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ELMER R. KIEHL, *Director*

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F. D. WHITAKER, H. G. HEINEMANN, AND W. E. LARSON

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Plant Population and Row Spacing Influence Maximum Corn Yield

F. D. WHITAKER, H. G. HEINEMANN, AND W. E. LARSON[1]

Considerable emphasis has been given recently to studying corn planting variables, in an effort to increase corn yield. Plant population, row spacing, and time of planting have been the variables most often studied.[2]

Higher populations and narrower row spacings have been considered on the basis that a greater and better spaced leaf surface may capture more light energy and thus increase photosynthesis. Higher populations and narrower row spacings than those used 20 years ago have become possible because of (a) availability of corn hybrids capable of producing at higher populations, (b) improved fertilizers, (c) availability of herbicides for weed control and pesticides for insect control, and (d) improved planting, cultivating, and harvesting equipment.

The literature on planting variables for corn, including plant populations and row spacings, was thoroughly reviewed in 1966 by Rossman and Cook.[2] The response to high populations and narrow rows was found to vary greatly, depending on hybrid, climate, soil, water availability, and management variables.

The objective of this study was to determine the yield response of corn to different levels of plant population and row width. However, since 24 plots were needed for the different combinations of population and row spacing for each hybrid, the study was limited to two hybrids. A truly maximum production study was thought to be possible because of the very suitable corn-growing environment at the experimental site. Excellent soil and favorable climate, along with the availability of irrigation water, were some of the factors that led to optimism.

The study showed that a different combination of population and row spacing than that commonly used in the area may be necessary, depending on a desire for high grain yield or high silage yield. Climatic variations are very important and may override the less pronounced effects of other variables.

RESEARCH PROCEDURE

The alluvial soils at the U. S. D. A. Soil Conservation Service Plant Materials Station at Elsberry, Mo., have produced as much as 180 bushels of corn per acre under high fertility and management conditions, using an adapted hy-

[1]Hydraulic Engineering Technician and Center Director, USDA ARS SWC, Columbia, Missouri; and Research Investigations Leader, Soil Management, USDA ARS SWC, St. Paul, Minnesota.

[2]Pierre, W. H., Aldrich, S. A., and Martin, W. P. Advances in corn production principles and practices, 1966. Chapter 3, by Rossman, E. C. and Cook, R. L. soil preparation and date, rate, and pattern of planting, 49 pp. Iowa State Press, Publisher.

brid. It was believed, however, that yields might be increased substantially if higher populations, narrower row spacing, irrigation (if necessary), and corn hybrids with full genetic potentials were used.

Soils

The soil at the Elsberry Plant Materials Station is Sharon silt loam and the slope is 0.25 percent. The surface topography has been modified so that a number of drainageways are available for removing excess surface water. Ground water is at a depth of about 5 to 6 feet.

Experimental Design

A two-dimensional, second-order composite design used in this study has five plant population (stand) levels and three row spacings. The geometric representation of this design is shown in figure 1. Population and row spacing were assigned to the horizontal and vertical directions, respectively, and were so selected that the center point (O, O) was estimated to give maximum yield. The response surface computed from a second-order polynomial gives a complete

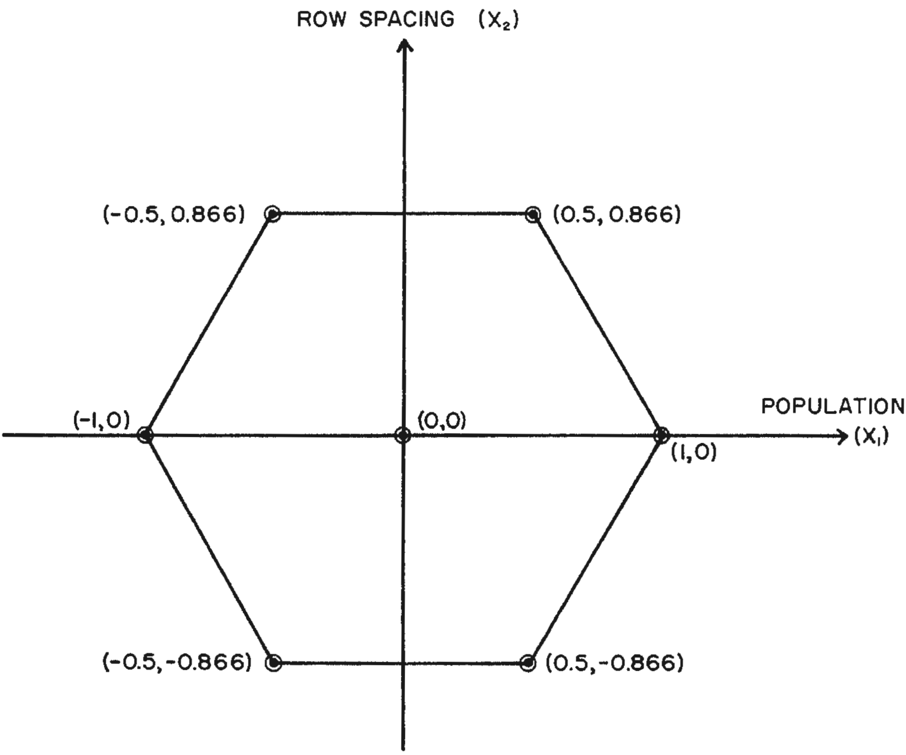

Fig. 1 Geometric representation of design for one hybrid.

summary of the results of the experiment and enables predicting responses for combinations of variables not actually tested in the experiment but lying within the ranges of those tested.[3]

In this experiment, the center point treatment has a population of 20,000 plants per acre and a row width of 30 inches. Figure 2 shows the population levels and row widths and their coded values. Three replicates were used and

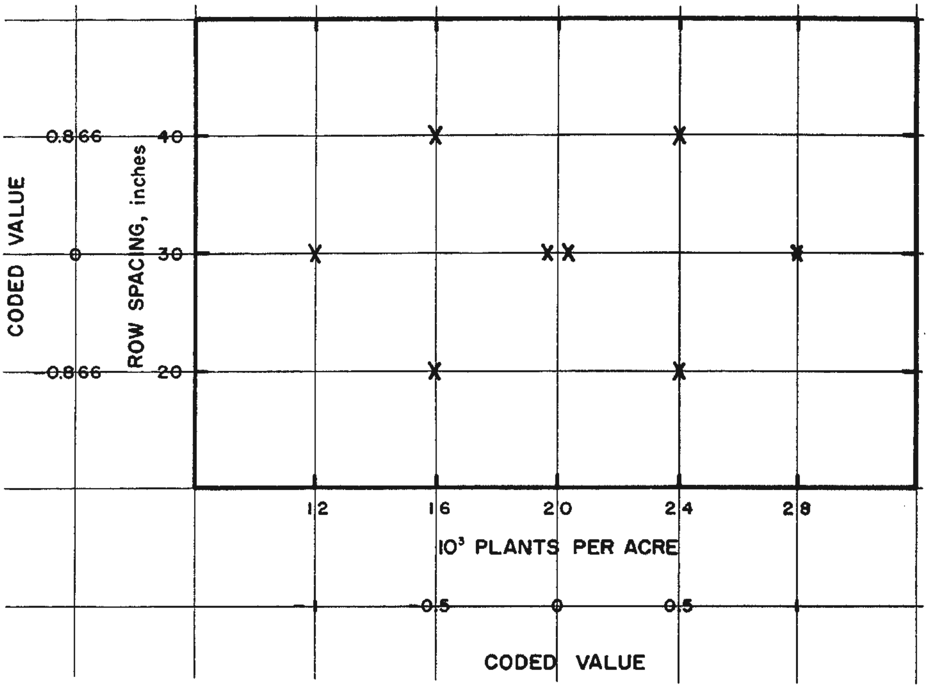

Fig. 2 One replication of experimental treatments for one hybrid.

two center point treatments were included in each replicate. Figure 3 presents the actual plot layout. The experimental treatments were placed on the same location each year.

The row length was 70 feet. There were 8, 4, and 4 rows per plot with row widths of 20, 30, and 40 inches, respectively.

Corn Hybrids

Pioneer 321 and United Hagie 152A hybrids were selected for this study.[4]

[3]Cockran, W. G., and Cox, G. M. experimental designs. Second Edition, pp. 335-376, 1957. Iowa State Press, Publisher.
[4]Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U. S. Department of Agriculture.

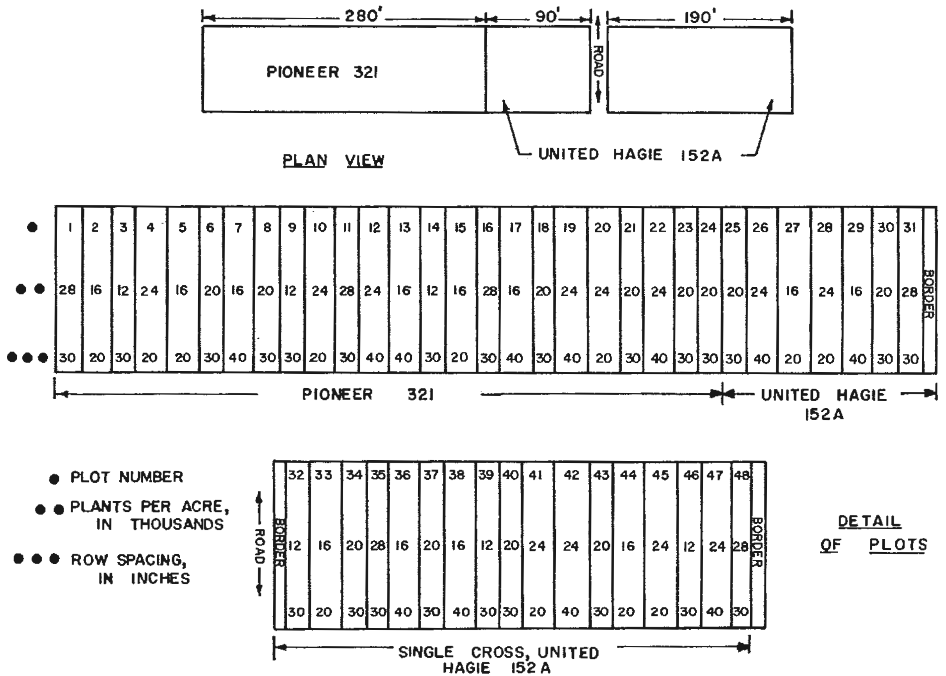

Fig. 3 Plot layout of the yield response study located on the Soil Conservation Plant Materials Station near Elsberry, Missouri.

