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COMPOSITIONAL CHANGES IN THE DATE FRUIT DURING GROWTH AND RIPENING

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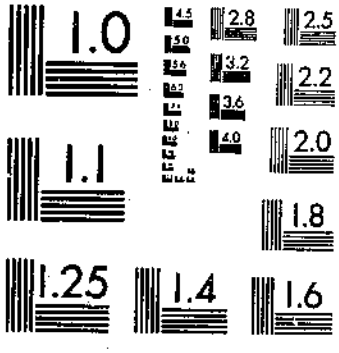

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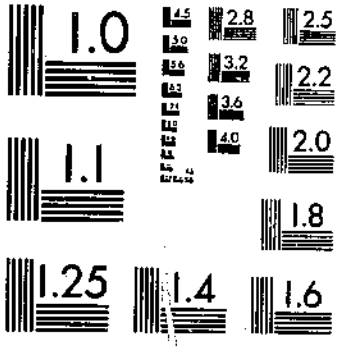

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Compositional Changes in the Date Fruit During Growth and Ripening [1]

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THE DATE INDUSTRY IN THE UNITED STATES

The economic importance of dates in American agriculture has increased rapidly since the first introduction of named varieties by the United States Department of Agriculture in 1890. That the American production is still far below consumption is shown by the fact that prewar importations ranged from 21,000 to 29,000 tons, as compared with the maximum domestic production of 10,500 tons in 1943 (*31*). [3] This crop compares with 870 tons in 1929. As a

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[2] The writer is grateful to the following growers for permission to use material from their date gardens in the course of this investigation: Ted C. Buck, Mrs. Chauncey D. Clarke, James McFarlan, and Robbins Russel; to the California Date Growers' Association for the use of its storage facilities; to M. P. Masure, formerly of the Bureau of Plant Industry, Soils, and Agricultural Engineering, for assistance in collecting fruit samples during one season; to W. W. Aldrich and R. W. Nixon, of this Bureau, through whose courtesy samples of fruit from palms with various leaf-to-fruit-bunch ratios were obtained; and to G. O. Burr and L. S. Moyer, of the University of Minnesota, for valuable suggestions on the preparation of the manuscript.

[3] Italic numerals in parentheses refer to Literature Cited, p. 50.

result of this fortunate increase in domestic production the date crop made a substantial contribution to the available food supply of the American people during the war years, when importations were reduced to insignificant amounts. In terms of energy supply, 100 pounds of fresh dates contains 60 pounds of sugar; hence, the 1943 crop contained 6,000 tons of sugar, or the equivalent of refined sugar from 39,000 tons of sugar beets, or the average yield of 3,300 acres; or 79,000 tons of sugarcane, or the average yield of 4,400 acres.[4]

During the war part of the date crop was used to replace some of the dried fruits that had been removed from the usual civilian trade channels for use by the armed forces. Part of the crop was used in the preparation of ration kits for the armed forces; the large amount of energy per unit weight and volume fits the date to this use. It is a fair source of the minerals calcium and iron.

Because of climatic limitations almost all the commercial dates produced in this country are grown in the Coachella and Imperial Valleys of California and in the Salt River Valley of Arizona; about 90 percent of the total crop is produced in the Coachella Valley.

FACTORS RELATED TO COMPOSITION AND QUALITY OF DATES

In spite of various studies, such as those of Vinson (*32*), Sievers and Barger (*29*), and Haas and Bliss (*13*), the available information on the composition of dates is small in comparison with that of many other crops. In order to obtain additional information the development of the fruit of Deglet Noor and Barhee varieties was followed near Indio, Calif., in 1938 and 1939 for periods up to 25 weeks, beginning about 6 weeks after pollination and extending to the end of the harvest period.

In this study it was found in general that after the main period of cell division the development of the date should be divided into three stages with different characteristics rather than into two stages as usually done.

The two periods, or stages, into which the development of the date is usually divided are characterized by (1) rapid increase in size and fresh weight and (2) rapid accumulation of dry matter, especially sugar. Associated with the first stage are a high proportion of reducing sugars, a high degree of hydration, relatively high active acidity, accumulation of almost all the solids which are insoluble in 80-percent alcohol, and green color. Associated with the second are a rapid increase in sucrose; a rapid decrease in percentage of reducing sugars, but not in amount; a gradual decrease in active acidity; a gradual increase in proportion of soluble pectin in the total pectin; a decrease in quantity of protopectin per fruit; a decrease in percentage of water and in quantity per fruit; and a characteristic color—red in Deglet Noor and yellow in Barhee.

The three stages into which the compositional development should be divided are characterized as follows: (1) Rapid increase in fresh

[4] Calculated from average yield and production figures for 1929 to 1943 (*31*).

weight and volume; rapid accumulation of reducing sugars; low but increasing rate of accumulation of total sugars and total solids; highest active acidity; hydration high, but not quite equal to that in the next period; and green color. (2) Reduced rate of gain in fresh weight and volume, greatly reduced rate of accumulation of reducing sugars, considerable reduction in the already low rate of accumulation of total sugars, high degree of hydration, slightly reduced active acidity, and green color. (3) Continued decrease in rate of gain in fresh weight, the actual weight possibly even decreasing late in the period; low rate of gain in reducing sugars; rapidly increasing rate of accumulation of sucrose, total sugars, and total solids; decreasing degree of hydration; continued decrease in active acidity; and red or yellow color, according to variety. The third stage continues until the fruits begin to ripen.

There was little difference between the composition of the basal and apical halves until after about the first of August, when the water and sucrose contents were lower and reducing sugars were higher in the apical half than in the basal. The concentration of sugars in the fruit sap remained low throughout the period of rapid growth and then increased rapidly. The ultimate concentration in immature Deglet Noor dates was 2.2 moles of sucrose and 1.0 mole of reducing sugars per liter of water, assuming all the water to be free. There was no increase in quantity of total sugars per fruit after a maturity of 50- to 90-percent-soft had been attained.

The maximum water content per fruit coincided with the maximum susceptibility of the dates to injury from checking, the forerunner of blacknose. In percentage of fresh weight the water content was high during the first two of the three periods of fruit development that have been described. It decreased during the third period and continued to decrease as the dates ripened. An abnormally high moisture content during and immediately preceding ripening seemed to be associated with inferior quality in the ripe dates. Excessive darkening in storage was associated with high moisture content. No consistent relation was found between the moisture content and the proportion of reducing sugars in ripe dates at different pickings from the same garden.

Hydrogen-ion concentration was usually slightly higher in the basal half than in the apical during the growing season and was highest at the time of the most rapid rate of increase in fresh weight. It decreased somewhat as the dates ripened, and in ripe dates the concentration was usually slightly higher in the apical half than in the basal.

Soluble nonsugar solids accumulated at rates such that a graph showing quantity per fruit has a shape similar to that representing total solids. A similar graph for insoluble solids more nearly resembles the one for the fresh weight per fruit. Most of the protopectin was accumulated while the dates were increasing in size and fresh weight; it was quantitatively related to the water content. There was no decrease in total alcohol-insoluble solids upon ripening of the Deglet Noor; in the Barhee there was a decrease which was quantitatively equal to the decrease in total pectic substances in that variety.

Reduction in leaf-to-fruit-bunch ratio tended to increase the water content and reduce the size of the ripe dates, but it did not affect the total sugar content in percentage of dry weight.

Differences in soil type did not produce any noticeable effects on the composition of the dates.

Although there was a trend toward a lower prevailing temperature at the end of the harvest season and a lowering of the proportion of reducing sugars in total sugars at the end of the season, no close relation between these two factors could be detected.

Changes associated with ripening include softening, change in color, decrease in fresh weight, decrease in water content, decrease in active acidity, decrease in sucrose, increase in reducing sugars, decrease in protopectin, increase in soluble pectin in the Deglet Noor and a slight decrease in the Barhee, and conversion of tannin from the soluble to an insoluble, tasteless form. The Barhee has very little astringency and is edible in the immature condition.

Many kinds of fruits continue to increase in size and weight after they have become sufficiently mature, or ripe, to be picked for the market; consequently, within limits, it is often worth while for the grower to delay picking for a time so as to take advantage of the increased yield. Fruits of which this is true include the apple, pear, plum, grapefruit, and orange. The date, however, does not fit into this category. In the varieties that have been investigated no further gain in dry matter occurs after the ripening process is well under way. On the other hand, the dry weight of dates in the preripe, or khalal, stage continues to increase until ripening has begun, and even if it were possible to prepare a satisfactory product from dates picked in the khalal stage, a reduction in yield would result from this practice.

The stage of maturity at which dates should be picked to the best advantage of the grower is determined partly by the cost of handling when picked at different stages of maturity, from 50-percent-soft to tree-ripe; partly by the facilities available for ripening and curing and the cost of operating them; and partly by the returns obtained for different grades of dates. Added to these factors or superimposed on them must be that of liability of the crop to injury from rain, excessive heat, birds, or other causes if picking is delayed. During periods of labor shortage it may become necessary, however, to employ procedures that would not normally be conducive to producing the highest quality or giving the greatest profit.

MATERIALS AND METHODS

Source of Material

Most of the work reported in this bulletin was done on the Deglet Noor variety, because most American-grown dates are of the cane-sugar group of which this variety is the most important representative. The Barhee was chosen as a second variety for two reasons. (1) It represents a large group of varieties in that it is an invert-sugar date. The invert-sugar group is important, although the total American crop of invert-sugar dates is far below that of the cane-sugar group. (2) It is also one of the few varieties in which the tannin

content of the immature dates is low. If the presence of soluble tannin has any effect on enzyme activity in immature dates, it might be expected that some evidence of this effect would be found in differences in the behavior of the two varieties. Soluble tannin, however, disappears from all varieties as the fruits ripen.

All the material was obtained from date palms growing in the Coachella Valley. All gardens of the Deglet Noor variety are within 7 miles of Indio, Calif.; one from which the Barhee was obtained is near Thermal, Calif., and the other is at Indio. All these gardens are within 50 feet of sea level. For convenience each garden was given a reference letter (table 1).

The gardens were selected for the purpose of representing several types of soil on which dates are grown. In view of the various cultural practices of the growers, however, any differences found might be related to treatment rather than to soil type. Size is affected by so many factors that specific experiments would have to be set up to determine the influence of each. The factors involved include soil type and texture; permeability of soil to air and water; soil reaction, composition, and structure; frequency and amount of irrigation; fertilization; and pollination and bunch-thinning practices. The presence of a tight, impervious layer of soil at varying depths near the surface in garden B made water penetration highly unsatisfactory; this probably had a greater effect on the results than the fine texture of the soil.

TABLE 1.—*Source of date material*

Garden designation	Variety	Year of sampling	Soil type [1]
A	Deglet Noor	1938; 1939	Coachella very fine sand, smooth phase.
B	do	1939	Indio clay loam, silty phase.
C	do	1939	Coachella fine sand.
D	do	1939	Coachella very fine sand.
E	Barhee	1939	Indio very fine sand.
F	do	1939	Indio loam.

[1] From U. S. soil survey (*18*).

DESCRIPTION OF SAMPLES

As dates develop they undergo color changes similar to those of some other fruits, such as the blackberry. The stage in which the color is green is referred to as kimri, after the Arabian usage. As the dates approach their maximum size they turn from green to yellow or various shades of red, depending upon the variety; this stage is referred to as khalal. The khalal color of the Deglet Noor variety is red, and that of the Barhee is yellow. The fruits remain turgid throughout the kimri and khalal stages. The khalal stage is followed by the rutab, which begins with the onset of ripening and continues up to but does not include curing. The typical khalal color disappears as the fruits ripen, and the characteristic varietal color of the ripe dates develops. Finally there is the tamar stage, which includes dates in a condition sufficiently cured to keep without spoilage from molding or fermentation at ordinary temperatures. The 50-percent-soft, 90-percent-soft, and tree-ripe stages of maturity used in the work reported in this bulletin are all in the rutab stage.

In 1938 only the Deglet Noor variety from garden A was sampled, whereas in 1939 samples were taken from all the gardens listed. In 1938 all bunches used had been pollinated with pollen from the same male palm between April 10 and 15. Each palm carried 10 to 12 moderately thinned bunches and gave an average yield of about 300 pounds of ripe dates. Soon after pollination 4 uniform bunches on each of 5 palms were selected and marked. Samples were picked from these bunches at 2-week intervals from May 17 to June 28 and then at weekly intervals until November 8, the end of the harvest season. Samples collected after some of the fruits had ripened were divided into 4 maturity groups as follows:

(1) Khalal; no part of the fruits had begun to ripen, but all of them had turned from green to red in color.
(2) Fifty-percent-soft; softening, which normally begins at the apex in the Deglet Noor variety, had progressed to the equatorial region.
(3) Ninety-percent-soft; softening had progressed to the region of the shoulder.
(4) Tree-ripe; the entire fruits had softened but had not cured.

No partly ripened dates were picked from garden D.

In presenting the results the four maturity groups were treated separately for various reasons. Primarily it was desirable to investigate the composition of dates at the various stages of maturity to learn at approximately what stage they had attained their maximum complement of total dry matter and sugar; it was also desirable to learn something about the constancy of the compositional relation of the groups during the entire period of ripening.

Samples were picked in 1939 in the manner described for 1938 except that collections were made at 2-week intervals until some of the fruits began to ripen and at weekly intervals thereafter. After the first two pickings each year the fruits were divided at the equator and the basal and apical halves were preserved and analyzed separately. This division was not made on fruits from gardens D and F.

The number of fruits per sample depended on size and availability, ranging from 400 at the first picking each season to as few as 25 for some stages of maturity at some pickings in which no more material was available from the bunches being used. With immature dates the number was gradually decreased to 80 per sample as the size increased. This number was maintained in order to assure representative samples.

Since the samples were picked immediately after sunrise, the fruits were hardly exposed to direct sunlight on the day they were picked; this prevented the introduction of variations due to different degrees of desiccation during days of varying intensities of heat. At each sampling, fruits were picked from scattered positions on the bunches in order to compensate for local variations.

The individual fruits of one bunch may differ as much as 6 to 12 weeks in reaching full ripeness. This wide variation in rate of development and ripening necessitated taking at each sampling date samples of fruits of definite stages of maturity rather than a single sample of the bunch as a whole. A composite sample of a bunch after ripening had begun would reveal very little exact information on the developmental, or ripening, process. The discussion applying to growth rates or rates of accumulation is concerned only with that part of the season preceding the beginning of harvest.

A heavy rain fell on September 4 and 5, 1939. A period of warm, humid weather followed the rain, with the result that a large portion of the fruit was made unfit for use by cracking and mold infection and was not included in the samples. Since samples were drawn from only the less mature, sound fruits, they showed a lower sugar content than would have been the case if more of the more mature fruits had been sound enough to be included. Another heavy rain fell on September 24.

Methods of Making Determinations

The perianths and seeds were removed, and only the flesh was retained in the samples. In 1938 a part of each sample was frozen at −15° C. for pH determinations; the remainder was ground in a coarse food chopper and mixed, and aliquots were immediately dropped into sufficient hot 95-percent alcohol to make the final concentration at least 80 percent. The samples were held at the boiling point for 30 minutes and then sealed. The sampling technique was the same in 1939 except that no pH determinations were made.

The pH of expressed juice was determined by means of a glass-electrode pH meter. The pH of ripe dates was determined on unfrozen ground flesh. It was found necessary to add three drops of water to each sample of ripe Deglet Noor dates in order to insert the electrodes; this was done uniformly on all the ripe samples of this variety. Freezing was omitted on ripe samples (1) because it was unnecessary, since the tissue broke up easily in the unfrozen state and no juice could be pressed even from frozen tissue; and (2) because even hard freezing did not change the physical condition of the fruit. The ripe dates did not freeze hard until a temperature of approximately −45° C. was reached.

In 1938 the material was extracted 16 hours in Soxhlet extractors. The 80-percent alcohol used for extraction was changed after the first 3 hours. Heating was done by a water bath maintained at approximately 92° C. In 1939 all extraction was done in Landsiedl extractors heated by the same bath; again 80-percent alcohol was used, but it was found that 3 hours was sufficient for complete extraction. Preliminary trials showed complete extraction in 2½ hours. This method has the advantage of speed and much shorter exposure to heat, which is important when dealing with material containing such relatively unstable substances as levulose. Small pieces of pumice rock eliminated bumping more effectively than glass beads or pieces of glass tubing.

The method adopted to determine moisture content consisted in weighing the insoluble residue in tared thimbles and drying and weighing aliquots of the extract. Both fractions were dried at 60° C. at a pressure of less than 1 inch of mercury. This method is more time-consuming but also more accurate than the method of Bidwell and Sterling (*2*), which is commonly used on dates, or any other similar one that was tried. The Bidwell-Sterling method is satisfactory for certain materials and purposes but is subject to variations in the results, which depend on the degree of dispersion of the material and rate and time of boiling as well as on the composition of the material. Dry levulose yielded 7.4 percent water when boiled in

toluene for 1½ hours. Water was not removed by boiling dextrose or sucrose in toluene for that period, but if xylene was substituted for toluene (*25*) water was removed from dextrose also. These methods are useful for quickly approximating the water content if the conditions are well controlled.

Sugars were determined by a modification of the Quisumbing and Thomas permanganate titration method, as described by Harvey (*15*). Reducing sugars were calculated as invert sugar. The sugars represented by the increase in reducing power after acid hydrolysis are referred to as sucrose. Separation of dextrose and levulose was done by the procedure of Jackson and Mathews, as given by Loomis and Shull (*22*). Total sugars are the sum of the reducing and nonreducing fractions.

Acid hydrolyzable polysaccharides were determined by the official procedure (*1*) and are reported as dextrose. No fractionation of this group was attempted.

