THE EFFECT OF VARIETY AND DATE OF PLANTING ON YIELD AND OTHER CHARACTERISTICS OF SOYBEANS

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SOYBEAN STUDIES

BADAWI

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Title: Effect of date of planting and variety on yield and other agronomic characteristics of soybeans.

An experiment was conducted in 1965 at the Agricultural Research and Education Center in the Beqaa Plain, Lebanon, to study the effect of four planting dates on four varieties of soybeans with respect to yield, seed compositional characteristics and other agronomic traits.

Highest seed yields and total dry weight, considering all the varieties tested, were obtained from the first planting date (April 10) and decreased successively thereafter. Number of days from planting to flowering and to maturity was reduced as the date of planting was delayed from April 10 to May 18. Number of pods per plant, number of seeds per pod and size of the seeds were only slightly affected by dates of planting.

Varieties differed appreciably in protein and oil content of the seed. Protein content increased while the oil content decreased with lower seed yields or delayed planting. The variety Clark produced the highest seed yield with the lowest protein and highest oil content of the seed. Wabash, one of the later maturing varieties, produced the lowest yield, the smallest seed, with the lowest oil content. The highest total dry weight was produced by Perry which had the smallest number of seeds per pod. Lindarin, the earliest variety, was second in seed yield, and produced the lowest amount of total dry weight.

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INTRODUCTION

Growing threats of violence in overpopulated areas of the world, triggered mainly by outbreaks of hunger as a consequence of adverse climatic cycles, inefficiency of production methods and materials, and shortages of distribution, make it imperative for research to find new crops and procedures to solve the basic problems of higher crop production. These include the development of more efficient cultural methods, better adapted varieties, and a greater understanding of the underlying principles of agricultural production.

The soybean (Glycine max), with an average of 21 per cent oil and 40 per cent protein content (32, pp. 149-152), serves a great potential in providing these basic nutrients for human diet and animal feeds. The high protein content of the soybean and its oil of high energetic value and complete digestibility (35, pp. 384-387) partly account for the rapid spread of its production in the world. Soybean meal now supplies nearly 56 per cent of the protein concentrate in the United States. Some eighteen amino acids containing about 95 per cent of the protein nitrogen are reported in soybean protein by Block and Weiss (30, pp. 300-301). Soybean oil is used mainly for food purposes, but it is also used in several

industrial products. Soybeans now supply 35 per cent of the total fats and oils produced in the United States, the principal uses of the oil being in margarine and shortening. Other uses include paints, varnishes, and other drying oil products.

The origin and early history of the soybean, being one of the oldest cultivated crops, is rather vague, only occasionally touched upon in old Chinese literature. The first written record of the plant in China dates back to 2038 B. C. (51, pp. 78-79). It was then considered one of five crops at the foundation of Chinese civilization.

Interest in the soybean plant in Europe and the United States has been limited to private collectors, botanical gardens, and experimental stations until the end of the 19th century when shipments were first made to Europe from Japan in 1908 following the Russo-Japanese War (36, pp. 6-7). In a relatively short period of less than a quarter century soybean production expanded in the Western Hemisphere to occupy the first place among the oil seed crops. Since the World War II practically all the leading nations have become more interested in the culture and production of the crop.

Many developments have contributed to the rapid increase in world soybean production, among these is a steady expansion in the market for soybean oil and meal. Research on production problems and development of superior varieties

by breeding have increased the efficiency of production. Complete mechanization of production from seeding to harvesting and processing has contributed its own share. Finally, the soybean culture has expanded horizontally to occupy additional areas thus partially displacing otherc crops. During the period 1949-1960 soybean acreage in the United States increased 124 per cent while the acreage of other crops decreased. The decrease in cotton was 44 per cent, in wheat 31 per cent, in oats 28 per cent, and in corn four per cent (12).

Soybeans can be grown satisfactorily on a wide diversity of soils and climates. The plant has been considered (36) a better forager on poor soil and under adverse conditions than corn. Today the plant breeders have pushed profitable soybean culture to areas that were considered a few years back as unadapted, or at best marginal. Minimum climatic requirements for soybean production, according to Weiss (51, pp. 80-83), are a 5-month growing period during which a total warmth of 2400° C - days and total precipitation of 300 mm are attained.

The cultivated soybean, Glycine max, is thought by many investigators to have been derived from Glycine ussuriensis, which grows wild throughout much of eastern Asia (32). The change from the wild species to the cultivated species is thought to have occured through gene mutation unaccompanied by any change in the chromosome number. A

plant with intermediate characters between the wild and the cultivated species has been described by a Russian botanist as Glycine gracilis (36, pp. 3-4).

Although considerable experimental work has been carried out on the various aspects of soybean culture and production, mainly in the United States and Canada, much still remains to be done particularly in the field of applied research, in other countries of the world. The prospects for the growth of soybean production in the Middle East area, considering the population growth rate and the increasing need for more food and feed, and the possibility of substituting part or all of the expensive animal protein and fat with plant protein and oil, are quite encouraging.

With these prospects in mind, the present study was undertaken to evaluate the effect of different dates of planting — as a means of adjusting time of planting — on the yield and other agronomic characters of different varieties of soybeans when grown under irrigation at the Agriculture Research and Education Center in the Beqa'a Plain, Lebanon.

