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# EFFECT OF PLANTING DATE AND VARIETIES ON YIELD, INTERNAL BROWN SPOT AND GROWTH CHARACTERISTICS OF POTATOES

by

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## ABSTRACT

A one year study involving the effect of different planting dates and varieties on yield, internal brown spot, germination, plant height and flowering of potatoes was conducted at the AUB Agricultural Research and Education Center in 1963.

Highest yield of tubers was obtained when potatoes were planted on April 22. In general, earlier plantings produced higher yield of tubers. Different planting dates had no effect on internal brown spot incidence. Germination of potato seed tubers was much lower but faster when potatoes were planted very late in the season. Plant hight gradually increased with delay of planting. Flowering in potatoes was materially affected by dates of planting and highest percentage of potato plants came into flowering when planted on May 20.

The variety Climax produced the highest yield. Climax and Bintje were completely resistant to internal brown spot but Arran Banner and Asoka were equally susceptible. Internal brown spot incidence increased with the tuber size. All varieties showed equally high germination. Arran Banner and Bintje produced taller plants than Asoka and Climax. A great variation was found among varieties in their capacity to flower with Arran Banner having the highest and Asoka having the lowest number of plants flowering.

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# INTRODUCTION

The potato (Solanum tuberosum L.) is one of the most popular foodcrops, especially in the European countries where it is the main source of carbohydrate food for many people. It was introduced to Europe as a domesticated plant which already, in its native home of Peru and Chili, had been cultivated possibly for over a thousand years. The potato reached Europe in the latter half of the sixteenth century, the first recorded mention being in 1587 by Clusius in Vienna (24).

Today, the potato is one of the major food crops and is grown throughout most of the world. It is the world's leading vegetable crop. The world area planted in potatoes is about 24.8 million hectares with an annual production of about 276 million metric tons (3). In annual production it ranks with wheat and rice - world's two leading food crops. Potatoes produce more food per unit area than is obtained from the cereal crops and it can be used in various ways - such as boiled, baked and fried potatoes and also as potato chips, dehydrated potatoes, canned potatoes and as starch for culinary purposes.

In Lebanon, potatoes rank first in area and production among vegetable crops. The area planted with potatoes is about 5000 hectares and production is about 45,000 metric tons per year. 70 per cent of the area under potato cultivation in Lebanon lies in the Beqa'a plain and 30 per cent in coastal areas and mountain regions as shown by Mankush.

Many varieties of potatoes are grown which differ morphologically

and physiologically from each other. Some have different maturation dates and can utilize a long growing season better than others. Since the yield potential of the crop is very high, it is imperative that the crop be planted at an optimum date. Because of the wide variation in climatic conditions in the different regions of the world, it is necessary to determine the most productive planting date for potatoes for each locality.

In Lebanon, Arran Banner and Up-to-date are the commercial varieties generally planted by the growers. Arran Banner, though a high yielder, is severely affected by internal brown spot disease. The occurrence of this physiological disease varies according to weather conditions, cultural practices and varietal susceptibility. Affected tubers show no external symptoms but isolated brownish areas occur scattered in the flesh of the tuber. The consumptive value of the affected tubers is thus much lowered. On the other hand, Up-to-date, the second potato variety grown in Lebanon, is less susceptible to internal brown spot than Arran Banner but is a low yielder.

In order to find better adapted, high yielding and internal brown spot disease resistant potato varieties for Lebanon, studies were conducted with four varieties planted on different dates during the year 1963.

## REVIEW OF LITERATURE

Potato production in any area depends largely on the climatic conditions of that locality. The two most important climatic factors affecting different stages of growth and ultimately the yield in potatoes are temperature and photoperiod. Their effects can be recognized either singly or in combination.

### Effect of temperature

The potato is a cool season crop but it is susceptible to frost injury. Growth and development of the potato plant is greatly influenced by temperature. Boswell and Jones (8) reviewed the work of Smith who stated that the region north of the July 70° F. isotherm produced higher yields than warmer areas to the south although good crop of early varieties are grown in the latter region in the spring and fall when the temperature is relatively low.

Bushnell (9) found that progressively lower tuber yields with progressively higher temperatures were due to reduction in the synthesis of surplus carbohydrates over that consumed in respiration. Respiration was the critical factor since the rate of photosynthesis was not as greatly influenced by temperature. Under the experimental conditions tuber production was decreased at constant temperatures above 68° F. and completely inhibited at 84° F. He suggested that under field conditions, the temperature giving complete inhibition may be somewhat higher.

Borah, et al (7) concluded from a series of investigations that the optimum temperature range for yield of tubers was 15-20° C. which constituted the best compromise between tuber initiation which was accelerated by low temperature and tuber growth which was promoted by high temperatures. The rate of bulking was increased by high radiation, high day temperatures and low night temperatures.

Tizio (28) found with Bintje variety that high temperatures during the vegetative growth period caused degeneration of potato plants. With an increase in the period of exposure to high temperatures, a progressive decrease in the capacity of the plants to form tubers was found.

Bodlaender (6) studied the influence of day and night temperatures on the development of potatoes with the late variety Gineke. Stem elongation increased as temperatures increased until an optimal 24 hr. average temperature range of 18-20° C. was reached. The influence of day and night temperatures on stem elongation was about the same. Below 7-8° C, no stem elongation was visible. Abundant flowering was observed at a night temperature of 18° C., while at a night temperature of 12° C. only buds and no flower formed. The number of tubers formed decreased with increasing night temperatures. Interaction of high day temperatures (18-24° C.) and low night temperatures (6-12° C.) were favourable for tuber growth. Similarly, Engel and Rauber (14) found that the greatest increase in tuber growth occurred with temperatures of 20° C. during the day and 14° C. during the night and with a soil moisture content of about 80 percent of field capacity.

In greenhouse experiments, Richards (23) observed that soil temperature requirements of potato plants vary with different stages

of growth. The young sprouts, while in the soil, grew most rapidly at 24° C. Growth was greatly retarded at 15° C. and below. With temperatures above 24° C., the plants exhibited abnormal responses such as excess branching, shortening of the internodes, decrease in segmentation of the leaves and decrease in the diameter of the stems. A soil temperature of approximately 18° C. proved optimum for later and continued development of the potato plant.

Effect of photoperiod

Varieties differ in their requirement of photoperiod for high production. Garner and Allard (16) found that the McCormick variety produced many tubers with a 10 hr. day, only a few with a 14 hr. day and none with an 18 hr. day.

Bodlaender (5) investigated the influence of various day lengths on the development of potatoes. He found the critical value of day length for the late variety Alpha to be between 12-14 hrs. Thus a day length of 12 hrs. or less constituted a short day and of 14 hrs. or more a long day. Plants grown under long days had longer and heavier stems, thicker leaves, and heavier underground parts than had plants grown under short days. Plants under short days set tubers 7-10 days earlier than did the plants under long days. Flower primordia were formed in all day lengths but flowers were formed only under long day conditions. The longer the day-length, the later the plants die off occurred.

