

How Plant Populations and Row Widths Affect Light Penetration, Yield, and Plant Characteristics of Irrigated Corn



AGRICULTURAL EXPERIMENT STATION / AUBURN UNIVERSITY

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Auburn, Alabama

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How Plant Populations and Row Widths Affect Light Penetration, Yield, and Plant Characteristics of Irrigated Corn

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YIELD OF CORN is a function of many interrelated plant and environmental factors. The number and arrangement of plants in the field influence the amount of light that penetrates the canopy. Highest yields are obtained not only when sunlight is best utilized, but also when the maximum amount of photosynthate produced in green parts translocates into the grain. With too few plants per unit area insufficient photosynthate may be produced for large grain yields, and with too many plants much of the photosynthate may be retained in the stover at the expense of grain.

Corn plants require an adequate amount of leaf area for optimum grain yields. However, excess leaf area may result in both decreased yields and increased harvesting problems. Hybrids may differ in the amount of leaf area required for highest yields.

The objectives of these investigations were to determine (1) the relationship among plant population, row width and grain yield of three hybrids; and (2) the effect of plant population, hybrids, row width, leaf area, and light penetration on plant characteristics.

METHODS

Corn was planted on Lucedale fine sandy loam the first week in April from 1969 through 1972, at Thorsby, Alabama. Hybrids 'Funk's G-5757 and G-5945' were planted thickly and thinned to

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populations of 8,000, 16,000, and 32,000 plants per acre. The 16,000 and 32,000 populations were planted in both 20- and 40-inch row widths, whereas the 8,000 was planted in 40-inch rows only. The 'G-5757' is a medium season, double-cross hybrid with horizontal leaves. The 'G-5945' is a tall, full season, double-cross hybrid with moderately upright leaves, especially above the ears.

Plots were 13.33 feet wide (four 40-inch or eight 20-inch rows) and 30 feet long with four replications in a randomized block design. Nitrogen at the rate of 215 pounds N per acre was added, one-half at planting and one-half when plants were 1 foot tall, to all plots except the no N control (8,000 plants in 40-inch rows). At planting, 72 pounds of P, 132 pounds of K, and 20 pounds of zinc sulfate per acre were applied broadcast to all plots. Soil pH was maintained between 6.0 and 6.5. Corn was cultivated once and thereafter weeds were controlled with herbicides. Sprinkler irrigation was applied as needed to maintain soil water at or above the 50 per cent available level in the surface 2 feet. Rainfall and irrigation records are given in the table.

RAINFALL AND IRRIGATION

Year	Month	Rainfall	Irrigation
		In.	In.
1969	April	4.4	
	May	5.1	1.0
	June	3.7	3.8
	July	2.4	1.2
	Season total	15.6	6.0
1970	April	4.3	1.0
	May	1.6	3.2
	June	4.8	3.3
	July	8.1	2.5
	Season total	18.8	10.0
1971	April	2.9	1.5
	May	2.8	1.2
	June	3.7	1.7
	July	8.8	1.2
	Season total	18.2	5.6
1972	April	2.1	0.8
	May	3.3	1.2
	June	2.9	3.5
	July	1.4	3.6
	Season total	9.7	9.1

Light was measured by the ozalid paper technique of Friend². Ozalid papers were placed midway between rows and left in the

² Friend, D. T. C. 1961. A simple method of measuring integrated light values in the field. *Ecology* 42:577-580.

field for 3 days. There were six light measurements per plot for each measuring period. Light was measured during early June, mid-June, early July, and mid-July, which spanned the silking and tasseling period.

Leaf area index (LAI) was determined in July during the grain-filling stage of growth. LAI was calculated by multiplying length \times width \times 0.75. Leaves were measured in each plot on one side of each plant on 20 feet of row during 1969-70, and on 10 plants during 1971-72.

Corn was harvested during the first week in September, and grain yields were adjusted to 15.5 per cent moisture. Two 40-inch or four 20-inch rows were harvested per plot.

Beginning in 1971, the following changes were made. The rate of N for all plots was increased to 286 pounds per acre. Treatments consisted of two hybrids ('Funk's G-5757' and 'Funk's

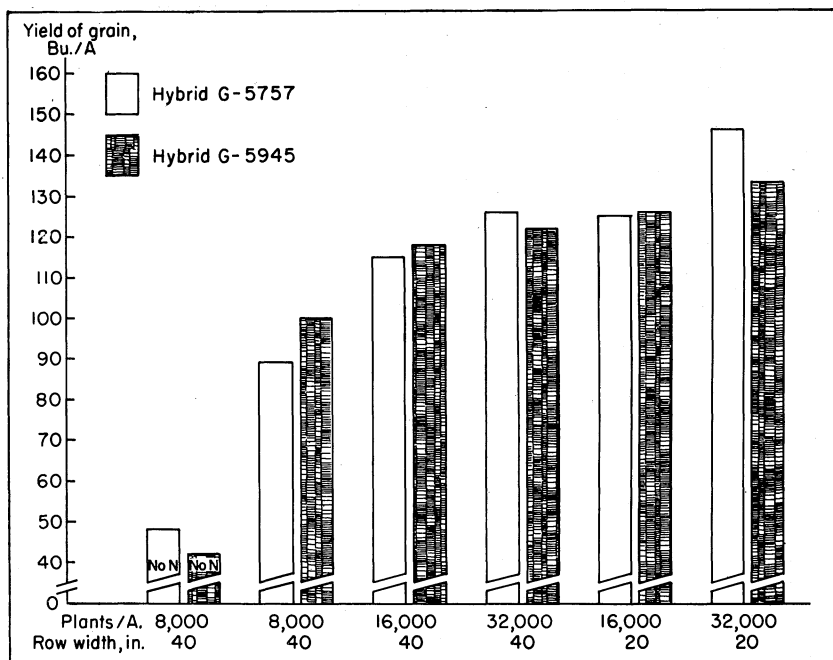


FIG. 1. Grain yields as affected by plant population, hybrids, and row width, 1969-70.

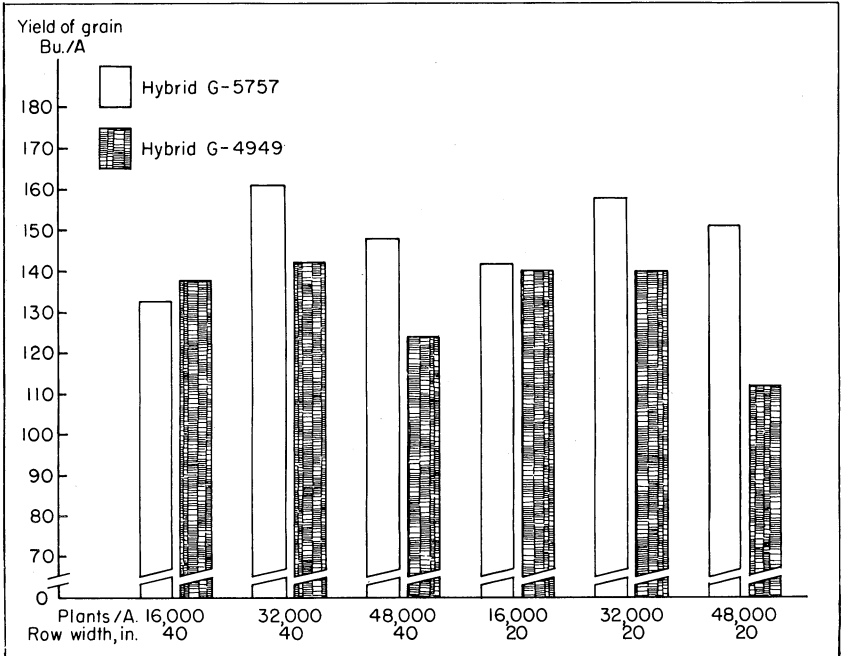


FIG. 2. Grain yields as affected by plant population, hybrids, and row width, 1971-72.

