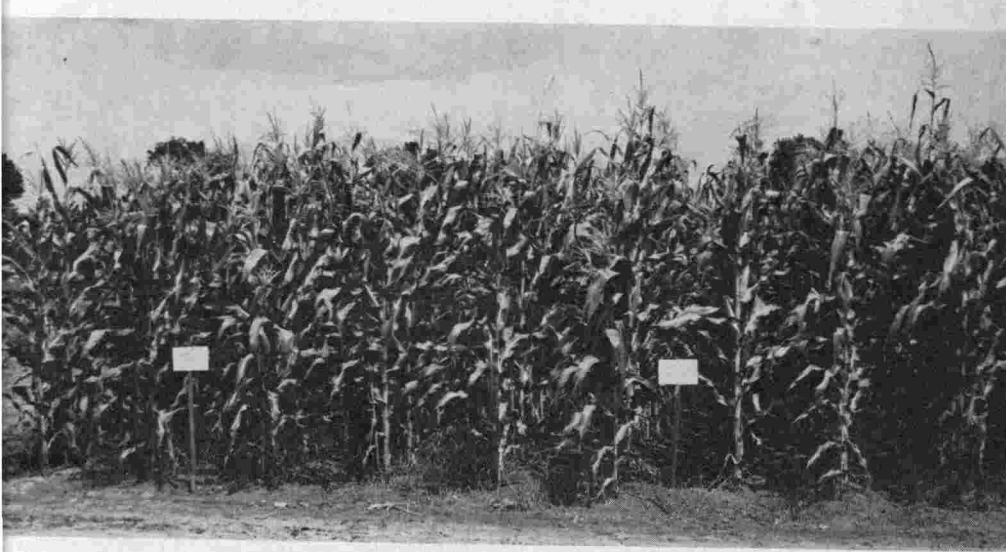
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LETIN 337 DECEMBER 1961

Nitrogen and Plant Population in Corn Production

by
O. H. Long

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The University of Tennessee
Agricultural Experiment Station
John A. Ewing, Director
Knoxville

Foreword

This bulletin replaces Bulletin No. 232, "Nitrogen and Spacing Experiments with Corn," written by the same author and published in 1953, which is now out of print. Since its publication, additional data have been obtained from one of the experiments then in progress, as well as from additional experiments conducted later under the supervision of Frank F. Bell and W. L. Parks. Dr. Bell supervised all the experiments conducted on private farms in Putnam County reported herein, and Dr. Parks was in charge of the later experiments conducted at the various experiment stations.

Certain data from Bulletin No. 232 have been summarized and incorporated in this new publication. This is in order to have in one place most of the information pertaining to the subject under discussion. The new experiments are presented in more detail.

Many people other than the two mentioned above had a part in conducting these experiments. The author wishes to acknowledge the contributions of Robert H. Gibson, who was charged with conducting the spacing experiments in 1955 and 1956 on the Decatur and Huntington soils near Knoxville; Porter L. Russ, who conducted the 1957 experiments in Knox County; and Charles R. Graves and Rural A. Peace, who were responsible for the 1958 and 1960 experiments in Putnam County. Each of these men used the data he obtained as material for his Master's thesis.

The author also wishes to thank the Soil Conservation Service whose personnel helped locate and harvest the experiments in Putnam County; the Tennessee Valley Authority, Division of Agricultural Relations, Soils and Fertilizer Research Branch, for its cooperation in the conduct of some of these experiments; and the National Plant Food Institute for grants in the conduct of other experiments.

FRONT COVER: One of the nitrogen, plant-population experiments reported in this publication. High yields of corn are the result of many factors, including proper soil selection, an adapted hybrid with the right stand of plants, adequately fertilized.

Summary and Conclusions

- In this publication the results from more than 175 separate experiments with corn have been presented and discussed. Only those experiments in which nitrogen and/or spacing variables were studied have been included.

- These experiments cover a period of over 50 years—1907 to 1960. They were conducted under a wide variety of soil, climatic, and fertility conditions; in years of adequate rainfall and extreme summer droughts; and from Greeneville in upper East Tennessee to Union City in the extreme northwestern part of the State.

- Yields ranged from less than 15 bushels per acre under unfertilized conditions on a soil with restricted internal drainage to as much as 170 bushels on a highly fertilized, well-drained bottom soil.

- The data presented in this publication clearly indicate that corn population must be adjusted to the soil and its productivity level. A good rule-of-thumb is to allow 100 plants for each bushel of expected yield. For example, 6,000 plants should be provided for a 60-bushel yield, or 10,000 plants for a 100-bushel yield.

- In most instances a stand not exceeding 12,000 to 15,000 plants per acre, fertilized with nitrogen at a rate between 90 and 120 pounds of N, appeared to be adequate for the full-season prolific hybrids used in these experiments. Higher plant populations not only resulted in no improvement in yield, but also they increased the lodging problem.

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Nitrogen and Plant Population in Corn Production

by
O. H. Long

Introduction

The importance of nitrogen in corn production is generally recognized. It is also recognized that the more productive the soil, the closer the plants should be spaced in order to obtain maximum yields. But what is the correct spacing on a given soil? Should the various hybrids be spaced differently for maximum production? How much nitrogen can be economically applied? What is the effect of dry weather on corn at different spacings? How much is corn benefited by irrigation in dry seasons? The results reported in this publication will help in answering some of these questions.

In confining the discussion to nitrogen it is not intended to minimize the importance in corn production of the other plant nutrients, such as calcium, phosphorus, and potassium. If the soil is acid, it is important that lime be added; if it is low in phosphorus and potassium, these deficiencies must be corrected by fertilizing with the required amounts of these elements. Corn's phosphate and potash requirements, however, are not as large as its nitrogen requirement. It has been estimated that a 100-bushel corn crop

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contains 160 pounds of nitrogen (N), 55 pounds of phosphoric acid (P_2O_5), and 110 pounds of potash (K_2O) in its various plant parts (6).

Results of Plant Population Studies In Other States

Many experiments on the spacing of corn have been conducted in recent years. Frequently populations up to 24,000 plants per acre have been recommended, based on experiments conducted largely in the Corn Belt. In Illinois, Lang *et al.* (9), in testing nine corn hybrids on a highly productive soil, obtained the highest average yield (117.7 bushels) with a stand of 20,000 plants per acre. Summer moisture conditions were about average in the 2 years these experiments were conducted. They showed that the different hybrids responded differently both to nitrogen levels of the soil and to plant populations. Experiments in Iowa (3) showed that the best yield on a highly fertile soil was obtained with a stand of 24,000 plants. But these experiments in Illinois and Iowa were conducted with hybrids quite different from those used in Tennessee and under different soil and climatic conditions.

More applicable to Tennessee conditions are the results from the Southeastern States where the hybrids, soils, and climate are more nearly comparable. On the basis of experiments conducted in North Carolina (7), Georgia (1), Mississippi (6), and Arkansas (4), populations between 10,000 and 16,000 plants per acre are most commonly recommended. Most of the adapted corns in the South are prolific; that is, they tend to produce more than one ear to the stalk. On the other hand, most corns grown in the Corn Belt tend to be single-eared. The South is fortunate in having prolific corns which have considerable elasticity in their yielding ability under different soil and weather conditions. Even if the stands are only approximately right, these corns will put on more ears under favorable conditions and fewer ears under adverse ones. There is also the problem of lodging which is accentuated at the closer spacings. This problem will be discussed in other sections of this publication.

Early Experiments In Corn Spacing In Tennessee

Experiments on alluvial soil at Knoxville.—In 1921, Mooers (11) published the results of some Tennessee experiments in which the distance between plants varied, but in which the number of plants

per acre (8,000) was the same. He planted corn in checks 28 inches, 39.6 inches, and 48.5 inches apart, leaving 1, 2, and 3 plants, respectively, per hill. The acre yields, as an average of a 5-year period, were essentially the same with the 1-, 2-, and 3-plant hills. However, when he compared the same plant population in 3½-foot and 7-foot rows, the yields were appreciably higher with the 3½-foot rows (85.5 versus 72.9 bushels per acre). He summarized this work as follows:

> The general conclusion seems warranted, therefore, that the best results in practice will probably be obtained with a width of row which permits the satisfactory use of tillage implements but allows the determined number of plants to be as widely spaced as possible.

Spacing experiments at two levels of fertility at Jackson.—A corn variety-spacing experiment was conducted on Olivier silt loam at the West Tennessee Experiment Station, Jackson, during the 18-year period 1932-1949. The Olivier soils are only moderately well-suited to corn because of restricted internal drainage due to the presence of a pan in the subsoil. In this experiment corn was planted every year on two ranges of land separated only by a roadway. One range received no fertilizer for 15 years. On the other range, farm manure was applied every year at a rate of approximately 10 tons per acre. Nitrate of soda also was applied as a side-dressing at a rate of 100 to 200 pounds per acre to the corn on the manured range. The entire area was level, but the soil was not uniform, chiefly because of differences in internal drainage; however, one range appeared to be about as uniform as the other.

Both open-pollinated and hybrid corns were used and, while some changes were made in the entries each year, the varieties were the same on both ranges in any given year. However, the open-pollinated variety, Jellicorse, was in the experiment every year and its average performance at three plant populations under unfertilized and fertilized conditions is shown in Table 1.

Table 1. Acre Yields of Corn (Jellicorse variety) at Various Plant Populations on Olivier Silt Loam at Two Levels of Fertility, West Tennessee Experiment Station, Jackson, 1932-1949.

Plants per acre			Plants per acre		
3,000	4,200	5,400	5,400	6,600	7,800
Range 10—Unfertilized[1] (Bushels per acre)			Range 11—Manured and nitrated[2] (Bushels per acre)		
18.0	16.2	14.6	65.6	73.6	70.9

[1] 15-year average, 1932-1946.
[2] 18-year average, 1932-1949.

