EFFECT OF POPULATION AND SPACING ON YIELD AND OTHER CHARACTERISTICS IN SOYBEANS

by
Mohammad Anwarul Quader Shaikh

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Population Study in Soybean

SHAIKH

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ABSTRACT

A one-year study involving the effect of different within-row and between-row spacings on soybean seed yield, protein content, oil content, seed size, plant height, plant weight at maturity, number of seeds per pod and number of days from planting to flowering was conducted at the AUB Agricultural Research and Education Center.

Closer spacing, such as 25 cm. and 50 cm. between rows, produced the highest soybean yields. Spacing within the rows did not influence the seed yield of soybeans. Protein percentage of soybean was not affected by the different plant populations. The variety Clark contained the highest protein percentage, while the variety Perry had the lowest protein content. Spacing treatments did not influence the oil content of the variety Ford. Soybean seed size was not affected by the different spacings within and between rows.

Plant height in soybeans was materially affected by spacing variations. Wider spacing between and within rows resulted in taller plants. The variety Clark had the tallest and Ford had the shortest plants. Weight of plants at maturity increased with wider spacing between and within rows. Number of seeds per pod was not influenced by the spacing treatments. The variety Ford had the highest and Perry had the lowest number of seeds per pod. The varieties varied widely in the number of days from planting to flowering.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

INTRODUCTION

Soybeans have served humanity from times immemorial. Ancient Chinese literature reveals that soybeans were extensively cultivated and valued as a food centuries before written records were kept (21). Many of the early writings record the advice of agricultural experts on different agronomic production procedures. Some of this expert advice dates back as far as 2207 B.C., indicating that the soybean was perhaps one of the oldest crop grown by man. It was also regarded as having many medicinal virtues for both man and animal. Many of the qualities attributed to soybean as food and drug by the Chinese have been proved by modern scientific research in America and Europe.

The production of soybeans, after being confined to countries of Asia, spread rapidly after World War I and especially after World War II to the Western Hemisphere. At present soybeans are grown in many areas of the world. In the United States it reached the first place among oil-seed crops from a relatively insignificant production in less than 25 years. The European countries such as U.S.S.R., Bulgaria, Austria, Yugoslavia, Czechoslovakia, Rumania and the Asian countries like China, Manchuria, Korea and Japan produce this crop successfully (21).

The general climatic and soil requirements of soybeans are about the same as for corn but the soybean makes a more satisfactory growth than corn in soils low in fertility, specially when inoculation is practiced.

The cultivated soybean is thought to have been developed from Glycine ussuriensis, which grows wild in Eastern Asia. Current studies indicate that the correct botanical name of the soybean should be Glycine max (L.) Merill (28).

Very few studies have been undertaken in the Middle East on the agronomic practices needed for successful soybean production. Since the conditions of many parts of the Middle East and some parts of Africa are favorable to soybean production, there is a great potentiality of this crop in the near future.

The present study was undertaken at the AUB Agricultural Research and Education Center in the Beqa'a plain, Lebanon. The soil and climate of this farm is quite representative of much agricultural area in the Middle East. This study was undertaken to determine the effect of plant population per unit area upon yield and other characteristics of the soybeans. Spacing of plants both between and within rows was varied to obtain different population per unit area. In Lebanon and other parts of the Middle East, soybeans, when fully adapted and developed may occupy a unique position in providing the much needed protein-rich feed to the animals and food to man.

REVIEW OF LITERATURE

The phenomenal increase in soybean production during the past few years has resulted primarily from the use of better adapted varieties and improved cultural practices contributing to higher yields per acre (5). Other factors involved have been its high oil and protein content and the expanded markets for oilseed crops and their by-products. Numerous studies have been conducted by various workers to find the most suitable cultural practices that would produce the highest soybean yields. In this review of literature only studies that are related to the effect of plant population on yield and other characteristics in soybeans have been considered.

Yield

Ali (2) reported, after a two year study with three varieties, three row-widths and three within-row spacings, that the row-width significantly affected the seed yield of soybeans. The highest seed yields were obtained when the rows were spaced 50 cm. apart and the lowest yield from the 75 cm. rows. Plantings of soybeans that were in 25 cm. rows yielded in between those grown 50 and 75 cm. between the rows. The seed yields were not affected by the different plant spacings within the rows (i.e. 2, 3 and 4 cm.). Significant differences in yield among the three varieties were obtained.

In experiments in Illinois, Hackleman et al. (11) found that 18- to 32-inch row-spacings were far better than 35- to 40-inch row-spacings for higher yield.

Johnson (16) in 1959 reported that as the spacing was decreased between intertilled rows, the yields were increased. This included intertilled row spacings of 18 to 42 inches.

Studies at the Delta Station, Mississippi (12), in 1949 and 1950 showed no yield differences between soybeans grown in 36- and 40-inch rows and yields were reduced as much as 10 percent when row widths of 24 to 28 inches were used. Additional trials were made in 1960 with Hill and Lee varieties to compare 40-inch and 27-inch rows. The planting rate was approximately 10 seeds per foot of row, regardless of the row width. It was found that the soybean yield was one bushel less per acre in the case of 27-inch row-width than that of 40-inch row-width.

Wiggans (36) studied the problem of plant population per unit area in spacings between rows varying from eight to 32 inches and the spacings within rows from one-half to six inches. These spacings gave from one to 18 soybeans plants per square foot. Three years' results showed that the narrower the space between rows the higher the soybean yields. The nearer the arrangement to an even distribution of the plants in the area, the nearer the approach to the maximum yield.

In another study on plant spacing, distances between plants in the row from one-half to six inches and distances between rows from 8 to 32 inches, Wiggans (37) found that the yield of soybean was affected materially by the spacing of the plants. Not only was the yield influenced by the distribution of the plants within the rows, but also by the distance between the rows. His conclusions indicated that greater yields will be obtained when the arrangement of plants on a given area approaches a uniform distribution. Other things being constant, the narrower the distance between rows until the distance between rows equals the space between plants in the row, the greater the yield. Within wide ranges, the number of plants per square foot of area has little effect on the net increases. Seeding beyond a given optimum does not add to the yield.

