PROGRESS REPORT NO. 1

BY EARL M. KROTH AND JOHN P. DOLL

# Response Of Corn Yields To Nitrogen Fertilization And Plant Population In Missouri, 1961

UNIVERSITY OF MISSOURI

AGRICULTURAL EXPERIMENT STATION

SPECIAL REPORT 13 MARCH, 1962

ACKNOWLEDGEMENTS

This report is a joint contribution of the Department of Soils and the Department of Agricultural Economics of the Missouri Agricultural Experiment Station. It is a progress report of Research Project 455, "The Economics of Fertilizer Use on Corn in Missouri." E. M. Kroth is an Assistant Professor of Soils; J. P. Doll is an Assistant Professor of Agricultural Economics.

Professors C. M. Woodruff, G. E. Smith, W. E. Decker, and T. R. Fisher of the Soils Department contribute significantly to this project. Professor Decker supplied the climatological data. The experimental work was directed by Earl L. Barnes, Theo M. Dean, Melton H. Brown and James A. Roth.

# RESPONSE OF CORN YIELDS TO NITROGEN FERTILIZATION AND PLANT POPULATION IN MISSOURI, 1961

Earl M. Kroth and John P. Doll

In 1960, Missouri farmers raised 224 million bushels of corn; their average yield was 53 bushels per acre. Research results suggest that this yield could be doubled through the use of sufficient fertilizers and appropriate management practices. The 1959 Agricultural Census reported that Missouri farmers used an average of 215 lbs. of fertilizer per acre. Because of the importance of fertilization in crop production, Research Project 455, "The Economics of Fertilizer Use on Corn in Missouri," was instituted to provide additional information useful in determining efficient and profitable rates of fertilization.

The experiments reported here are the first of a series designed to determine the response of major crops to rates of fertilization for soil and climate conditions in Missouri. They were conducted to relate corn yield response to nitrogen and plant population. Seven rates of nitrogen and four plant populations were used. Quantities of potash, phosphorus and lime were applied at each location so that plant nutrients other than nitrogen would not limit yields. The quantities applied were calculated from results of soil tests.

The 1961 growing season was favorable for corn production at all locations. The highest single plot yield in any experiment, 163.5 bushels per acre, was recorded for the experiment at the Southeast Missouri Research Center at Portageville; this experiment also had the highest average treatment yield, 144.1 bushels. In general, yields were high at all locations. Only the experiment on the Bradford Experimental Farm at Columbia failed to produce yields over 100 bushels per acre.

Some difficulty was encountered in obtaining desired plant populations. For this reason, plant population may have limited yields, particularly for the experiments in Saline County, Columbia, and Portageville. The 200 pound application of nitrogen was the highest utilized in these experiments. For this growing season, it appeared that even higher nitrogen rates could have been applied. At Portageville, the 200 pound rate of

Table 1. Climatological data from weather recording stations nearest the experimental sites.

| Location | Total Rainfall Inches* | No. Days With Rain May | June | July | Aug. | Sept. 15 | Dry Periods*** | Avg. Temp. | Departure From Normal | No. of Days 90° or More 1961 | Avg. | No. of Days 100° or More 1961 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spickard | 28.82 | 6 | 8 | 10 | 7 | 4 | 5/18-6/7 | 68.6 | -3.8 | 13 | 44 | 0 |
| Marshall** | 27.63 | 7 | 6 | 14 | 5 | 3 | 5/18-6/8;6/16-7/1 | 72.0 | -0.7 | 32 | 39 | 0 |
| Columbia | 24.43 | 8 | 9 | 14 | 9 | 4 | --- | 70.7 | -1.9 | 21 | 39 | 0 |
| Portageville | 18.26 | 10 | 7 | 15 | 5 | 7 | 6/22-7/12;8/7-8/22 | 74.1 | -1.9 | 45 | 51 | 0 |

*May 1 to September 15.