G-4949'), two row widths (20 and 40 inches) and three populations (16,000, 32,000, and 48,000 plants per acre) in a factorial arrangement. The G-4949 is a tall, full season, single-cross hybrid with moderately upright leaves.

RESULTS AND DISCUSSION

Grain yields from hybrids G-5757 and G-5945 were similar at most plant population levels, Figure 1. The highest average yield of 146 bushels per acre was obtained with G-5757 hybrid in 20-inch rows and a population of 32,000 plants. The 8,000-plant population produced yields of about two-thirds of those of higher populations during 1969-70 with both hybrids.

Hybrid G-5757 was better adapted to the 32,000- and 48,000-plant populations than was G-4949, Figure 2. However, each hybrid produced its highest yield with 32,000 plants. The 2-year average yield of 162 bushels per acre produced with G-5757 in 40-inch rows with 32,000 plants was the highest produced during these experiments. In contrast to results during 1969-70, there

was no difference during 1971-72 in yields from 20- or 40-inch rows. These results indicate that with these or similar hybrids 32,000 plants per acre are adequate for highest yield when grown under irrigation.

The trend of stover yields with populations up to 32,000 was similar to that of grain yields for hybrids G-5757 and G-5945, Figure 3. Stover yields as high as 12,000 pounds per acre were produced. With populations ranging from 16,000 to 48,000 plants, the higher the population, the more stover produced by hybrids, Figure 4. Row width had little effect on stover yields. The higher stover yields with 48,000 plants, as compared with thinner planting, had little effect on grain production with G-5757, but the excess vegetative growth with G-4949 sharply reduced grain yields.

When 215 pounds of N per acre was added in 1969-70, increasing the plant population resulted in decreased grain-to-stover ratios, Figure 5. Both hybrids had similar grain-to-stover ratios. Highest yields were associated with ratios of about 0.7.

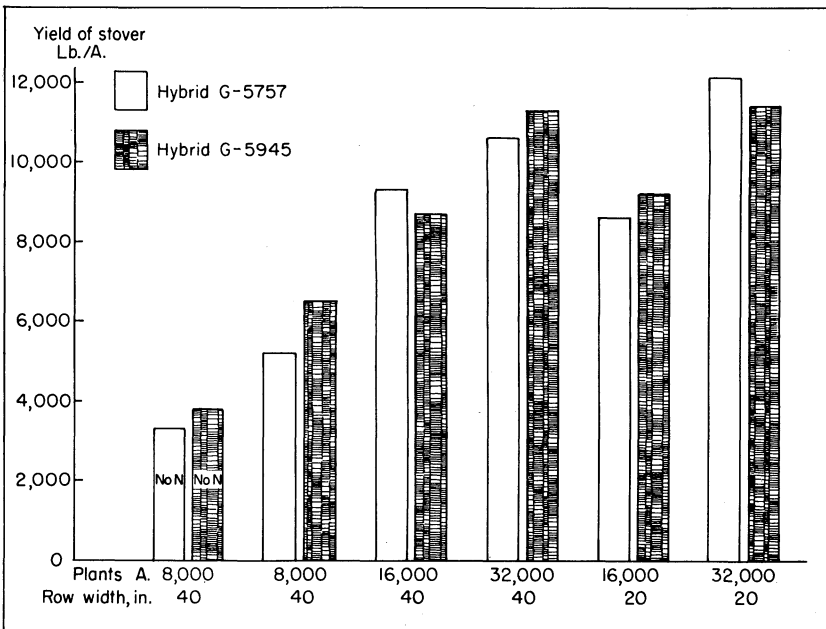


FIG. 3. Stover yields as affected by plant population, hybrids, and row width, 1969-70.

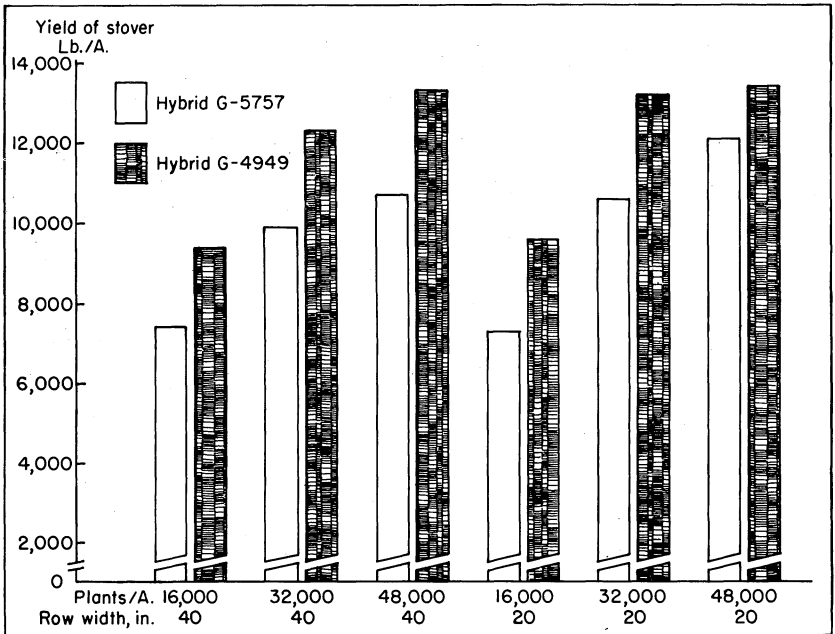


FIG. 4. Stover yields as affected by plant population, hybrids, and row width, 1971-72.

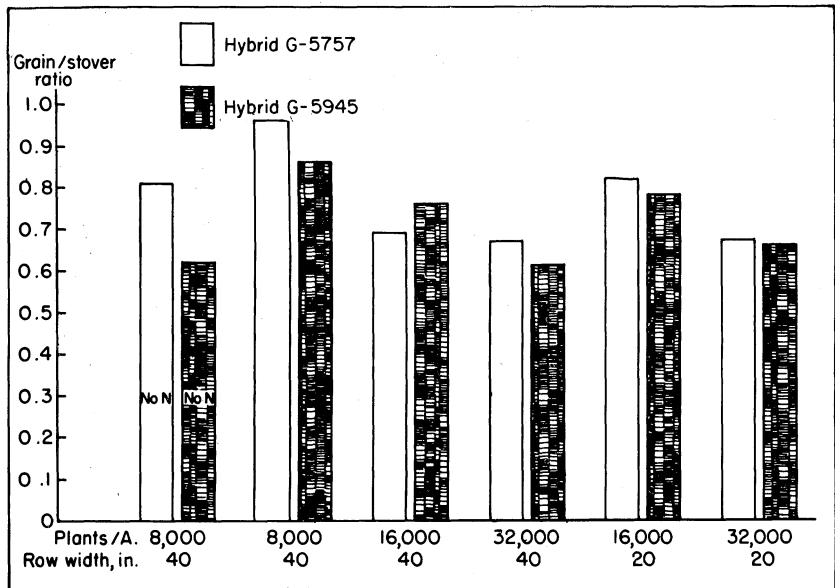


FIG. 5. Grain to stover ratio as affected by plant population, hybrids, and row width, 1969-70.

