EFFECT OF SPACING ON YIELD AND OTHER CHARACTERISTICS IN GRAIN AND OIL CROPS UNDER DRYLAND CONDITIONS

By

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DRYLAND CROP PRODUCTION

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AN ABSTRACT OF THE THESIS OF

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Title: Effect of spacing on yield and other characteristics in grain and oil crops under dryland conditions.

Experiments were conducted for two years at the AUB Agricultural Research and Education Center in the Beqa'a Plain, Lebanon, to study the effect of different plant spacings on several characters in maize, sorghum, sunflower, safflower, soybeans, and chickpeas.

Higher grain yield and more dry matter were obtained from the plots with greater plant density. Plants spaced closer were shorter and produced seed lower in protein and oil content and smaller in size as compared to those from wider plant spacings. Safflower gave the highest protein yield, oil yield, and gross return per dunum of all the crops under study.

The 1967 crop produced taller plants with higher grain yields and a greater amount of total dry matter than those from the 1966 crop. The seed from the plants grown in 1966 was larger and contained more protein than that obtained from the 1967 crop. However, the total protein per dunum was greater in 1967 than in 1966. Yields of all the crops grown under dryland conditions were very low for economic production.

TABLE OF CONTENTS

	Page
LIST OF TABLES	vii
CHAPTER	
I. INTRODUCTION	1
II. REVIEW OF LITERATURE	3
Grain Yield	3
Dry Matter	8
Protein Percentage	9
Oil Content	11
Plant Height	12
Seed Weight	14
III. MATERIALS AND METHODS	16
IV. RESULTS AND DISCUSSION	20
Grain Yield	20
Dry Matter	24
Protein Percentage	31
Protein Yield	35
Oil Content	39
Oil Yield	40
Plant Height	43
One-hundred Seed Weight	49
Economic Evaluation	54
V. SUMMARY AND CONCLUSIONS	59
SELECTED BIBLIOGRAPHY	61
APPENDIX	67

LIST OF TABLES

Table Page

1. Yield, in kg per dunum, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 21

2. Yield, in kg per dunum, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 23

3. Yield, in kg per dunum, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 25

4. Yield, in kg per dunum, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 25

5. Stover yield, in kg per dunum, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 26

6. Total drymatter, in kg per dunum, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 28

7. Total dry matter, in kg per dunum, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 30

8. Total dry matter, in kg per dunum, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 30

9. Protein percentage of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.. 32

10. Protein percentage of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 34

11. Protein percentage of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.. 36

Table		Page

12. Protein percentage of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.. 36

13. Yield of crude protein, in kg per dunum, of the crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon 37

14. Yield of crude protein, in kg per dunum, of the crops grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon 38

15. Percentage of oil of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 41

16. Percentage of oil of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 42

17. Oil yield, in kg per dunum, of the oil crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon 44

18. Oil yield, in kg per dunum, of the oil crops grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon 45

19. Plant height, in cm, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 46

20. Plant height, in cm, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 48

21. Plant height, in cm, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 50

22. Plant height, in cm, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 50

23. One-hundred seed weight, in gm, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 52

24. One-hundred seed weight, in gm, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 53

Table | Page

12. Protein percentage of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.. 36

13. Yield of crude protein, in kg per dunum, of the crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon 37

14. Yield of crude protein, in kg per dunum, of the crops grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon 38

15. Percentage of oil of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 41

16. Percentage of oil of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 42

17. Oil yield, in kg per dunum, of the oil crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon 44

18. Oil yield, in kg per dunum, of the oil crops grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon 45

19. Plant height, in cm, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 46

20. Plant height, in cm, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 48

21. Plant height, in cm, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 50

22. Plant height, in cm, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 50

23. One-hundred seed weight, in gm, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 52

24. One-hundred seed weight, in gm, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 53

Table | Page

25. One-hundred seed weight, in gm, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 55

26. One-hundred seed weight, in gm, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon 55

27. Gross return, in Lebanese Pounds per dunum, of the crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon 57

28. Gross return, in Lebanese Pounds per dunum, of the crops grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon 58

29. Average monthly temperatures, relative humidity and percipitation during 1965-66 and 1966-67 at the AUB Agricultural Research and Education Center, Beqa'a Plain, Lebanon 67

I. INTRODUCTION

Although a large proportion of people in the Middle East are engaged in agriculture, the area must import large quantities of grains and meat to feed its population.

Lebanon has made tremendous progress recently in the development of certain branches of agriculture, poultry and horticulture being the pioneers in this respect. In the past ten years the total production of crops has increased by an average annual rate of nearly six per cent, although the area under cultivation increased by less than one per cent (16, p. 1). However, crop production, the main source of food and feed, is still in its infancy of development. The average gross agricultural production index for cereals, pulses[1], and oils and oil seeds, respectively, is 86, 82, and 109 for the years 1964-66, when the years 1954-56 have been taken as a base period (1, pp. 27, 28, 49).

The import data show that a total amount of food and feed, worth 425.5 million Lebanese Pounds, were imported during 1965. This is 3.3 times the average imports of 1951-55. About 36,885 metric tons of maize alone, worth 7,691 thousand Lebanese Pounds, were imported to meet the increasing demand of home consumption, particularly for poultry (16, p. 25). Similar trends of import have been observed for all other grain and oil crops.

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1. Pulses include vetches, lentils, dry broadbeans, lupines, drypeas, chickpeas, and drybeans.

On an average of the last three years[1], Lebanon raised maize, sunflower, sorghum, and chickpeas on 5510, 83, 1352, and 2131 hectares, respectively. Safflower and soybeans were grown only under trials on some of the experimental stations. Out of this average only ten per cent of the maize crop and 40 per cent of the sunflowers were irrigated. Thus, to increase the total crop production in this region, greater yields need to be produced on dryland.

The annual rainfall varies greatly and in many areas of the Middle East is sufficient to produce a crop worth harvesting. Therefore, this study was undertaken to obtain comparable yield and other data on several grain and oil crops when grown under dryland conditions.

The production of crops is highly sensitive to several factors under a particular set of conditions, proper plant density being one of them. The present two-year study was conducted at the AUB Agricultural Research and Education Center in the North Beqa'a, Lebanon, to determine the effect of different plant spacings on the yield, quality, and other agronomic characteristics in maize, sorghum, soybeans, safflower, sunflower, and chickpeas under dryland conditions.

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1. Data taken from the records of the Department of Economics, Ministry of Agriculture, Lebanon

II. REVIEW OF LITERATURE

The highest economic production of crops depends on a number of factors such as soil, climate, cultural practices, and many others. The optimum plant density, which is attained by using a specific plant spacing, is one of the most important cultural practices. There is no ideal spacing for a particular crop throughout the world since it changes under different conditions.

The object of this chapter is to review the available information pertaining to the effect of different plant densities and spacings on the yield, quality, and other agronomic characteristics of some grain and oil crops.

Grain Yield

Maize: The highest grain yields of maize were obtained by DeWet and Engelbrecht (19) in South Africa, with plants spaced 12 to 18 inches in rows six feet apart. Safti *et al*. (53) reported from Romania that the best spacings for the semi-late maize variety 306 were 100 x 66 and 100 x 50 cm (two plants per hill). Bowers (11) concluded that by keeping the rows three feet apart, greater yields resulted from a within-row spacing of 24 inches than from those at 18 or 36 inches. Data recorded by Brandon (12) under low rainfall conditions in the west central great plains of the United States, revealed that the highest yield of corn was obtained from 24-inch-spaced plants in 44-inch-rows.

Bunting and Willey (14) suggested that lower yields were always associated with lower plant densities, whereas, Sommerfeldt (60) observed that row spacing had little effect on the yield when abundant moisture was coupled with low plant population.

In the recommendations of optimum plant population in Mississippi, Jordan (34) reported that under non-irrigated conditions with high fertility level, a stand of about one plant every 15 to 16 inches in 40-inch-rows had been satisfactory. Studies by Stickler and Laude (64) revealed that plant populations of 15,700 and 10,450 plants per acre in 40-and 20-inch-rows had no significant effect on the corn grain yield. Stickler (61) reported that a plant population of 16,000 plants per acre in 20-inch-rows proved superior in yield to that in 40-inch-rows. This was mainly due to more two-eared plants and fewer barren plants in the 20-inch-row plantings. Data reported from India (4) showed that spacings of 75 x 30 cm and 90 x 50 cm (two plants per hill) with a population of 44,000 plants per hectare, resulted in the highest yields. Viets (67) reported that for grain production, a stand of about 18,000 to 20,000 plants per acre was needed on irrigated land and 4,500 to 7,500 plants per acre was the best on dryland. Fayemi (23) in Nigeria observed a reduction in the cob weight with an increase in population from 4840 to 24,200 plants per acre. However, maximum yield of grain was obtained from a population of 14,520 plants per acre. Allesi and Power (3) obtained greater yields at a population of 10,000 as compared to 5,000 plants per acre at different levels of nitrogen application, but the yields were reduced significantly with 15,000 plants per acre. Norden (45) reported that with an increase in density from 5,000 to 25,000 plants per acre, the grain yield per plant decreased by 73 per cent.