REVIEW OF LITERATURE

The soybean plant is highly sensitive to photoperiodism, most of the varieties being short-day plants. Each variety, however, has its own critical daylength requirement for the initiation of flowering and pod formation (23). Inasmuch as daylength, together with temperature, determine the flowering date they also determine the stage of vegetative development at flowering when the plant shifts to reproductive activity. Varied dates of planting, therefore, become important considerations in adjusting plants to fit the environmental conditions under which they develop and mature. This fact was recognized early by Garner et al. (22).

General Environmental Factors

The importance of time of planting soybeans was stressed by Cartter and Hartwig (12) who found no single factor more important to soybean production than the planting date. Johnson et al. (31) noted that soil temperature and daylength determine the best time to plant soybeans. Morse (36, pp. 14-15) stated a particular variety is best adapted to a narrow strip of latitude. In a review of literature, Weiss (51, pp. 80-83) concluded that minimum climatic requirements for soybeans are a 5-month growing period with a total accumulated temperature of 2400° C and a total

precipitation of 300 mm.

The threshold for soybean germination and growth was found by Brown (8) and Brown and Chapman (9) to be at 50° F. Howel (30) obtained minimum germination time at 86° F.

Studying soybean competition with weeds, Robinson and Duncan (40) observed that plantings made late in June were less weedy at maturity than earlier plantings.

Howel (30) noted that most of the soybean root system is in the upper two feet of soil and that the total and the distribution of cation uptake varies with root temperature.

Runge and Odel (41) studying the effect of environmental factors suggested that soybeans have critical stages in their development when they are more responsive to moisture and temperature conditions, hail, mechanical damage and chemical injury. Howel (30) found soybeans to be fairly resistant to injury by temperature extremes. They were also found less susceptible to frost than corn, cowpeas, and field beans and to withstand high temperatures very well, although growth rate declined above 100° F. This was in agreement with the findings of Garner and Allard (23).

Time of planting soybeans in differnt countries was adequately discussed by Morse (31, pp. 32-33). In the United States he reported the time of planting to extend from early spring until mid-summer depending on the variety, latitude, and purpose.

Yield

Yields and maturity dates of several varieties of soybeans planted at different times in the Mississippi area were reported by Henson and Carr (26). Yields from plantings made several dates prior to early June were not significantly different, whereas, yields from plantings later than June were much reduced.

Feaster, (21) studying the performance of five soybean varieties, found that maximum yields were obtained from late - maturing varieties. Smith et al. (46), Osler and Cartter (38), Torrie and Briggs (48), Abel (1), and Camper and Smith (11) confirmed Feaster's findings. Dimmock and Warren (17), working near Ottawa, found that for each additional delay in planting date from May 19, there was a corresponding reduction in yield.

Uklein (49) obtained best conditions for plant growth and high yield in the Volga delta area when soil moisture was maintained at 80 per cent of the field moisture capacity throughout the vegetative period.

Lehman and Lambert (34) obtained significantly higher seed yields from Mandarin and Blackhauk varieties at 20-inch spacing than at 40-inch.

The effect of weed infestation on the growth and yield of soybeans was investigated by Staniforth (46) under four conditions of controlled soil moisture. Yield reduction of four bushels per acre due to competition occurred when the

moisture was limiting toward the later part of the growing season. Yield reductions of 3.7 bushels per acre due to competition with weeds were also obtained by Staniforth and Webber (47).

Dry Weight

The number of nodes and stem weight were found by Howel and Cartter (29) to increase with an increase in temperature.

Dry weight production of Dunfield and Manchu varieties was found by Earley and Cartter (18) to be restricted at root temperatures as low as 12° C and as high as 37° C.

Increases in dry weight of Biloxi soybeans were obtained by Garner and Allard (24) and Parker and Borthwick (39) when the photoperiod was increased from 8 to 13 hours.

Oil and Protein

The effect of environment on the soybean seed compositional characteristics has been studied extensively by many workers. Only studies pertaining to the effect of varying planting dates on protein and oil content of the seed will be reviewed. Performance of five soybean varieties planted at different dates was reported by Feaster (21). Oil content of beans for each variety was found highest at the date of planting giving maximum yields. Protein content was found to vary inversely with oil content, the lowest protein content

being at the planting dates giving maximum yields. Osler and Cartter (38) confirmed Feaster's findings.

Torrie and Briggs (48) working with five varieties planted at four dates stated that protein content showed no tendency to decrease with delay in planting, while Dimmock and Warren (17) observed that delayed planting tended to increase protein content of the seed.

Differences in oil and protein content with respect to position of the seed in the pod were observed by Collins and Cartter (16). Irrigation was found by Schwab et al. (43) to decrease oil content of soybeans in Iowa by four per cent and to increase protein content by 3.3 per cent.

Howel and Cartter (29) obtained oil contents of 23.2 per cent, 20.8 per cent and 19.5 per cent at day temperatures of 85, 77, and 70° F, respectively, during the pod filling stage.

Garner et al. (22) stated that the production of oil by the plant requires "favorable conditions for the accumulation of carbohydrates into oil during the second period".