However, when the rate of N was increased to 286 pounds per acre during 1971-72, the yields of G-5757 were highest, with a range of grain-to-stover ratios of 0.7 to 0.9, Figure 6. Increasing the population of G-4949 from 16,000 to 48,000 plants reduced the ratio from about 0.8 to 0.5. Grain yields were lowest where grain-to-stover ratios were above 0.9 or less than 0.65. It is not known whether the increase in grain-to-stover ratio of G-5757 in 1971-72 as compared to 1969-70 was the result of seasonal differences or the change in the rate of N added.

Amount of grain produced per stalk is an important yield component. A large amount of grain per stalk is associated with inadequate numbers of plants per unit area, whereas small yields per plant are often related to overly vegetative plants or barren plants. In these experiments, grain per stalk ranged from 0.70 pound with 8,000 plants to 0.13 pound with 48,000 plants, Figures

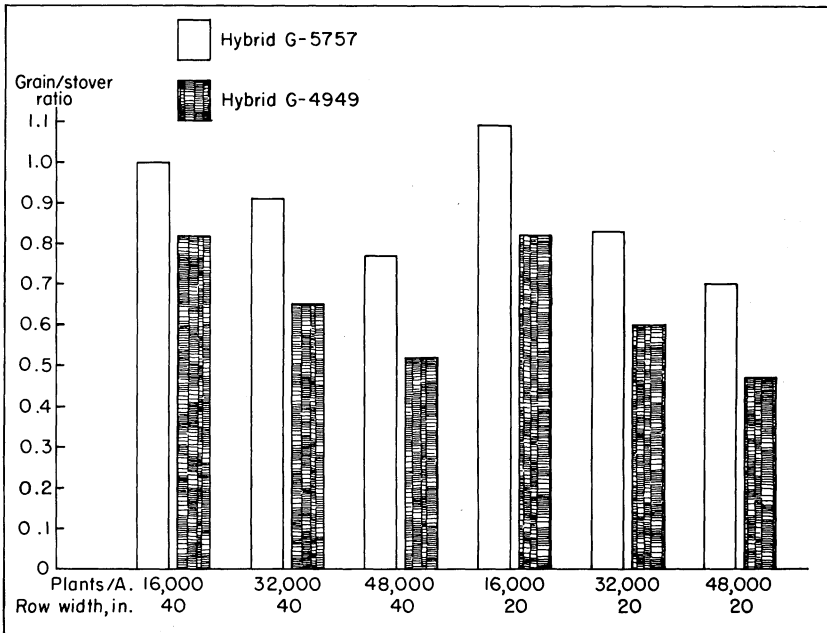


FIG. 6. Grain to stover ratio as affected by plant population, hybrids, and row width, 1971-72.

7 and 8. With all hybrids the highest per-acre yields were associated with about 0.25 pound of grain produced per stalk. This was generally one ear per stalk, except with the thinnest population of 8,000 plants, where there were many two-eared plants.

Nitrogen content of grain (and the crude protein content) decreased for all hybrids as the plant population was increased from 8,000 to 32,000 plants per acre, Figures 9 and 10. Further increases in numbers of plants had no effect on N content of grain. At each population the N content of G-5757 was slightly higher than that of either G-5945 or G-4949. The highest grain yields in 1969-70 were produced with N percentage as low as 1.5. As a result, the added N was increased to 286 pounds per acre in 1971-72. Highest yields of G-5757 then were found with about 1.7 per cent N. Highest N contents were around 1.8 per cent, and lowest about 1.5 per cent, except a low of 1.4 per cent N was found when no N was added in fertilizer. This corresponds to a range of about 9 to 11 per cent in crude protein content.

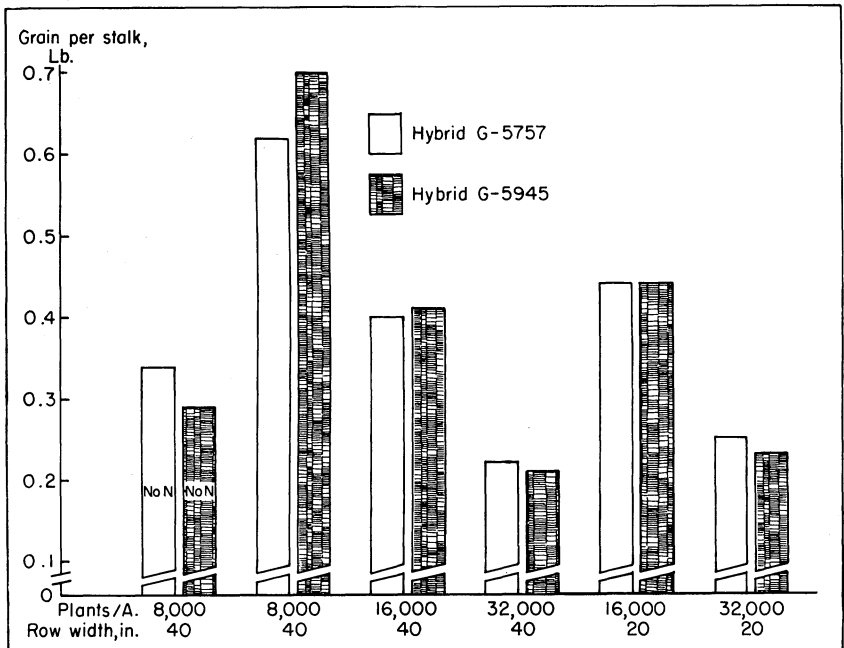


FIG. 7. Grain per stalk as affected by plant population, hybrids, and row width, 1969-70.

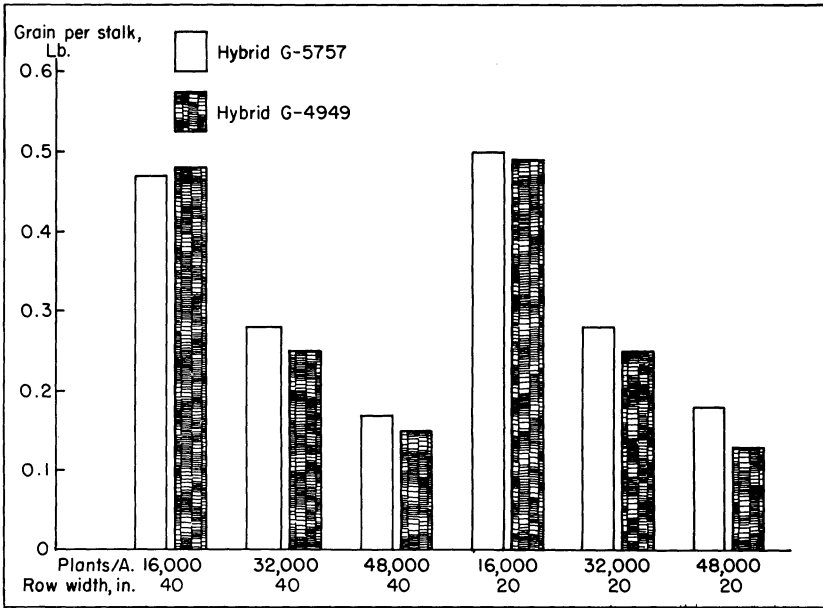


FIG. 8. Grain per stalk as affected by plant population, hybrids, and row width, 1971-72.

