EFFECT OF DATE OF PLANTING, VARIETIES AND SPACINGS ON INTERNAL BROWN SPOT AND YIELD OF POTATOES

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POTATO CULTURAL TRIALS

SHUJA

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AN ABSTRACT OF THE THESIS OF

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Title: Effect of date of planting varieties and spacings on internal brown spot and yield of potatoes.

An experiment was conducted in 1967 at the Agricultural Research and Education Center in the Beqa'a plain, Lebanon, to determine the effect of three planting dates, two varieties, and three spacings on germination, plant height, flowering, tuber size, yield, and incidence of internal brown spot in potatoes.

The mid-May planting and the 15 cm spacing produced the fewest plants. Plant height increased with delayed planting and closer spacing. There was the least flowering in the early planting. Wide spacing of plants also resulted in less flowering.

The variety Patroness produced greater numbers as well as yields of large tubers. The March 13 planting date and the 35 cm spacing also resulted in a greater number and yield of large tubers. However, the yield of marketable tubers was affected significantly by date of planting only. The March 13 planting produced the highest yield.

The incidence of internal brown spot was markedly decreased with delay in planting. The small size tubers were least affected. The variety Arran Banner was highly susceptible to the disorder, but Patroness was almost unaffected.

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I. INTRODUCTION

The potato (*Solanum tuberosum* L.) is known to have been grown as a food crop as early as the Inca civilization in South America (51, pp 372). Subsequently, it very quickly became one of the world's leading food crops following its introduction to Europe by the Spanish explorers from its native home of Chili and Peru in the early half of the sixteenth century (61, pp 11).

Potatoes produce more food per unit area than either wheat or rice. It is also used as a feed and as a source of chemicals (53, pp 190).

It is the world leading vegetable crop. About 20.25 million hectares are planted to potato on which is produced approximately 27.04 million metric tons per year (18, pp 173).

In Lebanon, the potato is the leading vegetable crop. According to the Agricultural Statistical Section of the Agricultural Economics and Statistics Service of the Lebanese Ministry of Agriculture potato covers about 5000 hectares which produces about 45000 metric tons of tubers annually, most of which (90%) is produced in the Beqa'a plain.

Many varieties are grown in Lebanon. The growing season stretches from March to September. Most varieties, especially the production leader Arran Banner, exhibit a physiological disorder (internal brown spot) which seems to be greatly influenced by weather, cultural practices, and size of the tuber (1, 14, 31, 61).

The present study was undertaken to determine the optimum date of planting, variety, and spacing to get highest disease (internal brown spot) free yields. The trial was conducted in the field at the Agricultural Research and Education Center of the American University of Beirut situated in the northern center of the Beqa'a plain, Lebanon during the growing season of 1967.

II. REVIEW OF LITERATURE

Effect of Temperature and Photoperiod on Growth of the Plant

There are probably more ways of circumventing climatic handicaps and cultural shortcomings with vegetables than there are with any other crop, yet these are still the main factors influencing quality and production. The effect of these factors on the potato, the world's leading vegetable crop, has been studied extensively. In the following review, the effects of temperature, photoperiod, date of planting, variety, and spacing on the yield, size, and internal brown spot of potatoes are summarized.

Temperature

The potato requires a long, cool, frost-free season for maximum production. Its growth and development is greatly influenced by the temperatures prevailing in the growing season. Temperatures ranging between 60^{o} and 75^{o}F are stated to be optimum for maximum production by Thompson and Kelley (51, pp 372-380). Borah *et al*. (8) reported the optimum temperature range as being between 15-20^{o}C because in that range there occurs a balance between tuber initiation (which is accelerated by low temperatures) and tuber growth (which is favoured by high temperatures).

abnormalities to develop like excessive branching of young sprouts, shortening of internodes, decrease in segmentation of leaves, and diminution in the diameter of stems.

Bushnal (13) found that higher temperatures caused higher rates of respiration, thus, fewer carbohydrates were available for tuber production. Respiration was a more critical factor than photosynthesis as it was more seriously affected by higher temperatures. Summarizing the results of a series of greenhouse experiments, he reported that he obtained decreases in tuber production at constant temperatures above 68° and complete inhibition at 84°F. However, he suggested that under field conditions the temperature causing complete inhibition may be somewhat higher.

Tizo, (52) working with the Bintji variety, reported that higher temperatures decreased the formation of tubers. Thompson and Kelley (51) and Box (10) reported similar results.

Photoperiod

The potato plant shows a more remarkable response to day length than is commonly recognized. Thompson and Kelley (51) reviewed the work of Edmundson who noticed differences in the response of varieties to various day lengths. While comparing day lengths of 9, 11, 13, and 17 hours under greenhouse controlled conditions, he found that most varieties produced the tallest plants, most flower buds, most seed balls, and greatest weight of seed when grown during the

Smith, as reviewed by Boswell and Jones (9, pp 373), reported that regions north of the July 70°F isotherm gave higher yields than warmer areas to the south, although good crops of early varieties are grown in regions below the July 70°F isotherm in the spring and fall when temperatures are relatively low.