Sorghum: It was reported by Bond et al. (10) that more grains were produced at a lower moisture level (less than five inches) with sorghum plantings made in 40-inch-rows than in 20-inch-rows, while the reverse happened with an increase in the available moisture. Laude et al. (36) reported that the narrow rows favored grain production at Manhattan, Kansas with annual precipitation of 31 inches. Robinson et al. (52) observed a linear trend for increased yield as rows narrowed from 40-to 10-inches, and Hittle et al. (31) found that 20- and 30-inch-rows outyielded the 40-inch-rows. Similar results were reported by Hughes and Henson (33, p. 252) and Stickler and Wearden (65).

Grimes and Musick (26) concluded from their field experiments in Kansas that with adequate soil moisture the optimum space per plant is 50 to 60 square inches. The rows should not be more than 14 inches apart although they may be increased up to 28 inches under limited moisture conditions. Four years of data collected by Stickler et al. (63) indicated that the average yield advantage of 20-inch-row plantings over the 40-inch-rows was six per cent, which was mainly due to the higher population in the narrow rows. On the basis of area per plant, the highest yields were derived from 60 to 80 square inches per plant.

Mann (41) suggested from his three years of study with sorghum that it would be a waste of seed, especially for hybrids, to plant more than four pounds of seed per acre under dryland conditions. No significant difference in yield was observed between 21-inch-and 42-inch-rows, but 21-inch-rows showed advantages over 42-inch-rows in competition with weeds as well as for the prevention of wind erosion hazards. The same conclusions were made by Herbert and Warren (40), from their trials under similar conditions.

The optimum population for the production of grain was suggested to be between 40,000 and 60,000 plants per acre by Norman _et al_. (46). The grain yields were not affected significantly by plantings made in 20- and 40-inch-rows at the lowest plant population.

Sunflower: It was suggested by Grozev and Donceva (27) in Bulgaria that the thinning of the sunflower plants should be undertaken when the first pair or the second pair of leaves have emerged. Delay after this stage will lead to reduction in the yield, head size, and the number of seeds per head. Derco (18) in Czechoslovakia compared three plant spacings at 50 x 50, 60 x 60, and 70 x 70 cm, with one, two, and three plants per hill for three years. The highest yields of seed were obtained from the 60 x 60 cm plant spacing with two plants per hill. The same author (17) concluded from another study that a plant spacing of 60 x 30 cm equivalent to 55,555 plants per hectare, was the best for high yields of sunflower. Lukasev (40) in the USSR concluded that the spacing of 90 x 90 cm with three plants per hill gave yields comparable with the spacing of 70 x 70 cm with two plants per hill, but the former method facilitated mechanical cultivation and reduced labor requirements and costs.

Knizhnikov (35) suggested from a three year study that the seed rate of 118,000 to 120,000 seeds per hectare, achieved by a plant spacing of 70 x 70 cm, was the best for yield. Direct correlation between seed yield per plant and the nutritional area of the plant was obtained by Sarpe and Olteanu (54). The best density for yield was suggested to be 30,000 to 40,000 plants per hectare on moderately leached chernozems and 40,000 to 42,000 plants per hectare on the brown-red forest soils. At the given densities the best yields were obtained from 80-cm-rows with within-row plant spacings of 30 to 35 cm, which allowed complete mechanization of the sunflower production.

Safflower: Brauns (13) reported that good yields of safflower seed were obtained from 14- and 21-inch-row spacings, using 27 and 18 pounds of seed per acre, respectively, whereas 7- and 28-inch-rows resulted in poor yields. It was recommended by the Queensland Department of Agriculture (7) that safflower should be drilled at a seeding rate of 20 to 25 pounds per acre in 7- or 14-inch-rows to get the best yields. Safflower was grown at a spacing of 50 x 50 cm at Rabba and 40 x 40 cm at Irbid and Jenin, the rainfed areas of Jordan (8, p. 34). It was observed that the wider spacing resulted in higher yields.

Soybeans: Schuster and Spennemann (55) from West Germany reported that the seed yields increased as the spacings decreased from 40 x 40 cm to 40 x 10 cm. Wiggans (68) concluded that the optimum plant spacing varied from 3 inches in 8-inch-rows to 1 inch in 32-inch-rows. At the Harrow Research Station (9), the closest spacing resulted in the highest yields when soybeans were planted 1 to 4 inches apart in 24-inch-rows. Lehman and Lambert (38) observed a tendency for the plantings in 20-inch-rows to result in higher seed yields than those in 40-inch-rows. Harty and Bygott (29) revealed that the 14- to 28-inch-rows proved to be superior in producing high seed yields to the 42-inch-rows. Reiss and Sherwood (51) got the highest yield from soybeans planted in 24-inch-rows, followed in order by 16-, 8-, 32-, and 40-inch-rows. Higher seed yields were obtained by Ali (2) and Shaikh (57) from 50-cm-rows than from 25- and 75-cm-rows. Intra-row spacings of 2-, 3-, and-4 cm had no significant effect on the yield.

On the basis of number of plants per unit area, Wiggans (68) noted a gradual fall in gross yield from 18 to 6 plants, a rapid decline from 6 to 3 plants and a precipitous drop from 3 to 1 plant per square foot.

Chickpeas: Nirad (44) concluded from his trials of different plant spacings at 3, 6, 9, 12, 15, and 18 inches in both directions, that the grain yield per plant increased with wider spacings. The highest yields were obtained from a 12- x 6- inch-plant spacing on non-manured plots and from a 12- x 12-inch-spacing on manured plots.

Dry Matter

Maize: Gill and Hussain (24) observed that maize plants spaced 6 inches apart resulted in higher stover yield than those planted 9 inches and 12 inches in rows 2.5 feet apart. Stickler and Laude (64) concluded that the stover yield was not affected by the row spacings of 20- and 40-inches with plant population of 15,700 and 10,450 plants per acre, respectively.

Sorghum: Siddiq (58) reported that the stover yield of sorghum increased with the thickness of stand. Bond et al. (10) concluded that a four pound per acre seeding rate, and a 20-inch-row spacing produced more stover than did the two pound seeding rate or the 40-inch-row spacing. Norman et al. (46) observed no effect of row spacing on the residue production in a trial of two row spacings of 20-and 40-inches at a population of 40,000 plants per acre. It was found, however, in Texas (6), that a seeding rate of two pounds per acre yielded 12 per cent more total dry matter than the seeding rate of four pounds per acre. Row widths of 20-and 40-inches had little effect on dry matter production. Similar results were reported by Greb (25) who found that the stover yield was greater when sorghum was planted in 42-inch-rows as compared to 21-inch-rows, although the seeding rate per acre was the same.

Soybeans: Studies by Lipman and Blair (39) showed that as the seeding rate of soybeans was increased, the amount of dry matter also increased. The plantings with 14 to 30 plants per pot gave about double the amount of dry matter as those with 2 to 8 plants per pot.

Protein Percentage

Maize: Stickler (61) concluded that under nonirrigated conditions the protein percentage in the grain decreased with increased stand density with plantings made in 40-inch-rows, but tended to remain rather stable with increase in stand density in 20- and 30- inch-rows. Pendleton and Seif (47) observed a decrease in per cent protein with an increase in population from 12,000 to 32,000 plants per acre, but the narrowing of rows from 40-inches to 20-inches had no significant effect. Sirajuddowla (59) reported that in the Beqa'a Plain, Lebanon, populations of 4,000, 5,000, and

6,000 plants per dunum grown in rows 75-and 100-cm apart had no significant effect on the protein percentage in the grain of maize.

Zuber, et al. (71) concluded that the protein percentage in the grain was decreased linearly by increasing the plant population per acre. According to Dungan, et al. (21), similar results were obtained by Earley and De Turk, in Illinois. On the other hand, Haque (28) observed no significant effect of populations of 4,000, 5,000, and 6,000 plants per dunum spaced as 1, 2, and 3 plants per hill, on the protein percentage in the grain of maize.

Sorghum: The spacing trials conducted on sorghum by Nelson (42) revealed that the different plant spacings tested had no effect on the protein content of the grain. This work was confirmed by Siddiq (58) who reported that the protein percentage in sorghum grain was not affected by either the plant spacings at 5, 10, and 15 cm, or the row widths of 50- and 75- cm. Stickler and Pauli (62), on the contrary, reported that protein contents were reduced due to the increase in stand and the planting in narrow rows. Norman et al. (46) concluded that plant population had little effect on the nitrogen content of the grain in 1961. However, in 1960 the nitrogen content of the sorghum grain from the control and the 50-pound nitrogen plots decreased gradually with increasing plant populations. The nitrogen content of the grain from the 100-pound nitrogen plots remained fairly constant with changes in plant population.