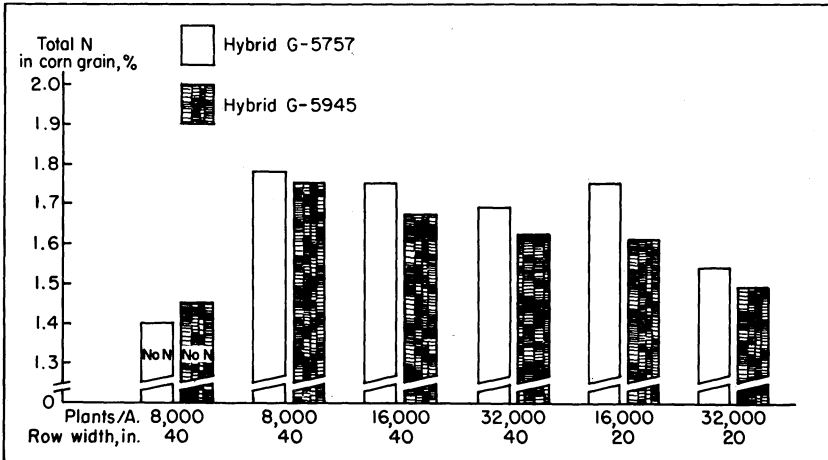


FIG. 9. Total nitrogen in corn grain as affected by plant population, hybrids, and row width, 1969-70.

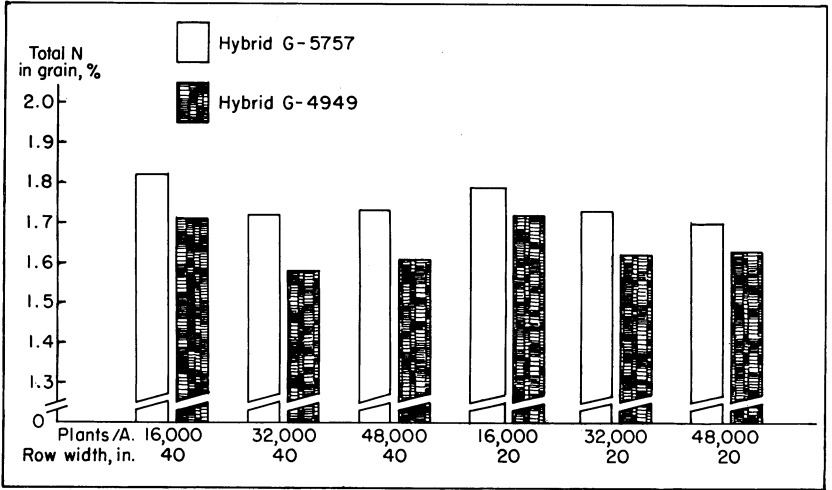


FIG. 10. Total nitrogen in corn grain as affected by plant population, hybrids, and row width, 1971-72.

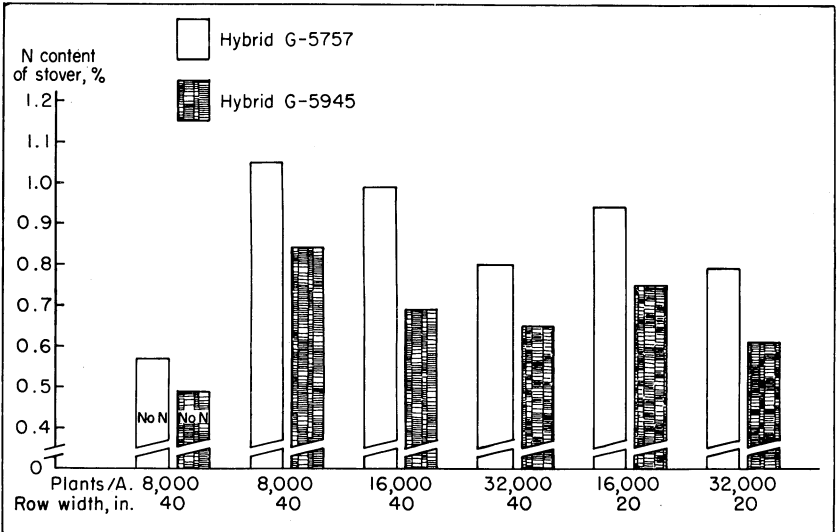


FIG. 11. Total nitrogen in stover as affected by plant population and row width, 1969-70.

Nitrogen content of stover decreased as population was increased from 8,000 to 32,000 plants for hybrids G-5757 and G-5945, Figure 11. As was found for grain, hybrid G-5757 contained more N in stover at each population than did G-5945.

With the higher rate of N in 1971-72, there appeared to be no relationship between population and N content of stover for either hybrid G-5757 or G-4949, Figure 12. The range in N content of stover was only from 0.98 to 1.15 per cent. Hybrid G-5757 had higher stover N levels at each comparable population level in 1971-72 than in 1969-70, probably as a result of the increase in N applied.

The 1969-70 experiment was designed to facilitate a determination of N recovery. The highest recovery of applied N (77 per cent) was measured where the largest grain yield was obtained, Figure 13, that is, where 32,000 plants of G-5757 were grown in 20-inch rows. In contrast, only 39 per cent of applied N was recovered with 8,000 plants. With hybrid G-5945 an N recovery of 49 per cent was observed with 8,000 plants, and the recovery ranged up to 64 per cent with 32,000 plants in 20-inch rows. It is evident that not only low yields but also inefficient use of N may result from plant populations that are inadequate for the management system.

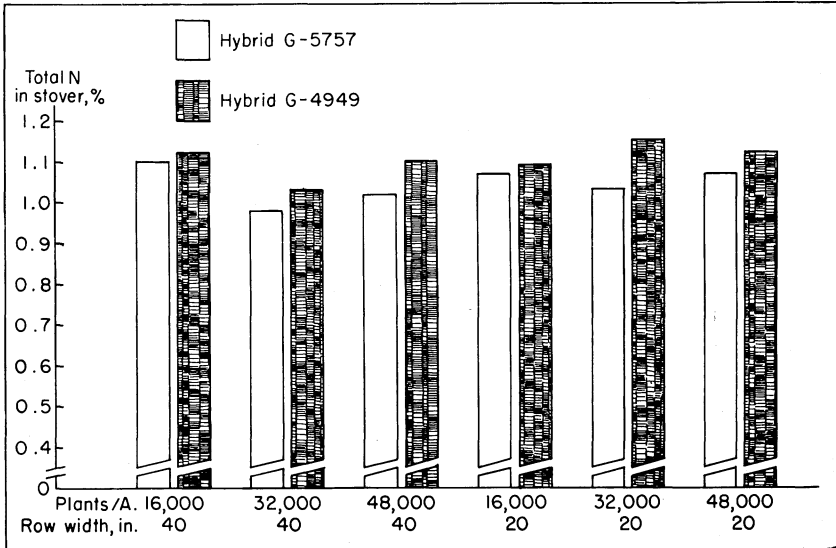


FIG. 12. Total nitrogen in corn stover as affected by plant population, hybrids, and row width, 1971-72.

