EFFECT OF POPULATION AND SPACING ON GRAIN AND FORAGE PRODUCTION OF MAIZE HYBRIDS

By

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ABSTRACT

A one-year study was made during the year 1964 at the Agricultural Research and Education Center, in the Beqa'a Plain, Lebanon, to determine the effect of three planting rates and three within-row spacings on the performance of two maize hybrids. The factors studied were grain and forage yields, protein content and other agronomic characteristics. Planting rates were 4,000, 5,000 and 6,000 plants per dunum and for each population three within-row spacings were superimposed. The within-row spacings were effected for each population by planting one plant, two plants and three plants per hill. The hybrids tested were S.D. 604 and Ind. 620.

The plant populations employed in this study did not affect significantly the grain and forage yield, protein content, number of days from planting to silking, plant and ear height and uniformity of ears. Fewer days were required from planting to tasseling and maximum base diameters were measured at 4,000 plant population.

Maize planted at the rate of one plant per hill gave higher forage yield, most uniform ears, and took less number of days from planting to silking and tasseling. The grain yield, protein content, plant and ear height, and base diameter were not affected significantly by the different

plant spacings employed.

Hybrid S.D. 604 took more days from planting to silking and fewer days from planting to tasseling and the ears were closer to the ground. The hybrids had no significant effect on the yield of grain and forage, protein content, plant height, base diameter and uniformity of ears.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Maize (Zea mays L.) is one of the few standard crops that originated in America. Early writers disagree as to the place of origin of maize, some maintaining that it came from eastern Asia, while others believe it is of American origin (39).

The striking increases in yield obtained in the U.S.A. through the use of hybrid varieties of maize, have aroused world-wide interest in this crop. Directly as food and feed or indirectly as industrial products, maize produces more food value per acre than does any other crop. Maize is the main cereal crop of the corn belt and, consumed directly or in the form of meat, dairy and poultry products, has been described as the principal source of food of the American people (38).

Yields of corn are closely related to plant population, since the corn plant is less capable of adjustment to poor stands than are other members of the grass family. Therefore, it is important that this aspect of the production of this crop receives great attention. Many comparisons between different corn planting patterns have been made. However, the superiority of any one planting pattern has not been clearly established because of the variations in locality, soil and performance of the different hybrids.

Maize is planted in many regions of widely different climatic conditions. Maize can be grown successfully in Lebanon, but only a limited amount of work has been done here on the culture of this crop. Therefore, the purpose of this study is to evaluate the effect of different plant populations and spacings on the yield of grain and forage, and on other agronomic characters of two maize hybrids when grown under irrigated conditions in the Beqa'a Plain in 1964.

REVIEW OF LITERATURE

Optimum plant population and spacing vary with location, time of planting, variety, soil moisture, fertility of soil and many other factors. It is seldom that two workers have recommended the same spacing or population for different areas.

Some of the literature dealing with some of the factors that are affected by population and plant spacing in maize is reviewed in this section.

Grain Yield

Brandon (3) reported that the highest yield of maize per acre, grown under low rainfall conditions for a 12 year period, was obtained from plants spaced 24 inches apart in rows 44 inches apart. Bowers (2) observed that corn thinned to two plants in hills, 24 inches apart produced significantly higher yields than did hills spaced 18 or 36 inches apart. Bunting and Willey (4) concluded that lower yields were always associated with lower plant densities, and that yield increased with an increase in plant density.

Caldwell (5) reported that recommendations in Minnesota vary from about 12,000 plants per acre on sandy droughty soils to 20,000 plants per acre on heavy soils of good water holding capacity. Colville and McGill (7) obtained optimum yields from 16,000 to 24,000 plants per acre and noted little difference between yields from populations within this range. In recommending for North Carolina, Fitts (12) reported that the plant populations for given yields per acre are as follows: for a yield of 50 to 75 bushels per acre, 8,000 to 9,000 plants are required; for 75 to 100 bushels, 12,000 to 14,000 plants; for 100 to 150 bushels, 14,000 to 16,000 plants; and for over 150 bushels, 16,000 to 20,000 plants are required.

Fayemi (11) observed a progressive increase in grain yield with increasing populations upto 14,520 plants per acre. Beyond this level, yield gradually decreased as population increased. A spacing of 9 inches between single plants within the row yielded more grain than did the same population spaced 36 inches between hills and planted four plants per hill. Dungan (9) reported that on productive soil, maize grown in single-plant hills was significantly superior when compared to the same population in multiple-plant hills. The greatest advantage of single-plant hills was obtained at relatively high plant population rates.