Soybeans: Donovan et al. (20) stated that the protein content of soybeans tended to be the lowest at the widest spacing among the inter-row spacings of 7- to 35-inches and intra-row spacings of 1- to

3-inches. Shaikh (57) observed that the protein percentage was not affected by the plant spacings of 25, 50, and 75 cm between the rows and 2, 3, and 4 cm within a row. Ali (2) reported from a similar experiment that soybeans harvested from 50- and 75-cm-row plots resulted in a significantly higher protein percentage than those from rows spaced 25 cm apart. Various plant spacings within a row had no significant effect on the protein percentage in the soybean seed.

Oil Content

Sunflower: Derco (17) reported from Czechoslovakia that in a year with a dry May and June, the oil contents were low as compared with those obtained in a normal year. Grozev and Donceva (27) observed that a delay in thinning the plants, after the first or the second pair of leaves have emerged, will lead to increased seed coat percentage and reduced oil contents.

Sarpe and Olteanu (54) found that 30,000 to 40,000 plants per hectare on moderately leached chernozems and 40,000 to 42,000 plants per hectare on the brown-red soils, is the best plant density for oil yield. The most suitable spacing for this density was suggested to be 80- x 30- to 35- cm.

Safflower: Seydlitz (56) reported that water deficiency during the flowering and ripening periods of the safflower reduced the oil percentage in the seed. Pittman and Draper (48) emphasized that safflower seed could result in higher oil content with one irrigation than under dry conditions. The data collected from five varieties indicated that, on an average, 33.1 and 32.4 per cent oil was derived with one irrigation and without irrigation, respectively.

Williams (69) concluded from spacing trials with two safflower varieties planted at 1, 7, 13, and 19 inches in rows 40 inches apart, that the oil content of the seed was inversely related to the plant density.

Soybeans: Donovan *et al*. (20) concluded that amongst inter-row spacings of 7- to 35-inches and intra-row spacings of 1- to 3-inches in soybeans, the widest spacings tended to result in the highest oil contents. Ali (2) and Shaikh (57) reported that the oil content in soybeans was not affected significantly by the plant spacings of 25-, 50-, and 75-cm between rows and 2-, 3-, and 4-cm within rows.

Plant Height

Maize: Dungan *et al*. (21) and Enzie (22) reported that plant population and spacing had little effect on plant height in maize. Stinson and Moss (66) revealed that under extremely high plant populations the plants were slightly taller which was probably due to the competition for light. Haque (28) observed that the plant height was neither affected by the populations of 4,000, 5,000, and 6,000 plants per acre, nor by placing 1, 2, and 3 plants per hill.

Norden (45) got an increase of 5 per cent in plant height and 17 per cent in lodging when the plant population was increased from 5,000 to 25,000 plants per acre. Pendleton and Seif (47) noticed similar effects with increased populations from 12,000 to 32,000 plants per acre, but narrowing of rows from 40- to 20-inches had no significant effect.

Sorghum: Burnside et al. (15) found that the plant height at maturity increased from 52- to 56-inches, with an increase in the row width from 10- to 40-inches. Similarly, Porter et al. (49) observed a highly significant increase in the plant height with increase in the row spacing from 12- to 40-inches. Stickler et al. (63) concluded that the plants were taller in 10- and 20-inch-rows as compared to those in 30- and 40-inch-rows. The increase of height in thick plantings was attributed to the competition for light. Siddiq (59) reported that sorghum planted 5-cm apart within rows produced taller plants than those 10- and 15-cm apart within rows.

Safflower: Seydlitz (56) observed that drought during the emergence to foliar rosette stage did not affect the plant growth but water deficiency during rosette formation to flowering highly hindered the growth.

Soybeans: Probst (50) concluded that plant spacing had little influence on the plant height of different varieties of soybeans, but there was a tendency for the plants spaced five inches apart within a row to remain shorter than when spaced closer. Shaikh (57) reported that plant height was materially affected by spacing variations between and within rows. The tallest plants were obtained from a spacing of 75 x 4 cm and the shortest from 25 x 2 cm. Ali (2) observed that the soybean plants grown in 50-cm and 75-cm rows were significantly higher than those in 25-cm rows. Reiss and Sherwood (51) found that the 24-, 32-, and 8-inch-row widths produced the tallest plants and the 16-inch row width produced the shortest plants. Zahan (70) noticed a positive correlation between plant height and the density of the plants. Plant height increased with an increase in the plant population at the Harrow Research Station (9).

Seed Weight

Sorghum: Stickler and Laude (64) reported that seed size was not materially affected by row spacing or plant population. Similar results were derived under Texas conditions (6), where test weight of the grain was not affected by either seeding rate or row spacing.

Siddiq (58) concluded that seed weight of sorghum was directly associated with an increase in plant spacing within rows. An increase of 3.7 per cent in the weight of 1000 kernels was obtained when the plant spacing within the rows was increased from 5- to 15-cm. Burnside *et al*. (15) reported that the 100-seed weight increased from 2.08 to 2.15 grams, with an increase in row spacing from 10- to 40-inches. Trials by Stickler and Wearden (65) revealed that growing sorghum in 20-inch-rows resulted in a five per cent reduction in the 1000-seed weight as compared to the grain obtained from the 40-inch-rows. Similar trends were noticed by Robinson *et al*. (52).

Soybeans: Schuster and Spennemann (55) concluded that 1000-seed weight was little affected by a change of plant spacing from 40 x 40-cm to 40 x 10-cm. Lehman and Lambert (38) observed no substantial effect of changes in plant spacings on the 100-seed weight. Probst (50) suggested that the spacing had little effect on the size of the seed, but in most of the cases seed was slightly heavier when the plants were spaced one inch apart than when spaced wider apart. The 100-seed weight increased with an increase in plant population at the Harrow Research Station (9).

It was observed by Shaikh (57) that the seed size was not affected significantly by different within-and between-row spacings in soybeans, whereas, Zahan (70) reported that the seed weight was inversely correlated with the plant density. Ali (2) reported that the seed weight in soybeans was greater when the plants were grown in wide spacings of both within-and between-row plant spacing trials. Nelson and Roberts (43) noticed that the seed size was decreased by delay in sowing and increase in plant density. Soybeans grown in 8-, 16-, 24-, 32-, and 40-inch-rows, according to Reiss and Sherwood (51), produced heavier seeds in the wider rows.

III. MATERIALS AND METHODS

The experiment was carried out for two years, 1966 and 1967, at the AUB Agricultural Research and Education Center, located in the north central part of the Beqa'a Plain, Lebanon. This area is characterized by dry summer months as indicated by the weather data reported in the appendix (Table 29). The soil of the dryland area is well drained and of calcareous clay type with a pH that varies from 7.4 to 8.0.

A smooth seed bed was prepared and eight kilograms of nitrogen (as ammonium sulfo-nitrate) and eight kilograms of P_2O_5 (as superphosphate) per dunum were broadcast and disked into the soil. A split plot design replicated four times was laid out. The main plots (10 x 5 m) were the six crops i.e. maize, sorghum, sunflower, safflower, soybeans, and chickpeas, and the sub-plots (5 x 5 m) were the two plant spacings under study for each crop. The varieties, spacings, and population per dunum used for each crop are shown as follows:

1966 Trials

Crop	Variety	Spacing (cm)	Population per dunum
Maize	SD 220	100 x 100	1,000
		100 x 50	2,000
Sorghum	Norghum	100 x 50	2,000
		100 x 25	4,000

1966 Trials (Continued)

Crop	Variety	Spacing (cm)	Population per dunum
Sunflower	Local	100 x 100	1,000
		100 x 50	2,000
Safflower	Local	100 x 50	2,000
		100 x 25	4,000
Soybeans	Lindarin	100 x 25	4,000
		100 x 12.5	8,000
Chickpeas	Local	100 x 25	4,000
		100 x 12.5	8,000

1967 Trials

Same as 1966 except for the following changes:

Sunflower	Armavirec	-	-
Soybean	-	50 x 25	8,000
	-	50 x 12.5	16,000
Chickpeas	-	25 x 25	16,000
		25 x 12.5	32,000

The crops were planted on March 30, 1966 and April 8, 1967. A few plots were replanted 15 days later due to poor germination caused by low soil temperatures. The plantings were done by the hand-drop planter with two to three seeds per hill. Thinning was done to one plant per hill when the plants had emerged four to five centimeters above the ground. Weeds were controlled by the hand hoe and notes were taken throughout the growing period. The sunflower and sorghum heads were covered with punched paper bags to avoid damage caused by the birds.

