EFFECT OF ROW-WIDTH AND PLANT POPULATION ON THE YIELD AND OTHER CHARACTERISTICS OF CORN

by

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ABSTRACT

A two-year study was made at the American University of Beirut farm to evaluate the effect of three planting rates and two between-row spacings on the performance of three corn hybrids. The factors studied were grain and forage yields, plant and ear-height, tillering percentage, percentage of barrenness, number of days from planting to flowering, uniformity of ears, lodging and protein percentage in the grain. Planting rates were 4,000, 5,000 and 6,000 plants per dunum and the row spacings were 100 cm. and 75 cm. The hybrids tested were S.D. 604, Ind. 620 and AES 808.

Plant populations employed in this study did not affect significantly the grain yields, plant height, ear-height, number of days from planting to flowering, uniformity of ears, lodging or protein percentage in the grain. Highest percentage of tillers, barrenness and highest forage yields were obtained at 4,000 plant population.

Corn planted in 75 cm. rows produced higher grain and forage yields than that planted in 100 cm. rows. However, the row spacings employed in this study did not affect the plant height, ear-height, tillering percentage, percentage of barrenness, number of days from planting to flowering, uniformity of ears, lodging and the protein per-

centage in the grain.

Hybrid S.D. 604 was found to have performed the best in both grain and forage yields though it had the lowest percentage of tillers and barrenness when compared to the other two hybrids, Ind. 620 and AES 808.

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INTRODUCTION

One of the important advances in food production in recent years is the development of hybrid maize (*Zea mays*). The striking increases in yield that have been obtained in the United States of America have aroused interest in the possibility of increasing production by similar methods in maize growing regions of the world.

The value of maize in world agriculture has been well emphasized by its acreage and its increased number of uses. In recent years the acreage devoted to maize in the different parts of the world is on a steady increase. According to F.A.O.'s estimate the area under maize in the world has increased from 91.1 million hectars in 1953 to 105.7 million hectars in 1960 (12). This steady increase in area as well as in yield may be attributed to the development of hybrid maize varieties of high yielding ability. Since high yield per acre warrants a high population and the maize plant is less capable of adjustment to a poor stand than other members of the grass family, it is necessary that the proper planting rate be chosen with minimum plant competition for nutrients, moisture, light, etc. Although many yield comparisons between different maize planting patterns have been made, the superiority of any one planting pattern has not been clearly established because of the variations in locality, soil, as well as the performances of different hybrids.

In the Middle East, very little work has been done on this subject even though the recent consumption of maize and maize products has increased. This experiment was conducted to evaluate the performance of three hybrid varieties of maize under the conditions prevailing in the Bekaa plain of Lebanon. The yielding ability, protein content and other agronomic characteristics were evaluated when maize was planted at different plant populations and row-spacings. The experiments were conducted during the two seasons of 1961 and 1962.

REVIEW OF LITERATURE

Dungan (9) reports that Basil Benson, formerly senior specialist of the department of Agriculture, Petrograd, Russia, once said, "...the factor which has had the greatest influence in determining the width of corn rows is the length of the ox yoke." However, with the advent and improvement of the tractor, planting and cultivating equipment, there has been considerable interest in changing the conventional spacings. Also, with the improvement of hybrid corn varieties, changing of spacing and population has been felt necessary by many workers to meet various requirements.

Stringfield and Thatcher (31) reported that Cunningham credited Mr. A.T. Patterson of Goodland, Kansas, as being the first to grow corn with double-width row spaces. The same authors also noted that "...the most comprehensive work yet reported dealing with the number and distribution of corn plants was by Mooers," who concluded, "...that the best results in practice will probably be obtained with a width of row which permits the satisfactory use of tillage implements but allows the determined number of plants to be as widely spaced as possible." Many workers have tried to achieve this goal but it is evident that the plant population and spacing for optimum yield and maintenance of soil fertility level varies with the variety, soil moisture, fertility of the soil and many other factors. It appears that no two workers working at two different places have recommended the same spacing or population for two different areas.

A brief review of the literature dealing with the factors that are affected by the change of population and plant spacing in maize is presented under the following headings: grain yield, forage yield, tillering, plant and ear-height, dates of tasseling and silking, lodging, barrenness, ear-size and uniformity of ears and composition of grains.

Grain yield

Stringfield and Thatcher (31) reported that in Iowa, Collins and Sedd compared corn in 21-by-21 inch check rows with 42-by-42 inch check rows at comparable acre planting rates. The results from eight years of research showed that the narrow rows, having 14 percent thicker stand, out-yielded the wider rows by 8.5 bushels per acre. Stringfield and Thatcher (31) from their experiments involving row spaces ranging from 30 to 80 inches reported, "...where the soil and season would produce less than 30 bushels of grain to the acre the yields dropped gradually as row spaces were wider than 30 inches. But with a soil and season that would produce 70 to 100 bushels of grain to the acre there was no perceptible loss by widening the row-spaces to 50 inches, a loss of only about 4 bushels at the 70-inch row space."

In Israel (28) making experiment with hybrid maize variety under irrigation, it was observed that under comparable populations and spacings, 6,000 plants per dunum at row spacings of 1 meter and within-row spacings of 16.5 centimeters gave the highest yield over 4,000 populations at between-row and within-row spacings of 1 meter and 25 centimeters, respectively.

Dumenil (7), considering soil fertility as the most important factor in Iowa, based on fifteen years of research, reported that the best stand level for corn at high fertility levels for most conditions is near 16,000 plants per acre. Lang (20) reported that Dungan of the University of Illinois came up with an estimate of 16,000 plants per acre for each 100 bushels of corn.

Caldwell (5) reported that recommendations in Minnesota vary from about 12,000 plants per acre on sandy drouthy soils to 18,000 to 20,000 plants per acre on heavy soils of good water holding capacity.