Epstein (25) found that the effect soil temperature has on potato growth depends on the stage of growth of the plant. He studied the growth in three stages: (a) planting to emergence (b) emergence to 30 days (c) 30 days to maturity. During the first stage plants failed to emerge at 48°F or lower. However, once the potato plants emerged and entered growth stage (b), top growth developed even when they were placed at 48°F. In stage (b), root growth was less sensitive to temperature differentials than top growth. In growth stage (c), soil temperatures affected root concentration in depth but had no influence on root distribution in a lateral direction. Tuber yields increased as temperatures increased up to 72°F and then decreased at 84°F. Isleib and Thompson (33) proposed that 50°F was the critical or best temperature for sprouting and reasonable root growth of potato seed pieces.

Richard (41) reported that young sprouts developed most rapidly in the soil at a constant temperature of about 75°F but that later growth was at its maximum at approximately 64°F. Soil temperatures above 75°F caused longest day.

Werner (58) reported that long days, high temperatures, and an abundant external supply of nitrogen favoured vegetative growth in all plant parts except tubers. Short days, low temperatures, or less nitrogen induced early tuberization. Days of intermediate length, low temperatures, and an abundant nitrogen supply brought about maximum tuberization. He concluded that with an increase in day length, temperature, or both, vegetative growth increased whereas tuber formation increased as these factors were decreased. Boswell and Jones (9) noted the same response.

Beaumont and Weaver (5) found that with 12-hour photoperiods and 60^{o}F temperature exposures potato plants reached their point of greatest economy as far as the proportion of tubers and top was concerned (51% top and 49% tubers). At 50^{o}F the greatest economy was reached with 15 hours of light (34% top and 66% tubers). From the standpoint of yield and early maturity he found the best combination was a 15-hour light exposure at 50^{o}F night and 60^{o}F day temperature. Went (57) reported that 12^{o}C was the optimum night temperature for tuber production. Driver and Hawkes (20) found that eight hours of light coupled with low night temperatures gave good tuber yields. Garner and Allard (27) reported that with 10-hour days the McCormick variety produced more tubers than it did in days having 14 hours of light.

Effect of Planting Dates, Varieties, and Spacings on Growth and Yield of Potatoes

Akeley *et al*. (2) reported that date of planting affected not only the yields but also the percentage of total solids in potatoes and the percentage of total solids in turn affected the cooking quality. After studying eight varieties and four dates of planting over a period of three years at Presque Isle, Maine, they noted an increase of 22 to 75% in yields of potato planted on May 5 as compared to those of June 4. The highest yield was obtained with the earliest date of planting; yields decreased with delay in planting. They recommended planting as early as possible for maximum production in Northern Maine. Similar results have been reported for other locations by Ahmadi *et al*. (1), Choudhry (14), Dyke (21), Hanson (30), Hoque (31), and Sawyer (43).

Beveridge (6) reported decreases in yield of ware size potatoes (less than $1\frac{3}{4}$") in one year by as much as 1.7 ± 0.59 tons/acre as a result of delayed planting but little effect in another year. The reason forwarded for the difference was that there was more loss of moisture due to delayed planting in the first described year than in the second.

Werner (60) reported that, to avoid severe losses caused by insects and diseases, late planting was the common practice in dry land areas of Western Nebraska though total yields were slightly lower than resulted from early plantings.

Terman _et al_. (49) reported that an average increase of about nine bushels per acre was obtained by delaying the harvesting of four potato varieties from August 6 to August 20. Terman _et al_. (50) found that yields continued to increase as long as a portion of the vines remained green. They observed a decline in the rate of increase of yield which fell from 11 bushels in late August to five bushels in early September. Smith (47) found that the fresh and dry weights of all plant parts increased with each successive harvest except for the fresh weight of tops.

Yield is highly influenced by varieties. Choudhry (14) and Hoque (31) reported that Climax outyielded three other varieties included in their trials. Bremen and Radley (12) reported that Majestic gave a high yield due to its bulking and early tuber initiation characters. Choudhry (15) reported that in a varietal trial conducted on 15 varieties at two locations in Bengal over a three year period varieties Ultimus and Voran gave significantly higher yields of tubers when compared with other early and late varieties respectively.

Houghland and Parker (32) reported that yields of marketable tubers were generally increased as the seed was spaced closer and closer but they pointed out that these increases were not always significant nor were they always economical from the standpoint of cost of the additional seed required.

Bishop and Wright (7) reported that total yields and, to a somewhat lesser degree, yields of US No. 1 tubers were increased by increasing the quantity of seed potatoes planted per acre through closer spacing and/or larger seed pieces. They further noted that the rate of yield increase declined with each additional increment of seed potatoes. They concluded that planting more than approximately 16 sacks of seed potatoes per acre did not increase the yield sufficiently to justify the greater expense.

Werner (59) found that his heaviest planting rate (23.5 bushels per acre) was desirable for producing the greatest total yields of seed size potatoes but least efficient in production per bushel of seed planted. He concluded that increased returns for the additional seed planted beyond that required for the intermediate rate were relatively small and that heavy rates were not likely to be economical except when seed potatoes were very cheap.

Rowberry and Johnston (42) reported that close spacing solved the problem of oversized potatoes. Mosher (38) found that total yields and yields of marketable sized tubers increased significantly as seed piece spacings decreased within the limit of his trials. Similar results were reported by Smeltzer and Mackay (46) and Nelson (40). Choudhry and Choudhry (16) reported that though their closer spacing (24" x 5") gave the highest yield of ware potatoes it also produced an unduly large percentage of undersized tubers.

Claypool (17) reported that yield was nearly as large when plants were spaced 6" apart as when the plants were spaced 24" apart. Mass (37) and Terman *et al*. (49) got the same results.