Harvesting was done with a hand sickle and represented an area of 3 x 3 meters from each plot, leaving one meter as border area on all sides. The missing plants were substituted by the plants from the border rows. All the crops were threshed by hand except safflower for which a wheat thresher was employed.

Maize yields were reported on a basis of 15 per cent moisture, whereas, for the other crops the yield data were recorded on an air dry basis. Representative seed samples were taken to evaluate the seed quality by laboratory tests. The weight of 100 seeds of each crop was determined according to the International Rules for Seed Testing (5, p. 542).

For protein and oil determinations in the seeds, representative small samples from each lot were dried in the oven for 24 hours at a constant temperature of 70°C, and then cooled. The oven-dried samples were ground in a Willey mill with 20 mesh sieve and collected in bottles. Due to high oil content, sunflower and safflower seeds could not be ground in the mill, and were finely crushed in a mortar and pestle. Before weighing, the ground samples were put in the oven at 70°C for several hours to remove the moisture, cooled in a desiccator, and duplicate samples weighed.

Protein determinations were made according to the modified Kjeldahl method as specified in A.O.A.C. (32, pp. 12-13) to determine nitrogen percentage. The nitrogen values obtained were multiplied by 6.25 to determine the crude protein percentage in the seeds.

Dry extraction methods were used for oil determinations. A continuous extraction apparatus similar to the Soxhlet type was set up and oil was extracted by means of an anhydrous solvent, ether. The percentage of oil was calculated on an oven-dry basis.

The crops were compared on the basis of protein yield, oil yield, and gross return per dunum. Gross returns of all the crops were calculated from the average prices over the last three years in Lebanon[1], except soybeans for which international prices were used (30 L. piasters per kg).

Statistical methods appropriate to the splitplot design were used to analyze the data. Analysis of variance, Duncan's Multiple Range Test, and the 't' test were employed to calculate the significant differences between treatments and the combinations of treatments (37, pp. 50-52, 144-146, 184-188).

1. Taken from the records of the Department of Economics, Ministry of Agriculture, Lebanon.

IV. RESULTS AND DISCUSSION

The present two year study was undertaken to determine the effect of different plant spacings on the yield and other associated agronomic characteristics of some grain and oil crops under dryland conditions. The crop comparisons were made on the basis of protein yield, oil yield, and gross return per dunum. The abbreviations S_1 and S_2 represent the wide and close plant spacings used for all crops, respectively.

The data pertaining to each plant character studied are presented in tables 1 to 28. Variation among the significantly different factors has been appraised by the Duncan's Multiple Range Test.

Grain Yield

Maize: The average yields of maize grain were about the same during each of the two years under study as shown in Table 1. However, plant spacings greatly affected the grain yields that were obtained during each of the years studied. On the average plant spacings at 100 x 100 and 100 x 50 cm resulted in grain yields of 18.3 and 8.0 kg. per dunum, respectively. This reflects the importance of using appropriate plant populations in obtaining high yields in maize. The results are in agreement with those given by Safti *et al*. (53).

Table 1. Yield, in kg. per dunum, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Maize			Sorghum		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	6.5	18.0	12.3	12.4	20.8	16.6
1967	9.4	18.6	14.0	21.3	30.0	25.7
Mean	8.0	18.3		16.9	25.4	

Analysis of Variance

Source	D.F.	M.S.S.	
		Maize	Sorghum
Replication	3	0.79	51.15
Year	1	12.41	329.15
Error (a)	3	14.47	67.38
Spacing	1	426.73**	291.30**
Year x Spacing	1	4.87	0.16
Error (b)	6	2.76	5.19

** Significant at the one percent level.

Sorghum: The sorghum grain yields were not affected significantly when grown in 1966 and 1967 as shown in Table 1. However, the average yields were 16.6 and 25.7 kg per dunum for 1966 and 1967, respectively.

The close plant spacing at 100 x 25 cm resulted in significantly greater grain yields than the wide plant spacing at 100 x 50 cm. The average grain yield was 25.4 kg per dunum for the narrow spacings and 16.9 kg per dunum for the wide spacings. The results agree with several authors (31, 33, 36, 52, 65) who derived greater yields from narrower plantings as compared to the wider plantings.

Sunflower: Although the local variety of sunflower was replaced in 1967 by Armavirec, an early maturing variety, the seed yields were not different in the two years of study.

A significant difference in yield was obtained due to plant spacings as is evident from the data in Table 2. An average seed yield of 39.7 kg per dunum was derived from the plantings done at 100 x 50 cm as compared to 35.6 kg per dunum from plant spacings of 100 x 100 cm. The higher yield from the narrow plant spacings may be attributed to more plants per unit area which utilized the soil moisture more efficiently.

Safflower: The data in Table 2 indicate that small differences were obtained in the grain yield of safflower grown in 1966 and 1967.

Safflower proved to be rather sensitive to plant density. Significantly greater seed yields were obtained from the narrow plant spacing than from the wide plant spacing. The plantings done at 100 x 25 cm and 100 x 50 cm resulted in the average seed yields of 60.1 and

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Table 2. Yield, in kg per dunum, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Sunflower			Safflower		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	33.5	38.5	36.0	47.0	57.3	52.2
1967	37.7	40.9	39.3	48.3	62.8	55.6
Mean	35.6	39.7		47.7	60.1	

Analysis of Variance

Source	D.F.	M.S.S.	
		Sunflower	Safflower
Replication	3	14.37	42.19
Year	1	42.71	47.34
Error (a)	3	30.36	29.91
Spacing	1	67.48**	617.77**
Year x Spacing	1	3.30	18.10
Error (b)	b	0.61	9.05

** Significant at the one per cent level.

47.7 kg per dunum, respectively. It appears, therefore, that higher plant populations of safflower will result in greater yields even under restricted moisture conditions.

Soybeans: Different plant spacings were used for soybeans in each year of the study. Higher seed yields were derived from the narrow plant spacings in both years as shown in Table 3. Similar results have been reported by other workers (9, 29, 38, 51).

The soybean yields were about the same for 1966 and 1967 even though closer spacings were used and more moisture was available in 1967 than in 1966. This may be due to the low temperature at the planting time in 1967 which hindered the early growth of the soybean plants.

Chickpeas: The average grain yields obtained from different plant spacings in the two years of study are given in Table 4. In 1966 chickpeas were planted in rows 100 cm apart. The plants spaced 25 cm apart within the row produced 20.3 kg of grain per dunum while those planted 12.5 cm apart yielded 18.8 kg.

In 1967 chickpea plantings were made in rows 25 cm apart. The yields were much higher in 1967 as compared with those obtained in 1966. Average grain yields of 74.5 and 58.0 kg per dunum were obtained from the plants spaced 12.5 and 25 cm apart within rows, respectively.

Dry Matter

Maize: Stover yields of maize were not significantly different in 1966 and 1967 as shown in Table 5. The average production of stover,

Table 3. Yield, in kg per dunum, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	50x25 cm	50x12.5 cm	Observed "t"
1966	10.1	14.5	-	-	20.6**
1967	-	-	13.4	16.9	9.4**

** Significant at the one per cent level.

Table 4. Yield, in kg per dunum, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	25x25 cm	25x12.5 cm	Observed "t"
1966	20.3	18.8	-	-	6.3**
1967	-	-	58.0	74.5	4.8*

* Significant at the five per cent level.
** Significant at the one per cent level.

Table 5. Stover yield, in kg per dunum, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Maize			Sorghum		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	28.1	37.2	32.7	37.5	63.5	50.5
1967	39.1	59.0	49.1	51.5	83.3	67.4
Mean	33.6	48.1		44.5	73.4	

Analysis of Variance

Source	D.F.	M.S.S.	
		Maize	Sorghum
Replication	3	76.28	212.74
Year	1	1079.61	1146.84
Error (a)	3	177.97	287.45
Spacing	1	845.79**	3332.18**
Year x Spacing	1	118.11	33.93
Error (b)	6	51.10	48.17

** Significant at the one per cent level.

however, was 49.1 kg per dunum in 1967 and 32.7 kg in 1966.

The plant spacings influenced the stover yield in maize. Plants spaced 50 cm apart within the row produced 48.1 kg of stover per dunum as compared to 33.6 kg from the plants 100 cm apart. The results agree with the findings of Gill and Hussain (24) who reported that greater stover yields were obtained from the narrower plant spacings.

Sorghum: The average stover production in soybeans was affected only slightly in the two years of the study (Table 5). However, a great difference in stover yield was obtained due to plant spacings. Sorghum plants from 100 x 25 cm spaced plots produced 73.4 kg of stover per dunum as compared to 44.5 kg obtained from plantings made at 100 x 50 cm. The results agree with the findings of several workers (10, 58) who reported that the dry matter increased as the plant density increased in sorghums.

Sunflower: Total dry matter yield was slightly lower in 1967 than in 1966 as shown in Table 6. The shorter stemmed variety, Armavirec, grown in 1967 probably reduced the total yield. Also, this variety was one month earlier in maturity than the variety used in 1966.