Morse (20) stated that the seed rate should be varied according to soil fertility, variety and row spacings.

Results obtained by Rouse (30) from a three year study comparing late planted soybeans in 30 and 40-inch rows at 30 and 60 pound seeding rate, show a three to five bushel advantage for the 30-inch rows over the 40-inch rows. There was no difference in yield between the 30 and the 60 pound seeding rates or between the varieties.

In another study by Rouse (30), comparing 10-, 20-, 30-, and 40-inch rows seeded at 60 pounds per acre and 10-, 20-, and 30-inch rows seeded at 240, 120 and 90 pounds per acre rates, it was shown that a marked increase in yield occurred from decreasing the row width. Yields were the highest when the seeding rate was 60 pounds per acre. Three year average yields at the 60-pound rate were 34 bushels per acre in 40-inch rows and 55 bushels in the 10-inch rows.

In the recent studies by Nelson and Roberts (22), the highest soybean yields were obtained from 1.0-inch plant spacing in the row. Yields decreased progressively with 2.0, 4.7, 7.3 and 8.2-inch plant spacings. The rows were 22 inches apart.

Weber and Weiss (33) analyzed soybean yield data from four States which showed that rows spaced 21 inches apart gave slightly higher yields than those spaced 7, 14, 25, 28 or 42 inches.

Probst (26), by studying the effect of population on yield and other characters, with four varieties of soybeans over a period of four years reported that maximum yields were most frequently obtained when the plants were spaced two or three inches apart in rows of 30 inch distance.

Thatcher (31) in his studies comparing soybeans planted solid with those grown in rows, with two varieties for a two-year period, found that the greatest total yield was produced where the soybeans were grown in 24-inch rows.

Ross (29) compared planting soybeans in rows and drilling them in solid (i.e. in rows 7-inch apart by a grain drill). The yields reported by him were 23.2 bushels per acre when drilled solid, 24.2 bushels per acre with 14-inch rows, 22.3

bushels with 20 to 24-inch rows and 17.8 bushels per acre with 36 to 42-inch rows.

Weber and Staniforth (34) studied competitive relationships in variable weed and soybean stands over a four year period. They reported that the growth of annual weeds increased markedly and bean yield reductions became more severe with soybean stands of less than 9 to 11 plants per foot of row.

Frans (9) found that the highest soybean yield was obtained in row-width spacings of ten inches and seven inches. He concluded that soybeans in the narrower rows probably shaded the soil relatively earlier than those grown in wider rows and reduced weed competition. He further concluded that killing of the weeds by herbicide plus narrow planting gave the higher yield.

Caviness and Smith (6) in experiments conducted in Arkansas found that the highest mean yield was obtained from the May 15 to 20 planting dates. Yields from the later dates (June 20 to 30) were significantly lower than from the May planting dates but not different than the yields of the early dates (April 15 to 20).

Wiggans (37) stated that the soybean plant can make wide adjustments to different spacings. Optimum rates of seeding and spacing arrangements have to be determined according to the variety and the local conditions. Large growing, late maturing varieties should not be expected to require the same rate or spacing for optimum yields that small growing, early maturing varieties require. A variety of soybean has an optimum number of plants per unit area for the maximum net increase.

In experiments in Illinois, involving four soybean varieties on several types of soils, Pendleton and co-workers (25) found that 24-inch spacings gave consistently higher yields than 40-inch rows. The Harosoy, Clark and Shelby varieties averaged over 40 bushels an acre in the narrow rows while Chippewa, an early variety produced about 35 bushels. The seeding rates used in these tests ranged from 60 to 105 pounds per acre. Although the seeding rate made very little difference in the final yield, they recommended 75 to 80 pounds of seeds per acre with the narrow spacing.

Lehman and Lambert (18) studied the effect of spacing on the components of yield and other plant characters at two locations in Minnesota by using two varieties, two spacings between rows and four spacings within the row. They found that the seed yield of both varieties at Waseca was significantly higher when planted at the 20-inch spacing between rows than in the 40-inch rows. Yield differences at St. Paul for spacing between rows were not significant. The results obtained on the effect of spacing on yield within rows were variable.

In experiments in Indiana by Beeson and Probst (3) it was found that the row widths of 24 to 32 inches usually produce the highest yields in early maturing soybean varieties. The varieties with a more spreading type of growth yielded best in wider rows. But it was indicated that 40-inch rows are too wide to obtain maximum yields. As far as spacing within row is concerned, it was shown that six to eight soybean plants evenly distributed per foot of row gave the highest yield and the least weeds, when the rows were 28- to 40-inch apart.

Protein and Oil

The influence of environmental and cultural factors on the protein and oil content of the soybean seed was studied by a number of workers.

Studies by Lipman and Blair (19) showed that as the seeding rate was increased the amount of dry matter returned also increased. The plantings with 14 to 30 plants per pot gave about double the amount of dry matter that was given by plantings with two to eight plants per pot. The percentage of nitrogen in the dry matter was slightly higher from plantings of two to eight plants per pot as compared to those with 14 to 30 plants per pot. But the total nitrogen recovery was far more from the 14 to 30 plants than from the two to eight per pot. With 20 to 30 plants a pot, the yield of nitrogen is more than twice that with two to eight plants a pot. This indicates increased or intensified utilization of atmospheric nitrogen by means of symbiotic bacteria with the thicker plantings.

Ali (2) reported that increase in distance between rows increased the protein content but it was not affected by within row plant spacings. The planting of soybeans in various row-widths and in different spacings within rows did not change the oil content of the three soybean varieties studied. The varieties differed significantly in their percentage of oil.

Howell and Cartter (14) found positive correlation between oil content and temperature near maturity. The highest correlation coefficient values were obtained for the periods 20 to 30 and 30 to 40 days before maturity, indicating that temperatures during these periods exert a greater effect on oil level than those at other times.