The populations were 3,000, 4,200, and 5,400 plants per acre on the unfertilized range, and 5,400, 6,600, and 7,800 plants on the range that received manure. The spacing of plants to provide such populations, along with some other populations to be presented later, is shown in Table 2.

Table 2. Required Spacing in the Row at Different Row Spacings to Provide Various Plant Populations.

(Spacings in the row to the nearest inch)

Plants per acre	Spacing in row for row spacings of:		
	36"	40"	42"
	Inches	Inches	Inches
3,000	58	52	50
4,200	41	37	36
5,400	32	29	28
6,600	26	24	23
8,000	22	20	19
12,000	15	13	12
16,000	11	10	9
20,000	9	8	7
24,000	7	7	6
28,000	6	6	5

On the unfertilized range the highest yield (18.0 bushels) was made at the lowest population (3,000 plants per acre). It is recognized that these results are not too meaningful because, even at the best spacing, the yields are too low for profitable corn production. They are cited chiefly to show that plant population must be adjusted to the productivity level of the soil.

On the manured and fertilized range the highest yield (73.6 bushels) was made at the 6,600-plant rate, a yield about four times greater than that obtained on the unfertilized range.

In Figure 1, the yearly average yields of all varieties at the three spacings are indicated by line drawings. Yields on the manured range fluctuated considerably, falling to a low of 40.5 bushels per acre in the dry summer of 1936 and reaching a peak of 94.2 bushels in 1940, a year characterized by adequate rainfall in mid-July when the corn was silking and tasseling. The average yield for the 18-year period was 62.1 bushels per acre.

On the other hand, yields on the unfertilized range declined sharply after the first 2 years and remained fairly constant thereafter. The average yield during the 15-year period, 1932-1946, was 15.6 bushels per acre. Note that in 1940—the year of maximum yield on the manured land—the yield on the unfertilized land was

only about 5 bushels greater than the average. This clearly demonstrates that the chief limiting factor on this area was something other than water.

Particular attention is called to the much higher yields obtained in 1947 and 1948 on certain plots on this previously-unfertilized range. Yields of 42.2 bushels in 1947 and 69.9 bushels in 1948 are indicated by the broken line on the graph. These yields were obtained by applying 60 pounds of N per acre to a stand of 5,400 plants in 1947 and 90 pounds of N to a stand of 6,600 plants in 1948.

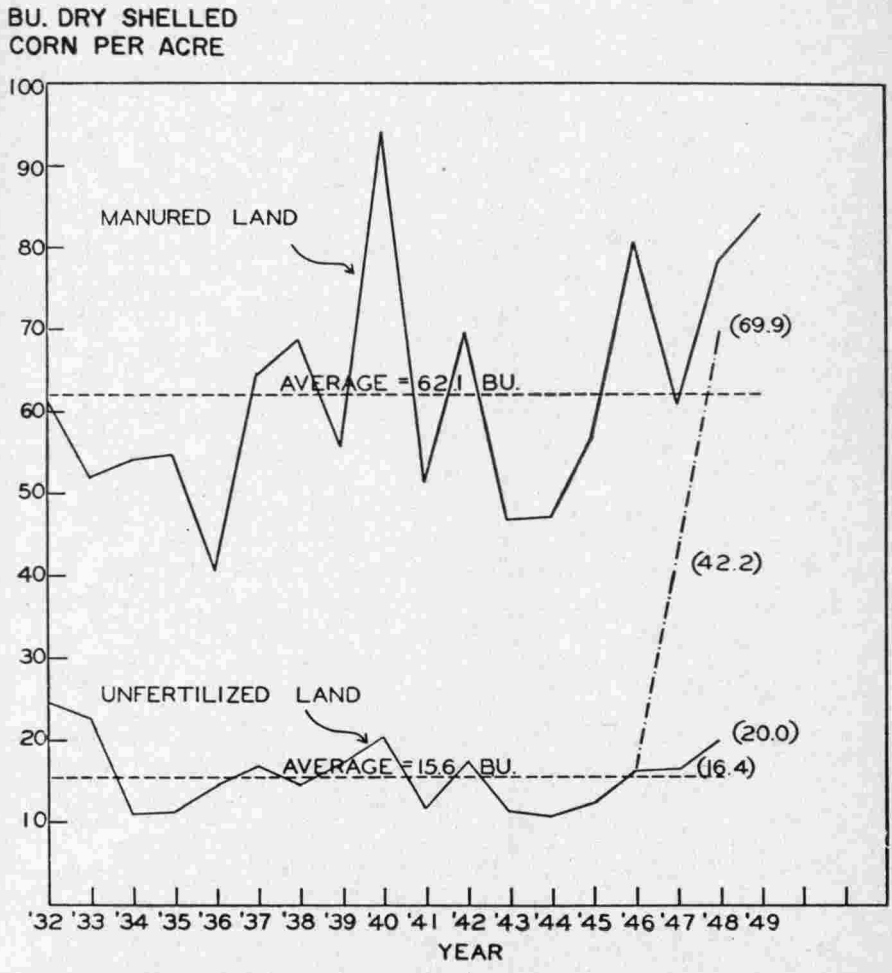


Figure 1. Comparison of corn yields on manured and unfertilized land. (Yields are averages of 5,400, 6,600, and 7,800 plants per acre on manured land and averages of 3,000, 4,200, and 5,400 plants on unfertilized land. Corns were the same on both areas.)

Soil tests had indicated adequate amounts of phosphate and potash.

That yields such as these cannot be attributed to seasonal effects is demonstrated by the fact that the plots which received no nitrogen produced only 16.4 bushels in 1947 and 20.0 bushels in 1948. These yields are indicated by a continuation of the unbroken line on the graph. Thus, on an area that had not been fertilized for 15 years, corn yields were more than doubled in 1947 and more than tripled in 1948 merely by adding nitrogen and adjusting plant spacing. A yield of 69.9 bushels in 1948 compares favorably with a yield of 78.5 bushels on the adjacent range which had received 18 annual applications of 10 tons of manure—a difference of only 8.6 bushels.

Nitrogen-Spacing Experiments With Two Hybrids, 1949-51

Fourteen corn experiments were conducted at widely separated locations in Tennessee during the 3-year period, 1949-1951 to compare two hybrids at different spacings and at different rates of nitrogen fertilization. In these experiments only soils well-suited to corn were selected. Some of the soil series represented were Huntington, Emory, Etowah, Elk, Ennis, and Lintonia—all found either in bottoms or on level terraces. Four were located near Knoxville, three at Jackson, two each at Crossville, Columbia and Springfield, and one at Greeneville. Two corns were planted: Dixie 17, a full-season, white, prolific hybrid; and Kentucky 103, an early-maturing, yellow, single-eared hybrid, typical of those grown in the Corn Belt. Three plant populations were studied, each at three rates of nitrogen. The populations were 8,000, 12,000, and 16,000 plants per acre; rates of nitrogen fertilization were 60, 90 and 120 pounds of N per acre.

The yields as an average of the 14 trials are shown in Figure 2. Dixie 17 equalled or exceeded 100 bushels of corn per acre in 11 of the 14 experiments; its range in yield as a location average was from 74 bushels to 145 bushels. Kentucky 103 equalled or exceeded 100 bushels in only 2 experiments; its range in yield was from 54 bushels to 120 bushels.

Dixie 17 yielded more than Kentucky 103 at all plant rates at all rates of nitrogen in all experiments; Kentucky 103, even at its best, averaged 21 bushels less than Dixie 17 (94 bu. versus 115 bu., fertilized with 90 pounds of N at the 16,000-plant rate).

Under the conditions of these experiments, a population of 12,000 plants per acre appeared to be best; the yield of Dixie 17 was no higher at the 16,000-plant rate and Kentucky 103 only

slightly so. Differences in yield between the 90-pound N rate and the 120-pound N rate, even if real, were not large enough to pay for the extra fertilizer. Even in the highest-producing experiment (on Lintonia soil at Jackson in 1949) Dixie 17 yielded only 7

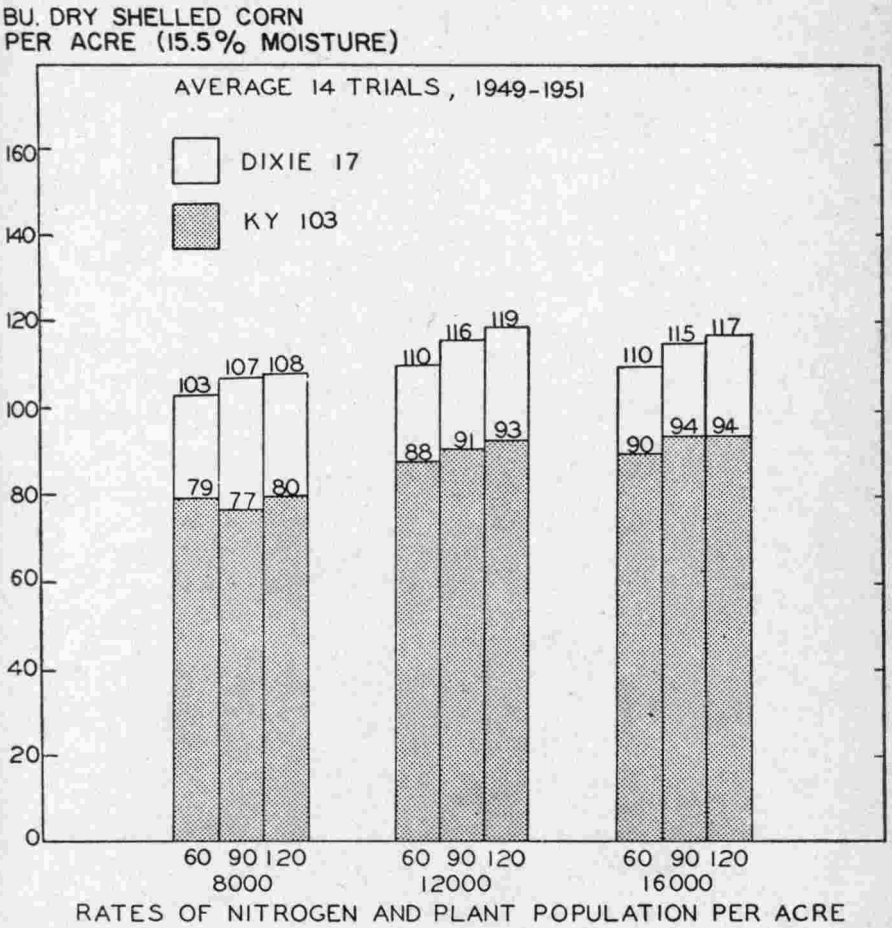


Figure 2. The influence of nitrogen and plant population on yield of corn.

bushels more with an application of 120 pounds of N per acre than with the 90-pound N rate (155 bu. versus 148 bu.). This occurred at the 16,000-plant rate.