A significant difference in dry matter yield was obtained with the two plant spacings studied. A greater amount of dry matter was obtained from the narrower plantings (159.6 kg per dunum) than that from the wider plantings (11.2 kg per dunum).

The interaction between year and spacing for dry matter in sunflower was highly significant. The influence of plant spacings

Table 6. Total dry matter, in kg per dunum, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

	Sunflower			Safflower		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	100.9	187.4	144.2	136.7	233.7	185.2
1967	121.5	131.7	126.6	120.3	201.6	161.0
Mean	111.2	159.6		128.5	217.7	

Sunflower:

Year x Spacing:	1966 (100x50)	1967 (100x50)	1967 (100x100)	1966 (100x100)
Mean:	187.4	131.7	121.5#	100.9

Safflower:

Year x Spacing:	1966 (100x25)	1967 (100x25)	1966 (100x50)	1967 (100x50)
Mean:	233.7	201.6	136.7	120.3

Analysis of Variance

Source	D.F.	M.S.S. Sunflower	M.S.S. Safflower
Replication	3	507.92	467.10
Year	1	1239.04	2046.43
Error (a)	3	643.79	481.42
Spacing	1	9366.37**	31781.97**
Year x Spacing	1	5798.82**	248.38*
Error (b)	6	82.71	35.70

\# Treatment means underlined do not differ significantly at the five per cent level.

* Significant at the five per cent level.

** Significant at the one per cent level.

was not consistent during either of the two years. The highest dry matter yield was obtained from the plants spaced 100 x 50 cm in 1966 and the lowest from those planted at 100 x 100 cm in 1967.

Safflower: The total dry matter per dunum in safflower in 1966 was slightly greater than that obtained in 1967 as shown in Table 6.

The data for safflower show that the plants spaced 25 cm produced more dry matter than those planted 50 cm apart in 100 cm rows. The average of total dry matter yield obtained was 217.7 kg and 128.5 kg per dunum for the narrow and wide plant spacings, respectively.

A significant interaction was found to exist for dry matter in safflower between the year and spacing. The highest amount of dry matter per dunum was obtained from the plants spaced 25 cm in 1966 and the lowest from those spaced 50 cm apart in 1967.

Soybeans: Soybean plants spaced 12.5 cm apart in the rows yielded more total dry matter than those planted 25 cm apart in both years of study as is evident in Table 7.

The row-width was reduced from 100 cm in 1966 to 50 cm in 1967. Although more and better distributed rainfall was received in 1967 than in 1966, there was no marked difference in the amount of dry matter produced in the two years. The poor development of the plants caused by low temperatures during the initial stages of plant growth in 1967 no doubt affected the amount of dry matter produced.

Chickpeas: It is evident from the data in Table 8 that the

Table 7. Total dry matter, in kg per dunum, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	50x25 cm	50x12.5 cm	Observed "t"
1966	31.7	45.2	-	-	32.6**
1967	-	-	33.0	49.0	9.0**

** Significant at the one per cent level.

Table 8. Total dry matter, in kg per dunum, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	25x25 cm	25x12.5 cm	Observed "t"
1966	45.1	47.9	-	-	4.8*
1967	-	-	126.7	157.6	4.4*

* Significant at the five per cent level.

total dry matter yield in chickpeas was affected greatly by the plant spacings especially in 1967. A greater amount of dry matter in chickpeas was obtained from the narrower plant spacings as compared to the wider plant spacings in each year. However, in 1967 there was a tremendous increase in the amount of dry matter produced over that in 1966. This was due to the higher population obtained by narrower plant rows as well as a favorable increase in the amount of rainfall.

Protein Percentage

Apart from other characteristics, protein content of a crop is the best measure to evaluate its nutritive quality.

Maize: The protein content of the maize grain differed greatly in each of the two years of the trials (Table 9). On an average, the protein content of the grain was 12.8 per cent in 1966 and 9.8 per cent in 1967. No reasonable cause is known as to the higher protein percentages that were obtained in the maize grain in 1966.

Plant spacing affected the protein content considerably. The mean protein content in the maize grain was 11.7 and 10.9 per cent from plant spacings of 100 x 100 cm and 100 x 50 cm, respectively. Similar results were reported by several workers (21, 61, 71) who got higher protein content in the maize grain from the wider plantings.

Sorghum: Protein content of the sorghum grain was affected slightly by the years and the plant densities under study (Table 9). The average protein percentage in the sorghum grain was 12.7 and 10.6

Table 9. Protein percentage of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Maize			Sorghum		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	13.2	12.4	12.8	12.5	12.9	12.7
1967	10.1	9.4	9.8	10.3	10.8	10.6
Mean	11.7	10.9		11.4	11.9	

Analysis of Variance

Source	D.F.	M.S.S.	
		Maize	Sorghum
Replication	3	0.81	2.64
Year	1	37.89**	17.54**
Error (a)	3	0.86	0.69
Spacing	1	2.08**	0.88*
Year x Spacing	1	0.01	0.004
Error (b)	6	0.105	0.104

* Significant at the five per cent level.
** Significant at the one per cent level.

in the years 1966 and 1967, respectively.

The seed from the plants spaced at 100 x 25 cm analyzed 11.9 per cent protein and that from 100 x 50 cm spaced plants 11.4 per cent protein. These results closely agree with the findings of a number of workers (42, 46, 58) who reported that the protein content of grain sorghum was not greatly affected by plant spacings.

Sunflower: The data presented in Table 10 indicate that the protein percentage in the sunflower seed was not markedly affected by the two years, 1966 and 1967. The average protein percentage, however, was 16.9 in 1966 and 15.9 in 1967.

The plant spacing slightly influenced the protein content of the sunflower seed. The average protein contents of the seed were 16.7 and 16.1 per cent from the plantings done at 100 x 100 cm and 100 x 50 cm, respectively.

Safflower: Mean protein percentages of the safflower seed obtained from the two plant spacings studied in 1966 and 1967 are given in Table 10. The protein content in the grain of safflower was higher in 1966 but not significant statistically.

Plant spacing also affected the protein content. The widely spaced plants produced better quality seed in terms of protein content as compared to the narrowly spaced plants. The average protein percentage of the seed was 14.2 from the plants spaced at 100 x 50 cm and 13.4 from those at 100 x 25 cm.

The lower protein content of the narrow plantings were due to greater yield from them than from the wide plantings. The total proteins obtained for safflower were more from the narrow plantings

Table 10. Protein percentage of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Sunflower			Safflower		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	17.2	16.6	16.9	14.7	13.9	14.3
1967	16.2	15.5	15.9	13.7	12.9	13.3
Mean	16.7	16.1		14.2	13.4	

Analysis of Variance

Source	D.F.	M.S.S.	
		Sunflower	Safflower
Replication	3	0.32	1.05
Year	1	4.00	3.97
Error (a)	3	3.23	6.62
Spacing	1	1.60*	2.36**
Year x Spacing	1	0.01	0.0098
Error (b)	6	0.17	0.11

* Significant at the five per cent level.
** Significant at the one per cent level.

than from the wide ones.

Soybeans: The protein contents of the soybean seed were slightly higher in the wide spaced plants than in the narrow spaced plants in 1966 and 1967 (Table 11). Similar findings were shown by Ali (2) who reported that higher protein contents were obtained from the plots with wider plant rows under irrigated conditions.

The protein contents of soybean seed were lowered in the second year of study. Because different spacings were used each year it is impossible to determine whether the higher protein percentages obtained in 1966 were due to spacings or years.

Chickpeas: The average protein percentages of the chickpeas affected by different plant spacings are presented in Table 12. The protein percentage in the grain of chickpeas was influenced significantly by plant spacings only from the 1967 crop. For this year the average protein content of the grain was 18.5 and 17.4 per cent for plants spaced 25 x 25 cm and 25 x 12.5 cm, respectively. The grain of chickpeas produced in 1966 contained more proteins than that harvested in 1967.

Protein Yield

Since the crops under study are very much different from one another in nature, morphology, composition, and many other characters, it is of interest to make crop comparisons in terms of the total kilograms of protein per dunum. Tables 13 and 14 report the data for protein yield of the crops at the two levels of plant spacing studied.

Significant differences were found in the protein yield of

Table 11. Protein percentage of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	50x25 cm	50x12.5 cm	Observed "t"
1966	31.5	30.1	-	-	5.0*
1967	-	-	30.0	28.3	2.4

* Significant at the five per cent level.

Table 12. Protein percentage of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	25x25 cm	25x12.5 cm	Observed "t"
1966	20.6	20.1	-	-	0.1
1967	-	-	18.5	17.4	5.9**

** Significant at the one per cent level.

Table 13. Yield of crude protein, in kg per dunum, of the crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon.