Making recommendations for South Dakota Termunde, Shank and Dirks (33) maintained that for central and northeastern South Dakota 8,000 to 10,000 plants per acre, for eastern South Dakota, 10,000 to 12,000 plants per acre and under irrigation, in south-eastern South Dakota 20,000 to 24,000 plants per acre, is the best.

Stringfield (30) for southern Ohio recommended between 12,000 and 16,000 plants per acre depending upon the variety, soil fertility and available soil moisture. Fitts (13), recommending for North Carolina, reported that the plant population for a given yield should be for 50-75 bushels, 8,000 to 9,000 plants per acre; 75-100 bushels, 12,000 to 14,000 plants; 100-150 bushels, 14,000 to 16,000 plants and over 150 bushels, 16,000 to 20,000 plants.

Jordan (18), recommending plant population for Mississippi, reported that under non-irrigated condition with high fertility level a stand of about one plant every 15 to 16 inches in 40-inch rows, which adds up to 10,000 plants per acre, has been satisfactory. He also reported, "We maintained a 10-year average of 99 bushels per acre with this treatment." Reporting the planting rates for corn in the eleven western states of the United States, Viets (34) maintained that for grain, stands of about 18,000 to 20,000 plants per acre are needed on irrigated lands while 4,500 to 7,500 plants per acre are best for dry lands.

Data reported by Duncan (8) who studied populations varying from 8,000 to 24,000 plants per acre, using three hybrids differing in maturity, reveals that under high fertility level late maturing variety gave the highest yield at 24,000 plant population when compared with early or medium maturing varieties at comparable treatments. Under low level of fertility, late maturing varieties performed best when population was between 12,000 and 16,000. He also reported that, "...even on the low fertility level plots, there was trend for all hybrids to increase yields as populations were increased to 16,000 plants per acre." Dungan (9), experimenting with populations ranging from

6,000 to 20,000 plants per acre, reported 16,000 to be the best for high yields on a productive soil in seasons with well-distributed and sufficient rainfall. Dungan, Lang and Pendleton (10) reported in Illinois that plant population studies with 4, 8, 12, 16, 20 and 24 thousand plants per acre revealed that the highest yield per acre was at a population of 20,000 plants.

Drake, Ishizuka and Gotoh (6), in Japan, averaging the yields of all hybrids at two locations, reported that the effect of increasing the population from 17,000 to 22,000 plants per acre was to increase the yield of 10.6 bushels of corn grains. Hoff et al (16), evaluating the performance of corn hybrids at populations of 8, 12, 16 and 20,000 plants per acre, observed that 16,000 population was the best in 42-inch rows. In their study with populations ranging from 4,000 to 28,000 plants per acre, Kohnke and Miles (19) observed that the highest corn yields were associated with planting rates between 15,000 and 19,000 kernels per acre. Data presented by Lang, Pendleton and Dungan (21), for the nine hybrids used in their experiment at populations ranging from 4,000 to 24,000 plants per acre, indicated that 16,000 gave the highest yield under medium soil fertility level, 12,000 in case of low fertility and 20,000 plants per acre in case of high fertility level.

McVicker and Shear (22), evaluating three open pollinated and three corn hybrids at populations ranging from 4,000 to 20,000 plants per acre, concluded, "Yield increased as the rate of planting increased but the maximum yield of two varieties of corn does not necessarily occur at the same planting rate." Pendleton and Seif (25) conducted an experiment with dwarf corn at populations from 12,000 to 32,000 plants per acre and reported as an average for all row spacings and trials, that a plant population of 16,000 to 20,000 plants per acre produced the highest yield. According to Mohr and Rost (23), who observed plant populations ranging from 12,000 to 31,000 plants per acre, the yield was maximum at the highest population of 31,000 plants per acre at a high fertility level. Stickler and Lande (29), evaluating 15,700 and 10,450 plants per acre at 20 inches and 40 inches between-row spacings, reported that the grain or stover yields of corn were not influenced by the plant populations or the row spacings employed.

According to Dungan, Lang and Pendleton (10), Jugenheimer in 1953 and Jugenheimer and Silow in 1954 reported that in corn growing areas of Europe, workers have found that populations required for maximum production are between 25,000 and 30,000 plants per acre and even at higher populations.

Bowers (2) reported that when the rows are 3 feet apart, within-row spacing of 24 inches gave better yields than 18 inches and 36 inches.

Stringfield and Thatcher (32) suggested that "...corn row spaces of 60 inches or even 70 inches without reducing the acre planting rate may permit same results with advantage of wheat seeding in between corn rows." According to Watson and Davis (35) 24x12 inches of spacing gave the highest yield of grain and stover in their experiment.

Experimenting with dwarf corn with row spacings of 20, 30 and 40 inches, Pendleton and Seif (25) reported that, as an average for all populations, 30-inch rows outyielded either 20 or 40-inch rows. The same authors also observed that the wider the row spacing, the lower was the plant population needed for highest yield up to a certain level. In their experiment, populations of 16,000 and 20,000 plants per acre produced their highest yields at 40 and 30-inch row-widths, respectively.

Haynes and Sayre (15) reported that in rows 8½ feet apart, highest ear corn yields occurred at within-row spacings closer than those usually give maximum yields at closer between-rpw spacings. Enzie (11) reported from the records taken over a 4-year period that highest average yield was obtained when plants were 0-inch apart in 30-inch rows. Three-year data on another variety showed that the highest yield was obtained in 30 or 36-inch rows with plants 12-inch apart. Experiments by Bryan, Eckhardt and Sprague (4) with row spacings of 21 inches and 42 inches revealed that, by planting the same number of plants per acre, minor variations in spacing had little effect on the acre yield. Brandon (3), under lower rainfall conditions, reported that the highest 12-year average yield of ear corn per acre was obtained from 24-inch spaced plants in 44-inch rows.