Werner (60) reported that 6" spacings of whole or halved tuber sets ($1\frac{1}{2}$ oz) produced significantly higher yields of standard seed tubers (3-12 oz) than did 12" spacings and that an increase in B size ($1\frac{1}{2}$-3 oz) tubers occurred as the distance between sets narrowed.

Boyd and Lessel (11), after a series of investigations, reported that if the optimum seed rate was obtained, then the particular combination of seed size and spacing distance appeared to be of minor importance. They concluded that the difference between practice and experiment in general was because growers usually use the same spacing regardless of the size of the seed which was usually high in case of certified, whole seed (usually almost $2\frac{1}{2}$ oz). Bates (4) reported that, beyond an optimum limit, the decrease in yield was proportionate to the increase in spacing between tubers. This limit was further affected by the size of the seed. He concluded that spacing controlled the intensity of competition between the hills while size of seed controlled the intensity of competition within the hill.

Effect of Planting Dates, Varieties, and Spacings on the Occurrence of Internal Brown Spot

Atanasoff (3) reviewed the work of Horne who appears to have reported this disease for the first time in 1911. Horne described it in two forms; internal disease and streak. The disease at present is found in nearly all potato growing areas of the world and is known by various names, e.g. kringeringheid in the Netherlands, bunt fleckigkert in Germany, sprain in England, internal brown fleck in South Africa, and internal browning and internal brown spot in the U.S. Atanasoff (3) saw no visible symptoms on the outside of the tubers but noted two types of microscopic internal symptoms, i.e. rusty brown blotches and streak areas. He did not believe that the disease was a physiological disorder but thought that an organism, which could enter the tuber without leaving any distinctive sign at the site of entrance, was responsible for it. He also discounted the idea that lack of moisture was responsible for it and, in fact, suggested that an excess of moisture was a pre-requisite for occurrence of the disease in severe cases.

Edmundson et al. (22) described the disease as dry brown spots scattered throughout the flesh of the tuber. The spots were comprised of dead cells free from bacteria and fungi. There were no definite foliage symptoms. He recommended that affected tubers should not be used for seed purpose as they did not produce strong plants.

Wolcot and Ellis (63) reported that internal browning injury to potato tubers was more severe when plants were grown under conditions of artificially maintained moisture supply than when under drought conditions. They observed necrosis symptoms first during, or just after, periods of rising temperatures in an improved moisture situation following periods of low temperature or drought. Severe internal browning developed concurrently with extensive resorption of tubers during periods of fluctuating temperatures under the shortening day length of September. They reported the observation of four types of symptoms and further reported that the distribution of the four types, i.e. internal brown spot, heart necrosis, corky ring spot, and canker type internal rust spot, among plantings made on different dates, supported the view that the different patterns of necrosis have a common physiological origin but vary in form and severity with differences in the developmental age of tuber tissues at the time of injury.

Larson and Albert (34) reported internal necrosis as being entirely a malady of the growing tuber, there being no manifestations of the disorder in the aerial parts of the plants in the field during the growing season. They noted a considerable increase in the amount and severity of necrosis in tubers with advance in season and tuber size. They observed differences in responses of varieties as only one variety, Triumph, out of 22 varieties in the trial showed complete resistance. By mulching they were able to reduce the disorder consistently and attributed the reduction to avoiding temperature fluctuations in the soil surrounding the tubers and roots. Similar results have been reported by Ellison (23) and Larson and Albert (34, 35).

Ellison (24) reported that the occurrence of internal brown spot decreased with delay in planting. Ahmadi et al. (1) and Mankush (36) reported similar results. Choudhry (14) conducted a split plot experiment on four potato varieties with four dates of planting at the AREC, Lebanon. He reported that the occurrence of internal brown spot was greatly influenced by dates of planting, varieties, and the size of the tuber. Tubers from the June planting showed a low occurrence of internal brown spot as compared to those of the March, April, and May plantings. Arran Banner was the most susceptible while Climax showed complete resistance. Large tubers were more frequently and severely affected than small ones. He concluded that planting should be done as early as possible (for maximum production) with a resistant variety like Climax. Hoque (31) later confirmed all the findings of Choudhry (14) except that he failed to find any effect of date of planting on the occurrence of internal brown spot.

III. MATERIALS AND METHODS

A field experiment was carried out during the spring and summer of 1967 at the Agricultural Research and Education Center (AREC) of the American University of Beirut.

The AREC is situated in the northern part of the Beqa'a plain, Lebanon. The soil in general is clay in texture and has an organic matter content of 2.2 per cent. The pH ranges from 8.0 to 8.4 with a high calcium carbonate content indicating that the soil is highly calcareous in nature (48).

The growing season extends from the end of February through September. Generally the summer is dry and mild. Average temperatures rise gradually with the maximum occurring in the month of July. Rainfall declines sharply as the season advances and generally there is no precipitation in June, July, August, and September. The last spring rainfall occurred on May 13 at AREC in 1967. Meteorological data regarding average monthly air and soil temperature, rainfall, and relative humidity for the potato growing season during 1967 at the AREC are given in Table 1.

The plots were planted with barley in 1966. A good seed bed was prepared in March as soon as the soil became suitable for cultivation. The plots were fertilized with

Table 1. The average monthly air and soil temperature in degree Centigrade, rainfall in millimeter, and relative humidity in percent at the Agricultural Research and Education Center from March through September, 1967.