Spacing	Maize	Sorghum	Sunflower	Safflower	Soybean	Chickpeas	Mean
S_1	0.9	1.6	5.8	6.9	3.2	4.2	3.8
S_2	2.2	2.7	6.4	8.0	4.4	3.8	4.6
Mean	1.6	2.2	6.1	7.5	3.8	4.0	

Crop:	Safflower	Sunflower	Chickpeas	Soybean	Sorghum	Mzize
Mean:	7.5	6.1	4.0	3.8	2.2	1.6#

Crop x Spacing:				
	Safflower (S_2)	Safflower (S_1)	Sunflower (S_2)	Sunflower (S_1)
Mean:	Soybeans (S_2) 4.4	Chickpeas (S_1) 4.2	Chickpeas (S_2) 3.8	Soybeans (S_1) 3.2
	Sorghum (S_2) 2.7	Maize (S_2) 2.2	Sorghum (S_1) 1.6	Maize (S_1) 0.9

Analysis of Variance

Source	D.F.	M.S.S.
Replication	3	3.04**
Crop	5	41.03**
Error (a)	15	0.39
Spacing	1	8.19**
Crop x Spacing	5	0.88**
Error (b)	18	0.03

\# Treatment means underlined do not differ significantly at the five per cent level.

** Significant at the one per cent level.

Table 14. Yield of crude protein, in kg per dunum, of the crops grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon.

Spacing	Maize	Sorghum	Sunflower	Safflower	Soybean	Chickpeas	Mean
S_1	1.0	2.2	6.1	6.6	4.0	10.7	5.1
S_2	1.8	3.2	6.3	8.1	4.8	12.9	6.2
Mean	1.4	2.7	6.2	7.4	4.4	11.8	

Crop:	Chickpeas	Safflower	Sunflower	Soybean	Sorghum	Maize
Mean:	11.8	7.4	6.2	4.4	2.7	1.4#

Crop x Spacing:

Chickpeas (S_2)	Chickpeas (S_1)	Safflower (S_2)	Safflower (S_1)	Sunflower (S_2)	Sunflower (S_1)	Soybeans (S_2)	Soybeans (S_1)	Sorghum (S_2)	Sorghum (S_1)	Maize (S_2)	Maize (S_1)
12.9	10.7	8.1	6.6	6.3	6.1	4.8	4.0	3.2	2.2	1.8	1.0

Analysis of Variance

Source	D.F.	M.S.S.
Replication	3	6.46*
Crop	5	112.05**
Error (a)	15	1.57
Spacing	1	14.02**
Crop x Spacing	5	0.96**
Error (b)	18	0.14

Treatment means underlined do not differ significantly at the five per cent level.

* Significant at the five per cent level.

** Significant at the one per cent level.

different crops in both years. The safflower and sunflower crops produced more crude protein per dunum in 1966 and chickpeas in 1967 than the other crops. The lowest amount of crude protein per dunum was obtained in both years from maize and sorghum.

The two levels of plant spacing, (S_1 wide, S_2 narrow), greatly affected the amount of protein obtained from the crops in both years. Except for chickpeas in 1966, higher amounts of crude protein were obtained in all crops from the narrower plant spacings than from the wider plant spacings.

The significant interaction between crops and spacings for the crude protein yield shows the different response of crops to the variation in the plant spacing. In 1966 the densely planted safflower plots produced the highest protein yield of 8.0 kg per dunum while maize from the thinnly planted plots gave the lowest amount of 0.9 kg of crude protein per dunum. However, in 1967 chickpeas planted thickly produced the greatest amount of protein (12.9 kg per dunum), whereas, the widely spaced maize plants produced the least amount of protein (1.0 kg per dunum).

Oil Content

Sunflower: It is evident from Table 15 that wide differences in the oil percentage of sunflower were obtained in the two years of the study. The per cent of oil obtained in the sunflower seed was 31.6 and 42.4 in 1966 and 1967, respectively. The tremendous increase in the oil content in 1967 was due mainly to the new sunflower variety, Armavirec, known to be very high in oil percentage.

Wider plant spacing increased the oil content in the seeds of sunflower. On the average 38.2 and 35.8 per cent oil was recorded from within-row planting done at 100 and 50 cm, respectively.

Safflower: Data in Table 15 show that a small difference in the oil content of safflower seed, was obtained in the two years of study. Oil percentages were 31.0 and 33.7 in 1966 and 1967, respectively. The higher oil percentage obtained in 1967 may be due to more favorable soil moisture in this year as compared to that in 1966. These results are in conformity with Pittman and Draper (48) who got 33.1 and 32.4 per cent oil with one irrigation and without irrigation, respectively.

The amount of oil increased in the safflower seeds as the plant spacings were increased. The per cent oil in seeds was 33.1 in the plants spaced at 100 x 50 cm and 31.6 in those at 100 x 25 cm. These observations agree with Williams (69) who concluded that the oil content of safflower seed was inversely related to the plant density.

Soybeans: Plant spacing slightly affected the oil content of the soybeans in both years of the study (Table 16). The wider plantings resulted in a little more oil in the seeds than the narrower plantings. Similar results were recorded by Donovan et al. (20).

An increase of about two per cent oil in the soybean seed was obtained in the second year of study, which may be due to higher soil moisture available in the soil in that year.

Oil Yield

Comparisons of the three oil crops, sunflower, safflower and soybean, were made on the basis of total oil yield in kilograms per

Table 15. Percentage of oil of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Sunflower			Safflower		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	32.9	30.2	31.6	31.8	30.2	31.0
1967	43.4	41.4	42.4	34.4	32.9	33.7
Mean	38.2	35.8		33.1	31.6	

Analysis of Variance

Source	D.F.	M.S.S.	
		Sunflower	Safflower
Replication		4.23	0.74
Year		468.83**	28.44*
Error (a)		2.45	1.67
Spacing		21.65**	10.01**
Year x Spacing		0.45	0.02
Error (b)		0.47	0.56

* Significant at the five per cent level.
** Significant at the one per cent level.

Table 16. Percentage of oil of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	50x25 cm	50x12.5 cm	Observed "t"
1966	23.9	23.3	-	-	11.7**
1967	-	-	25.9	25.2	3.6*

* Significant at the five per cent level.
** Significant at the one per cent level.

dunum. The data are shown in Tables 17 and 18.

In both years of the study safflower produced the greatest amount of oil per dunum and soybeans the least. The average oil returns per dunum were 16.2, 11.3, and 2.9 kg in 1966 and 18.7, 16.6, and 3.9 kg in 1967 from safflower, sunflower, and soybeans, respectively. However, the difference in oil yield between sunflower and safflower was not significant in 1967.

A small but statistically significant difference in the yield of oil was recorded due to plant spacing. Narrow plant spacing resulted in higher oil yield than the wide one in both years.

A highly significant interaction between crops and plant spacings was found on the production of oil. Safflower at the narrow plant spacing yielded the highest amount of oil and soybean at the wide plant spacing the least in both years.

Plant Height

Maize: The height of maize plants was greatly affected in the two years of study as shown in Table 19. Average plant heights were 74.2 cm and 101.5 cm in 1966 and 1967, respectively. The plants were probably taller in 1967 as higher soil moisture was present in that year as compared to 1966.

More densely populated maize plants were shorter than plants spaced wider apart. The average height of the maize plants was 92.0 cm at 100 x 100 cm spacings and 83.6 cm at 100 x 50 cm. These results are not in agreement with other workers (45, 47) who reported a direct relationship between the plant height and the plant population. They

Table 17. Oil yield, in kg per dunum, of the oil crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon.

Spacing	Sunflower	Safflower	Soybeans	Mean
S_1	11.0	15.0	2.4	9.5
S_2	11.6	17.3	3.4	10.8
Mean	11.3	16.2	2.9	

Crop:	Safflower	Sunflower	Soybean
Mean:	16.2	11.3	2.9

Crop x Spacing:	Safflower (S_2)	Safflower (S_1)	Sunflower (S_2)	Sunflower (S_1)	Soybean (S_2)	Soybean (S_1)
Mean:	17.3	15.0	11.6	11.0	3.4	2.4

Analysis of Variance

Source	D.F.	M.S.S.
Replication	3	2.20**
Crop	2	358.77**
Error (a)	6	0.22
Spacing	1	10.12**
Crop x Spacing	2	1.66**
Error (b)	9	0.08

** Significant at the one per cent level.

Table 18. Oil yield, in kg per dunum, of the oil crops grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon.