Dungan, Lang and Pendleton (10), in their review of literature on corn plant population in relation to soil productivity, reported that many workers (Kisselbach et al., 1935; McClelland, 1928b, 1940; Mooers, 1920; and Osborne, 1925) have investigated the possibilities of wide-row spacing in areas of favourable rainfall and observed that 7-foot rows yielded from 15 to 25 percent less than 3.5 feet rows even at the same population level. The report from these same authors also points out that Lasson and Willis (1957) obtained equal yields from 40-, 60-, and 80-inch spaced corn rows in the drier than normal seasons of 1954 and 1955. In reporting the work of Pendleton et al (1957), who found that 80-inch rows yielded much higher at 12,000 plants per acre than at 9,000 or 6,000 populations, the authors maintained that in order to have the same population in 80-inch rows as in 40-inch rows, the plant spacing within the 80-inch rows is often extremely close and there exists considerable inter-plant competition. But Haynes and Sayre (15) believed that the individual plant compensates for this by developing an oblong root pattern perpendicular to the rows. Hary and Moss (14) reported that where soil moisture and fertility are sufficient the lower yield per acre in high populations is due to lower light intensity though other factors also may contribute to the reduced yield.

Forage yield

Termunde, Shank and Dirks (33) reported that in South Dakota from stand-yield curves it is evident that total forage yields increased as the stand increased until a maximum was reached. The maximum stand depended on the season and the location.

In Israel, in comparing, 5, 6, 7, 8, 9, 10 and 11,000 plants per dunum, it was reported by Shlomi (28) that 8,000 plants per dunum was best for green fodder yield under irrigated condition. Below or above this population, the yield was reduced under optimum moisture and fertility level. Termunde, Shank and Dirks (33) reported that under irrigation the best population for forage yields lies between 24,000 and 32,000 plants per acre in South Dakota. Haynes and Sayre (15) reported that in 8½ feet rows differences in within-row spacings from 1 to 4 inches had little effect on total plant weight per acre. Brandon (3) reported that the highest total corn yield was obtained from the 12-inch spacing in 44-inch rows.

Tillering

Dungan, Lang and Pendleton (10) defined tillering as the cause of the response of plants to environmental conditions which can support a larger population than is present. As reported by the same authors, Williams and

Etheridge (1912) listed the following factors which favor the production of tillers, (1) highly productive soil with adequate moisture supply, (2) a strain of corn having a high tillering habit, (3) thin spacing of plants and (4) time of planting which is favorable for vigorous growth. Many workers have reported their results which are in general agreement with these principles. Kohnke and Miles (19) in Indiana, and Stringfield and Thatcher (31) in Ohio observed that, at optimum stands for grain production tillering percentage was relatively low. Other workers have observed that as the plant spacing was increased the number of tillers per plant also increased, (1, 11). Also, it was reported by Kohnke and Miles (19) that tillering was consistently decreased with the increase in plant population.

Plant and ear-height

As reported by Dungan, Lang and Pendleton (10), Stringfield and Thatcher (1947) found that in their tests in Ohio the ear-node was somewhat higher on thickly planted corn. Pendleton and Seif (25) reported that row spacing had no effect on tassel height and plant population also had no effect on the ear-height. Dungan, Lang and Pendleton (10) reported that tests in Illinois and Iowa revealed that plant population had little effect on plant height or ear-height. It was reported by Enzie (11) that there was no significant difference in plant height as a result of plant spacing. Reports from Hary and Moss (14) revealed that under extremely high plant populations the plants were slightly taller which he attributed to the competition for light.

Dates of Tasseling and Silking

Dungan, Lang and Pendleton (10) suggested that "Retardation of silk emergence may be looked upon as an operation of plant adjustment to high population which in extremely thick stands would bring about complete barrenness." It has been observed in many places that increasing the population density delays plant development. It is reported by Dungan et al (10) that a study in Central Illinois was carried out with dates of the half-tassel and the half silk stage of nine hybrids in rate of planting tests. It was observed in this test that the increase in time between silking and tasseling due to thick planting was not great. It amounted to only a little over one day when the population was increased from 8,000 to 20,000 plants per acre. The same authors also reported from the unpublished results of Lang that the interval was found to be much greater at populations above 20,000.

Kohnke and Miles (19) reported that silking was delayed by one day for every additional 3,500 to 4,000 kernels planted per acre. Stringfield and Thatcher (31) reported that the silking period for a stand of 5 plants per 42-inches of row space was roughly 2 days later than for a stand of 3 plants in the same space. Baily (1) working with sweet corn reported that wider spacings between plants enhanced the silking date. Enzie (11) reported significant effect of spacing on the maturity of all three hybrids he tested. Maturity was rapid when grown with abundant space, whether 36-inch check rows or 36-inch drill rows with plants 12-inch apart.

Lodging

Dungan, Lang and Pendleton (10) are of the opinion that increasing the corn population on soil of the same productivity decreases the strength of stalks and increases the likelihood of lodging. Bryan, Eckhardt and Sprague (4), evaluating a number of hybrids and open-pollinated varieties, using two hill spacings and row spacings of 21 inches and 42 inches at populations varying from 14,000 to 20,000 plants per acre, reported that closer spacings consistently had more lodged plants than wider spacings. Data presented by Termunde, Shank and Dirks (33) revealed that in thick stands stalk lodging is heavier. Plant populations studies ranging from 4,000 to 28,000 plants per acre by Kohnke and Miles (19) showed that the percentage of lodged plants increased up to a stand of 20,000 plants per acre. From 20,000 to 27,000, the amount of lodging decreased, which they credited to be due to wind protection afforded by the very heavy stand. Stringfield and Thatcher (31) from their experiment are of the opinion that the most effects of heavier stands is in the higher incidence of stalk breakage. Dungan, Lang and Pendleton (10) reported that Dungan et al observed in 1938 that 8,000, 12,000, 16,000 and 20,000 plants per acre lodged 22, 31, 39, and 46 percent, respectively. It was observed by Pendleton, Jackobs, Slife and Bateman (26) at Urbana, that under comparable population even though the plants were closer together in the 80-inch rows, there was less stalk breakage than in the narrower rows.