Weiss (51) obtained variations in oil and protein content from the same variety ranging from 12.7 to 22.1 per cent and from 32.6 per cent to 44.3 per cent for the oil and protein content, respectively, when grown at different locations. In the same location, oil and protein percentage differed by 2.9 and 4.2 per cent, respectively, indicating predominance of the climatic influence.

Flowering and Maturity

It has been recognized by many workers that flowering and pod formation are greatly influenced by photoperiodism, and to a lesser extent by thermoperiodism. While most soybean varieties are known to be short-day plants, varieties differ in their light period requirement.

The period from germination to flowering of four varieties of soybeans grown near Washington, D.C., ranging from 27 to 105 days, was reduced by Garner and Allard (25) to 25 days when daylight was shortened to 12 hours. The blossoming time of the earliest variety was reduced only slightly, whereas that of the later variety, Biloxi, was reduced to about one fourth. This was in agreement with the findings of Weiss (51) and Brown and Owen (10).

Parker and Borthwick (39) found that soybeans with flower primordia initiated upon them when transfered to photoperiods of 8 to 13 hours, blossomed and produced fruit. Flowering under 14 to 15 hours photoperiod was later and no fruits were formed, whereas, no flowers formed under 16 to 18 hours. The same workers (7), however, working with 13 varieties of soybeans grown under nine different photoperiods, found that some varieties initiated flower primordia on all photoperiodic treatments employed.

Abel (1) found that number of days to flowering was not affected by planting time of the earliest variety, but was reduced substantially in successive plantings of later

varieties. In contrast the number of days from flowering to maturity of the latest variety was essentially the same, but this period was greatly reduced by delayed planting of the earliest varieties.

Light intensity is another factor affecting initiation of flowering. Borthwick and Parker (6) observed that when whole plants of Biloxi soybeans are subjected to eight hours photoperiod, flower initiation occurs if the intensity of light is above 100 foot-candles. They suggested a hormone to be manufactured in the leaves and translocated to stimulate flower initiation.

Garner and Allard (23), Borthwick and Parker (7) and Vanschaik and Probst (50) studied flowering behavior in varieties ranging in maturity from group 0 (early) to VIII (late). These studies have shown that in general the earlier the variety matures, the longer the photoperiod on which floral initiation can occur. Varieties of group 0 to III may initiate primordia even on a 24-hour photoperiod (continuous light).

Working with five soybean varieties planted at 20-day intervals from April 20 to July 10, Feaster (21) found that early maturity can be obtained only by planting early maturing varieties at an early date; whereas, early planting of full-season varieties only slightly advances the maturity date. This was confirmed by Osler and Cartter (38).

Torrie and Briggs (48), on the other hand, working in

Wisconsin with five varieties of soybeans planted at four different dates during five years found maturity date for all varieties was retarded approximately one day for each two days delay in planting.

Varying the ratio of light to darkness in a 24-hour and a 36-hour cycles, Allard and Garner (3) found the time of flowering of Peking soybean was dependent both on the ratio of light to darkness and the length of the cycle. Brown (8) and Johnson and Bernard (32) found the number of days to flowering of soybeans to be directly related to the length of the dark period, although other factors such as temperature, nutrition, light intensity and quality influence the response.

Temperature is another factor affecting the period to flowering and maturity. Garner and Allard (25) found a close correlation between the length of the preflowering stage of growth with the mean temperature. In each variety the minimum vegetative period corresponded to the highest mean temperature of mid-summer. Borthwick and Parker (4) found the influence of temperature on flower initiation to be greater during the dark period. Brown and Chapman (9) plotted rate of development against air temperature and found that the minimum temperature for soybean development was 50° F, optimum near 86° F and maximum at 90° F. Above 90° F the growth curve starts dropping. The same workers developed a formula by which they divided the Great Lakes Region into zones defined by number of soybean development units (S.D.U.) available for

maturing soybeans.

Plant Height

Date of planting affects the ultimate plant height since the soybean plants are subjected to different day-lengths, temperatures, and other conditions of growth. Garner and Allard (24) stated in this reference that there is an optimum length of day for apogeotropic growth. Any change to sub-optimal conditions will result in other forms of expression such as lateral growth and rosetting. The same workers (23) observed that exposure to a length of day unfavorable to reproduction but favorable to growth tended to produce gigantism or indefinite vegetative development.

Osler and Cartter (38) obtained maximum plant height from the first date of planting (May 1) and it decreased progressively with delay in planting thereafter. Torrie and Briggs (48), Garner and Allard (25), Weiss et al. (52), and Abel (1) confirmed the results of Osler and Cartter. Caviness and Smith (14, pp. 18-19) on the other hand, stated that a reduction in plant height was associated with extremely early planting. This was attributed to a slower growth rate resulting from low soil temperatures and too early flowering under short-day conditions.

VanSchaik and Probst (50) noted that Clark and other Midwest varieties grew slowly and remained underdeveloped when kept at 60 and 70° F and at a 12-hour photoperiod. At

temperatures of 80 and 90° F and photoperiods of 14, 16, and 20 hours, plants grew faster and to a greater final plant height. Johnson and Bernard (32) found a negative correlation between height and earliness.