**Rainfall at the experimental site (8 miles west of weather station) after corn was planted; May, 0.20; June, 5.09; July, 7.56; August, 11.20; September 15, 8.45.

***Dry Period: At least 15 consecutive days with less than 0.25 in precipitation.

Table 2. Results of test on soil samples from the experimental sites.

| Location | Soil Type | O.M. % | $P_2O_5$ lbs/A | K lbs/A | Mg lbs/A | Ca lbs/A | PH $H_2O$ | PH Salt | Total Hydrogen Me/100g |
|---|---|---|---|---|---|---|---|---|---|
| Spickard | Seymour s. l. | 4.3 | 163 | 292 | 448 | 4920 | 6.0 | 5.4 | 5.0 |
| Marshall | Marshall s. l. | 3.2 | 131 | 595 | 665 | 4940 | 6.3 | 5.7 | 2.8 |
| Columbia | Mexico s. l. | 2.4 | 131 | 190 | 283 | 3660 | 6.2 | 5.6 | 3.0 |
| Portageville | Dubbs sandy l. | 1.9 | 343 | 487 | 360 | 3620 | 6.8 | 5.7 | 2.3 |

nitrogen caused substantial increments in yield above the next lower rate. The results presented here are for one growing season only and are given as a progress report.

## EXPERIMENTAL PROCEDURE

### Locations

The same basic experiment was conducted at four locations: the North Missouri Agricultural Research Center near Spickard, Missouri; the A. H. Orr farm near Malta Bend in Saline County; the Bradford Experimental Farm at Columbia, Missouri; and the Southeast Missouri Research Center, Portageville, Missouri. Climatological data for each location are given in Table 1.

### Field Design

A complete factorial was imposed on a randomized block split-plot design . Four levels of plant population were whole plot treatments. Seven nitrogen rates were applied to subplots within whole plots. Appropriate randomization procedures were used. This design estimates the main effects of plant population less precisely than main effects of nitrogen or the nitrogen-plant population interaction. Three replications were used.

### Soil Fertility Levels

Soil tests were made on each of the experimental sites. Results of these tests are given in Table 2.

### Soil Moisture Measurements

Soil moisture measurements were made at Columbia and the Orr farm using the neutron moisture meter. It is intended that eventually such measurements will be made at all sites.

### Nitrogen Applications

The nitrogen levels applied were 0, 25, 50, 75, 100, 150, and 200 pounds per acre. With the exception of Portageville, all nitrogen was plowed down in the spring. At Portageville, because of the nature of the soil, 50 pounds of the 150 pound and 100 pounds of the 200 pound rate were sidedressed.

### Plant Population

Plant populations were thinned to desired levels after emergence. Where possible, counts were obtained at harvest time; suckers were not counted. In general, difficulty was experienced in reaching the high plant population levels desired.

### Yield

The plots were harvested by hand. Dropped ears were included in yield calculations. Moisture determinations were made in the standard manner. Yields are on the basis of shelled corn and adjusted to a 15.5 percent moisture content.

Discussion of Statistical Measures Presented

To aid in the interpretation of the treatment means, two techniques of experimental statistics are utilized. They are the least significance difference (L.S.D.) and the analysis of variance. Each of these techniques, when properly interpreted, can be used to obtain valuable information about the experimental data.

Because of the nature of experimentation, most experimental measurements are subject to error. The valid experiment, however, is one in which the size of the error can be estimated. Once estimated, this error, defined as the variability among plots treated alike, can be used to determine whether differences among treatment means are due to the treatments applied or to "normal" variability among the soil plots.