Soybean seeds produced by Howell and Cartter (15) in the greenhouse under controlled conditions averaged 23.2 percent, 20.8 percent and 19.5 percent oil when grown at temperatures of 85, 77 and 70 degrees Fahrenheit, respectively, during the pod-filling stage. Temperature differences affected mainly the triglyceride materials (true oil) and only slightly affected the non-triglyceride, ether-soluble components of the crude oil. Plants were held at 70 degrees Fahrenheit during day and 65 degrees Fahrenheit during night throughout their life except for one week at 85 degrees Fahrenheit day and 65 degrees Fahrenheit night to determine the effect of a brief period of elevated temperature. Elevated temperature during the fourth to seventh week before maturity resulted in oil content of about 22 percent as compared to 19.6 percent when elevated temperature was given the second week before maturity.

In the studies conducted by Collins and Cartter (7) oil content of soybeans was found to vary with position of pod on the plant, position of pod on the raceme, and position of the seed in the pod. Seeds from lower half of the plants were 0.5 percent higher in oil and one percent lower in protein than those from the upper half. Soybeans near the tip of long terminal racemes had less oil than those farther down. Seed in the tip of the pod had the highest oil and the lowest protein content. These results call for procuring a thoroughly mixed representative sample in the chemical analysis for protein and oil.

Garner et al. (10), while studying the oil content as affected by the size of seed, considered only the large and small beans from the same lot of seed. It appeared that generally the percentage of oil was approximately the same in both larger and smaller seeds. They failed to lay down a fixed rule as to the relative percentages of oil in large and small soybeans, since there are all gradations in size. They suggested that the only practicable method of comparing different lots of seed, therefore, is to secure average values based on comparatively large quantities, simply counting out the seed as they come, without any attempt at separation into sizes. They also found varietal differences in soybeans both as to size of seed and as to oil content. Seasonal effects of the three years' of experiment did not influence the several varieties alike with respect to either of these characters. This led them to conclude that in soybeans heredity is a very important factor, not only with respect to the size and the oil content but also as regards the extent to which these characters respond to change in environment. On comparing their data the authors (10) concluded that the variations in the size of seeds and the oil content of soybeans attributable to differences in soil type are far less than those observed when both soil and climate differ. The results were interpreted to have indicated that under practical conditions climate is a major potent factor than the soil in modifying the size of seed and its oil content.

Seed Weight

Seed weight, according to Lehman and Lambert (18) was heavier in the 40-inch spacing for both varieties Blackhawk and Mandarin at St. Paul than in the 20-inch spacings. At Waseca seed weight was nearly the same in both 20 and 40-inch row spacing for Blackhawk but was heavier in the 20-inch spacing for Ottawa Mandarin. Seed weight increased as spacing within row increased at St. Paul but seed weight was not influenced by changes in spacing within row at Waseca.

Probst (26) reported that spacing had little effect on the size of the seed in the varieties studied.

Nelson and Roberts (22) and Ali (2) found in recent studies that seed weight varied directly with spacings between and within rows i.e. the larger the spacings within and between rows, the bigger the seed size.

Other Characteristics

Weber and Weiss (33) in Iowa found that branching increased as spacing between plants increased.

The work of Probst (26) also showed that the number of branches increased as the spacing was increased. The relative importance of branches in the production of seeds and pods varied with spacing while changes in spacing had little or no effect on the relative importance of main stems and branches with respect to seed weight and seeds per pod.

Ali (2) obtained the highest total weight at maturity (Stem, Pod and seed) when the row spacing was minimum i.e. 25 cm. and lowest total weight when row spacing was maximum i.e. 75 cm. The plant spacing of two, three and four cm. within rows did not influence the total weight of soybean.

Experiments by Burlison *et al.* (4) at Illinois showed that as spacing between rows and within rows were decreased, a decrease in the number of pods per plant was obtained.

Lehman and Lambert (18) reported that seeds per pod increased slightly but consistently as spacing was increased. Seeds per plant and pods per plant increased markedly as spacing was increased. The differences were small at the narrow spacings but became increasingly larger as the spacing between plants became greater.

The various soybean plant populations, as attained by various row-width and within-row plant spacings by Ali (2), did not influence the number of seeds per pod.

Probst (26) reported that varying the distance between soybean plants had little influence on the height of the plants. There was, however, the tendency for plants spaced five inches apart to grow slightly shorter than when spaced closer together. Decrease in plant height with increased plant spacing was also reported by Nelson and Roberts (22).

Ali (2) reported that height of the soybean plant was influenced very little by within-row spacings.

Results of the experiment by Probst (26) showed that spacing plants two to five inches apart hastened maturity in comparison with one inch spacing. The varieties averaged from two to four days earlier for spacings two to five inches apart in comparison with one inch spacing.

Ali (2) did not find any significant differences in the number of days from planting to flowering due to the spacing treatments for the two seasons of the study.

MATERIALS AND METHODS

The experiment was conducted for one crop season under irrigated conditions. The untreated soil at the University farm in the Beqa'a has a pH of about 8.0 and is high in clay content.

Ford, Clark and Perry, three adapted soybean varieties, were used in this trial. Ford is characterized by while flowers, tawny pubescence and dark brown pods (17). Clark is a pure line selection from the backcross Lincoln X (Lincoln X Richland). It is high yielding and a high oil content soybean variety (27). Perry has a high oil content (1) and is later in maturity than Ford and Clark.

A uniform fertilizer treatment of super-phosphate and ammonium sulfo-nitrate was disked and worked into the experimental plots at the rate of 20 kg. of P_2O_5 per dunum and 12 kg. of nitrogen per dunum. Since cutworms have been prevalent in the area, seven pounds of Heptachlor per dunum were also disked into the plots. Both the fertilizer and the insecticide were applied to the soil a few days before planting. Ammonium sulfo-nitrate at the rate of 4 kg. of nitrogen per dunum was side-dressed during the early part of the growing season when the plants were about 10 cm. in height and showed nitrogen defficiency symptoms.

A good seedbed was prepared and the seeds were inoculated with a commercial nitrogen-fixing organism before the soybeans were planted. Planting was done with a V-belt nursery planter on the 3rd of May 1963.

The experiment was laid out on a split-plot design in which the main plots were represented by the three spacings within rows two, three and four cm., sub-plots by the three spacings between rows 25, 50 and 75 cm. and the varieties represented the sub-sub-plots. The conventional rows were used in the case of the 50 and 75 cm. row spacings. For the 25 cm. rows, the soybeans were planted in two-15 cm. rows leaving 35 cm. between each pair of rows to facilitate more uniform irrigation. The test was planted in four replications.