In a study carried out at Nachingwea (Africa) in 1956, Hemingway (14) obtained maximum yields with populations of 15,000 to 30,000 plants per acre. This wide range in population suggests the adaptability over a wide range of growth conditions of the variety used. Kohnke and Miles (22) observed that the highest maize yields were associated with planting rates between 15,000 and 19,000 plants per acre. Lang (23) reported that Dungan of the University of Illinois estimated 16,000 plants were required per acre for each 100 bushels of grain. Pendleton and Seif (26) conducted an experiment with dwarf maize at populations from 12,000 to 32,000 plants per acre. It was found that as an average for all row spacings and trials, a plant population of 16,000 to 20,000 plants per acre produced the highest yield. Stringfield (32) in Ohio recommended between 12,000 and 16,000 plants per acre depending upon variety, soil fertility and available soil moisture.

Termunde et al. (34) made recommendations for South Dakota as follows: The best stand for central and northeastern South Dakota is 8,000 to 10,000 plants per acre, for eastern South Dakota 10,000 to 12,000 plants per acre, and under irrigation in southeastern South Dakota 20,000 to 24,000 plants per acre.

Viets (37) reported that for grain, stands of about 18,000 to 20,000 plants per acre are needed on irrigated land while 4,500 to 7,500 plants per acre are best for dry land. Experiments involving various plant populations and nitrogen levels were conducted by Hinkle and Garrett (15) at the Main Experiment Station of the University of Arkansas during the years 1949 to 1957. It was concluded that the optimum number of maize plants, when soil fertility is adequate, appears to lie between 12,000 and 16,000 plants per acre.

Ugărčinski (36) experimenting with various spacings, and plant populations ranging from 24,700 to 40,800 plants per hectare, found that 35,000 per hectare gave maximum yield. Good yields were obtained from maize in hills at spacings of 75 x 75 and 80 x 80 cm. with two plants per hill. Jordan (20) reported that under non-irrigated conditions and high fertility levels, a stand of about one plant every 15 to 16 inches in 40-inch rows (equivalent to approximately 10,000 plants per acre) has been satisfactory. Spacing trials with maize were carried out by Nezamuddin and Prashad (25) throughout Bihar (India). Rows two feet apart proved best in North Bihar and 1.5 feet apart in South Bihar. In all trials the best spacing between plants was found to be 12 inches.

Forage Yield

Termunde *et al*. (34) reported that under irrigated conditions in South Dakota the best population for forage yields lies between 24,000 and 32,000 plants per acre.

Brandon (3) reported that the greatest total yield was obtained from corn spaced 12 inches apart, in 44-inch rows. According to Watson and Davis (40), a spacing of 24 x 12 inches gave the best yield of grain and stover. Hoff and Mederski (16) observed that the number of plants being the same, an equidistant planting pattern did tend to produce more fodder.

Working with maize populations of 15,680 and 10,450 plants per acre in 40-inch and 20-inch rows, Stickler and Laude (31) noted that the grain and stover yields were not influenced by the plant populations or by the row spacings employed.

Silking

Kohnke and Miles (22) reported that silking was delayed by one day for every additional 3,500 to 4,000 kernels planted per acre. Baily (1), working with sweet corn, reported that wider spacings between plants hastened the silking date.

Inselberge (19) noted that with an increase in sowing rate the silking date of each ear shoot was delayed and the mean number of ears per plant was decreased.

Tasseling

Pendleton and Seif (26) showed that an increase in population resulted in an increase in height of tassel, that is, from ground level to the top of the tassel.

Dungan *et al.* (10) noted that silking is delayed more than is tasseling by an increase in plant population. The increase in time between silking and tasseling caused by thick planting was not great. It amounted to only a little over one day when the population was changed from 8,000 to 20,000 plants per acre. The interval was found to be much greater at populations above 20,000 than it was at or below this figure.

Protein in Grain

Colville (6) reported that crude protein percentage in grain was decreased linearly by increasing the plant population per acre. Pendleton and Seif (26) showed that an increase in population resulted in a decrease in the percentage of protein in the grain.

Working with populations ranging from 8,000 to 17,000 plants per acre, Zuber et al. (43) observed that crude protein percentage decreased with an increase in population. However, it was maintained that thicker planting increased the total protein harvest when protein in both grain and stover was taken into consideration.

Lang et al. (24) reported that in Illinois the protein and oil content of grain decreased with an increase in population. This was true with populations above 12,000 plants per acre.

Prince (28) from experiments with different plant populations, spacings, varieties, and levels of soil fertility concluded that nitrogen fertilization, in relation to plant population as well as variety, has an important effect on the protein composition of maize grain. It was found that with an increase of nitrogen in the soil, the protein percentage of the grain increased, but decreased with an increase in plant population.

Plant Height

An experiment was conducted by Bunting and Willey (4) to determine the effect of changes in plant density on plant height. It was concluded that differences in the plants as affected by density were generally small. However, in 1955, a highly significant reduction in plant height occurred with increasing density.

Dungan *et al*. (10) reported that in Illinois and Iowa plant population had little effect on plant height.

Harry and Moss (13) stated that under high plant populations the plants were slightly taller which was attributed to the competition for light.