Pectic substances were determined by the method of Carré (*7*) with Conrad's modification (*9*) of extracting protopectin with ammonium citrate instead of ammonium oxalate. These substances are reported as impure calcium pectate.

Sugars, pectic substances, and soluble and insoluble solids are reported as percentage of dry weight and also as quantity per fruit; water is given as percentage of fresh weight and as quantity per fruit. Where percentage composition of the whole fruit is given, the values were obtained from the weighted average of the values for the two halves analyzed separately. Quantities per fruit were calculated on the basis of the average size of the fruits in each sample.

RATE OF GROWTH AND ACCUMULATION OF SUGAR

The growth of dates as indicated by their fresh and dry weights at various times is shown in figure 1. The fresh weights of average fruits on various dates during the season are given in table 2 for gardens A to E; garden F was not sampled during the growing season. Crawford (*10*) and Haas and Bliss (*13*) showed that increases in length and girth are closely associated with increases in fresh weight.

The development of dates has long been divided into two stages: (1) Rapid increase in size and (2) rapid accumulation of sugar and consequent increase in dry weight. Although the data presented in figure 2 substantiate this concept, upon closer examination it will be seen that the development may be divided into three stages. This second interpretation is considered in the discussion beginning on page 18. Up to that point the discussion is based on the division of the development into two stages.

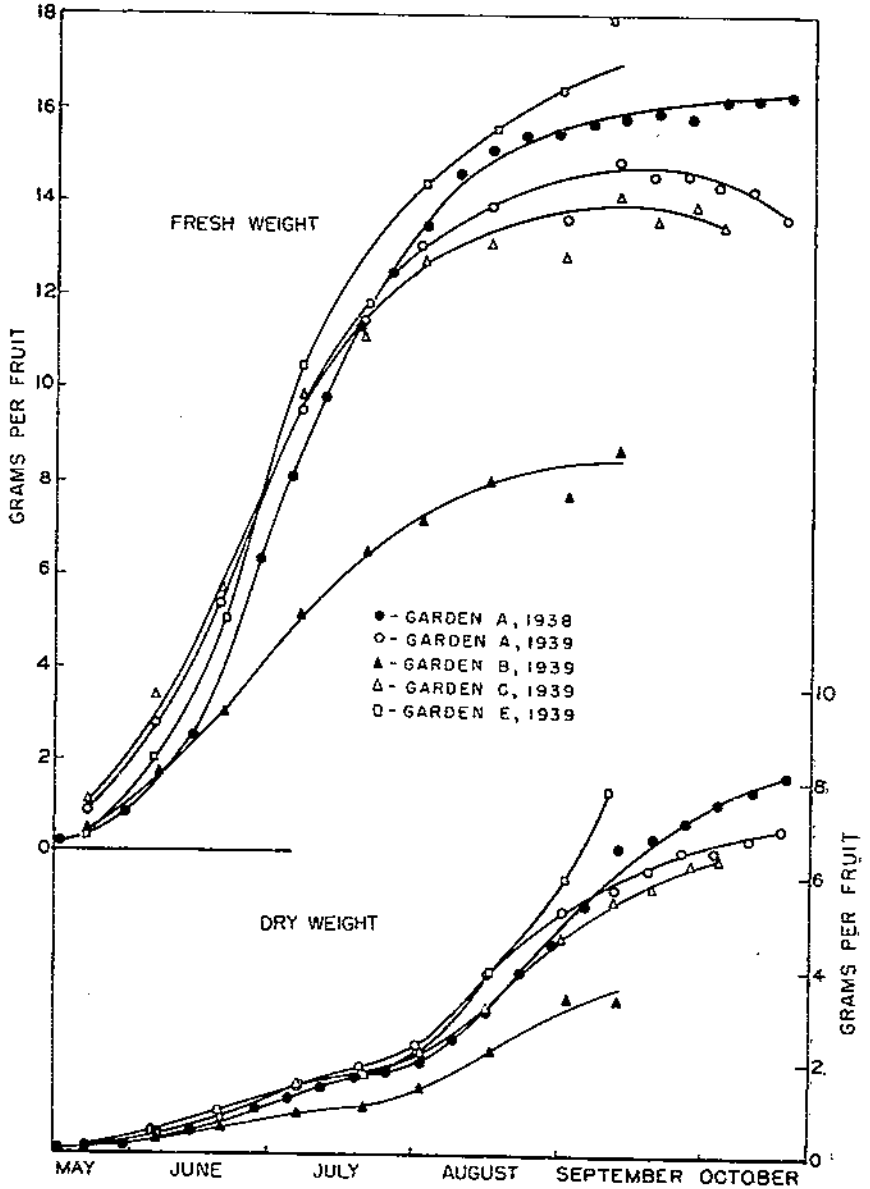

FIGURE 1.—Growth of immature dates as indicated by their fresh and dry weights.

TABLE 2.—*Water, reducing-sugar, sucrose, and total sugar contents and active acidity of dates at various stages of ripeness*

[Whenever no value is given for the apical half, the fruits were not divided and the value under the basal half is based on analysis of whole fruits]

DEGLET NOOR (GARDEN A, 1938)

Day of sampling	Stage	Fresh weight per fruit	Water (fresh-weight basis)		Reducing sugars (dry-weight basis)		Sucrose (dry-weight basis)		Total sugars (dry-weight basis)		Active acidity	
			Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
		Grams	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*pH*	*pH*
May 17	Kimri	0.2	78.1		5.5		7.9		13.4		5.49	
31	do	.9	80.8		14.6		6.5		21.1		5.29	
June 14	do	2.6	83.2	82.4	21.5	28.2	4.7	2.9	26.2	31.1	5.05	5.15
28	do	6.3	85.3	84.7	30.7	31.6	6.4	4.2	37.1	35.8	5.23	5.31
July 5	do	8.1	85.7	84.8	34.8	33.9	7.5	4.2	42.3	38.1	5.24	5.31
12	do	9.8	85.8	85.0	35.0	32.1	7.9	4.7	42.9	36.8	5.30	5.35
19	do	11.3	86.4	84.7	37.7	32.7	8.2	5.6	45.9	38.3	5.29	5.31
26	do	12.5	86.4	85.0	35.2	31.0	10.3	8.9	45.5	39.9	5.49	5.49
Aug. 2	Khalal	13.4	86.2	83.8	32.7	27.8	19.8	15.6	52.5	43.4	5.45	5.55
9	do	14.5	82.9	82.4	24.2	24.8	32.6	30.4	56.8	55.2	5.66	5.76
16	do	15.1	79.9	79.0	18.9	20.5	43.0	36.3	61.9	56.8	5.67	5.74
23	do	15.4	74.8	74.3	14.2	17.4	51.4	45.2	65.6	62.6	5.77	5.78
30	do	15.4	71.6	69.8	12.6	16.2	55.9	52.1	68.5	68.3	5.78	5.91
Sept. 6	do	15.6	66.8	64.7	11.6	15.3	61.7	56.0	73.3	71.3	5.77	5.97
	do	15.8	62.4	56.9	11.0	14.9	63.0	58.1	74.0	73.0	5.41	5.49
13	50-percent-soft	14.4	46.5	36.0	8.8	16.8	64.9	57.4	73.7	74.2	5.93	6.05
	90-percent-soft	12.9	38.2	31.0	18.0	20.1	61.4	54.5	79.4	74.6	6.11	6.13
	Tree-ripe	11.9	27.6	25.7	21.1	23.1	54.7	52.4	75.8	75.5	6.07	5.92
	Khalal	15.9	59.3	56.5	10.9	16.1	61.9	58.8	72.8	74.9	5.65	6.00
20	50-percent-soft	15.2	45.6	34.8	10.1	18.9	63.3	57.6	73.4	76.5	6.20	6.20
	90-percent-soft	13.5	38.8	30.6	19.0	20.3	57.9	54.4	76.9	74.7	6.11	6.06
	Tree-ripe	11.6	28.3	28.0	21.9	24.0	54.3	53.9	76.2	77.9	6.35	5.95
	Khalal	15.8	58.3	51.1	11.3	15.9	63.9	59.7	75.2	75.6	5.42	5.60
27	50-percent-soft	15.1	46.0	33.9	15.0	16.7	63.2	60.6	78.2	77.3	5.81	5.96
	90-percent-soft	13.6	38.3	31.3	19.5	20.5	59.8	56.0	79.3	76.5	5.96	5.95
	Tree-ripe	11.5	27.2	25.6	22.8	25.2	54.5	52.3	77.3	77.5	6.05	5.83
	Khalal	16.1	56.4	50.2	11.4	15.6	63.4	62.1	74.8	77.7	5.50	5.74
Oct. 4	50-percent-soft	15.1	44.5	34.0	13.9	17.4	64.6	58.2	78.5	75.6	5.98	5.97
	90-percent-soft	14.1	38.6	30.7	17.8	19.9	61.6	56.2	79.4	76.1	6.03	5.94
	Tree-ripe	11.7	27.5	25.7	24.3	26.4	53.5	51.1	77.8	77.5	5.93	5.90
	Khalal	16.1	55.0	48.3	10.9	15.4	67.6	61.8	78.5	77.2	5.55	5.67
11	50-percent-soft	15.1	43.0	33.8	14.7	17.8	66.1	59.1	80.8	76.9	6.17	6.20
	90-percent-soft	14.1	36.3	32.3	18.0	21.9	59.0	55.6	77.0	77.5	6.29	6.21
	Tree-ripe	12.6	31.5	29.5	23.4	25.4	53.6	52.6	77.0	78.0	6.32	6.10

DEGLET NOOR (GARDEN A, 1938)—Continued

Day of sampling		Stage	Fresh weight per fruit	Water (fresh-weight basis)		Reducing sugars (dry-weight basis)		Sucrose (dry-weight basis)		Total sugars (dry-weight basis)		Active acidity	
				Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
			Grams	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*pH*	*pH*
Oct.	18	Khalal	16.2	52.6	46.8	11.5	15.4	67.6	61.9	79.1	77.3	5.34	5.52
		50-percent-soft	15.5	42.6	33.9	13.0	16.7	66.5	60.0	79.5	76.7	5.90	6.20
		90-percent-soft	14.0	36.8	31.6	16.3	21.6	61.8	55.6	78.1	77.2	6.24	6.23
		Tree-ripe	12.5	29.3	28.3	22.4	26.4	54.7	51.2	77.1	77.6	6.32	6.21
	25	50-percent-soft	15.0	43.0	35.9	12.4	16.7	68.6	62.1	81.0	78.8	5.80	6.01
		90-percent-soft	14.6	36.8	31.3	16.5	21.5	63.0	56.1	79.5	77.6	6.06	6.15
		Tree-ripe	12.1	21.8	24.2	22.1	25.2	54.9	51.8	77.0	77.0	6.20	6.12
Nov.	1	50-percent-soft	14.8	41.1	32.3	13.2	16.8	66.7	60.2	79.9	77.0	6.05	6.14
		90-percent-soft	13.9	36.0	31.6	14.2	19.1	65.8	59.3	80.0	78.4	6.22	6.19
		Tree-ripe	12.5	27.7	26.2	19.5	21.1	58.3	55.3	77.8	76.4	6.19	6.10
	8	50-percent-soft	14.2	40.6	34.4	12.5	15.8	67.2	62.2	79.7	78.0		
		90-percent-soft	13.2	35.3	31.3	13.7	18.9	65.7	58.8	79.4	77.7		
		Tree-ripe	12.5	27.9	27.8	15.9	19.2	59.6	57.8	75.5	77.0		

DEGLET NOOR (GARDEN A, 1939)

May	23	Kimri	0.9	80.4		16.4		4.4		20.8			
June	6	do	2.8	82.6		24.4		4.1		28.5			
	20	do	5.4	83.6	84.2	29.8	31.2	3.9	4.0	33.7	35.2		
July	7	do	9.5	84.7	83.8	33.7	30.8	5.5	4.9	39.2	35.7		
	20	do	11.4	83.6	83.4	28.7	27.6	11.5	10.8	40.2	38.4		
Aug.	1	do	13.0	82.2	81.8	21.9	22.6	27.9	25.8	49.8	48.4		
	16	Khalal	13.9	72.7	71.3	12.1	14.8	52.0	47.8	64.1	62.6		
Sept.	1	do	13.6	63.9	59.1	11.7	15.7	62.4	59.6	74.1	75.3		
		do	14.9	63.9	58.7	11.1	14.8	63.6	61.1	74.7	75.9		
	12	50-percent-soft	14.4	45.5	36.1	18.4	21.0	61.2	56.6	79.6	77.6		
		90-percent-soft	14.0	40.1	34.5	20.9	22.5	59.9	59.1	80.8	81.6		
		Tree-ripe	12.0	34.3	32.0	22.2	23.9	58.6	56.3	80.8	80.2		
		Khalal	14.5	60.7	54.4	10.9	14.8	65.9	63.0	76.8	77.8		
	19	50-percent-soft	13.6	43.6	36.6	17.5	19.5	61.8	60.2	79.3	79.7		
		90-percent-soft	13.0	36.4	30.7	23.4	24.0	57.9	57.5	81.3	81.5		
		Tree-ripe	11.6	30.9	29.6	27.0	27.8	53.5	52.9	80.5	80.7		

TABLE 2.—*Water, reducing-sugar, sucrose, and total sugar contents and active acidity of dates at various stages of ripeness*—Continued

DEGLET NOOR (GARDEN A, 1939)—Continued

Day of sampling	Stage	Fresh weight per fruit	Water (fresh-weight basis)		Reducing sugars (dry-weight basis)		Sucrose (dry-weight basis)		Total sugars (dry-weight basis)		Active acidity	
			Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
		Grams	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*pH*	*pH*
Sept. 26	Khalal	14.5	58.1	51.8	10.6	14.9	65.3	62.1	75.9	77.0		
	50-percent-soft	13.7	43.0	34.0	15.9	18.1	63.3	61.0	79.2	79.1		
	90-percent-soft	12.9	31.5	30.4	18.8	21.5	62.8	59.2	81.6	80.7		
	Tree-ripe	11.0	24.8	23.9	20.6	29.5	50.6	51.1	80.2	80.6		
Oct. 3	Khalal	14.3	57.3	51.6	9.7	13.5	67.4	63.7	77.1	77.2		
	50-percent-soft	13.8	43.1	34.2	15.9	18.5	64.3	60.9	80.2	79.4		
	90-percent-soft	13.1	37.7	32.4	17.8	20.5	63.1	60.4	80.9	80.9		
	Tree-ripe	11.4	28.6	26.9	25.2	25.6	55.0	54.8	80.2	80.4		
10	Khalal	14.2	55.2	49.4	9.5	13.8	67.9	63.9	77.4	77.7		
	50-percent-soft	13.8	41.7	32.8	14.6	18.2	64.8	61.4	79.4	79.6		
	90-percent-soft	12.5	37.5	33.4	18.7	21.2	62.4	59.8	81.1	81.0		
	Tree-ripe	10.8	24.0	24.8	25.8	27.6	53.7	52.9	79.5	80.5		
17	Khalal	13.6	50.9	46.0	10.4	14.9	66.2	64.9	76.6	79.8		
	50-percent-soft	13.2	40.6	31.2	12.4	17.0	69.1	63.7	81.5	80.7		
	90-percent-soft	12.5	36.0	29.7	15.5	18.8	65.8	62.8	81.3	81.6		
	Tree-ripe	10.8	26.7	25.2	23.6	24.6	56.8	55.5	80.4	80.1		
24	50-percent-soft	13.1	39.7	32.2	14.1	16.7	66.6	64.2	80.7	80.9		
	90-percent-soft	12.4	35.7	30.2	14.9	17.1	67.5	64.0	82.4	81.1		
	Tree-ripe	11.3	28.9	27.0	18.5	20.6	62.8	60.4	81.3	80.0		
Nov. 7	Tree-ripe	11.2	27.1	25.0	15.3	18.0	66.4	62.6	81.7	80.6		

DEGLET NOOR (GARDEN B, 1939)

May 23	Kimri	0.5	78.4		15.4		5.2		20.6			
June 7	do	1.8	81.0		23.7		5.7		29.4			
21	do	3.0	82.0	81.8	32.1	35.0	6.7	6.0	38.8	41.0		
July 7	do	5.1	83.8	83.3	36.8	36.5	7.9	6.8	44.7	43.3		
21	do	6.5	84.0	83.7	31.4	32.0	16.0	15.9	47.4	47.9		
Aug. 2	do	7.2	80.1	80.4	20.7	23.1	36.5	33.1	57.2	56.2		
17	Khalal	8.0	72.2	72.3	13.3	16.1	57.2	53.6	70.5	69.7		
Sept. 2	do	7.7	56.9	55.8	13.6	16.1	62.6	59.9	76.2	76.0		
13	do	8.7	63.2	60.1	11.6	14.7	64.7	61.2	76.3	75.9		
	Tree-ripe	5.1	29.5		25.7		52.2		77.9			

DEGLET NOOR (GARDEN C, 1939)