The experimental area covered 24 x 21 meters. Each main plot involved an area of 7 x 5 meters. One row of five meters in length represented a treatment. Only four meters of each row was harvested to reduce border effects.

The number of seeds were calculated and hand counted for each of the two, three and four cm. within-row spacings each planted in rows 25, 50 and 75 cm. apart. Since the laboratory germination percentage of all of the three varieties was about 90 percent, 10 percent extra seeds were sown in all seeding combinations.

During the first four weeks following planting, only sprinkler irrigation was used to obtain good germination and seedling establishment. Furrow irrigation was practiced during the rest of the growing period. Weeding was done by hand during the early part of the soybeans' growth and later appropriate nursery equipments were used when the seedlings were well established.

The crop was harvested when the leaves were off the plant which is the indication of complete maturity. The plants were allowed to cure in the sun and were threshed after about 15 days following harvesting.

The data for germination percentage in the laboratory, number of days from planting to flowering, lodging, height of the plants, total weight at maturity (stem, pod and seed), number of seeds per pod, seed yield and size of seed (1000-kernel weight per plot) were obtained and recorded.

For the determination of oil and protein content of the seed, a representative sample of seed from each row was taken. The seed was dried, ground and weighed for the analysis.

Dry extraction methods were used to determine the oil content. Continuous extraction method approaching Soxhlet type were set up. According to dry extraction method, fat soluble substances were removed from the dried material by means of an anhydrous solvent ether. Calculation of percentage of oil was carried on an air dry basis.

The improved Kjeldahl method as specified in "Official methods of analysis" of the Association of Agricultural Chemists to determine nitrogen (13), was used to obtain the protein percentage. The nitrogen values obtained were multiplied by 6.25 to get the percentage of protein. Results of duplicates differing from the sample mean by six percent or more were rejected and the analyses were repeated.

Statistical methods appropriate to the split-plot design (24) were used to analyze the data. To calculate the difference between the treatment combinations, analysis of variance and L.S.D. test were used.

RESULTS AND DISCUSSION

This experiment was conducted to find the influence of different plant populations obtained by spacings within rows and between rows of three varieties of soybeans on eight plant characteristics. The data for the effect of these treatments on number of days from planting to flowering, number of seeds per pod, plant height, weight of five representative plants at maturity (stem, pod and seed), seed yield, 1000-kernel weight, percentage of oil and protein percentage are reported in Tables 1 to 8.

The abbreviations used in these tables are P, for spacing within rows, Q, for spacing between rows and V, for varieties. The suffixes 1, 2, 3, with P represent within-row spacings of 2 cm., 3 cm. and 4 cm., respectively, and the numbers 1, 2 and 3 with Q represent between-row spacings of 25 cm., 50 cm. and 75 cm., respectively. V_1, V_2, and V_3 were used to represent the varieties Ford, Perry and Clark, respectively. The L.S.D. figures at the one percent and five percent levels are given for those treatments and interactions only that were found statistically significant. The analysis of variance values for Tables 1 to 8 are given in Tables 9 to 16.

Seed yield

Soybean seed yields were not affected significantly by the planting of seeds at two, three and four cm. apart in the row (Tables 1 and 9). However, planting soybeans in rows that were 25,50 and 75 cm. apart greatly influenced the seed yield as shown in Table 1. The highest seed yields were obtained when the distance between the rows was 25 and 50 cm., the lowest seed yields resulted from rows spaced 75 cm. apart. On the average, the seed yields from 25 cm., 50 cm. and 75 cm. row-widths were 275.7, 270.2 and 235.7 Kg. per dunum, respectively. These results are in agreement with Ali (2) Nelson and Roberts (22) and Ross (29) who reported that yield was increased materially in closer spacing between rows than in wider spacing. The highest yields were obtained by Nelson and Roberts (22) from spacings of 1.0-inch within-row and 22.0-inch between-rows and by Ross (29) from 14-inch row widths. The distance between rows in their experiments are within the range of 25-50 cm. used in the present study.

The three soybean varieties varied slightly in seed yields but the differences are not statistically significant (Table 9).

Since there was no difference in the soybean yields from plantings made in 25 and 50 cm. rows, it may be desirable to sow soybeans in rows 50 cm. apart. This will reduce the seed rate by one-half and facilitate cultural practices such as irrigation and weed control.

Percentage of protein in the seed.

An inspection of Tables 2 and 10 shows that the different plant populations, obtained by planting the seed at varying

Table 1. Effect of between and within-row spacing on the seed yield of soybeans in Kg. per dunum during 1963 at the AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm.		Variety		Average
		Ford (V_1)	Perry (V_2)	Clark (V_3)	
$2(P_1)$	$25(Q_1)$	291.5	256.8	251.8	
	$50(Q_2)$	261.0	252.8	330.8	
	$75(Q_3)$	248.3	231.3	292.8	268.5
$3(P_2)$	$25(Q_1)$	297.0	274.3	271.0	
	$50(Q_2)$	258.8	258.8	281.5	
	$75(Q_3)$	229.8	227.8	215.5	257.1
$4(P_3)$	$25(Q_1)$	251.3	303.3	284.3	
	$50(Q_2)$	250.8	253.3	284.5	
	$75(Q_3)$	228.5	195.5	252.3	255.9
Average		257.4	250.4	273.8	

	L.S.D. (5%)	L.S.D. (1%)
Between-row spacing	21.1	28.9

Between-row spacing	25 cm.	50 cm.	75 cm.
Mean	275.7	270.2*	235.7

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

distances within and between rows, did not have any significant influence on the protein percentage of soybeans.

The soybean varieties did not differ significantly in their protein content as shown by the analysis of variance in Table 10. The data in Table 2 show that the variety Clark contained 36.19 percent of protein and Perry 35.58 percent protein.

There was significant interaction of within-row x variety as shown in Table 2. The highest protein content (36.35%) was obtained from Clark when planted at three cm. within-row spacings and the lowest protein content (34.76%) resulted from Ford when spaced four cm. within the row.