The "analysis of variance" can be used to estimate error inherent in an experiment. The split-plot designs utilized in these experiments have been analyzed using the analysis of variance technique; the results are presented in tables along with other relevant data for each experiment. Because of the nature of the split-plot design, two "error variances" must be estimated for each experiment. One, Error (a), estimates the error variance among the whole plot (plant population) treatments while the other, Error (b), estimates the error variance among the sub-plot (nitrogen) treatments. These variances may be found in the columns labelled "M.S." in the analysis of variance tables. An indication of the relative variation in the experiments can be gained by considering the size of the error variances of the four experiments. Do not, however, interpret the error variances in bushels per acre.

The error variance can be used to determine whether the treatments caused yield increases (or decreases) over and above the inherent variability in the experiment. For example, consider, in Table 4, the number in the column marked "M.S." and the row labelled "Plant Population." This number, 2623.29, is marked with two asterisks to indicate that the effects of plant population on corn yield were "significant," i.e., important differences exist over and above the error inherent in the experiment. One asterisk on the number, for example see Table 8, indicates that the treatment effect was considered significant but to a lesser degree. The absence of an asterisk indicates that significant effects could not be detected.

Only the treatment effects, nitrogen, plant population and their interaction (Nitrogen X Plant Population) are tested for significance. The significance of the interaction term in Table 4 has special meaning. Because nitrogen and plant population interact in this experiment, nitrogen effects cannot be interpreted without first specifying a plant population level and visa versa.

The least significant differences are presented below each table of treatment means. Again, because of the nature of the split plot design, the L.S.D. for plant population and the L.S.D. for nitrogen must be computed separately. The L.S.D. are based on the error variances of the experiments and therefore vary among experiments.

The L.S.D. is measured in units of bushels of corn. For example, the L.S.D. for nitrogen means in Table 3 is 6.0 bushels of corn. It has this interpretation: If two nitrogen means were selected at random and compared, their difference would have to be greater than 6 bushels to be significant. The L.S.D. is an attempt to reflect, in terms of bushels, the variability inherent in the experiment; it should not be used to

compare all possible treatment means in a search for "significant" results.

The probability levels quoted for both the L.S.D. and the variance tests for treatment effects, i.e., the 0.05 or 0.01 probability level, indicate the percent of times the tests will show significant differences when they do not actually exist. The L.S.D. for nitrogen in Table 3 is 6.0 bushels; the probability level of 0.05 associated with this L.S.D. means that two nitrogen treatments that are exactly alike may be judged to be different five times out of 100 due to the chance variability in the experiment.

## NORTH MISSOURI RESEARCH CENTER
## SPICKARD, MISSOURI

The experiment was conducted on Seymour silt loam that had been in corn for the past four seasons. Precipitation during the growing season was high. Extremely heavy rains occurred in June and July, some accompanied by high winds that broke stalks in the low population plots. The corn was planted June 2 and harvested October 4. The results are presented in Tables 3 and 4 and Figure 1. Intended plant populations per acre were: 9,000, 12,000, 15,000, and 18,000. Variety: Dekalb 423.

Table 3. Treatment means for experiment conducted at the North Missouri Agricultural Research Center, Spickard, 1961. Bushels per acre.

| No. of Plants Per Acre | Pounds of Applied Nitrogen Per Acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 150 | 200 |
| 8,404 | 70.3 | 69.0 | 65.1 | 68.6 | 71.4 | 71.4 | 68.5 |
| 11,164 | 81.1 | 79.5 | 81.0 | 88.9 | 90.2 | 90.7 | 92.9 |
| 16,324 | 71.1 | 77.5 | 94.6 | 100.2 | 105.8 | 113.8 | 108.0 |
| 19,024 | 52.9 | 73.2 | 83.9 | 97.2 | 96.9 | 104.5 | 102.6 |

L.S.D. for plant population (0.05 probability level): 9.5

L.S.D. for nitrogen treatment (0.05 probability level): 6.0

Table 4. Analysis of variance for experiment conducted at the North Missouri Agricultural Research Center, Spickard, 1961.