Combined effect of temperature and photoperiod

Gregory (17) reported that Driver and Hawkes showed that the two environmental factors - temperature and photoperiod affect tuberisation in potato plants, in some instances increasing, in the others decreasing the yield of tubers. Gregory himself worked on the effect of the two factors on tuber formation in Kennebee variety. He found that short days (8 hrs. of light) with low temperatures promoted good tuber yield while long days (16 hrs. or more of light) with high night temperatures suppressed tuber formation. The experiments indicated that the tuber formation resulted from a stimulus formed or activated by specific conditions of temperature and photoperiod. The stimulus remained active in the plant for a period of time even though the plant was moved to conditions unfavorable for tuber formation. Furthermore, the stimulus was transmitted through a graft union. Sugars as such were not the sole determining factor for tuberization or tuber initiation. The stimulus was systemic and was not restricted to underground parts.

Boswell and Jones (8) showed that long days (16-17 hrs.) were desirable for flowering and seed set in potatoes if accompanied by high temperatures and high relative humidity.

Went (30) found that seed potatoes produced under warm conditions were inferior to those developed in cool climates. Seed tubers produced in low night temperatures and short days have a higher production capacity than those produced under high temperature conditions. He believed that only the tendency towards tuber formation was transmitted to the next generation and not a specific substance. He concluded that it

was exactly like vernalization where it does not directly influence inflorescence but has a delayed effect.

Effect of planting dates on growth, development and yield of potato tubers

The rate of growth of potatoes followed a typical sigmoid curve as found by Smith (25) in 1931. He found that with successive harvests increases in fresh and dry weight occurred with all plant parts but a rather slow rate of growth occurred shortly after planting followed by a period of rapid growth which dropped off late in the season.

In Aroostook county, Maine, Terman (26) found that potato tubers began to form in early July. Under conditions of moderate fertilizer application and good growing conditions, rate of yield increase of tubers mounted gradually through July, maintained a fairly steady rate through most of August and then gradually declined until the vines were killed. The yield increase of tubers, therefore, was shown to have a typical growth curve.

Hawkins (18) showed that the peak rate of tuber development in the Green Mountain variety in 1939 occurred in early August or 82-91 days following planting.

Cunningham, et al (11) reported that the growth rate of tubers depended among other factors on the date at which the potatoes were planted and upon the portion of the season during which growth took place. Although the growth rate of late planted potatoes was more rapid than that of early planted potatoes, two of the principal advantages of early planting were the increased yield and higher specific

gravity of the tubers obtained by utilizing the longer growing seasons. The tuber numbers were not affected by length of growing season; the yield increases were the result of increases in the size of the tubers. Early planting is especially desirable with late maturing potato varieties. He found that a 10 day delay in planting of Kennebec potatoes, an early maturing variety, decreased the yield of tubers by four bushels as compared with a 76 bushel decrease for Katahdin, a late maturing variety. He concluded that since extending the growing season by delaying the harvest was not always desirable or possible because of early killing frosts, it appears to be advantageous in most years to plant potatoes as early as weather conditions permit. Akeley, et al (2), in Maine, also found that early planting of late maturing varieties was highly desirable. Yields of potatoes planted on May 5 exceeded those of June 4 by 22 to 75 per cent depending on the variety.

Dyke (12) presented evidence obtained in a survey (1948-'50) in England and Wales that yields were decreased by any delay in planting after April 11 by about 0.4 tons per acre per week. The effect was greater in years with fine springs and on high yielding fields. In his experiments at Rothamstead, the responses to dung and fertilizer were all greatly reduced when planting was delayed. Responses of different varieties to early planting was contradictory except for an indication that high yielding varieties responded better.

On the other hand Werner (29) found that relatively late planting of potatoes - between June 12-25 has become the practice in dryland areas of Western Nebraska. Late planting directly improved the color

and type of the tuber and reduced losses due to insects and diseases. The total yields were usually slightly lower and yields of U.S.A. No. 1 Grade A size were greater and tubers were more immature and consequently more susceptible to mechanical injury at harvest time with late plantings then with earlier plantings.

Effect of planting dates and varieties on the occurrence of internal brown spot in potatoes

The internal brown spot disease of potatoes is known by various synonyms throughout the world as stated by Atanassoff (4): ringiness (Holland), sprain (England), internal brown spot and internal browning (U.S.A.). The disease has been observed wherever the potatoes are grown. He found no distinguishable external symptoms in the diseased tubers but described two types of macroscopic internal symptoms, (1) rusty brown blotches, (2) streak areas or ring irregularly spread or radiating from certain centers having no connection with the vascular ring. Microscopic examination of the affected areas revealed dead reddish brown cells mostly packed with starch grains. No fungi, bacteria or other foreign organisms were visible in the dead tissues. He suggested that the cause of the disease might be a physiological disorder caused by a disturbed chemical equilibrium in the plant due to soil and climatic factors.

Wolcott and Ellis (31) found that the incidence of internal brown spot injury was closely correlated with variations in growth and tuberization which, in turn, were strongly influenced by photoperiod and temperature. They found that internal brown spot developed under conditions favouring fluctuating vine and tuber growth. Periods

of rising temperature in August were associated with resurgent terminal vine growth, resorption of smaller tubers and initiation of necrotic symptoms in large tubers. Alternating periods of high and low temperature during the short days in September were conducive of severe incidence of internal brown spot. Late planting, high water table and excessive nitrogen fertilization prompted extension of growth into this particularly damaging period. Wolcott and Ellis (32) found that different types of internal brown spot such as, (1) diffuse flecking to irregular blotches, (2) large central lesions, (3) corky ring spot and (4) canker type rust spot occurred in the same hill. It was suggested that these types were related in origin but differed in pattern as a result of injury to tuber tissues of different physiological ages.

Larson and Albert (19), in Wisconsin, noticed that internal brown spot was more prevalant on sand gravelly soils during seasons in which the temperatures were above normal and precipitation below normal. Soil management in the form of mulching to avoid great fluctuations in temperatures consistantly reduced the internal brown spot injury. They found that the incidence of the disease was significantly increased at successive periods in the development of tubers; the necrotic index in the late harvesting tubers was more than double that of the earliest. They also found that large sized tubers were considerably more affected than small sized tubers. The same result was reported by Friedman (15) and Chaudhry (10). Larson and Albert concluded that the degree of necrosis indicated a close relationship between growth processes and development of necrosis and that the

malady had its inception during initial tuber development and increased during the growth of the tubers. They also found that varieties differed in resistance to internal brown spot. In addition, since more internal brown spot occurred in shallow set tubers than in deep set tubers, shallow setting varieties were found to have a greater incidence of the disease than deep setting varieties. All varieties under test planted as an early crop (late April and early May) were free from internal brown spot. In contrast, Ahmadi, et al (1) and Chaudhry (10) in Lebanon found that delaying the planting dates decreased the intensity of internal brown spot disease in the variety Arran Banner.

Larson and Albert (20) found with 29 American and 13 British varieties that some varieties were entirely free, some intermediate and some highly susceptible to internal brown spot disease. Similar varietal differences were reported by Ellison (13) among potato varieties grown in Long Island. He recommended testing of new varieties for several years before drawing conclusions because great fluctuations in the incidence of the disease occurred from year to year.