Day of sampling	Stage	Fresh weight per fruit	Water (fresh-weight basis)		Reducing sugars (dry-weight basis)		Sucrose (dry-weight basis)		Total sugars (dry-weight basis)		Active acidity	
			Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
		Grams	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*pH*	*pH*
May 23	Kimri	1.1	75.4		14.5		3.7		18.2			
June 6	do	3.3	82.7		25.5		5.6		31.1			
20	do	5.6	84.2	83.9	28.7	35.0	5.5	5.2	34.2	40.2		
July 7	do	9.8	84.5	84.7	33.4	35.2	7.3	7.3	40.7	42.5		
21	do	11.0	84.4	84.8	29.3	29.9	19.3	18.2	48.6	48.1		
Aug. 2	do	12.7	82.8	82.1	22.0	23.7	33.9	30.9	55.9	54.6		
16	do	13.1	75.7	75.4	14.5	17.7	52.7	47.8	67.2	65.5		
Sept. 1	Khalal	12.8	65.7	61.3	14.0	17.4	59.4	58.9	73.4	76.3		
	do	14.1	63.1	59.0	12.6	16.3	64.3	59.9	76.9	76.2		
12	50-percent-soft	12.9	44.9	36.7	21.1	24.8	59.3	56.9	80.4	81.7		
	90-percent-soft	12.2	39.1	34.9	26.7	27.3	51.4	51.3	78.1	78.6		
	Tree-ripe	9.7	30.0	29.1	29.5	31.6	48.0	46.3	77.5	77.9		
	Khalal	13.6	60.6	55.1	12.8	17.0	63.1	59.5	75.9	76.5		
20	50-percent-soft	12.7	45.7	34.4	22.4	22.4	58.7	59.5	81.1	81.9		
	90-percent-soft	11.7	36.4	28.8	25.7	22.3	52.2	55.8	77.9	78.1		
	Tree-ripe	10.1	28.6	27.3	30.3	30.8	47.9	47.4	78.2	78.2		
	Khalal	13.9	58.0	52.2	10.5	14.9	68.3	64.8	78.8	79.7		
28	50-percent-soft	12.9	45.6	36.3	18.1	20.2	62.8	61.3	80.9	81.5		
	90-percent-soft	12.9	40.0	34.9	24.1	23.7	53.9	54.0	78.0	77.7		
	Tree-ripe	10.5	27.8	27.5	32.9	30.0	44.6	48.3	77.5	78.3		
	Khalal	13.5	55.9	49.7	10.7	13.3	69.0	67.0	79.7	80.3		
Oct. 4	50-percent-soft	12.7	44.5	35.5	16.1	20.4	65.5	60.8	81.6	81.2		
	90-percent-soft	11.2	37.8	33.7	23.4	24.3	53.1	52.7	76.5	77.0		
	Tree-ripe	10.0	30.9	30.1	33.1	32.8	42.8	44.8	75.9	77.6		
	50-percent-soft	13.0	39.0	32.5	11.6	15.6	69.1	63.6	60.7	79.2		
11	90-percent-soft	11.0	31.2	29.5	15.5	18.1	63.0	59.3	78.5	77.4		
	Tree-ripe	9.8	23.6	25.4	30.5	32.6	47.1	44.9	77.6	77.5		
24	Tree-ripe	10.0	21.6	21.3	14.8	17.5	62.9	60.8	77.7	78.3		

DEGLET NOOR (GARDEN D, PLOT A, 1939)

May 23	Kimri	1.1	[1] 81.1		[1] 21.1		[1] 3.8		[1] 24.9			
June 6	do	2.4	83.4		24.5		5.2		29.7			
20	do	4.4	84.6		32.8		4.4		37.2			

[1] Composite sample from all plots before the application of differential treatments.

TABLE 2.—*Water, reducing-sugar, sucrose, and total sugar contents and active acidity of dates at various stages of ripeness*—Continued

DEGLET NOOR (GARDEN D, PLOT A, 1939)—Continued

Day of sampling	Stage	Fresh weight per fruit	Water (fresh-weight basis)		Reducing sugars (dry-weight basis)		Sucrose (dry-weight basis)		Total sugars (dry-weight basis)		Active acidity	
			Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
		Grams	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*pH*	*pH*
July 7	Kimri	8.5	85.5		34.5		5.4		39.9			
20	do	10.4	84.6		33.1		11.8		44.9			
Aug. 1	do	11.3	83.0		25.8		26.0		51.8			
16	Khalal	12.3	74.2		16.8		47.6		64.4			
Sept. 1	do	12.4	61.1		15.9		58.8		74.7			
10	Tree-ripe	8.3	24.1		37.5		43.7		81.2			
13	Khalal	12.2	62.0		14.3		60.1		74.4			
24	Tree-ripe	8.9	23.2		37.5		43.2		80.7			
27	Khalal	12.9	58.5		12.6		62.5		75.1			
Oct. 9	Tree-ripe	9.2	23.5		33.7		49.4		83.1			

DEGLET NOOR (GARDEN D, PLOT B, 1939)

May 23	Kimri	1.1	[1] 81.1		[1] 21.1		[1] 3.8		[1] 24.9			
June 6	do	2.6	83.4		21.3		5.3		29.6			
20	do	4.3	84.5		33.4		4.1		37.5			
July 7	do	8.6	85.1		35.8		7.7		43.5			
20	do	10.5	84.8		33.5		13.1		46.6			
Aug. 1	do	12.0	83.0		26.0		26.7		52.7			
16	Khalal	13.2	76.0		16.7		47.9		64.6			
Sept. 1	do	13.5	64.4		14.9		58.2		73.1			
10	Tree-ripe	8.4	24.0		38.0		41.5		79.5			
13	Khalal	13.5	63.4		15.1		60.4		75.5			
24	Tree-ripe	9.0	27.9		35.3		44.6		79.9			
27	Khalal	14.1	58.5		12.7		62.4		75.1			
Oct. 9	Tree-ripe	9.7	24.2		34.3		48.4		82.7			

DEGLET NOOR (GARDEN D, PLOT C, 1939)

May 23	Kimri	1.1	[1] 81.1		[1] 21.1		[1] 3.8		[1] 24.9			
June 6	do	2.3	83.0		24.3		4.1		28.4			
20	do	4.1	84.5		33.0		4.1		37.1			
July 7	do	6.7	85.3		36.0		5.8		41.8			

DEGLET NOOR (GARDEN D, PLOT C, 1930)—Continued

Day of sampling	Stage	Fresh weight per fruit	Water (fresh-weight basis)		Reducing sugars (dry-weight basis)		Sucrose (dry-weight basis)		Total sugars (dry-weight basis)		Active acidity	
			Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
July 20	Kimri	*Grams* 8.5	*Percent* 85.0	*Percent*	*Percent* 31.4	*Percent*	*Percent* 11.3	*Percent*	*Percent* 45.7	*Percent*	*pH*	*pH*
Aug. 1	do	10.1	84.5		30.2		20.0		50.2			
16	Khalal	10.9	79.5		20.8		40.7		61.5			
Sept. 1	do	10.7	70.9		15.5		55.0		70.5			
10	Tree-ripe	7.1	29.3		39.4		39.6		79.0			
13	Khalal	10.8	66.1		14.6		58.4		73.0			
24	Tree-ripe	8.1	29.5		36.1		45.3		81.4			
27	Khalal	11.0	62.9		13.3		60.5		73.8			
Oct. 9	Tree-ripe	8.2	28.5		38.3		44.5		82.8			
DEGLET NOOR (GARDEN D, PLOT D, 1930)												
May 23	Kimri	1.1	[1] 81.1		[1] 21.1		[1] 3.8		[1] 24.9			
June 6	do	2.4	83.4		25.0		4.6		29.6			
20	do	4.4	84.6		32.9		4.2		37.1			
July 7	do	7.4	85.2		35.3		6.7		42.0			
20	do	9.3	84.7		32.7		13.1		45.8			
Aug. 1	do	10.5	83.7		27.4		21.8		49.2			
16	Khalal	11.5	76.9		18.2		46.6		64.8			
Sept. 1	do	11.6	66.2		15.9		57.2		73.1			
10	Tree-ripe	8.0	29.2		42.7		35.9		78.6			
13	Khalal	11.4	65.2		14.1		58.2		72.3			
24	Tree-ripe	8.3	29.2		35.3		46.0		81.3			
27	Khalal	11.9	59.5		13.1		63.2		76.3			
Oct. 9	Tree-ripe	8.3	25.0		35.5		47.5		83.0			
BARHEE (GARDEN E, 1930)												
May 23	Kimri	0.5	81.3		16.9		4.9		21.8			
June 7	do	2.1	84.7		31.0		7.6		38.0			
21	do	5.0	80.4	85.7	41.3	43.7	6.1	4.9	47.4	48.6		
July 7	do	10.5	87.3	86.8	48.8	48.5	5.4	4.6	54.2	53.1		
21	do	12.8	86.9	86.8	49.7	50.6	4.4	3.9	54.1	54.5		
Aug. 2	do	14.4	85.8	85.1	45.7	44.7	14.7	13.6	60.4	58.3		
17	Khalal	15.5	74.4	74.9	28.5	33.2	44.6	41.2	73.1	74.4		
Sept. 2	do	16.4	65.2	62.7	14.8	20.4	64.1	59.4	78.9	79.8		
11	do	17.9	57.8	54.9	17.2	15.7	63.5	65.6	80.7	81.3		
	Tree-ripe	13.7	38.7	39.4	77.9	80.2	.3	.2	78.2	80.4		

[1] Composite sample from all plots before the application of differential treatments.

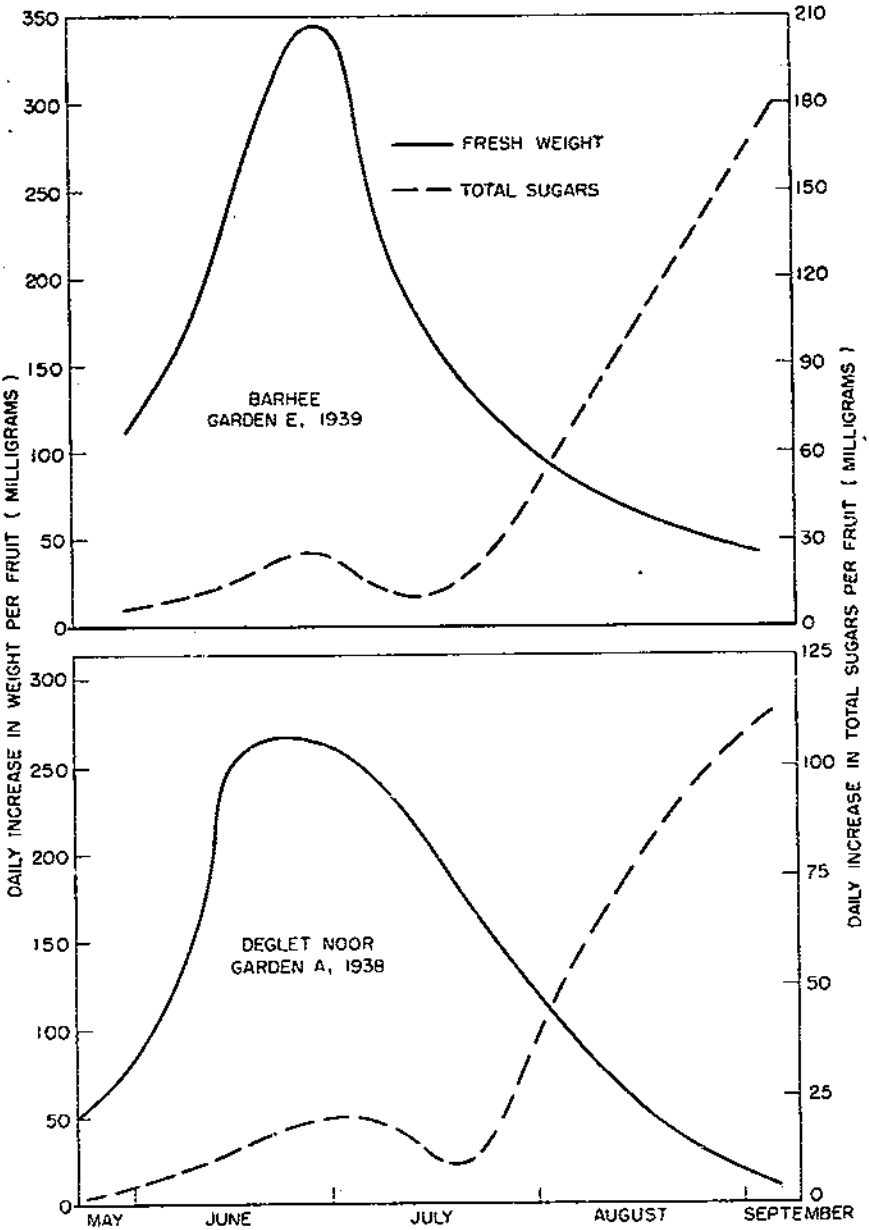

FIGURE 2.—Daily increases in fresh weight and total sugars of immature dates.

Figure 2 shows smoothed curves which indicate the rates of change in fresh weight and in total sugars in Deglet Noor dates from garden A, 1938, and in Barhee dates from garden E. Both show a rapid increase in rate of gain in fresh weight during the second half of June and both maintained a high rate during the first half of July, but the maximum rate came a little later in the Barhee than in the Deglet Noor. There are seasonal differences in this respect, but the Barhee is known to be later in maturing. The rate of gain in fresh weight continued to decrease in the latter part of July, but that in total sugars increased rapidly in both varieties until the beginning of harvest. After that the rate was probably as high as before, but since fruits were continually ripening and being removed from the trees it was not possible to obtain an accurate measure of it.

In each series the rate of increase in dry weight during the first period was low compared with that during the second. The percentage of total sugars in dry matter increased at a relatively constant rate from about 20 percent in the latter part of May to from 39 to 48 percent on or about July 20 in the Deglet Noor series and from 22 percent to 54 percent in the Barhee. In spite of these increases the actual accumulation of sugar in the fruit was small compared with that during the second period.

The two periods in the development of dates are also distinguished by a difference in the kind of sugar accumulated during each period. In table 3, which shows the average daily gain in reducing sugars, sucrose, and total sugars during the two periods, it will be noted that there is a striking similarity in the behavior of all the series in both varieties.

TABLE 3.—*Average daily gain in sugar per fruit during each of the two main periods of development of dates*

Variety	Garden designation	Year of sampling	Period			Average daily gain per fruit		
			No.	Inclusive dates	Duration	Reducing sugars	Sucrose	Total sugars
					Days	*Milligrams*	*Milligrams*	*Milligrams*
Deglet Noor	A	1938	1	May 17 to July 25	70	8.4	1.6	10.0
			2	July 26 to Sept. 12	49	5.0	79.0	84.0
Do.	A	1939	1	May 23 to July 19	58	9.1	3.5	12.6
			2	July 20 to Aug. 31	43	4.9	78.1	83.0
Do.	B	1939	1	May 23 to July 20	59	5.8	2.7	8.5
			2	July 21 to Sept. 1	43	2.5	48.4	50.9
Do.	C	1939	1	May 23 to July 20	59	8.1	5.4	13.5
			2	July 21 to Aug. 31	42	5.2	69.2	74.4
Barhee	E	1939	1	May 23 to Aug. 1	71	13.0	4.0	17.0
			2	Aug. 2 to Sept. 10	40	8.3	118.0	126.3

The rate of accumulation of reducing sugars was always considerably greater during the first period than during the second and usually several times as great as that of sucrose during the first period. On the other hand, the rate for sucrose was very low during the first period but increased to a rate as much as 49 times as fast during the

second (table 3, garden A, 1938). Total sugars increased 6 to 8 times as fast in the second period as in the first.

The sugar content in five series at various times during the entire growing season is shown in figure 3. It will be noted that all series behaved much alike, irrespective of the type of soil on which the palms were growing or of differences in cultural treatment. The two varieties also behaved much alike, but during the second period the Barhee gained considerably more rapidly in sugar than the Deglet Noor. Any differences among the series are largely due to size rather than to percentage composition.

The uniformity in sugar content among the series is shown in figure 4. In all series the reducing sugars increased rapidly until some time in July, attaining a maximum of 32 to 37 percent of the dry weight in the Deglet Noor and 50 percent in the Barhee (table 2). The exact time at which the maximum occurred varied with season and variety. Subsequently the percentage dropped as rapidly as it had increased, but this drop was due to the rapid increase in sucrose rather than to an actual decrease in quantity of reducing sugars per fruit. After late August the percentage of reducing sugars remained about constant until the fruits began to ripen.

The percentage of sucrose remained very low for several weeks while the dates were growing at the maximum rate. Later it increased rapidly not only in quantity per fruit but also in percentage of dry weight. All series gained in percentage of sucrose at about the same rate.

The curves for total sugars show an interesting and consistent reduction in rate of increase during the first part of July, the exact time varying somewhat with the season. This decrease in rate occurred in both halves in both varieties in all series under observation. These reductions, which can also be seen in both the sugar curves in figure 2, introduce a third stage in the dry-weight accumulation in dates. No compensatory factor has been found in the accumulation of any other component of the fruit. Perhaps there is some relation to the seed development, such as has been observed in stone fruits by Connors (*8*), Lilleland (*19*), Brooks (*5*), and others. The balance between vegetative and reproductive growth in a plant is delicate; the development of the seed within a fruit and that of its fleshy parts are both important, according to McCollum (*24*), who found that parthenocarpic fruits of cucumbers did not reduce vegetative growth as much as normal fruits. The fresh weights of the seeds at the various pickings in 1938 are shown in figure 5, but no dry weights were obtained and no observations were made on the development of the various portions of the seeds. The seeds increased in weight uniformly until early in July; by the end of that month growth had ceased entirely. The decrease in rate of gain in sugar occurred when the quantity of sugar per fruit was still small and the dates were completely green (kimri stage). Hardening of the seed coincided with this period of reduced rate of sugar accumulation.