	March	April	May	June	July	August	September
Air temperature							
Mean maximum	10.94	16.65	21.79	26.05	29.27	26.60	26.50
Mean minimum	0.95	3.47	8.43	9.68	12.16	12.25	10.00
Soil temperature							
Sod 10 cm	8.65	13.78	18.84	21.27	23.82	24.64	21.69
Bare earth 10 cm deep	8.90	15.25	20.62	23.98	26.18	26.24	22.96
Rainfall	167.1	20.5	34.5	0.0	0.0	0.0	0.0
Relative humidity							
Mean maximum	88.1	77.7	76.4	64.1	60.2	63.3	75.1
Mean minimum	54.8	39.5	36.8	32.4	30.8	34.1	37.9

12 kg nitrogen as ammonium sulphonitrate and 20 kg P_2O_5 as super phosphate per dunum. Plantings were carried out on three dates (at four-week intervals) starting on March 13 and ending on May 15.

Uniform sized seed pieces, weighing from 40 to 50 grams, were used. Large tubers were cut into two or more seed pieces, while small tubers were used entire.

Standard cultural practices for the area were followed. The crop was irrigated weekly during the growing season. Plots were irrigated by a sprinkler system until mid-June, then were furrow-irrigated for the rest of the growing season. The crop was sprayed once with metasystox at the rate of one cc per liter of water against aphids. Weeding was done as and when required.

Two potato varieties, imported from Holland, were planted. One was Arran Banner which is commonly grown in Lebanon but is highly susceptible to internal brown spot and the second was Patroness which is a new and promising variety. The within row spacings of 15, 25, and 35 cm were used between seed pieces; all rows were 75 cm apart.

A split-split-plot design, with four replications, was followed. Planting dates were main plots, varieties were sub-plots, and spacings were sub-sub-plots. All treatments were randomized separately. Each sub-sub-plot consisted of four rows; each row was five meters long and was spaced 75 cm from its neighbor.

Data on germination, plant height, and flowering were obtained from the central two rows of each plot. Germination percentage was calculated on the basis of the number of plants germinated of the seed pieces planted. Ten plants were selected at random for measuring plant height. The tallest shoot of each plant was measured from the soil surface to the tip of the growing point at the time of flowering. The mean of these measurements was considered as the average plant height. Flowering percentage was determined on the basis of plants producing flowers out of the total that germinated. A plant was considered to flower if it produced a single flower.

The plants were harvested after the vines were completely dried. Harvesting of the three plantings was carried out by hand respectively on August 22, August 29 and September 5. For the purpose of determining yield, grades, and other tuber characteristics only the central two rows were harvested. The end plants of these two rows were discarded to reduce the border effects. Due to differences in spacing between tubers, 6.3 square meters in the 15 cm spacing, 6.0 square meters in the 25 cm spacing and 6.075 in the 35 cm spacing were harvested. The resulting data were calculated and are reported on a uniform kilogram per dunum basis. Statistical analyses were done on the adjusted data.

The tubers from each sub-sub-plot were graded into three sizes, taking into account their largest diameter, viz; large (larger than 7 cm), medium (4-7 cm), and small (less than 4 cm). Later the tubers were counted and weighed. Large and medium sized tubers together constituted the marketable size.

Thirty tubers (ten from each size grade) were selected by random and cut, each into four pieces. All eight resulting surfaces were examined for presence of internal brown spot. Any discoloration which could be identified as internal brown spot was recorded.

The data were compiled and analyzed according to the method appropriate to the design according to Snedecor and Cochran (45, pp 367).

IV. RESULTS AND DISCUSSION

The effects of planting dates, varieties, and spacings on the yield per dunum of potatoes in the Beqa'a plain, Lebanon, were examined during the 1967 growing season. In addition, their effects upon germination, plant height, flower production, and incidence of internal brown spot were noted. The results are summarized in Tables 2 through 10. The data were statistically analyzed and where significance occurred the least significant differences (L.S.D.) were calculated and are presented as part of the above tables. The analyses of variance are presented in the Appendix in Tables 11-19.

Since the practice of the area is to plant as early as weather and soil conditions permit (1, 14, 31), the planting made on March 13 was taken as a check. Arran Banner, which is highly susceptible to internal brown spot, was selected as the standard variety as it is the most commonly grown variety in Lebanon (1, 14, 31). Similarly, since the common spacing in the area is 25 cm between seed pieces within the row, this spacing was taken as a check for spacing treatments.

Germination

Planting dates influenced germination as is shown

Table 2. Effect of planting date, variety, and spacing on germination percentage in potatoes during 1967.

Planting date	Varieties	Spacings 15 cm	25 cm	35 cm	Mean	Mean of planting date
March 13	Arran Banner	99.62	100.00	100.00	99.87	99.80
	Patroness	99.24	100.00	100.00	99.74	
	Mean	99.43	100.00	100.00		
April 12	Arran Banner	97.74	99.37	100.00	99.70	99.66
	Patroness	98.87	100.00	100.00	99.62	
	Mean	98.30	99.68	100.00		
May 15	Arran Banner	85.71	91.87	93.75	90.44	92.60
	Patroness	92.86	95.00	96.42	94.76	
	Mean	89.28	93.43	95.08		
Mean Arran Banner		94.35	97.08	97.91	96.67	
Mean Patroness		96.99	98.33	98.80	98.36	
Mean Spacings		95.67	97.70	98.36		

	LSD (5%)	LSD (1%)
Planting date	1.42	2.15
Spacings	1.07	1.45
Planting date x spacings	3.66	N.S.
All others	N.S.	N.S.

in Table 2. The germination of the tubers planted on May 15 was highly significantly lower than those planted March 13 or April 12. This can be attributed to a loss of vitality in the tubers in storage (stored at room temperature) as profuse sprouting occurred during the latter period of storage. These results are in agreement with Choudhry (14). Vincent (56) reported that for seed potato storage a temperature range of 33^{o} to $38^{o}F$ and a relative humidity of 80% was essential for satisfactory germination of potato tubers.