Mankush (21) observed during surveys in Lebanon from 1955-'57 that internal brown spot occurred in many varieties and locations, Arran Banner was more susceptible to this disease than any of the other generally grown in Lebanon.

## MATERIALS AND METHODS

A field plot experiment was carried out during the year 1963 at the Agricultural Research and Education Center of the American University of Beirut, situated in the Beqa'a plain. The soil of the farm is of a clay type, low in organic matter and available phosphorus and has a pH of about 8.0.

The length of the growing season in the Beqa'a plain stretches from the end of February to September. In general, the average temperature rises gradually as the season progresses and starts declinning in September. Meteriological data regarding monthly rainfall and air and soil temperature for the growing season of the 1963 potato crop are given in Table 1.

Fertilizer was applied at the rate of 12 kgs. per dunum of nitrogen as ammonium sulpho-nitrate and 24 kgs. per dunum of $P_2O_5$ as superphosphate in November, 1962. Early in March 1963, the soil was prepared for planting. The planting was done on four dates starting on March 25 and ending on June 17 at four-week intervals.

Four potato varieties, imported from Holland, were planted. One, Arran Banner, is the commercial variety in Lebanon but is susceptible to internal brown spot. A second variety, Asoka, is also susceptible to internal brown spot. The other two varieties tried in comparison with Arran Banner were Bintje and Climax which were resistant to internal brown spot.

Table 1. Average monthly air and soil temperature in degrees C and rainfall in m.m. at the Agricultural Research and Education Center from March to September 1963

| | March | April | May | June | July | August | Sept. |
|---|---|---|---|---|---|---|---|
| **Air Temperature** | | | | | | | |
| Mean Maximum | 12.97 | 18.71 | 21.0 | 28.76 | 30.45 | 32.74 | 29.68 |
| Mean Minimum | 0.95 | 5.24 | 7.0 | 12.34 | 13.51 | 14.37 | 12.45 |
| Soil Temperature | | | | | | | |
| Sod 10 cm. deep | 10.27 | 15.83 | 19.6 | 24.6 | 25.23 | 26.00 | 23.41 |
| Bare earth 10 cm deep | 10.93 | 16.82 | 21.0 | 25.78 | 26.25 | 26.94 | 23.44 |
| Rainfall | 82.35 | 53.3 | 11.7 | -- | -- | -- | -- |
| Relative Humidity % | | | | | | | |
| Mean Maximum | 96.67 | 95.23 | 96.7 | 88.2 | 80.5 | 75.50 | 86.2 |
| Mean Minimum | 47.61 | 45.60 | 43.0 | 36.2 | 37.39 | 30.7 | 30.6 |

A split-plot design was used. The planting dates were randomized in the mainplots and the varieties in the subplots. Each subplot consisted of four rows. Each row was 5 meters long and the distance between rows was 75 cms. Seventeen seedpieces were planted in each row with a spacing of 30 cms. between plants. Large seed tubers were cut into four seedpieces. Otherwise single piece seed tubers were used. Seed pieces weighed approximately 40-50 gms. each. The seed tubers were stored at 40° F in the cold storage and were

taken from time to time for planting as required for the different dates of planting. Seed pieces were planted at a depth of about 12-15 cm. After the emergence of seedlings, earthing-up was done. Weeds were controlled as and whenever required.

The potato crop was irrigated by a sprinkler system of irrigation at weekly intervals up to the end of June and furrow irrigated during the latter part of the season. The crop was sprayed regularly at two-week intervals for the potato tuber moth. The emerging seedlings of the May and June plantings were attacked by cut-worms, but by spreading heptachlor mixed with sand immediately after the first symptom was noticed insects were controlled efficiently by a single application. The varieties Climax and Asoka, during the latter stages of their growth, showed marginal drying and black spots in the leaves. This was diagnosed as a natural dieback of leaves and not a pathological symptom. Data were collected concerning germination, plant height and flowering. Percentage of germination was calculated on the basis of the number of plants germinated out of the 34 plants in the middle two rows of each subplot. The length of the tallest shoot of ten plants selected at random from the middle two rows in each subplot were measured from the soil surface to the tip of the growing point at the time of flowering. The average length of these ten plants was considered as the average plant height. Percentage of flowering was determined on the basis of the number of plants producing flowers out of the 34 plants in the middle two rows of each subplot. A plant was considered as flowering if it produced a single flower.

Harvesting was done after maturing of the crop of each planting. The dates of harvests were August 9, August 30, September 13 and October 3, 1963. Four meters from the middle of the central two rows were harvested from each plot to minimize the border effect.

The tubers from each plot were graded after harvest into three sizes, based on their largest diameter, large (more than 7 cm.), medium (4-7 cm.) and small (less than 4 cm.). The tubers from each grade were counted and weighed and yield data was calculated. The tubers from the large and medium size groups constituted the marketable tubers.

To determine the intensity of internal brown spot, 30 tubers (i.e. 10 tubers from each grade) were taken at random. Each tuber was then cut into four pieces. All eight surfaces were examined and the incidence of internal brown spot was recorded.

Analysis of the data was done according to the method given by V. G. Panse and Sukhatme (22) appropriate to the design used.

## RESULTS AND DISCUSSION

The results are summarized and presented in Tables 2 to 10 and Fig. 1. Analysis of variance tables are reported in the Appendix in Tables 11 - 17. The L.S.D.'s were calculated at the five percent and one percent levels for the treatments and their interactions whenever significance occurred. For the purpose of comparisons all numbers of tubers and yield data were converted to a per dunum basis.

Arran Banner was selected as the check variety because it is the most important and highest yielding variety grown in Lebanon even though it is highly susceptible to internal brown spot. Similarly, March 25 planting was taken as standard because the common practice in the area according to Chaudhry (10), Ahmadi, et al (1) and Mankush (21) is to plant potatoes as soon as the field can be prepared at the beginning of the growing season.

### Germination

Germination of potato seed tubers was influenced by dates of planting as shown in Table 2. The June 17 planting showed a highly significantly lower germination than the check planting of March 15. Germination of potato seed tubers planted on April 22 and May 20 was slightly lower than the check. The lower germination of the May 20 and June 17 plantings may be due partly to cutworm attacks during the germination period of these two plantings. Potato varieties did not differ significantly in germination, but the three new varieties under

Table 2. Effect of planting date and variety on germination percentage in potatoes during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | Mean |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | |
| Arran Banner | 99.3 | 94.8 | 87.5 | 76.5 | 89.5 |
| Asoka | 98.5 | 94.8 | 95.5 | 77.9 | 91.7 |
| Bintje | 100.0 | 98.5 | 94.8 | 80.1 | 93.4 |
| Climax | 99.3 | 97.0 | 96.3 | 76.5 | 92.2 |
| | 99.2 | 96.2 | 93.5 | 77.8 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | 6.4 | 9.7 |
| Varieties | N.S. | N.S. |
| Planting dates x varieties | N.S. | N.S. |

trial showed slightly better germination than the check. There was no interactions between varieties and planting dates.