Base Diameter

Dungan (9) grew corn in single-plant hills versus the same population in multiple-plant hills. It was found that the diameter at the base of stalks was greater for the single-plant method of planting.

Watson and Davis (40) reported that the diameter of the lowest internode of the corn stalk increased with an increase in the area available per plant. This increase in stem diameter was noted up to, but not beyond, an area of 3.95 square feet per plant.

Dungan *et al*. (10) reported that, at maturity, the basal area of stalks, grown in five-plant hills was less than half that of stalks from one-plant hills.

Uniformity

Termunde *et al.* (34) reported that uniformity of ears decreased progressively as plant population was increased. It was also found (35) that in all areas of South Dakota ear uniformity was best where the recommended planting rate was used.

Ear Height

From the reports of Dungan *et al.* (10) it was disclosed that Stringfield and Thatcher in Ohio found that the ear-node was somewhat higher on thickly planted corn. Zuber and Grogan (42) also noted that with an increase in plant stand, ear-height increased slightly.

Barrenness

While working with sweet corn, Baily (1) observed that close spacing caused many barren plants. Lang *et al.* (24) found that stalk barrenness was affected more by population than by the hybrid or the fertility level.

Pendleton and Seif (26) reported that where populations ranged from 12,000 to 32,000 plants per acre at row spacings of 20, 30 and 40 inches, row spacings had no effect on percent of barren plants. However, as plant population was increased, the number of barren stalks also increased.

Dungan *et al*. (10) suggested that extremely thick stands would bring about complete barrenness.

MATERIALS AND METHODS

The experiment was carried out under irrigation during the year 1964 at the Agricultural Research and Education Center situated in the Beqa'a Plain. The trial was conducted on a clay type soil, high in potassium content, low in organic matter, nitrogen and phosphorous, calcareous in nature, and has a pH of about 8.0 (29, 33). Two American varieties of hybrid maize, S.D. 604 and Ind. 620 were used in this trial. The varieties used in the experiment are considered to be high yielding (41) and adapted to the locality.*

Fertilizer was applied at the rate of 12 kg of nitrogen per dunum in the form of ammonium nitrate and 20 kg of P_2O_5 per dunum in the form of superphosphate. These fertilizers were broadcast and disced into the soil before planting was done. An additional application of nitrogen at the rate of four kg per dunum was applied in June as a side dressing.

The experimental plot was irrigated weekly throughout the growing season. Sprinklers were used during the early growth period and furrow irrigation during the later stages of the crop.

During the early stage of growth the plants were

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* Information obtained through personal communication with Dr. W.W. Worzella.

attacked by cutworms, so all the plots were sprayed with endrin to control insects. Later, in the season Metasystox was sprayed on the plants to control leafhoppers. No disease symptoms were observed throughout the study with the exception of one or two plants which were attacked by common smut (*Ustilago maydis* Cda.).

Weeding was done by hand with nursery equipment. In the early stages of growth weeds were controlled by hand at regular intervals but at the later stages of growth the maize crop itself smothered most of the weeds.

The experiment was laid out in a split-split-plot design with four replicates. Populations were the main effects. The arrangement of the plants within the row in each population was the sub-plot. The varieties were the sub-sub-plots. All the rows were 75 cm. apart. Each entry consisted of two rows, each five meters long. One of these rows was harvested for forage and the other for grain yield. Border plants were maintained around each sub-plot.

The details of populations, spacing, and number of plants per hill are furnished below:

Population	Number of seeds per hill	Within-row spacing (cm.)
4000 seeds/dunum	1	33
	2	66
	3	99
5000 seeds/dunum	1	26
	2	52
	3	78
6000 seeds/dunum	1	21
	2	42
	3	63

The hills were planted thickly and then thinned to the required number of plants per hill after the plants had emerged and become well established. Tillers were removed at this time.

Plant height, silking and tasseling date, base diameter, uniformity of ears, ear height, barrenness, yield of grain and air-dry yield of forage were determined. The forage row of each plot was harvested when the kernels were at the milk stage. From the two plants per hill, and three plants per hill plots, one hill from each end of the rows was not harvested. From the rows which had one plant per hill, two hills at each end of the row were left as border plants. Hence different distances for different rows were harvested and calculations for yield per dunum were made accordingly.

Plant height was measured in centimeters from the base of the plant at the ground level to the top of the tassel. Ear height was measured in centimeters from the base of the plants to the point of attachment of the ear with the stock, that is, the level of the ear-node. Dates of tasseling and silking were recorded when more than 75 percent of the plants had reached these stages. For determining moisture percentage of the grain, only the central portion of the ear of a representative sample from each treatment, taken immediately after harvest, was used. From the oven-dry weight of these samples, the yield of grain was adjusted to a basis of 15.5% moisture (21).