Barrenness, Ear-size and Uniformity of Ears

Lang, Pendleton and Dungan (21) found that stalk barrenness was affected more by population than by the hybrid or the fertility level. Hoff and Mederski (16) reported that percentage of barrenness was low at lower population and did not increase significantly with high population in his study of population of 8, 12, 16 and 20 thousand plants per acre. With populations ranging from 12,000 to 32,000 plants per acre and row spacings of 20, 30 and 40 inches Pendleton and Seif (25) reported that row spacings had no effect on percent of barren plants but as plant populations increased, the number of barren stalks also increased at all row spaces.

Baily (1), working with sweet corns reported that between-row spacing of three feet and within-row of four inches or less decreased the percentage of usable ears. Hoff and Mederski (16) reported that ear weight was decreased gradually as the population was increased from

8,000 to 20,000 plants per acre. Enzie (11) reports that the length of ear was increased significantly in all the three varieties he had used by increasing the spacing but there was no significant difference between the 36-inch check row and 30-inch drill row with plants 12 inches apart.

Composition of Grains

From their study of plant populations and nitrogen levels, it was reported by Pendleton and Seif (25) that protein content in grains was highest at the lowest plant population under all fertility levels. Oil content was significantly decreased with increasing populations in all of the nine hybrids tested.

Prince (27) studied the influence of population on the composition of protein in corn grain and reported that increased plant stand decreased total leucine content, but that this decrease was not so great in crude protein content. Thus, the net effect of population rise was to decrease the percentage of leucine in the protein. He also reported that tryptophan tended to decrease with heavier plant stands. The zein fraction tended to increase faster under thinner stands than did total crude protein. Also increasing the population tended to increase the total amount of isoleucine as well as its percentage in the crude protein. Lang, Pendleton and Dungan (21) reported that, in Illinois, the oil content of grain decreased with population increase. This was true with population above 12,000 plants per acre. According to Dungan, Lang and Pendleton (10), Earley and DeTurk found in 1948, in Illinois, that on each level of soil nitrogen the percentage of protein in the grain decreased with increasing field stand. Working with populations ranging from 8,000 to 17,000 plants per acre Suber, Smith and Gehrke (36) obtained similar results in Missouri. They observed that the crude protein percentage decreased with the increase of population but maintained that thicker planting increased the total protein harvest when proteins in both grains and stovers are taken into account. It is reported by Dungal, Land and Pendleton (10) that Genter <u>et al</u> (1956) observed, in Virginia, that the highest protein yield was obtained from the higher plant stand and the heaviest application of nitrogen. They did not find any appreciable effect of plant population on the oil content. In Israel (28), recent studies revealed that a population of 8,000 plants per dunum was better in respect of protein, fiber, oil and ash content of both corn grains and forage. A population below or above this level was low in quality. Prince (27) from his experiment with different plant populations, spacings, varieties and soil fertility in 1954 concluded, "...Nitrogen fertilization in relation of plant population, as well as variety, has an important effect on protein composition" of corn grains.

MATERIALS AND METHODS

The experiment was conducted for two years at the American University farm in the Bekaa plain, located 80 kilometers east of Beirut, under irrigated condition. The soil was a clay type with a pH value of 8.0. Three U.S.A. developed varieties of hybrid maize, S.D. 604, Ind. 620 and AES 808, varying in maturity, were used in this trial. The soil was fertilized at the rate of 12 kilogram of nitrogen per dunum in the form of ammonium nitrate and 20 kilogram of P_2O_5 per dunum in the form of super phosphate. The fertilizers were broadcast and disced into the soil before planting time. Later, in June and August additional applications of nitrogen were made as a side dress at the rate of four kilogram of nitrogen per dunum in each application. The experimental plot was irrigated every week throughout the growing season. Sprinklers were used during the early growth period, and furrow irrigation, during the later stages of the crop. Moisture and nutrients were not allowed to be a problem in the experiment, and were kept at an optimum during the growth period.

At the two-leaf stage a few of the plants were attacked by cutworms so all of plots were sprayed with endrine to control them. Later in the season metasystox was sprayed on the maize plant to control the leaf hoppers. However, insects and diseases were never a serious problem.

The experiment was laid out on a split-plot design involving three populations and two spacings with four replications. The three populations of 4,000, 5,000 and 6,000 plants per dunum were established at two different between-row spacings of one meter and 75 centimeters. Populations were the main plot factors and each subplot was split for the two spacings. Each of the three varieties were used in each treatment. Each treatment consisted of two rows, each five meter long. One of these rows was harvested for forage and the other for grain yield.

The planting was made thick and was thinned down to the desired number of plants in each row. Thinning was performed when the plants were about six to ten inches tall. The plot was weeded every week during the early part of the experiment with regular nursery equipments. During later stages of the experiment, weeds were not a problem and during the early part the plot was kept weed free.

Plant height, tillering percentage, number of 1-ear, 2-ear and 0-ear plants per four meters of each row, ear-height from the ground, uniformity in position of the ears, date of tasseling and silking, yield of grains on the basis of 15.5 percent moisture and air-dry yield of forage were determined and recorded. The rows for forage were harvested at the "dent" stage. From the five meter rows only four meters were harvested for grain yield and forage yield, leaving fifty centimeters at each end of the row to eliminate border effect. Border rows were also planted between two subplots dividing the spacing treatments and on each side of the experimental plot.

For determining air-dry yield of forage, representative ten pounds sample for each treatment was used to make a composite sample for all the four replications. For determining moisture percentage of the grain, only the central portion of the ear of a representative sample from each treatment, taken immediately at harvest, was used. From the oven-dry weight of the samples of representative ears, the yield of grain was calculated to a 15.5 percent moisture basis using the conventional conversion table.