Lodging.—Lodging is a serious fault of some corns, particularly when a mechanical picker is used. Lodging was of such a magnitude in some of these experiments that detailed notes were taken in 10 of them. Lodging may be classified into two types: stalk breakage and root lodging. A plant was considered lodged if at

harvest the stalk was broken below the ear, or if the plant was leaning more than 30 degrees from the perpendicular. Therefore, it should not be inferred that the ears of all lodged plants were touching the ground or that they would have been missed by a mechanical picker.

Lodging was much more severe with Dixie 17 than with Kentucky 103. This is shown in graphic form in Figure 3, where the

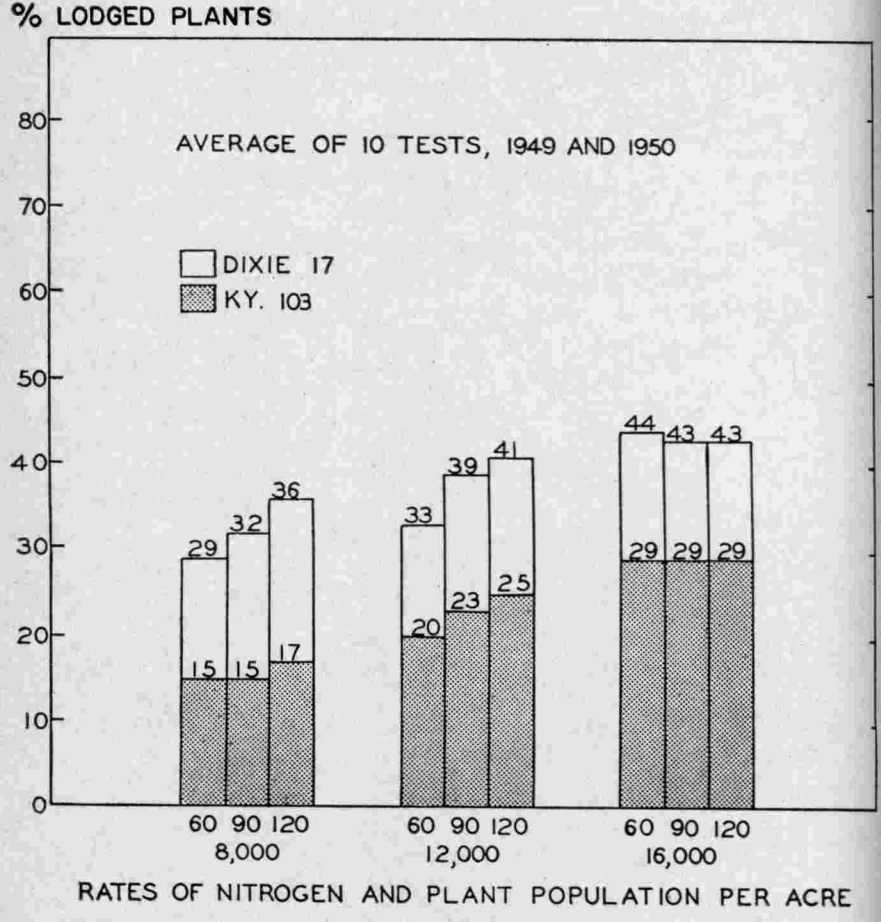


Figure 3. Lodging of corn as influenced by nitrogen fertilization and plant population.

average percent lodging with the two corns is shown at the three plant rates and at the three rates of nitrogen fertilization. At the 8,000- and 12,000-plant rates, the percentage of lodged plants of Dixie 17 was almost twice that of Kentucky 103, and at the 16,000-

plant rate about 50% more. Plant population was more of a factor in lodging than was rate of nitrogen. With both corns at the 16,000-plant rate, the highest rate of nitrogen resulted in no more lodging than occurred with the lowest rate of nitrogen. These findings agree with those obtained in other states (2, 8).

Prolificacy.—The prolificacy (the number of ears per plant) of the two corns is shown in Figure 4. Prolificacy decreased with an increase in plant population. As an average of the 14 tests, Dixie 17

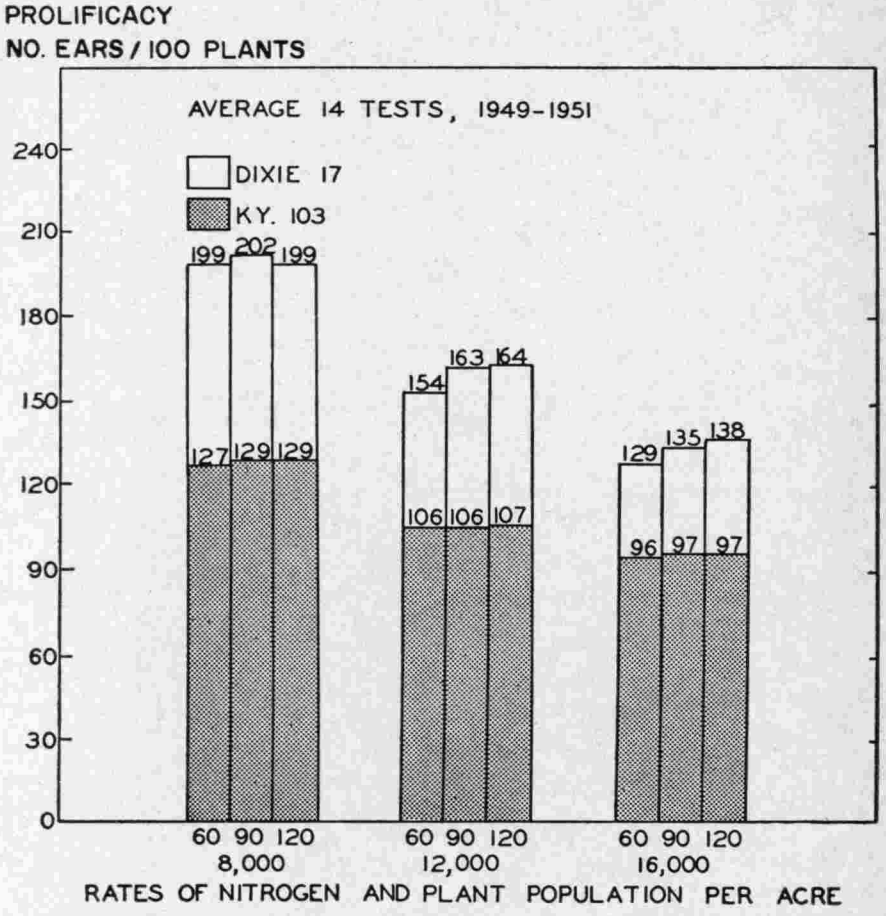


Figure 4. Prolificacy of corn as influenced by nitrogen fertilization and plant population.

produced about 2 ears per stalk (199 to 202 ears per 100 plants) at the 8,000-plant population, about 1.6 ears per plant at the 12,000-plant population, and about 1.3 ears per plant at the 16,000-plant rate. Kentucky 103 averaged about 1.25 ears per stalk at the low-

est plant population and slightly less than one ear per stalk at the highest plant population.

Ear size decreased as plant population was increased. This relationship is shown in Figure 5. About 150 ears of Dixie 17 were required to make a bushel of shelled corn at the 8,000-plant rate,

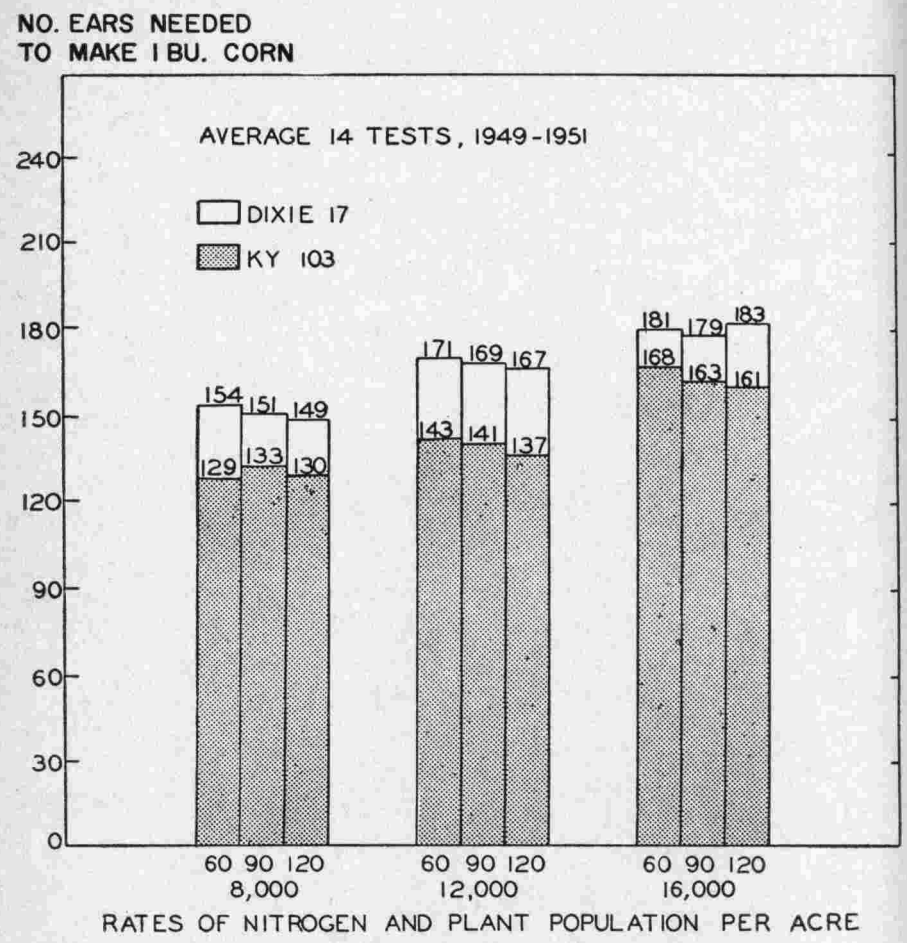


Figure 5. Ear size of corn as influenced by nitrogen fertilization and plant population.