It is evident from Table 10 that there was significant interaction of within-row x between-row x variety treatments in soybeans. The highest protein (36.83%) was obtained in the combination of 3 cm. x 25 cm. x Ford and the lowest protein content (34.55%) was found in the combination of 4 cm. x 25 cm. x Ford. In this interaction there was inconsistency in the response of the varieties.

<u>Percentage of oil in the seed.</u>

The data in Tables 3 and 11 show that various within-row and row-width spacings of soybean plants did not have significant effect on the oil content of the soybean variety Ford. The variety averaged 22.39 percent oil. Oil content was determined only on one variety because it was found by Ali (2) that

Table 2. Effect of between and within-row spacing on the percentage of protein of soybeans during 1963 at the AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm.	Variety: Ford (V_1)	Perry (V_2)	Clark (V_3)	Average
$2(P_1)$	$25(Q_1)$	36,68	35.20	35.75	
	$50(Q_2)$	35.83	35.50	36.22	
	$75(Q_3)$	36.15	36.22	36.63	36.02
$3(P_2)$	$25(Q_1)$	36.83	34.98	35.40	
	$50(Q_2)$	35.45	35.70	36.18	
	$75(Q_3)$	35.33	35.98	36.48	35.93
$4(P_3)$	$25(Q_1)$	34.55	36.78	35.48	
	$50(Q_2)$	34.73	35.23	36.75	
	$75(Q_3)$	35.00	34.60	34.80	35.4
Average		35.62	35.58	36.19	

	L.S.D. (5%)	L.S.D. (1%)
Within-row x Variety	1.08	1.44

Within-row x Variety

P_2V_3	P_1V_1	P_1V_3	P_2V_1	P_3V_3	P_1V_2	P_2V_2	P_3V_2	P_3V_1
36.35	36.21	36.20	35.87	35.68	35.64	35.65	35.53	34.76*

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

the oil percentage of different soybean varieties was not influenced by the various distances between and within rows that were used in this experiment.

Seed size (1000-kernel weight).

Results given in Table 4 show that soybean seed size, as determined by 1000-kernel weight, was not affected by different within-row and row-width planting treatments.

The three soybean varieties studied in this experiment had significant bearing upon size of the seed. On the average, the variety Clark produced the largest seed size, 192.9 gms. per 1000 kernels, followed by Perry and Ford, 183.9 gms. and 175.9 gms. respectively.

There was significant interaction of within-fow x variety as shown in Tables 4 and 12. The largest soybean seeds were obtained with Clark when seeds were sown two, three and four cm. in the row and the smallest seed size were in Ford when grown at the three and four cm. within-row spacing. Also, the interaction of between-row x variety was found to be significant (Table 4 and 12). The largest soybean seed size was obtained from the variety Clark when grown in 50 cm. rows, whereas the smallest seed size was developed in the variety Ford when planted in rows 50 cm. apart.

It will also be noted from Table 12 that there was significant interaction of within-row x between-row x variety in the evaluation of soybean seed size. The largest seed size

Table 3. Effect of between and within-row spacing on the percentage of oil in Ford Variety of soybean during 1963 at the AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm. 25 (Q_1)	50 (Q_2)	75 (Q_3)	Average
2(P_1)	21.38	21.35	22.13	21.62
3(P_2)	23.95	22.25	22.43	22.88
4(P_3)	24.23	21.73	22.23	22.68
Average	23.23	21.73	22.23	
Average of variety = 22.39				

Table 4. Effect of between and within-row spacing on the 1000-kernel weight of soybeans in grams during 1963 at AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm.	Variety Ford (V_1)	Perry (V_2)	Clark (V_3)	Average
$2(P_1)$	$25(Q_1)$	184.5	183.8	184.3	
	$50(Q_2)$	181.8	191.5	199.3	
	$75(Q_3)$	187.5	179.5	199.3	186.8
$3(P_2)$	$25(Q_1)$	182.0	182.0	188.5	
	$50(Q_2)$	173.5	183.5	199.3	
	$75(Q_3)$	177.3	176.8	187.5	183.4
$4(P_3)$	$25(Q_1)$	169.3	195.8	202.8	
	$50(Q_2)$	167.5	189.0	191.8	
	$75(Q_3)$	169.8	173.5	184.0	182.6
Average		175.9	183.9	192.9	

	L.S.D. (5%)	L.S.D. (1%)
Variety	2.9	3.8
Within-row x Variety	5.0	6.6
Between-row x Variety	5.0	6.6

Variety	Clark	Perry	Ford
Mean	192.9	183.9	175.9

Within-row x Variety:-

P_1V_3	P_3V_3	P_2V_3	P_3V_2	P_1V_2	P_1V_1	P_2V_2	P_2V_1	P_3V_1
194.3	192.8	191.8	186.1	184.9	181.3	180.8	177.6	168.8*

Between-row x Variety:-

Q_2V_3	Q_1V_3	Q_3V_3	Q_2V_2	Q_1V_2	Q_1V_1	Q_3V_2	Q_3V_1	Q_2V_1
196.8	191.8	190.3	188.0	187.2	178.6	176.6	174.8	174.3*

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

resulted from the combination of 4 cm x 25 cm. x Clark (202.8 gms. per 1000-kernels). The smallest size seed was obtained from the combination of 4 cm. x 50 cm. x Ford (167.5 gms. per 1000-kernels).

In all of these three interactions, when the interaction means are compared among themselves, it is noted that the soybean varieties are responsible to a much greater extent than the spacing treatments in determining the seed size. In all of these interactions Clark produced the largest seed size at any spacing treatment and Ford produced the smallest size seed with any combination of spacing treatments (Table 4). From the foregoing consideration it appears that seed size is a varietal characteristic and not affected by conventional cultural practices.

Plant height.

An examination of the data in Table 5 and 13 shows that the height of soybean plants was influenced by within-row spacings, between-row spacings, variety and interactions of within-row x between-row and between-row x variety.