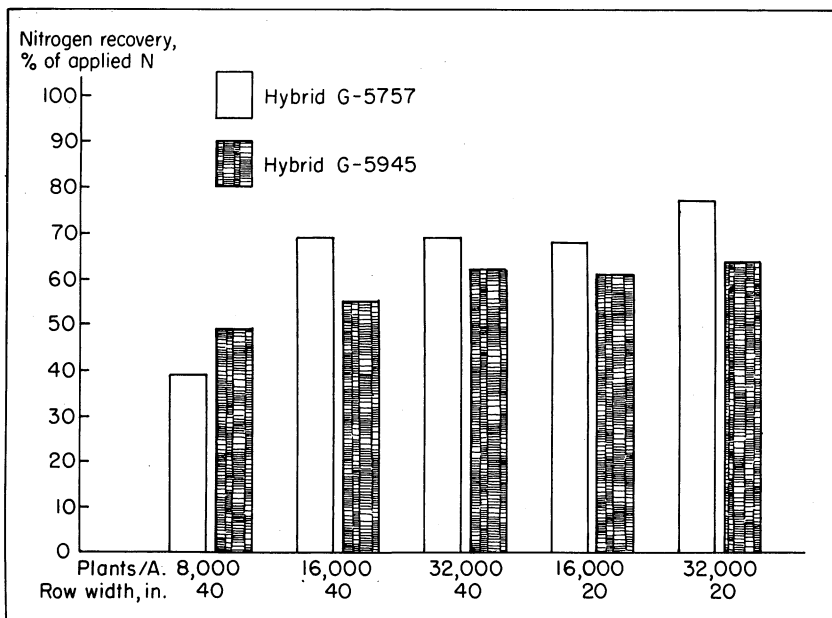


FIG. 13. Nitrogen recovery as affected by plant population, hybrids, and row width, 1969-70.

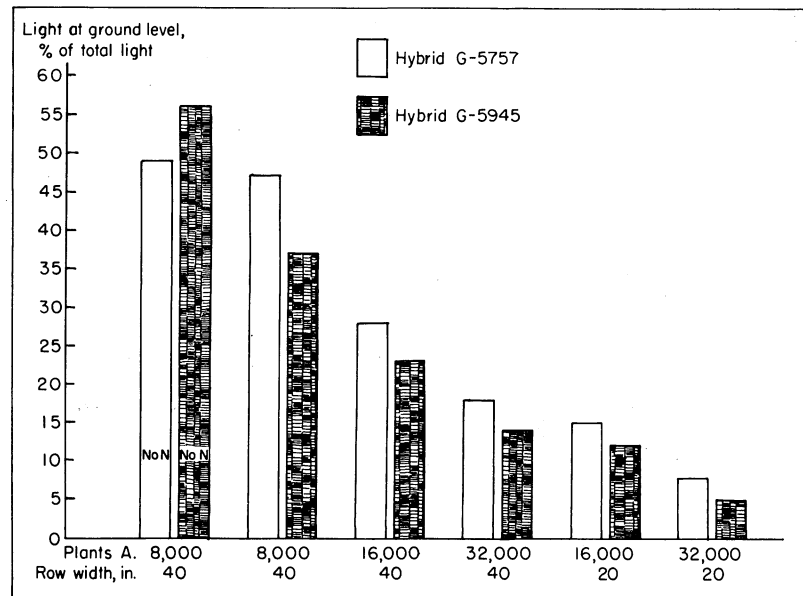


FIG. 14. Light penetration of the canopy as affected by plant population, hybrids, and row width, 1969-70.

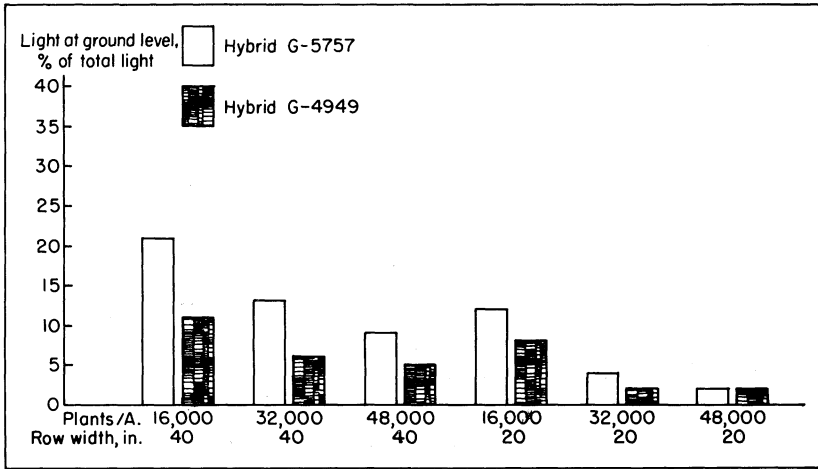


FIG. 15. Light penetration of the canopy as affected by plant population, hybrids, and row width, 1971-72.

For highest yields sufficient light must penetrate the plant canopy to permit leaves to produce the maximum amount of usable photosynthate per unit area. Little light should be allowed to reach the ground in the canopy, because this is lost to the plant's food-making process. As population increased, amount of light measured at ground level decreased markedly, Figure 14. With 8,000 plants and no N added, about one-half the incident sunlight reached the ground, which partially accounts for the low yields produced without added N. The denser canopy produced with added N resulted in more light being absorbed or reflected. At all population levels above 8,000 plants per acre, more light reached the ground with hybrid G-5757 than with the taller-growing hybrid G-5945.

Less light reached the ground in 20-inch than in 40-inch rows, which may partially account for the higher grain yields measured in 20-inch rows during 1969-70. Only 5 to 8 per cent of sunlight reached the ground with 32,000 plants in 20-inch rows. Generally, yields were highest where the canopy intercepted 85 to 95 per cent of incident sunlight.

During 1971-72, with a range of plant populations of 16,000 to 48,000 plants, there was the same inverse relationship between numbers of plants and light at ground level that was found in

1969-70, Figure 15. With either 32,000 or 48,000 plants in 20-inch rows, almost no light was measured at ground level. Hybrid G-4949, which was taller than G-5757, produced the denser canopy and resulted in less light being measured at the ground.

One striking observation was the effect of low light levels on numbers of dead leaves. Whenever the light level measured at any depth in the canopy was less than about 10 per cent of sunlight, the lower leaves died. At the highest population, as many as 6 or 8 of the bottom leaves died before corn was mature. While upper leaves are more important in the photosynthetic process than the lower ones, the large number of dead leaves found with the 48,000 population probably was a factor in the reduced yields.

The generally higher grain yields for hybrid G-5757 were partly due to fewer barren plants than for hybrids G-5945 and G-4949, Figures 16 and 17. Apparently a major factor in the much lower grain yields observed with G-4949 with 48,000 plants as compared with lower populations was the 22 to 30 per cent barren plants. All hybrids had more barren plants as population increased. Highest grain yields of all hybrids were obtained at populations that resulted in 10 per cent or fewer barren plants. However, a small percentage of barren plants did not necessarily result in a high yield.