as compared to about 180 ears at the 16,000-plant rate. At a population of 12,000 plants per acre, the average weight of ear (dry) was 0.42 pound, figuring ear corn at 70 pounds to the bushel. This is somewhat less than the ear weight of 0.54 pound which was obtained with the highest yields of single-eared hybrids in the Illinois experiments (9). The ears of Kentucky 103 were larger, the range

being from about 130 ears per bushel at the lowest plant population to about 165 ears at the highest plant population.

Rainfall and Corn Yields

Outlying experiments in East and West Tennessee.—Fourteen corn experiments were conducted in 1946 and 1947 on seven private farms in East Tennessee and on a like number in West Tennessee. Nitrogen was applied at rates of 0, 30, 60, and 90 pounds of N per acre to stands of 5,000, 7,000, and 9,000 plants. These experiments were located on level bottoms, terraces, and uplands where the soils were deep and friable and erosion was no problem. Some of the soils represented were Lindside, Emory, Etowah, and Waynesboro (East Tennessee), and Shannon, Tigrett, Ina, and Memphis (West Tennessee). Tennessee 10 and Dixie 17 were the hybrids planted. Phosphate and potash were applied at rates of 40 pounds of P_2O_5 and 50 pounds of K_2O per acre. All fertilizers were applied in the row and thoroughly mixed before planting; no sidedressing was made.

A rain gauge was installed at each experimental site and the farmer-cooperator kept a daily record of rainfall during the months of June, July, and August. One of the objectives was to correlate corn yields with rainfall. A summary of the results is presented in Table 3.

Table 3. Corn Yields at Various Plant Populations and with Nitrogen at Various Rates in Two Regions of the State, 1946-1947.

Acre yields of dry-shelled corn (15.5% moisture)—average of seven experiments in each region

Plants per acre				
5,000	7,000	7,000	9,000	9,000
Nitrogen applied (pounds per acre)				
0	30	60	60	90
Knox County (East Tennessee) (Bushels per acre)				
61.1	71.2	85.5	87.5	92.1
Carroll, Henderson and Gibson counties (West Tennessee) (Bushels per acre)				
63.2	80.7	86.8	90.4	99.9

There was a remarkable similarity in the yield pattern in the two areas. Corn yields were increased from about 60 bushels per

acre with no nitrogen fertilization on a stand of 5,000 plants to between 90 and 100 bushels where nitrogen was applied at a rate of 90 pounds of N per acre on a stand of 9,000 plants. At the 7,000-plant population, an increase of about 6 to 14 bushels was obtained by increasing the nitrogen application from 30 to 60 pounds of N. Likewise, at the 9,000-plant population a 5- to 10-bushel increase was brought about by raising the nitrogen fertilization from 60 to 90 pounds of N per acre. At the 90-pound N rate on a stand of 9,000 plants the yield was never lower than 75 bushels and reached a maximum of 124 bushels.

Summer rainfall (June, July, and August) was less than normal in 11 of the 14 experiments. Most important is the July rainfall because it is in this month that the ears are being formed. The records indicate that rainfall during this month was less than normal at eight locations—four in each region. At 4 of these 8 locations rainfall in July did not exceed 60% of normal.

These results clearly demonstrate the possibilities of corn production on suitable soils with an adapted hybrid, properly spaced and adequately fertilized, even under conditions of deficient rainfall.

Table 4. Performance of Two Corn Hybrids at Three Populations Each at Three Rates of Nitrogen Fertilization for 5 Years of Continuous Cropping on Lintonia Silt Loam, West Tennessee Experiment Station, Jackson, 1949-1953.

(Yields of dry-shelled corn, 15.5% moisture)

Year	Plant population and pounds of nitrogen applied per acre									Av.
	8,000			12,000			16,000			
	60	90	120	60	90	120	60	90	120	
	DIXIE 17 (Bushels per acre)									
1949	134	138	148	143	148	149	140	148	155	145
1950	126	138	139	130	150	144	125	130	140	136
1951	105	104	106	108	108	110	102	102	106	106
1952	33	40	41	34	35	31	29	40	36	35
1953	87	85	92	96	91	97	89	98	87	91
5-yr. av.	97	101	105	102	106	106	97	104	105	103
	KENTUCKY 103 (Bushels per acre)									
1949	79	75	78	100	100	93	104	107	109	94
1950	84	83	81	92	95	103	97	100	102	93
1951	78	77	74	88	90	91	84	93	90	85
1952	31	33	25	30	23	24	23	23	20	26
1953	74	78	69	82	81	79	83	87	84	80
5-yr. av.	69	69	65	78	78	78	78	82	81	76

Experiments at the West Tennessee Experiment Station, Jackson.—The nitrogen-spacing experiments with two hybrids, which have already been discussed, were continued on the same area of land at Jackson for a period of 5 years. The yields for the first 3 years (1949-1951) were included in the averages shown in Figure 2, but are presented in detail in Table 4 along with the yields for 2 additional years. The soil is Lintonia silt loam.

The 5-year production record at this one location (Table 4) lends further support to the conclusion drawn from the previously-discussed 14 experiments at all locations—that a population of 12,000 plants per acre fertilized with 90 pounds of nitrogen was about right for the hybrid Dixie 17. The average yield for this treatment was 106 bushels of corn per acre. The highest average yield of Kentucky 103 was 82 bushels, which was obtained with a population of 16,000 plants fertilized with 90 pounds of nitrogen, but the yield at this population was only 4 bushels greater than it was at the 12,000-plant rate. The superior yielding ability of Dixie 17 over Kentucky 103 is also clearly demonstrated in this set of experiments; the 5-year average of Dixie 17 was 103 bushels as compared to 76 bushels for Kentucky 103.

A U. S. Weather Bureau Station at the West Tennessee Experiment Station is located only a few hundred feet from the areas where all the experiments were conducted. Here a daily record of temperatures and rainfall is maintained. The rainfall record for the 4-month period, May through August, for the 12-year period 1949-1960, is shown in Table 5.

Table 5. Rainfall Record at the West Tennessee Experiment Station, Jackson, for the 4-Month Period, May through August, for the 12-Year Period, 1949-1960.

Year	May	June	July	August
		Inches of rainfall		
1949	5.52	8.76	3.60	4.92
1950	5.43	3.93	8.44	7.76
1951	0.84	4.76	5.82	2.17
1952	3.09	1.36	1.53	5.32
1953	8.48	3.83	4.13	0.00
1954	3.41	1.22	1.48	1.62
1955	5.05	2.33	12.97	3.01
1956	2.40	5.09	0.88	1.49
1957	5.29	6.85	6.76	2.30
1958	2.66	3.33	3.37	1.03
1959	2.75	4.16	4.71	2.55
1960	2.62	3.68	5.35	2.13
Long-time av.	4.21	4.09	4.63	3.65

The year 1952 was extremely dry; in this year Dixie 17 averaged only 35 bushels per acre and Kentucky 103 only 26 bushels. While it is true that in this dry year the highest yields of both corns were obtained with the lowest plant population (8,000 plants), yields were not appreciably lower at higher plant populations. The year