The additional stage in the development of the date is not obvious in curves showing fresh or dry weights or in those showing the rate of increase in fresh weight, but it is clear in curves showing the rate

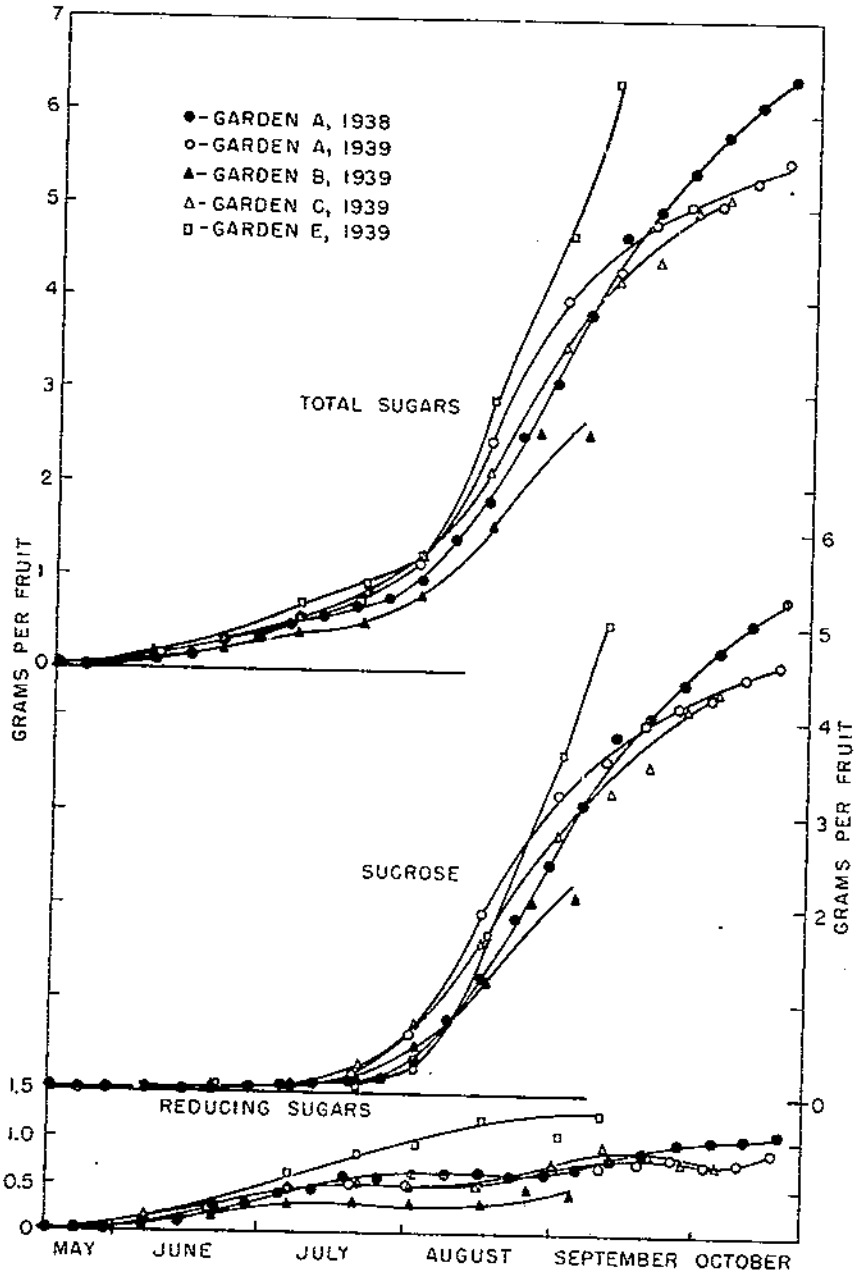

FIGURE 3.—Reducing sugars, sucrose, and total sugars in immature dates, expressed as quantity per fruit.

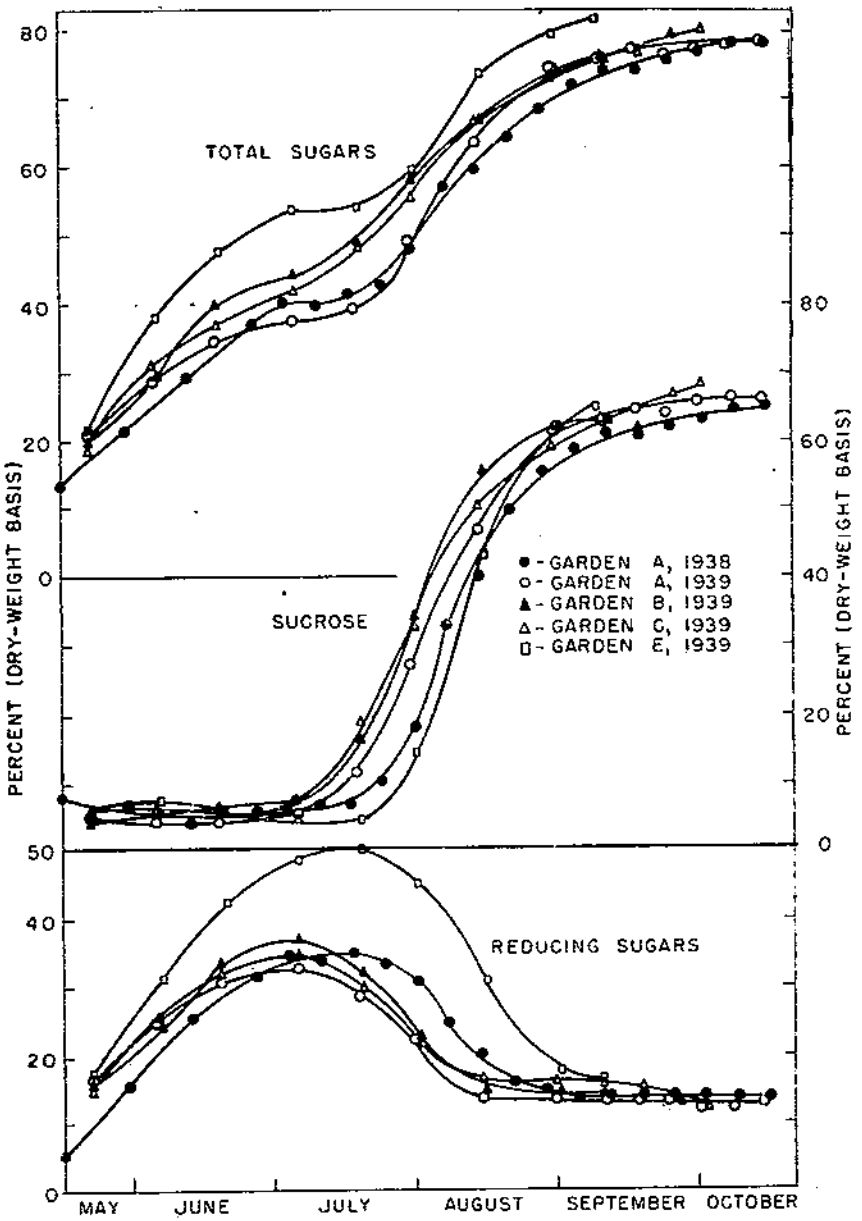

FIGURE 4.—Sugar content of immature dates, expressed as percentage of dry weight.

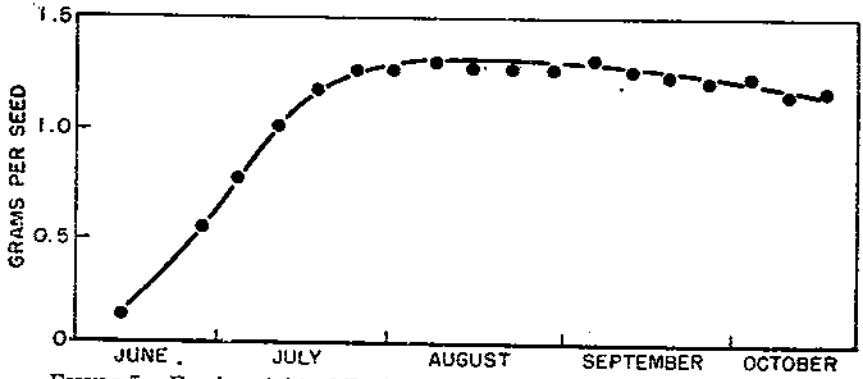

FIGURE 5.—Fresh weight of Deglet Noor date seeds of different pickings, garden A, 1938.

of increase in total sugars (fig. 2). According to these results, the development of dates should be divided into three stages such as have been reported for stone fruits, as already indicated, rather than into two, as stated by Vinson (*32*), Haas and Bliss (*13*), and others. These stages can be characterized as follows:

(1) Rapid increase in fresh weight and volume; rapid accumulation of reducing sugars; low but increasing rate of accumulation of total sugars and total solids; highest active acidity; hydration high, but not quite equal to that in the next period; and green color.

(2) Reduced rate of gain in fresh weight and volume, greatly reduced rate of accumulation of reducing sugars, considerable reduction in the already low rate of accumulation of total sugars, high degree of hydration, slightly reduced active acidity, and green color.

(3) Continued decrease in rate of gain in fresh weight, the actual weight possibly even decreasing late in the period; low rate of gain in reducing sugars; rapidly increasing rate of accumulation of sucrose, total sugars, and total solids; decreasing degree of hydration; continued decrease in active acidity; and red or yellow color, according to variety.

The first and second stages are in the kimri stage of development, and the third is in the khalal. The first corresponds approximately to Long's third and fourth stages in the anatomical development of the date (*21*), the second to his fifth, and the third to his sixth. The third stage continues until the fruits begin to ripen.

The high proportion of reducing sugars in dates during the time they are growing rapidly is further shown in figure 6. Reducing sugars are expressed as percentage of total sugars rather than by the usual ratio of reducing sugars to sucrose, since doing this gives a clearer picture of the relation. The curves for the two varieties are much alike until the beginning of ripening; at that time the reducing sugars in the Barhee increase to about 100 percent of the total sugars, whereas in the Deglet Noor they usually increase to only 30 to 40 percent. Reducing sugars constituted over 80 percent of the total during much of the first two periods of development, attaining a maximum of 89 percent in the Deglet Noor (June 20, garden A, 1939) and 92 percent in the Barhee (July 21, garden E). As sucrose accumulated, the percentage of reducing sugars decreased to about 15 or 20 percent of the total in both varieties.

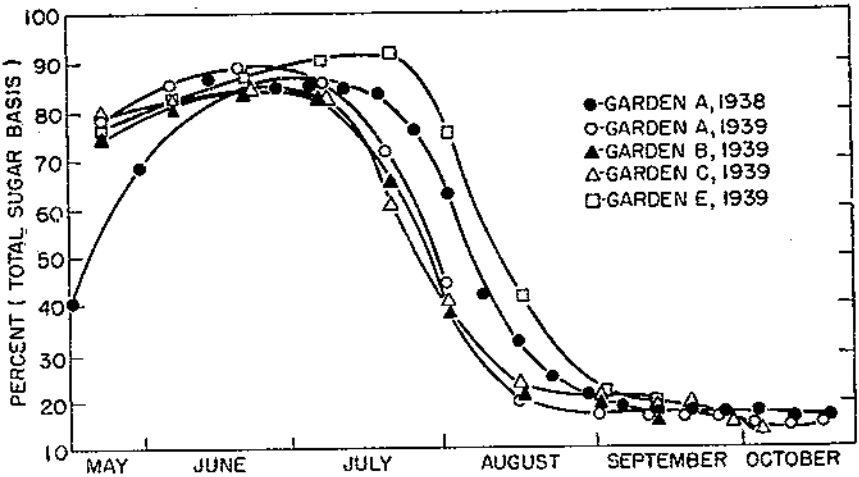

FIGURE 6.—Reducing sugars in immature dates, expressed as percentage of total sugars.

Changes that occur in the sugars of dates during ripening differ widely among varieties according to the type to which the variety belongs. In the fruit of both varieties discussed in this bulletin the sugar was predominantly sucrose immediately before ripening began (table 2 and figs. 4 and 6). At the time the first fruits ripened this form of sugar amounted to 80 to 83 percent of the total sugar present in the remaining immature fruits in the series under observation. As soon as ripening began, part of the sucrose was inverted, the amount undergoing this change depending on the variety, environmental conditions, and internal variations in the fruit. An indication of the extent to which the sucrose was inverted in the series under observation by the time the dates were tree-ripe may be obtained from table 4.

TABLE 4.—*Proportion of reducing sugars in total sugars in dates immediately after they were picked*

Variety	Garden designation	Year of sampling	Reducing sugars (total sugar basis) in—	
			Immature fruits [1]	Ripe fruits [2]
			Percent	*Percent*
Deglet Noor	A	1938	15	30
Do	A	1939	16	30
Do	B	1939	17	33
Do	C	1939	18	37
Do	D, plot A	1939	18	44
Do	D, plot B	1939	19	45
Do	D, plot C	1939	19	47
Do	D, plot D	1939	16	47
Barhee	E	1939	20	100
Do	F	1939	20	98

[1] Average during harvest season only.

[2] Average for the season.

The contrast in invertase activity during the ripening of the Deglet Noor and the Barhee is striking. Previous to the beginning of ripening, the proportion of reducing sugars in total sugars was about the same in the two varieties, or close to 20 percent. Upon completion of ripening, the reducing sugars had increased to about 35 percent of the total sugars in average Deglet Noor dates, whereas in the Barhee they had increased to about 100 percent. The length of time required for the ripening of an individual fruit is no greater for the Barhee than for the Deglet Noor. Inversion in fruit still retaining any sucrose continued after harvest at a rate influenced by the factors already mentioned and also by storage temperature, moisture content, and processing treatment.

SUGAR CONTENT

Since it was found that the reducing sugars in dates are composed of approximately equal parts of dextrose and levulose, this fraction is reported as invert sugar. This is in agreement with results reported by Vinson (*32*). It was likewise found that the reducing substances obtained upon acid hydrolysis of the alcoholic extracts were also composed of approximately equal parts of dextrose and levulose: the nonreducing sugar is therefore reported as sucrose. Cleared date extracts, either before or after acid hydrolysis, did not contain any appreciable amounts of reducing substances that were not readily fermented by yeast.

Comparison of Basal and Apical Halves

In five series the fruits of all samples after the first two were divided at the equator and the two halves were preserved and analyzed separately (table 2). As the differences between the two halves were similar in all the series, only one set of typical curves (garden A, 1939) is presented (fig. 7). The reducing sugars were nearly equal in the two halves until August 1, after which time those in the apical half exceeded those in the basal half by about 4 percent. Likewise, the two halves were equal in sucrose content until August 1, after which that in the basal half was higher. As a result, the total sugars of the two halves remained nearly equal during the entire developmental period of the fruit. In the series under discussion the apical half was slightly higher in total sugars than the basal half at the end of the growing season but this was not always true; the averages for partly ripe and ripe fruits in three series appear in table 5. It was always true in the Deglet Noor, however, that reducing sugars were higher and sucrose was lower in the apical half than in the basal during the latter part of the season until the dates had ripened (table 2).

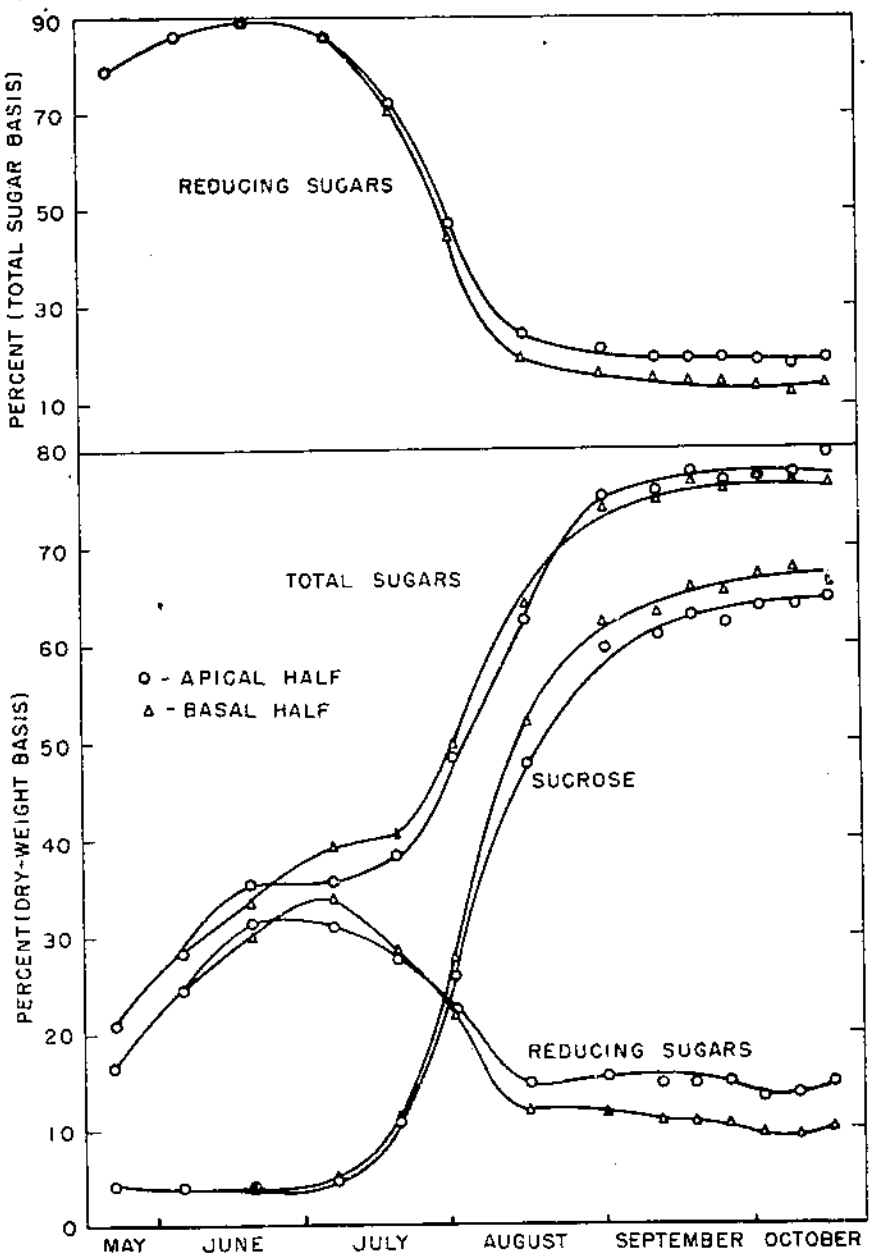

FIGURE 7.—Comparison of sugar content of basal and apical halves of immature Deglet Noor dates, garden A, 1939.