Leaf area can be a critical factor in production even when only the grain is harvested. There should be enough leaves to pro-

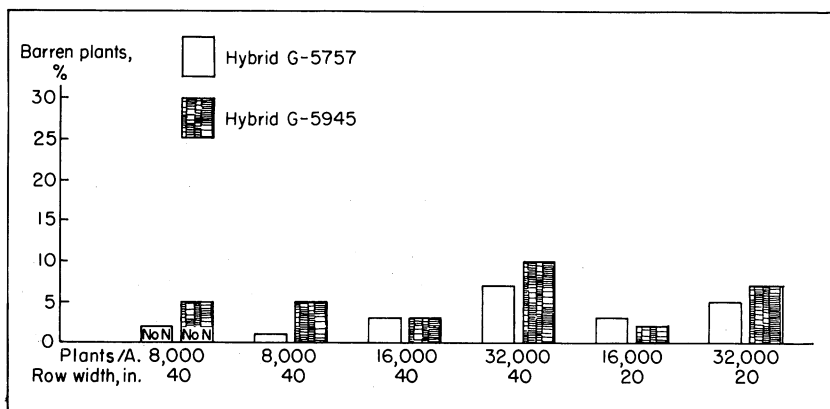


FIG. 16. Barren plants as affected by plant population, hybrids, and row width, 1969-70.

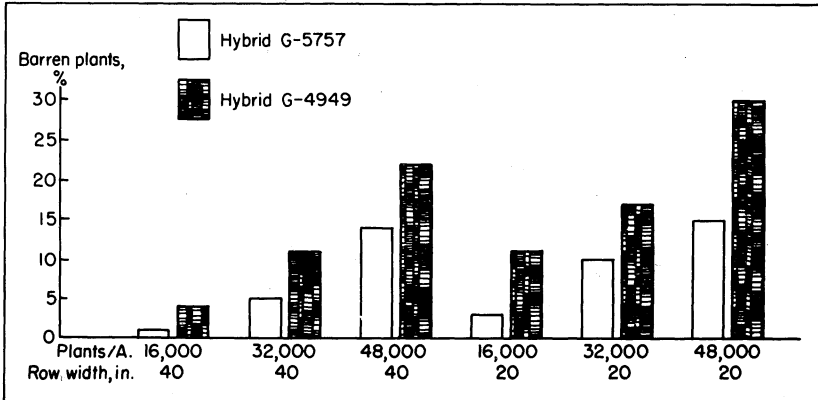


FIG. 17. Barren plants as affected by plant population, hybrids, and row width, 1971-72.

duce sufficient photosynthate for maximum grain production, yet not enough to result in excess vegetative growth at the expense of grain production. Highest yields of hybrids G-5757 and G-5945 were associated with LAI's of about 5, Figures 18 and 19. LAI's between 3.5 and 5.0 were associated with highest grain yields of G-4949, and higher LAI's resulted in sharply reduced grain yields. A complicating factor in assessing the relationship between LAI and yield is the effect of dead leaves. These were not measured

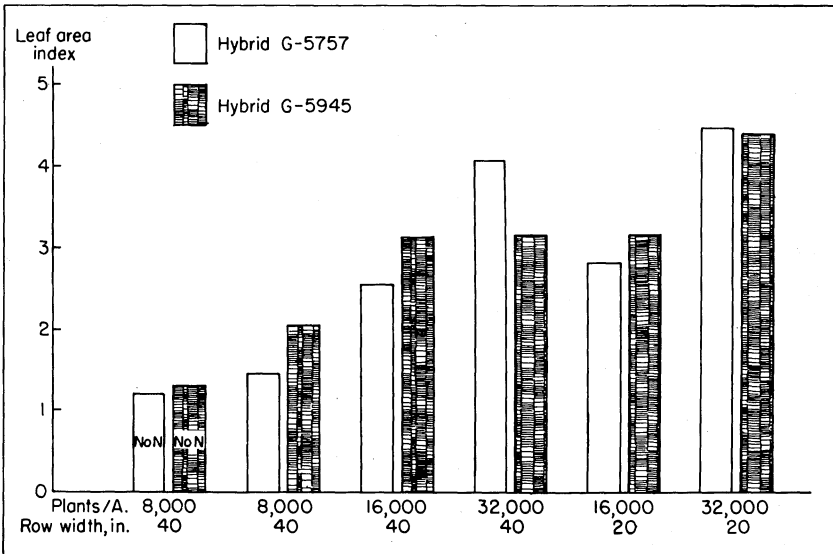


FIG. 18. Leaf area index as affected by plant population, hybrids, and row width, 1969-70.

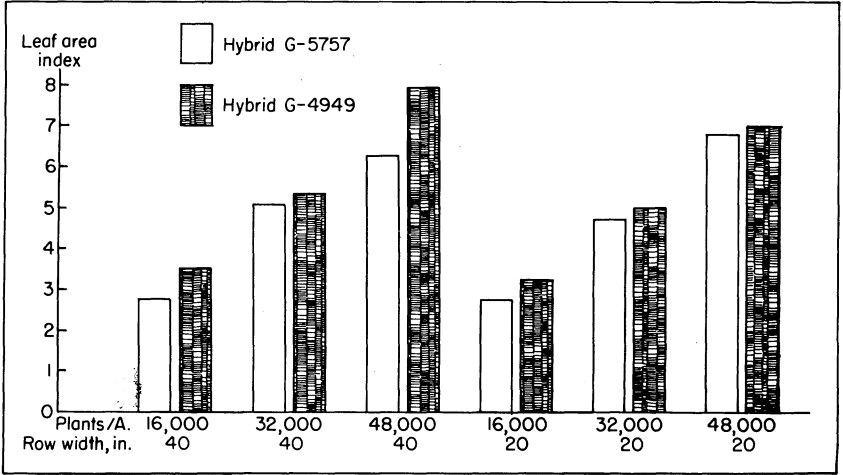


FIG. 19. Leaf area index as affected by plant population, hybrids, and row width, 1971-72.

for LAI, but inasmuch as they were alive early in the life of the plant, they must have contributed to the total photosynthate produced.

Lodging was less than 10 per cent for both hybrids except with 32,000 plants during 1969-70, Figure 20, when lodging ranged from 20 to 28 per cent. Weather was not conducive to lodging during 1971-72 and, as a result, even with 48,000 plants lodging

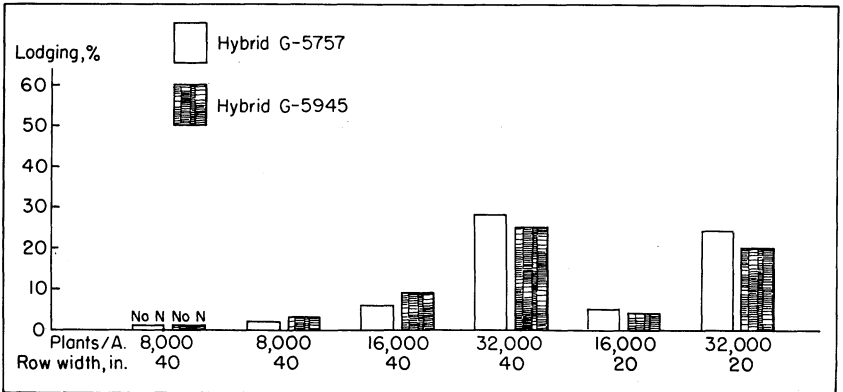


FIG. 20. Lodging as affected by plant population, hybrids, and row width, 1969-70.