Tillage

Cornstalks were shredded in the fall. In the spring, the land was plowed and then disked several times as needed for good seedbed conditions. After planting, the corn was cultivated three times at intervals most effective in controlling weeds. Conventional farm equipment was used for these operations. Atrazine herbicide and Aldrin insecticide were also applied on all plots at planting. After the last cultivation, the corn was sprayed with DDT to prevent damage by European corn borers.

Fertilizer

Adequate fertilizer was applied to the plots in an attempt to remove soil nutrients as a variable. Before the first corn planting, the soil was tested and brought to a high and uniform fertility level (P—86 lbs./ac, Ca—80% saturation and K—2.4% saturation) by University of Missouri soil test standards.[5] Each year thereafter, 100 pounds of N, 43 pounds of P, and 83 pounds of K was applied after plowing and disked in before planting. Additional N was applied at the second and third cultivations, at the rate of 100 pounds N per acre per cultivation.

Irrigation

The plots were irrigated as needed to remove soil water as a variable in the study. No irrigation was needed in 1965, since rainfall was ample from the seedling stage through silking and ear development. Four and one-half inches of water was applied in two irrigations on July 14 and 20, 1966. Water was adequate during the remainder of the season.

Corn Thinning

The corn was overplanted approximately 35 to 50 percent and thinned to the planned levels in three steps. They were thinned to near the desired level when the corn was 4 to 5 inches tall. Suckers were removed, and further adjustments were made after the second cultivation. Thinning was completed and the yield sample areas were chosen after the last cultivation.

Corn Leaf Samples

Leaf samples were obtained at silking and were analyzed to determine the uptake of nitrogen, phosphorus, and potassium as a measure of the nutrition available for corn grain production. Twenty leaves were randomly selected from the interior rows of each plot.

The leaf selected for sampling was the first one below and opposite the ear leaf. The portion collected was a transverse section of the leaf, approximately one-fourth as long as the entire leaf and located midway along its length. Only one section was taken from any one plant.

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[5]Graham, E. R. an explanation of theory and methods of soil testing. Univ. Mo. Agr. Expt. Sta. Bul. 734, 20 pp., July 1959.

Whole Plant Samples

Ten whole plants were taken from the center rows of all treatments as the plants approach maturity in September. Uptake of nitrogen, phosphorus, and potassium was determined on the samples to determine the total uptake of these elements and their distribution between the grain and forage. These tests also reflected the adequacy of the fertilizer applications.

Corn Yield Samples

Grain yield was determined from 50-foot lengths of the two center rows of each plot. The entire sample was weighed, and the yield determination was based on 15.5 percent moisture in the grain and 72.6 percent moisture in the silage. Dry matter yields of forage are reported on an oven-dry weight at 60°C.

Miscellaneous

Quantitative estimates of weed growth, insect damage, and stalk lodging were made for each treatment, as needed, throughout each season. Pictures were taken and careful observations were made of factors that might affect corn growth and grain production.

DATA

Climatic Conditions

Climatic conditions during periods of each of the 2 years of study (1965-1966) were unfavorable for maximum corn production. During 1965, a dry period of 17 days following seedbed preparation and planting resulted in slow germination of the corn seed and irregular emergence of the corn plants. A severe windstorm and heavy rain severely damaged the corn plants on June 20. After the storm, nearly all of the plants were leaning badly (angles greater than 60° from vertical), and on many areas of the plots the corn had been flattened by the wind. However, after 2 weeks, the leaning corn had almost straightened and the top two-thirds of the flattened stalks had goosenecked to a vertical position and continued to grow.

Cool weather retarded early growth of the corn during 1966. Mean temperatures during April, May, and June were about 4°F. below the long-time (1933-1965) average for this period. Nighttime temperatures in the 30's and lower 40's were frequent until mid-June. Temperatures during July were above normal, and precipitation was nearly 3 inches below normal. Total rainfall during July was 0.52 inch. No precipitation occurred from June 28 to July 19, when 0.32 inch was received. During this 20-day period, the average maximum daily temperature was 95°F. During five consecutive days (July 11 to July 15), the maximum temperatures were 103°F. and 104°F. Adequate water was provided by irrigation; however, the plants were damaged somewhat by hot winds during the silking period.

The Collected Data

Average measured values for the seven treatments on the two hybrids for 1965 and 1966 are given in table 1 in the appendix. The corn grain yields are expressed as bushels per acre at 15.5-percent moisture and the grain and forage dry matter in pounds per acre are based on oven-dry weights. The nitrogen, phosphorus, and potassium contents of the grain and forage are shown as the percentage of the dry weights. The composition of the leaves shown at the right of table 1 are the percentages of nitrogen, phosphorus, and potassium in the leaf samples taken at silking time. These data were used in a response surface analysis. This type of analysis enables the researcher to predict responses for combinations of variables not actually tested in the experiment but lying within the limits of the data obtained. This was done and the results are shown in table 2 in the appendix.

The discussions in the remainder of this manuscript concern the computed values given by the response surface analysis. Where practical, however, the experimental data are presented in the response surface figures to give the reader an idea of the goodness of fit. In most cases, the experimental values fit very well.

An analysis of variance was calculated for each attribute for each year, as given in the following table. Regression coefficients for the equation $Y = b_0 + b_1S + b_2P + b_{11}S^2 + b_{22}P^2 + b_{12}SP$ were also calculated, as were the multiple correlation coefficients. In addition, an analysis of variance for determining whether there was a difference in response between the two years of the experiment was calculated thus:

$$F = \frac{\text{Years x treatment mean square}}{(\text{Years x replication mean square}) + (\text{years x replication x treatment mean square})}$$

The F values from an analysis of variance for each variable for the two hybrids are presented in table 3 of the appendix.

Table 4 in the appendix lists the regression coefficients for the second-order polynomials. In most cases, the treatment x year interaction was not significant (table 3, appendix).

RESULTS

Grain

Figures 4 and 5 show the effect of stalk population and row width on corn yields (15.5-percent moisture) in bushels per acre from the Pioneer 321 and United Hagie 152A hybrid corn, respectively. These data are the averages of 1965 and 1966. Statistically, the yield differences for the Pioneer hybrid were significant at the 10-percent level in 1965 and at the 1-percent level in 1966. The

ANALYSIS OF VARIANCE FOR RESPONSE SURFACE DESIGN IN RANDOMIZED LAYOUT

Source of Variation	df
Total	24
Mean	1
Replication	2
Treatment	6
Linear	2
Quadradic	3
Lack of fit	1
Duplicate Plots	3
Experimental Error	12

Regression Coefficients

Variable	Symbol
Mean	b_0
Row Spacing, S	b_1
Population, P	b_2
Row Spacing^2	b_{11}
Population^2	b_{22}
S x P	b_{12}

highest calculated average yield, 159.3 bushels, was obtained in 30-inch rows at 24,000 plants per acre (figure 4 and table 2 of the appendix). This is the highest point (corn yield axis) above a plot of the row width and stalk population on the base of the diagram. The distance of this high point above the plotted point (width/population) can be transferred to the corn yield scale for determining yield in bushels per acre. The response to population was much greater than to row width.

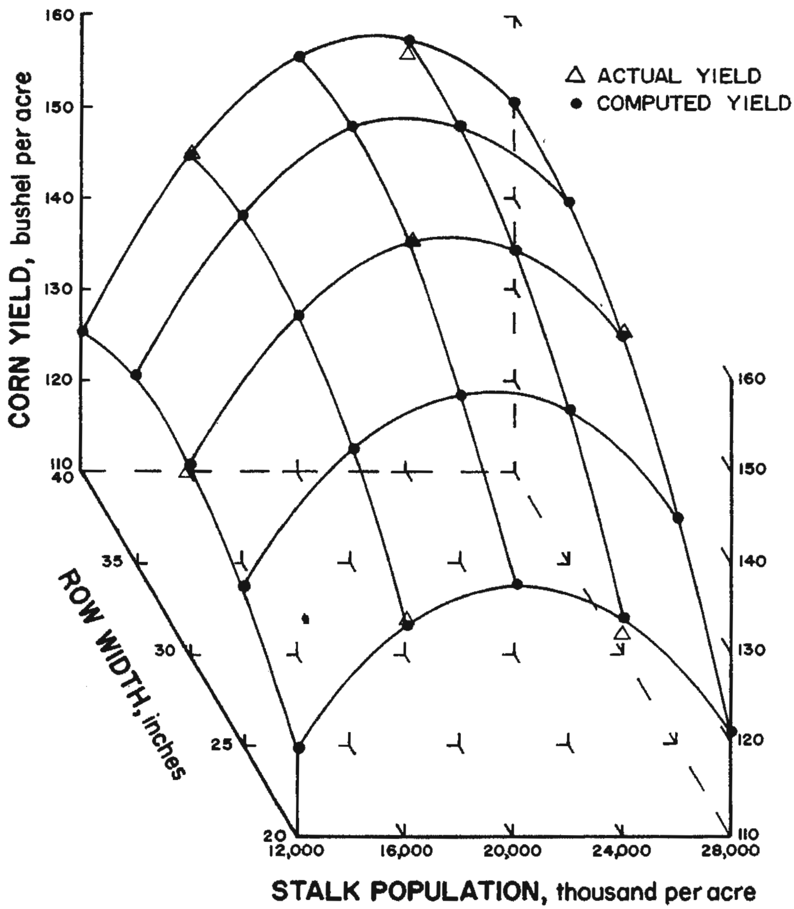


Fig. 4 Corn yield (grain) response surface from stalk population and row width. Pioneer 321 hybrid yield average for 1965 and 1966.

Statistically, the yield differences for the United Hagie hybrid were significant at the 1-percent level in 1965 and at the 5-percent level in 1966. Since the response to treatment was different in each year, the response surface for each year is presented in figures 6 and 7. The highest yield in 1965 was from 20,000 plants and with 35-inch row width. In 1966, it was from 28,000 plants and with 40-inch row width. Figure 5 shows that the response to population was much greater than response to row width.