TABLE 5.—*Comparison of average total sugar content of basal and apical halves of partly ripe and ripe Deglet Noor dates*

Garden designation	Year of sampling	Sugar content (dry-weight basis) at indicated stage of maturity					
		50-percent-soft		90-percent-soft		Tree-ripe	
		Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
A	1938	78.3	76.8	78.9	76.7	76.8	77.2
A	1939	80.0	79.6	81.2	81.2	80.6	80.5
C	1939	80.9	81.1	77.8	77.8	77.4	78.0

These results are not in agreement with those of Haas and Bliss (*13*), who found considerable differences in the reducing, nonreducing, and total sugars in the two halves of Deglet Noor throughout the growing season. They reported differences as high as 9 percent in the reducing sugars of the two halves and as high as 17 percent in the nonreducing, with the result that the percentage of the latter in the basal half was more than twice as high as that in the apical. The fact that there were some ripe fruits in their sample picked on September 20 could partly explain the difference on this date, but earlier samples showed even greater proportional differences in the nonreducing sugar contents of the two halves; e.g., they found 9.9 and 2.2 percent in the basal and apical halves on July 1 and 13.1 and 3.9 percent, respectively, on July 22.

The constancy of the differences in the relative amounts of the various sugars in the two halves of ripe dates of the Deglet Noor variety is shown in table 6. The difference in total sugars between the two halves was not as great or as consistent as that between the two fractions. In 20 of 23 lots the apical half was higher in reducing sugars, in 3 in sucrose, and in 13 in total sugars. Total sugars in the 2 halves were equal in 2 instances. These differences were continuations of those which began developing in the sugar-accumulating period of fruit growth and were remarkably constant throughout the season. These results agree with those of Haas and Bliss (*13*), who reported that reducing sugars were higher in the apical half and nonreducing in the basal. They differ, however, in that Haas and Bliss found total sugars to be higher in the basal half.

TABLE 6.—*Frequency with which one half of ripe Deglet Noor dates exceeded the other in sugar content (dry-weight basis) in 23 lots*

Garden designation	Year of sampling	Reducing sugars		Sucrose		Total sugars[1]	
		Basal half	Apical half	Basal half	Apical half	Basal half	Apical half
A	1938	0	9	9	0	3	5
A	1939	1	7	7	1	4	4
C	1939	2	4	4	2	1	4

[1] In 2 lots the halves were equal in total sugars.

Concentration of Sugars in the Sap of Immature Dates

The concentration of sugars in the sap of immature dates has been calculated in an arbitrary manner, based on the assumptions that the water in the fruit is uniformly distributed throughout the tissues involved in each sample and that none of it is bound. Both of these assumptions are in error, but it is considered that the data give approximate information, valuable for purposes of comparison. No attempt was made to determine the bound water, but doubtless some was present. However, if any bound water was present this fact would reduce the amount of free water that could act as a solvent, and the actual concentration would be somewhat greater than that shown.

The data from garden A, 1939, are used to illustrate the concentration of sugars in the sap of growing dates of the Deglet Noor variety and those from garden E that of the Barhee (fig. 8). The concentration of reducing sugars was almost the same and remarkably constant in both halves throughout the period of rapid growth in size. In the Deglet Noor it increased from 40 gm. per liter of water on May 23 to 59 gm. on June 20, remained constant until July 20, and then decreased slightly until early August. Subsequently there was a gradual increase in both halves, but this was more rapid in the apical half; this increase continued as the dates ripened. On October 17 the concentrations in immature dates were 100 and 174 gm. per liter in the basal and apical halves, respectively.

The sucrose concentration in the Deglet Noor dates remained at an almost constant value of 7 to 10 gm. per liter of water from May 23 to July 7. By August 1 it had increased until it exceeded that of reducing sugars: afterward it increased rapidly for the duration of the life of the fruit. The sucrose concentrations in the two halves were alike up to the middle of August (fig. 8), but by October 17 they had increased to 638 gm. per liter of water in the basal half of the fruit and 761 gm. in the apical half. The break in this increase early in September (fig. 8) was caused by rain which fell on the fourth and fifth. The higher concentration in the apical half than in the basal during the latter portion of the season was largely the result of a lower moisture content rather than of a higher sugar content (table 2).

During the period of rapid growth of Deglet Noor dates the concentration of reducing sugars (dextrose and levulose) in grams per liter of water was about six times that of sucrose; thus the molecular concentration of each of the two reducing sugars was about six times that of sucrose.

During the growing period the concentration of reducing sugars in Barhee dates (garden E) increased slowly from 40 gm. per liter of water in the whole fruits on May 23 to 76 gm. in the basal half and 78 gm. in the apical half on August 2 (fig. 8). The increase continued at a uniform rate, except for the influence of rain, until September 11, when the two halves had concentrations of 125 and 128 gm., respectively. The sucrose concentration decreased from 13 gm. per liter on June 7 to 7 gm. in the basal half and 6 gm. in the apical half on July 21. After this the concentration increased rapidly up to 465 and 538 gm. per liter of water, respectively, on September 11 (fig. 8).

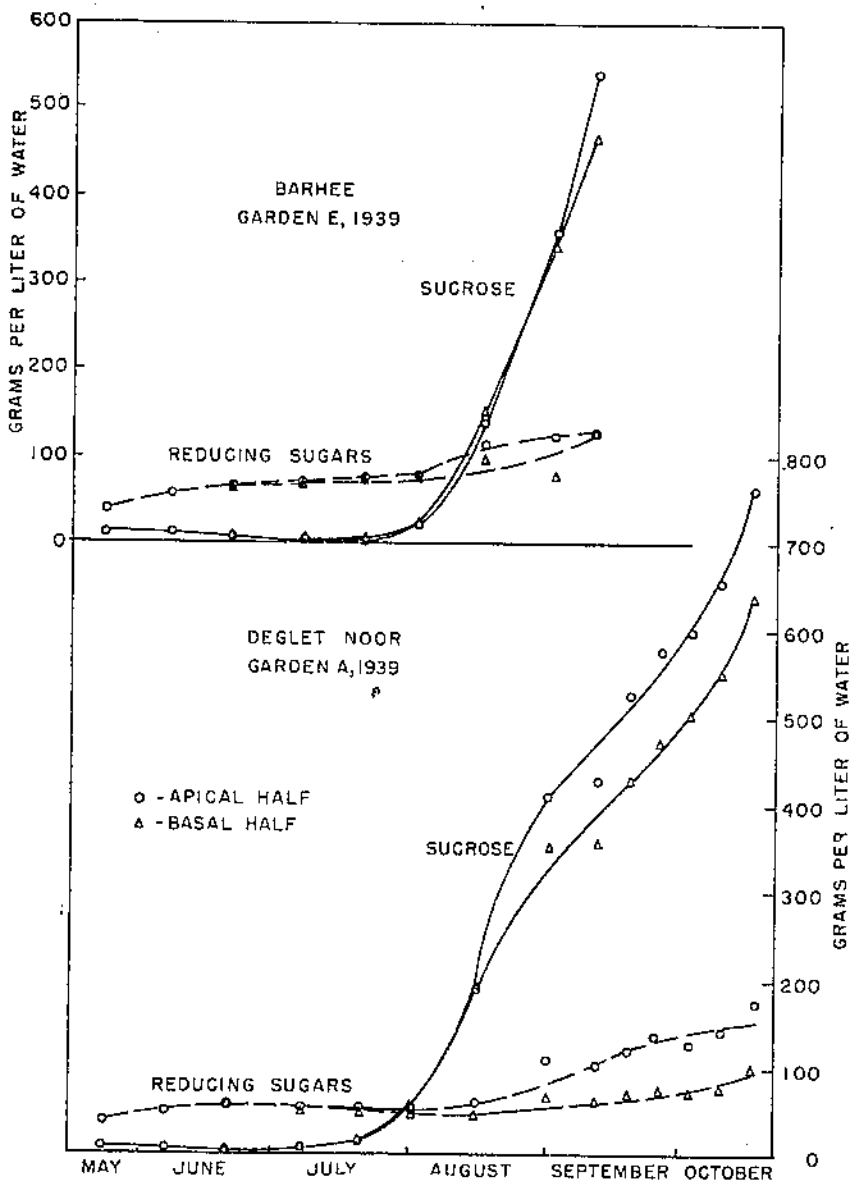

FIGURE 8.—Concentration of sugars in the sap of immature dates, expressed as grams per liter of water.

No additional samples were obtained in this series, as the crop was almost ruined by rain.

The ultimate concentration of sugar found in the immature Deglet Noor dates was equivalent to 2.2 moles of sucrose and 1.0 mole of reducing sugars, or a total of 3.2 moles per liter of water. In addition to the sugars there were other solids soluble in 80-percent alcohol (most of them water-soluble), which amounted to as much as 99.5 gm. per liter of water; also there were some solids insoluble in alcohol but soluble in water (e.g., pectin). In spite of these high concentrations of sugars and other soluble solids immature dates lost water at this stage of development, whereas earlier, with a sugar concentration of about 60 gm. of reducing sugars and 10 gm. of sucrose per liter of water, or a total of about 0.36 mole per liter, the water content increased rapidly in quantity and at least held its own in percentage. The hydration is probably causally related to the active acidity, as Caldwell (*6*) suggested in his discussion on hydration of growing and ripening fruits.

Influence of Stage of Maturity

Fruits of the Deglet Noor variety begin to ripen at the apical end. Ripening progresses inward and toward the basal end until, after 10 days to several weeks, the whole fruit is ripe. The length of time required for the ripening process depends on the environment, especially the temperature. Barhee dates turn translucent as they ripen; the process begins with the appearance of one to several soft, translucent spots anywhere on the surface. These spots increase in size until they coalesce and the entire fruit becomes soft and ripe. The curing process which follows consists in completion of the breakdown of the tissues and in dehydration.

Dates attain their maximum sugar content soon after they begin to ripen. The exact stage of maturity at which they contain the maximum amount of sugar appears to vary somewhat, but it is at some stage from 50-percent-soft to something less than tree-ripe in the Deglet Noor; it may be at least as early in the Barhee. This stage is influenced to a certain extent by the growing conditions, the part of the harvest season in question, and the variety. In very few instances in the Deglet Noor series was the total sugar content of ripe dates as high as that of those from the same series at some earlier stage of maturity picked on the same day. At times the sugar content of khalal fruit was as high as that of partly ripe or ripe dates when computed as percentage of dry weight, but not when computed as quantity per fruit. Figure 9 indicates that the dates failed to gain in sugar during the final stages of ripening. This is true whether the sugar is considered on a percentage basis or as quantity per fruit. Consistent results have been obtained in this respect in the three series on which detailed observations have been made. Similar results were obtained on the Barhee, but the number of observations was too small to permit drawing definite conclusions. Table 7 shows the average results for the various gardens. Ripe dates from all the gardens contained less total sugar per fruit than partly ripe ones from the same

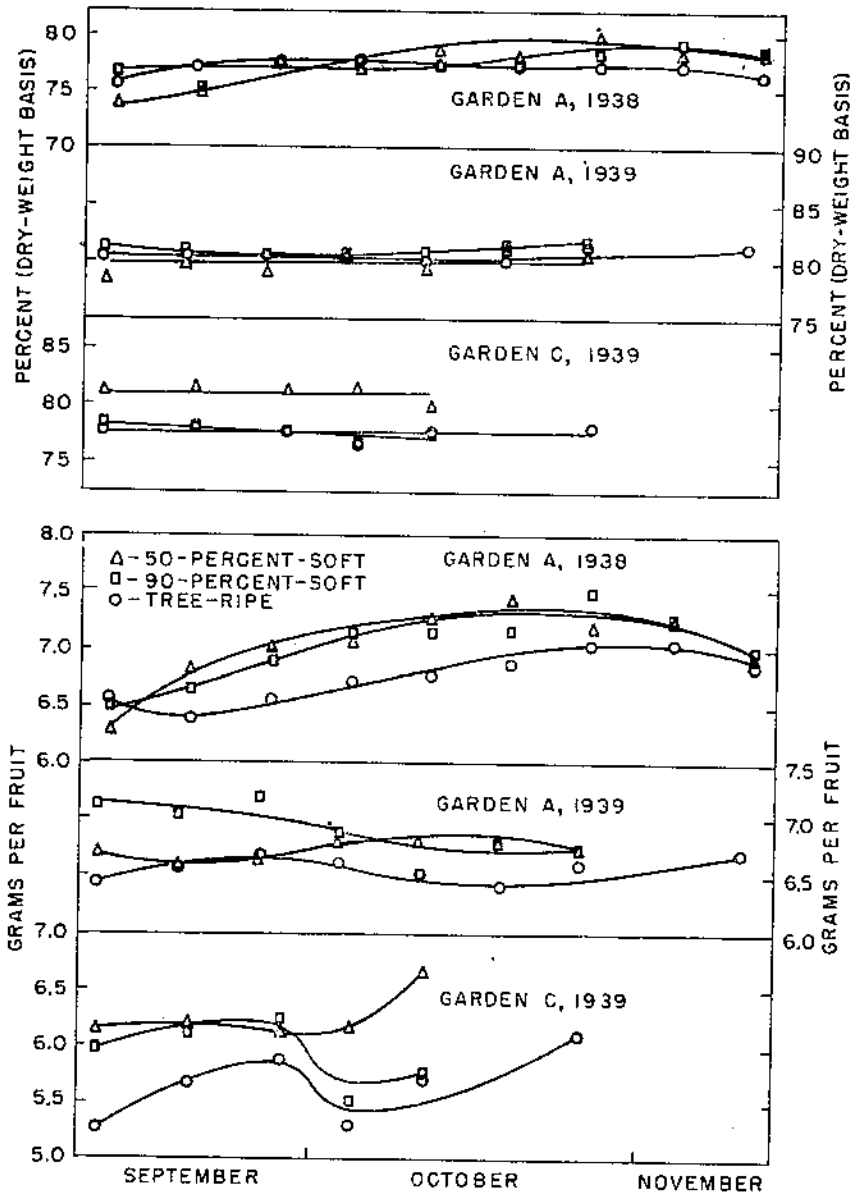

FIGURE 9.—Total sugar content of partly ripe and ripe Deglet Noor dates, expressed as percentage of dry weight and quantity per fruit.

garden at the same picking. The differences were small in the series from garden A, 1938 and 1939, but very noticeable in that from garden C. The only exception to this was the first picking of ripe dates in garden A, 1938 (fig. 9).

TABLE 7.—*Comparison of total sugar contents of dates at various stages of maturity*

Variety	Garden designation	Year of sampling	Sugar content (dry-weight basis) at indicated stage of maturity				Quantity of sugar per fruit at indicated stage of maturity			
			Translucent-spot	50-per-cent-soft	90-per-cent-soft	Tree-ripe	Translucent-spot	50-per-cent-soft	90-per-cent-soft	Tree-ripe
			Percent	*Percent*	*Percent*	*Percent*	*Grams*	*Grams*	*Grams*	*Grams*
Deglet Noor	A	1938	.....	77.4	77.6	77.0	.....	7.0	7.0	6.8
Do	A	1939	.....	80.1	81.5	80.5	.....	6.8	6.9	6.6
Do	C	1939	.....	81.0	77.7	77.6	.....	6.3	6.0	5.7
Barhee	E	1939	81.0	.....	.....	79.3	6.3	.....	.....	5.6
Do	F	1939	82.5	81.2	.....	80.6	5.7	5.6	.....	5.5

Hilgeman and Smith (*17*) obtained a similar reduction in the sugar content of ripe Maktoom dates but not Khadrawy. Like the Barhee, both these varieties are of the invert-sugar group. Other constituents besides sugar contribute to the quality of the fruit; consequently, it must not be assumed without further investigations that as good a finished product can be obtained from fruits picked when only partly ripe as from those allowed to ripen on the palm. From a practical point of view the additional cost of handling dates that are only partly ripe must also be considered, since facilities would be required with which to complete the ripening process and additional time would be required for dehydration.

The total sugar content of ripe dates from a given garden remained almost constant in percentage of dry weight throughout the entire harvest season of a given year, though there was a slight tendency for an increase as the season advanced and also a tendency for the later ripening fruit to be slightly larger.

In 1938 the khalal Deglet Noor dates in garden A contained as much total sugar (dry-weight basis) as partly ripe or ripe ones after the first part of the harvest season, but in 1939 the khalal dates from the same trees never quite equaled the more mature (table 2). The difference between the two seasons was due to the higher sugar content of ripe dates in 1939 than in 1938. The sugar contents during the two growing seasons were very nearly alike, a consistent difference occurring only after the fruit began to ripen (table 2). The average sugar content of the ripe fruit was 77 in 1938 and 81 percent in 1939. This difference was presumably due to the effects of a severe freeze which nearly defoliated the palms in January 1937. Since recovery was not so far advanced in 1938 as in 1939, the reserves in the palms were drained to a lower level at the end of the growing season of 1938 than at the corresponding time in 1939.

In garden C the khalal dates had a total sugar content as high as the ripe ones picked from the same garden on the same day, after the first part of the harvest season, but the total sugar content of the

ripe dates was lower than that of ripe ones from garden A in 1939 (table 2). Accurate cultural records are not available for the two gardens, but the lightness of the soil in garden C may be partly responsible for the difference. Garden A also received heavier applications of fertilizer than garden C. Another important factor is that garden C was more severely injured by the freeze in 1937 than was garden A. Ripe dates from garden A had more sucrose and less reducing sugars (dry-weight basis) than those from garden C (table 2); reducing sugars in dates from garden A averaged 30 percent, whereas those from garden C averaged 37 percent of the total. In considering the composition of the 1939 crop it is necessary to keep in mind the possibility that the heavy rains of September 4, 5, and 24 influenced the results. It will also be recalled that, although the 50-percent-soft dates from garden C had almost as high total sugar content as those at any stage of maturity from garden A, there was a greater decrease in the sugar content of the dates from garden C than in those from garden A as they ripened.