There were highly significant differences among the means of within-row spacing treatments. Soybean seeds spaced four cm. apart produced the tallest plants, those planted at two cm. in the row resulted in the shortest plants, while the three cm. spaced plants were intermediate in size. These data are not in conformity with Ali (2) and Probst (26) who found very little influence of within-row spacing on plant height. Nelson and Roberts (22) reported a decrease in plant height with increase in spacing. Probst (26) found a "tendency for plants spaced fove inches apart to grow slightly shorter than when spaced closer together". Plant spacing within the row by Probst (26) and Nelson and Roberts (22) was wider than in the present study. Plants with higher spacing treatments in those experiments had opportunity to produce more branches; as a consequence apical dominance was diverted to the branches resulting in shorter plants. Plants in the four cm. within-row treatment in the writer's experiment were too close to have enough branching for diverting apical dominance and hence the plants grew taller than the plants spaced at three cm. or two cm.

Soybean plants varied greatly in plant height when planted in different row-widths as shown in Tables 5 and 13. Rows spaced at a distance of 75 cm. produced the tallest plants followed by 50 cm. and 25 cm. row-width. However, 50 cm. and 25 cm. row-width means did not differ significantly.

The mean plant height of the three soybean varieties showed significant difference among them. On the average, the variety Clark had the tallest plants, 88.6 cm. followed by Perry, 82.6 cm. and Ford, 79.2 cm. (Table 5).

There was significant interaction of within-row x between-row as shown in Table 13. The highest plant height

Table 5. Effect of between and within-row spacing on the plant height of soybeans in cm. during 1963 at the AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm.	Ford (V_1)	Variety Perry (V_2)	Clark (V_3)	Average
2(P_1)	25(Q_1)	69.8	73.0	77.5	
	50(Q_2)	81.0	76.3	84.5	
	75(Q_3)	69.5	79.3	81.0	76.9
3(P_2)	25(Q_1)	72.8	77.0	78.5	
	50(Q_2)	79.3	81.3	88.0	
	75(Q_3)	78.5	84.8	96.5	81.9
4(P_3)	25(Q_1)	85.5	98.8	93.3	
	50(Q_2)	81.0	75.8	97.3	
	75(Q_3)	95.0	97.0	100.5	91.6
Average		79.2	82.6	88.6	

	L.S.D. (5%)	L.S.D. (1%)
Within-row spacing	1.5	2.3
Between-row spacing	3.0	4.1
Variety	2.7	3.6

Within-row spacing	4 cm.	3 cm.	2 cm.
Mean	91.6	81.9	76.9
Between-row spacing	75 cm.	50 cm.	25 cm.
Mean	86.9	<u>82.7</u>	<u>80.7*</u>
Variety	Clark	Perry	Ford
Mean	88.6	82.6	79.2

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

was obtained from 4 cm. x 75 cm. spacing combination and the lowest plant height was obtained from 2 cm. x 25 cm. spacing combination. In general, it was found that plant height increased with increase in spacing both within and between-row.

The interaction of row-width x variety was found to be statistically significant (Table 13). The tallest plants were obtained when the variety Clark was planted in rows 75 cm. apart; however, Ford in 25 cm. row-width produced the shortest plants. On the average, taller plants resulted from the 75 and 50 cm. row-widths and the variety Clark and shorter plants were produced from the variety Ford with all the three between-row spacings. The variety Perry did not respond to spacing treatment as consistently as Clark and Ford.

Weight of five plants at maturity (Stem, pod and seed):

Weight of soybean plants at maturity was found to be affected significantly by both within-row and row-width spacing treatments as shown in Tables 6 and 14.

The mean weight of soybean plants from within-row spacing treatments differed significantly (Table 6). Seeds spaced four cm. apart produced the heaviest plants and those having two cm. distance between them produced the lightest plants. The three cm. spacing treatment produced plants with medium weight.

A survey of Table 6 shows that there were highly significant differences among the means of the weight of soybean plants grown in 25, 50 and 75 cm. row-widths. Plants in the 75 cm. rows were the heaviest and those in 25 cm. rows were the lightest. The average weight of the plants obtained from the 50 cm. row was intermediate to that from the 25 and 75 cm. rows.

It is evident from the results that the weight of soybean plants at maturity increased consistently with increase in spacing both within and between rows. A possible explanation for higher weight of plants in the wider spacing treatments may be the greater amount of nutrients and moisture available to these plants and more room for branching than for the plants in the narrow spacing treatments.

A significant interaction of within-row spacing x between-row spacing x variety was obtained as shown in Table 14. The heaviest plants were produced when the variety Clark was grown in 4 cm. x 75 cm. spacing combination and the lightest plants were obtained when Ford was grown in the minimum spacing both within and between rows i.e. two cm. x 25 cm. In general, the three soybean varieties reacted uniformly to the spacing treatments i.e. the higher plant weights were associated with the wider spacings.

Number of seeds per pod.

There was no significant effect of within-row and between-row spacings on the number of seeds per pod in the soybeans as shown in Tables 7 and 15. These findings are in

Table 6. Effect of between and within-row spacing on the weight in gms. of five plants of soybeans at maturity (stem, pod and seed) during 1963 at the AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm.	Variety Ford (V_1)	Perry (V_2)	Clark (V_3)	Average
2(P_1)	25(Q_1)	84.3	123.5	99.8	
	50(Q_2)	129.8	120.8	150.3	
	75(Q_3)	192.8	190.5	165.2	139.6
3(P_2)	25(Q_1)	140.3	144.3	101.8	
	50(Q_2)	171.8	132.8	180.0	
	75(Q_3)	214.3	177.6	172.8	159.5
4(P_3)	25(Q_1)	104.8	108.8	155.0	
	50(Q_2)	273.8	199.3	174.8	
	75(Q_3)	194.8	197.5	345.5	194.8
Average		167.4	155.0	171.6	

	L.S.D. (5%)	L.S.D. (1%)
Within-row spacing	41.16	62.35
Between-row spacing	29.70	40.79

Within-row spacing	4 cm.	3 cm.	2 cm.
Mean	194.8	159.5	139.6*

Between-row spacing	75 cm.	50 cm.	25 cm.
Mean	205.64	170.25	118.03

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

agreement with Ali (2), but contrary to the results obtained by Lehman and Lambert (18) who reported that seeds per pod increased slightly but consistently as spacing was increased.