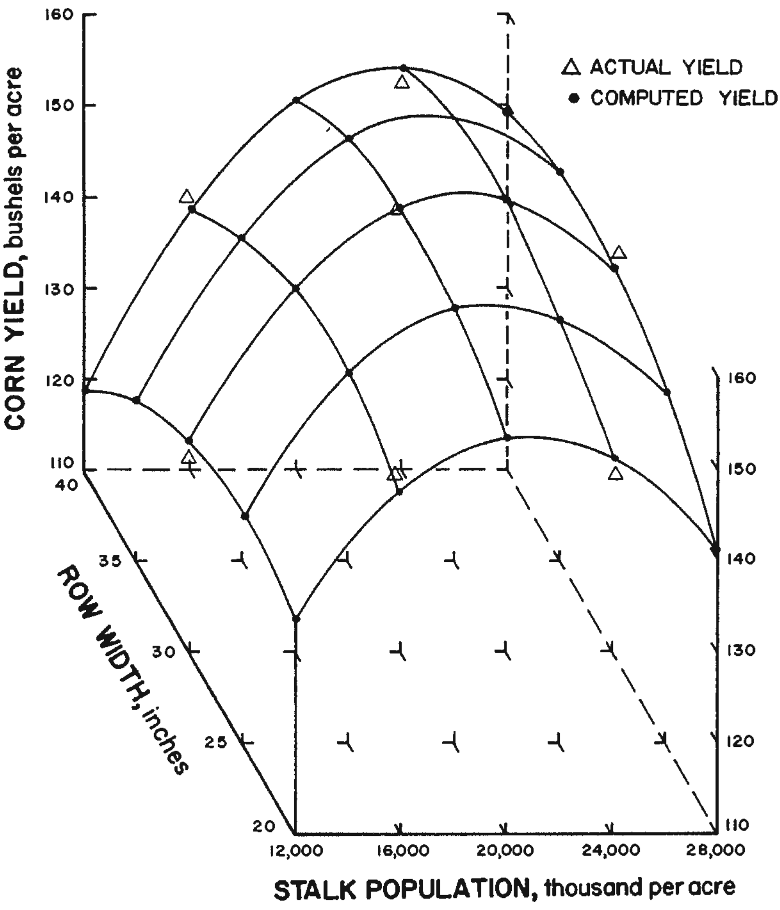


Fig. 5 Corn yield (grain) response surface from stalk population and row width. United Hagie 152A hybrid yield average for 1965 and 1966.

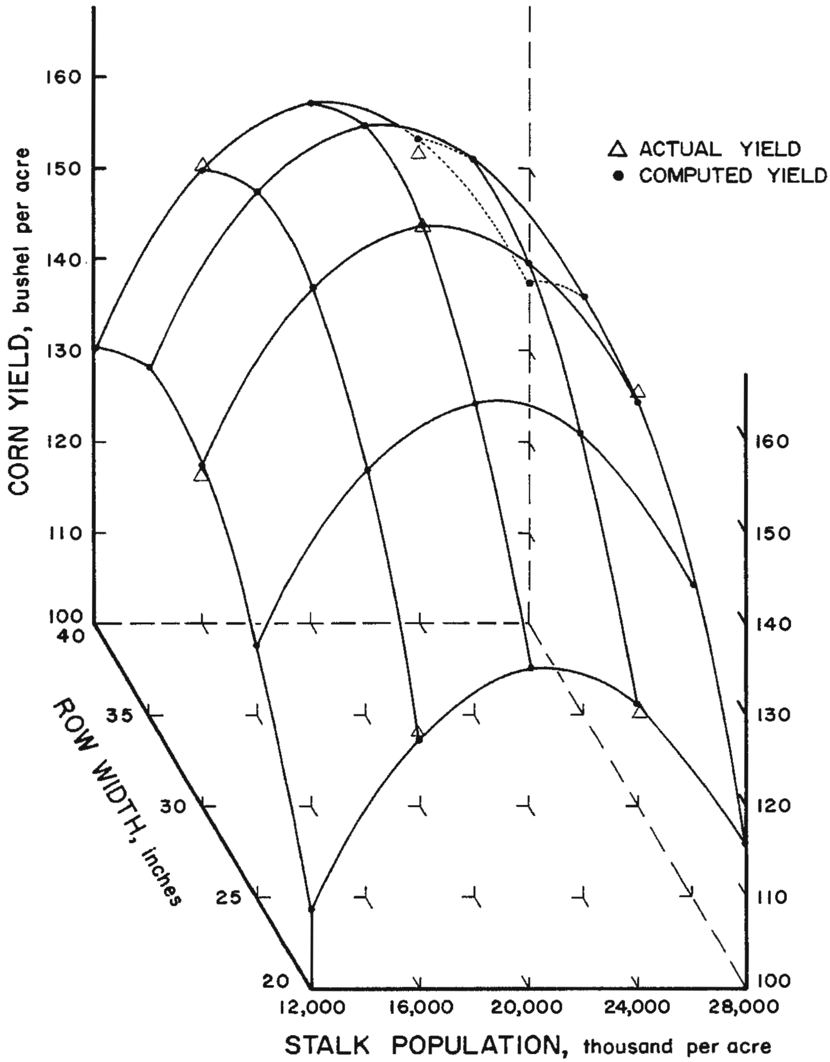


Fig. 6 Corn yield (grain) response surface from stalk population and row width. United Hagie 152A yield for 1965.

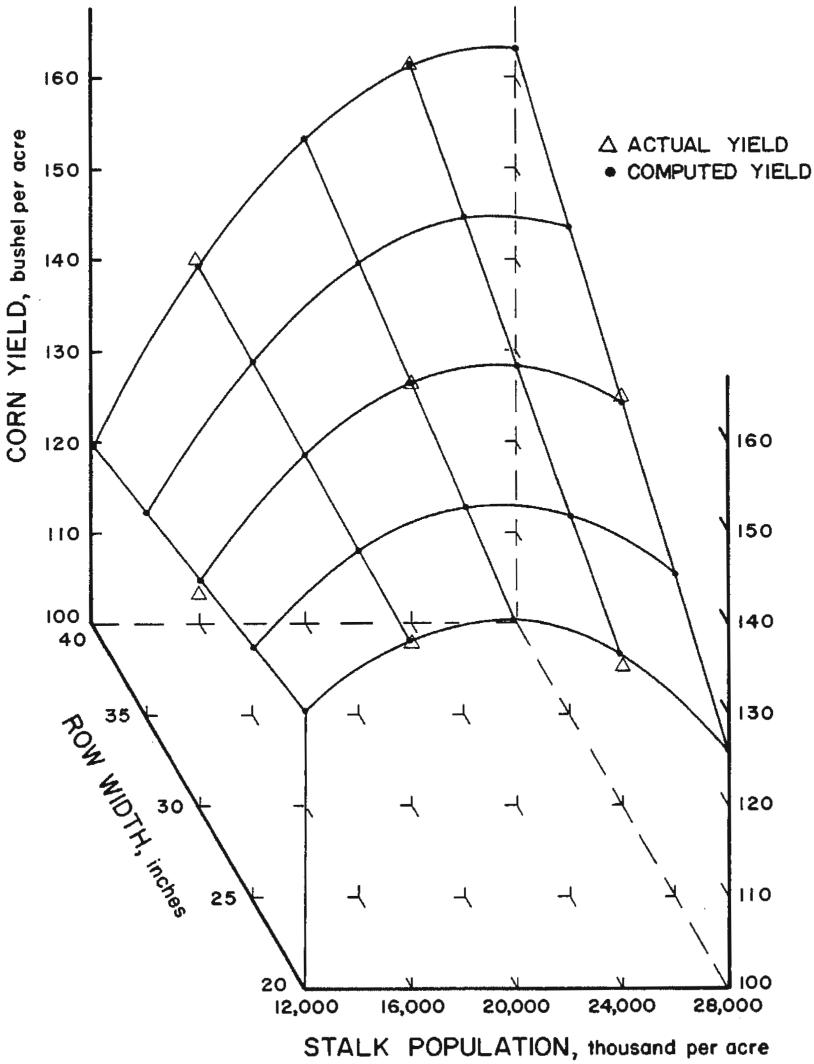


Fig. 7 Corn yield (grain) response surface from stalk population and row width. United Hagie 152A yield for 1966.

Silage

Figures 8 and 9 show the effects of stalk population and row width on silage yields (total dry matter adjusted to 72.6 percent moisture) in tons per acre from the same hybrid corns. These data are the averages for both years, since the treatment x years interaction was not significant.

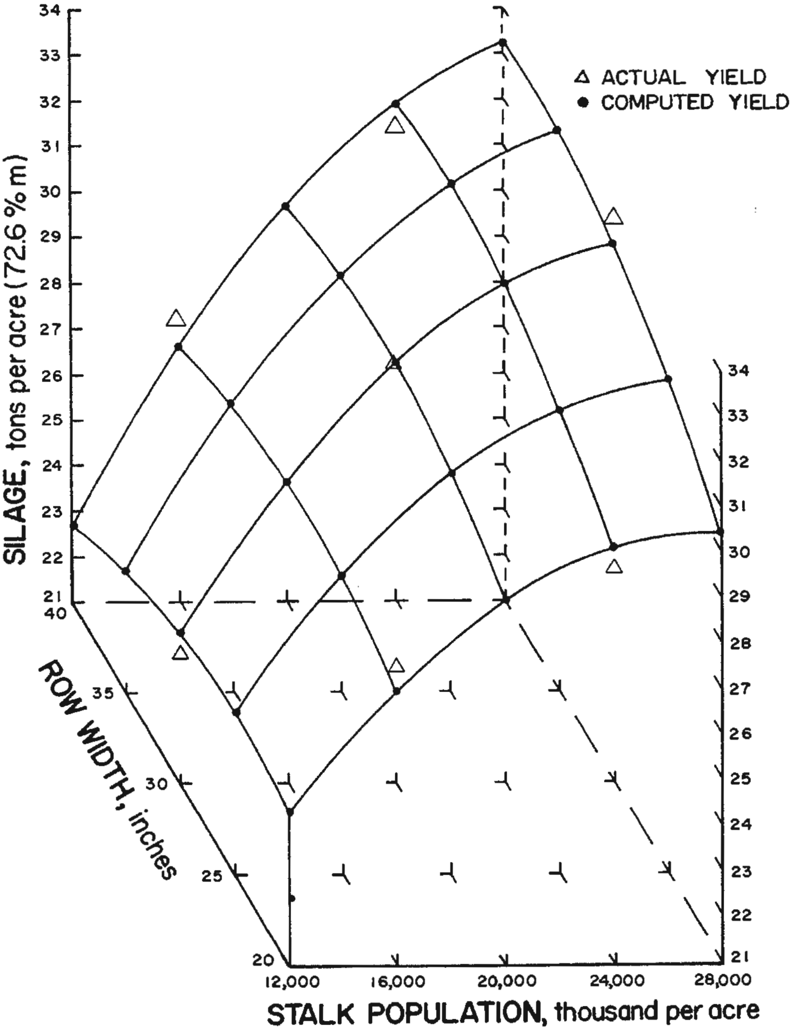


Fig. 8 Yield response (silage) surface from stalk population and row width. Pioneer 321 hybrid average for 1965 and 1966.