Varieties did not show any difference, but the wide spacing had a favourable effect on germination while the close spacing of 15 cm highly significantly reduced germination. Increased competition, especially for moisture, could be the reason for this effect.

The interaction between planting date and spacing was found to be significant. The last planting produced a lower number of plants with all three different spacings but the closer spacing had more of an effect than the wider spacing (35 cm). This was, perhaps, because the tubers had sprouted and shriveled and were then forced to compete for moisture.

Plant Height

An examination of the data in Table 3 shows that

Table 3. Effect of planting date, variety, and spacing on height of potato plants in centimeters during 1967.

Planting date	Varieties	Spacings 15 cm	25 cm	35 cm	Mean	Mean of planting date
March 13	Arran Banner	49.00	45.75	43.50	46.08	45.74
	Patroness	48.00	45.25	43.00	45.41	
	Mean	48.50	45.50	43.25		
April 12	Arran Banner	70.50	68.00	66.25	68.25	66.37
	Patroness	67.00	64.50	62.00	64.50	
	Mean	68.75	66.25	64.12		
May 15	Arran Banner	71.50	67.75	69.75	69.66	70.70
	Patroness	75.00	70.50	68.75	71.41	
	Mean	73.20	69.12	69.25		
Mean Arran Banner		63.66	60.50	59.83	61.33	
Mean Patroness		63.33	60.08	57.91	60.44	
Mean Spacings		63.50	60.29	58.87		

	LSD (5%)	LSD (1%)
Planting date	4.67	7.08
Spacings	1.38	1.86
All others	N.S.	N.S.

the heights of the potato plants were greatly influenced by the planting date. Both of the later plantations of April 12 and May 15 produced plants close to 50% or more taller than those of the check plantation of March 13, but after April 12 plant height was only slightly increased by the delay in plantation. Shorter plants in the earliest plantation may be due to the early tuberization which is induced by short photoperiods with low temperature (29). Werner (59) reported that long days or high temperatures or both delayed tuberization and encouraged vegetative growth. The results are also in agreement with Choudhry (14) and Hoque (31).

Plant heights were gradually adversely affected as tuber spacings were increased. The wider spacing of 35 cm produced significantly shorter plants and the closer spacing of 15 cm produced highly significantly taller plants than the check.

Flowering

Results given in Table 4 show that flowering of potato plants was greatly influenced by the planting date. Both later plantings produced highly significantly more flowering plants than the check. The Beqa'a plain enjoys a relatively cool summer and the combination of long photoperiods with low temperature induces flowering in potato plants (9). The results are in agreement with Choudhry (14)

Table 4. Effect of planting date, variety, and spacing on percentage of potato plants flowered during 1967.

Planting date	Varieties	Spacings 15 cm	25 cm	35 cm	Mean	Mean of planting date
March 13	Arran Banner	85.55	79.37	75.00	79.79	81.10
	Patroness	85.98	81.25	79.46	82.12	
	Mean	85.76	80.31	78.12		
April 12	Arran Banner	95.00	89.39	87.50	90.63	91.62
	Patroness	94.67	91.25	91.96	92.60	
	Mean	94.83	90.32	89.73		
May 15	Arran Banner	98.68	89.11	88.57	93.12	90.38
	Patroness	94.73	84.86	83.33	87.64	
	Mean	96.70	86.54	85.95		
Mean Arran Banner		93.07	85.95	83.69	87.90	
Mean Patroness		91.79	85.78	84.91	87.46	
Mean Spacings		92.43	85.87	84.25		

	LSD (5%)	LSD (1%)
Planting date	1.59	2.41
Spacings	1.07	1.45
All others	N.S.	N.S.

and Hoque (31). Varieties did not exhibit any difference. Spacing showed a continual decrease in number of plants flowered with increase in distance. Tubers placed 15 cm apart produced highly significantly greater numbers of plants which flowered and tubers placed 35 cm apart produced highly significantly lower numbers of flowering plants than the check. This kind of response may be because wider spacing provides more nutrients and moisture to plants and hence results in more vegetative growth while with close spacing there are limited resources and space for vegetative growth and the plants are obliged to direct their food material to reproduction at an earlier stage of growth.

Number and Yield of Large Tubers

Both numbers and yields of large tubers were influenced by date of planting, variety, and spacing of seed tubers as is shown in Tables 5 and 6. The March 13 planting gave a highly significantly greater number and yield of large tubers than did either of the later planting dates. This can be attributed to earlier tuberization and the increased length of the growing period. Patroness produced a highly significantly greater number of large tubers and a significantly greater yield than Arran Banner. This is due to its characteristic habit of growth which is to produce large oval shaped tubers (26). The interaction

Table 5. Effect of planting date, variety, and spacing on numbers of large size tubers per dunum of potatoes during 1967.