| Source | d.f. | S.S. | M.S. |
|---|---|---|---|
| Replications | 2 | 914.45 | 457.23 |
| Plant Population | 3 | 7869.88 | 2623.29** |
| Error (a) | 6 | 954.29 | 159.05 |
| Nitrogen | 6 | 7140.96 | 1190.16** |
| Nitrogen X Plant Population | 18 | 4448.33 | 247.13** |
| Error (b) | 48 | 2531.27 | 52.73 |
| Total | 83 | 23859.18 | |

**Significant at the 0.01 probability level.

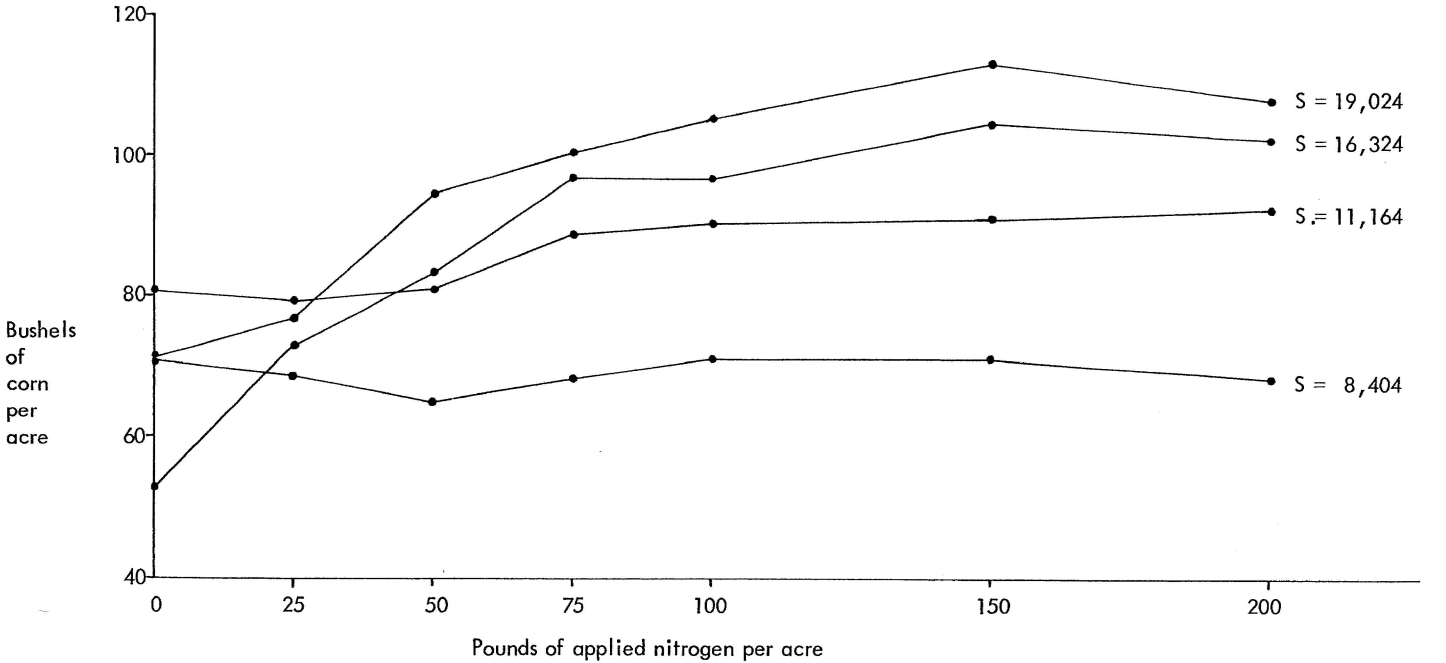


Figure 1. Response of Corn Yield to Nitrogen Applications. North Missouri Agricultural Research Center, Spickard, 1961. (S indicates plant population.)

