RESEARCH BULLETIN 1008 OCTOBER 1974

UNIVERSITY OF MISSOURI-COLUMBIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

HYBRID-ROW SPACING-PLANT POPULATION STUDIES WITH CORN IN MISSOURI

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(Publication Authorized October 29, 1974)

COLUMBIA, MISSOURI

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INTRODUCTION

With the advent of single cross corn (*Zea mays* L.) hybrids, improved methods of weed control by herbicides, and the avilability of large-capacity farm machinery, a need for the evaluation of traditional methods of corn production was evident in the mid-1960's. Because of the increased use of herbicides in many farming systems, it was no longer necessary to consider the clearance capacity of farm equipment over corn plants for weed control. The traditional corn row spacing of 38 to 42 inches could now be considered expendable instead of necessary. For maximum efficiency of both labor and equipment, six planter units could now be used for planting narrower rows, rather than the four planter units used for the traditional spacing. However, farmers needed information on the effect of narrower row spacings with varying plant populations on corn production, before using these new practices.

The objective of these studies was to evaluate how various row spacings, different plant populations, and several environments affected corn production of currently grown hybrids. This publication presents the results of these studies and their implication to the Missouri corn grower.

LITERATURE REVIEW

The effect of different plant populations on corn grain yields has been verified throughout the literature. The response of yield to increased plant population may depend on locations (26), row spacings (8, 17), hybrids (5, 10, 21), and moisture availability during the growing season (5, 21, 24). Plant population levels as low as 7,000 (24) and as high as 28,000 to 30,000

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plants per acre have yielded highest in some environments (5, 9, 14, 25). A population of 12,000 plants per acre was optimum for grain production earlier (22, 26, 27), but more recently, 20,000 to 24,000 plants per acre have produced maximum grain yield (1, 2, 3, 4, 6, 11, 12, 15, 18, 21, 23).

Plant population levels also affect factors in corn production that contribute to yield. Stalk lodging has been found to increase with increasing plant population (4, 5, 6, 21, 23, 26, 27), whereas root lodging seems to be little affected by number of plants per acre (26, 27). Stalk crushing strength, a trait that may be related to stalk breakage or lodging, was shown by Singh to be negatively correlated with stalk lodging (16). Stalk diameter, another factor in lodging, decreased as plant population levels were increased (4, 14, 21). Ear height may increase with increased plant populations (4, 5, 14, 26) or may not be significantly affected (6, 8, 27). This trait is important since a higher ear placement would place more leverage on the stalk and possibly increase lodging and stalk breakage.

A standing stalk that is barren or has dropped its ear is also a negative factor in grain yield. Therefore, the effect of plant population levels on dropped ears or barren plants is of interest to the corn grower. At plant populations below 16,000 plants per acre, the number of dropped ears has been shown not to be affected by the number of plants (26, 27). In contrast, dropped ears increased linearly as plant populations were increased from 16,000 to 28,000 plants per acre (2). Increasing plant populations increased barren stalks (5, 6, 10, 20).

Stand percentages were found by Sharma and Gupta (15) to decrease linearly when plant populations were more than 28,000 plants per acre. Colville (2) reported that the weight per 100 kernels decreased linearly with each increase of 4,000 plants from 12,000 to 28,000 plants per acre. However, no difference in bushel weight (test weight) was found when plant population levels were changed (12).

Sommerfeldt (17) noted that leaf distribution on the stalk was affected by stand. At 22,000 plants per acre, the leaves tended to concentrate nearer the top of the plant, whereas they were distributed more uniformly along the stalk at lower plant population levels. Leaf area per plant was found to decrease linearly as plant population levels were increased to 28,000 plants per acre (11), but leaf area index increased with increasing number of plants per acre (9, 11).

The effect of row spacing on corn grain production is well documented. Narrow rows (18 to 24 inches) have been shown by numerous research efforts to be best for maximum grain production (8, 11, 13, 18, 20, 25) in relation to wide row spacings, especially when the higher populations of 20,000 to 24,000 plants per acre were used (8, 17). Part of the yield increase from the narrow rows was attributed to a higher efficiency of water use (25), the presence of fewer barren plants (18, 20), or both. Both of these phenomena were brought about by the greater distance between plants within the narrow rows at a given plant population level, thereby reducing competition for water and nutrients. On the other hand, some researchers have found no real advantage in using the narrow rows for increased grain yield (5, 6, 19).

Hayes, Douglas, and Beaty (8), Gill (6), and Giesbrecht (5) found that neither lodging nor ear height was significantly affected by row spacing. These results suggest that within-row plant competition, rather than between-row competition, affected lodging, since stalk lodging was shown to increase when plant populations were increased.

The difference in the amount of moisture available during the growing season has been shown to change the optimum plant population for maximum yields (5, 21, 24). The incidence of more barren plants in the higher populations has been shown to be altered by the environment (5).

Location effects have been shown to be similar to year effects, since each location, as each year, presents a different environment. Thus, either of these factors may alter the row spacing effect (9) or plant population effect (26) on grain yield. These findings suggest that corn yield response to a change in these two factors may be location-specific.

Some reports have indicated that some hybrids may have responded differently in grain yield as the plant population (10, 20, 21) or row spacing (23) was changed. Others, however, have reported little or no difference in grain yield among different hybrids as these two variables were changed (3, 9). Giesbrecht (5) found that the later-maturing, taller hybrids yielded more in competition brought about by high plant populations.

EXPERIMENTAL PROCEDURE

This study was begun in 1966 at four locations in Missouri to evaluate how row spacing and plant population would affect agronomic performance of three corn hybrids. The test sites were the North Missouri Research Center near Spickard, the Southwest Research Center near Mt. Vernon, the Agronomy Research Center near Columbia, and the Delta Research Center near Portageville. The study was conducted for 3 years, from 1966 to 1968, at each location. However, the 1968 test at Mt. Vernon was abandoned because of an excessive amount of volunteer corn. The hybrids 'Pioneer 3306', 'MFA 2222', and 'Dekalb XL65A', representing a relative maturity of 110 to 120 days, were selected for the study. Plots were overplanted and thinned to attain populations of 12,000, 16,000, 20,000, and 24,000 plants per acre in rows of 20, 30, and 40 inches in width. A factorial arrangement of treatments was used in a randomized complete block design with three replications at Mt. Vernon and Portageville and four replications at Spickard and Columbia. Three-row plots were used, each row being 33 feet long. Variables were measured on the center row of each plot.

The soil type at Spickard was a Seymour silt loam. It has a clay subsoil with 5 inches of available water in the upper 3 feet of soil. It is slowly permeable to air and water, but surface drainage was good. The Mt. Vernon tests were located on a Huntington silt loam. This well drained soil has a high available water holding capacity (7 inches in the upper 3 feet) and is well aerated. The Columbia experiments were conducted on a Mexico silt loam which has a claypan subsoil and an available-water holding capacity of 5.5 inches in the upper 3 feet. It is very slowly permeable to air and water. Surface drainage was good. At Portageville, the tests were located on a Tiptonville silt loam soil. This well-drained soil has a moderately permeable subsoil and a high water holding capacity of 6.5 to 7.0 inches.

Each year, all test sites received N, P_2O_5, and K_2O in the amounts of 150-75-100. Five pounds of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine)[3] as the active ingredient (a.i.) were applied per acre on each test site, except at Columbia, where 2 pounds of atrazine (a.i.) in combination with 0.5 pounds of linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] (a.i.) was applied. Aldrin (1, 2, 3, 4, 10, 10-hexachloro-1, 4, 4a, 5, 8, 8a-hexahydro-1, 4-endo-exo-5, 8-dimethano-naphthalene) insecticide was applied at all locations at the recommended rate.

Stand percentages for each test were computed on the basis of the total plants present, divided by the number of plants required for a perfect stand. Stands were counted after ear formation to permit the measurement of ear height at the same time. Ear height was graded as the number of feet from the ground level to the upper ear-bearing node.

Lodging counts were made prior to harvest. A plant was considered root-lodged if it leaned more than 30 degrees from the vertical and stalk-lodged if it was broken below the ear. A plant that was both root- and stalk-lodged was recorded in both categories. The percentage was based on the total number of plants present.

Grain moisture was determined at harvest. Grain from each replicate was thoroughly mixed, and the moisture content was determined on one sample with a Steinlite[4] moisture meter.

The ear corn from each plot was hand-harvested and weighed. Yield was determined on the basis of shelled corn with a moisture content of 15.5%.

To determine shelling percentage, we weighed the ears from each plot with grain intact and then weighed the cobs after shelling. The difference in

[3]This is a report on the current status of research involving use of certain chemicals that require registration under the Federal Environmental Pesticide Control Act (FEPCA). This report does not contain recommendations for the use of such chemicals, nor does it imply that the uses discussed have been registered. All uses of these chemicals must be registered by the appropriate State and Federal agencies before they can be recommended.