Planting date	Varieties	Spacing 15 cm	Spacing 25 cm	Spacing 35 cm	Mean	Mean of planting date
March 13	Arran Banner	8385	9749	11586	9907	12691
	Patroness	14239	15166	17023	15476	
	Mean	11312	12457	14304		
April 12	Arran Banner	2427	3832	6583	4281	4077
	Patroness	2798	4499	4325	3874	
	Mean	2626	4165	5454		
May 15	Arran Banner	6296	3499	5237	5011	7630
	Patroness	8435	10999	11313	10249	
	Mean	7365	7249	8275		
Mean Arran Banner		5702	5693	7802	6399	
Mean Patroness		8490	10221	10887	9866	
Mean Spacings		7097	7957	9344		

	LSD (5%)	LSD (1%)
Planting date	2586.7	3494.6
Varieties	1192.1	1714.3
Planting date x varieties	2919.9	4199.9
Spacing	1225.7	N.S.
All others	N.S.	N.S.

Table 6. Effect of planting date, variety, and spacing on the yield of large size tubers in kilograms per dunum of potatoes during 1967.

Planting date	Varieties	Spacings 15 cm	Spacings 25 cm	Spacings 35 cm	Mean	Mean of planting date
March 13	Arran Banner	1152	1612	1952	1572	1752
	Patroness	1722	1912	2162	1932	
	Mean	1437	1762	2057		
April 12	Arran Banner	492	725	1060	759	660
	Patroness	405	630	650	561	
	Mean	448	677	855		
May 15	Arran Banner	1055	605	850	836	1136
	Patroness	1140	1505	1665	1436	
	Mean	1097	1055	1257		
Mean Arran Banner		899	980	1287	1056	
Mean Patroness		1089	1349	1492	1310	
Mean Spacings		994	1165	1390		

	LSD (5%)	LSD (1%)
Planting date	259.70	610.56
Varieties	196.85	N.S.
Planting date x varieties	481.38	N.S.
Spacings	181.69	N.S.
All others	N.S.	N.S.

between planting date and varieties was significant. Patroness planted on March 13 gave a highly significantly greater number of tubers but did not differ in weight from the check variety. Both varieties in the April 12 plantation and Arran Banner in the May 15 plantation produced significantly lower yields than the check combination. The wider spacing of 35 cm produced significantly greater numbers and yields of large size tubers than the 25 cm normal spacing. This increase in yield can be explained by the fact that the increase in spacing decreased the competition for nutrients among the tubers within a single hill. The result is in agreement with Claypool (17), and Bremner and Radley (12).

Number of Marketable Tubers

The data given in Table 7 show the influence of planting date on the numbers of marketable tubers. The early plantation of March 13 produced approximately the same number as the plantation of April 12 but produced significantly greater numbers of marketable tubers than did the late plantation of May 15. This may be because a certain minimum length of growing season, which has to be provided to the potato plants for maximum production, was not available to the plants in the latest plantation. Choudhry (14) also got the greatest number of marketable tubers with his two early plantings of March 15 and April 12

Table 7. Effect of planting date, variety, and spacing on number of marketable tubers per dunum of potatoes during 1967.

Planting date	Varieties	Spacings 15 cm	25 cm	35 cm	Mean	Mean of planting date
March 13	Arran Banner	43500	50500	51250	48416	50750
	Patroness	42500	53000	63750	53083	
	Mean	43000	51750	57500		
April 12	Arran Banner	33250	41250	46500	40333	46583
	Patroness	47250	57000	54250	52833	
	Mean	40250	49125	50375		
May 15	Arran Banner	32750	38000	35500	35416	37625
	Patroness	36750	38250	44500	39833	
	Mean	39250	38125	40000		
Mean Arran Banner		36500	43250	44416	41388	
Mean Patroness		42166	49416	45166	48583	
Mean Spacings		39333	46333	49291		

	LSD (5%)	LSD (1%)
Planting date	4116.0	5560.8
Varieties	4294.0	6175.0
Spacings	3914.0	5301.0
All others	N.S.	N.S.

and Hoque (31) found that only the June 17 plantation reduced the production of marketable tubers. Patroness produced a highly significantly greater number of marketable tubers than Arran Banner which is characteristic of the varieties (26).

Spacing also affected the number of marketable tubers at the 5% level of significance. The closer spacing of 15 cm produced a highly significantly lower number than the normal spacing. This can be attributed to more competition among tubers within a hill.

Yield of Marketable Tubers

Yield was strongly influenced by planting date (Table 8), being reduced in each succeeding plantation. This highly significant difference can be attributed to the longer growing season and better climatic conditions for tuberization available to the earlier planted crops. Akeley (2), Dyke (21), and Sawyer (43) reported similar results. Choudhry (14) found that the last planting date of June 7 gave significantly lower yields, but Hoque (31) did not find any significant differences. Varieties, spacing, and interaction showed no real differences.

Internal Brown Spot

Planting date had a marked effect on the occurrence of internal brown spot in potatoes (Table 9). Least

Table 8. Effect of planting date, variety, and spacing on the yield of marketable tubers in kilograms per dunum of potatoes during 1967.