Rain damage prevented comparisons of sugar contents of ripe and unripe dates from gardens B and E for the latter part of the season. The one sample of ripe Deglet Noor obtained from garden B had a higher sugar content than khalal fruits picked on the same day (September 13); total sugars in these samples amounted to 78 and 76 percent of the dry weight, respectively.

In garden D (table 2) the average total sugar content of khalal Deglet Noor dates during the harvest season was 74 percent of the dry weight and that of the ripe fruit 81 percent. The sugar content of the khalal dates never equaled that of the ripe ones in the same plot.

The reason for the high proportion of reducing sugars in the dates from garden D is not evident, but this condition is associated with low quality. High moisture content before and during ripening may have been involved. This high reducing-sugar content is barely suggested in the sugar composition during the growing season. However, the moisture content of the fruit from garden D was markedly higher than that from garden A. The moisture contents of immature dates from these gardens are compared as follows:

Garden A, 1939:	*Moisture (percent)*	Garden D, 1939:[1]	*Moisture (percent)*
August 16	62	August 16	74–80
September 1	61	September 1	61–71
September 12	61	September 13	62–66
September 26	55	September 27	59–63

[1] Range covers plots in this garden.

The dates in garden A ripened with what may be considered a normal proportion of reducing sugars and with good color for the variety, whereas those in garden D ripened with a high proportion of reducing sugars and with color undesirably dark for the variety.

These sugar analyses agree in most respects with those reported by other workers. Vinson's sugar analyses (*32*) were apparently made by means of a polariscope. The average of nine samples of ripe Deglet Noor dates was 81 percent when calculated on the dry-weight

basis. His results with immature dates are not directly comparable with those found in the present work, as his samples consisted of abnormal fruit; even the pea-size dates (1.15 gm.) were picked late in September, whereas normal fruits attain that size by the middle of May to early June, depending on location and season. He found 45 percent total sugars in these dates on the basis of dry weight, whereas in the series reported in this paper the total sugar content of dates that had a fresh weight of 1.1 to 2.8 gm. was from 18 to 29 percent. He also found a higher proportion of reducing sugars than was found in the present work; e.g., in a sample picked on October 17 and described as "bright red, none ripe," he reported 27 percent of the total sugars as reducing sugars (compared with values below 20 percent in the present work). It is possible that some of the lack of agreement was brought about by differences in methods, for he did not give his method of preserving his samples. He determined water content by drying in a partial vacuum over sulfuric acid at 70° C. for 46 hours.

Freeman's sugar values (*12*), which were reported in the same bulletin as those of Vinson (*32*), ranged from 82 to 88 percent; 23 analyses averaged 84 percent. His method was not given, but it may be assumed that it was the same as that employed by Vinson.

Haas and Bliss (*13*) used the method of Shaffer and Hartmann for their sugar analysis. The general shape of their curve for total sugars is similar to those reported in the present paper, but their values are considerably lower. They reported a total sugar content of about 6 percent (dry-weight basis) on May 21 as compared with 13 percent found by the writer on May 17, 1938, and 21, 21, 18, and 25 percent on May 23, 1939 (table 2). Similarly, on and after September 2 they found a total of about 62 percent in samples which included some ripe fruits. On corresponding dates, the present report shows immature fruits (in the khalal stage) as having amounts increasing slightly from 72, 75, 76, 75, 75, 73, 71, and 73 percent in the various gardens as the season advanced. In the first part of the season the discrepancy was caused mainly by differences in the reducing sugars, but after about August 1 the bulk of the difference was in the nonreducing fraction. Their values for reducing sugars were lower in the first part of the season and higher in the latter part than those found in the course of the present work.

The results reported here agree reasonably well with those reported by Sievers and Barger (*29*). The average of 23 determinations of total sugars in ripe Deglet Noor dates as reported by them was 76 percent of the dry weight, with a range of 71 to 83 percent. They used about the same method for sugar analysis as the one used in the present work, but moisture was determined the first year by drying partially extracted material and the extract at temperatures not exceeding 90° C. and subsequently by the method of Bidwell and Sterling (*3*).

Fattah (*11*) used one of the iodometric methods for the determination of sugars and dried the material in vacuum at 70° C. for 12 hours for determining moisture. He reported 61 to 84 percent total sugars in a number of varieties, with 72 to 93 percent in Deglet Noor. No analyses of dates during the growing season were given.

MOISTURE CONTENT

The water content of both varieties was over 80 percent (fresh-weight basis) in all series throughout the period of rapid growth (table 2). The maximum was 86 percent in the Deglet Noor (garden A, 1938, July 26) and 87 percent in the Barhee (garden E, July 7). The high moisture content coincided with rapid growth and high active acidity and also with the time when most of the sugar was in the form of reducing sugars, but water and total sugars were inversely related (figs. 2, 6, and 10). Differences in moisture content of dates from different soil types or after different cultural treatments were generally small (table 2). Differences in the moisture content of the two halves were also small during the growing period, although in general a slightly lower percentage of water was found in the apical

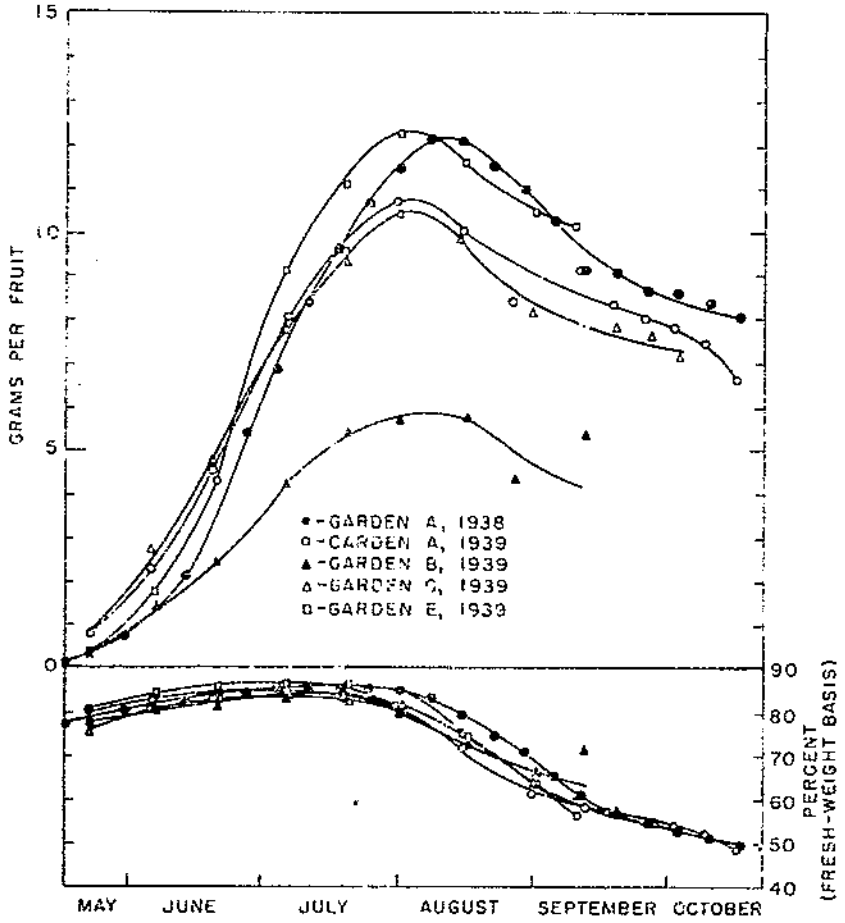

FIGURE 10.—Water content of immature dates, expressed as percentage of fresh weight and quantity per fruit.

half (table 2). This difference increased in the Deglet Noor until the fruits had ripened from the tip to the equator.

Moisture content expressed as quantity per fruit presents a picture quite different from that obtained when it is expressed as percentage of fresh weight (fig. 10). During the period of high hydration the amount of water contained in each fruit increased rapidly with the increase in size. Even after the percentage of moisture had begun to decrease, the amount per fruit continued to increase for a short time. The maximum quantity per fruit was reached early in August in the series observed in 1939; dates from garden B had a lower peak and the maximum occurred slightly later than in those from the other gardens in the same year. Fruits from garden A reached their maximum several days later in 1938 than in 1939. The quantity of water per fruit began to decrease immediately after the maximum was attained in each series; this occurred 5 to 6 weeks before any fruit began to ripen. The percentage of moisture began to decrease in July.

The relatively short period of maximum moisture content (expressed as quantity per fruit) during late July and early August coincides with the time at which dates are most susceptible to checking of the epidermis near the tip. This blemish consists of minute transverse breaks in the cuticle and the epidermis. At first it is limited to the surface layer of cells, but later it may affect cells many layers deep. Haas and Bliss (*13*) described the condition in some detail. High susceptibility to this type of injury continues for only a relatively short period in the development of the fruit (*13*). Severe checking will develop into blacknose, one of the most serious of the physiological disturbances of dates from the economic point of view (*13*, *26*, *27*, *28*). Data given by Haas and Bliss (*13*) show that this relation between moisture content and susceptibility to checking also existed in the dates with which they worked, but they did not call attention to it. The time at which the maximum water content (expressed as quantity per fruit) occurs varies from one season to another. That of the series under observation in 1938 occurred between August 9 and 16, whereas in 1939 all except that from garden B had the maximum about August 1; the maximum in garden B occurred between August 2 and 17. The maximum moisture in amount per fruit in the series reported by Haas and Bliss (*13*) was found on August 12, but the highest percentage of moisture was found in the sample collected on July 1. The greatest susceptibility to checking in this series was found on August 12. It is of interest to note that dates from garden B, unlike those in the other series, had no sharp maximum water content (quantity per fruit); it was also considerably smaller than that in dates from the other gardens. Nixon (*27*) and Nixon and Crawford (*28*) reported that small fruits are not as susceptible to checking and blacknose as are large ones, at least when the difference in size is brought about by differential thinning treatments. The period of maximum water content (quantity per fruit) coincided with the beginning of the change in color from green to red or yellow, according to variety, that is, from kimri to khalal.

Water is lost at an increased rate when the fruits begin to ripen. Khalal Deglet Noor dates from garden A, 1939, contained 61 percent

moisture at the beginning of the harvest season, whereas 50-percent-soft dates contained 41 percent, 90-percent-soft 37 percent, and tree-ripe 33 percent moisture (table 2). These figures decreased somewhat later in the season so that on October 17 they were 48, 36, 33, and 26 percent, respectively. Other series gave similar results.

The apical portion of Deglet Noor dates began having a lower moisture content than the basal early in the sugar-accumulating period, and this difference increased as the fruits began to ripen (table 2). The average differences between the apical and basal halves of Deglet Noor dates from garden A, 1939, at the various stages of maturity follow:

Stage of maturity:	*Moisture (percent)*
Khalal (during harvest)	5.7
50-percent-soft	8.6
90-percent-soft	4.8
Tree-ripe	1.4

This value increased until the fruits were 50-percent-soft, and subsequently it decreased as the basal half ripened; it was as high as 12 percent in individual samples (table 2, garden A, 1938, September 27). Similar results were obtained with the other series of the same variety, but the difference in moisture content between the basal and apical halves of the Barhee was not so great (table 2).

The moisture content of dates in the late khalal stage from all the plots in garden D [6] was higher than that of similar ones from gardens A and C (table 8). The color of the ripe fruit from all plots in garden D, especially plots C and D, was darker and therefore less desirable in appearance than that from gardens A and C. The darker color of the ripe dates and the higher proportion of reducing sugars in total sugars in immature and ripe fruits from the plots with a low leaf-to-fruit-bunch ratio as compared with similar ones from the plots with a high ratio might well be associated with the difference in moisture content in the two groups. This supposition is strengthened by the fact that the higher moisture content of the late khalal dates from the plots in garden D as compared with similar fruits from gardens A, 1938 and 1939, and C (table 8) tends to be reflected in the quality of the ripe dates (p. 47). The comparison is most striking in plots A and C, for which the respective average moisture contents of late khalal dates were 61 and 65 percent (average of values on September 13 and 27, table 8) and the respective percentages of fruits in the two best grades were 51 and 6 percent (p. 47). The consistently darker color of the ripe dates from garden D as compared with that of dates from the other gardens sampled does not always find expression in the grades, since additional factors must necessarily be considered in determining the grade.

[6] For a description of the treatments of the plots in garden D see p. 45.

TABLE 8.—*Moisture content of khalal Deglet Noor dates at various times during the harvest season*

Garden, plot, and day of sampling	Moisture content (fresh-weight basis)	Garden, plot, and day of sampling	Moisture content (fresh-weight basis)
	Percent		*Percent*
A:		C:	
1938		*1939*	
Sept. 13	60	Sept. 12	61
Sept. 20	58	Sept. 20	58
Sept. 27	55	Sept. 28	55
Oct. 4	53	Oct. 4	53
Oct. 11	52	D, plot A:[1]	
Oct. 18	50	Sept. 13	62
		Sept. 27	59
		D, plot B:[1]	
1939		Sept. 13	63
Sept. 12	61	Sept. 27	59
Sept. 19	58	D, plot C:[1]	
Sept. 26	55	Sept. 13	66
Oct. 3	54	Sept. 27	63
Oct. 10	52	D, plot D:[1]	
Oct. 17	48	Sept. 13	65
		Sept. 27	60

[1] For description of plots see p. 45.

Another relation that may be significant is the fact that the moisture percentage of khalal dates at the beginning of the harvest season is higher than later in the season (tables 2 and 8). It is common packing-house experience that Deglet Noor dates ripening at the beginning of the season are likely to be inferior in quality as compared with those from the same garden ripening later. The inferiority of early-ripening dates consists in their tendency to darken more quickly and to spoil from molding and fermentation more readily than those that ripen later in the season. This fact suggests that the high moisture content of the khalal dates immediately before they ripen may predispose them to these forms of deterioration.

The rate at which water is lost by dates before and during ripening is an important factor in determining the quality of the final product. If water is lost too rapidly before the chemical changes accompanying ripening have taken place, the processes will be slowed down or stopped (*32*) and a poor product will result. Too rapid dehydration in dates that have already softened completely also gives an inferior product. On the other hand, too slow dehydration makes the dates subject to various forms of deterioration including excessive darkening, fermentation, molding, and loss of flavor.

The association of excessive darkening of the flesh with high moisture content was demonstrated in one series of stored Deglet Noor dates in which the moisture content was determined on light and dark fruit from seven lots, which had been stored an average of 7 months at 28° F. (about −2° C.). The moisture content of the dark fruit ranged from 32 to 35 percent with an average of 33 percent; that of the light fruit ranged from 27 to 30 percent, with an average of 29 percent. These results substantiate experience in packing houses, where excessive darkening has been found to be associated with a high moisture content. In unpublished experiments Barger[6] found that

[6] Unpublished notes on cold storage of dates by W. R. Barger, Division of Fruit and Vegetable Crops and Diseases.

in excessively dark Deglet Noor dates the reducing sugars constituted an abnormally high percentage of the total sugars. A high proportion of reducing sugars in itself may not be objectionable inasmuch as the sucrose is completely inverted in many excellent varieties of invert-sugar dates, but the conditions conducive to rapid inversion in the Deglet Noor variety are also conducive to other changes which lower the quality.

The causes of excessive hydration are varied and may be external or internal. Precipitation or high humidities during ripening can bring it about, but even under favorable atmospheric conditions are found variations in this respect which make some dates more inclined to retain an excessive amount of moisture than others, thus predisposing them to fermentation and darkening. It might be supposed that this could be due to the flesh of some varieties being more hygroscopic than that of others; but Vinson (*33*) found that this was not true, since both kinds, once brought to the same moisture content, gained or lost water at approximately the same rates under similar conditions of humidity and temperature.

Data available from other experiments suggest that a contributing factor tending toward excessive hydration and darkening in ripe dates may be found in inadequate irrigation during the early part of the growing season followed by ample irrigation during the latter part. Ripe Deglet Noor dates from the adequately irrigated palms in three sets of paired plots had an average of 2 percent less moisture (fresh-weight basis) in the six collections that were made than those from the inadequately irrigated palms. All the lots from the inadequately irrigated palms had higher moisture contents than those from the palms provided with sufficient water. Inadequate irrigation resulted in the production of abnormally dark dates.