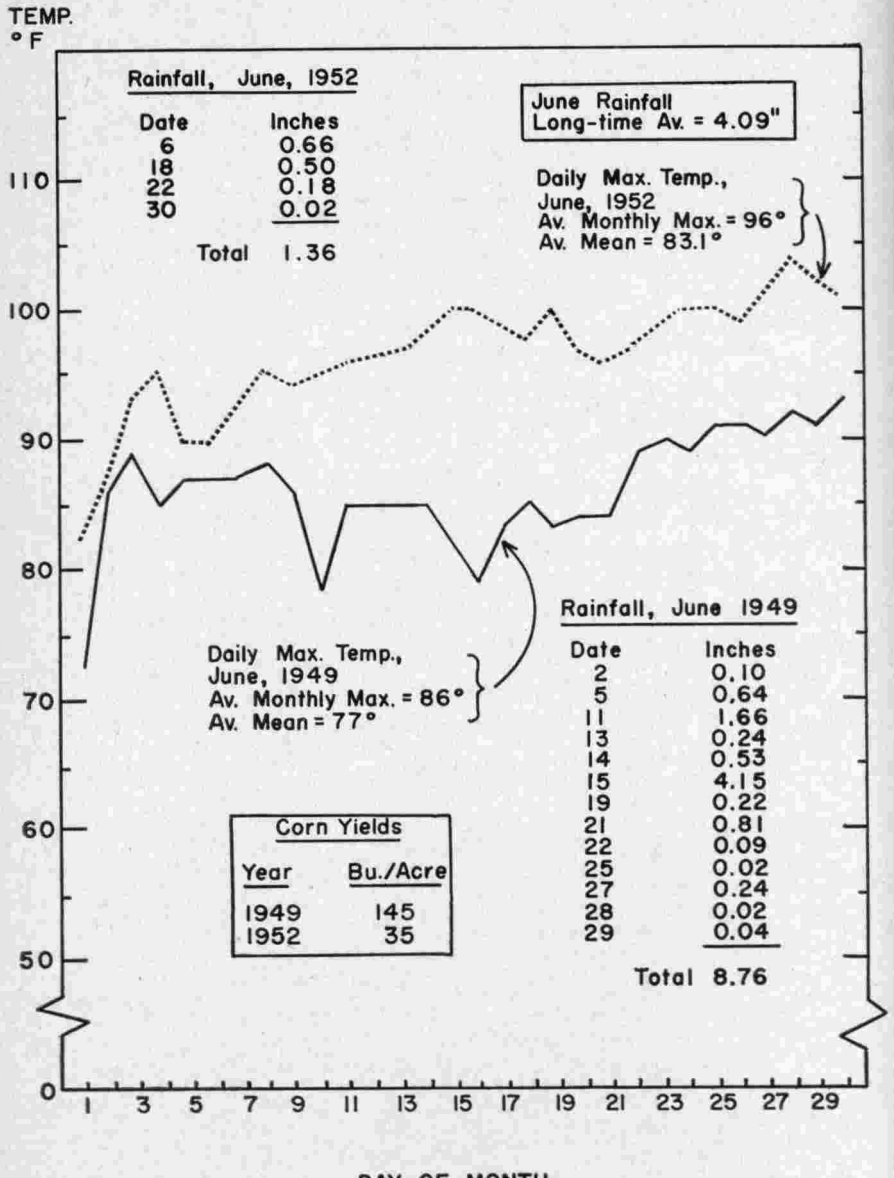


Figure 6. Daily record of rainfall and maximum temperature in June, 1949 vs. June, 1952.

1954 was also a relatively dry year; Dixie 17 averaged 91 bushels and Kentucky 103 averaged 80 bushels. A look at the summer rainfall record will explain these low yields. In 1952 only 1.36 inches of rain fell in June, followed by a dry July with only 1.53 inches. The rains in August came too late for early-planted corn. These amounts are considerably lower than the normal or long-time averages.

As was pointed out in an earlier publication (10), for corn

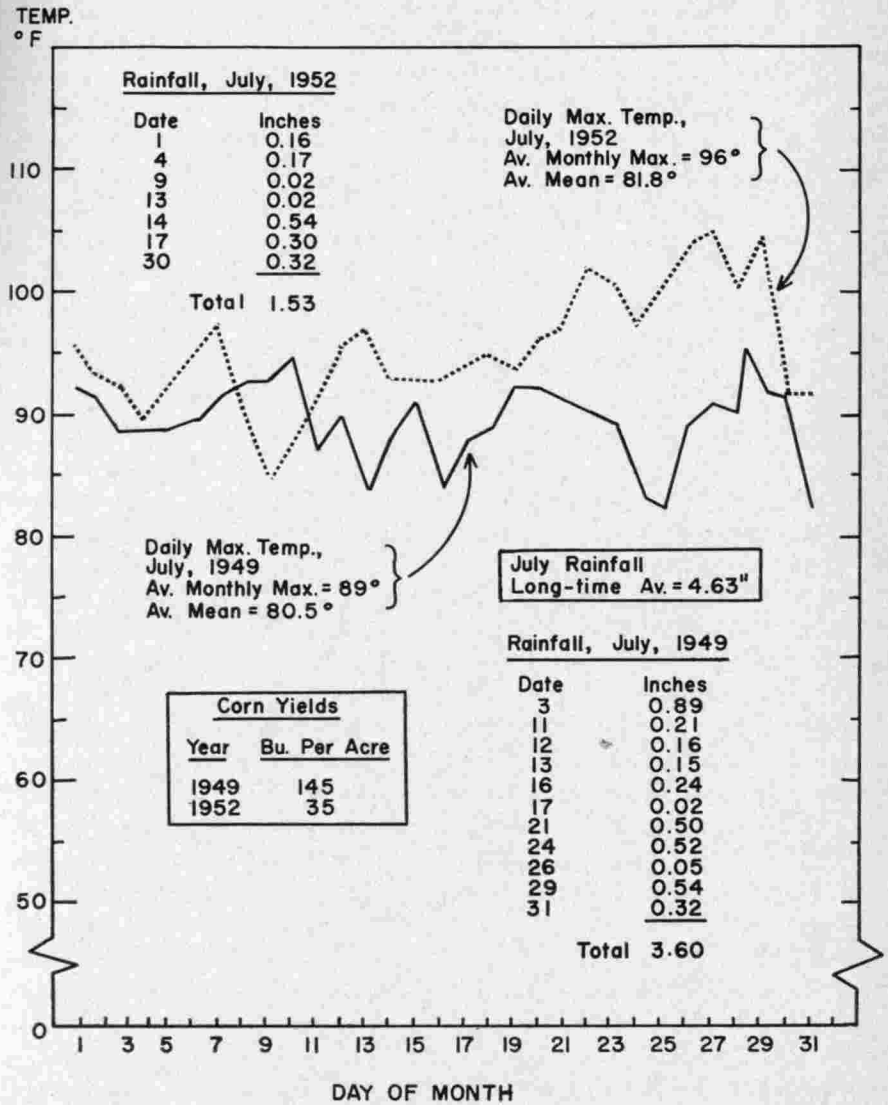


Figure 7. Daily record of rainfall and maximum temperature in July, 1949 vs. July, 1952.

planted the latter part of April, the most critical period from the standpoint of water is the rainfall about 3 months after planting, which in the experiments under discussion was mid-July. Corn can tolerate dry weather fairly well up to the time of tasseling and silking, but from this period to the roasting-ear state its daily production of total dry matter is at the maximum (5).

Dixie 17 produced an average of 145 bushels of corn per acre in 1949, but only 35 bushels in 1952. The data presented in Figures 6 and 7 indicate that these yields reflect rainfall and temperature during the crop's critical period of growth. In these figures daily records of rainfall and maximum temperatures are shown for the months of June and July in these 2 years.

The rainfall of 8.76 inches in June 1949 was more than twice the normal amount. While rainfall the following month (3.60 inches) was about 1 inch less than normal, the record shows that the rains were fairly well distributed with some precipitation being recorded on 11 days of the month. In contrast, the rainfall in June 1952 was only 1.36 inches, and in July only 1.53 inches. Of the 11 days on which some rain fell in these 2 months, only on three occasions did the amount equal or exceed ½-inch.

Not only was rainfall much less than normal in June and July of 1952, but the temperature in this 2-month period was much higher than it was in 1949. For example, in the dry summer of 1952, temperatures reached 90 degrees F or above 28 days in June and 29 days in July, as compared to only 7 days in June and 17 days in July in the wetter summer of 1949. The average monthly maximum of 96 degrees F in June and July of 1952 was 7 to 10 degrees higher than it was in the same months of 1949. On no day in June 1949 did maximum temperature equal that recorded on the corresponding day in June 1952. Likewise, in July 1949 maximum temperatures were less than those in July 1952, except for the 4-day period July 8-11. Mean temperatures also were lower.

Experiments in other states have shown that low rainfall and high temperatures are a double hazard in corn production. Other weather factors being equal, loss of water—either directly from the soil (evaporation) or through the plant (transpiration)—increases with a rise in temperature. At the Nebraska Experiment Station, for example, it was found "that a full-grown corn plant will transpire daily about 4 pounds of water at a mean temperature of 70 degrees, whereas at 80 degrees it will transpire about 7 pounds." (14).

Nitrogen-spacing experiments with Dixie 29 hybrid, 1954-1957.—A 4-year study on the performance of the white hybrid Dixie 29

was conducted on Lintonia silt loam at the West Tennessee Experiment Station, Jackson, during the period 1954-1957. In 3 of these 4 years the experiment was located on the same land area where the previously-reported nitrogen-spacing-hybrid work was done. This means that the years 1954, 1955, and 1956 represent the 6th, 7th, and 8th years of continuous corn on this land.

The hybrid was planted so as to provide 8,000, 10,000 and 12,000 plants per acre. Nitrogen fertilization was at a uniform overall rate of 90 pounds of N per acre, 30 pounds being applied at planting and 60 pounds as a side-dressing. Phosphate and potash also were applied at planting in adequate amounts. The yield and lodging record is shown in Table 6. All treatments are averages of five replications.

Table 6. Acre Yields and Lodging Data on Dixie 29 Corn at Various Plant Populations on Lintonia Silt Loam, West Tennessee Experiment Station, Jackson, 1954-1957.

Year	Population (plants per acre)						L.S.D. (5%)
	8,000		10,000		12,000		
	Yield	Lodging	Yield	Lodging	Yield	Lodging	
	Bu.	%	Bu.	%	Bu.	%	Bu.
1954	22	7	23	11	21	13	N.S.
1955	108	30	119	36	129	46	11
1956	77	2	77	2	80	3	N.S.
1957	110	28	119	46	118	44	4
4-Yr. Av.	79	15	85	22	87	25	..

In the very dry year of 1954 (see Table 5), yields were less than 25 bushels per acre and were essentially the same at the three populations. Again in 1956, a year of less than normal rainfall, yields were about the same at the different populations and averaged about 78 bushels per acre. In 1955 and 1957, years of better-than-average July rainfall, the yields were significantly lower at the 8,000-plant rate than they were at the 10,000- and 12,000-plant rates. In one of these years (1955), the 12,000-plant rate yielded 10 bushels more than the 10,000-plant rate, a difference which approached statistical significance.

The greater degree of lodging in the two best corn production years should also be noted. Lodging reached a maximum of 46% at the 10,000-plant rate in 1957 and the same at the 12,000-plant rate in 1955.

From the above data a population between 10,000 and 12,000 plants per acre is indicated for this hybrid under the conditions of this experiment.