Spacing	Sunflower	Safflower	Soybeans	Mean
S_1	16.3	16.6	3.5	12.1
S_2	16.9	20.7	4.3	14.0
Mean	16.6	18.7	3.9	

Crop:	Safflower	Sunflower	Soybean
Mean:	18.7	16.6#	3.9

Crop x Spacing	Safflower (S_2)	Sunflower (S_2)	Safflower (S_1)	Sunflower (S_1)
Mean:	20.7	16.9	16.6	16.3

	Soybean (S_2)	Soybean (S_1)
Mean:	4.3	3.5

Analysis of Variance

Source	D.F.	M.S.S.
Replication	3	1.83
Crop	2	515.99**
Error (a)	6	5.90
Spacing	1	19.98**
Crop x Spacing	2	7.74**
Error (b)	9	0.88

\# Treatments underlined do not differ significantly at the five per cent level.

** Significant at the five per cent level.

Table 19. Plant height, in cm, of maize and sorghum grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Maize			Sorghum		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	76.8	71.4	74.2	73.2	65.3	69.3
1967	107.2	95.7	101.5	93.2	85.1	89.2
Mean	92.0	83.6		83.2	75.2	

Analysis of Variance

Source	D.F.	M.S.S.	
		Maize	Sorghum
Replication		38.92	54.17
Year		2989.36*	1588.02*
Error (a)		178.58	122.53
Spacing		286.46*	259.21**
Year x Spacing		37.51	0.07
Error (b)		26.13	9.81

* Significant at the five per cent level.
** Significant at the one per cent level.

attributed it to the competition of plants for light under higher plant populations. Under the present study light was not the limiting factor as the plants were all relatively small in size.

Sorghum: Data recorded in Table 19 show that sorghum plants were taller in 1967 than in 1966. This was probable due to the more favorable soil moisture in 1967 as compared to that in 1966.

The wide plant spacing in sorghum resulted in higher plants than those obtained from narrow plant spacing. The average height of the plants spaced 100 x 50 cm was 83.2 cm, and 75.2 cm for those planted at 100 x 25 cm. The results are in conformity with some workers (15, 49) who reported an increase in the plant height with increase in the row spacings, but in contrast with Stickler et al. (63).

Sunflower: The plant height in sunflower was slightly different in the two years of study as shown in Table 20. However, there was an average decrease of 6.6 cm in the plant height in 1967 as compared to 1966.

Sunflower plants spaced wider apart grew taller than those planted closer together in the row. The average height of the plants spaced 100 cm apart in a row was 110.6 cm, and 98,4 cm for those planted 50 cm apart.

Safflower: The height of safflower plants was different in the two years of study, though not significant statistically, as reported in Table 20. The average plant height was 52.5 cm in 1966 and 64.2 cm in 1967.

A significant difference, though not appreciable quantitatively in the height of safflower plants was observed due to plant spacings.

Table 20. Plant height, in cm, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Sunflower			Safflower		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	112.9	102.7	107.8	53.6	51.3	52.5
1967	108.3	94.1	101.2	65.8	62.5	64.2
Mean	110.6	98.4		59.7	56.9	

Analysis of Variance

Source	D.F.	M.S.S.	
		Sunflower	Safflower
Replication	3	110.71	31.50
Year	1	177.55	553.43
Error (a)	3	135.96	86.54
Spacing	1	596.58**	31.64**
Year x Spacing	1	15.80	0.95
Error (b)	6	10.98	0.86

** Significant at the one per cent level.

The average height of the plants spaced 100 x 50 cm was 59.7 cm and 56.9 for those planted at 100 x 25 cm.

Soybeans: Plant spacing affected the height of soybean plants in both years of the study as is evident from the data in Table 21. The plants were higher in the wide spaced plots than in the narrow spaced plots. The average height of the plants spaced 25 cm and 12.5 cm apart in one meter wide rows was 17.4 and 15.8 cm, respectively, in 1966. In the 1967 trials the row width was reduced to 50 cm. The within-row plant spacings of 25 and 12.5 cm resulted in a plant height of 21.0 and 17.7 cm, respectively. Similar results were reported by Ali (2) and Shaikh (57) who obtained taller plants in the wider plant spacings.

The results obtained with soybeans do not agree with some workers (9, 70) who noticed positive relationship between the height and the density of plants.

The plants grew taller in 1967 than those in 1966. This may be attributed to narrow plant rows and more soil moisture in 1967.

Chickpeas: Wide plant spacings resulted in slightly higher plants than narrow plant spacings in both years as shown in Table 22.

Chickpea plants attained more height in 1967 than in 1966. This possibly may be due to narrower plantings and higher soil moisture in 1967

One-hundred Seed Weight

Seed weight is one of the measures employed to evaluate the quality of seed in field crops. Seed weight is usually related

Table 21. Plant height, in cm, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	50x25 cm	50x12.5 cm	Observed "t"
1966	17.4	15.8	-	-	3.7*
1967	-	-	21.0	17.7	4.6*

* Significant at the five per cent level.

Table 22. Plant height, in cm, of chickpeas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	25x25 cm	25x12.5 cm	Observed "t"
1966	19.7	17.2	-	-	4.3*
1967	-	-	22.9	20.1	3.7*

* Significant at the five per cent level.

directly to the vigor of a particular seed lot.

Maize: The data for 100-seed weight for maize grown at two plant spacings are reported in Table 23. It will be noted that the seed size in maize was different in the two years of study. The average weight of 100 seeds was 20.5 gm in 1966 and 18.0 gm in 1967.

The spacing of maize plants 50 or 100 cm apart did not affect the resulting seed size.

Sorghum: The size of sorghum seed was not influenced by the years in which the crop was grown or by the two plant spacings used, as is evident from the data in Table 23. The results are in conformity with some workers (6, 64) who reported that the test weight of sorghum grain was not materially affected by row spacing or plant population. However, other workers (15, 52, 58, 65) concluded that the seed weight of sorghum was directly associated with increase in the spacing within or between rows.

Sunflower: The size of sunflower seed was not the same for the two years of the study as shown in Table 24. The average 100-seed weight was 7.1 gm in 1966 and 5.5 gm in 1967. Since different varieties were used, it is not possible to determine whether the size of the seed was influenced by variety or season.

The seed weight in sunflower was influenced by the plant spacing. Plants grown wider apart within the row produced larger seeds than those spaced closer. This may be due to more nutritional area per plant in the wide plantings. The average weight of 100 seeds was 6.6 gm and 5.9 gm from the plantings done at 100 x 100 cm and 100 x 50 cm, respectively.

Table 23. One-hundred seed weight, in gm, of maize and sorghum grown at two plant spacings in the Beqa'a Plain, Lebanon.

Year	Maize			Sorghum		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	20.4	20.5	20.5	1.8	1.7	1.8
1967	17.9	18.1	18.0	1.7	1.7	1.7
Mean	19.2	19.3		1.8	1.7	

Analysis of Variance

Source	D.F.	M.S.S.	
		Maize	Sorghum
Replication	3	0.65	0.005
Year	1	24.36**	0.0106
Error (a)	3	0.53	0.0338
Spacing	1	0.14	0.0027
Year x Spacing	1	0.0	0.0138
Error (b)	6	0.46	0.003

** Significant at the one per cent level.

Table 24. One-hundred seed weight, in gm, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Sunflower			Safflower		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	7.2	6.9	7.1	5.2	5.0	5.1
1967	6.0	4.9	5.5	5.1	5.1	5.1
Mean	6.6	5.9		5.2	5.1	

Analysis of Variance

Source	D.F.	M.S.S.	
		Sunflower	Safflower
Replication	3	0.29	0.05
Year	1	10.31**	0.0012
Error (a)	3	0.04	0.022
Spacing	1	1.96*	0.0167
Year x Spacing	1	0.52	0.0336
Error (b)	6	0.19	0.012

* Significant at the five per cent level.
** Significant at the one per cent level.

Table 24. One-hundred seed weight, in gm, of sunflower and safflower grown at two plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	Sunflower			Safflower		
	100x100 cm	100x50 cm	Mean	100x50 cm	100x25 cm	Mean
1966	7.2	6.9	7.1	5.2	5.0	5.1
1967	6.0	4.9	5.5	5.1	5.1	5.1
Mean	6.6	5.9		5.2	5.1	

Analysis of Variance

Source	D.F.	M.S.S.	
		Sunflower	Safflower
Replication	3	0.29	0.05
Year	1	10.31**	0.0012
Error (a)	3	0.04	0.022
Spacing	1	1.96*	0.0167
Year x Spacing	1	0.52	0.0336
Error (b)	6	0.19	0.012

* Significant at the five per cent level.
** Significant at the one per cent level.

Safflower: The size of safflower seed was not affected by season or plant spacing as shown in Table 24. In both seasons the weight of 100 safflower seeds was 5.1 gm.

The average weight of 100 seeds was 5.2 gm from the wide spacing and 5.1 gm from the narrow spacing.

Soybeans: Plant spacings exhibited a slight influence on the soybean seed weight in 1966 as is clear from the data in Table 25. The seed weight increased with an increase in the within-row plant spacings. The results are in conformity with the findings of several workers (2, 43, 51).