Number of Pods and Seeds Per Plant

The number of pods per plant was found by Lehman and Lambert (34) to increase markedly as spacing between rows increased from 20-inches to 40-inches. The number of seeds per pod increased slightly but consistently as spacing between rows was increased.

Howel and Cartter (29) found that the number of pods per plant and the number of seeds per pod were not significantly affected by increasing temperature from 70 to 85° F.

Osler and Cartter (38) found seed weight was not appreciably affected by delay in planting although a difference between varieties in this respect was observed. Abel (1) found seed size was not affected by planting dates from early May to the end of June.

Working with two varieties of soybeans, Dimmock and Warren (17) found reduction in yield, resulting from delayed planting, was not accompanied by a corresponding reduction in 1000-seeds weight indicating that yield losses resulted from a reduction in number rather than size of seed.

No appreciable association was found by Weiss et al. (52) between seed size and oil and protein content.

Lodging

Abel (1) found lodging decreased as the planting date was delayed. Osler and Cartter (38), on the other hand, stated that delay in planting was associated with a greater degree of lodging. Torrie and Briggs (48) stated that the date of planting had no effect on lodging. A negative correlation between height and lodging resistance was obtained by Johnson and Bernard (32).

MATERIALS AND METHODS

The data reported were collected from an experiment on planting dates of soybeans carried out in 1965 at the Agricultural Research and Education Center of the American University of Beirut located in the Beqaa Plain, Lebanon.

The experiment consisted of four varieties of soybeans: Lindarin, Wabash, Clark and Perry, each variety planted at four different dates in the spring. The varieties were chosen from among several others tested over a number of years in the soybean variety trials (53) at the Agriculture Research and Education Center. Lindarin is an early maturing variety derived from a cross between Mandarin and Lincoln (4, 5). It has been regarded as a high yielder with a relatively high oil content of the seed. It is resistant to downy mildew and phytophthora root rot diseases (4). Clark is another high yielding variety with seed of a high protein and oil content developed from a backcross of Lincoln x (Lincoln x Richard) by L. F. Williams (37). Perry and Wabash were classified as early maturing varieties (13, 14, 15, pp. 8-12, 37) but in the Beqaa Plain they are medium in maturity.

The performance of all these varieties at the Agricultural Research and Education Center over several years

has been satisfactory, although considerable variation in yield and moderate fluctuations in earliness from year to year have been observed.

Soil temperature and daylength determine the best time to plant soybeans. The average monthly temperature and rainfall data from March to October of 1965, as recorded at the Agricultural Research and Education Center, and the average of 10 years, from 1956 to 1965, are presented in the appendix (Table 11).

Plantings of each variety were made on four different dates at approximately 15-day intervals starting when the soil condition of moisture and temperature at the 5 cm depth were considered favorable enough for rapid germination and emergence of the seed. Plantings of all four varieties were made on April 10, April 24, May 8, and May 18.

The soils of the central Beqaa Plain have been characterized by Salib (42, pp. 65-66) as of a fine texture, alkaline in reaction and calcar ous, fairly low (0.08 — 0.18%) in total nitrogen and low to medium (2.03 - 4.62%) in organic matter content. They have been considered variable in available phosphorus (6.70 - 53.12 p.p.m.), adequate in exchangeable potassium, and of a high cation exchange capacity with a pH of about 8.

Treatment of the experimental plots prior to seeding consisted of a uniform application of 12 kg of nitrogen in the form of granulated ammonium sulfo-nitrate (26.5% N) and

20 kg of P_2O_5 in the form of superphosphate (18% P_2O_5) per dunum, disked into the soil before planting. Additional nitrogen at the rate of 4 kg per dunum was applied as a side dressing early in August. Seeding was done by a V-belt planter that spaced the seed about 3 cm in the row at a depth of 4 cm.

The experiment was laid out in a Latin square design for the dates of planting as the main treatments and the varieties were super-imposed as sub-plots of the individual dates in a randomized complete block pattern. Each sub-plot was made up of four rows, five meters long and 50 cm apart. On the basis of germination percentage determined by a laboratory test, the seeding rate was adjusted to obtain a uniform stand of about 165 plants per row. Inoculation of the seed with a commercial inoculum was done immediately before planting.

The plots were irrigated at first with sprinklers for uniform seed imergence and seedling establishment. After the plants were about 15 cm tall, furrow irrigation was maintained at weekly intervals through-out the growing season. The plots were weeded by hand hoes. Cutworms appeared on the second date of planting but were promptly controlled by the application of heptaclor.

Data were collected for each of the following characteristics: flowering and maturity date, plant height, lodging score, seed yield, seed size, and protein and oil percentages of the seed. Dates of flowering and maturity

were recorded at the 50 per cent blooming stage and when 90 to 100 per cent of the pods had ripened, respectively. For the determination of average height, average number of pods per plant, and average number of seeds per pod, four plants were selected at random from each sub-plot at full maturity.

Yield and total dry weight, calculated to a dunum[1] basis, were obtained from the central two rows of each sub-plot leaving one-half meter on each end to eliminate border effect. The total dry weight including pods, stems, and some unshed leaves was recorded one month after harvesting after it was sun-cured.