Nitrogen-spacing-irrigation experiments with corn, 1958-1960.—An experiment was started in 1958 at the West Tennessee Experiment Station to study simultaneously the effects of nitrogen, plant population, and irrigation on corn yields. Nitrogen was applied at two rates—120 and 240 pounds of N per acre. Plants were spaced in 3-foot rows to provide stands of 9,000, 12,000, and 15,000 plants per acre. These three stands fertilized at these two rates of nitrogen were subjected to two different moisture conditions. In one case the corn received only the natural rainfall; in the other case the rains were supplemented with irrigation. On the irrigated treatment 2 inches of water was added when soil moisture was depleted to a certain level—in this instance to a level where the water was held by the soil at a tension (suction force) of 2 atmospheres. At this tension, about two-thirds of the total available water in the surface 6 inches of this soil will have been depleted.

This experiment is still in progress; yield data for the first 2 years, or for 1958 and 1959, have already been published (12). Results for a 3-year period, or 1958-1960, are shown in Table 7. Dixie 29 was the hybrid used.

It will be observed that corn yields were lowest in 1958, when

Table 7. Performance of Dixie 29 Corn at Three Plant Populations at Two Rates of Nitrogen Fertilization Under Unirrigated and Irrigated Conditions on Richland Silt Loam, West Tennessee Experiment Station, Jackson, 1958-1960.

Year	Plant population and rate of nitrogen fertilization						Av. of all population- and N-rates
	9,000		12,000		15,000		
	120 lb. N	240 lb. N	120 lb. N	240 lb. N	120 lb. N	240 lb. N	
	NO IRRIGATION (Bushels per acre)						
1958	85	91	79	87	83	82	85
1959	138	141	159	152	163	165	153
1960	109	106	117	121	126	125	117
3-yr. average	111	113	118	120	124	124	118
	IRRIGATED AT 2 ATMOSPHERES (Bushels per acre)						
1958	90	93	97	108	103	108	100
1959	144	143	164	167	171	170	160
1960	119	120	138	136	141	140	132
3-yr. average	118	119	133	137	138	139	131

unirrigated corn averaged 85 bushels per acre, and irrigated corn 100 bushels. Production in 1959 and 1960 was much higher; yields as an average of all treatments were 156 bushels in 1959 and 125 bushels in 1960. Irrigated corn yielded 7 bushels more than non-irrigated corn in 1959 and 15 bushels more in 1960. There were two irrigations each year. In 1958 corn was approaching the silage stage when the first application of water was made on July 21; the second was made on August 7. In 1959 the two irrigation dates were June 22 and July 16, and in 1960, June 11 and July 20.

There was little or no yield response to the higher rate of nitrogen fertilization either with or without irrigation. Therefore, it appears that an application of 120 pounds of N per acre was ample under the conditions of this experiment.

Except for unirrigated corn in 1958, all the evidence points to the conclusion that a population of 9,000 plants was too low for maximum production in this series of experiments. Thus, the comparison narrows down to the intermediate and highest plant populations. Since there was so little response to the higher rate of nitrogen, the two rates of nitrogen can be averaged. When this is done it will be seen that the 15,000-plant population produced on the average between 4 and 5 bushels more than the 12,000-plant population. Calculations indicate that this difference is statistically significant, but the lodging problem must also be considered.

In Table 8 data are presented which show the degree of lodging

Table 8. Lodging of Corn as Affected by Plant Population, Nitrogen Fertilization and Irrigation, West Tennessee Experiment Station, Jackson, 1958-1960.

Year	Plant population and rate of nitrogen fertilization					
	9,000		12,000		15,000	
	120 lb. N	240 lb. N	120 lb. N	240 lb. N	120 lb. N	240 lb. N
	NO IRRIGATION (Percent of lodging)					
1958	15	12	15	17	14	30
1959	36	30	39	42	46	61
1960	48	54	52	61	59	59
3-yr. av.	33	32	35	40	40	50
	IRRIGATED AT 2 ATMOSPHERES (Percent of lodging)					
1958	18	32	13	21	17	10
1959	31	35	30	34	38	46
1960	45	45	38	45	44	49
3-yr. av.	31	37	27	33	33	35

with the various treatments. Lodging was much less severe in 1958 than in the other 2 years. This might well be related to a lower yield level, but this did not hold true for 1959 and 1960, because more lodging occurred in 1960 than in 1959, while the yields were in reverse order, or higher in 1959 than in 1960. What was much more consistent was that more lodging occurred at the higher nitrogen rate. On the average, 33% of the plants lodged at the 120-pound N rate compared to 38% at the 240-pound N rate. Lodging also increased as plant population increased, the average here being 33%, 34%, and 40% respectively at the 9,000-, 12,000-, and 15,000-plant rates. In most years lodging was more pronounced on unirrigated than on irrigated corn, but 1958 was an exception.

Spacing Experiments Without Cultivation

Many experiments have shown that the chief benefit derived from cultivating most row crops is in the control of weeds. Most of the common annual weeds and grasses in corn can be controlled with chemicals; 2,4-D, Simazine, and Atrazine are very effective. If these chemicals are properly applied as an overall surface application at planting, frequently no cultivation is required. In fact, these chemicals are more effective if the soil is not disturbed. The chemicals are not effective on certain perennial



Figure 8. A stand of 12,000 plants per acre in 3½-foot rows leaves considerable exposed area between rows.

species, such as Bermudagrass, Johnsongrass, and Trumpet vine. With chemical weed control it is no longer necessary to crowd plants close together in rows which are themselves quite far apart. If present planting and harvesting equipment did not dictate otherwise, all corn plants could be spaced equidistant from each other.

Several advantages are claimed for a planting arrangement which will allow the determined number of plants to be as widely spaced as possible. Some of these are:

1. More total leaf surface is exposed to the sun's rays.
2. The soil surface is shaded more effectively.
3. Weeds are better controlled. (See figures 8 and 9.)
4. The soil is less compacted by rains.
5. Soil moisture is used more efficiently.

Some experiments have already been conducted in other states in which the corn plants were arranged in various spacing patterns and in which weeds were controlled chemically. These patterns



Figure 9. When 12,000 plants per acre are more evenly distributed, they form a complete canopy.

have ranged from conventional row spacings (3½ feet) to equidistant spacings, all at the same plant population. In some experiments, at a yield level of about 100 bushels, equidistant spacings resulted in a 10% to 15% increase in yield over that obtained with conventional spacings; in other experiments there was no advantage.

In order to obtain additional information on different spacing patterns under Tennessee conditions, experiments were conducted at Knoxville, Spring Hill, Jackson, and Crossville in 1960. Plant populations were 9,000, 12,000, 15,000, and 18,000 plants per acre. Also, the "rows" were spaced 42, 36, 30, 24, and 18 inches apart at each population. A progress report on this work has already been published (13). Some of these planting arrangements approached an equidistant spacing of stalks. For example, at the 12,000-plant population, in a "row" spacing of 24 inches, the plants were spaced approximately 22 inches apart in the row. Also, at the 18,000-plant population, in a "row" spacing of 18 inches the plants were spaced about 19 inches apart in the row. Dixie 29 was the hybrid used. Nitrogen was applied at the rate of 150 pounds of N per acre at all locations. Phosphate and potash fertilization varied from one location to another, depending on soil test, but supplies were adequate.

The yields obtained with the various plant populations (all "row" spacings combined and averaged) are shown in Table 9.

Table 9. Acre Yields of Corn at Four Plant Populations at 4 Locations, 1960.

(Average of all row spacings)

Plants per acre	Location and soil type				Average of 4 locations
	Knoxville (Sequatchie loam)	Spring Hill (Huntington silt loam)	Jackson (Lintonia silt loam)	Crossville (Hartsells loam)	
	Bushels per acre				
9,000	77	104	95	82	90
12,000	86	111	96	88	95
15,000	101	118	95	84	100
18,000	95	116	93	83	97
L.S.D. (5%)	6	9	N.S.	N.S.	4

As an average of the four locations the highest yield was obtained with a population of 15,000 plants, which was significantly higher than the yields obtained with populations of 9,000 and 12,000 plants. There was no advantage in increasing the population to 18,000 plants per acre. Populations of 9,000 and 12,000 plants were definitely too low at Knoxville, and a population of 9,000 plants was too low at Spring Hill; however, all populations were equally satisfactory at Jackson and Crossville. Although lodging data are not presented in detail, the highest degree of lodging occurred at the highest plant rate.

Differences in yield among the various row spacings were not large enough to be significant at any location or in the combined

average for all locations. However, the narrower rows produced slightly higher yields than the wider rows. These studies are being continued.

Experiments in Obion County, 1946 and 1947

Twenty-five experiments were conducted in Obion County over a period of 2 years—14 experiments in 1946 and 11 in 1947. Many soils were represented in these studies—soils of the Mississippi River bottoms, of the Bluff area, and of the flat lands and terraces around the town of Union City. All experiments were on private farms. Only a summary of the response to nitrogen is presented in Table 10; a detailed account of the yields has already been given in a previous publication (10).

Table 10. Response of Corn to Nitrogen, Obion County, 1946 and 1947.

(Average per acre yields of 14 experiments in 1946 and 11 experiments in 1947, population of 8,000 plants. Each treatment was replicated four times in each experiment. All yields corrected to 15.5% moisture.)

Year	Phosphate and potash[1] plus:			
	No nitrogen	30 lb. N	60 lb. N	90 lb. N
	(Bushels per acre)			
1946	64.2	72.3	76.6	81.6
1947	61.1	64.2	65.4	67.3

[1] Phosphate and potash fertilization was 40 pounds of P_2O_5 and 50 pounds of K_2O per acre.

That these soils had a fair supply of nitrogen is demonstrated by the fact that without any nitrogen fertilization they produced about 60 bushels of corn per acre. In both years corn yields increased progressively with each increment of nitrogen added up to 90 pounds of N per acre. However, the response to nitrogen was more pronounced in 1946 than in 1947 due to more favorable moisture conditions.