[4]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture nor imply its approval to the exclusion of other products that may also be suitable.

the two weights, divided by the cob-with-grain weight, was recorded as percentage of grain or shelling percentage.

To determine stalk-crushing strength, we obtained 2-inch sections from the second above-ground internode of 10 to 15 stalks from each plot and recorded the number of load pounds needed to break a 2-inch stalk section with a hydraulic press. We determined cob-crushing strength in the same manner.

Planting and harvest dates for each year at each location are presented in Table 1.

Table 1. Planting and harvest dates for the corn hybrid-row spacing-plant population study at four locations in Missouri.

Location	Planting date	Harvest date
	1966	
Spickard	May 9	November 8
Mt. Vernon	May 25	October 27
Columbia	May 17	October 24
Portageville	May 10	October 5
	1967	
Spickard	May 9-10	October 17
Mt. Vernon	April 6	October 12
Columbia	April 26	November 5
Portageville	April 3	September 6
	1968	
Spickard	May 1	November 1
Mt. Vernon	April 18	*
Columbia	May 16	October 29
Portageville	April 22	September 11

*Experiment abandoned.

Analysis of variance was applied to the combined yearly data from each location. Treatment means were subjected to Duncan's multiple range test. For tests of significance, a probability level of 0.05 was chosen.

RESULTS AND DISCUSSION

Rainfall

Monthly rainfall from April to September 30 at each location appears in Tables 2 to 5. At Spickard in 1966, rainfall was considerably less than average (Table 2). The deficits were greatest during April, May, and September. In 1967, total rainfall there was essentially normal, although in July, August, and September, rainfall was well below each monthly average. In 1968, total rainfall was below the long-term average. However, the above-normal rainfall during July more than offset this deficit, as reflected in the higher yields.

Table 2. Monthly rainfall (inches) from April 1 to September 30 at Spickard, Missouri, plus average monthly rainfall.

Month	Year 1966	1967	1968	Average 1957-1965
April	1.72	5.03	6.12	3.76
May	2.85	4.87	3.80	5.11
June	4.60	9.86	1.47	4.54
July	4.56	2.71	7.67	5.00
August	4.07	1.65	3.07	4.53
September	1.17	3.88	3.19	5.77
Total	18.97	28.00	25.32	28.71

Rainfall at Mt. Vernon during the 1966 growing season (April to September) was more than 5 inches less than average (Table 3). In May, June, and September, rainfall was well below average. In 1967, rainfall was about 2 inches below average for the 6 months. September accounted for most of this deficit. Amount of rainfall in 1968 has no bearing, since the experiment for that year was abandoned.

Rainfall at Columbia from April through September of 1966, 1967, and 1968 was less than the 6-month average of 24.56 inches (Table 4). In May and August of 1966 and in July, August, and September of 1967, rainfall was much lower than average. In April, 1968, rainfall was 2 inches less than average. The excellent distribution pattern throughout the 1968 season caused the higher yields.

At Portageville, rainfall from April through September of each year was greater than the 6-month average of 22.95 inches (Table 5).

Table 3. Monthly rainfall (inches) from April 1 to September 30 at Mt. Vernon, Missouri, plus average monthly rainfall.

Month	Year 1966	1967	1968	Average 1941-1965*
April	4.12	4.88	2.38	4.64
May	3.14	4.76	6.31	5.93
June	1.47	7.74	4.12	4.90
July	4.56	3.17	2.00	3.51
August	5.87	2.23	6.05	3.11
September	2.03	1.42	3.60	4.25
Total	21.19	24.20	24.46	26.34

Table 4. Monthly rainfall (inches) from April 1 to September 30 at Columbia, Missouri, plus average monthly rainfall.

Month	Year 1966	1967	1968	Average 1941-1965
April	4.12	3.12	1.74	3.70
May	2.22	5.32	5.46	4.74
June	3.28	4.97	3.01	4.36
July	4.08	2.04	3.18	4.07
August	1.46	0.87	2.13	3.44
September	3.32	1.96	4.64	4.25
Total	18.48	18.28	20.16	24.56

Table 5. Monthly rainfall (inches) from April 1 to September 30 at Portageville, Missouri, plus average monthly rainfall.

Month	Year 1966	1967	1968	Average 1952-1965
April	7.93	4.15	4.66	3.69
May	5.45	10.00	7.40	5.54
June	1.40	5.80	1.75	3.47
July	4.21	5.14	2.82	3.54
August	5.19	1.17	1.46	3.27
September	1.85	3.96	5.34	3.44
Total	26.03	30.22	23.43	22.95

Stand Percentage

Since the plots were overplanted and thinned to the desired population, there should have been little, if any, deviation from the intended plant population. However, the data in Table 6 show occasional deviations. Stand percentage differed somewhat between years within locations. These differences were undoubtedly related to environmental stresses, such as lack of timely rainfall immediately after planting. The major deviations, however, were due to within-row competition. As the row spacing was widened or the plant population was increased, stands were reduced significantly at all locations. This competition between plants established a trend in which stands were always lowered when planting rates were increased. These results agree with the findings of Sharma and Gupta (15).

The interaction of row spacing and plant population was significant for stand percentage at three locations (Fig. 1). At Spickard, changes in plant population did not significantly affect percentage of stand in the 20-inch row spacing. However, as plant populations were increased in the 30- and 40-inch row spacings, stands decreased significantly. At Mt. Vernon, percentage of stand decreased only when the plant population was increased at the 40-inch row spacing. At Columbia, the general trend was a decrease in stand as plant population was increased in all row spacings, with the magnitude of the decrease becoming larger as row spacing was increased.

The significant interactions of year and row spacing at Spickard and Portageville and year and plant population at Spickard and Columbia emphasize

Table 6. Percentage stand at Spickard, Mt. Vernon, Columbia, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year †					
1966	96.4 a*	97.6 b	96.6 b	94.8 a	96.4
1967	94.7 a	99.5 a	98.5 a	95.7 a	97.1
1968	94.8 a	‡	88.4 c	92.0 b	91.7
Hybrid §					
Pioneer 3306	94.1 a	98.9 a	94.5 a	93.1 a	95.2
MFA 2222	96.3 a	99.2 a	96.1 a	95.9 a	96.9
Dekalb XL65A	95.5 a	98.1 a	95.3 a	93.7 a	95.6
Row Spacing ¶					
20 inches	98.1 a	99.3 a	97.5 a	96.2 a	97.8
30 inches	96.4 b	99.2 a	96.0 b	95.6 a	96.8
40 inches	89.9 c	97.5 b	91.7 c	90.4 b	92.4
Plants per acre Π					
12,000	99.0 a	99.8 a	98.8 a	99.3 a	99.2
16,000	96.3 b	99.0 ab	95.1 b	94.9 b	96.3
20,000	93.0 c	97.9 bc	93.3 bc	90.5 c	93.7
24,000	91.0 c	97.7 c	92.4 c	88.9 c	92.5
CV(%)	13.2	9.6	12.8	14.6	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡Experiment abandoned.

§Averaged across 3 years, three row spacings, and four plant population levels.

¶Averaged across 3 years, three hybrids, and four plant population levels.

ΠAveraged across 3 years, three hybrids, and three row spacings.