Protein and oil percentage are reported on a dry weight basis. A representative sample from each sub-plot was oven-dried at 70° C for 72 hours, ground to pass through a fine mesh screen in a Wiley grinding mill, and weighed to the 4th decimal on a Mettler balance for analysis. Protein percentage was determined by the modified Kjeldal method (27, pp. 12-13). The dry extraction method, which involves continuous extraction by an ether solvent of a dry, finely ground meal, was followed in the determination of oil content (28, p. 287).

Statistical treatment of the data consisted of conducting an analysis of variance for each character. Statistical methods appropriate to the Latin square split-plot design were used (45). Lindarin and April 10 were used as controls.

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1. dunum = 1000 square meters.

RESULTS AND DISCUSSION

The experiment was carried out in order to evaluate the effect of different dates of planting on four adapted varieties of soybeans as measured by their seed yield, total dry weight, protein and oil content of the seeds, plant height, number of days to flowering and maturity, number of pods per plant and number of seeds per pod, and the test weight of the seeds. The data are presented, together with the analysis of variance, in tables 1 through 9 on the above mentioned characters. The L.S.D. values at the five per cent and one per cent levels are shown below each table for those treatments found to be significant.

Grain Yield

The seed yields for the four varieties of soybeans as affected by different planting dates appear in Table 1. Differences in mean seed yields of soybeans from the various planting dates were found not to be statistically significant This was in agreement with the findings of Henson and Carr (26). Each variety, however, produced its highest yield on the first date of planting (April 10) and its lowest yield on the third date of planting (May 8), except Lindarin which gave its lowest yield on the second planting date (April 24), then maintained its original yield over the third and fourth

Table 1. Average seed yield of soybeans in kg per dunum as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	247.6	189.6	238.3	237.5	228.2
Wabash	218.0	194.9	175.9	185.6	193.6**
Clark	258.3	269.8	216.3	242.1	246.6**
Perry	229.4	219.0	191.4	221.3	215.3
Mean	238.3	218.3	205.5	221.6	

**Denotes difference significant at the 1% level.

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	1412.05	0.84		
Columns	3	4594.78	2.74		
Dates	3	3313.46	1.98	35.43	53.67
Error (a)	6	1677.02			
Varieties	3	1834.15	4.03*	15.71	21.07
Dates x varieties	9	1327.43	2.92*		
Error (b)	36	455.29			

* Denotes F values significant at the 5% level.

planting dates.

Varieties responded differentially to varied dates of planting. Reduction in yield due to delayed planting was greatest in Wabash (32 kg per dunum) and least in Perry and Lindarin (8 and 10 kg per dunum, respectively).

Significant differences in seed yields of the four varieties were obtained. Clark and Lindarin produced the highest yield at all planting dates except on April 24 where Lindarin yielded less than Perry and Wabash. The highest seed yield was obtained from Clark (246.6 kg per dunum) and the lowest yield was obtained from Wabash (193.6 kg per dunum). Lindarin and Perry did not vary significantly in seed yield.

Total Dry Weight

Significant differences in the total dry weight of soybeans were obtained on the various dates of planting as shown in Table 2. The highest yields in total dry weight of 770 kg per dunum were obtained from the first date of planting made on April 10. This was in agreement with the findings of Farhaduddin (20). There was a reduction in yield of dry matter with successive delays in planting dates. Daylength and temperature unfavorable for flowering during the early part of the growing season, yet favorable for vegetative growth, might have r esulted in the production of a greater amount of total dry matter. With the initiation

Table 2. Average total dry weight (stems, pods, and seeds) of soybeans in kg per dunum as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	635.2	521.4	585.6	561.4	575.9
Wabash	796.2	694.6	714.6	657.9	715.8**
Clark	808.6	748.7	774.2	629.3	740.2**
Perry	838.9	850.6	706.3	711.8	777.1**
Mean	770.0	703.8	695.2*	640.1**	

* Denotes difference significant at the 5% level.
**Denotes difference significant at the 1% level.

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	21993.02	3.29*		
Columns	3	48436.52	7.24		
Dates	3	45298.62	6.77	71.65	107.23
Error (a)	6	6693.40			
Varieties	3	123477.90	161.69**	19.83	26.60
Dates x Varieties	9	8847.16	11.58**		
Error (b)	36	763.65			

* Denotes F values significant at the 5% level.
**Denotes F values significant at the 1% level.

of flowering vegetative growth appears to be suppressed in favor of the reproductive phase of development. Other investigators have found this to be true (1, 23, 25, 28, 48)

Varieties differed significantly in their total dry weight production as shown in Table 2. Perry produced the highest total dry weight, 777 kg per dunum, while Lindarin produced the lowest total dry weight, 576 kg per dunum. Clark and Wabash were intermediate in total dry matter production.

Protein Percentage

Mean protein percentages of soybean varieties grown at the various planting dates appear in Table 3. The first plantings made on April 10 produced seeds containing the lowest per cent of protein (32.8) while the highest protein content of 37.0 per cent was obtained from the last or May 18 plantings. The seeds from the second and third planting dates (April 24 and May 8) did not vary significantly from the last planting date with respect to protein content. Feaster (21), Osler and Cartter (38) and Dimmock and Warren (17) found that delayed planting tended to increase protein content of the seed.