In 1967, plant spacing had no significant influence on the size of soybean seed. These results agree with several workers (30, 50, 55) who reported that plant spacing did not affect the seed weight in soybeans.

Chickpeas: The seed weight in chickpeas was not affected appreciably by the plant spacings (Table 26). The average 100-seed weight from the 1966 crop was 31.2 and 30.4 gm from the plants spaced at 25 and 12.5 cm in a row, respectively.

The average weight of 100 seeds in 1967 was 29.5 gm from the plants spaced 25 cm and 27.9 gm from those planted 12.5 cm apart, in 25 cm wide rows.

Economic Evaluation

The crops were compared in terms of their gross return in Lebanese Pounds (L.L.) per dunum. Highly significant differences were found among the crops for gross return in both years of the study

Table 25. One-hundred seed weight, in gm, of soybeans grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	50x25 cm	50x12.5 cm	Observed "t"
1966	8.6	8.1	–	–	3.4*
1967	–	–	7.8	7.2	1.6

* Significant at the five per cent level.

Table 26. One-hundred seed weight, in gm, of chick-peas grown at different plant spacings in 1966 and 1967 in the Beqa'a Plain, Lebanon.

Year	100x25 cm	100x12.5 cm	25x25 cm	25x12.5 cm	Observed "t"
1966	31.2	30.4	–	–	2.5
1967	–	–	29.5	27.9	2.6

as shown in Tables 27 and 28. In 1966, safflower gave the highest return of L.L. 28.70, whereas, maize the least, which was L.L. 2.50 per dunum. The same trend was observed in 1967 when safflower and maize gave returns of L.L. 30.60 and L.L. 2.80, respectively. However, soybeans, sorghum, and maize were not much different in their gross return in both years; while safflower, chickpeas, and sunflower gave almost same gross return in 1967.

Plant spacing greatly influenced the gross returns obtained from the crops. Narrow plant spacing (S_2) resulted in higher returns from the crops than did the wide plant spacing(S_1) in both years.

The interaction between crops and the plant spacings was found highly significant for gross returns. Safflower at narrow plant spacing gave the highest returns and maize at wide plant spacing the least, in both years. In 1966, narrowly spaced safflower plants gave a gross return of L.L. 31.50 per dunum and widely spaced maize of L.L. 1.30 per dunum. This trend was maintained in 1967 with safflower giving L.L. 34.60 and the maize L.L. 1.90 per dunum.

However, no appreciable difference was found in 1967 in the gross returns of safflower and chickpeas planted at narrow level of spacing(S_2).

Table 27. Gross return, in Lebanese Pounds per dunum, of the crops grown at different plant spacings in 1966 in the Beqa'a Plain, Lebanon.

Spacing	Maize	Sorghum	Sunflower	Safflower	Soybeans	Chickpeas	Mean
S_1	1.30	2.40	25.10	25.80	3.00	9.40	11.20
S_2	3.60	3.90	28.90	31.50	4.30	8.60	13.50
Mean	2.50	3.20	27.00	28.70	3.70	9.00	

Crop:	Safflower	Sunflower	Chickpeas	Soybeans	Sorghum	Maize
Mean:	28.70	27.00	9.00	3.70	3.20	2.50#

Crop x Spacing:

Safflower (S_2)	Sunflower (S_2)	Safflower (S_1)	
31.50	28.90	25.80	
Sunflower (S_1)	Chickpeas (S_1)	Chickpeas (S_2)	
25.10	9.40	8.60	
Soybean (S_2)	Sorghum (S_2)	Maize (S_2)	Soybeans (S_1)
4.30	3.90	3.60	3.00
Sorghum (S_1)	Maize (S_1)		
2.40	1.30		

Analysis of Variance

Source	D.F.	M.S.S.
Replication	3	5.56**
Crop	5	1200.15**
Error (a)	15	0.96
Spacing	1	64.14**
Crop x Spacing	5	9.66**
Error (b)	18	0.15

\# Treatment means underlined do not differ significantly at the five per cent level.

** Significant at the one-per cent level.

Table 28. Gross return, in Lebanese Pounds per dunum, of the crops, grown at different plant spacings in 1967 in the Beqa'a Plain, Lebanon.

Spacing	Maize	Sorghum	Sunflower	Safflower	Soybeans	Chickpeas	Mean
S_1	1.90	4.10	28.30	25.60	4.00	26.70	15.20
S_2	3.70	5.70	30.70	34.60	5.10	34.30	19.00
Mean	2.80	4.90	29.50	30.60	4.60	30.50	

Crop:	Safflower	Chickpeas	Sunflower	Sorghum	Soybeans	Maize
Mean:	30.60	30.50	29.50	4.90	4.60	2.80#

Crop x Spacing:	Safflower (S_2)	Chickpeas (S_2)	Sunflower (S_2)
Mean:	34.60	34.30	30.70

	Sunflower (S_1)	Chickpeas (S_1)	Safflower (S_1)
	28.30	26.70	26.60

Sorghum (S_2)	Soybean (S_2)	Sorghum (S_1)	Soybeans (S_1)	Maize (S_2)	Maize (S_1)
5.70	5.10	4.10	4.00	3.70	1.90

Analysis of Variance

Source	D.F.	M.S.S.
Replication	3	24.66
Crop	5	1639.34**
Error (a)	15	15.81
Spacing	1	169.35**
Crop x Spacing	5	20.01**

\# Treatment means underlined do not differ significantly at the five per cent level.

** Significant at the one per cent level.

V. SUMMARY AND CONCLUSIONS

Six crops, maize, sorghum, sunflower, safflower, soybeans, and chickpeas, were grown at the AUB Agricultural Research and Education Center in the Beqa'a Plain, Lebanon, in 1966 and 1967. The objective was to determine the effect of plant spacing on the grain yield, quality and other characteristics of the crops under dryland conditions.

The plantings were done in rows 100, 50, and 25 cm apart, with two within-row plant spacings for each crop. The within-row spacings for maize and sunflower were 100 and 50 cm, for sorghum and safflower 50 and 25 cm, and for soybean and chickpeas 25 and 12.5 cm.

Higher grain yields were obtained from the narrow plantings of all crops in both years of the study, except chickpeas in 1966.

Narrow plant spacings consistently resulted in greater total dry matter in all crops than the wide plant spacings.

The protein percentage of the grain was reduced by the narrowing of plant spacings in all crops except sorghum. However, more crude protein per dunum was obtained from the narrower plantings of all the crops than from the wider plantings. In 1966, the highest yield of crude protein per dunum was obtained from safflower and the lowest from maize. In 1967, chickpeas produced the highest amount of crude protein per dunum.

The oil content of the three oil crops (sunflower, safflower, and soybeans) decreased, but the total oil yield per dunum increased with a decrease in the plant spacing. Safflower consistently produced the highest amount of oil per dunum and soybeans the least.

Plant spacings significantly influenced the plant height. Plants were taller in the narrower plantings than in the wider plantings in all the crops.

Seed size was influenced slightly by the plant spacing. In sunflower, soybeans, and chickpeas, the seeds from wider plantings were slightly heavier than those from the narrower spacings.

In general, grain yield, dry matter, oil content, and plant height increased, but protein content and seed weight decreased in 1967 as compared to 1966.

The six crops were compared on the basis of gross return (in Lebanese Pounds) per dunum. Safflower gave the highest returns per dunum and maize the least, in both years of the study.

Safflower proved to be the best and most suitable crop for growing under dryland conditions in the Beqa'a Plain, Lebanon, during 1966 and 1967. The experiment should be conducted for several years to more adequately represent the growing conditions of the Beqa'a Plain.

Although some crops gave a fairly good yield under dryland conditions, the yields in all the crops were rather low for economic production.

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APPENDIX

Table 29. Average monthly temperatures, relative humidity and precipitation during 1965-66 and 1966-67 at the AUB Agricultural Research and Education Center, Beqa'a Plain, Lebanon.

Month	Temperature (°C)		Relative Humidity %		Rainfall (mm)	
	1965-66	1966-67	1965-66	1966-67	1965-66	1966-67
September	20.2	20.2	48.4	62.2	23.2	0.9
October	13.2	16.1	59.9	64.1	46.8	28.0
November	10.0	14.1	60.4	63.2	24.8	11.0
December	6.7	7.3	77.2	75.5	155.7	187.8
January	5.7	4.1	75.3	72.8	70.9	139.3
February	6.4	4.1	72.8	78.3	68.7	85.1
March	7.1	5.9	67.9	71.5	96.7	167.1
April	11.8	10.5	62.1	58.6	0.0	20.5
May	14.5	15.1	58.0	56.6	2.6	34.5
June	19.6	17.9	53.3	48.3	0.0	0.0
July	22.9	20.7	53.4	45.5	0.0	0.0
August	23.7	20.5	53.6	48.7	0.0	0.0