For protein determination of the kernels, a representative sample from each treatment was dried in an oven for 48 hours at a temperature of 100°C to 103°C and then cooled and ground in a Wiley-mill with a 40-mesh sieve and the ground material was collected in a screw top bottle. Before weighing, the samples were put in the oven at 70°C for 6 hours to remove the air-moisture, cooled in a dessicator and weighed on the electrical balance to the nearest tenth of a milligram. Analyses for protein were then made according to the modified Kjeldahl method, as specified in the Association of Official Agricultural Chemists' official method of analysis to determine the percentage of nitrogen (17). The nitrogen values obtained were multiplied by the factor 6.25 and the data reported as percent protein. Results of duplicates differing from the sample mean by 6 percent or over were rejected and the analysis repeated. The following formula was used to calculate the range of variation:

$$\frac{X - Xm}{Xm} \times 100 = 6\%$$

where, X = percent nitrogen in the sample.

Xm = mean percentage total nitrogen in the sample.

Statistical methods, appropriate to the split-plot design were used to analyze the data (24). Analysis of variance and the 't'-test were used to calculate the difference between the treatments and their interactions (24).

The experiment was conducted during the two years period, 1961 and 1962. Because of limited time the data for yield and protein content are not reported in this thesis for the 1962 crop. It was not possible to include information in this report that was collected after August 15, 1962.

RESULTS AND DISCUSSION

A two-year study was made to evaluate the effect of three plant populations and two row-spacings on the grain yield, forage yield, tillering percentage, plant height, ear-height, number of days from planting to flowering, barrenness percentage, uniformity of ears, protein percentage in the grain and lodging of three corn hybrids. Data for only the tillering percentage and number of days from planting to flowering are reported for the two years, as it was not possible to mature two corn crops within the period of this study. All other data were collected and reported for the year 1961. The data for the various characters studied are discussed and reported in tables 1 to 8. Analysis of variance tables are given in the appendix. The LSD figures were calculated and are presented at the bottom of the tables only for the treatments that were statistically significant.

Grain yield

Significant differences were found in grain yields between the three hybrids as shown in Table 1. Ind. 620 was found to yield the lowest, 981 kg. per dunum, while S.D. 604 and AES 808 yielded 1123 kg. and 1126 kg. per dunum, respectively. Ind. 620 yielded significantly lower than the other two hybrids. However, S.D. 604 and AES 808, though yielding more than Ind. 620, did not differ significantly

Table 1. Effect of row-width and plant population on the grain yield of corn hybrids in kg. per dunum during 1961 (15.5% moisture level).

Hybrid	Row-width cm.	Plant population per dunum		
		4000	5000	6000
S.D. 604	100 75	985 1379	920 1269	911 1283
Ind. 620	100 75	939 1160	883 1088	725 1094
AES 808	100 75	1062 1341	905 1222	1043 1181
Means of population		1143	1048	1039

	LSD (5%)	LSD (1%)
Hybrid	109	146
Spacing	58	84

Means:

Spacings	100 cm.	75 cm.	
	926	1226	
Hybrid	Ind. 620	S.D. 604	AES 808
	981	1123	1126 //

// Treatments underlined do not differ significantly at the 5 percent level.

at the 5 percent level between themselves.

No significant differences were observed in grain yields due to variations of plant populations, 4,000, 5,000 and 6,000 per dunum. However, there was a consistent trend in the grain yield obtained since 4,000 plants per dunum produced more than 5,000 which in turn yielded more than 6,000 plants per dunum. Even though the differences were not significant, the possibility of this trend in yield response cannot be completely overruled. Further studies may reveal the significance of such a consistency in yields.

Grain yields were found to differ significantly because of the change in row spacing. Plots having 75 cm. between-row spacing yielded 1226 kg. per dunum while those with 100 cm. spacing yielded 927 kg. per dunum which is significantly lower at the 1 percent level (Table 1). A possible explanation for the higher yield at the 75 cm. between-row spacing may be that, even though under the same population individual plants enjoy the facilities of the same square area, the pattern of the area distribution does not remain the same when the row-width is changed. At 100 cm. between-row spacing plants are more closer within the row when compared to plants in the 75 cm.-wide rows. Naturally, the competition for soil nutrients within the row is less in the 75 cm.-rows than in 100 cm.-rows. Higher yields were obtained in narrower rows by many other workers also (10, 11, 31, 35).

Interactions between any other two treatments were not found to be significant (Table 9). However, it seems that at any plant population closer between-row spacings that will not hamper other tillage operation facilities, may be desirable from the yield point of view.

Forage Yield

There were significant differences in corn forage yield due to variations in plant populations. The corn plots with 4,000 and 5,000 plants per dunum yielded significantly higher than those with 6,000 plants (Table 2). Yield differences between 4,000 and 5,000 populations were not statistically significant but the consistency that was observed for higher yield at lower plant populations is not negligible.

Forage yields were found to differ significantly between the two row spacings studied. Corn planted in 75 cm.-rows gave higher yields than when grown in 100 cm.-rows. A possible explanation for higher yields at lowest plant population, 4,000 per dunum and closest spacing of 75 cm. between-rows, may be offered as follows. At low population and close spacing the plant competition for soil nutrients was at its minimum and the plants became more vigorous and stimulated more tillers (Table 3) which in turn accounted for the higher forage yield. The effect of tillering will be discussed in the next section.

The three hybrids studied were not significantly

Table 2. Effect of row-width and plant population on the forage yield of corn hybrids in kg. per dunum during 1961 (Air dry weight).

Hybrid	Row-width, cm.	Plant population per dunum 4000	5000	6000	Mean of Hybrid
S.D. 604	100	2016	1585	1279	1759
	75	1921	2345	1413	
Ind. 620	100	1707	1648	1282	1722
	75	2306	1853	1535	
AES 808	100	1857	1781	1480	1886
	75	2662	2015	1520	
Means of population		2078	1871	1418	

	LSD (5%)	LSD (1%)
Plant population	344	522
Spacing	109	157
Hybrid x spacing x population	360	482

Means

Plant populations	4000	5000	6000
	2078	1871 //	1418
Spacing	100 cm.		75 cm.
	1626		1952

// Treatments underlined do not differ significantly at 5 percent level.

different in their forage yields. The weight of forage produced by AES 808 appears greater than that of Ind. 620 and S.D. 604 but these differences were not statistically significant.