HYDROGEN-ION CONCENTRATION

Determinations of the active acidity, or pH values, were made on the expressed juice of frozen Deglet Noor dates from garden A, 1938, until they began to ripen. Later the determinations were made on the ground flesh, as it was impossible to obtain any juice by squeezing. The acidity increased from pH 5.5 in the whole fruit on May 17, 1938, to pH 5.1 in the basal half and pH 5.2 in the apical on June 14 (table 2). Subsequently the acidity decreased gradually until the fruit was ripe. The basal half was usually more acid than the apical in the growing dates, although the difference was not great (table 2). A close relation existed between the active acidity of the basal half of immature Deglet Noor dates and the rate of increase in fresh weight until early September, when some of the fruits began to ripen (fig. 11). High acidity was associated with a high rate of increase in fresh weight and size. These results are in general agreement with Caldwell's statements (*6*) that there is a close relation between the rate of growth and the active acidity of fruit and that the greatest active acidity occurs simultaneously with the period of greatest hydration. The water content in each series remained at a nearly constant value within 1 percent of the maximum throughout the month of July

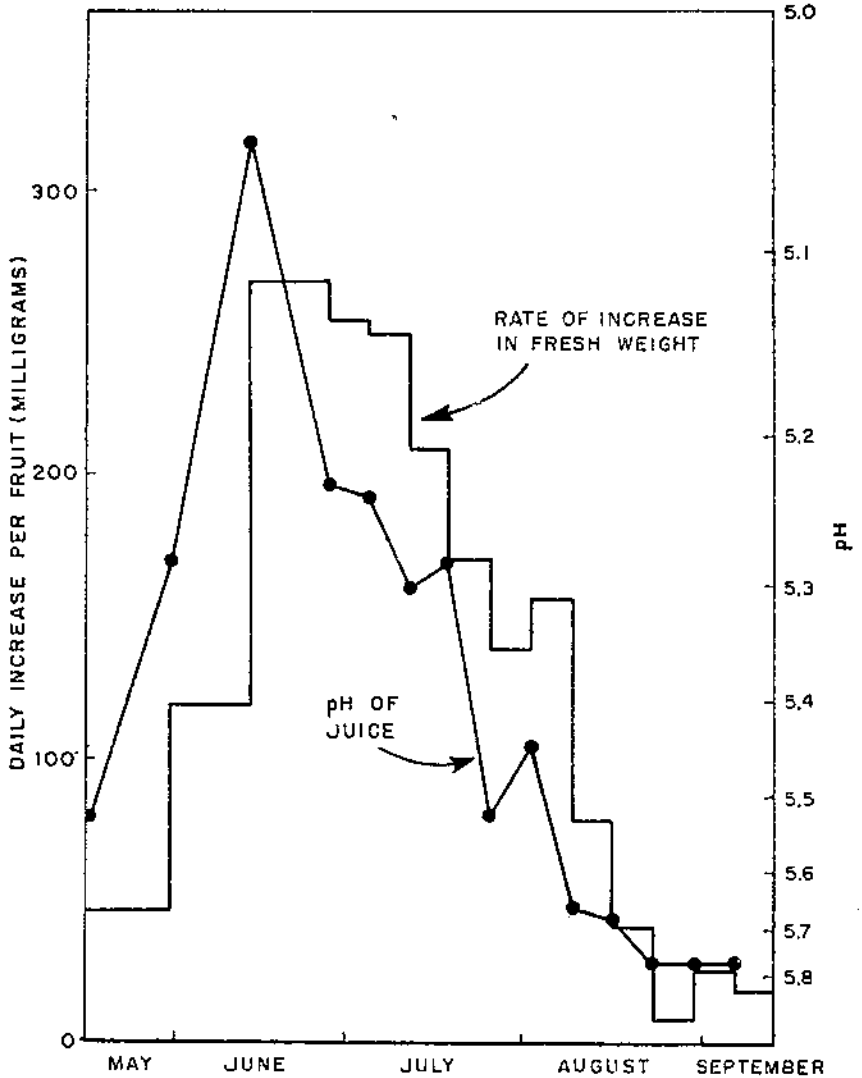

FIGURE 11.—Relation of hydrogen-ion concentration of the expressed juice of the basal half of immature Deglet Noor dates to rate of increase in fresh weight, garden A, 1938.

(fig. 10), but the active acidity had decreased somewhat by the end of that month (fig. 11 and table 2). The greater active acidity of the basal half as compared with that of the apical half also supports Caldwell's statement that actively growing tissue has a higher active acidity than does less active tissue, since Haas and Bliss (*13*) and Long (*21*) have shown that most of the elongation of dates takes place at the basal end. The range of active acidity was less than 1 pH unit for the entire season previous to the beginning of ripening.

The hydrogen-ion concentration of the dates decreased somewhat during ripening. Observations on the 1938 crop in garden A showed a pH range of 5.9 to 6.4 in the basal half and of 5.8 to 6.2 in the apical half of ripe dates (table 2). In contrast to the situation in immature fruits the apical half of mature ones was usually slightly more acid than the basal at any given picking; the difference ranged from 0.03 to 0.4 pH unit. There was no seasonal trend in the active acidity of ripe dates.

NONSUGAR-SOLIDS CONTENT

The nonsugar solids were divided on the basis of their solubility in the extracting medium, 80-percent alcohol. The time of accumulation of these solids is shown in figure 12. Prior to September 1 soluble nonsugar solids were accumulated at rates such that the graph assumes a shape similar to that for total dry matter provided the ordinates are sufficiently magnified. Among these solids are minerals, enzymes, tannins, and pigments.

The only available data on the mineral content of American-grown dates are those of Haas and Bliss (*13*), who found that all the elements on which analyses were made were accumulated at fairly constant rates during the entire life of the fruit. The elements reported include potassium, sodium, calcium, sulfur, phosphorus, magnesium, copper, manganese, nitrogen, and chlorine. Haas and Bliss stated that there was no greater correlation between the potassium and sugar contents than between those of any other element and sugar. As with the storage tissues of other plants, by far the most abundant single element in the ash of the date was potassium, which constituted over 40 percent of the total. This proportion remained fairly constant during the life of the fruit.

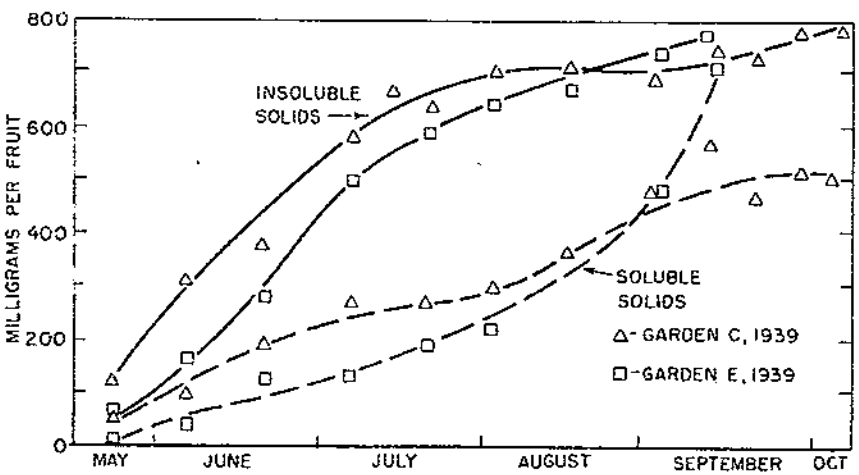

FIGURE 12.—Soluble and insoluble nonsugar solids in immature dates, expressed as quantity per fruit.

The only enzyme in dates which has been studied in detail is invertase. Vinson (*33*) found that the invertase of unripe dates is in the intracellular form and cannot be extracted with water or glycerin even after the cells are killed with acetone or toluene. He found that as soon as the dates begin to ripen the invertase changes to an extracellular form and is readily soluble, at least in the invert-sugar varieties. The pulp of unripe dates was found to be capable of inverting solutions of cane sugar very rapidly even though no invertase could be extracted. Vinson's enzyme work was done on invertase, not so much because of any importance it might have in connection with the ripening processes as because of the ease of following the activities of this enzyme. Vinson felt that conditions which influenced the activity of this enzyme would also influence that of other enzymes involved in the ripening process. The addition of tannin did not prevent invertase from remaining in solution in glycerin, and invertase precipitated by tannin did not lose its ability to invert sucrose.

The changes in tannin and related substances in ripening dates are not well understood. Lloyd (*20*) differentiated the tannin substances into plastic and aplastic. He concluded (*20, p. 119*) that the plastic tannin "occurs and disappears at such times and in such situations as to warrant the conclusion that it is a nutrient, and in this is analogous to starch, reserve cellulose, oil, etc." He found that plastic tannin underwent translocation, but there was no evidence that changes in the tannins were involved in the rapid accumulation of sugar. Lloyd found that the aplastic tannin was transformed into hard, insoluble tannin bodies in the cells in which it occurred originally and that there was no translocation and no accumulation of this type of tannin at the time of ripening. The formation of insoluble tannin bodies is characteristic of the ripening process in dates; the nature of this deposition is unknown.

Vinson (*33*) concluded that the tannin might form insoluble bodies by condensing with some product of enzymatic action. He found that the tannin of unripe dates was not removed by long digestion with ripening date pulp and hence the deposition was not a direct enzymatic action; but if immature fruits were heated to 70° C. for 10 minutes or more, the astringency became permanent as a result of the destruction of an enzyme occurring in the fruit. Bigelow, Gore, and Howard (*3*) reported observations on persimmons in which the tannin grains passed through a transitory viscous stage before they condensed into the hard insoluble condition. These writers also noted that these cells at a certain stage of development would burst when placed in contact with saliva and concluded that the cells had been prevented from taking up water and bursting while in the fruit because of the osmotic pressure of the fruit juice. A few varieties of dates, such as the Barhee and the Braim, have so little tannin in the immature state that they are only slightly or not at all astringent; the astringency of any date variety, however, disappears during normal ripening.

Turrell, Sinclair, and Bliss (*30*) discussed the possible relation between the various tannins and tanninlike substances and the susceptibility of dates to fungus attack.

The yellow pigment of the Barhee variety in the khalal stage was found by qualitative tests to be a flavone or flavonol, and the red pigment in the Deglet Noor in the same stage was found to be an anthocyanin. Although carotene is associated with chlorophyll in the kimri stage, much of it may subsequently be lost since ripe Deglet Noor dates have been found by the rat-growth method to have the relatively low vitamin A potency of 66 International Units per 100 gm. (4). Fresh tree-ripened Halawy dates were found to have a vitamin A potency of the same order of magnitude, whereas the Saidy had a potency of about 350 International Units (4).

The quantity of soluble nonsugar solids per fruit did not change appreciably during the ripening process. They averaged 5 percent of the fresh weight, or 7 percent of the dry weight, of ripe Deglet Noor dates and 5 percent of the fresh weight, or 9 percent of the dry weight, of ripe Barhee. The soluble nonsugar solids constituted 7 to 10 percent of the total soluble solids in the ripe dates of both varieties. The tannin compounds are included in this group in the immature fruits, but in the ripe ones they are included in the insoluble solids.

The insoluble solids include all substances insoluble in 80-percent alcohol. Curves representing these solids (fig. 12) resemble those for the fresh weight of the fruit. Most of the accumulation of these materials occurred at the period of rapid increase in fresh weight, with only a slight increase after the first part of August. This is to be expected in view of the fact that these solids include the cell-wall materials, most of which are laid down about the time of cell enlargement. The increase continued at a low rate up to the beginning of ripening, so that all samples of partly ripe or ripe dates of the Deglet Noor variety contained more of these substances than the immature samples. In this variety there was no decrease in the total amount of these substances during ripening, but there were changes in the relative quantities of fractions within the group; for instance, a decrease in protopectin and an increase in water-soluble pectin. In the available sample of ripe Barhee there was a decrease in insoluble solids from 770 mg. per fruit in the unripe sample to 724 mg. in the ripe sample picked on the same day. This loss could be due to a loss in pectic substances (p. 43).

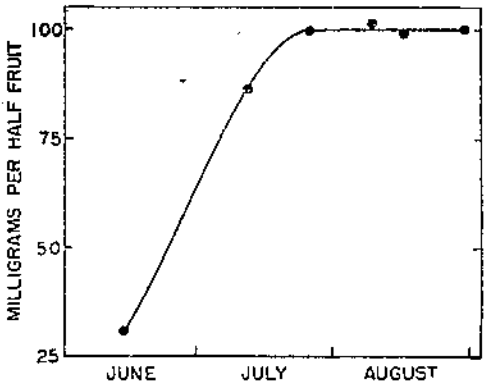

FIGURE 13.—Acid-hydrolyzable polysaccharides in the apical half of immature Deglet Noor dates, garden A, 1938.

A single series of determinations indicated that the total acid-hydrolyzable polysaccharides in the apical halves did not increase subsequent to the time the rapid increase in total insoluble solids had ended (fig. 13). Analyses of whole-fruit samples of partly ripe and ripe dates

indicated that there was no reduction in the total quantity of these substances as the dates ripened. While the identity of these substances was not determined, qualitative tests for starch and dextrin were negative. This is in agreement with the results obtained by Lloyd (*20*), who found that dates contain a small amount of starch at about the time of pollination but none thereafter. When the residue after alcoholic extraction was hydrolyzed by acid, an indicator which was deep red in solutions more acid than pH 5.4 was formed. When the solution was brought to pH 5.4 or higher the pigment turned blue and quickly precipitated.

Analysis of pectic materials was made on dates from gardens A, 1938 and 1939, and E only. Most of these substances (reported as impure calcium pectate) were accumulated during the period of rapid

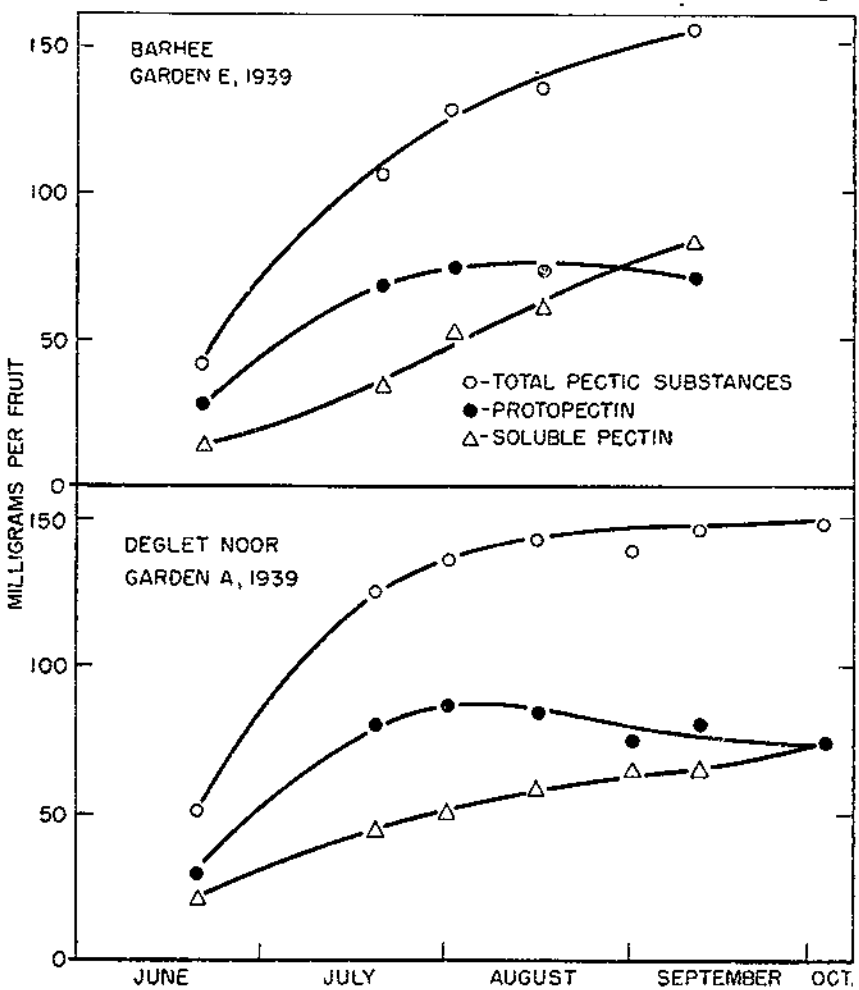

FIGURE 14.—Pectic substances in immature dates, expressed as impure calcium pectate per fruit.

increase in fresh weight (table 9 and fig. 14). All the protopectin was stored during this period, but soluble pectin was accumulated at a fairly constant rate during the entire life of the fruit up to the time it began to ripen. The quantity of total pectic materials per fruit continued to increase somewhat after the end of the period of rapid increase in fresh weight. The protopectin per fruit was at its maximum at the beginning of the period of rapid sugar accumulation and decreased with the advance of the season. The decrease in protopectin coincided with the decrease in quantity of water per fruit (figs. 10 and 14).

An interesting coincidence, which may be significant, is the fact that the maximum quantity of protopectin per fruit occurred when the dates had their highest quantity of water per fruit and also were most susceptible to checking. While Barhee dates do not develop typical blacknose, they may develop a type of water injury similar to it. In the Deglet Noor the subsequent increase in soluble pectin was slightly greater than the decrease in protopectin; consequently the total quantity of pectic materials per fruit continued to increase but at a reduced rate (fig. 14). In the Barhee both protopectin and soluble pectin decreased as the fruits ripened (table 10). The ripe dates contained 40 mg. less total pectic materials than the immature ones: this compares with a difference of 46 mg. in the amount of total insoluble solids found in the same samples (p. 41).