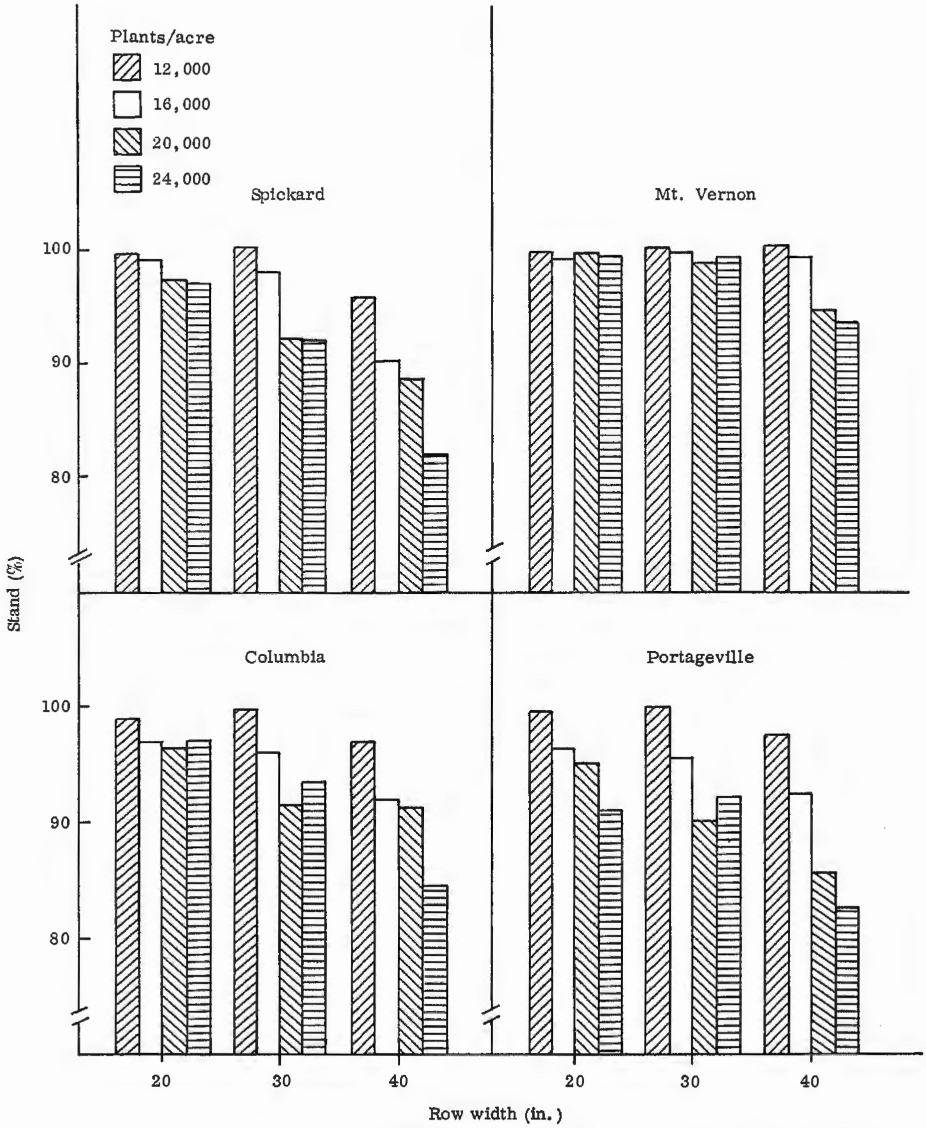

Figure 1. Percentage of stand of corn grown at three row spacings and four plant populations (across 3 years and three hybrids).

the influence of the environment on plant-to-plant competition in establishing stand (Appendix Table 1). Even though stand percentage decreased in all years as the number of intended plants within rows was increased, the magnitude of the decrease in stand was altered considerably by the environment or stresses of the different years.

Root Lodging, Barren Plants, and Dropped Ears

Data were recorded for root lodging, barren plants, and dropped ears. The means resulting from the data analysis are too small to be of significant value. Rarely, if ever, were values larger than 1%, and most of the mean values were well below 0.5%. From these data, different row spacings and plant populations appear to have little effect on the above variables. The findings for root lodging agree with those of other research on plant population (26, 27) and row spacing (5, 6, 8). However, these results do not support the findings of other researchers who found that the number of dropped ears (2) and barren stalks (5, 6, 10, 20) increased as plant populations were increased when using plant population levels similar to those of this study. This lack of agreement can probably be attributed to differences in weather, effect of European corn borer (*Ostrinia nubilalis* (Hübner)) on dropped ears, and hybrids. Moisture supply would greatly influence the number of barren stalks (5). Our findings also support the results of other research about the lack of effect of different row spacings on barren plants (5). However, Stickler (18) attributed part of the yield advantage of 20-inch rows to the presence of fewer barren plants.

Stalk Crushing

The stalk crushing data for the four locations is summarized in Table 7. The pressure (psi) required to crush a 2-inch mature stalk section was greater from the tests grown in 1967 than those grown in 1966 or 1968 at all locations. The Spickard data ranged most (290 to 1,448 psi) in stalk-crushing values, and Portageville ranged least (798 to 931) among years. Differences among hybrids were highly significant at all sites. Differences in stalk crushing strength among row spacings were significant only at Mt. Vernon. As plant populations were increased, stalk crushing strength was decreased at all locations. These results point out that within-row competition affects stalk crushing strength more than does between-row competition.

The significant year x hybrid interaction at Spickard and Columbia indicates how stalk strength differs as the different hybrids respond to the environment (Appendix Table 2). The year x plant population interaction was significant at Spickard, Mt. Vernon, and Portageville. Thus, the effect of within-row competition on stalk strength was affected greatly by the growing

Table 7. Corn stalk crushing strength (psi) at Spickard, Mt. Vernon, Columbia, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year†					
1966	290 c*	215 b	798 b	798 b	525
1967	1,448 a	903 a	1,007 a	931 a	1,072
1968	525 b	‡	439 c	915 a	626
Hybrid §					
Pioneer 3306	835 a	624 a	857 a	1,022 a	834
MFA 2222	675 c	470 c	621 c	784 c	638
Dekalb XL65A	753 b	583 b	766 b	837 b	735
Row spacing ¶					
20 inches	783 a	585 a	761 a	885 a	754
30 inches	735 a	558 ab	725 a	881 a	725
40 inches	745 a	533 b	757 a	878 a	728
Plants per acre‖					
12,000	962 a	692 a	904 a	1,042 a	900
16,000	807 b	595 b	816 b	918 b	784
20,000	646 c	481 c	670 c	797 c	648
24,000	602 c	468 c	601 d	768 c	610
CV (%)	23.5	19.9	28.4	18.1	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡Experiment abandoned.

§Averaged across 3 years, three row spacings, and four plant population levels.

¶Averaged across 3 years, three hybrids, and four plant population levels.

‖Averaged across 3 years, three hybrids, and three row spacings.

conditions of different years. Only at Mt. Vernon was the year x row spacing interaction significant.

The interactions of hybrid and row spacing and hybrid and plant population were significant only at Spickard (Appendix Table 2). MFA 2222 and Dekalb XL65A stalks showed no significant change in stalk crushing strength among row spacings, but Pioneer Brand 3306 stalks increased in crushing strength when rows were narrowed from 30 to 20 inches (Table 8). Pioneer Brand 3306 decreased significantly in stalk crushing strength with each successive increase in plant population, whereas the stalks of the other hybrids did not. These results indicate that stalk crushing strength of the Pioneer hybrid was more responsive to within-row competition than the other two hybrids.

Table 8. Corn stalk crushing strength (psi) for three corn hybrids grown at three row spacings and four plant populations at Spickard, Missouri.

Factor	Hybrid: Pioneer	Hybrid: MFA 2222	Hybrid: Dekalb XL65A
Row Spacing			
20 inches	900 a*	691 de	757 bcd
30 inches	829 b	661 e	716 cde
40 inches	776 bc	673 e	784 bc
Plants per acre			
12,000	1,117 a	846 bc	923 b
16,000	882 b	743 d	795 cd
20,000	723 de	564 gh	650 efg
24,000	618 fgh	546 h	642 efg

*Values within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

Stalk Lodging

The pattern for stalk lodging among years closely followed that for stalk-crushing strength (Table 9). At all locations, except Columbia, the percentage of lodged stalks was greatest in 1966, when stalks had the lowest crushing strength. However, this pattern did not hold for differences in lodging among hybrids. Thus, factors other than stalk strength may affect the lodging of a particular hybrid.

Stalk lodging did not differ significantly among different row widths, but it did at all locations as plant population was increased. That this trend was noted for stalk-crushing strength suggests that these two traits were more subject to within-row than between-row competition. This probability is further substantiated by the lack of a significant interaction between row spacing and plant population (Appendix Table 3). Also, the magnitude of increase in the stalk lodging as plant populations were increased was essentially the

Table 9. Percentage of corn stalk lodging at Spickard, Mt. Vernon, Columbia, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year†					
1966	12.3 a*	2.8 a	0.9 c	2.1 a	4.5
1967	0.2 b	0.3 b	4.8 a	0.3 c	1.4
1968	0.1 b	‡	3.3 b	1.4 b	1.6
Hybrid §					
Pioneer 3306	1.6 b	1.6 a	3.1 a	1.0 a	1.8
MFA 2222	2.7 a	1.2 a	3.0 a	1.0 a	2.0
Dekalb XL65A	1.7 b	1.0 a	2.2 b	1.3 a	1.6
Row Spacing ¶					
20 inches	1.7 a	1.5 a	2.7 a	0.9 a	1.7
30 inches	2.0 a	1.2 a	2.8 a	1.3 a	1.8
40 inches	2.2 a	1.2 a	2.7 a	1.2 a	1.8
Plants per acre Π					
12,000	0.7 c	0.7 b	1.6 b	0.5 c	0.9
16,000	1.4 b	1.3 a	2.1 b	1.0 b	1.4
20,000	2.8 a	1.5 a	3.9 a	1.6 a	2.4
24,000	3.2 a	1.7 a	3.8 a	1.7 a	2.6
CV (%)	77.4	62.2	57.1	70.8	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡Experiment abandoned.

§Averaged across 3 years, three row spacings, and four plant population levels.

¶Averaged across 3 years, three hybrids, and four plant population levels.

ΠAveraged across 3 years, three hybrids, and three row spacings.

reverse of stalk crushing strength response. A negative relationship is suggested between these two variables. This same relationship has been noted by Singh (16). The lack of a row-spacing effect on stalk lodging agrees with reports in the literature (5, 6, 8), as does the significant effect of increasing plant population on lodging (4, 5, 6, 21, 23, 26, 27).