The interaction between hybrid x population x spacing was found to be significant (Table 10). The hybrid AES 808 yielded the highest, 2662 kg. per dunum, at plant population of 4,000 per dunum and row spacing of 75 cm. On the other hand S.D. 604 produced the lowest amount of forage (1279 kg. per dunum) at 6,000 plant population and 100 cm. spacing. No other interactions were found to be significant.

<u>Tillering percentage</u>

A significant difference in tillering percentage was found between the three plant populations studied (Table 3 and Table 11). In both of the years 1961 and 1962, the tillering percentage differed significantly between each plant population, with the lowest population, 4,000 per dunum, resulting in the highest percentage 56 and 66 in 1961 and 1962, respectively. The highest plant population, 6,000 per dunum, produced the lowest percentage of tiller, 9 and 11 percent in 1961 and 1962, respectively. The data for both of the years are very consistent and in agreement with other investigations (1, 11, 19, 31).

Hybrid AES 808 produced a higher percentage of tillers than S.D. 604 and Ind. 620 during both of the years, 1961 and 1962. The difference in tillering percent-

Table 3. Effect of row-width and plant population on the tillering percentage of corn hybrids during I96I and I962.

Hybrid	Row-width cm.	Plant population per dunum					
		4000 (PI)		5000 (P2)		6000 (P3)	
		I96I	I962	I96I	I962	I96I	I962
S.D. 604 (VI)	I00	45	43	20	I9	4	I3
	75	38	55	II	I9	8	8
Ind. 620 (V2)	I0C	35	34	I7	I8	5	7
	75	45	65	2I	29	3	9
AES 808 (V3)	I00	76	85	28	35	I4	I7
	75	93	II5	53	50	I9	I5

	LSD (5%)		LSD (I%)	
	I96I	I962	I96I	I962
Plant population	I4	I2	22	I8
Hybrid	8	7	II	I0
Hybrid x population	I5	I2	20	I6

Means:

Plant population

	I96I			I962		
	4000	5000	6000	4000	5000	6000
	56	25	9	66	28	II

Hybrid

	I96I			I962		
	S.D. 604	Ind. 620	AES 808	S.D. 604	Ind. 620	AES 808
	2I	2I //	47	26	27	53

Hybrid x population

I96I	V2P3	VIP3	VIP2	V3P3	V2P2	V2PI	V3P2	VIPI	V3PI
	4	6	I5	I6	I9	40	40	42	85
I962	V2P3	VIP3	V3P3	VIP2	V2P2	V3P2	V2PI	VIPI	V3PI
	8	I0	I6	I9	24	43	49	49	I00

// Treatments underlined do not differ significantly at 5% level.

age between S.D 604 and Ind. 620 was not significant in either year. Interaction between hybrid and population was found to be significant (Table 11). Ind. 620 at 6,000 plant population produced the lowest percentage of tillers while AES 808 gave out the highest percentage of tillers at 4,000 plants per dunum during both of the years.

It appears that higher tillering percentage is a hybrid characteristic of AES 808 but the same is not true in the case of S.D. 604 and Ind. 620.

Plant height

The data in Table 4 shows a significant difference in plant height between the three hybrids under study. AES 808 was found to be the tallest with an average height of 271 cm. The hybrid Ind. 620 was intermediate with a height of 259 cm., while S.D. 604 was the shortest with a height of 249 cm. This significant difference in plant height can be attributed as a hybrid characteristic.

No significant difference in plant height was observed due to difference in plant population or row-width (Table 12). This observation is in agreement with the findings of other investigators (10, 11, 25). As reported by Hary and Moss (14), it seems that the plant populations used in this study cannot be termed "extremely high" under the conditions prevailing during this experiment. Experiments in Israel also showed that the plant populations employed in this experiment cannot be termed "extremely high"

Table 4. Effect of row-width and plant population on the plant height of corn hybrids in centimeters during 1961.

Hybrid	Row-width cm.	Plant population per dunum		
		4000	5000	6000
S.D. 604	100	248	249	254
	75	239	250	255
Ind. 620	100	252	264	249
	75	265	265	260
AES 808	100	267	266	267
	75	272	277	277

	LSD (5%)	LSD (1%)
Hybrid	8	10

Means:

Hybrid:	S.D. 604	Ind. 620	AES 808
	249	259	271

under the conditions prevailing in Naveh Yaar, Israel (28).

Ear-height

Plant population and row-width used in this experiment did not seem to influence the ear-height significantly in the hybrids studied as shown in Table 5. Hybrids, however, were significantly different in their ear-height. Hybrid AES 808 was found to have the highest ear-height with an average of 124 cm. The other two hybrids, S.D. 604 and Ind. 620, did not differ significantly in their average ear-height. Height of the ear may be regarded as a hybrid characteristic, since corn hybrids are known to vary greatly in average ear-height.

Number of days from planting to flowering

The data reported in Table 6 indicate no difference in the number of days from planting to flowering due to the plant populations and row spacings employed in this experiment. An inspection of the means reveals that they are the same for any one year. The three hybrids showed differences in the number of days from planting to flowering. S.D. 604 and Ind. 620 were found to be earlier than AES 808 in both of the years, 1961 and 1962. Since the three hybrids were selected for their difference in maturity, it is assumed that this is a corn hybrid characteristic. No statistical analysis was, therefore, made and only the means of the treatments are reported in Table 6.

Table 5. Effect of row-width and plant population on the ear-height of corn hybrids in centimeters during 1961.