For protein determination of the grain, a representative sample from all entries was taken, dried in an oven for 48 hours at a temperature of 100°C to 103°C (8), cooled in a dessicator, and then ground in a Willey-mill using a 20-mesh sieve. Before weighing, the samples were put in the oven at 70°C for 6 hours to remove the air moisture (17), cooled in a dessicator and weighed on an electrical balance. Analyses for protein content were then made according to the modified Kjeldahl method (18).

Statistical methods, appropriate to the split-split-plot design were used to analyze the data (27, 30).

RESULTS AND DISCUSSION

An experiment was conducted during the year 1964 at the Agricultural Research and Education Center, in the Beqa'a Plain, Lebanon, to evaluate the effect of three plant populations and three within-row spacings on the grain and forage yield, number of days from planting to silking and tasseling, protein content in the grain, plant height, base diameter, uniformity of ears, ear-height, and barrenness of two maize hybrids. The data and results of various characters studied are summarised and reported in tables 1-9. The analysis of variance tables are given in the Appendix (tables 10-18).

Grain Yield

In Table 1 it may be observed that a population of 5,000 plants per dunum gave a higher grain yield than did the other two populations studied. This trend towards greater yield from 5,000 plants per dunum, which was not significant statistically, may however be real, and possibly is a result of a more nearly optimum population regarding inter plant competition for soil moisture, nutrients, etc. In addition, a possible reason for the lack of significance may be attributed to the environmental variation within the plot area, or the inability of the experimental design to

Table 1 - Effect of plant population and spacing on the grain yield of maize hybrids in kg per dunum during 1964 (15.5% moisture level).*

Hybrids	No. of plants per hill	Yield of grain in kg per dunum: 4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	532.50	535.50	518.25
	2 (S_2)	439.25	495.75	555.00
	3 (S_3)	493.75	594.25	549.25
Ind. 620 (V_2)	1 (S_1)	567.00	549.25	492.00
	2 (S_2)	516.50	558.00	526.25
	3 (S_3)	482.00	495.50	451.00
Means:	Population:	505.16	538.04	515.29
	Spacing:	S_1	S_2	S_3
		532.41	515.12	510.95
	Varieties:	V_1	V_2	
		523.60	515.20	

* The grain was dried so that yield was determined on a moisture free basis. These yield data were then adjusted to a standard of 15.5% moisture.

detect the small differences in yield. The results are in partial agreement with the data of Dowlah (8) obtained at the Agricultural Research and Education Center during 1962. It was found that a population of 5,000 plants gave a greater yield than did 6,000.

Grain yields did not differ significantly because of the effect of within-row spacing, but there was a trend toward a decrease in yield with more plants per hill. These results are in agreement with the work of Fayemi (11) and Dungan (9).

The two hybrids S.D. 604 and Ind. 620 did not differ in grain yielding ability.

Forage Yield

The greatest yield was obtained from a population of 6,000 plants per dunum (Table 2), but these results were not significant statistically. However, this trend agrees with the recommendation of Termunde *et al*. (35).

Forage yields were found to differ significantly between the three within-row spacings studied. A planting arrangement where there was only one plant per hill resulted in a yield of forage that was significantly higher (1% level of significance) than that from two plants per hill. Though there was no significant difference between one and three plants per hill, the trend was toward greater yield from the one plant per hill plots.

The varieties did not differ significantly in their

Table 2 - Effect of plant population and spacing on the forage yield of maize hybrids in kg per dunum during 1964 (air dry weight).

Hybrids	No. of plants per hill	Yield of forage in kg per dunum: 4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	1475.50	1425.75	1457.50
	2 (S_2)	1119.75	1258.50	1323.25
	3 (S_3)	1168.75	1343.75	1483.00
Ind. 620 (V_2)	1 (S_1)	1356.50	1589.00	1587.25
	2 (S_2)	1243.25	1348.00	1308.75
	3 (S_3)	1474.25	1421.00	1377.75
Mean:	Population:	1306.33	1397.66	1422.91
	Variety:	V_1	V_2	
		1339.53	1411.75	

Spacing:	LSD (5%)	LSD (1%)
	124.53	171.97

Mean: Spacing:

S_1	S_3	S_2
1481.91	1378.08	1266.91 *

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

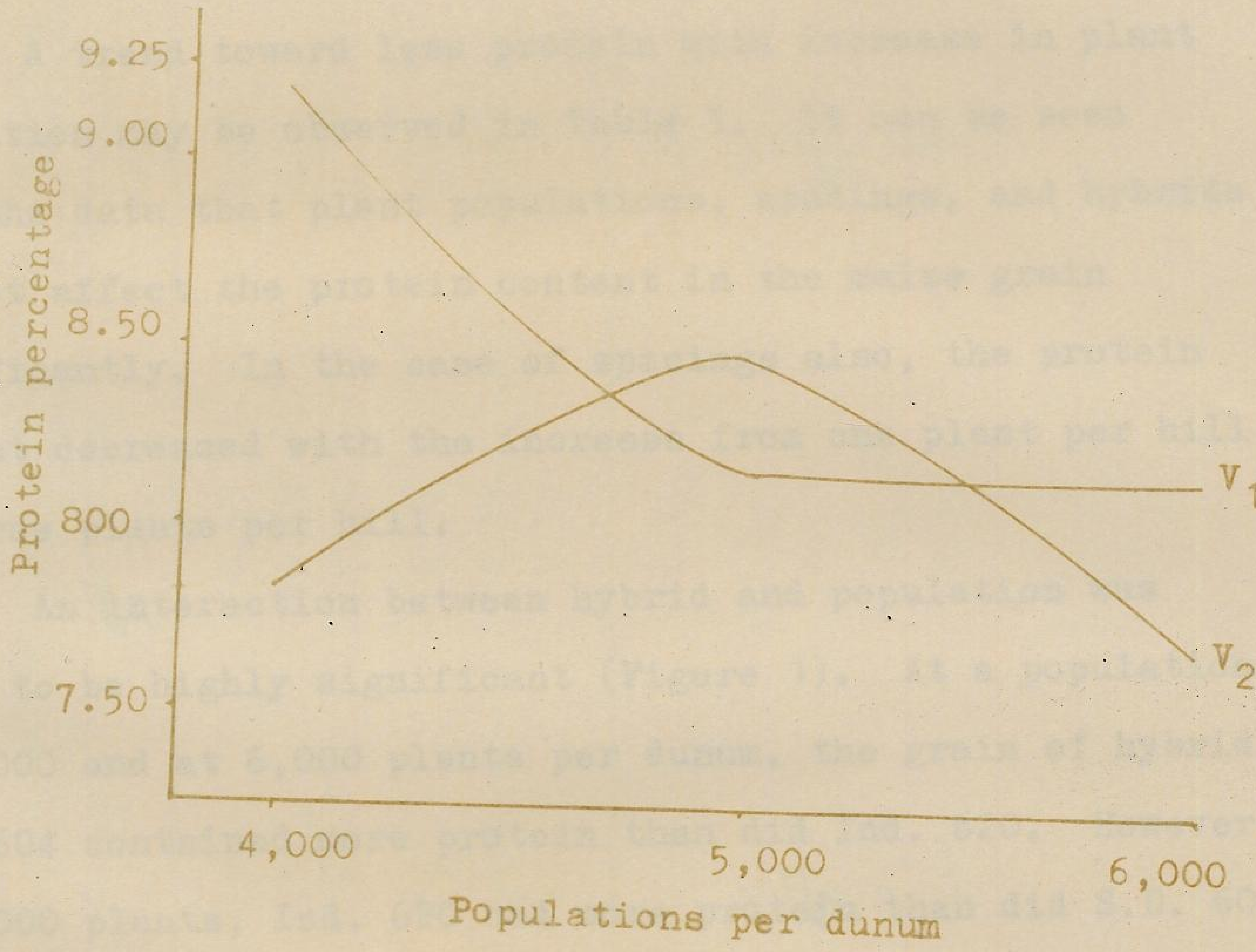

Figure 1 - Curve showing interaction between population and variety for protein content.

V_1 = S.D. 604

V_2 = Ind. 620

forage yield.

Protein Content

A trend toward less protein with increase in plant population may be observed in Table 3. It can be seen from the data that plant populations, spacings, and hybrids did not affect the protein content in the maize grain significantly. In the case of spacings also, the protein content decreased with the increase from one plant per hill to three plants per hill.

An interaction between hybrid and population was found to be highly significant (Figure 1). At a population of 4,000 and at 6,000 plants per dunum, the grain of hybrid S.D. 604 contained more protein than did Ind. 620. However, at 5,000 plants, Ind. 620 had more protein than did S.D. 604. No clear explanation can be offered in this connection. It may have been because of the difference in genetic make up of the individual hybrids.

Number of Days from Planting to Silking

A study of the data in Table 4 reveals that with an increase in population the silking date was delayed, although this delay was not significant statistically. A similar trend was observed by Kohnke and Miles (22) and by Inselberge (19).

The one plant per hill arrangement took significantly

Table 3 - Effect of plant population and spacing on the protein content in maize hybrids during 1964.

Hybrids	No. of plants per hill	Percentage protein in the grain: 4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	9.85	8.47	8.62
	2 (S_2)	9.09	8.15	7.75
	3 (S_3)	8.53	7.83	8.07
Ind. 620 (V_2)	1 (S_1)	7.91	8.72	7.24
	2 (S_2)	7.48	8.31	8.47
	3 (S_3)	8.10	9.22	7.43
Means:	Population:	8.49	8.45	7.93
	Spacing:	S_1 8.47	S_2 8.21	S_3 8.20
	Variety:	V_1 8.49	V_2 8.10	

Table 4 - Effect of plant population and spacing on the number of days from planting to silking of maize hybrids during 1964.