At Spickard, the hybrid x row spacing interaction was significant (Appendix Table 3). Lodging of the MFA hybrid increased as row spacing increased, whereas the Pioneer and Dekalb hybrids showed no significant lodging response to row spacing. The year x hybrid interaction was significant at Mt. Vernon, Columbia, and Portageville (Table 10), and the year x plant population interaction was significant at Spickard and Portageville (Table 11). These results further substantiate previous findings that environment greatly influences the magnitude of stalk lodging and its components.

Table 10. Percentage of corn stalk lodging for 1966-1968 of three hybrids grown at Mt. Vernon, Columbia, and Portageville, Missouri, (across three row spacings and four plant populations).

Year	Hybrid Pioneer 3306	MFA 2222	Dekalb XL65A
		Mt. Vernon	
1966	4.0 a*	2.7 b	2.0 b
1967	0.3 c	0.3 c	0.4 c
1968	†	†	†
		Columbia	
1966	0.8 d	0.5 d	1.5 c
1967	7.7 a	3.7 b	3.4 b
1968	2.5 bc	6.3 a	1.9 c
		Portageville	
1966	2.2 a	2.1 a	2.1 a
1967	0.5 b	0.2 b	0.2 b
1968	0.7 b	1.4 a	2.2 a

*Values within each location followed by the same letter are not significantly different at the 0.05 level of probability.

† Experiment abandoned.

Table 11. Percentage of corn stalk lodging for 1966-1968 for four plant populations of corn at Spickard and Portageville, Missouri, (across three hybrids and three row spacings).

Year	Plants/acre			
	12,000	16,000	20,000	24,000
		Spickard		
1966	5.1 c*	9.9 b	16.8 a	20.2 a
1967	0.01 e	0.03 e	0.3 de	0.6 d
1968	0.02 e	0.04 e	0.05 e	0.1 de
		Portageville		
1966	1.1 b	2.4 a	2.7 a	2.4 a
1967	0.3 c	0.3 c	0.4 c	0.3 c
1968	0.3 c	0.8 b	2.2 a	3.1 a

*Values within each location followed by the same letter are not significantly different at the .05 level of probability.

Ear Height

Among the variables studied, only years and hybrids affected ear-height variation (Table 12). Among years, differences ranged from a high of 1.00 ft at Columbia to a low of 0.18 ft at Portageville, with all locations showing significant yearly differences. Pioneer 3306 had the highest ear placement at all locations, although the difference in ear height between any two hybrids did not exceed 0.40 ft at any location.

Ear height differed significantly because of row spacings, plant population, or both only at Mt. Vernon. However, the actual difference between any two row spacings or any two plant populations there did not exceed 0.11 ft.

All significant interactions for ear height involved the year component of variance. The year x hybrid interaction was significant at all locations, the year x plant population interaction was significant at three locations, and the year x row spacing interaction was significant at two locations (Appendix Table 4). These results show that environment strongly influences ear placement.

Since stalk lodging increased at all locations as plant population increased (Table 9), and only small differences were noted in ear height among plant populations (significant at only one location), it appears that ear height had little effect on the degree of stalk lodging in this study.

Table 12. Corn ear height (ft) at Spickard, Mt. Vernon, Columbia, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year †					
1966	3.33 b*	2.61 b	2.81 c	2.70 a	2.86
1967	3.66 a	3.05 a	3.81 a	2.52 b	3.26
1968	2.80 c	‡	3.50 b	2.55 b	2.95
Hybrid§					
Pioneer 3306	3.38 a	3.07 a	3.59 a	2.82 a	3.22
MFA 2222	3.25 b	2.66 c	3.25 b	2.42 c	2.90
Dekalb XL65A	3.16 c	2.76 b	3.28 b	2.53 b	2.93
Row Spacing ¶					
20 inches	3.28 a	2.78 b	3.36 a	2.59 a	3.00
30 inches	3.26 a	2.82 ab	3.36 a	2.57 a	3.00
40 inches	3.25 a	2.89 a	3.40 a	2.61 a	3.04
Plants per acre ‖					
12,000	3.25 a	2.86 ab	3.37 a	2.62 a	3.02
16,000	3.23 a	2.79 b	3.38 a	2.59 a	3.00
20,000	3.26 a	2.78 b	3.38 a	2.56 a	3.00
24,000	3.31 a	2.89 a	3.36 a	2.59 a	3.04
CV(%)	10.0	8.9	7.3	15.4	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡Experiment abandoned.

§Averaged across 3 years, three row spacings, and four plant population levels.

¶Averaged across 3 years, three hybrids, and four plant population levels.

‖Averaged across 3 years, three hybrids, and three row spacings.

Cob Crushing

Cob crushing strength may be associated with machine harvesting capability. This trait was measured in 1967 and 1968 at Spickard and Columbia and 1967 at Mt. Vernon and Portageville. A large yearly difference occurred at the

Table 13. Corn cob crushing strength (psi) at Spickard, Mt. Vernon, Columbia, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year†					
1967	1,799 a*	1,352	1,208 a	1,223	1,395
1968	810 b	‡	836 b		823
Hybrid §					
Pioneeer 3306	1,439 b	1,486 b	1,086 b	1,548 a	1,390
MFA 2222	1,505 a	1,607 a	1,226 a	1,330 b	1,417
Dekalb XL65A	969 c	962 c	754 c	790 c	869
Row Spacing ¶					
20 inches	1,338 a	1,417 a	1,044 a	1,254 a	1,263
30 inches	1,269 b	1,345 ab	1,020 a	1,212 a	1,212
40 inches	1,305 ab	1,292 b	1,001 a	1,202 a	1,200
Plants per acre II					
12,000	1,467 a	1,598 a	1,196 a	1,287 a	1,387
16,000	1,375 b	1,402 b	1,120 b	1,255 a	1,288
20,000	1,213 c	1,232 c	931 c	1,224 a	1,150
24,000	1,161 d	1,174 c	839 d	1,125 b	1,075
CV(%)	12.1	14.0	20.8	14.6	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡No measurements.

§Averaged across three row spacings, and four plant population levels. Spickard and Columbia averages across 2 years.

¶Averaged across three hybrids and four plant population levels. Spickard and Columbia averages across 2 years.

IIAveraged across three hybrids and three row spacings. Spickard and Columbia averages across 2 years.

first two sites (Table 13). MFA 2222 had the soundest cobs at three locations. Cob strength did not differ as much among row spacings as among hybrids or between years. The effect of plant population on cob strength was significant at all locations. Cobs with the greatest strength were produced at the lower populations.

Year x hybrid and year x plant population interactions were significant at both Spickard and Columbia (Appendix Table 5).

The hybrid x plant population interaction was significant at Spickard only.

Test Weight

Analysis of variance (Appendix Table 6) and the test weight data (Table 14) indicated that, one way or another, the environment significantly affected

Table 14. Test weight (lb/bu) of corn grain from Spickard, Mt. Vernon, Columbia, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year†					
1966	59.6 b*	60.2 a	60.1 a	59.4 a	59.8
1967	60.7 a	60.1 a	59.9 b	59.3 a	60.0
1968	59.1 c	‡	58.9 c	57.6 b	58.5
Hybrid§					
Pioneer 3306	58.7 c	59.9 b	58.7 c	58.3 b	58.9
MFA 2222	61.0 a	61.0 a	61.2 a	59.9 a	60.8
Dekalb XL65A	59.7 b	59.5 c	59.0 b	58.1 b	59.1
Row Spacing¶					
20 inches	59.8 a	60.0 a	59.6 a	58.6 a	59.5
30 inches	59.8 a	60.3 a	59.6 a	58.8 a	59.6
40 inches	59.9 a	60.1 a	59.7 a	58.9 a	59.6
Plants per acre Π					
12,000	59.7 a	60.0 b	59.5 b	58.7 a	59.5
16,000	59.8 a	60.0 b	59.6 b	58.8 a	59.6
20,000	59.9 a	60.2 ab	59.6 b	58.8 a	59.6
24,000	59.9 a	60.4 a	59.8 a	58.8 a	59.7
CV (%)	1.2	1.0	1.1	1.8	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡Experiment abandoned.

§Averaged across 3 years, three row spacings, and four plant population levels.

¶Averaged across 3 years, three hybrids, and four plant population levels.

ΠAveraged across 3 years, three hybrids, and three row spacings.

test weight at all locations. Three of the locations (Spickard, Columbia, and Portageville) differed significantly in test weight among years.

The largest variation in test weight was due to hybrids. MFA 2222 had the highest test weight at all locations.

Row spacing did not significantly affect test weight. Test weight increased slightly as plant population was increased, but the increase was significant only at Mt. Vernon and Columbia. These findings indicate that within-row plant completition had little or no effect on test weight, and these results agreed with the findings of others (12).

The year x hybrid interaction was significant at Spickard, Columbia, and Portageville. The year x plant population interaction was significant at Spickard and Columbia. These results stress the importance of environmental influence on hybrid performance, as well as on within-row plant competition with respect to test weight.