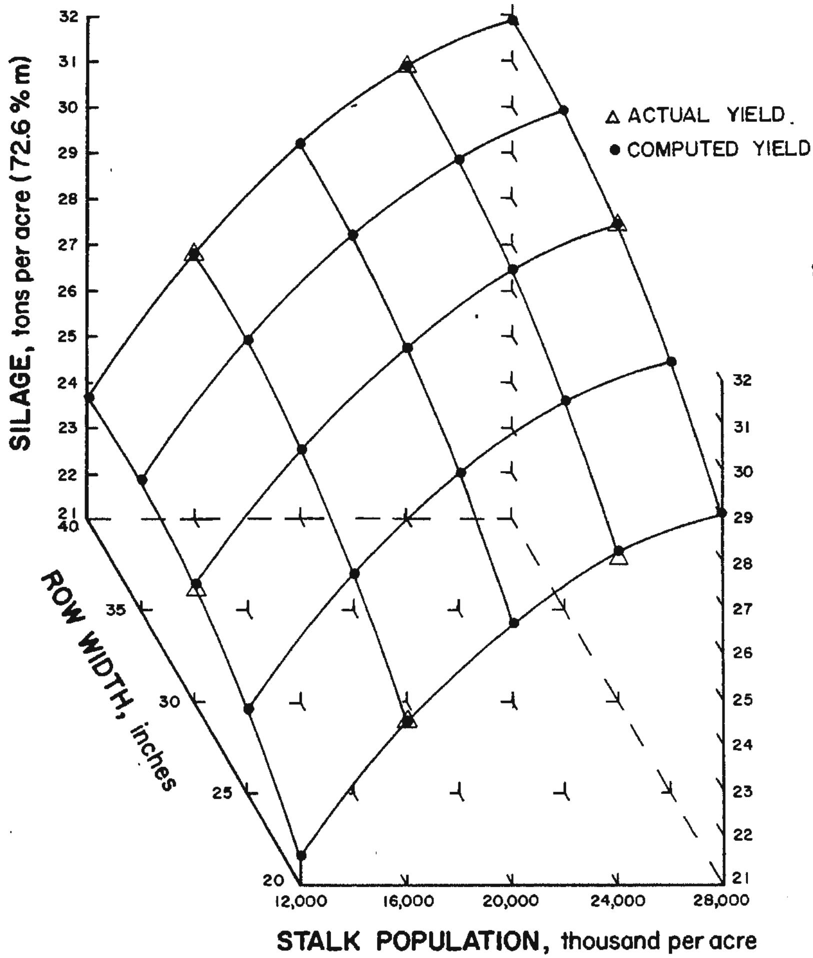


Fig. 9 Yield response (silage) surface from stalk population and row widtl United Hagie 152A average for 1965 and 1966.

Statistically, the yield differences for the Pioneer hybrid are significant at the 1-percent and 5-percent levels for 1965 and 1966, respectively. The highest production was with 30-inch rows from 28,000-stalk population in 1965. In 1966, it was with 40-inch rows from 28,000-stalk population. The response (fig. 8) was greater to population than to row spacing. There was little difference in yields between 35- and 40-inch rows at 28,000 stalks.

Statistically, the yield differences for the United Hagie hybrid are significant at the 1-percent level for both years. The highest production was from 28,000-stalk population with 30-inch rows in 1965 and with 40-inch rows in 1966. The response (fig. 9) was again greater to population than to row spacing.

Forage (Dry Matter)

Figures 10 and 11 show the effect of plant population and row width on forage yields, expressed as dry matter in tons per acre. These figures show that total dry matter production, as influenced by plant population, increased linearly from 12,000 to 28,000 plants per acre on both hybrids. Row width exerted minor influence. It ranged from 3.4 tons per acre for the low population in the Pioneer hybrid to 5.6 for the high population. United Hagie varied from 3.1 tons per acre for the low population to 5.2 for the higher population.

Ear Production

Figure 12 shows the effect of plant population and row width on the number of ears produced for various population and row spacing combinations. Even though the ear production response to treatments was not alike for the 2 years, the data were averaged over the years for brevity. However, the differences due to treatments were statistically significant at the 5-percent level for the 2 years. For a given population of both Pioneer and United Hagie corn, the number of ears increased with decreased row widths. The number of barren stalks increased with increased population and increased row widths.

Ear Weights

Figure 13 shows the effect of plant population and row width on the average ear weights from the Pioneer 321 and United Hagie 152A hybrids. Data in the left portion of figure 13 (Pioneer) show that row width has far less effect than population on ear weight. It is usually considered that stalk populations that produce 0.5-pound ears produce near maximum yields. This occurred at about 24,000 stalks per acre. The treatment x years interaction was significant for both hybrids.

Data in the right portion of figure 13 (United Hagie) show that, for row widths of less than 30 inches, average ear weight decreases and is about uniform above 30 inches for a given population. Population is still the more important parameter; 24,000 stalks produce ears averaging about 0.5 pound each.

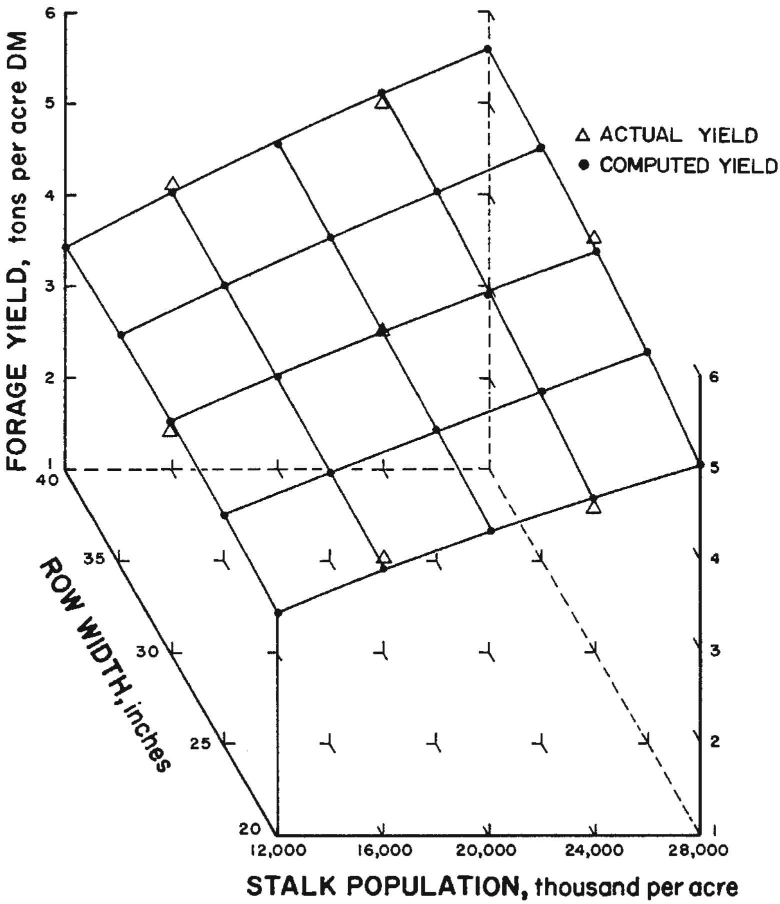


Fig. 10 Yield response (forage dry matter) surface from stalk population and row width. Pioneer 321 hybrid average for 1965 and 1966.

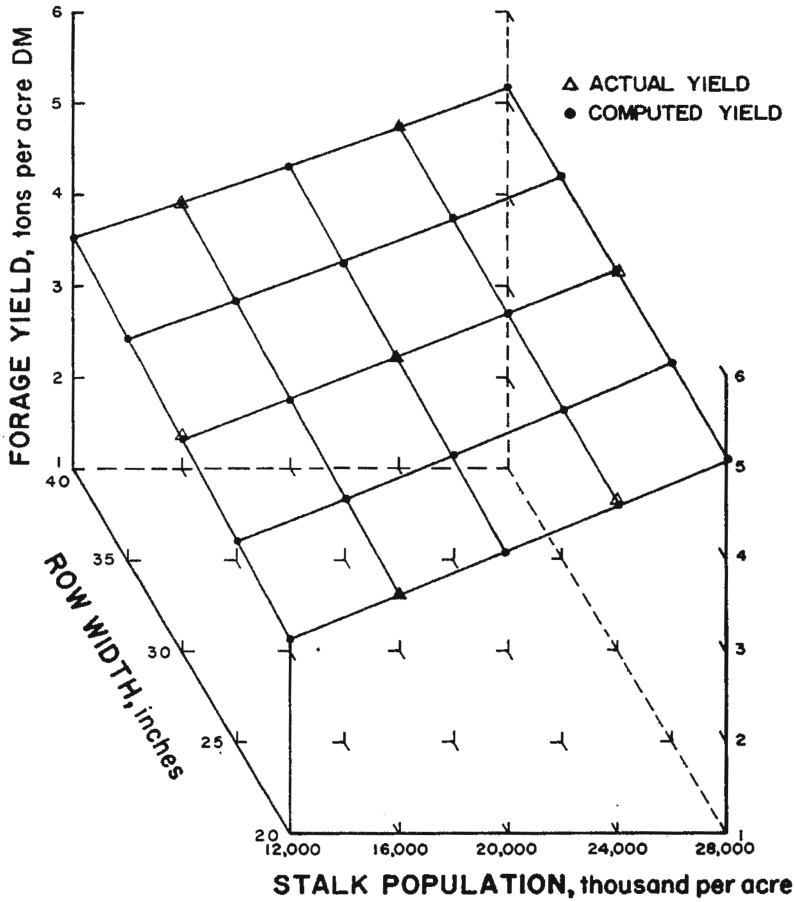


Fig. 11 Yield response (forage dry matter) surface from stalk population and row width. United Hagie 152A average for 1965 and 1966.