Hybrids	No. of plants per hill	No. of days from planting to silking: 4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	115.50	116.25	118.00
	2 (S_2)	117.75	118.00	119.75
	3 (S_3)	116.50	118.50	119.50
Ind. 620 (V_2)	1 (S_1)	114.75	115.50	116.50
	2 (S_2)	117.00	116.75	118.75
	3 (S_3)	115.75	119.25	118.41
Mean :	Population:	116.20	117.37	118.41

	LSD (5%)	LSD (1%)
Spacing:	.903	1.24
Variety	.33	.45

Means:	Spacing	S_1	S_2	S_3
		116.08	118.00	117.91 *
	Variety:	V_1	V_2	
		117.75	116.91	

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

fewer days from planting to silking as compared to two and three plants per hill. No significant difference was observed between two and three plants per hill.

A highly significant difference was also observed between the two hybrids regarding the number of days from planting to silking. Variety Ind. 620 took fewer days than did S.D. 604.

Number of Days from Planting to Tasseling

The number of days from planting to tasseling was greatly affected by populations, spacings and varieties as is seen in Table 5. It took a greater number of days for the plants to reach the tasseling stage at the highest population (6,000). There was no significant difference between the populations of 4,000 and 5,000, though there was some delaying tendency at the 4,000 plant population.

The effect of spacing on number of days from planting to the tasseling stage was highly significant. From Table 5 it can be seen that the tasseling time increased with an increase in number of plants per hill. One plant per hill took the fewest number of days and three plants per hill took the greatest number of days for tasseling.

The difference in tasseling time as a result of the maize hybrids was highly significant. Hybrid S.D. 604 took fewer days for tasseling than did Ind. 620. This result agrees with the work of Hoque (17). Hoque found that

Table 5 - Effect of plant population and spacing on the number of days from planting to tasseling of maize hybrids during 1964.

Hybrids	No. of plants per hill	No. of days from planting to tasseling: 4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	108.50	108.25	109.25
	2 (S_2)	110.25	109.25	111.00
	3 (S_3)	109.75	111.00	111.50
Ind. 620 (V_2)	1 (S_1)	108.75	108.75	110.25
	2 (S_2)	110.00	110.00	112.00
	3 (S_3)	110.50	112.00	112.00

	LSD (5%)	LSD (1%)
Population	.98	1.50
Spacing	.70	.98
Variety	.205	.277

Means:			
Population	P_1	P_2	P_3
	* 109.62	109.87	111.00
Spacing:	S_1	S_2	S_3
	108.95	110.41	111.12
Variety:	V_1	V_2	
	109.86	110.47	

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

S.D. 604 took less time than did Ind. 620 to reach the tasseling stage.

Plant Height

The plant height was not affected significantly by the various populations, spacings and varieties, as is noted in Table 6.

Though there was no significant difference in plant height as a result of different plant populations, slightly taller plants were observed where the population was 4,000 as compared to 6,000 plants per dunum. This observation is in agreement with the findings of other investigators (4, 10).

Stem Diameter

It can be seen from Table 7 that plant populations significantly affected the base diameter of the maize hybrids. From the table it is noted that with an increase in population there was a decrease in base diameter.

No significant difference in stem diameter was observed as a result of different spacings. However, there was a decrease in base diameter with an increase in number of plants per hill. One plant per hill had the greatest base diameter as compared to two and three plants per hill. This is in agreement with the work of Dungan (9) and Dungan et al. (10). The base diameters of the two hybrids did not differ significantly.

Table 6 - Effect of plant population and spacing on the plant height of maize hybrids in centimeters during 1964.

Hybrids	No. of plants per hill	Plant height in centimeters		
		4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	249.50	248.00	245.00
	2 (S_2)	247.25	244.75	241.75
	3 (S_3)	252.50	244.75	259.25
Ind. 620 (V_2)	1 (S_1)	243.50	247.50	242.50
	2 (S_2)	248.75	246.75	222.00
	3 (S_3)	259.50	246.25	251.75
Mean:	Population	P_1	P_2	P_3
		250.54	246.33	243.70
	Spacing	S_1	S_2	S_3
		245.96	241.88	252.75
	Variety	V_1	V_2	
		248.08	245.39	

Table 7 - Effect of plant population and spacing on the base diameter of maize hybrids in centimeters during 1964.