Attention is called to the fact that almost as much increase in yield was obtained from the first 30-pound increment of nitrogen as was obtained from the next two increments. For example, in 1946 a 30-pound application of nitrogen resulted in an increase of 8.1 bushels, but 60 pounds more nitrogen was required to obtain a further increase of 9.3 bushels.

Experiments on Decatur and Huntington Soils In 1955 and 1956

Two experiments involving four hybrids at four plant populations were conducted near Knoxville in 1955 and 1956. The 1955

experiment was on a Decatur silty clay loam (B slope), and the 1956 experiment was nearby on a Huntington fine sandy loam. In these two tests the objective was to determine the optimum plant population for two hybrid types: a medium- to full-season single-eared type and a full-season prolific one. Each hybrid was grown at populations ranging from 10,000 to 18,000 plants per acre. The fertilization was the same over the entire test area and was considered to be adequate. The 1955 results on Decatur soil are presented in Table 11.

Table 11. Acre Yields of Four Corn Hybrids at Different Plant Populations on Decatur Silty Clay Loam, Knoxville, 1955.

(Average of 6 replications)

Hybrid	Type*	Plant population (in thousands of plants per acre)				Average all plant rates
		8	10	12	16	
		(Bushels per acre)				
Tenn. 90	S.E.—Full	69.7	66.2	66.4	60.4	65.7
PAG 631	S.E.—Med.	70.6	77.9	67.2	70.3	71.5
Dixie 29	Prol.—Full	71.5	72.3	63.3	68.7	69.0
Dixie 22	Prol.—Full	59.9	70.7	70.6	52.0	63.3
Average all hybrids		67.9	71.8	66.9	62.9	...

*S.E. = single-eared; Prol. = prolific; Full and Med. (medium) refer to length of time required to reach maturity.

Soil moisture conditions were not too favorable in the summer of 1955, particularly in the months of July and August, when total rainfall was 81% and 22% of normal, respectively. Moreover, Decatur silty clay loam is not ideal for corn. While it is capable of holding a great deal of water, the amount that is available to plants is not as large as it is in a soil with less clay and more silt.

The yield was about 65 bushels per acre as an average of all treatments. An analysis of the data indicates no significant differences in yield among the hybrids at the different populations. However, it should be pointed out that 3 of the 4 hybrids produced their highest yields at the 10,000-plant rate; as a group the lowest yields were obtained at the 16,000-plant rate. Lodging of corn was negligible.

A similar hybrid-spacing experiment was conducted the following year (1956) at a new site. This experiment was located on a more suitable soil for corn—Huntington fine sandy loam—and soil moisture conditions were more favorable than they were in the 1955 experiment. Some changes were made in the list of hybrids and in their spacing. The 1956 yield results are presented in Table 12.

Table 12. Acre Yields of Four Corn Hybrids at Different Plant Populations on Huntington Fine Sandy Loam, Knoxville, 1956.

(Average of 6 replications)

Hybrid	Type*	Plant population (in thousands of plants per acre)				Average for plant rates
		10	12	16	18	
		(Bushels per acre)				
Tenn. 90	S.E.—Full	112.6	133.6	128.8	130.5	126.4
Tenn. 501	Prol.—Med.	93.1	116.8	110.5	119.1	109.9
Dixie 29	Prol.—Full	115.4	136.7	124.5	143.7	130.1
Pioneer 505W	S.E.—Med.	96.5	116.0	101.4	116.3	107.6
Average all hybrids		104.4	125.8	116.3	127.4	...

L.S.D. (5%) for plant population means = N.S.
L.S.D. (5%) for hybrid means = 7.9 bu.

*See Table 11 for explanation of type symbols.

Corn yields in this experiment were about double those in the 1955 experiment, the average being about 118 bushels per acre. The two full-season hybrids yielded considerably more than the two earlier-maturing hybrids. The hybrids as a group produced the lowest yield at the 10,000-plant rate (104.4 bu.), a yield which is lower (at the 10% level of probability) than those obtained at the 12,000-, 16,000-, and 18,000-plant rates, between which the yields were not significantly different. Lodging was much more severe at the two highest rates. For example, about 15% of the plants lodged at the 10,000- and 12,000-plant rates and twice this amount (30%) lodged at the 16,000- and 18,000-plant rates.

Experiments on Four Soils in Knox County, 1957

Four experiments were conducted on four different soils on a private farm in Knox County in 1957. The soils were Congaree loam, State loam, Robertsville silt loam, and Etowah silt loam. The Congaree is a well-drained alluvial soil which occupies a bottomland position; the depth of the A horizon is about 22 inches. The State is a well-drained soil occupying a low terrace position; the depth of the A horizon is about 9 inches. The Robertsville is a poorly-drained dark gray soil with a fragipan. The Etowah is a well-drained soil occupying a terrace position, which in this instance is about 15 feet higher than the Robertsville. The depth of the A horizon is about 9 inches. All these soils lie along the French Broad River and are within a mile of each other.

Corn population varied from 4,000 to 28,000 plants per acre and nitrogen fertilization from 0 to 300 pounds of N per acre, depending on the soil. Phosphate and potash fertilization was more than ade-

Table 13. Performance of Dixie 29 Corn at Different Plant Populations and Fertilized with Different Amounts of Nitrogen on Four Soils in Knox County, 1957.[1]

Nitrogen applied (lb. per acre)	Plant population (in thousands of plants per acre)							Average of all plant populations
	4	8	12	16	20	24	28	
				Congaree loam (Bushels per acre)				
0	....	110.3	115.9	124.9	118.7	117.5	114.0	116.9
60	....	112.0	122.9	133.0	132.2	136.5	136.4	128.8
120	....	113.6	130.3	138.0	144.8	136.1	136.0	133.1
180	....	109.2	134.4	140.4	146.4	128.2	136.5	132.5
240	....	114.8	127.4	142.1	149.5	138.2	138.1	135.0
300	....	115.4	128.9	141.4	136.2	141.8	130.9	132.4
Av. of all N rates	....	112.6	126.6	136.6	138.0	133.1	132.0	....
L.S.D. (5%) for population and nitrogen rates = 4.2 bu.								
				State loam (Bushels per acre)				
0	....	97.6	105.0	115.9	118.5	117.0	....	110.8
60	....	96.7	111.8	121.4	117.5	130.7	....	115.6
120	....	104.5	109.1	120.4	131.6	123.0	....	117.7
180	....	99.7	112.4	120.6	124.7	136.0	....	118.7
240	....	103.4	112.2	119.0	128.1	122.9	....	117.1
Av. of all N rates	....	100.4	110.1	119.5	124.1	125.9	....	....
L.S.D. (5%) for populations = 6.1 bu.; for nitrogen rates = N.S.								
				Robertsville silt loam (Bushels per acre)				
0	58.6	66.8	71.1	76.3	....	....	....	68.2
60	59.2	80.3	76.8	80.2	....	....	....	74.1
120	54.0	72.5	84.2	80.9	....	....	....	72.9
180	62.6	71.8	86.9	89.2	....	....	....	77.6
240	61.7	79.7	86.4	88.4	....	....	....	79.1
Av. of all N rates	59.2	74.2	81.1	83.0	....	....	....	....
L.S.D. (5%) for populations = 4.9 bu.; for nitrogen rates = 5.4 bu.								
				Etowah silt loam (Bushels per acre)				
0	....	50.0	53.8	46.6	55.0	38.8	....	48.8
60	....	58.6	67.1	56.5	57.5	48.7	....	57.7
120	....	48.2	51.6	64.3	52.9	48.3	....	53.1
180	....	57.0	59.9	50.4	63.0	37.5	....	53.6
240	....	51.7	48.1	61.8	55.6	54.6	....	54.4
Av. of all N rates	....	53.1	56.1	55.9	56.8	45.6	....	....
L.S.D. (5%) for populations = 5.8 bu.; for nitrogen rates = N.S.								

[1] All yields expressed in terms of dry-shelled corn (15.5% moisture), and are averages of four replications of each population at each rate of fertilization on each soil.

quate—500 pounds each of P_2O_5 and K_2O per acre over the entire test area. All of the nitrogen was applied as a side-dressing on both sides of the row at the time the corn was thinned to the desired spacings. Dixie 29 was the hybrid used.

Moisture conditions were good throughout the growing season, rainfall being above normal in June and August with rains well distributed. The yields obtained on the different soils with the various plant population and nitrogen rates are shown in Table 13.

Of the four soils, the highest yields of corn were obtained on the Congaree, which produced about 130 bushels per acre as a field average. A population of 20,000 plants per acre fertilized with 120 pounds of nitrogen produced near maximum yields on this soil.

The second highest yield was obtained on State loam, which produced 116 bushels per acre as a field average. On this soil the yield at the 24,000-plant rate was significantly higher than at the 16,000-plant rate, but not significantly higher than at the 20,000-plant rate.

Corn on Robertsville silt loam produced about 75 bushels per acre as a field average. A population of 12,000 plants fertilized with 120 pounds of nitrogen gave near maximum yields (84.2 bushels); no higher plant population or rate of nitrogen produced a significantly higher yield. A population of 8,000 plants was definitely too low.

The relatively low average yield of about 54 bushels per acre on Etowah silt loam should be considered separately. Although this experiment was planted on or about the same date as the others, it was 3 weeks later in germinating. It is believed that this delay in germination was brought about by the turning under of a heavy crop of winter rye, which had depleted the soil of its moisture and prevented the making of a good seedbed. Therefore, the crop on this soil experienced a drought at its critical period of development, or during silking and tasseling, which the crops on the other soils escaped. The yield results are included since, other than for the conditions as stated above, there appeared to be no valid reason for excluding them. At this yield level, or about 50 bushels, a population of 12,000 plants per acre fertilized with 60 pounds of nitrogen appeared to be best. Yields were significantly depressed at a population of 24,000 plants. There were many more barren plants on the Etowah than on the other soils—an average of 32% versus 5% to 8%.