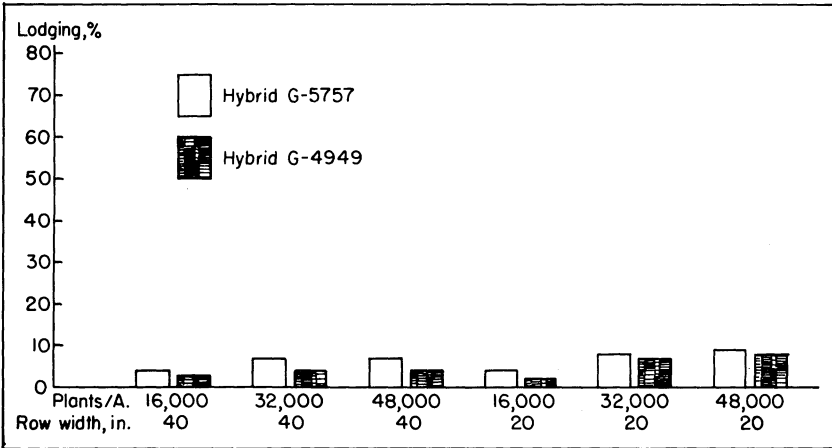


FIG. 21. Lodging as affected by plant population, hybrids, and row width, 1971-72.

was less than 10 per cent for both hybrids G-5757 and G-4949, Figure 21.

Plants grew taller as population was increased up to 32,000, Figures 22 and 23. Further crowding of these hybrids resulted in slightly reduced plant height when compared with the 32,000 population. Both hybrids G-5945 and G-4949 were 10 to 15

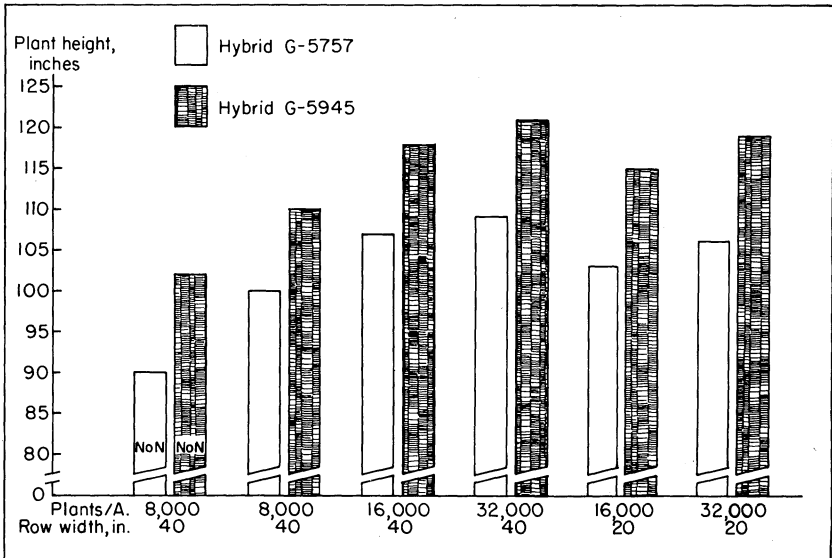


FIG. 22. Plant height as affected by plant population, hybrids, and row width, 1969-70.

inches taller than G-5757 at maturity. Plant height was a major reason why less light penetrated to the ground with the taller hybrids than with G-5757, as shown in Figures 14 and 15.

Increasing the numbers of plants per acre caused the stalk diameter (measured at the fifth internode from the ground) or the cross-sectional area to decrease, Figures 24 and 25. Where N was added, the cross-sectional area with 32,000 plants was about one-half the area with 8,000 plants. The stalk cross-sectional area with 48,000 plants was about two-thirds that where the population was 16,000. These smaller stalks would increase their susceptibility to breakage.

Ear height is another factor affecting the tendency of corn plants to lodge. Ear heights of all hybrids were increased (some as much as 1 foot) as populations were increased up to 32,000 plants, Figures 26 and 27. Populations of 32,000 and 48,000 had similar ear heights.

Increased plant height, decreased size of stalk, and increased ear height as a result of population increases combine to increase susceptibility to lodging. Although high populations did increase tendency to lodging, wind conditions were not severe enough during 1971-72 to result in serious lodging.

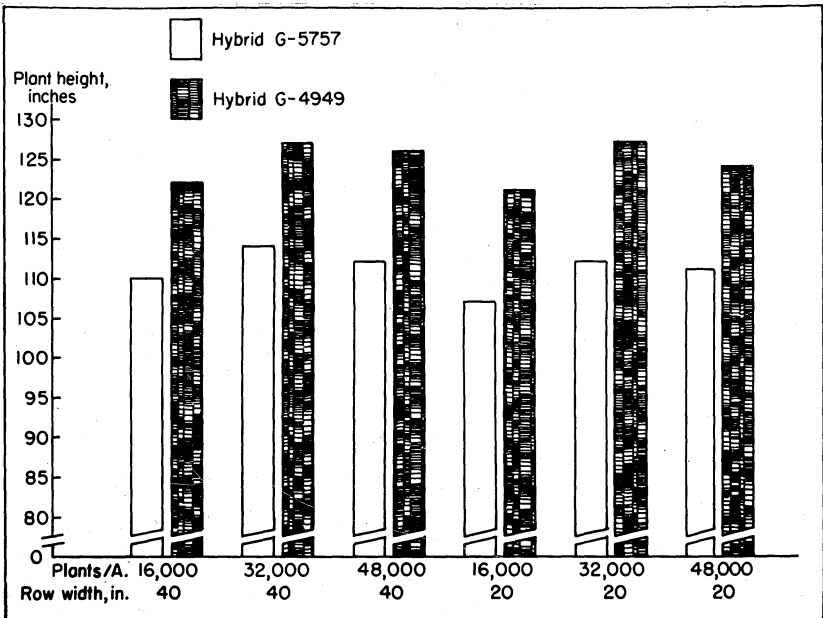


FIG. 23. Plant height as affected by plant population, hybrids, and row width, 1971-72.

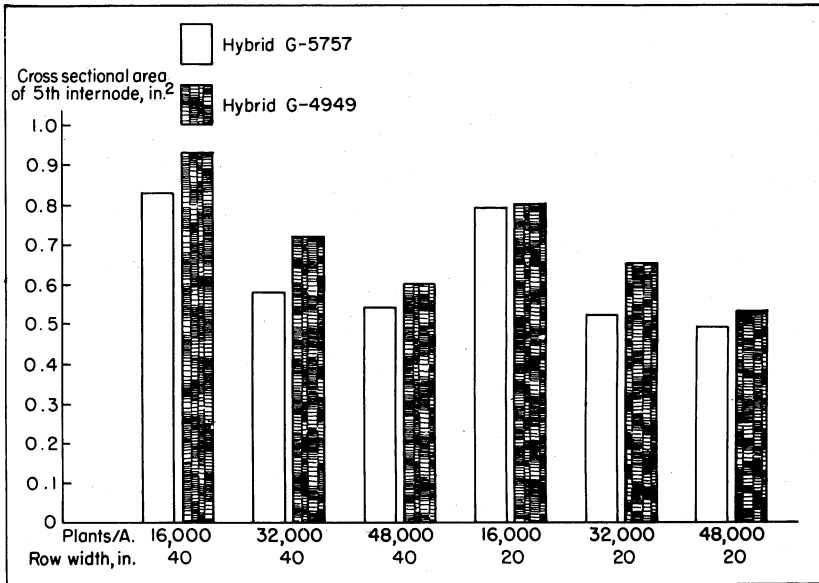


FIG. 24. Stalk cross sectional area as affected by plant population, hybrids, and row width, 1969-70.