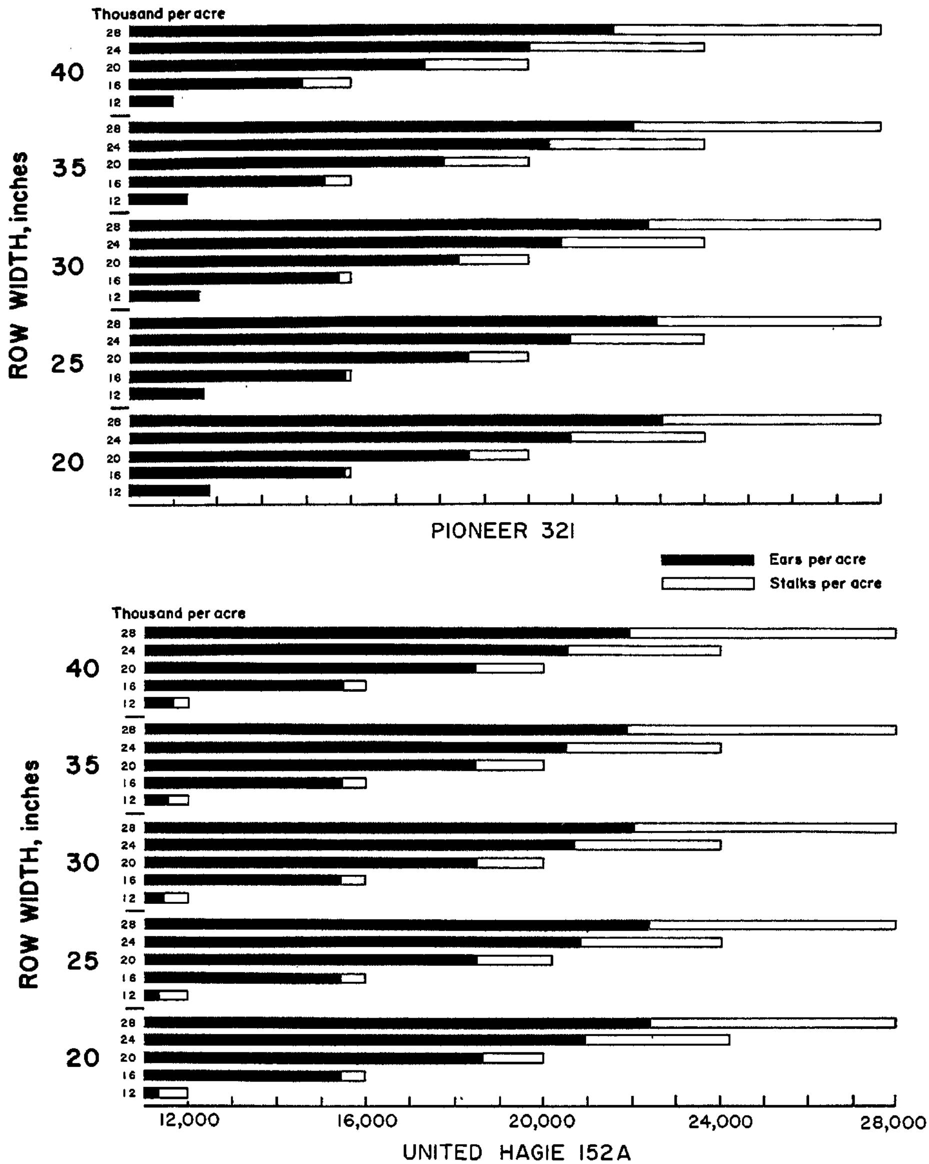


Fig. 12 The number of ears produced and barren stalks, as affected by stalk population and row widths, 1965 and 1966.

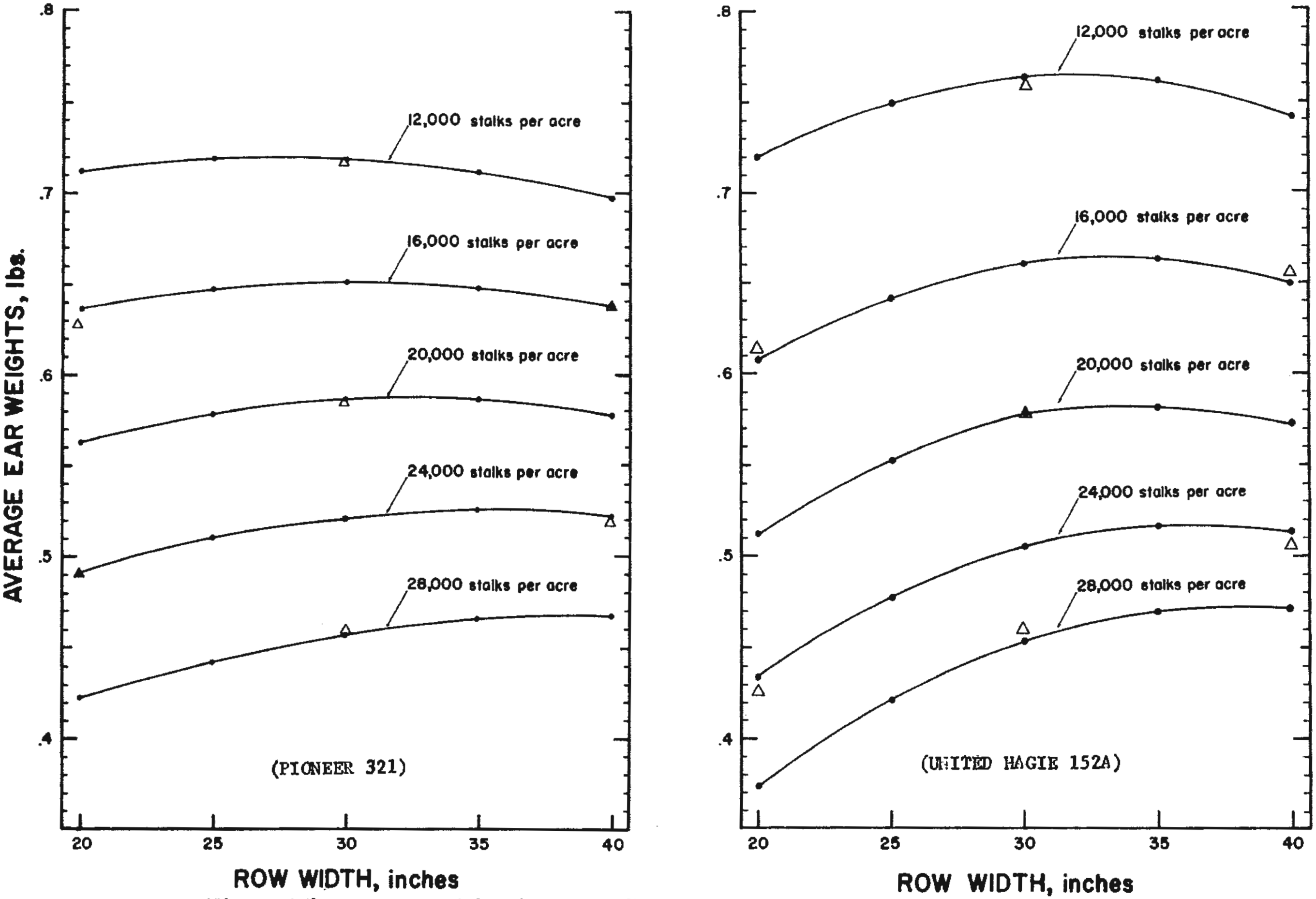


Fig. 13 The average weight of ears as affected by stalk population and row widths. Average of 1965 and 1966.

Stalks (Machine Harvestable)

In figure 14 are plotted the standing stalks and the stalks broken below the ear, as influenced by row spacing and population for the two hybrids studied. These data are for 1966 only, since a windstorm on June 20, 1965 badly damaged the corn on all treatments. The effects of stalk population and row spacing variables on standability were virtually impossible to ascertain at harvest time. For this analysis, it is assumed that the standing and leaning stalks would be machine harvestable, while the ears on stalks broken below the ear would be left in the field. On this basis, the numbers given in the clear portion of the bars represent the grain yields that would be machine harvestable and those in the shaded portion the grain left in the field.

The data for both hybrids indicate that the number of broken stalks increases with increasing population and decreasing row widths. However, the number of broken stalks for a given treatment is roughly twice as great for the United Hagie hybrid as for the Pioneer hybrid, which stresses the importance of selecting stiff-stalked hybrids when planting at high populations.

Total Nutrient Uptake

The total nitrogen, phosphorus, and potassium contents of the grain and forage as influenced by plant population and row spacing are given for the Pioneer hybrid in figure 15 and for the United Hagie hybrid in figure 16. For comparative purposes, the corn yields and forage dry matter yields are shown on the top of the figure. The percentage of nutrients (N, P, K) in the grain and forage was usually not significantly different (see appendix table 2) for all populations and row widths. Therefore, the total uptake differences in figures 15 and 16 generally reflect differences in yield.

Pioneer

The total nitrogen uptake in grain and forage varied between approximately 160 and 230 pounds per acre (fig. 15). Of the total, the amount in the grain ranged from 91 to 120 pounds per acre and the amount in the forage ranged from 68 to 115 pounds per acre. Total uptake of nitrogen in both grain and forage increased with increased population. At the lower populations, the total nitrogen uptake decreased with increasing row width. This difference was largely reflected in the amount contained in the grain which, in turn, is the result of lower grain yields. At the higher populations, the total nitrogen uptake increased with increasing row widths. In contrast with the lower populations, the total nitrogen uptake increase was due to higher yields of both grain and forage.

Total phosphorus uptake, that contained in the grain and forage for the Pioneer hybrid, ranged from about 26 pounds at the lower populations to about 34 pounds per acre at the higher populations. Of the total, the amount in the grain ranged from about 18 pounds per acre at the lower populations to 23 pounds per acre at the higher populations.

Total uptake of potassium, as influenced by plant population and row width, varied between 140 and 245 pounds per acre for the Pioneer hybrid. Potassium content of the grain was relatively low when compared with the total uptake, ranging from approximately 15 to 30 pounds per acre. The differences in uptake were related to differences in dry matter and grain yields.

United Hagie

For this hybrid (fig. 16), total nitrogen uptake varied between 166 and 227 pounds per acre and increased with increasing plant populations. Total nitrogen uptake was largely a reflection of the forage and grain yields.

Total phosphorus uptake ranged from about 26 pounds per acre at the lower populations to 33 pounds per acre at the higher populations. Of the total, the amount in the grain varied from about 18 to about 24 pounds per acre. This did not vary according to population.