At Spickard, the hybrid x plant population interaction was significant. The test weight of the Dekalb hybrid increased significantly as plant populations were increased, whereas the test weights for the other hybrids hardly increased (Table 15).

Table 15. Test weight (lb/bu) of three corn hybrids grown at four plant populations at Spickard, Missouri, (across 3 years and three row spacings).

	Plants per acre			
Hybrid	12,000	16,000	20,000	24,000
Pioneer	58.6 d*	58.8 d	58.8 d	58.6 d
MFA 2222	61.0 a	60.9 a	60.9 a	61.1 a
Dekalb XL65A	59.4 c	59.7 bc	59.9 b	60.0 b

*Values followed by the same letter are not significantly different at the 0.05 level of probability.

Shelling Percentage

Shelling percentage differences among the 3 years were not consistent for the four locations. At Spickard, percentages were highest in 1966 and 1968; at Mt. Vernon and Portageville, in 1967, and at Columbia in 1968 (Table 16).

Table 16. Shelling percentages of corn grown at Spickard, Mt. Vernon, Columbia, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year †					
1966	69.5 a*	67.6 b	68.5 c	62.6 c	67.0
1967	68.7 b	69.5 a	70.8 b	67.8 a	69.2
1968	69.3 a	‡	71.7 a	64.4 b	68.5
Hybrid §					
Pioneer 3306	68.9 b	68.8 b	70.4 b	64.9 b	68.2
MFA 2222	66.9 c	65.5 c	67.7 c	62.1 c	65.6
Dekalb XL65A	71.7 a	71.3 a	72.8 a	67.8 a	70.9
Row Spacing ¶					
20 inches	68.9 b	68.2 b	70.4 a	64.2 b	67.9
30 inches	69.2 ab	68.7 a	70.1 a	65.1 ab	68.3
40 inches	69.4 a	68.8 a	70.5 a	65.6 a	68.6
Plants per acre Π					
12,000	68.7 c	68.0 b	69.7 b	64.2 a	67.6
16,000	69.0 bc	68.5 ab	69.9 b	65.2 a	68.2
20,000	69.7 a	68.7 a	70.8 a	65.0 a	68.6
24,000	69.4 ab	69.0 a	71.0 a	65.3 a	68.7
CV(%)	1.9	1.7	2.4	4.2	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡Experiment abandoned.

§Averaged across 3 years, three row spacings, and four plant population levels.

¶Averaged across 3 years, three hybrids, and four plant population levles.

ΠAveraged across 3 years, three hybrids, and three row spacings.

Hybrid differences for shelling percentages were the same at all locations. Dekalb XL65A shelled the highest percentage of grain whereas MFA 2222 shelled the lowest (Table 16).

Except at Columbia, row spacing differences for shelling percentage existed, and shelling percentage tended to decrease as row spacing decreased. Except at Portageville, plant population means significantly differed, and shelling percentage tended to decrease as plant population decreased (Table 16). Thus decreased between-row spacing appeared to adversely affect shelling percentage, whereas decreased within-row spacing (higher within-row plant population) appeared to increase shelling percentage.

The year x hybrid interaction was significant at all locations.

Grain Yield

Yields ranged from a high of 152.6 bushels per acre at Spickard in 1967 to a low of 57.3 at Mt. Vernon in 1966 (Table 17).

The grain yields for 1967 were the highest of the 3 years at Spickard, Mt. Vernon, and Portageville. This year also had the most rainfall from April through September at two of these locations (Tables 2, 5). In 1966, their yields were the lowest, and except for Portageville, they had the lowest rainfall from April through September. At Columbia, yields were highest in 1966 and 1968, when rainfall was greatest. However, the difference in rainfall there was only 0.2 inches more in 1966 than in 1967 (Table 4), whereas the 1966 yield was 43.7 bushels per acre more than the 1967 yield (Table 17). This large difference in yield was attributed to the low amount of rainfall (4.87 inches) from July through September, 1967. The final number of kernels to be filled is being determined during the early part of this period (7). Stress at this time then, may cause an abortion of a significant number of kernels. Also, the size of the kernel, determined during the mid-to-latter part of this period, is greatly affected by stress. In either or both cases, the net result is a significant yield decrease.

Yields differed consistently among hybrids within each location.

At Spickard and Columbia, yields increased significantly with each 10-inch reduction in row width from 40 to 20 inches. At Mt. Vernon and Portageville, 20-inch rows significantly outyielded 40-inch rows. These data confirm the yield superiority of narrow rows over the traditional 40-inch row width, as do data of most other research (8, 11, 13, 17, 18, 20, 25). The decreased within-row plant competition brought about by the narrowed rows must have allowed for an increase in some factor (or factors) contributing to final grain yield, such as ears per stalk, number of kernels per year, or kernel weight. Also, number of plants present at a given population, especially the higher populations, was greater in the narrow rows, as evidenced by the interaction of row spacing and plant population for stand percentage (Fig. 1). More stalks would by necessity produce more grain if the components of yield remained constant.

At Spickard and Mt. Vernon, grain yield increased significantly with each successive increase of 4,000 plants from 12,000 to 24,000 per acre. At Portageville, the two highest plant populations had the highest yield. At

Table 17. Corn grain yield (bu/acre) at Spickard, Columbia, Mt. Vernon, and Portageville, Missouri.

Factor	Location				
	Spickard	Mt. Vernon	Columbia	Portageville	Mean
Year†					
1966	109.6 c*	88.2 b	129.2 a	57.3 c	96.1
1967	152.6 a	122.2 a	85.5 b	112.4 a	118.2
1968	133.1 b	‡	131.2 a	102.5 b	122.2
Hybrid §					
Pioneer 3306	139.1 a	113.6 a	123.3 a	98.4 a	118.6
MFA 2222	128.6 b	98.0 c	109.9 b	85.9 b	105.6
Dekalb XL65A	127.8 b	103.9 b	112.6 b	87.9 b	108.0
Row Spacing ¶					
20 inches	141.8 a	108.5 a	122.9 a	95.1 a	117.1
30 inches	132.1 b	106.2 a	114.4 b	90.8 ab	110.9
40 inches	121.6 c	100.7 b	108.6 c	86.4 b	104.3
Plants per acre Π					
12,000	118.0 d	93.6 d	107.3 b	83.3 c	100.6
16,000	130.4 c	101.9 c	118.8 a	89.4 b	110.1
20,000	136.2 b	108.0 b	117.3 a	92.7 ab	113.6
24,000	142.8 a	117.2 a	117.6 a	97.6 a	118.8
CV(%)	10.5	12.9	12.0	19.3	

*Values in individual columns within each factor followed by the same letter are not significantly different at the 0.05 level of probability.

†Averaged across three hybrids, three row spacings, and four plant population levels.

‡Experiment abandoned.

§Averaged across 3 years, three row spacings, and four plant population levels.

¶Averaged across 3 years, three hybrids, and four plant population levels.

ΠAveraged across 3 years, three hybrids, and three row spacings.

Columbia, the three highest plant population levels gave the highest yield, with no significant differences among them. These results agree with those of most of the recent research that has reported optimum population levels for grain production to be 20,000 to 24,000 plants per acre (1, 2, 3, 4, 6, 11, 12, 15, 18, 21, 23). Percentage of stalk lodging increased significantly as plant population level increased (Table 9). Nevertheless, lodging would not have contributed to a decrease in yield unless lodging occurred during pollination, grain filling, or both, since all plots were harvested by hand. Plant barrenness, root lodging, and number of dropped ears were unaffected by the plant population levels used in this study. Therefore, the increased number of plants gave a corresponding increase in number of harvestable ears. As a result, yields increased with increased plant population.

The hybrid x row spacing interaction was significant only at Spickard (Appendix Table 7). No hybrid x plant population interaction was significant. Thus, hybrid yields were consistent across the plant populations and row spacings. These findings agree with those of Hunter, Kannenberg, and Gamble (9), who found no significant interaction between hybrids and plant population or hybrids and row spacings, when hybrids of like maturity were compared. The presence of few or no significant interactions of this type suggests that hybrids of similar maturity are similar in their response to changes in row spacing and population. However, when hybrids with maturities ranging from very early to late were used, grain yields of hybrids responded differently to changes in plant population (21).

The year x hybrid interaction was significant for yield at three locations (Appendix Tables 8, 10, 11), indicating a differential yield response of the three hybrids to changes in environment. The year x row-spacing interaction was significant at only Spickard (Appendix Table 8), whereas the year x plant-population interaction was significant at all locations (Appendix Tables 8, 9, 10, 11). Thus, yield response was affected more by within-row plant competition than between-row plant competition.