## SALINE COUNTY, MISSOURI

This experiment was conducted on Marshall silt loam that had been in corn for the past three seasons. Climatic conditions were nearly ideal for the entire growing season. The experiment was planted May 23 and 24 and harvested on October 14. The results are presented in Tables 5 and 6 and Figure 2. Intended plant populations per acre were 9,000, 12,000, 15,000, and 18,000. Actual populations were somewhat below these figures. Variety: Kansas 1639.

Table 5. Treatment means for experiment conducted in Saline County, Missouri, 1961. Bushels per acre.

| No. of Plants Per Acre | Pounds of Applied Nitrogen Per Acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 150 | 200 |
| 9,000 | 77.6 | 84.2 | 89.3 | 89.2 | 100.0 | 96.9 | 90.6 |
| 12,000 | 75.4 | 88.6 | 97.7 | 96.2 | 100.5 | 102.0 | 99.2 |
| 15,000 | 80.0 | 94.1 | 101.5 | 106.6 | 107.0 | 112.4 | 110.8 |
| 18,000 | 78.8 | 90.7 | 99.0 | 102.6 | 107.8 | 110.8 | 114.6 |

L.S.D. for plant population (0.05 probability level): 10.7

L.S.D. for nitrogen treatment (0.05 probability level): 5.8

Table 6. Analysis of variance for experiment in Saline County, Missouri, 1961.

| Source | d.f. | S.S. | M.S. |
|---|---|---|---|
| Replication | 2 | 345.89 | 172.94 |
| Plant Population | 3 | 2024.65 | 674.88 |
| Error (a) | 6 | 1211.65 | 201.94 |
| Nitrogen | 6 | 705[illegible].34 | 1175.72** |
| Nitrogen X Plant Population | 18 | 664.52 | 36.92 |
| Error (b) | 48 | 2385.19 | 49.69 |
| Total | 83 | 13686.24 | |

**Significant at the 0.01 probability level.

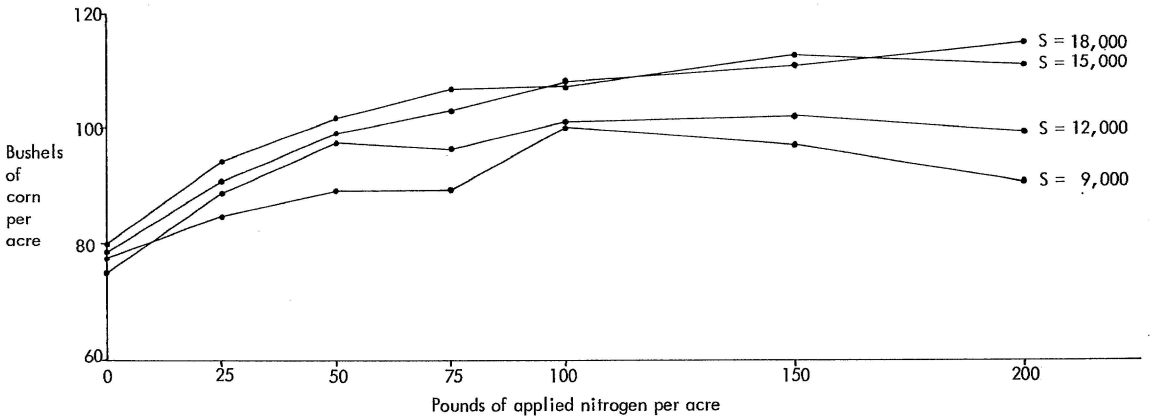


Figure 2. Response of Corn Yield to Nitrogen Applications. Saline County, 1961. (S indicates plant population.)