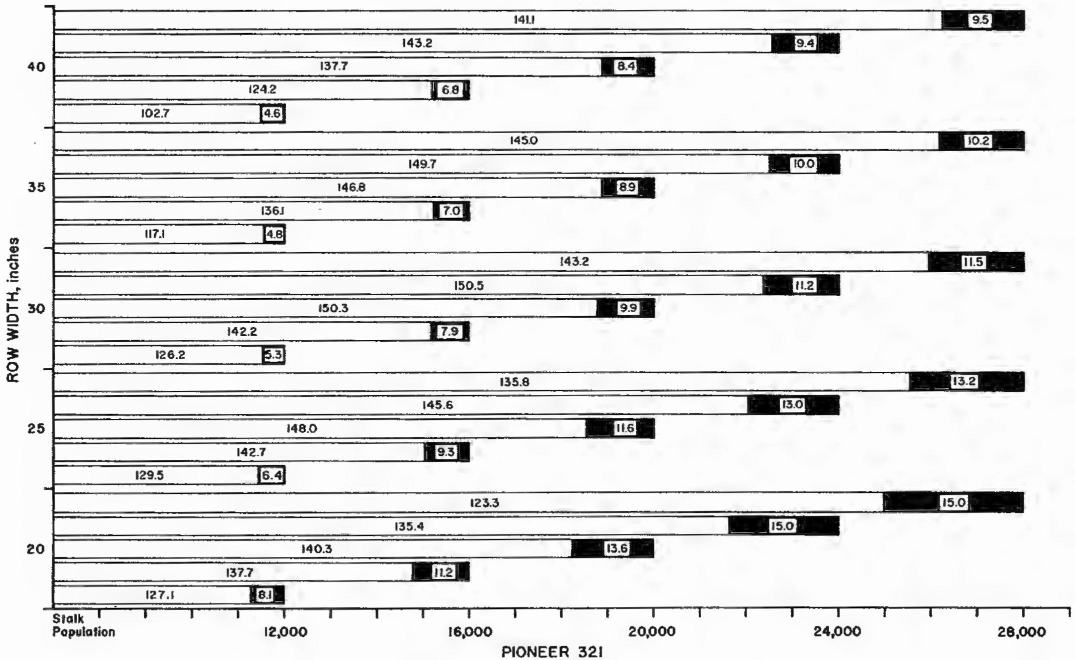
The total uptake of potassium, as influenced by plant population and row width, varied between 139 at low populations and 208 pounds per acre at the high populations. The highest uptake in the forage was in the 25- and 30-inch rows. The uptake in the grain was very similar throughout, the values ranging from 21 to 26 pounds per acre.

If one assumes that about 75 pounds of N per acre was contained in the roots, then that amount plus the approximately 225 pounds contained in the Pioneer 321 forage and grain at the higher populations (fig. 15) is equal to the total amount of mineral nitrogen applied per year. If only the grain is harvested, however, less than 50 percent of the total applied N is removed. If the grain plus forage is harvested, then about 75 percent of the applied N is removed.

Total uptake of P nearly equaled the amount applied if it is assumed that about 5 to 8 pounds was contained in the roots. Approximately 50 and 75 percent of the P would be removed in grain and in grain plus forage, respectively.

In contrast to N and P, the total amounts of K taken up by the plants at the high populations were probably more than three times the amount applied annually (83 pounds). However, most of the amount absorbed by the plant is contained in the forage and roots. Thus, if only the grain is harvested, only about 25 percent of the K is removed from the field.

The amounts of N. P, and K contained in the grain plus forage were very different at the lowest and highest plant populations. For the 30-inch rows of United Hagie 152A (fig. 16), 26 percent more N was taken up at the 28,000-plant population as compared with the 12,000-plant population. Comparable figures for P and K are 12 and 39 percent, respectively. Total dry matter increased 27 percent, for the United Hagie 152A hybrid when the population was increased from 12,000 to 28,000 plants per acre.


ROW WIDTH, inches
40
35
30
25
20
141.1
9.5
143.2
9.4
137.7
8.4
124.2
6.8
102.7
4.6
145.0
10.2
149.7
10.0
146.8
8.9
136.1
7.0
117.1
4.8
143.2
11.5
150.5
11.2
150.3
9.9
142.2
7.9
126.2
5.3
135.8
13.2
145.6
13.0
148.0
11.6
142.7
9.3
129.5
6.4
123.3
15.0
135.4
15.0
140.3
13.6
137.7
11.2
127.1
8.1
Stalk Population
12,000
16,000
20,000
24,000
28,000
PIONEER 321

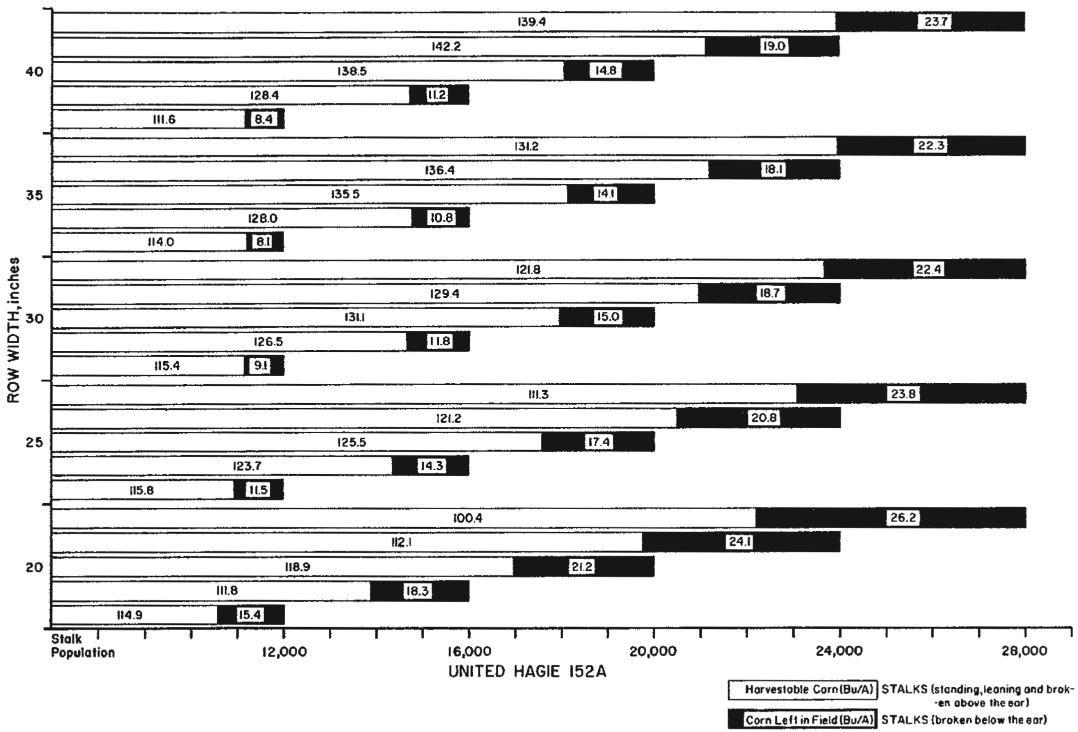


Fig. 14 The effect of stalk population and row width on lodging and harvestability of corn. Averages for 1966.

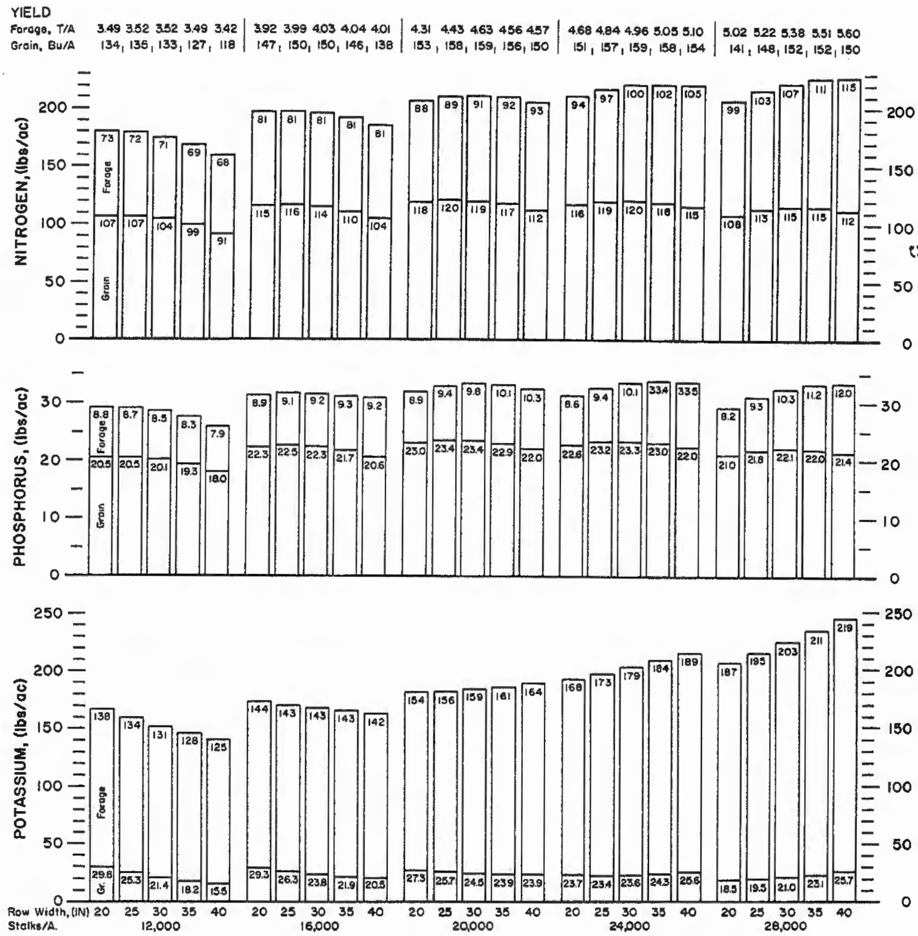


Fig. 15 Total nitrogen, phosphorus, and potassium uptake by corn, as influenced by plant population and row width. (Average of 1965 and 1966, Pioneer 321).

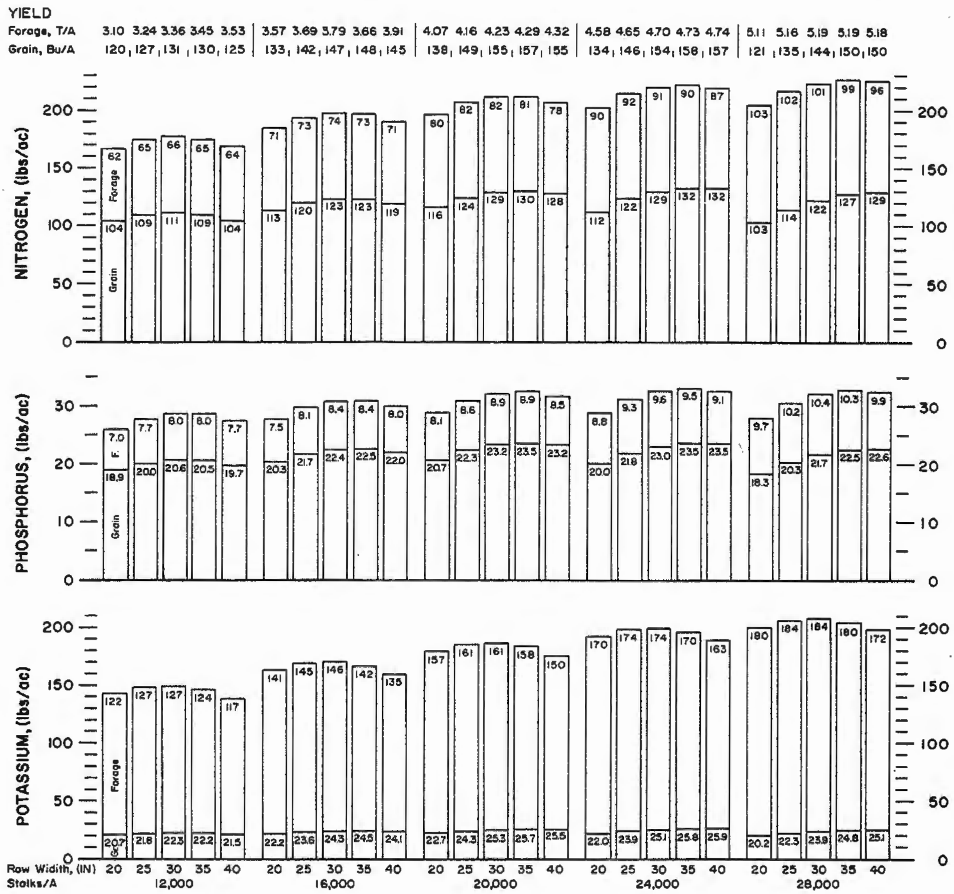


Fig. 16 Total nitrogen, phosphorus, and potassium uptake by corn, as influenced by plant population and row width. (Average of 1965 and 1966, United Hagie 152A).