Varieties differed significantly in protein content of the seed as shown in Table 3. Lindarin and Perry produced the highest protein content (36.4 and 36.3 per cent, respectively) and the lowest protein content (33.8 per cent) was

Table 3. Average percentage of protein in oven-dry seeds of soybeans as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	33.6	36.7	37.0	38.1	36.4
Wabash	32.4	37.4	36.0	36.7	35.6
Clark	31.4	33.4	34.9	35.6	33.8**
Perry	34.0	36.6	37.2	37.4	36.3
Mean	32.8	36.0	36.3	37.0*	

* Denotes difference significant at the 5% level.
**Denotes difference significant at the 1% level.

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	32.70	1.90		
Columns	3	50.60	2.94		
Dates	3	172.10	10.00**	3.60	5.45
Error (a)	6	17.21			
Varieties	3	46.84	9.33**	1.61	2.14
Dates x varieties	9	11.30	2.25		
Error (b)	36	5.02			

**Denotes F values significant at the 1% level.

obtained from Clark which gave the highest yield. Wabash, which produced the lowest seed yield, was not significantly different in protein content from Lindarin and Perry.

No significant interaction of varieties with planting dates for protein was observed.

Oil Percentage

The percentages of oil in the soybean seeds obtained from different dates of planting are shown in Table 4. Significant differences in oil percentage of the seed were obtained from the various planting dates. The highest oil percentage (22.1 per cent) was produced on the April 10 planting date which also gave the highest seed yield. The lowest oil content of the seed was obtained from the May 8 and May 18 planting dates which also gave the lowest seed yield. This was in agreement with the findings of other investigators.(21, 38).

The varieties of soybeans differed significantly in mean oil content as shown in Table 4. Wabash, the variety with the lowest seed yield, produced seeds of the lowest oil content, 19.2 per cent, while the varieties Clark, Lindarin, and Perry, in order of decreasing seed yield, produced seeds containing 21.9, 21.0, and 20.3 per cent oil, respectively. This was in agreement with the findings of Feaster (21), and Osler and Cartter (38).

Differential performance of the varieties at varied

Table 4. Average percentage of oil in oven-dry seed of soybeans as affected by date of planting and variety in 1965.

Variety	Dates of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	23.1	20.0	20.5	20.3	21.0
Wabash	20.6	18.8	18.2	19.1	19.2**
Clark	23.1	22.5	20.7	21.4	21.9
Perry	21.6	21.2	20.2	18.2	20.3
Mean	22.1	20.6	19.9	19.8	

**Denotes difference significant at the 1% level.

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	29.53	1.87		
Columns	3	30.48	1.93		
Dates	3	42.79	2.71	1.26	1.68
Error (a)	6	15.79			
Varieties	3	32.95	10.70**	3.45	5.22
Dates x varieties	9	11.86	3.85**		
Error (b)	36	3.08			

**Denotes F values significant at the 1% level.

dates of planting for oil percentage was found to be significant.

Number of Days to Flowering

The number of days from planting to flowering of soybeans for the different dates of planting appear in Table 5. Delayed dates of planting resulted in progressively later dates of flowering for all varieties tested. Soybeans planted on April 10, April 24, May 8 and May 18 flowered on the average on July 2, 6, 12 and 17, respectively. The delay in flowering resulting from delayed planting was observed by several investigators (1, 10, 13, 14, 36, 38).

Soybean varieties planted earlier required more time to flower than those planted later. Soybeans planted on April 10 required about 83 days to flower while those planted on May 18 required only 60 days. Varieties differed in the mean number of days from planting to flowering. Lindarin required the shortest time to come to flowering (64 days) while Wabash required the longest time (74 days). This was in agreement with the findings of Farhaduddin (20). When plantings were delayed 38 days the period required from planting to flowering was reduced 20, 22, 24 and 25 days for Clark, Lindarin, Perry, and Wabash, respectively. Although the varieties responded differentially to dates of planting, the differential response was not great enough to be statistically significant.

Table 5. Average number of days from planting to flowering of soybeans as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	76.3	67.1	62.0	54.6	64.2
Wabash	88.5	77.6	68.0	63.1	74.3**
Clark	80.3	70.9	63.3	60.4	68.7*
Perry	86.3	76.1	68.4	62.3	73.3**
Mean	82.8	72.9**	65.4**	60.1**	

* Denotes differences significant at the 5% level
**Denotes differences significant at the 1% level

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	192.73	5.26*		
Columns	3	139.60	3.81		
Dates	3	3289.37	89.78**	5.25	7.96
Error (a)	6	36.64			
Varieties	3	1064.86	43.34**	3.56	4.74
Dates x varieties	9	50.86	2.07		
Error (b)	36	24.57			

* Denotes F values significant at the 5% level.
**Denotes F values significant at the 1% level.

Number of Days to Maturity

The number of days from planting to maturity of soybean varieties planted on various dates is shown in Table 6. As the date of planting was delayed from April 10 to May 18 (38 days) there was a corresponding delay in maturity of 21 days. Therefore, for a delay in planting of each two days there was a corresponding delay of about one day in maturity. This behavior was consistent among all the varieties tested. Considering mean number of days from planting to maturity of the varieties tested, Lindarin needed the shortest time (119 days) to mature seed, Clark was intermediate, while Perry and Wabash required the longest time (143 and 144 days, respectively). No significant interaction between varieties and dates of planting for soybean maturity was obtained.