Planting date	Varieties	Spacings 15 cm	25 cm	35 cm	Mean	Mean of planting date
March 13	Arran Banner	4015	4415	4242	4224	4248
	Patroness	4277	4555	3987	4273	
	Mean	4146	4435	4114		
April 12	Arran Banner	3765	3517	3200	3494	3589
	Patroness	3650	3892	3510	3684	
	Mean	3707	3704	3355		
May 15	Arran Banner	3275	3025	2840	3046	3220
	Patroness	3467	3347	3367	3364	
	Mean	3371	3186	3103		
Mean Arran Banner		3685	3652	3427	3588	
Mean Patroness		3798	3931	3621	3783	
Mean Spacings		3741	3792	3524		

	LSD (5%)	LSD (1%)
Planting date	470.40	635.52
All others	N.S.	N.S.

Table 9. Effect of planting date, variety and spacing on percentage incidence of internal brown spot in marketable potato tubers during 1967.

Planting date	Varieties	Spacings 15 cm	25 cm	35 cm	Mean	Mean of planting date
March 13	Arran Banner	73.75	86.25	88.75	82.91	41.87
	Patroness	1.25	0.00	1.25	0.83	
	Mean	37.50	43.12	45.00		
April 12	Arran Banner	67.50	68.75	61.25	65.83	33.12
	Patroness	0.00	0.00	1.25	0.41	
	Mean	33.75	34.37	31.25		
May 15	Arran Banner	38.75	46.25	42.50	42.50	21.25
	Patroness	0.00	0.00	0.00	0.00	
	Mean	19.37	23.12	21.25		
Mean Arran Banner		60.00	67.08	64.16	63.74	
Mean Patroness		0.41	0.00	0.83	0.41	
Mean Spacings		30.20	33.54	32.50		

	LSD (5%)	LSD (1%)
Planting date	1.76	2.67
Varieties	1.19	1.61
Planting date x varieties	2.90	3.93
All others	N.S.	N.S.

affected tubers were produced with May 15 planting while the earliest planting produced the most affected tubers. This highly significant difference can be attributed to the comparatively lower temperature at the time of tuber maturation with delayed planting. Hoque (31) found no real difference due to planting date but Ahmadi et al. (1), Choudhry (14), Ellison and Jacob (24), and Hanson (30) reported positive results. Arran Banner was highly significantly more susceptible than Patroness. Interaction of planting date with varieties was also found to be significant. Arran Banner produced the greatest number of affected tubers when planted on March 13, less with April 12 planting, and least with the May 15 planting. Patroness produced completely healthy tubers with the last date of planting.

The incidence of internal brown spot in individual tubers was greatly influenced by their sizes (Table 10). Tubers of large and medium sizes were affected to a much greater extent than those of small size. This highly significant difference can be attributed to the differences in the maturity of the tubers at harvesting time. The occurrence of internal brown spot generally appears during the maturing stage of tubers. Small tubers are physiologically immature at the time of harvest so are less affected. The results are in agreement with those obtained by Choudhry (14), Hoque (31), and Larson and Albert (34).

The interaction between varieties and sizes was also found to be significant at the 1% level (Table 10). Arran Banner produced the greatest number of affected tubers in the large size, the next greatest in the medium size,and the least in the small size. Patroness produced a very small number (0.83%) of affected tubers in the large size but none in the medium or small sizes.

Table 10. Effect of tuber size on percentage incidence of internal brown spot in potatoes during 1967.

Varieties	Size of tubers			Mean of varieties
	Large	Medium	Small	
Arran Banner	77.22	48.88	9.16	45.08
Patroness	0.83	0.00	0.00	0.27
Mean of sizes	39.02	24.44	4.56	

	LSD (5%)	LSD (1%)
Varieties	7.09	13.02
Sizes	4.03	5.64
Varieties x sizes	9.43	13.20

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A field experiment was carried out during 1967 to evaluate the effects of date of planting, variety, and spacing on yield, plant characteristics, and occurrence of internal brown spot in potatoes at the Agricultural Research and Education Center, situated in the northern Beqa'a plain of Lebanon. Two varieties, Arran Banner and Patroness, were planted at three spacings of 15 cm, 25 cm, and 35 cm on March 13, April 12, and May 15.

Both of the early plantings gave more than 99% germination but in the last planting the population was reduced highly significantly. The spacing of 15 cm also reduced the germination significantly.

The plant height increased highly significantly with the later plantings, the tallest plants being produced in the last plantation. The wide spacing of 35 cm resulted in a significant decrease and the close spacing of 15 cm resulted in a highly significant increase in plant height when compared with the normal 25 cm spacing.

The least amount of flowering occurred in the early plantation. This was significant at the 1% level. Flowering percentage was higher in close spaced plants.

The number and yield of large tubers were influenced by planting date, variety, and spacing. Both were greatest when seed potatoes were planted 35 cm apart and on March 13. Patroness outyielded Arran Banner in both number and yield of large tubers.

The latest planted potatoes produced the least number of marketable tubers. Of the two varieties, Patroness produced more tubers than Arran Banner. A gradual decrease in the number of marketable tubers occurred as the spacing became closer. Yield was unaffected either by variety or spacing but it decreased sharply with delay in planting.

Delay in planting decreased the occurrence of internal brown spot; however, its occurrence was not affected by spacing. Patroness was practically free of this physiological disorder as only 0.41% of the tubers were affected in the first two plantings and none in the last. In general, large tubers showed a much greater susceptibility to internal brown spot than did the small ones.