Hybrids	No. of plants per hill	Base diameter in centimeters: 4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	2.78	2.63	2.40
	2 (S_2)	2.76	2.59	2.48
	3 (S_3)	2.56	2.49	2.44
Ind. 620 (V_2)	1 (S_1)	2.86	2.63	2.39
	2 (S_2)	2.74	2.57	2.29
	3 (S_3)	2.55	2.54	2.44
Mean:	Spacing:	S_1	S_2	S_3
		2.62	2.57	2.50
	Variety:	V_1	V_2	
		2.57	2.56	
Population:	LSD (5%) .216	LSD (1%) .33		
Mean:	Population	P_1	P_2	P_3
		2.71	2.57	2.41 *

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

Ear Height

From the data in Table 8, it is revealed that with an increase in population the height of the ear-node increased slightly. This increase was, however, not significant. The population of 4,000 plants per dunum had the minimum ear-height while that of 6,000 was the maximum. The population of 5,000 was intermediate in ear-height. This observation agrees with the reports of Dungan *et al*. (10) and of Zuber (42).

The hybrids differed significantly from one another in ear-height. The hybrid Ind. 620 had higher ear-nodes than did S.D. 604. This agrees with the work of Hoque (17).

The ear-height was not affected significantly by the number of plants per hill. However, it can be seen in the data that with an increase in number of plants per hill, the ear-height also increased.

Uniformity

It appears from Table 9 that uniformity of ears decreased progressively as populations were increased. However, this difference in uniformity of ears was not significant. At a population of 4,000 plants the ears were most uniform. This result agrees with the report of Termunde *et al*. (34).

The different number of plants per hill had a

Table 8 - Effect of plant population and spacing on the ear height of maize hybrids in centimeters during 1964.

Hybrids	No. of plants per hill	Ear height in centimeters		
		4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	105.25	105.25	105.00
	2 (S_2)	107.00	107.75	106.00
	3 (S_3)	102.00	105.25	115.75
Ind. 620 (V_2)	1 (S_1)	106.50	113.50	107.50
	2 (S_2)	110.50	110.75	106.50
	3 (S_3)	116.75	110.50	122.50
Means:	Population:	108.00	108.83	110.54
	Spacing:	S_1	S_2	S_3
		107.16	108.08	112.12

	LSD (5%)	LSD (1%)
Hybrids	3.7	5.1

Mean:	Hybrids	V_1	V_2
		106.60	111.66

Table 9 - Effect of plant population and spacing on the uniformity of maize hybrids during 1964.

Hybrids	No. of plants per hill	Uniformity of ears		
		4,000 plants per dunum (P_1)	5,000 plants per dunum (P_2)	6,000 plants per dunum (P_3)
S.D. 604 (V_1)	1 (S_1)	4.25	3.25	2.75
	2 (S_2)	3.00	3.25	2.75
	3 (S_3)	3.00	3.00	2.75
Ind. 620 (V_2)	1 (S_1)	4.25	3.25	3.00
	2 (S_2)	3.75	3.50	2.75
	3 (S_3)	4.00	2.50	2.75
Mean:	Population:	3.70	3.12	2.70
	Variety:	V_1	V_2	
		3.11	3.31	
Spacing:	LSD (5%) .40	LSD (1%) .55		
Mean:	Spacing:	S_1	S_2	S_3
		3.45	3.16	2.91*

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

significant effect on the uniformity of the ears. One plant per hill had more uniform ears and as the number of plants per hill was increased the uniformity was decreased.

No significant difference was observed between the maize hybrids so far as the uniformity of ears was concerned.

Barrenness

There was no difference in the number of barren plants due to plant populations, spacings or hybrids used in this study. Hence the data are not reported.

SUMMARY AND CONCLUSIONS

The experiment was conducted during the year 1964 at the Agricultural Research and Education Center, Lebanon. The purpose of this study was to evaluate the effect of three different plant populations and three spacings on the yield of grain and forage, protein content, number of days from planting to silking and tasseling, plant and ear height, base diameter, uniformity of ears, and barrenness of two maize hybrids when grown under irrigated conditions.

The experiment was laid out in a split-split-plot design. The rates of planting employed were 4,000, 5,000, and 6,000 plants per dunum. Three within-row spacings were effected for each population by planting one plant, two plants and three plants per hill. All the rows were 75 cm. apart. The hybrids tested were S.D. 604 and Ind. 620.

There was no difference in yield of grain or forage nor in protein content between the three populations tested. Certain trends were indicated: greater yields of grain and forage and lower protein content were observed from the higher population.

Spacings had a significant effect on forage yield, one plant per hill giving the greatest yield. There was no significant difference in grain yield and protein percentage but a trend was observed in that fewer plants per hill gave greater grain yield and protein content.

Plant height and ear height were not affected by the populations nor by the spacings used in this experiment. The hybrids differed significantly in ear height, the ears of S.D. 604 being lower than were those of Ind. 620.

Plant populations, spacings, and hybrids did affect the number of days from planting to tasseling. The lowest plant population, one plant per hill, and hybrid S.D. 604 took the least number of days to reach this stage of growth.

Plant population did not affect significantly the number of days from planting to silking. Spacings and hybrids did have a significant effect on silking date, where one plant per hill and hybrid Ind. 620 took fewer days from planting to silking.