Lodging.—Lodging was more severe on the Congaree and State soils (average about 20%) than it was on the Robertsville and Etowah soils (average about 10%). In general, lodging increased as

nitrogen fertilization was increased and as the plants were spaced closer together. However, in one experiment (on Etowah soil), lodging was related almost entirely to nitrogen fertilization, with plant population having little effect.

Experiments in Putnam County, 1958

Some corn experiments were conducted on private farms in Putnam County on soils of the Huntington, Waynesboro, and Dickson series. Huntington is a well-drained bottom soil; Waynesboro a well-drained terrace soil; and Dickson a moderately well-drained upland soil with a fragipan layer at a depth of about 2 feet.

Some 60 sites were selected—about 20 on each soil. All operations, other than the harvesting of selected portions of the field, were performed by the farmer. He decided what variety to plant, the rate of planting and fertilization, and the cultivation practices. The two requests made by the Experiment Station personnel were 1) that he leave four rows unfertilized, and 2) that he apply ammonium nitrate as a side-dressing at a rate of about 300 pounds per acre on part of the field.

As can well be imagined, several varieties and hybrids were planted, the rate of fertilization varied widely, and populations at harvest ranged from 2,300 to 12,300 plants per acre. In general, the farmers met or exceeded the amount of nitrogen recommended as a side-dressing.

Corn yields varied widely among the three soil groups as well as among sites within each group. Also, in general, the yield of fer-

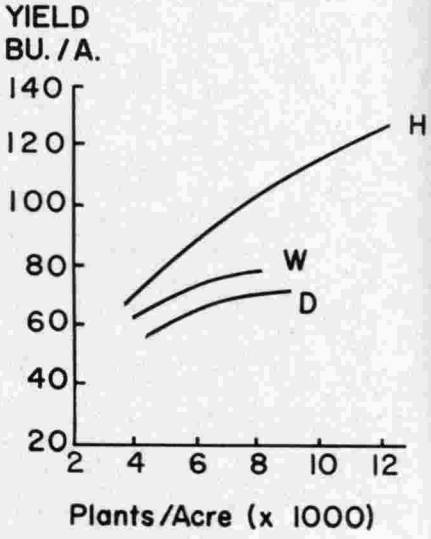


Figure 10. Relation of plant population to corn yield on Dickson (D), Waynesboro (W), and Huntington (H) soils in Putnam County, 1958.

tilized corn exceeded that of the unfertilized check by about 12%, and an even greater increase in yield (24%) was obtained where additional nitrogen was applied as a sidedressing to the fertilized corn.

In Figure 10 yields of corn on the three soils are plotted as a function of plant populations, using data obtained through multiple correlation analysis. In calculating the yield-population relationship, the other factors used in the multiple regression equation were held constant at an average level.

The yield curves for the Dickson and Waynesboro soils are similar in slope, with the curve for Waynesboro (W) lying above that for Dickson (D). Both curves flatten out at a population of about 8,000 plants per acre, indicating that on these two soils there was little yield advantage in increasing the number of plants beyond this figure. The yield curve for the Huntington soil (H), however, is quite different in that it rises much higher at the higher plant populations and shows little tendency to flatten out. Therefore, it is reasonable to conclude that yields would have continued to increase at populations above 12,000 plants. At this 12,000-plant rate a yield as high as 128 bushels per acre was obtained. One very striking fact brought out in the experiments on Huntington soil was the relative inefficiency of high rates of nitrogen at the lower plant populations. This soil has a high corn production potential, but in order to realize maximum yields, an increase in plant population must go hand-in-hand with increased nitrogen fertilization.

Experiments on Huntington, Waynesboro, and Dickson Soils, Putnam County, 1960

Eighteen experiments were conducted in Putnam County in 1960 on three soil series—six experiments each on Huntington, Waynesboro, and Dickson. A brief description of these soils has already been given.

The objective in these experiments was to determine the maximum capacity of these three soils to produce corn under conditions of natural rainfall. Therefore, fertilization was at rates considerably above what would be considered economical. These per-acre rates were: nitrogen, 220 and 420 pounds of N; phosphate 220 and 420 pounds of P_2O_5; and potash, 220 and 420 pounds of K_2O. A special mixture also was added to take care of any possible minor element deficiencies. All these fertilizer materials were applied broadcast and mixed with the soil before planting except for a small amount (20-20-20), which was applied in the row. Dixie 29 was the hybrid used in most plantings; Dixie 17 was used at three locations.

Corn was planted to stands of 15,000 and 25,000 plants per acre on Huntington; 14,000 and 24,000 plants on Waynesboro; and 10,000 and 16,000 plants per acre on Dickson. Planting was in rows spaced 21 inches apart; the crop was not cultivated; weed control was accomplished by a pre-emergence application of Atrazine. In general, growing conditions for corn were good throughout the summer with no prolonged droughts. The yields obtained on the soils at the two plant populations and at the various rates of fertilization are presented in Table 14.

Table 14. Acre Yields of Corn at Two Plant Populations and at Four Rates of Fertilization on Three Soil Series, Putnam County, 1960.

(All yields are averages of 6 locations on each soil series)

Fertilizer treatment*	Huntington soil		Waynesboro soil		Dickson soil	
	Plants per acre					
	15,000	25,000	14,000	24,000	10,000	16,000
	(Bushels per acre)					
N_1, P_1, K_1	137	126	133	123	95	105
N_1, P_2, K_2	128	122	128	126	110	113
N_2, P_1, K_1	129	131	123	117	97	105
N_2, P_2, K_2	114	119	118	118	101	111
Average	127	124	126	121	101	109

* N_1 and N_2 = 220 and 420 pounds of N per acre, respectively.
P_1 and P_2 = 220 and 420 pounds of P_2O_5 per acre, respectively.
K_1 and K_2 = 220 and 420 pounds of K_2O per acre, respectively.

On Huntington soil the yields exceeded 100 bushels per acre at almost all locations. Also in most instances the yields were higher at the lower plant population (15,000 plants per acre). At only one site did the thicker planting appear to be superior. The lowest rate of fertilization (220-220-220) also appeared to be adequate, as evidenced by the fact that its yield ranked first or second at 4 of the 6 locations. This fertilizer treatment averaged 137 bushels per acre at the 15,000-plant rate. This treatment also resulted in the least amount of lodging.

Yields were almost as high on the Waynesboro soil as they were on the Huntington soil. Here also yields were higher at the lower population (14,000 plants) than they were at the higher population (24,000 plants) at 5 of the 6 locations. The average yield for all locations at all rates of fertilization was 126 bushels at the 14,000-plant rate and 121 bushels at the 24,000-plant rate. Also, as was the case on Huntington soil, the lowest rate of fertilization (220-220-220) was on the average superior to the higher rates. This rate ranked first or second in yield 4 times out of 6 at a population of

14,000 plants and 3 times out of 6 at a population of 24,000 plants. Also lodging was least severe at this rate of fertilization on the lower plant population.

Corn yields on the Dickson soil, while lower than those on the Huntington and Waynesboro soils, were remarkably good for a soil of this type. The average yield for the six tests was 105 bushels per acre. The yields ranged from an average of about 94 bushels to about 118 bushels. On the average yields were higher at the higher plant rate (16,000 plants per acre). This was true for every fertilizer treatment. The highest yield, or average of 113 bushels, was produced with the lower rate of nitrogen and the higher rate of phosphate and potash (220-420-420). This was followed by an average yield of 111 bushels where the fertilization rate was the highest (420-420-420) on a stand of 16,000 plants, but the 220-420-420 fertilizer rate on a stand of 10,000 plants was a close third, with an average yield of 110 bushels. Lodging was much less severe on the Dickson soil than it was on the Huntington and Waynesboro soils, but was greatest (25%) on the highest-yielding treatment.

Time and Method of Applying Nitrogen

In all of the experiments discussed in this publication, all of the phosphate and potash was applied before planting—in the row when the amounts were small, or broadcast and disked into the soil when the amounts were large. In most cases, some of the nitrogen was applied along with the phosphate and potash and in the same manner. For example, in the nitrogen-spacing-irrigation experiments discussed above, part of the nitrogen (30 pounds of N per acre) was applied broadcast before planting along with the phosphate and potash. The rest of the nitrogen, or as much as 210 pounds of N, was applied as a side-dressing when the corn was about knee high. However, in the variable-row spacing experiments all of the nitrogen (150 pounds of N per acre) was applied broadcast before planting.

Which is better? Should all of the nitrogen be applied at or before planting or should some of it be applied later? In the 11 experiments conducted in Obion County in 1947, discussed earlier in this bulletin, the results indicated that it makes no difference which one of the two methods is used, at least at high rates of application. In one treatment of these experiments at the 90-pound N rate all of the nitrogen was applied with the phosphate and potash in the row and thoroughly mixed before planting. This mixing was considered necessary because of the high rate of fertilization and the concentration of fertilizer salts within a limited zone. This treat-

ment was compared with another which was the same in all respects, except that 30 pounds of N was applied in the row and 60 pounds of N was applied as a side-dressing about 1 month after planting. As an average of the 11 experiments, the side-dressed treatment produced 67.8 bushels of corn per acre as compared with 67.3 bushels where all the nitrogen was applied at planting (Table 10).

There are, however, some advantages in the practice of applying part of the nitrogen as a side-dressing. Withholding part of the nitrogen until after the first cultivation relieves somewhat the weed and grass problem. Also, if part of the nitrogen is withheld at planting, the decision can be made later as to whether the stand and general growing conditions justify the second application. The disadvantages are that it makes for more labor, and—in the case where a herbicide has been applied over the entire soil surface for weed control—the breaking of this film cover in making the side-dressing is undesirable.

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