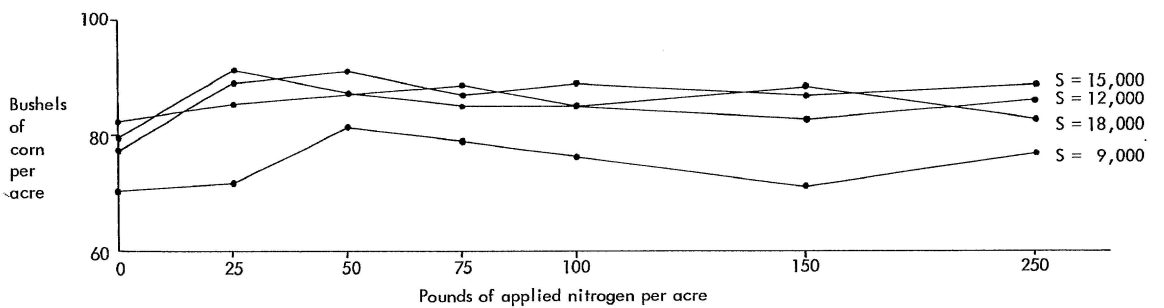


Figure 3. Response of Corn Yield to Nitrogen Applications. Bradford Experimental Farm, Columbia, 1961. (S indicates plant population.)

BRADFORD EXPERIMENTAL FARM
COLUMBIA, MISSOURI

This experiment was conducted on Mexico silt loam that was fallow in 1960, resulting in high available nitrogen on the no nitrogen plots. Rainfall was probably in excess of ideal during the growing season. The corn was planted May 24 and harvested October 3. Stand counts were not obtained at harvest time. The results are shown in Tables 7 and 8 and Figure 3. Intended plant populations per acre were 9,000, 12,000, 15,000, and 18,000. These rates were not obtained due to soil insect damage. Variety: Kansas 1693.

Table 7. Treatment means for experiment conducted on the Bradford Experimental Farm, Columbia, Missouri, 1961. Bushels per acre.

| No. of Plants Per Acre | Pounds of Applied Nitrogen Per Acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 150 | 200 |
| 9,000 | 70.4 | 71.9 | 81.8 | 79.4 | 76.5 | 71.3 | 77.1 |
| 12,000 | 82.3 | 85.8 | 86.8 | 88.8 | 85.2 | 82.9 | 86.1 |
| 15,000 | 77.8 | 89.4 | 91.1 | 87.2 | 89.6 | 87.4 | 89.0 |
| 18,000 | 79.9 | 91.5 | 87.1 | 84.9 | 85.5 | 88.3 | 83.2 |

L.S.D. for plant population (0.05 probability level): 7.0
L.S.D. for nitrogen treatment (0.05 probability level): 4.7

Table 8. Analysis of variance for experiment conducted on the Bradford Experimental Farm, Columbia, Missouri, 1961.

| Source | d.f. | S.S. | M.S. |
|---|---|---|---|
| Replication | 2 | 321.05 | 160.53 |
| Plant Population | 3 | 1846.67 | 615.56* |
| Error (a) | 6 | 523.55 | 87.26 |
| Nitrogen | 6 | 604.99 | 100.83* |
| Nitrogen X Plant Population | 18 | 431.14 | 23.95 |
| Error (b) | 48 | 1611.06 | 33.56 |
| Total | 83 | 5338.46 | |

*Significant at the 0.05 probability level.

SOUTHEAST MISSOURI RESEARCH CENTER
PORTAGEVILLE, MISSOURI

This experiment was conducted on a fine sandy loam soil that had been in cotton for the several years previous. Precipitation during the growing season was high. Because of the sandy nature of the soil, 50 pounds of the 150 pound nitrogen treatment and 100 pounds of the 200 pound nitrogen treatment were sidedressed. The planting rates used in this experiment were higher than those used in the other three. The corn was planted May 16 and harvested September 18. The results are shown in Tables 9 and 10 and Figure 4. Intended plant populations per acre were: 12,000, 15,000, 19,000, and 24,000. Variety: 523 W.