Base diameter was affected significantly by plant population. A population of 4,000 plants per dunum had plants with thicker stems. However, spacings and hybrids did not differ significantly in this regard.

Uniformity of ears was not affected significantly by plant populations nor by hybrids. However, spacings were found to have a significant effect on uniformity, with one plant per hill producing more uniform ears.

On the basis of this study under the conditions prevailing during 1964 the following trends were observed:

i) At a population of 5,000 plants per dunum the grain yield was best.

ii) One plant per hill gave the greatest grain yield.

iii) The forage yield was greatest with a plant population of 6,000 plants per dunum.

iv) One plant per hill gave the greatest forage yield.

v) The protein content of the grain was the greatest at a population of 4,000 plants per dunum.

vi) Maximum protein was produced by the planting consisting of one plant per hill.

In general, a planting arrangement of one plant per hill appears to have made better use of space and nutrients, and thus grain and forage yield as well as protein content were enhanced. A population of 5,000 plants per dunum appears to offer optimum inter plant competition, contributing to high yields of high quality plant products.

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* Obtained through the courtesy of Dr. W.W. Worzella.

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A P P E N D I X

Table 10 - Analysis of variance for grain yield of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	6803.50
Replication	3	168370.66
Error (a)	6	20090.50
Spacing	2	3107.50
Population x spacing	4	6840.00
Error (b)	18	23069.72
Variety	1	1283.00
Variety x spacing	2	18133.50
Variety x population	2	10693.00
Variety x population x spacing	4	1406.00
Error (c)	27	10282.00

Table 11 - Analysis of variance for forage yield of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	90284.00
Replication	3	324790.00
Error (a)	6	82418.00
Spacing	2	277457.00**
Population x spacing	4	2078.00
Error (b)	18	42147.00
Variety	1	93889.00
Variety x spacing	2	1850.00
Variety x population	2	21422.00
Variety x population x spacing	4	62666.00
Error (c)	27	28161.00

** Significant at 1 percent level.

Table 12 - Analysis of variance for the protein content in the grain of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	2.36
Replication	3	1.89
Error (a)	6	2.40
Spacing	2	0.56
Population x spacing	4	0.45
Error (b)	18	0.36
Variety	1	2.69
Variety x spacing	2	2.02
Variety x population	2	5.56**
Variety x population x spacing	4	1.22
Error (c)	27	0.67

** Significant at 1 percent level.

Table 13 - Analysis of variance for number of days from planting to silking of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	27.27
Replication	3	37.22*
Error (a)	6	5.68
Spacing	2	28.66**
Population x spacing	4	4.08
Error (b)	18	2.22
Variety	1	12.50**
Variety x spacing	2	00.00
Variety x population	2	1.29
Variety x population x spacing	4	1.16
Error (c)	27	0.45

* Significant at 5 percent level.
** Significant at 1 percent level.

Table 14 - Analysis of variance for number of days from planting to tasseling of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	12.88*
Replication	3	9.96*
Error (a)	6	2.06
Spacing	2	29.29**
Population x spacing	4	2.29
Error (b)	18	1.46
Variety	1	6.72**
Variety x spacing	2	.60
Variety x population	2	.27
Variety x population x spacing	4	.26
Error (c)	27	.24

* Significant at 5 percent level.
** Significant at 1 percent level.

Table 15 - Analysis of variance for plant height of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	285.18
Replication	3	2611.61
Error (a)	6	580.57
Spacing	2	724.27
Population x spacing	4	339.74
Error (b)	18	217.42
Variety	1	162.00
Variety x spacing	2	36.29
Variety x population	2	217.04
Variety x population x spacing	4	93.15
Error (c)	27	115.99

Table 16 - Analysis of variance of base diameter of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	00.55*
Replication	3	00.07
Error (a)	6	00.09
Spacing	2	00.08
Population x spacing	4	00.06
Error (b)	18	00.03
Variety	1	00.00
Variety x spacing	2	00.02
Variety x population	2	00.01
Variety x population x spacing	4	00.01
Error (c)	27	00.02

* Significant at 5 percent level.

Table 17 - Analysis of variance for ear height of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	40.29
Replication	3	425.94
Error (a)	6	213.39
Spacing	2	167.04
Population x spacing	4	154.21
Error (b)	18	143.71
Variety	1	465.12*
Variety x spacing	2	70.30
Variety x population	2	16.15
Variety x population x spacing	4	34.78
Error (c)	27	61.87

* Significant at 5 percent level.

Table 18 - Analysis of variance for uniformity of ears of maize hybrids during 1964.

Sources	D.F.	M.S.
Population	2	6.05
Replication	3	6.42
Error (a)	6	1.46
Spacing	2	1.77*
Population x spacing	4	0.59
Error (b)	18	0.34
Variety	1	0.34
Variety x spacing	2	0.18
Variety x population	2	1.02*
Variety x population x spacing	4	0.41
Error (c)	27	0.30

* Significant at 5 percent level.