Hybrid	Row-width cm.	Plant population per dunum		
		4000	5000	6000
S.D. 604	100	121	118	113
	75	115	117	117
Ind. 620	100	113	119	116
	75	122	119	122
AES 808	100	124	119	123
	75	130	122	124

	LSD (5%)	LSD (1%)
Hybrid	3.6	4.8

Mean:

Hybrid	S.D. 604	Ind. 620	AES 808
	117	118 ≠≠	124

≠≠ Treatments underlined do not differ significantly at 5 percent level.

Table 6. Effect of row-width and plant population on the number of days from planting to flowering of corn hybrids during I96I and I962

Hybrid	Row-width cm.	Plant population per dunum					
		4000		5000		6000	
		I96I	I962	I96I	I962	I96I	I962
S.D. 604	I00	75	80	75	80	75	80
	75	75	80	75	80	75	80
Ind. 620	I00	76	80	76	80	75	80
	75	77	8I	78	80	77	80
AES 808	I00	79	83	79	82	80	82
	75	8I	82	80	82	80	83

Means:

I96I

<u>Hybrid</u>:

S.D. 604 - 75
Ind. 620 - 76
AES 808 - 80

<u>Population</u>:

4000 - 77
5000 - 77
6000 - 77

<u>Spacing</u>:

I m. - 77
75 cm. - 77

I962

<u>Hybrid</u>:

S.D. 604 - 80
Ind. 620 - 80
AES 808 - 82

<u>Population</u>:

4000 - 8I
5000 - 8I
6000 - 8I

<u>Spacing</u>:

I m. - 8I
75 cm. - 8I

Barrenness percentage

The percentage of barrenness in corn hybrids was found to be influenced significantly by the different plant populations under study (Table 14). Corn hybrids planted at the rate of 4,000 plants per dunum had the highest percentage of barrenness, 26 percent, while when planted at the rate of 6,000 plants per dunum, the hybrids had the lowest percentage of barrenness, 13 percent (Table 7). The barrenness percentage was calculated on the basis of all the stocks including the tillers. A possible explanation for the lowest percentage of barrenness at high populations and highest percentage of barrenness at the lowest population may be that, at lower population there was maximum tillering percentage. Because of the high percentage of tillering at the lower populations many tillers remained barren because of the probable shortage of soil nutrients.

It will be noted that hybrid AES 808 had the highest percentage of barrenness while S.D. 604 and Ind. 620 were not significantly different in their barrenness. In Table 3 it was shown that hybrid AES 808 also had the highest percentage of tillering. It appears that the high tillering is associated or may result in a high percentage of barrenness in corn hybrids. Row spacings studied in this experiment did not affect the barrenness significantly (Table 14). Also, no interaction was found to affect the percentage of barrenness in this experiment during the period of study in 1961.

Table 7. Effect of row-width and plant population on the percentage of barrenness of corn hybrids during 1961.

Hybrid	Row-width cm.	Plant population per dunum		
		4000	5000	6000
S.D. 604	100	30	19	20
	75	23	7	7
Ind. 620	100	22	16	11
	75	24	17	5
AES 808	100	32	26	18
	75	26	22	18

	LSD (5%)	LSD (1%)
Plant population	5	8
Hybrid	4	6

Means:

Hybrid	S.D. 604	Ind. 620	AES 808
	18	16 //	24

Population	4000	5000	6000
	26	18	13

// Treatments underlined do not differ significantly at 5 percent level.

Uniformity of ears

From the means calculated from the raw data it appeared that there was no consistent difference in the uniformity of ears due to plant populations, row spacings or hybrids used in this study. Since the results obtained were the same for all of the plots, the data are not reported.

Protein percentage in the grain

The data reported in Tables 8 and 15 show that plant populations, row spacings and hybrids did not significantly affect the protein percentage in the grain of corn. However, an interaction between hybrid x population x spacing was found to be significant. Ind. 620, at 6,000 population with row spacing of 75 cm., and S.D. 604, at 5,000 population with row spacing of 75 cm., were found to have the lowest percentage of protein, 9.1 percent, (Table 8). Hybrid AES 808, however, had the highest percentage of protein in its grain at 4,000 plant population both at 100 cm. and 75 cm. row spacings, 11.2 percent, (Table 8). No explanation can be offered until more data are collected from further experiments.

Lodging

No lodging was observed in any of the treatments during any one of two years of studies in 1961 and 1962.

Table 8. Effect of row-width and plant population on the protein percentage in grain of corn hybrids during 1961.

Hybrid	Row-width cm.	Plant population per dunum		
		4000	5000	6000
S.D. 604	100	10.9	10.8	9.8
	75	10.1	9.1	10.7
Ind. 620	100	10.9	9.9	10.2
	75	10.1	10.3	9.1
AES 808	100	11.2	10.7	10.2
	75	11.2	10.6	9.4

	LSD (5%)	LSD (1%)
Hybrid x population x spacing	1.1	1.4

SUMMARY AND CONCLUSION

This study deals with the evaluation of the effect of three planting rates, two between-row spacings, and three corn hybrids on the yield of grains, forage, plant and ear-height, tillering percentage, number of days from planting to flowering, percentage of barrenness, uniformity of ears, protein percentage in the grain and lodging. Rate of plantings employed were 4,000, 5,000 and 6,000 plants per dunum and row spacings were 100 cm. and 75 cm. The three hybrid varieties tested were S.D. 604, Ind. 620 and AES 808.

Grain yield was not affected significantly by the three plant populations investigated. Hybrids grown in 75-cm. rows resulted in higher yields than when planted in 100-cm. rows. S.D. 604 and AES 808 were the two high yielding hybrids when compared to Ind. 620, the third hybrid tested.

Forage yields were lower when the hybrids were planted at 6,000 plants per dunum as compared to populations of 5,000 and 4,000 plants per dunum. Corn hybrids planted in 75-cm. rows resulted in significantly higher forage yield than those planted in 100-cm. rows. The hybrids did not differ significantly between themselves in forage yield.