Most noticable feature in this connection was the influence of dates of planting and varieties on the speed of germination (Fig. 1). In the earlier stages of germination, the fastest rate of germination was shown by the June 17 planting when 16-24 plants out

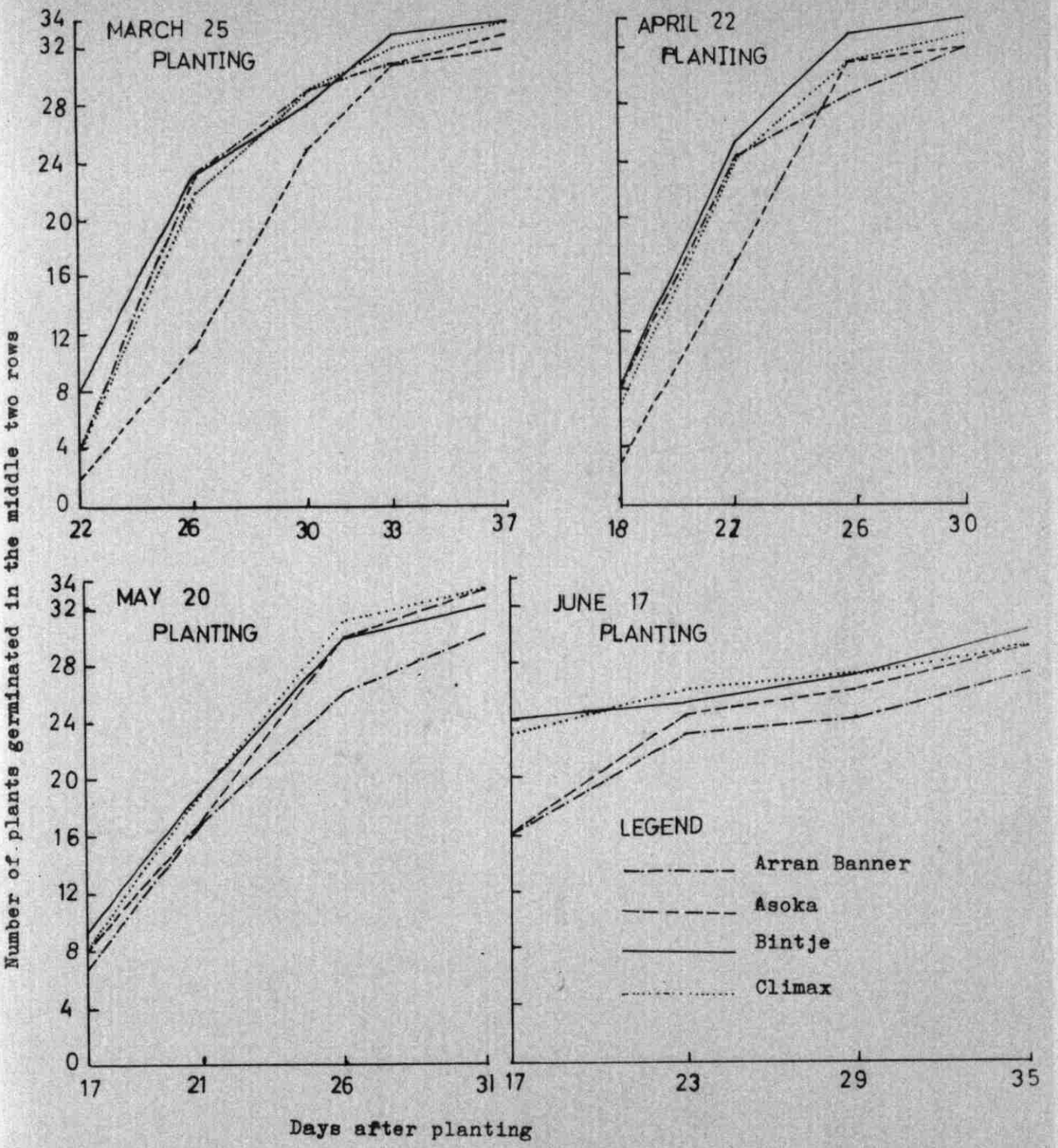


Fig. 1. The effect of planting dates and varieties on the number of potato plants germinated on different dates after planting.