The row spacing x plant population interaction was significant for yield at Spickard (Appendix Table 8). At the two lowest plant population levels, yields from 20- and 30-inch rows did not differ significantly, although they were higher than yields from 40-inch rows. At the two high plant population levels, yields increased significantly with each successive 10-inch decrease in row spacing. These results indicate that the narrow rows are superior in yield when used with the higher plant population at Spickard. In favorable environments, increases in grain yield can be expected for some hybrids with a plant population of 24,000 plants per acre, when the row spacing is decreased from 40 to 20 inches. Decreased row spacing decreased the within-row plant competition, thus giving the plants a greater opportunity to respond. The significance of this interaction is diminished, since it was found at only one of the four locations. However, it is significant to growers planning to irrigate corn to eliminate moisture stress.

SUMMARY AND CONCLUSIONS

The yield at each location was highest in that growing season with the greatest amount of well-distributed rainfall. Grain yield increased significantly at all locations as rows were narrowed from 40 to 20 inches (Table 17). The largest increase was 20.2 bushels per acre at Spickard, and the smallest was 7.8 at Mt. Vernon. Twenty-inch rows were significantly superior in yield to 30-inch rows at Spickard and Columbia.

Within locations, the percentage of perfect stand followed the pattern of grain yield. As rows were narrowed from 40 to 20 inches, the actual increase in stand of the 20-inch over the 40-inch spacing ranged from 8.2% at Spickard to 1.8% at Mt. Vernon (Table 6). Therefore, the narrow rows had an advantage in grain production, partly because of a better stand caused by less within-row plant competition. The effect of stand establishment on grain yield among varying row spacings might be even more pronounced, since stalk lodging, root lodging, barren plants, test weight and dropped ears were not significantly affected by row spacing.

Grain yields increased significantly at all locations as plant populations were increased from 12,000 to 24,000 plants per acre (Table 17). The highest plant population produced the largest yield at Spickard and Mt. Vernon and a numerically, though nonsignificantly, higher yield at Portageville. At Columbia, no advantage in yield was realized for plant populations of more than 16,000 plants per acre. The yield was higher with the 24,000 plants per acre despite the decrease in stand and greater stalk lodging as plant populations were increased. However, since root lodging, barren plants, number of dropped ears, and test weight were little affected by plant number, we assume that the negative effect of the above two variables was not severe enough to reduce yields. Also important, plots were hand harvested, and ears borne by lodged plants were harvested for yield determination, thus virtually eliminating the lodging factor as a negative yield determinant. Under machine harvesting, yields could have been reduced by the increased lodging associated with the higher populations.

Stalk strength, as determined by stalk crushing, appeared to contribute to stalk lodging as plant populations were increased. At all locations, stalk crushing strength decreased (Table 7), and stalk lodging increased (Table 9) as population was increased.

The significant row spacing x plant population interaction for percentage of stand at three locations (Appendix Table 1), points out the importance of within-row competition on plant establishment. Increasing population level had little or no effect on number of plants established in the 20-inch rows, but increasing plant population had a large effect as rows were widened to 30 and 40 inches. The absence of any significant interactions for the remaining variables emphasizes the independent effect of the row spacing and plant populations on variables other than stand establishment.

Numerous year x hybrid interactions for the several measured variables emphasized the differential effect of growing conditions on the performance of different hybrids. The several instances of year x row spacing and year x plant population interactions indicated that the influence of these factors on the measured traits of this study depended strongly on the environment.

Lack of any consistent significant hybrid x row spacing or hybrid x plant population interactions indicated that hybrids of the same maturity were rather uniform in their response to between-row and within-row plant competition.

From these results, a population of 20,000 to 24,000 plants per acre should be attained in rows of 20 inches for maximum grain yield in Missouri, if the grower can be assured of adequate moisture during pollination and grain filling.

LITERATURE CITED

1. Beer, C. E., W. D. Shrader, and R. K. Schwanke. 1967. Interrelationships of plant population, soil moisture, and soil fertility in determining corn yields on Colo clay loam at Ames, Iowa. Iowa Agric. Expt. Sta. Res. Bull. 556. 15 pp.
2. Colville, W. L. 1962. Influence of rate and method of planting on several components of irrigated corn yields. Agron. J. 54:297-300.
3. Colville, W. L., A. Dreier, D. P. McGill, P. Grabouski, and P. Ehlers. 1964. Influence of plant population, hybrid, and "productivity level" on irrigated corn production. Agron. J. 56:332-335.
4. Colville, W. L., and D. P. McGill. 1962. Effect of rate and method of planting on several plant characters and yield of irrigated corn. Agron. J. 54:235-238.
5. Giesbrecht, John. 1969. Effect of population and row spacing on the performance of four corn (*Zea mays* L.) hybrids. Agron. J. 61:439-441.
6. Gill, William J. 1969. Narrow spacing of row adds to corn yields. Miss. Farm Res. 32:1-4.
7. Hanway, John J. 1966. How a corn plant develops. Iowa Agric. Expt. Sta. Spec. Rep. No. 48. 17 pp.
8. Hayes, D. D., A. G. Douglas, and E. R. Beaty. 1967. Influence of fertility and plant population on yield of corn in northwest Georgia. Georgia Agric. Res. 8:12-13.
9. Hunter, R. B., L. W. Kannenberg, and E. E. Gamble. 1970. Performance of five maize hybrids in varying plant populations and row widths. Agron. J. 62:255-256.
10. Lang, A. L., J. W. Pendleton, and G. H. Dungan. 1956. Influence of population and nitrogen levels on yield and protein and oil contents of nine corn hybrids. Agron. J. 48:284-289.
11. Nunez, Roberto, and Eugene Kamprath. 1969. Relationships between N response, plant population, and row width on growth and yield of corn. Agron. J. 61:279-282.
12. Painter, L. I., H. W. Hough, and P. C. Singleton. Corn for grain; Nitrogen fertilization and plant populations. Wyoming Agric. Expt. Sta. Bull. 493. 14 pp.
13. Parks, W. L., J. A. Odom, J. R. Overton, and E. J. Chapman. Plant population and row spacing for corn. Tenn. Agric. Expt. Sta. Bull. 392. 16 pp.
14. Rutger, J. N., and L. V. Crowder. 1967. Effect of high plant density on silage and grain yields of six corn hybrids. Crop Sci. 7:182-184
15. Sharma, K. C., and P. C. Gupta. 1968. Effect of plant population and rates of nitrogen on the performance of hybrid maize. Indian J. of Agron. 13:76-82.

16. Singh, T. P. 1967. Rind thickness and crushing strength as a measure of stalk lodging resistance in maize. Indian J. of Genetics and Plant Breeding. 27:271-274.
17. Sommerfeldt, Theron G. 1960. Effect of irrigation, plant population, and row spacing on corn yield. North Dakota Farm Res. 21:16-20.
18. Stickler, F. C. 1964. Row width and plant population studies with corn. Agron. J. 56:438-441.
19. Stickler, F. C., and H. H. Laude. 1960. Effect of row spacing and plant population on performance of corn, grain sorghum, and forage sorghum. Agron. J. 52:275-277.
20. Stivers, R. K., D. R. Griffith, and E. P. Christmas. Corn row spacings, populations, and hybrids on five soils in Indiana. Purdue Univ. Agric. Expt. Sta. Res. Bull. 860. 8 pp.
21. Termunde, Darrold E., D. B. Shank, and V. A. Dirks. 1963. Effects of population levels on yield and maturity of maize hybrids grown on the northern Great Plains. Agron. J. 55:551-555.
22. Thomas, Winfred. 1956. Effect of plant population and rates of fertilizer nitrogen on average weight of ears and yield of corn in the South. Agron. J. 48:228-230.
23. Whitaker, F. D., H. G. Heinemann, and W. E. Larson. 1969. Plant population and row spacing influence maximum corn yield. Missouri Agric. Expt. Sta. Res. Bull. 961. 36 pp.
24. Wofford, I. M., E. S. Horner, and D. E. McCloud. 1956. Plant populations, date of planting and nitrogen levels for field corn. Soil and Crop Sci. Soc. of Florida. 16:352-359.
25. Yao, Augustine Y. M., and R. H. Shaw. 1964. Effect of plant population and planting pattern of corn on water use and yield. Agron. J. 56:147-152.
26. Zuber, M. S., and C. O. Grogan. 1956. Rates of planting studies with corn. Missouri Agric. Expt. Sta. Res. Bull. 610.
27. Zuber, M. S., and C. O. Grogan, and O. V. Singleton. 1960. Rate of planting studies with prolific and single-ear corn hybrids. Missouri Agric. Expt. Sta. Res. Bull. 737. 20 pp.

APPENDIX

Appendix Table 1. Analyses of variance for percentage of perfect stand of corn at four Missouri locations, 1966-68 (arcsin transformed data).