TABLE 9.—*Pectic substances in immature dates expressed as percentage of dry weight of impure calcium pectate*

DEGLET NOOR (GARDEN A, 1938)				DEGLET NOOR (GARDEN A, 1939)			
Day of sampling	Soluble pectin	Protopectin	Total	Day of sampling	Soluble pectin	Protopectin	Total
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
June 14	1.5	4.6	6.1	June 20	2.5	3.5	6.0
June 28	1.7	4.2	5.9	July 20	2.4	4.3	6.7
July 5	2.0	4.1	6.1	Aug. 1	2.2	3.7	5.9
July 12	1.7	4.3	6.0	Aug. 16	1.5	2.2	3.7
July 19	1.8	4.6	6.4	Sept. 1	1.2	1.4	2.6
July 26	1.7	4.5	6.2	Sept. 12	1.1	1.4	2.5
Aug. 2	1.7	4.1	5.8	Oct. 3	1.2	1.1	2.3
Aug. 9	1.8	4.0	5.8				
Aug. 16	1.3	3.7	5.0	BARHEE (GARDEN E, 1939)			
Aug. 23	1.3	2.8	4.1				
Aug. 30	1.4	2.1	3.5	June 21	2.1	4.2	6.3
Sept. 6	1.2	1.7	2.9	July 21	2.2	4.1	6.3
Sept. 13	1.1	1.4	2.5	Aug. 2	2.5	3.6	6.1
Sept. 20	1.0	1.3	2.2	Aug. 17	1.6	1.9	3.5
Sept. 27	1.0	1.2	2.2	Sept. 11	1.1	.9	2.0

TABLE 10.—*Pectic materials in immature and ripe Barhee dates, garden E*

Substance	Quantity per fruit		Loss during ripening
	Immature	Ripe	
	Milligrams	*Milligrams*	*Percent*
Protopectin	71	42	41
Soluble pectin	83	72	13
Total pectic materials	154	114	26

In 1939 the percentage of protopectin (dry-weight basis) was higher in the apical half than in the basal in five of seven samples of immature Deglet Noor dates and in all five of the immature Barhee samples that were analyzed (garden E). On June 20 the Deglet Noor contained 3.6 and 3.5 percent in the basal and apical halves, respectively; by September 1 these values had dropped to 1.3 and 1.5 percent. Likewise, on June 21 the Barhee contained 4.1 and 4.3 percent in the basal and apical halves, respectively, and by September 11 the percentages had dropped to 0.9 and 1. Subsequent decreases in the protopectin content of immature dates were only slight, but appreciably smaller quantities were found in the ripe ones of both varieties; for example, on September 12 khalal Deglet Noor dates from garden A, 1939, contained 81 mg. protopectin per fruit, whereas ripe fruits from the same garden on the same day contained 44 mg.

On the basis of percentage of dry weight, protopectin increased slightly between June 20 and July 20 in dates from garden A, 1939, whereas in those from gardens A, 1938, and E, the percentage did not increase after June 14 and June 21, respectively (table 9). Although the quantity per fruit was increasing, sugar was also accumulating at an increasingly rapid rate so that the percentage of protopectin soon began to decrease. This was equally true for both varieties.

Soluble pectin in the Barhee increased from 33 percent of the total pectic materials in June to 54 percent just before ripening began in September and to 63 percent upon ripening. The proportional increase in soluble pectin associated with ripening was not as great as might be expected with this variety since the quantity per fruit actually decreased as ripening progressed; the rate, however, was lower than the decrease in protopectin.

The soluble pectin in the Deglet Noor variety increased from two-fifths of the total pectic materials in June to nearly one-half just before ripening and to two-thirds immediately after ripening. The comparative proportions of total pectic materials that were soluble at different stages of maturity of Deglet Noor dates, garden A, 1939, follow:

Part of fruit and stage of maturity:	Percent	Part of fruit and stage of maturity—Con.	Percent
Basal half:		Apical half:	
Kimri (in June)	42	Kimri (in June)	41
Khalal (during harvest)	47	Khalal (during harvest)	46
50-percent-soft	58	50-percent-soft	51
90-percent-soft	60	90-percent-soft	60
Tree-ripe	65	Tree-ripe	64

Similar results were obtained in 1938. Presumably the proportion of soluble pectin continues to increase as the fruit cures. Total pectic materials in ripe Barhee dates amounted to 1.4 percent of the dry weight as compared with an average of 1.8 percent in the Deglet Noor in both 1938 and 1939. The increase in proportion of soluble pectin as the dates ripen is in agreement with results reported on other fruits, such as apples (*7*), pears (*14, 23*), and tomatoes (*9*). It would be expected that the proportion of soluble pectin would increase earlier in the apical portion than in the basal of Deglet Noor dates,

since the former softens first as ripening progresses, but the comparison given shows that the two ends were nearly alike in this respect.

Since the pectic fractions of the two portions of partly ripe dates were approximately alike, it is difficult to relate the difference in appearance of the two halves to composition; it is quite true that the apical half is lower in moisture and sucrose and higher in reducing sugars but this difference could hardly be responsible. Possibly the separation of the material called protopectin in this bulletin into cell-wall and middle-lamella fractions would have been informative.

INFLUENCE OF VARIOUS FACTORS ON COMPOSITION

Leaf-to-Fruit-Bunch Ratio

The influence of the ratio of leaves to fruit bunches on the Deglet Noor variety was studied in garden D. Different ratios were obtained by pruning all the palms to 30 leaves each and varying the number of fruit bunches retained by each palm. Normally the leaves on a date palm remain functional for about 5 years. The experiments undertaken required the removal of all the leaves from each palm with the exception of those which had emerged in 1937 in 1 set of paired plots; in the other all the leaves were removed with the exception of those which had emerged in 1938. All the new leaves produced during the 1939 season were allowed to remain on the palms. In each of these groups of plots there was 1 plot in which each palm carried 3 moderately thinned bunches, and 1 in which each palm carried 10. This arrangement provided 2 plots having a leaf-to-fruit-bunch ratio of 10 to 1 and 2 having one of 3 to 1. For convenience these plots will be referred to as follows:

Plot A (leaf-to-fruit-bunch ratio 10 to 1; leaves produced in 1937).
Plot B (leaf-to-fruit-bunch ratio 10 to 1; leaves produced in 1938).
Plot C (leaf-to-fruit-bunch ratio 3 to 1; leaves produced in 1937).
Plot D (leaf-to-fruit-bunch ratio 3 to 1; leaves produced in 1938).

There was little difference in the sugar content of the dates resulting from the variation in leaf-to-fruit-bunch ratio. The average total sugar content (dry-weight basis) of the immature fruits from the plots with a ratio of 10 to 1 was only 1 percent higher than that from those with a ratio of 3 to 1. The reducing sugars averaged 27 percent of the total sugars in the last five collections of immature dates from plots A and B, 31 percent in those from plot C, and 28 percent in those from plot D. The slight increase in proportion of reducing sugars when the leaf-to-fruit-bunch ratio was reduced may not be of practical significance, but the percentage of reducing sugars was lower in immature dates from the plots with the high leaf-to-fruit-bunch ratio than in those from plots with the low ratio after the first part of the season. This difference was retained in the ripe dates, reducing sugars constituting 44 percent of the total sugars in ripe dates from plot A and 47 percent in those from plot C. Both of these values are higher than those associated with good quality in this variety. Total sugar content of the ripe dates in percentage of dry

weight was not influenced by the leaf-to-fruit-bunch ratio or by the year in which the leaves were produced.

The most obvious influence of the variation of leaf-to-fruit-bunch ratio upon the ripe dates was the effect on size. The fresh weights per average fruit from each plot are given in table 2 and the dry weights in table 11. The average fresh weight of ripe dates from the plots with a ratio of 3 to 1 (plots C and D) was 90 percent of that of fruit from the plots with a ratio of 10 to 1 (plots A and B). Similarly, the average dry weight per fruit from the plots with a ratio of 3 to 1 was 85 percent of that of dates from the plots with a ratio of 10 to 1.

TABLE 11.—*Influence of leaf-to-fruit-bunch ratio upon dry weight per fruit of Deglet Noor dates, garden D, 1939*

Day of sampling	Stage	Plots [1] with leaf-to-fruit-bunch ratio of—			
		10 to 1		3 to 1	
		A	B	C	D
		Grams	*Grams*	*Grams*	*Grams*
May 23	Kimri	[2] 0.2	[2] 0.2	[2] 0.2	[2] 0.2
June 6	do	.4	.4	.4	.4
June 20	do	.7	.7	.6	.7
July 7	do	1.2	1.3	1.0	1.1
July 20	do	1.6	1.6	1.3	1.4
Aug. 1	do	1.9	2.1	1.6	1.7
Aug. 16	Khalal	3.2	3.2	2.2	2.6
Sept. 1	do	4.8	4.8	3.1	3.9
Sept. 13	do	4.6	4.9	3.7	4.6
Sept. 27	do	5.3	5.9	4.1	4.8
Sept. 10	Tree-ripe	6.3	6.4	5.0	5.6
Sept. 24	do	6.8	6.5	5.7	5.9
Oct. 9	do	7.0	7.3	5.9	6.2

[1] For description of plots see p. 45.
[2] Composite sample from all plots before the application of differential treatments.

An outstanding difference in the composition of the dates from the plots with high and low leaf-to-fruit-bunch ratios was that of moisture content in late khalal and ripe fruits (tables 2 and 8 and fig. 15). Dates from the plots with the high ratio had appreciably lower moisture content than those from the plots with the low ratio, the difference between plots A and C being 9.8 percent on September 1. Similar but less pronounced differences were noted when the 1938 leaves were retained on the palms instead of those produced in 1937. The possible influence which an excessively high moisture content might have upon the quality of the ripe dates has been discussed in the section on moisture content (p. 35). Hendrickson and Veihmeyer (*16*) also found high drying ratios associated with high yields in French prunes. They found that the ratios were not changed materially by irrigation treatment.

Commercial grading of ripe Deglet Noor dates from these gardens[7] include the following:

[7] Dates from gardens A and C were graded by a commercial packing house; those from garden D, by the Section of Citrus, Avocado, and Other Subtropical Fruit Investigations, Division of Fruit and Vegetable Crops and Diseases.

Garden and plot designation:	*Edible dates in grades 1 and 2 (percent)*	Garden and plot designation—Con.	*Edible dates in grades 1 and 2 (percent)*
A, 1938	65	D, plot B	72
A, 1939	77	D, plot C	6
C	65	D, plot D	35
D, plot A	51		

Grades 1 and 2 were the two best of five grades of edible fruits. A comparison of the grades with the moisture content of dates in the late khalal stage as given in table 8 suggests that a high moisture content (percentage of fresh weight) is associated with low quality when the fruits ripen. Additional work will need to be done to determine definitely whether a causal relation exists, and if so, what cultural practices may be adopted to improve the quality of the crop.

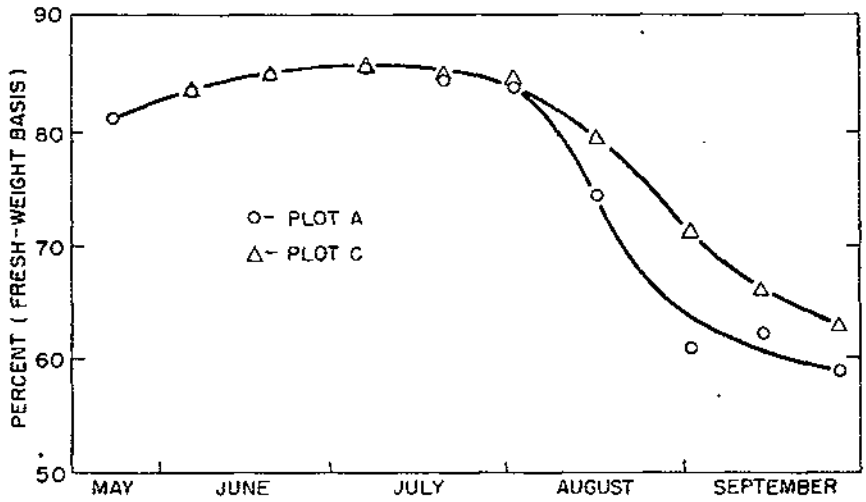

FIGURE 15.—Water content of immature Deglet Noor dates as affected by leaf-to-fruit-bunch ratio, expressed as percentage of fresh weight, garden D. Plot A, 10 leaves per fruit bunch; plot C, 3 leaves per fruit bunch.

SOIL TYPE

Differences among the Deglet Noor series with respect to sugar content of immature dates were so small that it is not possible to ascribe them to variations in the soils. Not only was the percentage of total sugars remarkably uniform in all the series (table 2), but the relation between the reducing and the nonreducing fractions was also uniform.

In the ripe dates there were some differences in the total sugar content of fruits from gardens on the various soil types, but they were not great and they were not necessarily related to the soil type on which the palms were growing. The average total sugar contents of ripe dates harvested from gardens A, 1938 and 1939, and C and the four plots in D were 77, 81, 78, 82, 81, 81, and 81 percent, respectively (table 2). Only one picking of ripe dates was obtained from garden

B and that one had been damaged by rain; however, the total sugar content of this sample was 78 percent. These figures show a remarkable uniformity considering the diversity of soil conditions and cultural treatment. The sugar content of dates from garden A varied sufficiently in two successive seasons to cover nearly the entire range represented by all the gardens. There were large differences in the proportion of reducing sugars in total sugars but, on the basis of the evidence at hand, they cannot be said to be related to the soil.

Such differences in moisture content of ripe fruit as occurred could not be related to soil type. In the case of garden D the higher water content of the late khalal dates cannot be ascribed to the soil texture, since palms growing on both coarser (garden C) and finer (garden B) textured soils produced dates with lower moisture contents during the late khalal stage. The texture of the soil in garden A is close to that in garden D (table 1).

Temperature at Ripening Time

Sievers and Barger (*29*) stated that the inversion of sucrose during ripening of dates was apparently accelerated by high temperatures, for they found that fruits picked in November had a lower percentage of reducing sugars than those of comparable maturity which ripened earlier. Similar results were obtained in the present work to the extent that dates which ripened in the latter part of the season had a lower percentage of reducing sugars than those which ripened earlier. The percentages of reducing sugars in total sugars in ripe dates from garden A, 1939, and from garden C are shown in figure 16. The moisture contents of the same samples and the mean temperature[8] for the 5 days preceding each picking (based on the picking dates of garden A) are shown. An examination of the figure will show that there is no close relation between the mean temperature and either the water content or the proportion of reducing sugars in total sugars. Similar results were obtained if maximum or minimum temperatures were used instead of the mean. The temperature dropped from September 19 to October 10, rose considerably during the following 2 weeks, and then dropped slightly. The reducing sugars in fruit from garden A increased from September 12 to 26 and decreased during the remainder of the season. On the other hand, the reducing sugars in dates from garden C remained nearly constant but increased slightly from September 12 to October 3, decreased slightly by October 10, and decreased greatly by October 24. Fruits picked on October 24 were too dry and shriveled to be considered normal.

There was a tendency for the moisture content of ripe fruit from both gardens to decrease as the season advanced. This was also the general tendency of the mean temperature, but the two variables did not agree in detail. There was no definite trend in the moisture content of the ripe dates from garden A, 1938, although there was a definite downward trend in the mean temperature during the harvest season (table 2). The proportion of reducing sugars was low at the last two pickings of this series, but there was no trend previous to this.

[8] Temperature records obtained from Dewey C. Moore, of the U. S. Date Garden, who was observer for the U. S. Weather Bureau at the time.

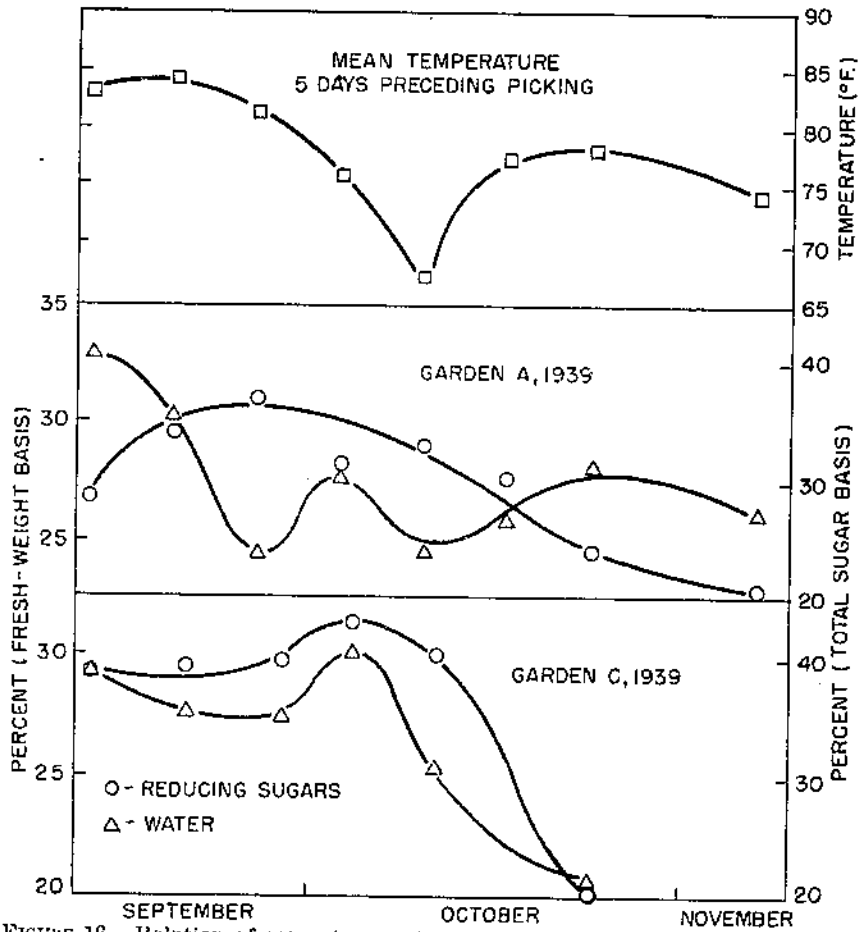

FIGURE 16.—Relation of mean temperature 5 days before harvest to proportion of reducing sugars in total sugars and to water content of ripe Deglet Noor dates.

The interrelation of temperature, reducing-sugar content, and moisture content is rather complicated. Immediately before Deglet Noor dates begin to ripen they are low in reducing sugars and high in sucrose and water, as compared with ripe fruits. During ripening, reducing sugars increase and sucrose and moisture contents decrease. The rate of each process is dependent to a considerable extent on the prevailing temperature. Thus at higher temperatures water is lost more rapidly and sucrose is inverted more rapidly than at lower temperatures, but the fruit also ripens more rapidly so that the processes operate for a shorter time than at the lower temperatures; hence the end results depend on time as well as on temperature. The moisture content at the time the dates are ripe is also affected by the relative humidity at the time of ripening as well as by the moisture content before they began to ripen. In turn, the rates of the other processes are influenced by the moisture content.

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