The three varieties of soybeans differed significantly for the number of seeds per pod (Table 7). Ford, on the average had the highest number of seeds per pod i.e. 2.7 and Clark and Perry had 2.6 and 2.4 seeds per pod, respectively. From the results it appears that the number of seeds per pod is a varietal characteristic.

Number of days from planting to flowering.

A perusal of the results presented in Table 8 and 16 reveals that the number of days from planting to flowering in soybeans was affected significantly by spacings both within and between rows, the varieties and interactions such as within x between rows, within-row x variety and between row x variety.

Among the within-row spacing treatments, plants spaced three cm. apart required the maximum number of days to flower.

In the case of distance between rows the treatment with 50 cm. between rows recorded the maximum period from planting to flowering. Plants in the 75 cm. between-row treatment required significantly less number of days from both 25 and 50 cm. spacings between-rows. These results indicate that there is a trend of hastening maturity with wider spacing between rows.

The differences in the number of days from planting

Table 7. Effect of between and within-row spacing on the number of seeds per pod of soybeans during 1963 at the AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm.	Variety Ford (V_1)	Perry (V_2)	Clark (V_3)	Average
2(P_1)	25(Q_1)	2.7	2.3	2.5	
	50(Q_2)	2.6	2.4	2.6	
	75(Q_3)	2.7	2.4	2.7	2.53
3(P_2)	25(Q_1)	2.6	2.5	2.5	
	50(Q_2)	2.7	2.4	2.7	
	75(Q_3)	2.7	2.5	2.6	2.59
4(P_3)	25(Q_1)	2.7	2.4	2.5	
	50(Q_2)	2.6	2.5	2.6	
	75(Q_3)	2.7	2.4	2.6	2.54
Average		2.7	2.4	2.6	

	L.S.D. (5%)	L.S.D. (1%)
Variety	0.08	0.10

	Ford	Clark	Perry
Variety Mean	2.7	2.6	2.4

Table 8. Effect of between and within-row spacing on the number of days from planting to flowering of soybeans during 1963 at the AUB Agricultural Research and Education Center.

Within-row spacing in cm.	Between-row spacing in cm.	Variety Ford (V_1)	Perry (V_2)	Clark (V_3)	Average
2(P_1)	25(Q_1)	48.5	56.5	58.0	
	50(Q_2)	48.0	57.3	59.0	
	75(Q_3)	46.8	56.5	58.5	54.3
3(P_2)	25(Q_1)	47.5	57.5	59.8	
	50(Q_2)	48.5	57.0	60.5	
	75(Q_3)	47.3	58.8	61.3	55.3
4(P_3)	25(Q_1)	47.0	57.8	60.8	
	50(Q_2)	48.3	57.0	59.8	
	75(Q_3)	47.0	54.8	59.8	54.7
Average		47.7	57.0	59.7	

	L.S.D. (5%)	L.S.D. (1%)
Within-row spacing	0.33	0.50
Between-row spacing	0.40	0.55
Variety	0.14	0.19

Within-row spacing	3 cm.	4 cm.	2 cm.
Mean	55.3	54.7	54.3

Between-row spacing	50 cm.	25 cm.	75 cm.
Mean	<u>55.0</u>	<u>54.7</u>	54.0*

Variety	Clark	Perry	Ford
Mean	59.7	57.0	47.7

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

to flowering is more spectacular in the varieties than in any other treatment. The variety Ford flowered about 9 and 12 days earlier than Perry and Clark, respectively.

There were significant interactions of within-row x between-row, within-row x variety, between-row x variety and within-row x between-row x variety as shown in Table 16. Even though the interactions are statistically significant and the fact that very small differences were found in row-width and within-row spacing treatments, these have no practical significance.

SUMMARY AND CONCLUSIONS

This study involved the effect of plant populations and spacing treatments in three soybean varieties on seed yield, protein content, oil content, seed size, plant height, weight of plant at maturity (stem, pod and seed), number of seeds per pod and number of days from planting to flowering. The three soybean varieties were Ford, Perry and Clark. The within-row spacings were two, three and four cm. and the between-fow spacings were 25, 50 and 75 cm.

Seed yields were highest when the distance between the rows was 25 and 50 cm. and the lowest seed yields resulted from rows spaced 75 cm. apaft. Higher seed yields from closer spacings may have resulted from more plants per unit area and more efficient use of nutrients and moisture than the wider spacings. The three soybean varieties differed slightly in seed yields but the differences are not statistically significant. The two, three and four cm. within-row spacings did not influence the seed yield of soybeans.

Protein percentage of soybeans was not affected by the different plant populations as obtained by planting the seed at varying distances within and between rows. The variety Clark contained the highest percentage of protein and Perry had the lowest protein content.

The various within-row and row-width spacings did not have any significant influence on the oil content of the soybean variety Ford. The variety averaged 22.39 percent oil.

Soybean seed size was not affected by the different spacings within and between rows. The variety Clark produced the largest seed size and the smallest size seed was obtained from the variety Ford.

Plant height in soybeans was materially affected by spacing variations between and within-rows. The tallest plants were obtained when the varieties were planted at 4 cm. x 75 cm. spacings and the shortest plants were obtained from spacings of 2 cm.x 25 cm. The mean plant height of the three soybean varieties showed significant differences among them. The variety Clark had the tallest plants, 88.6 cm. followed by Perry, 82.6 cm. and Ford 79.2 cm.

The within-row and row-width spacings had significant bearing upon the weight of soybean plants at maturity. Seeds spaced four cm. apart produced the heaviest plants and those having two cm. distance between them produced the lightest plants. Plants in the 75 cm. rows were the heaviest and those in 25 cm. rows were the lightest. It is evident that the weight of soybean plants at maturity increased consistently with increase in spacing both within and between rows. The mean weight of plants at maturity of the three varieties did not differ significantly.

There was no significant effect of within-row and between-row spacings on the number of seeds per pod in the soybeans. But the three varieties of soybeans differed significantly for the number of seeds per pod. Ford had the highest and Perry had the lowest number of seeds per pod. From the results it appears that the number of seeds per pod is a varietal characteristic.