Source	Spickard		Mt. Vernon		Columbia		Portageville	
	df	ms	df	ms	df	ms	df	ms
Year (A)	2	0.0798	1	0.4126**	2	1.9169**	2	0.1796**
Hybrid (B)	2	0.0924	2	0.0464	2	0.0549	2	0.1132
Row spacing (C)	2	1.3205**	2	0.1274**	2	0.6670**	2	0.4543**
Plant population (D)	3	0.8502**	3	0.1314**	3	0.6423**	3	1.0668**
A x B	4	0.0527	2	0.0115	4	0.2226**	4	0.0718
A x C	4	0.1869**	2	0.0026	4	0.0251	4	0.1043*
A x D	6	0.0715*	3	0.0243	6	0.0696*	6	0.0192
B x C	4	0.0327	4	0.0200	4	0.0481	4	0.0311
B x D	6	0.0340	6	0.0054	6	0.0224	6	0.1328**
C x D	6	0.0898*	6	0.0554*	6	0.0784*	6	0.0347
A x B x C	8	0.2590	4	0.0134	8	0.0232	8	0.0416
A x B x D	12	0.0423	6	0.0190	12	0.0334	12	0.0438
A x C x D	12	0.0307	6	0.0120	12	0.0312	12	0.0335
B x C x D	12	0.0418	12	0.0059	12	0.0184	12	0.0226
A x B x C x D	24	0.0418	12	0.0224	24	0.0143	24	0.0322
Error	324	0.0321	144	0.0194	324	0.0300	216	0.0378

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Appendix Table 2. Analyses of variance for corn stalk crushing at four Missouri locations, 1966-68.

Source	Spickard		Mt. Vernon		Columbia		Portageville	
	df	ms	df	ms	df	ms	df	ms
Year (A)	2	54,008,640**	1	25,583,072**	2	11,862,205**	2	570,933**
Hybrid (B)	2	922,664**	2	457,774**	2	2,030,506**	2	1,690,367**
Row spacing (C)	2	92,575	2	48,304*	2	55,469	2	1,359
Plant population (D)	3	2,917,451**	3	601,342**	3	2,034,961**	3	1,277,337**
A x B	4	86,452*	2	23,846	4	233,457**	4	14,863
A x C	4	23,545	2	45,550*	4	29,650	4	26,980
A x D	6	198,794**	3	128,191**	6	41,928	6	110,057**
B x C	4	80,580*	4	23,593	4	75,633	4	24,399
B x D	6	91,247**	6	8,635	6	57,099	6	43,610
C x D	6	19,785	6	18,555	6	28,841	6	34,432
A x B x C	8	19,453	4	24,467	8	11,083	8	12,952
A x B x D	12	35,258	6	1,943	12	32,091	12	34,246
A x C x D	12	18,476	6	6,325	12	27,488	12	15,182
B x C x D	12	35,412	12	20,304	12	27,254	12	27,119
A x B x C x D	24	14,308	12	14,075	24	39,027	24	31,307
Error	324	31,392	144	12,352	324	45,020	216	26,416

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Appendix Table 3. Analyses of variance for percentage stalk lodging of corn at four Missouri locations, 1966-68 (arcsin transformed data).

Source	Spickard		Mt. Vernon		Columbia		Portageville	
	df	ms	df	ms	df	ms	df	ms
Year (A)	2	5.140**	1	0.6763**	2	0.5983**	2	0.2289**
Hybrid (B)	2	0.068**	2	0.0121	2	0.0334*	2	0.0059
Row spacing (C)	2	0.001	2	0.0038	2	0.0012	2	0.0118
Plant population (D)	3	0.265**	3	0.0235**	3	0.1453**	3	0.0617**
A x B	4	0.025	2	0.0224*	4	0.1607**	4	0.0222**
A x C	4	0.005	2	0.0121	4	0.0074	4	0.0133
A x D	6	0.095**	3	0.0006	6	0.0148	6	0.0216**
B x C	4	0.028*	4	0.0015	4	0.0182	4	0.0048
B x D	6	0.004	6	0.0045	6	0.0143	6	0.0048
C x D	6	0.007	6	0.0014	6	0.0124	6	0.0032
A x B x C	8	0.017	4	0.0024	8	0.0120	8	0.0073
A x B x D	12	0.014	6	0.0008	12	0.0111	12	0.0010
A x C x D	12	0.009	6	0.0057	12	0.0052	12	0.0105*
B x C x D	12	0.008	12	0.0045	12	0.0194	12	0.0075
A x B x C x D	24	0.007	12	0.0035	24	0.0158	24	0.0049
Error	324	0.012	144	0.0050	324	0.0090	216	0.0056

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Appendix Table 4. Analyses of variance for corn ear height at four Missouri locations, 1966-68.

Source	Spickard		Mt. Vernon		Columbia		Portageville	
	df	ms	df	ms	df	ms	df	ms
Year (A)	2	27.12**	1	10.67**	2	38.19**	2	1.06**
Hybrid (B)	2	1.76**	2	3.30**	2	5.03**	2	4.76**
Row spacing (C)	2	0.03	2	0.27*	2	0.06	2	0.03
Plant population (D)	3	0.15	3	0.16*	3	0.01	3	0.06
A x B	4	0.46**	2	0.26*	4	0.57**	4	0.47*
A x C	4	0.29*	2	0.18	4	0.22**	4	0.02
A x D	6	0.47**	3	0.59**	6	0.72**	6	0.07
B x C	4	0.03	4	0.12	4	0.06	4	0.01
B x D	6	0.02	6	0.04	6	0.08	6	0.16
C x D	6	0.04	6	0.05	6	0.05	6	0.10
A x B x C	8	0.07	4	0.12	8	0.08	8	0.06
A x B x D	12	0.04	6	0.09	12	0.08	12	0.09
A x C x D	12	0.08	6	0.11	12	0.04	12	0.11
B x C x D	12	0.07	12	0.04	12	0.07	12	0.06
A x B x C x D	24	0.09	12	0.04	24	0.05	24	0.10
Error	324	0.11	144	0.06	324	0.06	216	0.16

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Appendix Table 5. Analyses of variance for corn cob crushing at four Missouri locations, 1966-68.

Source	Spickard		Mt. Vernon		Columbia		Portageville	
	df	ms	df	ms	df	ms	df	ms
Year (A)	1	70,445,482**			1	9,969,229**		
Hybrid (B)	2	8,221,408**	2	4,228,028**	2	5,644,705**	2	5,478,983**
Row spacing (C)	2	114,242*	2	142,293*	2	45,291	2	26,778
Plant population (D)	3	1,442,466**	3	980,607**	3	1,953,912**	3	133,509**
A x B	2	1,140,048**			2	165,205*		
A x C	2	10,827			2	81,414		
A x D	3	83,426*			3	328,283**		
B x C	4	11,053	4	23,588	4	46,629	4	13,426
B x D	6	135,737**	6	79,505	6	55,058	6	60,696
C x D	6	12,591	6	43,132	6	18,511	6	44,711
A x B x C	4	4,900			4	18,095		
A x B x D	6	82,556			6	13,768		
A x C x D	6	10,864			6	24,932		
B x C x D	12	33,150	12	45,441	12	37,686	12	24,928
A x B x C x D	12	31,808			12	74,313		
Error	216	24,833	72	36,044	216	45,176	72	31,664

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Appendix Table 6. Analyses of variance for corn test weight at four Missouri locations, 1966-68.

Source	Spickard		Mt. Vernon		Columbia		Portageville	
	df	ms	df	ms	df	ms	df	ms
Year (A)	2	89.08**	1	1.04	2	60.40**	2	112.99**
Hybrid (B)	2	189.06**	2	44.63**	2	251.18**	2	112.05**
Row spacing (C)	2	0.72	2	0.94	2	0.78	2	2.37
Plant population (D)	3	1.02	3	2.00**	3	2.86**	3	0.40
A x B	4	9.48**	2	0.71	4	26.69**	4	5.92**
A x C	4	0.24	2	0.55	4	0.23	4	0.24
A x D	6	1.43**	3	0.22	6	1.09*	6	2.49
B x C	4	0.64	4	0.79	4	0.38	4	0.72
B x D	6	1.07*	6	0.33	6	0.77	6	1.39
C x D	6	0.50	6	0.26	6	0.33	6	0.63
A x B x C	8	0.78	4	0.55	8	0.32	8	0.43
A x B x D	12	0.50	6	0.25	12	0.55	12	0.60
A x C x D	12	0.56	6	0.12	12	0.46	12	1.20
B x C x D	12	0.71	12	0.49	12	0.42	12	0.51
A x B x C x D	24	0.47	12	0.39	24	0.44	24	0.92
Error	324	0.47	144	0.35	324	0.46	216	1.19

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Appendix Table 7. Analyses of variance for corn grain yield at four Missouri locations, 1966-68.