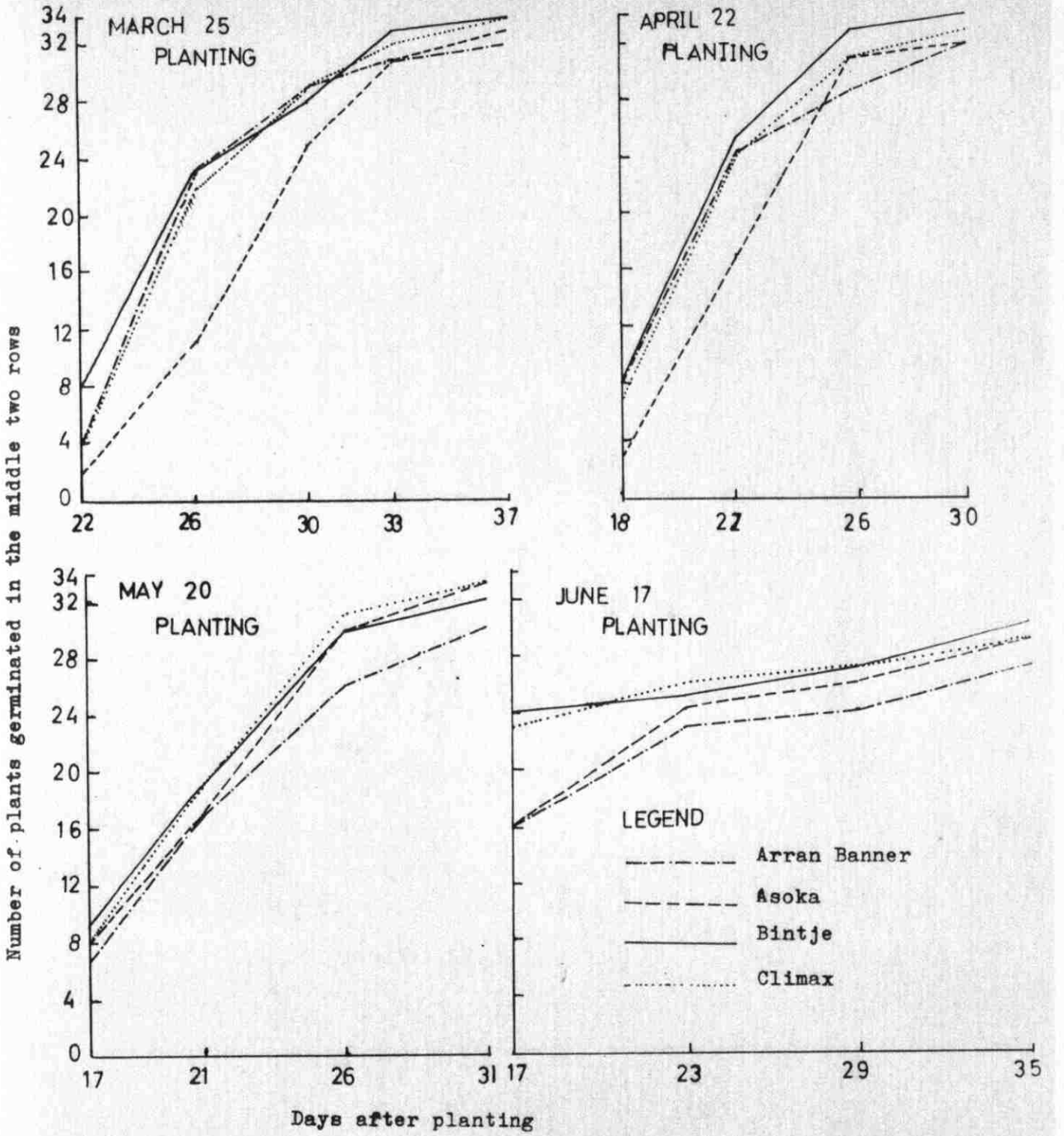


Fig. 1. The effect of planting dates and varieties on the number of potato plants germinated on different dates after planting.

of 34 germinated during an interval of 17 days from planting to first date of record compared with 7-9 plants within the same interval by the May 20 planting, 3-8 plants within an 18-day interval by the April 22 planting and less than 2-8 plants by the March 25 planting. Furthermore, 22 days after planting, only 2-8 plants had germinated in the March planting compared with 17-25 in the April planting, 19-22 in the May planting and 22-25 in the June planting. To obtain a 90% germination or better it took 35 days for the March planting, 30 days for the April, 31 days for the May and 23 days for the June planting. The higher rate of germination by plants with the later dates of planting is probably due to higher soil and air temperatures during that period. Varieties differed in speed of germination also. Asoka was the slowest to emerge when planted in March or April but was similar to other varieties during May and June plantings. The other varieties showed little difference among themselves in this regard.

Plant Height

Means of all planting dates differed significantly from the check in respect to plant height (Table 3). Plantings on March 25 produced the shortest plants and the June 17 planting produced the tallest plants. Plant height increased as the planting dates became later. An examination of the weather data collected during the growing period shows that the daily mean temperature increased from March 1st to its highest point in August (Table 1) and that the maximum photoperiod occurred on June 23rd (Fig. 2). This indicates that more vegetative growth and stem elongation took place when potatoes were

Table 3. Effect of planting date and variety on plant height in cms. in potatoes during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | Mean |
| Arran Banner | 40.2 | 48.6 | 60.6 | 81.6 | 57.7 |
| Asoka | 25.2 | 31.1 | 45.9 | 51.7 | 38.5 |
| Bintje | 31.6 | 39.2 | 60.2 | 70.1 | 50.5 |
| Climax | 25.2 | 32.0 | 46.6 | 52.2 | 39.0 |
| Mean | 30.6 | 37.7 | 53.3 | 64.1 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | 3.5 | 5.3 |
| Varieties | 1.5 | 2.1 |
| Planting dates x Varieties | 3.1 | 4.1 |

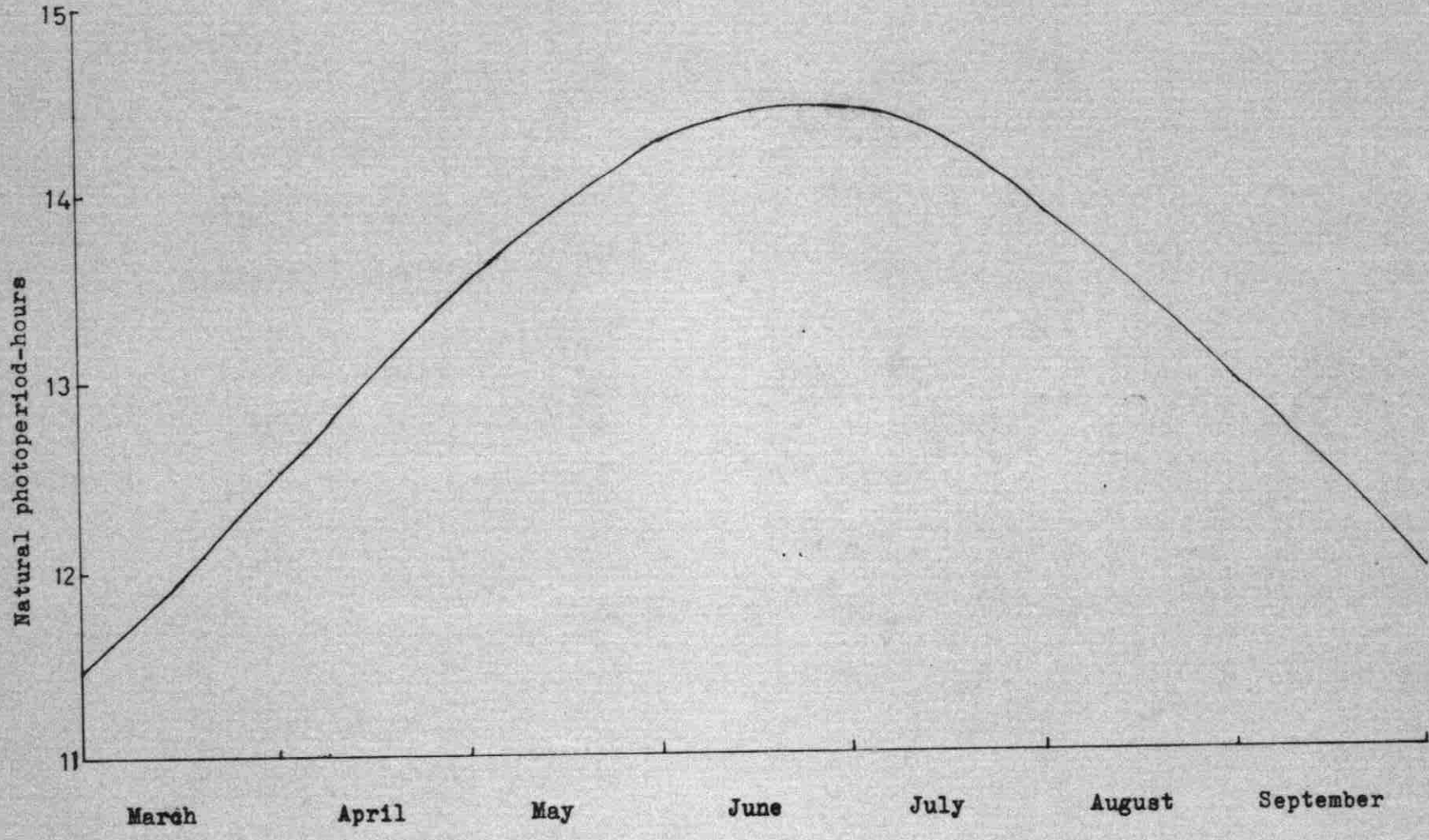


Fig. 2. Natural photoperiod hours during March to September in Lebanon.