SUMMARY

A study was conducted in 1965 and 1966 on a fertile Sharon silt loam near Elsberry, Missouri, to determine the maximum yield response of corn for different levels of plant population and row widths, using two hybrids. Adequate fertilizer and irrigation were applied as needed to limit the study to the above variables. Analyses of corn leaf and whole-plant samples showed that plant nutrition was not a variable. Adequate soil water was maintained so that the plants were not under severe water stress after the seedling stage.

Other climatic conditions such as cold, wet periods during the early growing season and above-average temperatures during silking and ear-shoot formation limited the yields to below the maximum potential for this soils area. It is believed, however, that the differences in yield response to the various treatments are representative.

Average grain yields from the Pioneer 321 hybrid corn were highest from the 24,000- and 20,000-plant populations and 30-inch row widths. The average yields for the 2 years was 159 bushels per acre from both populations.

Average grain yields from the United Hagie 152A hybrid corn were highest from the 24,000-plant populations and 35-inch row widths. The yields for both the 20,000- and 24,000-population levels were almost equal for row widths of 30 inches or more, with the maximum harvestable yield obtained from the 20,000-plant population and 35-inch row width.

Total dry matter production response was much greater to plant population than to row width. Dry matter production increased linearly from 12,000 to 28,000 plants per acre for both hybrids.

The percentage of barren and broken stalks increased with increased population. The yield increase expected from higher populations was offset to a considerable degree by these unproductive stalks, especially on populations of more than 20,000 stalks per acre.

Ear weight is highly dependent on population. Most studies in the Corn Belt show that an average ear weight of approximately 0.5 pound is associated with maximum yield of full-season hybrids.[6] If the 0.5-pound value is accepted as near ideal, this study shows that the row width should be about 30 inches and the plant population should not exceed 22,000 to 24,000 plants per acre.

The total amounts of nitrogen, phosphorus, and potassium in the corn grain and forage were determined for background data for guiding fertilizer usage when the grain is removed and when both the grain and forage are removed from the land. About 60 percent of the total nitrogen is contained in the grain at the 12,000-plant-per-acre population and about 50 percent at the 28,000-plant-per-acre population. If the forage is returned to the land, the amount of nitro-

[6]Pierre, W. H., Aldrich, S. A., and Martin, W. P. advances in corn production principles and practices, 1966. Chapter 3, by Rossman, E. C., and Cook, R. L. soil preparation and date, rate, and pattern of planting, 49 pp. Iowa State Press, Publisher.

gen returned ranges from about 62 to 115 pounds per acre. In the case of phosphorus, about two-thirds of the phosphorus is contained in the grain and one-third in the forage (8 to 12 pounds). About 12 to 18 percent of the potassium is contained in the grain. The remainder contained in the forage varies from about 120 to 220 pounds per acre. Therefore, when corn is used for silage, larger amounts of nutrients are removed from the land than when the grain only is harvested. This requires increased application of fertilizer to maintain the land at a high nutrient level.

A two-dimensional, second-order composite design was used in this study. The response surface computed from a second-order polynomial gives a complete summary of the results of the experiment and enables prediction of responses for combinations of variables not actually tested in the experiment but lying within the ranges of those tested. The analysis of variance and prediction equations showed that the design used for experiments was well suited to this study.

TABLE 1.--Yield and composition of corn, Elsberry, Missouri, 1965-1966
(Measured Values)

Row Inches	Pop. Stalks/A	Yield Bu/A	Dry M Lbs/A Grain	Dry M Lbs/A Forage	Grain % N	Grain % P	Grain % K	Forage % N	Forage % P	Forage % K	Composition of Leaf Samples % N	Composition of Leaf Samples % P	Composition of Leaf Samples % K
1965													
Pioneer 321 (Averages of replications)													
20	16,000	146	6924	7542	1.60	.31	.55	1.02	.11	2.02	2.80	.36	2.04
20	24,000	152	7173	8873	1.58	.32	.33	.99	.09	1.91	2.70	.34	2.03
30	12,000	134	6338	6609	1.63	.32	.34	1.02	.12	2.09	2.89	.35	2.02
30	20,000	157	7428	9255	1.59	.32	.34	1.00	.10	1.89	2.84	.36	1.95
30	28,000	150	7076	11090	1.56	.31	.32	.96	.09	1.89	2.75	.33	2.04
40	16,000	146	6890	7809	1.54	.31	.34	1.01	.10	1.86	2.86	.37	1.90
40	24,000	155	7332	8849	1.53	.30	.33	1.05	.10	1.85	2.79	.36	1.87
United Hagie 152A (Averages of replications)													
20	16,000	129	6099	7500	1.75	.31	.34	.94	.10	1.90	2.46	.27	2.32
20	24,000	130	6168	9825	1.69	.32	.33	.91	.09	1.83	2.47	.26	2.20
30	12,000	136	6451	7097	1.77	.34	.35	.95	.12	1.97	2.46	.28	2.20
30	20,000	164	7760	8921	1.69	.31	.33	.93	.10	1.95	2.43	.28	2.24
30	28,000	146	6895	11295	1.72	.32	.34	.93	.09	1.76	2.37	.26	2.25
40	16,000	151	7128	7537	1.67	.32	.33	.91	.10	1.82	2.50	.29	2.16
40	24,000	152	7193	9273	1.69	.31	.33	.91	.09	1.84	2.44	.27	2.13
1966													
Pioneer 321 (Averages of replications)													
20	16,000	152	7190	8620	1.70	.32	.31	1.03	.11	1.65	2.91	.36	2.05
20	24,000	147	6976	9369	1.66	.31	.30	1.02	.10	1.70	2.83	.33	2.03
30	12,000	128	6079	6997	1.67	.32	.30	1.00	.13	1.66	3.00	.37	2.15
30	20,000	160	7583	8795	1.59	.31	.32	1.02	.11	1.63	2.91	.35	2.02
30	28,000	158	7464	10931	1.64	.31	.30	1.03	.09	1.87	2.69	.34	2.06
40	16,000	134	6344	8737	1.65	.31	.32	.99	.12	1.67	3.09	.36	2.07
40	24,000	150	7079	11058	1.62	.31	.34	1.02	.13	1.89	2.95	.35	2.15
United Hagie 152A (Averages of replications)													
20	16,000	139	6584	6742	1.84	.32	.36	1.03	.11	1.93	2.76	.29	2.27
20	24,000	135	6398	8561	1.87	.32	.37	1.10	.11	1.96	2.78	.29	2.28
30	12,000	124	5849	6385	1.81	.33	.37	1.03	.12	1.94	2.91	.30	2.31
30	20,000	146	6913	8021	1.83	.32	.37	1.02	.12	1.87	2.73	.28	2.30
30	28,000	145	6871	9409	1.85	.31	.35	1.03	.11	1.71	2.65	.27	2.32
40	16,000	141	6653	8065	1.81	.32	.37	.88	.10	1.55	2.70	.29	2.40
40	24,000	160	7583	9737	1.85	.32	.37	.94	.10	1.68	2.74	.28	2.38

APPENDIX

TABLE 2. -- Yield and composition of corn, Elsberry, Missouri, 1965-1966
[Computed values]

Row Spacing	Population	Grain	Dry Matter		Silage (72.6% M)	Grain	Dry Matter		Silage (72.6% M)
			Forage	Total			Forage	Total	
Inches	Stalks/A	Bu/A	T/A	T/A	T/A	Bu/A	T/A	T/A	T/A
		Pioneer 321 (Averages of replications)				United Hagie 152A (Averages of replications)			
20	12,000	133.5	3.49	6.65	24.3	119.5	3.10	5.93	21.6
	16,000	147.5	3.92	7.41	27.0	132.9	3.57	6.72	24.5
	20,000	153.3	4.31	7.94	29.0	137.7	4.07	7.33	26.7
	24,000	151.1	4.68	8.26	30.1	133.8	4.58	7.75	28.3
	28,000	140.7	5.02	8.35	30.5	121.2	5.11	7.98	29.1
25	12,000	134.9	3.52	6.71	24.5	127.4	3.24	6.25	22.8
	16,000	150.3	3.99	7.55	27.5	142.3	3.69	7.06	25.8
	20,000	157.7	4.43	8.16	29.8	148.5	4.16	7.68	28.0
	24,000	156.9	4.84	8.55	31.2	146.0	4.65	8.11	29.6
	28,000	148.1	5.22	8.72	31.8	134.9	5.16	8.35	30.5
30	12,000	132.8	3.52	6.67	24.3	131.0	3.36	6.46	23.6
	16,000	149.7	4.03	7.58	27.6	147.3	3.79	7.27	26.5
	20,000	158.6	4.51	8.26	30.2	155.0	4.23	7.90	28.8
	24,000	159.3	4.96	8.73	31.9	154.0	4.70	8.35	30.5
	28,000	152.0	5.38	8.98	32.8	144.4	5.19	8.60	31.4
35	12,000	127.2	3.49	6.50	23.7	130.3	3.45	6.54	23.9
	16,000	145.7	4.04	7.49	27.3	148.1	3.86	7.36	26.9
	20,000	156.0	4.56	8.25	30.1	157.2	4.29	8.00	29.2
	24,000	158.3	5.05	8.79	32.1	157.7	4.73	8.46	30.9
	28,000	152.5	5.51	9.11	33.3	149.5	5.19	8.73	31.9
40	12,000	118.2	3.42	6.22	22.7	125.2	3.53	6.49	23.7
	16,000	138.2	4.01	7.28	26.6	144.5	3.91	7.33	26.8
	20,000	150.1	4.57	8.12	29.6	155.2	4.32	7.99	29.2
	24,000	153.8	5.10	8.74	31.9	157.1	4.74	8.46	30.9
	28,000	149.5	5.60	9.14	33.3	150.4	5.18	8.74	31.9