Source	Spickard		Mt. Vernon		Columbia		Portageville	
	df	ms	df	ms	df	ms	df	ms
Year (A)	2	67,128.5**	1	62,256.8**	2	95,965.5**	2	93,072.2**
Hybrid (B)	2	5,734.0**	2	4,456.0**	2	7,281.1**	2	4,889.0**
Row spacing (C)	2	14,707.3**	2	1,157.6**	2	7,506.6**	2	2,058.5**
Plant population (D)	3	11,991.3**	3	5,371.0**	3	3,076.2**	3	2,929.1**
A x B	4	951.4**	2	272.6	4	2,718.0**	4	749.9*
A x C	4	932.1**	2	348.9	4	410.3	4	129.5
A x D	6	902.9**	3	1,718.7**	6	2,749.6**	6	1,502.3**
B x C	4	508.2*	4	97.1	4	292.3	4	86.2
B x D	6	292.3	6	154.0	6	199.8	6	538.5
C x D	6	813.4**	6	123.7	6	372.1	6	329.8
A x B x C	8	168.4	4	86.4	8	126.4	8	173.3
A x B x D	12	85.3	6	130.5	12	248.9	12	213.3
A x C x D	12	193.6	6	282.6	12	251.5	12	159.9
B x C x D	12	165.1	12	178.2	12	247.9	12	180.8
A x B x C x D	24	129.0	12	190.8	24	238.4	24	252.0
Error	324	190.4	144	185.3	324	190.5	216	305.7

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Appendix Table 8. Corn grain yields as influenced by various factors at Spickard, Mo.

Year	Hybrid	Row width	Population (plants/acre)				Mean
			12,000	16,000	20,000	24,000	
		(inches)					
1966	Pioneer 3306	20	114.7	126.6	127.5	133.1	125.5
		30	108.0	122.6	116.1	119.6	116.6
		40	91.8	106.3	107.9	98.0	101.0
	MFA 2222	20	105.3	108.8	114.9	124.4	113.4
		30	94.9	97.1	106.3	94.3	98.2
		40	95.1	102.1	104.4	88.8	97.6
	Dekalb XL65A	20	107.3	115.8	120.2	133.5	119.2
		30	105.7	113.1	110.6	118.4	112.0
		40	87.2	108.1	108.1	109.4	103.2
	Mean		101.1	111.2	112.9	113.3	109.6
1967	Pioneer 3306	20	148.2	167.4	205.2	206.1	181.7
		30	152.6	150.7	159.0	174.4	159.2
		40	131.9	144.3	135.9	149.5	140.4
	MFA 2222	20	141.3	158.0	178.6	178.6	164.1
		30	136.2	151.5	151.1	160.5	149.8
		40	130.0	141.6	139.5	147.1	139.6
	Dekalb XL65A	20	129.3	162.4	162.8	175.4	157.5
		30	119.7	142.0	156.6	165.8	146.0
		40	119.5	129.8	137.8	159.1	136.6
	Mean		134.3	149.7	158.5	168.5	152.8
1968	Pioneer 3306	20	126.5	142.7	156.0	172.6	149.4
		30	132.9	144.1	144.7	158.2	145.0
		40	121.0	129.0	135.3	145.7	132.8
	MFA 2222	20	124.2	119.3	136.6	154.8	133.7
		30	124.2	136.0	140.4	142.9	135.9
		40	110.5	131.8	127.7	128.7	124.7
	Dekalb XL65A	20	105.7	132.3	137.5	150.7	131.6
		30	114.2	119.3	132.0	138.6	126.0
		40	105.9	116.7	125.7	125.4	118.4
	Mean		118.3	130.1	137.3	146.4	133.1

Appendix Table 9. Corn grain yield as influenced by various factors at Mt. Vernon, Mo.

Year	Hybrid	Row width (inches)	Population (plants/acre) 12,000	16,000	20,000	24,000	Mean
1966	Pioneer 3306	20	96.1	108.9	92.0	96.0	98.2
		30	83.2	91.1	95.4	107.7	94.4
		40	84.9	88.5	91.2	97.1	90.4
	MFA 2222	20	78.0	84.5	76.8	96.3	83.9
		30	77.3	79.6	77.9	83.0	79.4
		40	74.2	83.4	83.6	89.2	82.6
	Dekalb XL65A	20	83.7	94.5	82.3	114.0	93.6
		30	84.0	89.6	71.0	102.9	86.9
		40	80.1	75.7	91.9	88.1	84.0
	Mean		82.4	88.4	84.7	97.1	88.2
1967	Pioneer 3306	20	105.3	144.3	148.6	151.8	137.5
		30	122.2	127.3	139.6	141.9	132.8
		40	110.1	127.7	130.2	144.5	128.1
	MFA 2222	20	97.2	102.3	121.2	136.8	114.4
		30	101.4	111.6	127.0	138.0	119.5
		40	93.8	105.2	115.3	118.1	108.1
	Dekalb XL65A	20	109.4	96.0	137.7	149.6	123.2
		30	101.0	113.6	144.7	139.1	124.6
		40	101.8	109.9	116.6	115.5	111.0
	Mean		104.7	115.3	131.2	137.3	122.1

Appendix Table 10. Corn grain yield as influenced by various factors at Columbia, MO.

Year	Hybrid	Row width (inches)	Population (plants/acre) 12,000	16,000	20,000	24,000	Mean
1966	Pioneer 3306	20	144.3	167.2	159.3	140.2	152.8
		30	143.3	144.9	144.6	132.8	141.4
		40	123.3	142.5	128.6	145.5	135.0
	MFA 2222	20	118.3	127.7	130.5	129.2	126.4
		30	115.1	127.6	124.4	135.2	125.6
		40	115.3	126.3	114.8	133.9	122.6
	Dekalb XL65A	20	109.2	127.1	129.7	128.9	123.7
		30	113.9	122.9	126.3	106.9	117.5
		40	107.7	118.6	120.3	123.6	117.6
	Mean		121.2	133.9	130.9	130.7	129.2
1967	Pioneer 3306	20	98.4	110.3	116.0	88.1	103.2
		30	87.1	115.6	88.9	92.0	95.9
		40	93.0	93.5	80.9	73.6	85.2
	MFA 2222	20	76.6	93.8	85.1	76.5	83.0
		30	82.9	65.9	81.6	58.8	72.3
		40	68.2	75.4	66.9	55.6	66.5
	Dekalb XL65A	20	97.6	99.1	72.5	103.6	93.2
		30	82.5	92.8	89.9	65.4	82.6
		40	89.1	92.5	88.1	79.4	87.3
	Mean		86.2	93.2	85.5	77.0	85.5
1968	Pioneer 3306	20	121.9	134.6	146.7	165.8	142.2
		30	123.0	132.2	134.9	141.4	132.9
		40	116.2	122.7	120.7	125.4	121.2
	MFA 2222	20	120.4	143.3	146.3	154.5	141.1
		30	116.6	131.5	133.1	142.9	131.0
		40	112.9	117.8	120.7	130.2	120.4
	Dekalb XL65A	20	106.9	136.7	151.2	166.6	140.4
		30	111.4	128.5	135.1	144.8	130.0
		40	102.5	116.9	129.8	135.2	121.1
	Mean		114.6	129.4	135.4	145.2	131.1

Appendix Table 11. Corn grain yield as influenced by various factors at Portageville, Mo.

Year	Hybrid	Row width (inches)	Population (plants/acre) 12,000	16,000	20,000	24,000	Mean
1966	Pioneer 3306	20	79.5	74.3	60.8	63.2	69.4
		30	50.9	63.0	78.3	52.5	61.2
		40	52.0	64.5	68.4	54.3	59.8
	MFA 2222	20	77.3	44.7	56.0	54.9	58.2
		30	51.7	50.9	49.3	50.6	50.6
		40	42.9	42.5	53.7	48.2	46.8
	Dekalb XL65A	20	44.5	53.9	62.9	51.1	53.1
		30	53.4	56.4	54.1	81.8	61.4
		40	47.5	60.0	41.0	72.3	55.2
	Mean		55.5	56.7	58.3	58.8	57.3
1967	Pioneer 3306	20	125.5	121.3	142.5	125.7	128.8
		30	105.5	127.4	140.2	141.1	128.6
		40	92.8	107.0	121.3	141.8	115.7
	MFA 2222	20	95.5	105.8	122.0	133.2	114.1
		30	96.0	101.5	124.7	116.6	109.7
		40	86.1	103.7	102.0	120.4	103.0
	Dekalb XL65A	20	82.9	102.9	121.0	128.7	108.9
		30	81.8	103.4	109.2	118.2	103.2
		40	83.8	97.9	100.2	115.2	99.3
	Mean		94.4	107.9	120.3	126.8	112.4
1968	Pioneer 3306	20	114.8	97.9	108.2	130.9	113.0
		30	111.3	108.7	101.9	107.4	107.3
		40	98.8	111.2	91.7	106.2	102.0
	MFA 2222	20	99.2	106.5	105.2	89.7	100.2
		30	102.2	94.4	87.7	90.6	93.7
		40	96.2	96.8	91.0	101.1	96.3
	Dekalb XL65A	20	93.7	113.2	113.7	120.0	110.2
		30	94.8	105.4	103.4	100.7	101.1
		40	88.3	97.3	91.7	119.2	99.1
	Mean		99.9	103.5	99.4	107.3	102.5