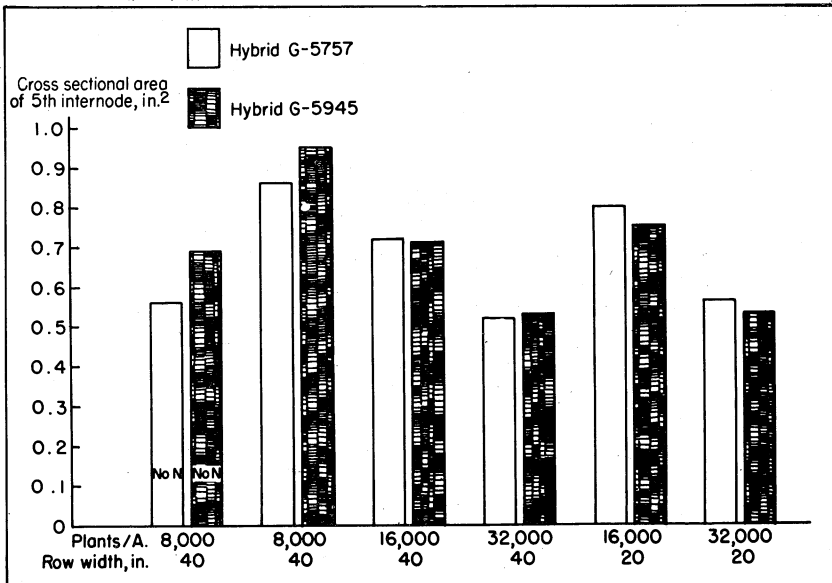


FIG. 25. Stalk cross sectional area as affected by plant population, hybrids, and row width, 1971-72.

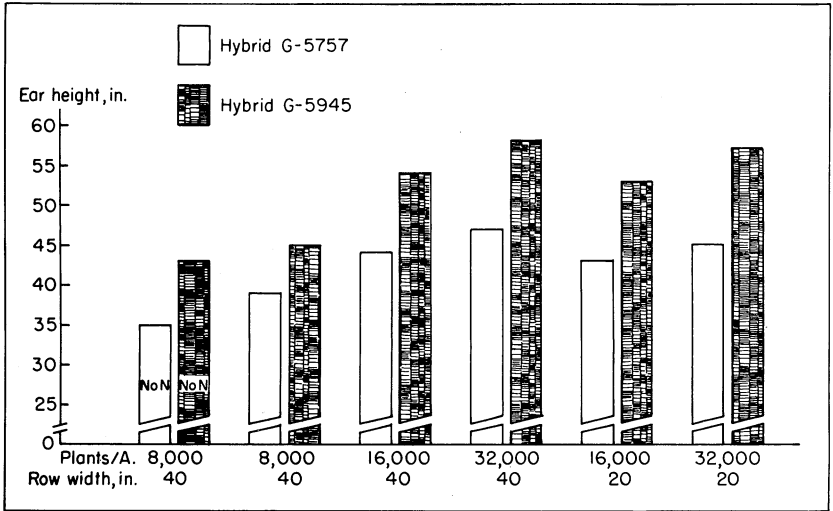


FIG. 26. Ear height as affected by plant population, hybrids, and row width, 1969-70.

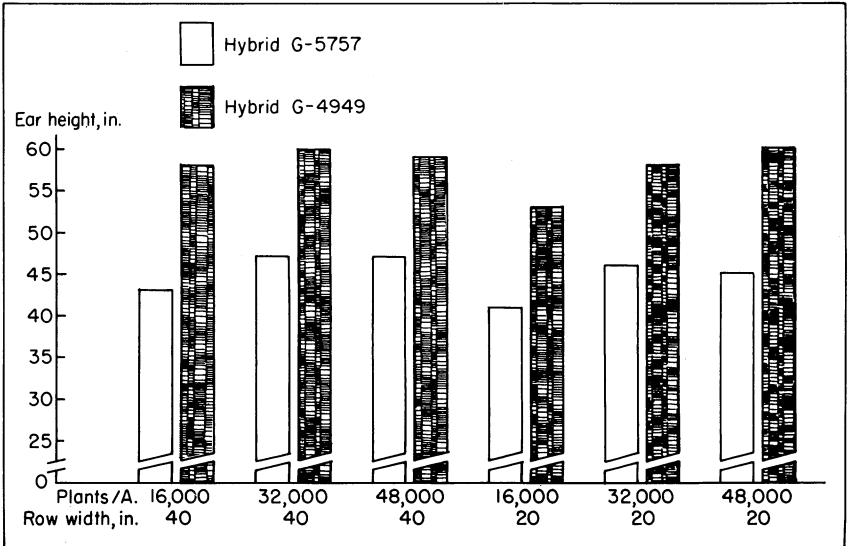


FIG. 27. Ear height as affected by plant population, hybrids, and row width, 1971-72.

CONCLUSIONS

Highest average grain yields produced with irrigation were 146 and 162 bushels per acre during 1969-70 and 1971-72, respectively.

Hybrids G-5757 and G-5945 produced highest yields with 32,000 plants per acre. Hybrid G-4949 produced similar yields with 16,000 or 32,000 plants per acre.

Grain yields were lower with plant population above 32,000 plants per acre.

Grain yield was slightly higher with 20-inch as compared with 40-inch rows during 1969-70, but there was no difference during 1971-72.

Plant population and stover yields were directly related. Highest stover yields were about 13,000 pounds per acre.

Highest grain yields were associated with grain-to-stover ratios of 0.7 to 0.9.

Grain yields were highest when about 0.25 pound of grain was produced per stalk.

Highest grain yield was observed with 32,000 plants where N recovery was 77 per cent, which was about twice the N recovery with 8,000 plants per acre.

Grain yields were maximum where 85 to 95 per cent of the sunlight was intercepted by the plant canopy.

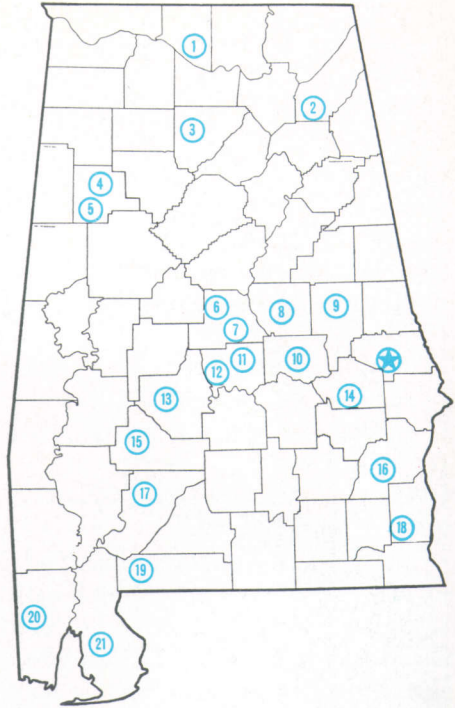
Lowered grain yields with 48,000 plants was partially the result of 20 to 30 per cent of the plants being barren.

Hybrids G-5757 and G-5945 produced highest grain yields with LAI's of about 5.0, whereas G-4949 produced highest yields with LAI's of 3.5 to 5.0.

Increasing plant population resulted in sharply reduced stalk diameter. Increasing plant population up to 32,000 plants resulted in increased stalk and ear height. Because of these effects, dense populations are more susceptible to lodging than low populations.

AGRICULTURAL EXPERIMENT STATION SYSTEM OF ALABAMA'S LAND-GRANT UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, live-stock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Tuskegee Experiment Field, Tuskegee.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Ornamental Horticulture Field Station, Spring Hill.
21. Gulf Coast Substation, Fairhope.