4/3 = 81.8$; $290.1/3 = 96.7$; $292.5/3 = 97.5$; $151.3/3 = 50.4$; $217.7/3 = 72.6$; $264.9/3 = 88.3$.

[12] (98-97) minus (88-73) = 14.

$N_{1a} + N_{2a} + N_{3a}$ in both tables 1 and 2). Therefore, since the computation using the data from both bedded and level plots showed the yield to be a straight line function of the logarithm of the nitrogen application rate, it may also be concluded that the yield response on the bedded plots approaches a straight line function of the logarithm of the nitrogen application rate. The response slopes for nitrogen were computed for the data from the bedded plots. This analysis was made for continuous corn using the data from fertilizer treatments 4 through 8. The results are shown in table 8.

TABLE 8. YIELD INCREASE PER POUND OF NITROGEN ADDED ON BEDDED PLOTS; CONTINUOUS CORN

| Nitrogen level (lb./A.) | Response slope (bu. corn yield/lb. N.) |
|---|---|
| 0-30 | 0.565 |
| 30-60 | 0.384 |
| 60-120 | 0.308 |
| 120-240 | 0.070 |
| av. (30-240) | 0.154 |

## SUMMARY AND CONCLUSIONS

Surface drainage (bedding) is not feasible on a planosol soil (claypan soils of flat lands) for conditions comparable to those described in this experiment, which include 100-foot-wide beds, 0.15 percent grade in the channel and tillage operations performed at right angles to the channel grade. A summary for the years 1954 through 1959 shows that the average corn yield was higher on some of the bedded plots than on the level plots, while, in other cases, there was a yield depression in the bedded plots. The magnitude of the difference between the level and bedded plots is dependent upon the type of cropping system used. The yield on the bedded plots was depressed about 12.5 percent in the continuous corn system, while, in the COM rotation, a slight (2 percent) increase in yield was obtained.

The results also show that within the continuous corn plots, the difference in yields between the bedded and level plots is significantly greater for the higher rates of nitrogen application (30, 60, 120 and 240 pounds per acre) than for the lower fertilizer rates (0, 30 pounds per acre nitrogen and phosphorus factorial). The 6-year period is considered a fair test of the effect of bedding on yields since it contained years with wide differences in precipitation amounts. The amount of precipitation recorded at the experimental plots for the period April through August varied from 12.41 inches in 1956 to 23.6 inches in 1958. The long-term mean for this period is 19.12 inches of precipitation.

Within the bedded plots, the corn yields vary with respect to the position of the sampled area on the bed. Disturbing and removing the topsoil to build up the crown or top of the bed, as well as year-to-year climatic factors, influence the corn yields. When averaged over the 6-year period, the yield was much lower in the lower portion of the bed which is adjacent to and a part of the channel for the bedding system. The average differences in yield between the two positions are 21.5 bushels per acre and 22.9 bushels per acre, respectively, for rotation corn and continuous corn. These differences reflect a 22-percent and 34-percent reduction in yield in the lower position. The data also show that the higher rates of nitrogen are effective in offsetting the detrimental effects of the poorer environment in the lower position of the beds. A statistical test shows that, if yield were plotted as a function of increasing nitrogen application, the differential increase in yield for the higher nitrogen applications is greater in the lower than in the upper position of the bed.