It can be concluded that selecting a resistant high yielding variety is the most practical method to overcome the losses from internal brown spot and that the earlier the plantation the higher the yield. Spacing did not affect the total yield but a larger number of large tubers developed with the widest spacing; for this reason and to overcome cost of seed the 35 cm spacing appears most favourable. Therefore it is recommended that the farmers growing potatoes in the Beqa'a plain should plant a high yielding variety resistant to internal brown spot like Patroness as early as weather and soil conditions become suitable and at a spacing of about 35 x 75 cm apart.

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A P P E N D I X

Table 11. Analysis of variance for germination.

Source of variance	d.f.	M.S.S.	F value
Replications	3	.86	2.09
Dates	2	92.55	225.73**
Error "a"	6	.41	-
Varieties	1	14.30	2.53
Dates x varieties	2	8.40	1.48
Error "b"	9	5.65	-
Spacings	2	8109.70	1279.13**
Dates x spacings	4	17.35	2.73*
Varieties x spacings	2	4.80	-
Dates x varieties x spacings	4	1.52	-
Error "c"	36	6.35	-
Total	71		

* Significant at 5% level.
** Significant at 1% level.

Table 12. Analysis of variance for plant height.

Source of variance	d.f.	M.S.S.	F value
Replications	3	1.00	-
Dates	2	4229.51	95.86**
Error "a"	6	44.12	-
Varieties	1	14.23	1.03
Dates x varieties	2	45.59	3.32
Error "b"	9	13.73	-
Spacings	2	134.76	24.63**
Dates x spacings	4	3.82	-
Varieties x spacings	2	4.76	-
Dates x varieties x spacings	4	5.45	-
Error "c"	36	5.47	-
Total	71		

** Significant at 1% level.

Table 13. Analysis of variance for number of flowers.

Source of variance	d.f.	M.S.S.	F value
Replications	3	10.16	1.95
Dates	2	124.29	23.85**
Error "a"	6	5.21	-
Varieties	1	8.68	4.27
Dates x varieties	2	.60	-
Error "b"	9	2.03	-
Spacings	2	7961.16	2348.42**
Dates x spacings	4	3.64	1.07
Varieties x spacings	2	.72	-
Dates x varieties x spacings	4	2.70	-
Error "c"	36	3.39	-
Total	71		

** Significant at 1% level.

Table 14. Analysis of variance for number of large size tubers.

Source of variance	d.f.	M.S.S.	F value
Replications	3	29032	-
Dates	2	449844	33.62**
Error "a"	6	133792	-
Varieties	1	2163200	43.17**
Dates x varieties	2	677054	13.51**
Error "b"	9	50098	-
Spacings	2	308674	7.36**
Dates x spacings	4	30392	-
Varieties x spacings	2	91954	2.19
Dates x varieties x spacings	4	77779	1.85
Error "c"	36	41895	-
Total	71		

** Significant at 1% level.

Table 15. Analysis of variance for yield of large size tubers.

Source of variance	d.f.	M.S.S.	F value
Replications	3	709	-
Dates	2	71948	28.35**
Error "a"	6	2537	-
Varieties	1	11628	8.50*
Dates x varieties	2	10044	7.34*
Error "b"	9	1367	-
Spacings	2	9441	10.09**
Dates x spacings	4	1241	1.32
Varieties x spacings	2	590	-
Dates x varieties x spacings	4	2402	2.56
Error "c"	36	935	-
Total	71		

* Significant at 5% level.
** Significant at 1% level.

Table 16. Analysis of variance for number of marketable tubers.

Source of variance	d.f.	M.S.S.	F value
Replications	3	156	4.58
Dates	2	1079	31.73**
Error "a"	6	34	-
Varieties	1	93	14.10**
Dates x varieties	2	127	1.92
Error "b"	9	66	-
Spacings	2	627	35.91**
Dates x spacings	4	49	-
Varieties x spacings	2	30	-
Dates x varieties x spacings	4	71	2.02
Error "c"	36	35	-
Total	71		

** Significant at 1% level.

Table 17. Analysis of variance for yield of marketable tubers.

Source of variance	d.f.	M.S.S.	F value
Replications	3	2734	-
Dates	2	65138	14.68**
Error "a"	6	4436	-
Varieties	1	6884	3.06
Dates x varieties	2	1338	-
Error "b"	9	2245	2.45
Spacings	2	4899	-
Dates x spacings	4	1656	-
Varieties x spacings	2	412	-
Dates x varieties x spacings	4	1517	-
Error "c"	36	1973	-
Total	71		

** Significant at 1% level.

Table 18. Analysis of variance for incidence of internal brown spot.

Source of variance	d.f.	M.S.S.	F value
Replications	3	8.3	1.2
Dates	2	102.8	16.0**
Error "a"	6	6.4	-
Varieties	1	2888.0	465.0**
Dates x varieties	2	94.8	15.2**
Error "b"	9	6.2	-
Spacings	2	2.7	-
Dates x spacings	4	2.0	-
Varieties x spacings	2	3.6	-
Dates x varieties x spacings	4	2.4	-
Error "c"	36	3.8	-
Total	71		

** Significant at 1% level.

Table 19. Analysis of variance for incidence of internal brown spot for sizes.

Source of variance	d.f.	M.S.S.	F value
Replications	3	37.8	1.25
Varieties	1	9760.7	324.27**
Error "a"	3	30.1	-
Sizes	2	1937.0	140.36**
Varieties x sizes	2	1850.6	614.81**
Error "b"	12	13.8	-
Total	23		

** Significant at 1% level.