Plant Height

The data for plant height for the soybean varieties and for the four planting dates appear in Table 7. Significant differences in plant height resulted from planting soybeans on different dates. Maximum plant heights were attained at the first date of planting and diminished successively at later dates of planting. This behavior was consistent for all varieties except Lindarin which attained its maximum height on the second date of planting. Other workers have reported reduction in plant height as a result of delayed planting (1, 38, 48, 51).

Table 6. Average number of days from planting to maturity of soybeans as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	129.0	123.0	119.2	105.0	119.1
Wabash	155.0	146.2	138.5	132.0	142.9**
Clark	149.8	140.8	133.8	131.8	138.8**
Perry	153.2	151.0	140.2	132.8	144.2**
Mean	146.8	140.2*	132.9*	125.4*	

* Denotes difference significant at the 5% level.
** Denotes difference significant at the 1% level.

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	224.40	7.30*		
Columns	3	172.45	5.61*		
Dates	3	2072.80	67.43**	4.81	7.25
Error (a)	6	30.74			
Varieties	3	1103.16	53.19**	3.27	4.35
Dates x varieties	9	38.99	1.88		
Error (b)	36	20.74			

* Denotes F values significant at the 5% level.
**Denotes F values significant at the 1% level.

Table 7. Average plant height in cm. of soybeans as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	92.1	93.6	77.2	64.3	81.8
Wabash	108.8	97.6	84.8	65.5	89.2*
Clark	111.2	92.7	81.4	67.3	88.2*
Perry	98.5	93.5	85.3	66.4	85.9
Mean	102.6	94.4	82.2**	65.9**	

* Denotes difference significant at the 5% level.
**Denotes difference significant at the 1% level.

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	600.84	4.90*		
Columns	3	328.62	2.68		
Dates	3	4685.31	38.21**	9.61	14.56
Error (a)	6	122.62			
Varieties	3	137.12	3.24	4.67	6.22
Dates x varieties	9	106.65	2.52*		
Error (b)	36	42.32			

* Denotes F values significant at the 5% level.
**Denotes F values significant at the 1% level.

A significant difference in plant height was obtained among the varieties tested. Wabash and Clark had the greatest plant height. Perry was of intermediate height but did not vary significantly from Lindarin, the shortest variety. A significant interaction of varieties with planting dates was obtained with respect to plant height. On the first planting date (April 10) the variety Clark exceeded Lindarin in height by 19.1 cm. However, on the May 18 planting the plant height of both varieties was essentially the same with only a difference of 3 cm.

Weight of 1000 Seeds

Mean seed sizes, expressed in grams per 1000 seeds, for the soybean varieties at the various dates of planting are shown in Table 8. The largest mean seed sizes were obtained from the April 10 date of planting with an average of 162.8 grams per 1000 seeds. The seed size tended to decrease with successive planting dates, although the differences were not statistically significant. Abel (1) and Osler and Cartter (38) found that seed size was not appreciably affected by dates of planting.

Wabash possessed the smallest seeds with 152.5 grams for 1000 seeds. The 1000 seed weights of Perry, Clark and Lindarin were 164.5, 162.7 and 162.4, respectively, and not significantly different.

Table 8. Average weight in grams per 1000 seeds of soybeans as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	166.8	164.2	158.3	160.3	162.4
Wabash	154.0	155.5	146.4	152.8	152.2*
Clark	163.2	162.5	161.9	163.2	162.7
Perry	167.1	161.9	166.6	162.4	164.5
Mean	162.8	161.0	158.3	159.6	

*Denotes difference significant at the 5% level

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D 5%	L.S.D 1%
Rows	3	457.70	2.17		
Columns	3	759.31	3.60		
Dates	3	586.36	2.78	12.61	19.10
Error (a)	6	210.92			
Varieties	3	829.71	5.40**	8.93	11.89
Dates x varieties	9	248.91	1.62		
Error (b)	36	153.65			

* Denotes F values significant at the 5% level.
**Denotes F values significant at the 1% level.

Number of Pods Per Plant

Mean number of pods per plant for soybean varieties at various dates of planting appear in Table 9. The highest mean number of pods per plant (30.7) was obtained from the first date of planting (April 10). The number of pods per plant decreased with delayed plantings. This might be due to the fact that the crop from the first date of planting was borne by a greater vegetative growth than were later plantings.

The variety Clark had the greatest mean number of pods per plant, while Wabash had the lowest mean pod number. Perry and Lindarin were intermediate in mean pod number per plant.

Number of Seeds Per Pod

Table 10 shows mean number of seeds per pod for soybean varieties as affected by dates of planting. Mean number of seeds per pod appear to be a varietal characteristic and not influenced by dates of planting.

Varieties differed significantly with respect to the number of seeds per pod. The variety Clark produced an average of 2.8 seeds per pod, whereas, Lindarin and Perry contained 2.4 seeds per pod.