Table 9. Treatment means for experiment conducted at Southeast Missouri Research Center, Portageville, Missouri, 1961. Bushels per acre.

| No. of Plants Per Acre | Pounds of Applied Nitrogen Per Acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 150 | 200 |
| 12,231 | 53.0 | 82.8 | 99.3 | 108.9 | 114.2 | 128.4 | 124.6 |
| 15,251 | 57.1 | 71.5 | 98.7 | 115.9 | 126.5 | 136.6 | 139.1 |
| 19,134 | 41.3 | 74.3 | 99.8 | 106.7 | 117.5 | 129.0 | 136.8 |
| 20,517 | 53.3 | 81.2 | 96.8 | 106.2 | 122.6 | 123.5 | 144.1 |

L.S.D. for plant population (0.05 probability level): 10.0
L.S.D. for nitrogen treatment (0.05 probability level): 8.9

Table 10. Analysis of variance for experiment conducted at Southeast Missouri Research Center, Portageville, Missouri, 1961.

| Source | d.f. | S.S. | M.S. |
|---|---|---|---|
| Replication | 2 | 3423.26 | 1711.63 |
| Plant Population | 3 | 417.99 | 139.33 |
| Error (a) | 6 | 1061.02 | 176.84 |
| Nitrogen | 6 | 65843.65 | 10973.94** |
| Nitrogen X Plant Population | 18 | 1608.44 | 89.36 |
| Error (b) | 48 | 5636.02 | 117.42 |
| Total | 83 | 77990.39 | |

**Significant at the 0.05 probability level.

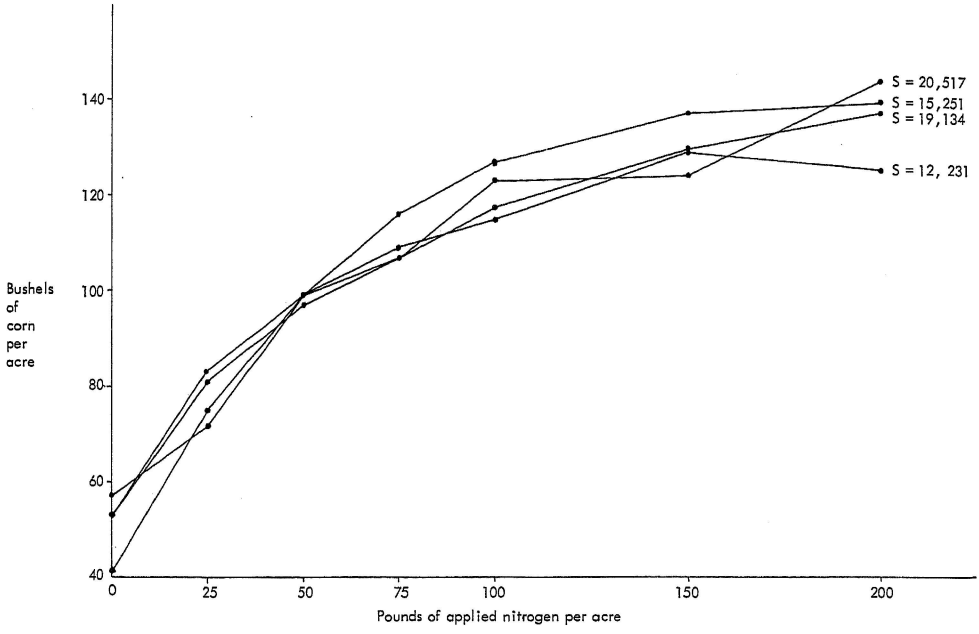


Figure 4. Response of Corn Yield to Nitrogen Applications. Southeast Missouri Research Center, Portageville, 1961. (S indicates plant population.)

## Summary

Adequate plant populations are necessary to use both soil moisture and plant nutrients efficiently. The optimum plant population and fertility level for a given section of the state can only be estimated from several years data. For this reason, extreme care should be taken when interpretating data from a single year's observations. Provisions of Project 455 call for detailed cost-return analysis as additional data become available.