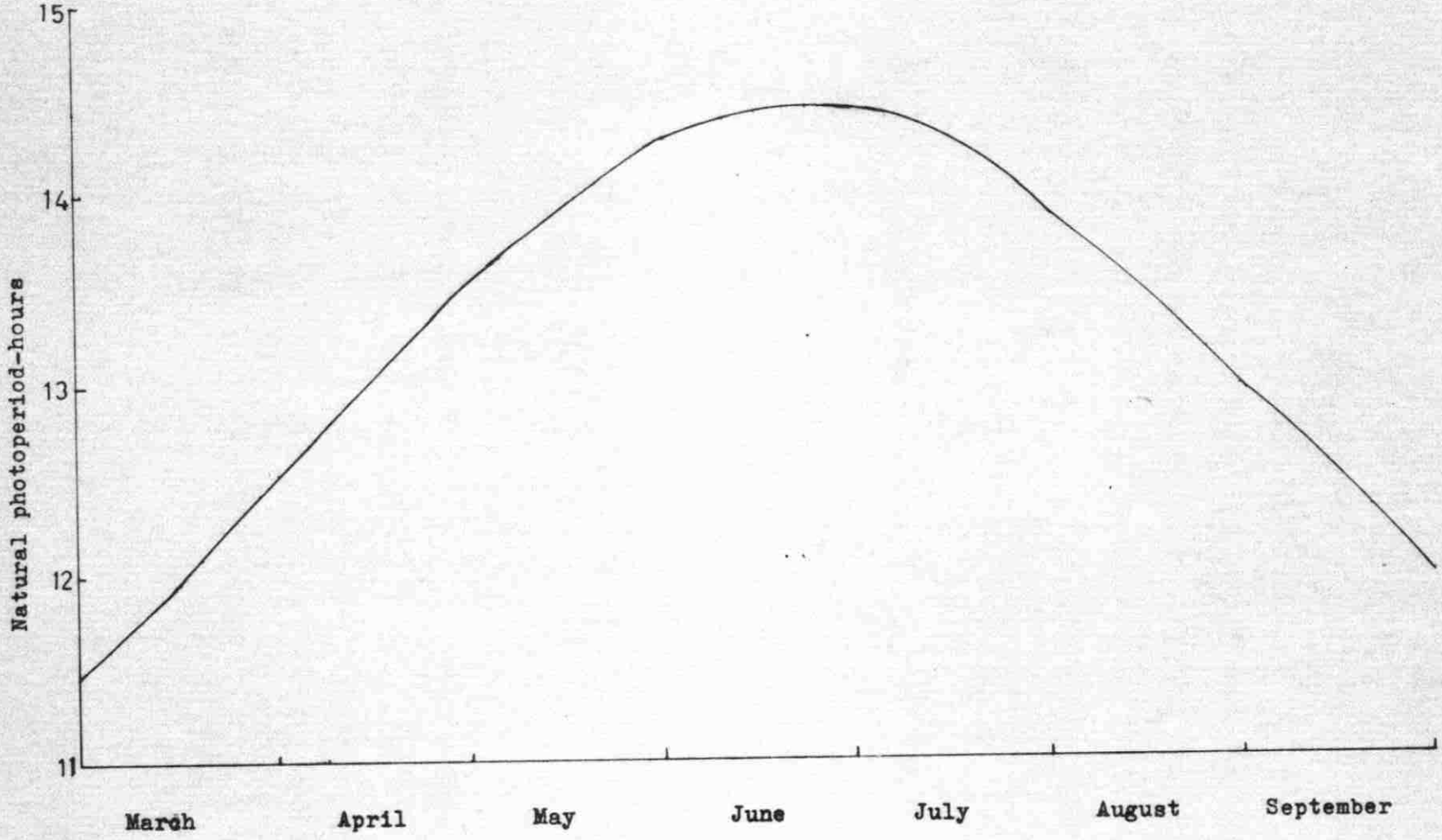


Fig. 2. Natural photoperiod hours during March to September in Lebanon.

grown in high temperature and in long photoperiods. These results concur with those of Bodlaender (5,6). The three varieties under trial produced highly significantly shorter plants than Arran Banner; Arran Banner produced the tallest plants, Bintje produced the next tallest plants and Asoka and Climax produced the shortest plants. The striking variation among varieties indicates that plant height is a varietal character. Interactions between varieties and planting dates were found at the 1% level. Arran Banner when planted on June 17th produced the tallest plants and was highly significantly different from the check combination of Arran Banner planted on March 25. Similar variation in plant height was shown by Bintje. Asoka and Climax produced the shortest plants when planted on March 25 and also differed significantly from the check combination. Asoka and Climax showed a gradual and regular increase in contrast with Arran Banner and Bintje which showed abrupt increases in plant height with later plantings.

Flowering

The data reported in Table 4 indicates that date of planting influenced flowering in potatoes. The lowest number of plants flowered when planted on March 25. The April 22 plantings had a significantly higher and the May 20 planting had a highly significantly higher percentage of flowering than the check. The June 17 planting was not significantly different from the March 25 planting. The photoperiod was longer and the temperature relatively cooler during the growing season of the May 20 planting than those of the June and March plantings. The long photoperiods in combination with cool temperatures

Table 4. Effect of planting date and variety on percentage of potato plants flowered during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | Mean |
| Arran Banner | 80.2 | 95.6 | 84.6 | 35.3 | 73.9 |
| Asoka | -- | -- | 8.1 | 1.5 | 2.4 |
| Bintje | 19.8 | 38.9 | 89.7 | 42.6 | 47.8 |
| Climax | -- | 4.4 | 66.9 | 43.4 | 28.7 |
| Mean | 25.0 | 34.7 | 62.3 | 30.7 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | 7.7 | 11.6 |
| Varieties | 7.9 | 10.6 |
| Planting dates x Varieties | 15.8 | 21.2 |

during the flower initiation period appears to induce more flowering. This is an agreement with Boswell and Jones (8). Varieties also differed significantly in the number of plants flowering. In the three varieties under trial, flowering was highly significantly less than the check. Asoka showed the least number of plants flowering. A striking interaction occurred between varieties and the planting

dates. Flowering in Arran Banner increased from the March to April plantings and then decreased in the May and June plantings. In constrast the three varieties under trial showed increases in flowering from the March to the May plantings and then a decrease in the June planting. Bintje showed the greatest fluctuation in flowering among all the varieties. No flowers were produced by Asoka planted on March 25 or April 22, nor by Climax planted on March 25 but plants of both varieties flowered when planted on later dates. This indicates that flowering in a variety is controlled by genetic factors modified by environment and climate.

Number and Yield of Large Tubers

Planting dates had no significant influence on the number (Table 5) or yield (Table 6) of large tubers. The May 20 planting showed the highest numbers and yield of large tubers and the April 22 planting the lowest. Asoka, Bintje and Climax produced a highly significantly greater number and yield of large tubers than Arran Banner. Interactions between varieties and planting dates were significant at the 5% level for the number of large tubers but not for yield. The production of large tubers by Arran Banner did not vary appreciably from the check combination with any planting date. The other varieties produced considerably larger numbers and yields of large tubers with all planting dates except for Asoka planted on June 17 and Bintje planted on April 22.