TABLE 3.--F values from analysis of variance

Variable	Unit	United Hagie 152A 1965	United Hagie 152A 1966	United Hagie 152A 1965 x 1966	Pioneer 321 1965	Pioneer 321 1966	Pioneer 321 1965 x 1966
Grain Yield	Bu/A	1/ 9.7	2/ 4.27	1/ 4.48	3/ 2.7	1/ 9.8	1.60
Dry Matter	Lbs/A	1/ 13.6	1/ 6.20	1.26	1/ 8.4	2/ 4.1	2.10
No. of Ears		1/ 83.6	1/ 73.6	2/ 4.01	1/ 107.2	1/ 28.3	2/ 3.66
Ear Weight	Lbs	1/ 70.1	1/ 52.2	2/ 4.08	1/ 42.0	1/ 124.2	1/ 7.14
Grain N	%	1.9	0.21	0.62	1.9	3/ 2.5	1.06
Grain P	%	1.3	0.45	0.57	1.3	0.8	0.52
Grain K	%	1.6	2.1	1.49	1.2	0.4	0.94
Forage N	%	0.6	2/ 4.0	0.60	.5	0.1	0.30
Forage P	%	7.6	1.0	1.15	1.4	2.0	1.47
Forage K	%	0.6	1/ 5.1	0.93	2.1	2.0	2/ 3.82
Leaf N	%	3/ 2.9	2/ 4.2	2/ 3.46	3/ 2.3	2/ 5.4	3/ 2.54
Leaf P	%	2/ 3.4	2/ 3.0	0.98	2/ 3.0	3/ 2.3	3/ 2.72
Leaf K	%	1.6	.36	1.34	1.0	0.8	2/ 4.08
Grain N	Lbs/A	1/ 5.5	1/ 5.3	1/ 5.07	1.7	1/ 7.4	3/ 2.46
Grain P	Lbs/A	1/ 5.4	3/ 2.3	1/ 4.69	1.2	2/ 4.0	1.82
Grain K	Lbs/A	2/ 4.0	2/ 3.9	3/ 2.71	1.0	1.3	0.70
Forage N	Lbs/A	1/ 12.1	1/ 5.9	0.46	1/ 5.7	1/ 6.3	0.80
Forage P	Lbs/A	2/ 3.1	1.2	0.65	1.2	2.1	3/ 2.73
Forage K	Lbs/A	1/ 10.5	2.2	0.54	1/ 6.1	1/ 9.1	2/ 3.49
Total N	Lbs/A	1/ 8.2	1/ 5.2	1.45	2/ 4.4	1/ 7.5	1.13
Total P	Lbs/A	1/ 6.9	1.8	3/ 2.75	1.4	2.1	1.82
Total K	Lbs/A	1/ 10.8	2.2	0.63	2/ 3.3	1/ 7.9	3/ 2.73
Stalks broken below ear	%	----	1.7		----	1.5	
Total Dry Matter	Lbs/A	1/ 18.0	1/ 6.4	1.26	1/ 6.8	1/ 5.7	1.50

1/ Significant at the 1-percent level.

2/ Significant at the 5-percent level.

3/ Significant at the 10-percent level.

TABLE 4.--Regression coefficients for second-order polynomial

Variable	Unit	United Hagie 152A						Pioneer 321					
		b_0	b_1	b_2	b_{11}	b_{22}	b_{12}	b_0	b_1	b_2	b_{11}	b_{22}	b_{12}
Grain Yield													
1965	Bu/A	163.9	3.58	12.5	-23.0	-23.7	- 0.02	1569	7.63	0.770	- 15.23	- 4.74	2.35
1966	Bu/A	146.1	9.81	7.64	-11.75	.805	13.59	160.2	11.6	- 4.52	- 17.2	- 13.6	11.6
Combined Dry Matter													
1965	Lbs/A	8920	2076	-148	275	-608	- 340	9253	1888	70.05	-405.3	- 1179	-167.8
1966	Lbs/A	8020	1590	721	-124	381	-84.7	8993	1822	521	169	812	907
No. of Ears													
1965		18933	5198	126	-2613	-126	1006	18585	5254	-263.8	-1103	837.2	427.2
1966		18062	5387	-327	-929	300	453	18208	4881	- 918	- 377	- 1573	- 427
Ear Weight													
1965	Lbs	.592	-.167	.039	.034	- .076	.017	.577	- .140	.012	.017	- .040	- .009
1966	Lbs	.556	-.142	.032	.026	- .0076	.025	.594	- .120	.006	- .010	.002	.043
Grain N													
1965	Percent	1.69	-.023	- .021	.0253	- .009	.046	1.593	- .030	- .033	.002	- .043	.008
1966	Percent	1.830	.027	- .013	.003	.0017	.004	1.587	- .023	- .024	.065	.070	.002
Grain P													
1965	Percent	.313	-.007	.001	.017	- .002	- .006	.315	- .006	- .005	.000	- .003	- .010
1966	Percent	.320	-.006	- .002	.000	.002	.004	.308	- .007	- .004	.005	.007	.004
Grain K													
1965	Percent	.325	-.005	- .003	.023	.002	.006	.340	- .047	- .060	- .008	.067	.127
1966	Percent	.367	-.006	.003	- .005	.003	- .006	.315	- .001	.014	- .017	.009	.013
Forage N													
1965	Percent	.925	-.013	- .007	.013	- .014	.013	.998	- .018	.014	.005	.025	.036
1966	Percent	1.022	.022	- .089	.010	- .049	- .002	1.018	.014	- .010	- .003	- .003	.023
Forage P													
1965	Percent	.097	-.012	.003	.008	- .006	- .002	.102	- .13	.000	.005	- .004	.008
1966	Percent	.115	-.005	- .005	.000	- .012	.002	.113	- .012	.010	- .002	.001	.012
Forage K													
1965	Percent	1.952	-.079	- .019	- .087	- .107	.054	1.888	- .086	- .062	.102	- .004	.052
1966	Percent	1.868	-.050	- .189	- .045	- .105	.054	1.633	.112	.061	.130	.083	.100
Leaf N													
1965	Percent	2.432	-.037	.003	- .015	.057	- .040	2.837	- .073	.045	- .018	- .057	.013
1966	Percent	2.733	-.073	- .029	.045	.000	.012	2.913	- .137	.086	- .068	.066	- .036

TABLE 4.--Continued

Variable	Unit	United Hagie 152A						Pioneer 321					
		b_0	b_1	b_2	b_{11}	b_{22}	b_{12}	b_0	b_1	b_2	b_{11}	b_{22}	b_{12}
Leaf P													
1965	Percent	.275	-.013	.006	-.005	-.001	-.004	.357	-.010	.011	-.018	.005	.006
1966	Percent	.278	-.012	-.001	.003	.011	-.002	.350	-.137	.004	.003	-.001	.012
Leaf K													
1965	Percent	2.242	-.010	-.065	-.015	-.004	.054	1.953	.002	-.086	.077	-.015	-.013
1966	Percent	2.298	.002	.065	.020	.036	-.019	2.015	-.018	.040	.090	.048	.054
Grain N													
1965	Lbs	131.4	1.53	8.69	-14.78	-19.74	2.92	118.2	3.69	-1.77	-11.43	-6.45	2.10
1966	Lbs	126.4	10.10	6.00	-9.75	1.65	12.58	120.3	7.45	-5.20	-8.66	-5.41	9.46
Grain P													
1965	Lbs	24.31	.060	1.90	-2.31	-3.64	-.390	23.41	.719	-.234	-2.31	-.941	-.363
1966	Lbs	22.12	1.12	1.07	-1.82	.284	2.375	23.38	1.26	-.927	-2.223	-1.460	2.012
Grain K													
1965	Lbs	25.21	.256	1.77	-1.98	-3.52	.362	25.23	-2.16	-4.29	-3.03	4.19	9.73
1966	Lbs	25.34	1.30	1.53	-2.42	.352	1.96	23.82	1.733	.318	-3.563	-1.264	2.621
Forage N													
1965	Lbs	82.49	18.13	-1.90	3.45	-6.84	-1.90	92.20	17.14	2.01	-5.08	-9.22	1.50
1966	Lbs	81.60	17.54	-.165	-.448	-.291	-1.70	89.50	19.36	4.40	1.49	7.92	11.06
Forage P													
1965	Lbs	8.620	1.070	.096	.827	-1.122	-.1394	9.45	.83	.11	-.32	-1.53	.44
1966	Lbs	9.17	1.33	.416	-.200	-.532	.101	10.06	.911	1.55	-.368	1.10	2.44
Forage K													
1965	Lbs	173.8	31.46	-4.34	-4.96	-20.24	-1.60	174.6	29.6	-3.78	-1.08	-22.08	.11
1966	Lbs	148.7	24.92	-2.91	-6.69	-.391	.075	142.5	41.85	15.29	18.06	22.54	25.58
Total N													
1965	Lbs	213.8	19.7	6.79	-11.3	-26.6	1.02	210.4	20.8	.246	-16.51	-15.67	3.61
1966	Lbs	208.1	27.6	5.83	-10.20	1.35	10.9	209.8	26.81	-.805	-7.170	2.520	20.52
Total P													
1965	Lbs	32.92	1.33	2.00	-1.49	-4.76	-.78	32.86	1.55	-.122	-2.64	-2.47	.076
1966	Lbs	31.29	2.45	1.49	-2.02	-.249	2.48	33.34	2.17	.261	-2.59	-.358	4.25
Total K													
1965	Lbs	199.0	31.72	-2.57	-6.93	-23.8	-1.24	199.8	27.5	-8.07	-4.11	-17.90	9.84
1966	Lbs	174.0	26.2	-1.38	-9.11	-.039	2.04	166.3	43.6	15.6	14.5	21.3	28.2
Stalks broken below ear													
1965	Percent	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1966	Percent	10.29	4.11	-3.19	1.13	2.82	-.387	6.21	1.70	-1.78	-.463	1.47	-.834
Total Dry Matter													
1965	Lbs/A	16677	2245	445	-812	-1730	-341	16679	2250	106.5	-1126	-1404	-56.7
1966	Lbs/A	14933	2054	1082	-680	420	558	16374	2371	207	-642	167	1455