Both the plant height and the ear-height were not affected by the plant populations or the row spacings used in this experiment. The three hybrids used were significantly different in their plant and ear-height. AES 808 had the highest plant height and the ear-height while Ind. 620 and S.D. 604 did not differ between themselves.

During both of the years, 1961 and 1962, tillering percentage was found to be maximum at 4,000 plants per dunum. Row spacings employed, did not affect the tillering percentage. Hybrid AES 808 produced the highest percentage of tillers while Ind. 620 and S.D. 604 did not differ significantly between themselves in tillering percentage.

Barrenness percentage was significantly influenced by plant populations. A population of 6,000 plants per dunum resulted in the lowest percentage of barrenness while, 4,000 plants per dunum showed the highest percentage of barrenness. Row spacings did not affect barrenness but hybrids were significantly different in the percentage of barrenness. AES 808 had the highest percentage of barrenness while S.D. 604 and Ind. 620 were similar in this character.

Plant populations and row spacings did not affect the number of days from planting to flowering. However, hybrids were found to be different with S.D. 604 and Ind. 620 being earlier than AES 808.

Uniformity of ears was not affected by plant populations, row spacings and the hybrids used. Lodging was not found to be induced by plant populations, row spacings and the hybrids used.

No significant effect was observed on the protein percentage in the grains due to different plant populations, row spacings and hybrids. However, a significant interaction was found between hybrid x population x spacing. It appears therefore, that AES 808 had a higher protein percentage in its grains at the lower rates of planting, while S.D. 604 and Ind. 620 had lower percentage of protein in grains at the higher planting rates.

It appears from this study that under the conditions prevailing during 1961 in the Bekaa, 4,000 plants per dunum planted in 75-cm. rows produced higher grain and forage yields than the 5,000 and 6,000 plants per dunum plantings in 100-cm. rows. This is because the additional tillers were found to more than compensate for the lower plant populations. However, further studies conducted for several years are needed to come to any definite conclusion.

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APPENDIX

Table 9. Analysis of variance for grain yield of corn hybrids during 1961.

Sources	D.F.	M.S.
Population	2	78985.6
Replication	3	940645.7
Error (a)	6	100704.4
Spacing	1	1603542.0 ⌿⌿
Spacing x population	2	936.8
Error (b)	9	11968.5
Hybrid	2	163259.1 ⌿
Hybrid x spacing	2	35150.8
Hybrid x population	4	8688.1
Hybrid x population x spacing	4	18742.1
Error (c)	36	34546.5

⌿ significant at 5 percent level.

⌿⌿ significant at 1 percent level.

Table 10. Analysis of variance for forage yields of corn hybrids during 1961.

Sources	D.F.	M.S.
Population	2	2738593 ≠≠
Replication	3	962137
Error (a)	6	237137
Spacing	1	1909709 ≠≠
Spacing x population	2	154443
Error (b)	9	41844
Hybrid	2	177673
Hybrid x spacing	2	16629
Hybrid x population	4	84127
Hybrid x population x spacing	4	322923 ≠≠
Error (c)	36	62918

≠≠ significant at 1 percent level.

Table 11. Analysis of variance for tillering percentage of corn hybrids during 1961 and 1962.

Sources	D.F.	M.S. 1961	M.S. 1962
Population	2	13508.1 ++	18877.4 ++
Replication	3	374.9	289.6
Error (a)	6	415.3	295.1
Spacing	1	475.4	2016.2
Spacing x population	2	42.2	527.1
Error (b)	9	367.2	533.8
Hybrid	2	5442.8 ++	5588.9 ++
Hybrid x spacing	2	579.5	300.1
Hybrid x population	4	747.9 +	1367.1 ++
Hybrid x population x spacing	4	164.9	285.9
Error (c)	36	207.8	146.1

+ significant at 5 percent level.

++ significant at 1 percent level.

Table 12. Analysis of variance for plant height of corn hybrids during 1961.

Sources	D.F.	M.S.
Population	2	147.5
Replication	3	2549.4
Error (a)	6	316.7
Spacing	1	401.4
Spacing x population	2	38.1
Error (b)	9	231.7
Hybrid	2	2900.7 ≠≠
Hybrid x spacing	2	218.8
Hybrid x population	4	165.4
Hybrid x population x spacing	4	73.8
Error (c)	36	164.9

≠≠ significant at 1 percent level.

Table 13. Analysis of variance for ear-height of corn hybrids during 1961.

Sources	D.F.	M.S.
Population	2	20.5
Replication	3	688.7
Error (a)	6	33.9
Spacing	1	117.5
Spacing x population	2	10.3
Error (b)	9	45.8
Hybrid	2	297.5 ≠≠
Hybrid x spacing	2	52.2
Hybrid x population	4	38.7
Hybrid x population x spacing	4	40.9
Error (c)	36	37.7

≠≠ significant at 1 percent level.

Table 14. Analysis of variance for percentage of barrenness of corn hybrids during 1961.

Sources	D.F.	M.S.
Population	2	1004.2 ≁≁
Replication	3	122.9
Error (a)	6	50.4
Spacing	1	414.7
Spacing x population	2	6.0
Error (b)	9	172.7
Hybrid	2	378.3 ≁≁
Hybrid x spacing	2	160.5
Hybrid x population	4	59.5
Hybrid x population x spacing	4	36.8
Error (c)	36	53.3

≁≁ significant at 1 percent level.

Table 15. Analysis of variance for the protein percentage in the grain of corn hybrids during 1961.

Sources	D.F.	M.S.
Population	2	4.13
Replication	3	0.47
Error (a)	6	1.20
Spacing	1	3.34
Spacing x population	2	0.07
Error (b)	9	1.29
Hybrid	2	1.49
Hybrid x spacing	2	0.08
Hybrid x population	4	0.98
Hybrid x population x spacing	4	2.47 ++
Error (c)	36	0.57

++ significant at 1 percent level.