Lodging

Lodging was observed only in the variety Wabash

Table 9. Average number of pods per plant of soybeans as affected by date of planting and variety in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	31.4	27.5	27.4	27.7	28.5
Wabash	29.5	28.8	27.4	27.4	28.3
Clark	31.8	29.6	28.3	29.5	29.8
Perry	30.0	29.8	27.6	27.3	28.7
Mean	30.7	28.9	27.7*	28.0*	

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	29.56	2.98		
Columns	3	47.81	4.82*		
Dates	3	48.91	4.93*	2.72	4.13
Error (a)	6	9.92			
Varieties	3	13.84	1.86	1.96	2.62
Dates x varieties	9	5.51	0.74		
Error (b)	36	7.44			

* Denotes F values significant at the 5% level.
**Denotes F values significant at the 1% level.

Table 10. Average number of seeds per pod of soybeans as affected by date of planting and variety in 1965.

Variety	Dates of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	2.4	2.3	2.4	2.5	2.4
Wabash	2.7	2.5	2.5	2.5	2.6
Clark	2.8	2.7	2.8	2.7	2.8**
Perry	2.5	2.3	2.3	2.3	2.4
Mean	2.6	2.5	2.5	2.5	

**Denotes difference significant at the 1% level.

Analysis of Variance

Source	d.f.	M.S.S.	F	L.S.D. 5%	L.S.D. 1%
Rows	3	1.09	3.20		
Columns	3	0.59	1.74		
Dates	3	0.72	2.13	0.50	0.76
Error (a)	6	0.34			
Varieties	3	0.53	5.29*	0.23	0.31
Dates x varieties	9	0.13	1.32		
Error (b)	36	0.10			

* Denotes F values significant at the 5% level.
**Denotes F values significant at the 1% level.

which lodged at all four planting dates tested. No association between dates of planting and lodging was observed.

Cumulative Day-degrees

The cumulative day-degrees for the period from planting to maturity for the soybean varieties appear in Table 12 (appendix). The highest number of day-degrees (2965) was received by the second date of planting and the lowest number (2800) was received by the fourth planting date. The highest yield, however, was obtained from the first planting date which received 2883 day-degrees.

Variety Lindarin, consistently requiring the lowest number of day-degrees over all dates, produced the second best yield. Considering total dry weight, however, there seemed to be a close association between the number of day-degrees received by a variety and the total dry weight produced. Weiss (51) stated that a minimum of 2400° C-days are required by soybeans. Other investigators are in disagreement over the use of day-degrees as a development index (8, 9, 50).

SUMMARY AND CONCLUSION

An experiment was conducted to study the agronomic and seed compositional characters of soybean varieties planted at different dates in 1965 at the Agricultural Research and Education Center in the Beqa'a Plain, Lebanon.

Four varieties of soybeans - Lindarin, Wabash, Clark and Perry - were planted each on April 10, April 24, May 8, and May 18. The following characters were studied: seed yield, total dry weight, protein percentage, oil percentage, number of pods per plant, number of seeds per pod, weight of 1000 seeds, plant height, number of days to flowering, number of days to maturity and lodging.

The highest seed yields, considering all dates of planting, were attained by the variety Clark, followed by Lindarin and then Perry. Wabash, one of the later maturing varieties, produced the lowest seed yield. Considering all varieties, progressively lower seed yields were obtained from dates of planting after April 10.

The maximum plant height and the greatest amount of total dry weight were attained at the first planting date and diminished with successively later dates of planting. Lindarin, the shortest variety, produced a significantly lower amount of total dry weight.

The varieties differed significantly in protein and oil

content of the seed. The highest percentage of protein was obtained from varieties Lindarin and Perry. Clark, the highest seed yielding variety, had the lowest percentage of protein and the highest percentage of oil in its seed. Wabash, on the other hand, yielded the least and had the lowest oil percentage in the seed. In general protein content of the seed increased, while oil content decreased with delayed planting date.

The number of days from planting to flowering and to maturity varied with the varieties. Lindarin required the shortest and Wabash and Perry the longest period for flowering and maturity. Flowering and maturity dates were retarded approximately one day for each two days' delay in planting.

Clark produced slightly greater number of pods per plant and number of seeds per pod, which might have accounted for its greater seed yield. Wabash, the low yielding variety, produced the smallest seeds.

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APPENDIX

Table 11. Average monthly temperatures and precipitation at the Agricultural Research and Education Center, Beqaa Plain, Lebanon, from March to October 1965 and ten years' average 1956-65.

Months	Temperature °C		Rainfall (mm)	
	1965	1956-1965	1965	1956-1965
March	8.1	8.2	46.3	48.0
April	9.2	11.7	48.7	25.8
May	14.0	14.8	3.0	11.9
June	25.7	20.7	03.0	0.9
July	22.5	22.6	0.0	0.0
August	23.7	23.5	0.0	0.0
September	20.2	20.5	23.2	3.2
October	13.2	16.5	46.8	11.0

Table 12. Cumulative temperatures (day-degrees C)*for the days from planting to maturity of soybeans in 1965.

Variety	Date of planting				Mean
	April 10	April 24	May 8	May 18	
Lindarin	2486	2603	2615	2391	2524
Wabash	3063	3086	3019	2937	3026
Clark	2961	2985	2898	2917	2940
Perry	3022	3187	3039	2957	3051
Mean	2883	2965	2893	2800	

* $\frac{1}{2}$(daily maximum + daily minimum) x number of days from planting to maturity.