Table 5. Effect of planting date and variety on the number of large tubers per dunum during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | Mean |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | |
| Arran Banner | 2458 | 2292 | 2708 | 2208 | 2416.6 |
| Asoka | 7625 | 5542 | 6958 | 4041 | 6041.6 |
| Bintje | 6542 | 3959 | 9917 | 7375 | 6948.8 |
| Climax | 6417 | 5083 | 6583 | 4875 | 5739.6 |
| Mean | 5760.4 | 4218.8 | 6541.6 | 4624.9 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | N.S. | N.S. |
| Varieties | 1143.9 | 1532.7 |
| Planting dates x Varieties | 2287.7 | N.S. |

Table 6. Effect of planting date and variety on the yield of large tubers in kgs. per dunum of potatoes during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | Mean |
| Arran Banner | 377.4 | 359.4 | 497.6 | 361.3 | 398.9 |
| Asoka | 846.6 | 533.4 | 798.4 | 537.2 | 678.9 |
| Bintje | 756.8 | 384.0 | 1137.0 | 864.6 | 785.6 |
| Climax | 813.5 | 664.0 | 849.4 | 626.2 | 738.3 |
| Mean | 698.6 | 485.2 | 820.6 | 597.4 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | N.S. | N.S. |
| Varieties | 143.7 | 192.6 |
| Planting dates x Varieties | N.S. | N.S. |

Number of Marketable Tubers

The number of marketable tubers was affected by dates of planting as shown in Table 7. The April 22 and May 20 plantings did not differ significantly from the check, but the June 17 plantings produced a highly significantly lower number of marketable tubers. The largest number was produced by the April 22 planting which exceeded the other dates of planting by more than 4000 tubers. This probably increased competition for food materials between tubers and consequently resulted in the lower number of large tubers produced by the April 22 planting (Table 5). Climax and Bintje produced approximately the same as the check but Asoka produced highly significantly fewer marketable tubers. Interactions between planting dates and varieties was found to be significant at the 5% level. Bintje and Arran Banner planted on April 22 produced the highest numbers of marketable tubers and Asoka planted on June 17 produced the lowest number.

Yield of Marketable Tubers

The data reported in Table 8 indicate that the planting dates did not influence the yield of marketable tubers significantly. The April 22 planting produced the highest yield and the June 17 planting the lowest. The April 22 planting showed the highest tuber-set (Table 7), the highest yield of marketable tubers (Table 8) but the lowest number and yield of large tubers (Tables 5 & 6 respectively). The increase in yield by April planting was produced by an increase in numbers of medium sized tubers. June 17 planting produced lower

Table 7. Effect of planting date and variety on the number of marketable tubers per dunum during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | Mean |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | |
| Arran Banner | 33792 | 39750 | 28167 | 21208 | 30729.2 |
| Asoka | 29125 | 30958 | 28750 | 16709 | 26385.4 |
| Bintje | 34750 | 39916 | 26792 | 19209 | 30166.6 |
| Climax | 32958 | 36542 | 32875 | 22959 | 31333.4 |
| Mean | 32656.3 | 36791.6 | 29145.8 | 20020.9 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | 6898.2 | 10445.9 |
| Varieties | 2326.4 | 3117.1 |
| Planting dates x Varieties | 4652.7 | N.S. |

Table 8. Effect of planting date and variety on the yield of marketable tubers in kgs. per dunum of potatoes during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | Mean |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | |
| Arran Banner | 1808.5 | 2547.1 | 2302.8 | 1698.7 | 2089.3 |
| Asoka | 1895.6 | 1863.4 | 2028.2 | 1365.4 | 1788.2 |
| Bintje | 2164.6 | 2151.3 | 2014.9 | 1446.8 | 1944.4 |
| Climax | 2227.0 | 2507.3 | 2522.5 | 1657.0 | 2228.5 |
| Mean | 2023.9 | 2267.3 | 2217.1 | 1541.9 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | N.S. | N.S. |
| Varieties | 175.9 | 235.8 |
| Planting dates x Varieties | N.S. | N.S. |

yields (Table 8) and number (Table 7) of marketable tubers and higher numbers and yields of large tubers (Table 5 & 6 respectively) than the April 22 planting. The low yield of marketable tubers by the June 17 planting can be attributed partly to low germination and to high temperatures received by the crop during the growing period which caused low initiation of tubers and an increased respiration rate in vegetative parts without a corresponding increase in photosynthesis. The higher number and yield of large tubers by the June 17 planting compared with the April 22 planting seems to be due to more availability of food materials by each tuber because of the lower tuber set. The trend for the early plantings to give higher yield than the late plantings is in agreement with the findings of Cunningham, et al (11) and Chaudhry (10). Asoka and Bintje produced lower yields of marketable tubers, significant at the 5% and 1% level respectively, than the check. Asoka produced a higher number (Table 5) of large tubers but a lower number (Table 7) of marketable tubers than Arran Banner. Thus, it produced a considerably lower number of medium sized tubers. The latter tubers also had a lower average weight and consequently had a much lower total yield of tubers (Table 8) than the check. Bintje produced approximately the same number of marketable tubers but a higher number of large tubers and, therefore, produced a lower number of medium sized tubers than Arran Banner. Also the medium sized tubers were of lowest average weight resulting in a significantly lower marketable yield than the check. Climax produced a slightly lower number of medium sized tubers of approximately equal average weight but a higher yield of large tubers than Arran Banner

and consequently Climax produced the highest yield of all varieties although not significantly higher than Arran Banner. There was no interaction between planting dates and varieties on yield of marketable tubers.

Internal Brown Spot

Internal brown spot as affected by planting dates and varieties is shown in Table 9. The planting dates had no influence on the incidence of internal brown spot. In contrast, varieties differed highly significantly in this respect. Arran Banner and Asoka were equally susceptible to this disease, but Bintje and Climax were found to be immune. Interactions between planting dates and varieties were found to be statistically significant at 5% level. Arran Banner planted on June 17 showed a significantly lower incidence of internal brown spot than the check combination. These results concur with those of Ahmadi (1) and Chaudhry (10). However, this trend was found to be reversed in the case of Asoka as its lowest incidence of internal brown spot occurred when it was planted early.

The occurrance of internal brown spot in different sizes of tubers differed at the 1% level (Table 10). Internal brown spot occurred in a much higher percentage in large and medium sized tubers. There were no differences between Arran Banner and Asoka either between total numbers of tubers affected nor between numbers of each size class affected. These results are in agreement with Freidman (15) and Larson and Albert (19) who showed that the internal brown spot incidence increased with the increase of tuber size.