Number of days from planting to flowering was influenced by the spacing treatments and variety. Among the within-row spacing treatments, plants spaced three cm. apart required the maximum number of days to flower. The treatment with 75 cm. between rows required significantly less number of days from both 25 and 50 cm. spacing treatments. The differences in the number of days from planting to flowering was more spectacular in the varieties than in any other treatment. The variety Ford flowered about 9 and 12 days earlier than Perry and Clark, respectively. The small differences resulting from spacing within and between rows on the number of days from planting to flowering do not seem to have any practical significance.

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APPENDIX

Table 9. Analysis of variance of seed yield of soybeans.

Source	D.F.	M.S.	F.
Block	3	41936.0	12.38
Within-row spacing	2	1737.0	N.S.
Error (a)	6	3385.2	
Between-row spacing	2	16893.0	9.42 **
Within-row x Between-row	4	2208.3	N.S.
Error (b)	17†	1792.7	
Variety	2	5198.0	N.S.
Within-row x Variety	4	2026.0	N.S.
Between-row x Variety	4	3189.5	N.S.
Within-row x Between-row x Variety	8	4305.1	N.S.
Error (c)	54	47028.9	

** significant at the 1 percent level.

† I d.f. has been removed because between-row spacings were not randomized due to irrigation problems.

Table 10. Analysis of variance for protein percentage in soybeans.

Source	D.F.	M.S.	F.
Block	3	2.93	N.S.
Within-row spacing	2	5.15	N.S.
Error (a)	6	7.87	
Between-row spacing	2	0.25	N.S.
Within-row x Between-row	4	1.68	N.S.
Error (b)	17≠	1.64	
Variety	2	2.80	N.S.
Within-row x Variety	4	5.30	3.05 *
Between-row x Variety	4	1.12	N.S.
Within-row x Between-row x Variety	8	3.86	2.22 *
Error (c)	54	1.74	

* significant at 5 percent level.

≠ I d.f. has been removed because between-row spacings were not randomized due to irrigation problems.

Table 11. Analysis of variance for oil percentage in soybeans.

Source	D.F.	M.S.	F.
Block	3	24.93	7.02
Within-row spacing	2	5.55	N.S.
Error (a)	6	3.55	
Between-row spacing	2	7.00	N.S.
Within-row x Between-row	4	2.95	N.S.
Error (b)	17≠	2.47	

≠ I d.f. has been removed because between-row spacings were not randomized due to irrigation problems.

Table 12. Analysis of variance for seed size (1000-kernel weight).

Source	D.F.	M.S.	F
Block	3	119.3	N.S.
Within-row spacing	2	181.5	N.S.
Error (a)	6	280.8	
Between-row spacing	2	370.5	N.S.
Within-row x Between-row	4	202.8	N.S.
Error (b)	17≠	244.0	
Variety	2	2621.0	70.46 **
Within-row x Variety	4	210.0	5.65 **
Between-row x Variety	4	159.8	4.30 **
Within-row x Between-row x Variety	8	328.9	8.80 **
Error (c)	54	37.2	

** significant at the 1 percent level.

≠ I d.f. has been removed because between-row spacings were not randomized due to irrigation problems.

Table 13. Analysis of variance for plant height of soybeans.

Source	D.F.	M.S.	F
Block	3	35.33	5.05 *
Within-row spacing	2	2011.00	287.29 **
Error (a)	6	7.00	
Between-row spacing	2	362.50	9.97 **
Within-row x Between row	4	317.00	8.72 **
Error (b)	17≁	36.35	
Variety	2	828.00	25.58 **
Within-row x Variety	4	8.50	N.S.
Between-row x Variety	4	138.50	4.22 **
Within-row x Between-row x Variety	8	32.38	N.S.
Error (c)	54	32.85	

* significant at the 5 percent level.

** significant at the 1 percent level.

≁ I d.f. has been removed because between-row spacings were not randomized due to irrigation problems.

Table 14. Analysis of variance for weight of five plants at maturity.

Source	D.F.	M.S.	F
Block	3	11173.3	N.S.
Within-row spacing	2	28111.0	5.52 *
Error (a)	6	5094.8	
Between-row spacing	2	69931.5	19.62 **
Within-row x Between-row	4	4876.0	N.S.
Error (b)	17≁	3564.1	
Variety	2	2683.5	N.S.
Within-row x Variety	4	4762.3	N.S.
Between-row x Variety	4	3991.0	N.S.
Within-row x Between-row x Variety	8	12794.5	3.78 **
Error (c)	54	3381.6	

* significant at the 5 percent level.

** significant at the 1 percent level.

≁ I d.f. has been removed because between-row spacings were not randomized due to irrigation problems.

Table 15. Analysis of variance for number of seeds per pod in soybeans.

Source	D.F.	M.S.	F
Block	3	0.017	N.S.
Within-row spacing	2	0.035	N.S.
Error (a)	6	0.010	
Between-row spacing	2	0.055	N.S.
Within-row x Between-row	4	0.005	N.S.
Error (b)	17≠	0.018	
Variety	2	0.525	19.44 **
Within-row x Variety	4	0.015	N.S.
Between-row x Variety	4	0.025	N.S.
Within-row x Between-row x Variety	8	0.025	N.S.
Error (c)	54	0.027	

** significant at the 1 percent level.

≠ I d.f. has been removed because within-row spacings were not randomized due to irrigation problems.

Table 16. Analysis of variance for number of days from planting to flowering in soybeans.

Source	D.F.	M.S.	F
Block	3	1.00	N.S.
Within-row spacing	2	9.50	28.79 **
Error (a)	6	0.33	
Between-row spacing	2	2.50	3.85 *
Within-row x Between-row	4	4.00	6.15 *
Error (b)	17≁	0.65	
Variety	2	1441.50	16016.67 **
Within-row x Variety	4	4.75	52.80 **
Between-row x Variety	4	1.75	19.44 **
Within-row x Between-row x Variety	8	6.13	68.11 **
Error (c)	54	0.09	

* significant at the 5 percent level.

** significant at the 1 percent level.

≁ I d.f. has been removed because between-row spacings were not randomized due to irrigation problems.