Table 9. Effect of planting date and variety on percentage incidence of internal brown spot in potatoes during 1963 at the Agricultural Research and Education Center

| Varieties | Planting Date | | | | |
|---|---|---|---|---|---|
| | March 25 | April 22 | May 20 | June 17 | Mean |
| Arran Banner | 64.2 | 62.5 | 55.0 | 45.8 | 56.9 |
| Asoka | 45.0 | 62.5 | 61.6 | 55.0 | 56.0 |
| Bintje | — | — | — | — | — |
| Climax | — | — | — | — | — |
| Mean | 27.3 | 31.2 | 29.1 | 25.2 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Planting dates | N.S. | N.S. |
| Varieties | 5.89 | 7.89 |
| Planting dates x Varieties | 11.77 | N.S. |

Table 10. Effect of tuber size and variety on percentage incidence of internal brown spot in potatoes during 1963 at the Agricultural Research and Education Center

| Varieties | Size of Tubers | | | Mean |
|---|---|---|---|---|
| | Large | Medium | Small | |
| Arran Banner | 88.1 | 66.6 | 16.9 | 56.9 |
| Asoka | 86.3 | 67.6 | 14.4 | 56.0 |
| Mean | 87.2 | 67.1 | 15.6 | |

| | L.S.D.(5%) | L.S.D.(1%) |
|---|---|---|
| Varieties | N.S. | N.S. |
| Sizes | 38.3 | 51.1 |
| Varieties x Sizes | N.S. | N.S. |

In general, the results of this study concur with those of Chaudhry (10) who conducted a similar experiment in the Beqa'a during 1962.

## SUMMARY AND CONCLUSIONS

This study was conducted to find the effect of planting dates and four varieties of potatoes on yield and number of tubers, incidence of internal brown spot, germination, plant height and flowering. The four varieties were Arran Banner, Asoka, Bintje and Climax. Arran Banner was taken as check. The four planting dates were March 25, April 22, May 20 and June 17 of which the March 25 planting was taken as standard.

Dates of planting influenced germination of potato seed tubers. The April and May plantings showed slightly lower germination but the June planting showed a highly significantly lower germination than the check. The June planting gave faster germination than the earlier plantings. All the varieties showed approximately the same percentage germination but in early plantings Asoka showed the slowest rate of germination.

The March planting produced the shortest plants and the June planting the tallest. The plant hight increased significantly with each delay of planting. All varieties produced highly significantly shorter plants than the check.

Flowering percent was higher with all planting dates than that of the check date. Much less flowering was observed in all varieties than with the check variety. Asoka showed the lowest flowering. Asoka and Climax produced no flowers when planted early but later Asoka flowered sparingly and Climax flowered rather profusely.

Production of large tubers was not affected by planting dates. The varieties Asoka, Bintje and Climax produced highly significantly higher numbers and yields of large tubers than did the check.

The tuber set and marketable yield of tubers were highest when planted on April 22. Though the yield differences between planting dates and the check were not statistically significant earlier plantings had a tendency to produce higher yields than late plantings. The variety Climax set the highest number of tubers and also produced the highest yield. Climax was not significantly different from Arran Banner but was a much better yielder than Asoka and Bintje.

Incidence of internal brown spot was almost the same for all planting dates. The varieties greatly differed in this respect. Arran Banner and Asoka were highly and equally susceptible whereas Climax and Bintje were completely free from this disease. Internal brown spot incidence was related to the size of the tubers as a greater incidence occurred in large and medium sized tubers than in small sized tubers.

It may, therefore, be recommended to the potato growers in the Beqa'a valley that potatoes should be planted sometime in mid-April and to prevent great losses from internal brown spot, the variety Climax should be grown.

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# APPENDIX

Table 11. Analysis of variance for percentage germination in potatoes

| Source | D.F. | M.S. |
|---|---|---|
| Plantings | 3 | 1472.51* |
| Rows | 3 | 48.18 |
| Columns | 3 | 112.02 |
| Error(a) | 6 | 53.83 |
| Varieties | 3 | 42.06 |
| Varieties x Plantings | 9 | 16.96 |
| Error(b) | 36 | 2412.32 |

Table 12. Analysis of variance for plant height in potatoes

| Source | D.F. | M.S. |
|---|---|---|
| Plantings | 3 | 3672.10** |
| Rows | 3 | 13.00 |
| Columns | 3 | 2.29 |
| Error(a) | 6 | 16.35 |
| Varieties | 3 | 1400.93** |
| Varieties x Plantings | 9 | 65.12** |
| Error(b) | 36 | 4.56 |

*denotes F values significant at the 5% level.

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

Table 13. Analysis of variance for flowering in potatoes

| Source | D.F. | M.S. |
|---|---|---|
| Plantings | 3 | 4390.64** |
| Rows | 3 | 170.28 |
| Columns | 3 | 7.98 |
| Error(a) | 6 | 78.63 |
| Varieties | 3 | 14609.19** |
| Varieties x Plantings | 9 | 2040.23** |
| Error(b) | 36 | 121.80 |

Table 14. Analysis of variance for number of potato tubers per dunum

| Source | D.F. | M.S.(Large tubers) | M.S.(Marketable tubers) |
|---|---|---|---|
| Plantings | 3 | 18014581.06 | 816071176.6 |
| Rows | 3 | 8816979.20 | 9054370.0 |
| Columns | 3 | 3123402.86 | 27104420.0 |
| Error(a) | 6 | 8591498.93 | 63421049.3 |
| Varieties | 3 | 62785604.23** | 79587286.6** |
| Varieties x Plantings | 9 | 6524218.40* | 23727681.1* |
| Error(b) | 36 | 2540071.07 | 10506405.4 |

*denotes F values significant at the 5% level.

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

Table 15. Analysis of variance for yield of potato tubers per dunum

| Source | D.F. | M.S.(Large tubers) | M.S.(Marketable tubers) |
|---|---|---|---|
| Plantings | 3 | 327472.30 | 1750910.63 |
| Rows | 3 | 130287.50 | 246434.83 |
| Columns | 3 | 95875.22 | 337682.50 |
| Error(a) | 6 | 138552.24 | 463404.58 |
| Varieties | 3 | 480331.44** | 573278.71** |
| Varieties x Plantings | 9 | 79647.34 | 116236.00 |
| Error(b) | 36 | 40106.74 | 60178.80 |

Table 16. Analysis of variance for percentage internal brown spot in potatoes

| Source | D.F. | M.S. |
|---|---|---|
| Plantings | 3 | 107.1 |
| Rows | 3 | 12.3 |
| Column | 3 | 129.8 |
| Error(a) | 6 | 83.8 |
| Varieties | 3 | 17000.8** |
| Varieties x Plantings | 9 | 145.4* |
| Error(b) | 36 | 68.3 |

*denotes F values significant at the 5% level.

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

Table 17. Analysis of variance for percentage internal brown spot in poratoes

| Source | D.F. | M.S. |
|---|---|---|
| Plantings | 3 | 725.00 |
| Rows | 3 | 47.22 |
| Columns | 3 | 775.00 |
| Error(a) | 6 | 520.83 |
| Variety | 1 | 37.50 |
| Variety x Plantings | 3 | 984.72 |
| Error(b) | 12 | 403.47 |
| Sizes | 2 | 43626.04** |
| Plantings x Sizes | 6 | 188.54 |
| Varieties x Sizes | 2 | 21.87 |
| Error(c) | 54 | 5862.46 |

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