GROWTH AND DEVELOPMENT OF THE BLUEBERRY FRUIT (VACCINIUM CORYMBOSUM L. AND V. ANGUSTIFOLIUM AIT.)

by

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A THESIS

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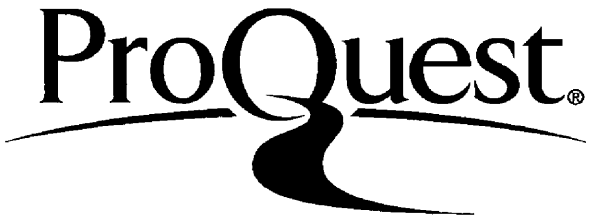

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A C K N O W L E D G M E N T S

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INTRODUCTION

Various native lowbush and highbush species of blueberry have been used as a source of commercial production. Only since about 1900 has the blueberry been cultivated in North America. The cultivated blueberry industry has reached importance for many specialized growers and has increased the need for a basic study on the growth of the fruit.

Botanical Relationship

The taxonomic classification of the blueberry has not yet been definitely settled. Camp (4) has attempted a classification but still has difficulty in placing many of the natural hybrids.

The blueberry belongs in the suborder Vaccinieae of the Ericaceae or Heath family (8). The plants are shrubs or somewhat woody plants, with scaly buds. The flower is a raceme with terminal buds opening last. The Vaccinieae have a calyx-tube adherent to the ovary, which forms an edible berry or berry-like fruit, crowned with short teeth like calyx lobes. The Vaccinieae (Whortleberry group) contains the genus Vaccinium, a 4- or 5-celled (or imperfectly 8- or 10-celled by false partitions), many seeded berry; Gaylussacia, a 10-celled ovary with a single ovule in each cell; and Chiogenes, a 4-celled, many seeded berry.

There are four species of blueberries (Vaccinium) which are marketed in quantity in the United States; namely, the highbush blueberry (Vaccinium corymbosum L.), the lowbush blueberry (Vaccinium angustifolium Ait.), the dry-land blueberry (Vaccinium pallidum Ait.), and the rabbit-eye blueberry (Vaccinium ashei Reade).

The highbush blueberry (V. corymbosum L.) is a native from Maine to

southern Michigan, and south to the Gulf of Mexico. It is the most important commercial species grown in Michigan. It is found in swamps, moist woods, or upland areas. The plants growing to a height of 1 to 4 meters have blue or black fruits, 5 to 10 mm. in diameter and of good to excellent quality. The berries ripen in no definite order within the cluster, but when blossoming, the terminal blossom is last to open and the basal first. Where several clusters are located on the same fruiting shoot, the terminal cluster blossoms open first followed by the next more basal cluster and so on to the most basal cluster. Some clusters may have all their fruits matured before September while others have only one or two berries matured at this time. From this species have been selected wild forms of large fruit size and good flavor that have been used in producing new varieties.

The lowbush blueberry (V. angustifolium Ait.) is native to the northeastern United States and parts of Canada. It is an upland species with fruits of 5 to 7 mm. in diameter and of a bright blue color ripening earlier than the highbush blueberry (V. corymbosum). The plant grows to a height of 5 to 20 cm.

The dry-land blueberry (V. pallidum Ait.) is found in northern Alabama and northward to Maryland. The plants growing from 30 to 80 cm. high, have dark blue to black fruits, 5 to 7 mm. in diameter, and usually of fair quality.

The rabbiteye blueberry (V. ashei Reade) is native of Louisiana to North Carolina. The plant grows 1.5 to 6 meters high and has dull black fruits 8 to 18 mm. in diameter which are usually of poor quality and often seedy.

REVIEW OF LITERATURE

Relatively few studies have been made of the growth of fruits. In all cases the resulting grand growth curves fall into two classes: (1) the curve is essentially a straight line as shown by the works of Anderson, Gustafson, and Sinnot on cucurbits and (2) a sigmoid-shaped curve as shown to occur in the peach (Prunus persica [L.] Batsch.) (5), fig (Ficus carica L.) (6), and both sweet and sour cherry (Prunus avium L. and P. cerasus L.) (21—22).

The sigmoid curve has a period of accelerated growth from blossoming to 49 days after blossoming in the case of the peach (P. persica) (5) or 22 days after blossoming for the sour cherry (P. cerasus) (22). This period has become known as Stage I (Figure 1). The duration of the period immediately following this accelerated rate of growth determines the time of maturity of the fruit as shown by Conners (5) and Tukey (21—22) for the peach and sweet and sour cherries. The duration of this stage for the sour cherry (P. cerasus) is 5 days for Early Richmond, an early variety, and 28 days for English Morelo, a late ripening variety. In this period, known as Stage II (Figure 1), there is little increase in fruit size but embryo and seed development is known to occur for the fig (6), peach (5), and cherries (21—22). A second period of accelerated rate of growth occurring at the end of Stage II and continuing to fruit maturity is known as Stage III (Figure 1). During this last stage of development the fruit reaches its greatest size. Stage III is inconsistant in duration for either early or late maturing varieties.

Bailey (3) has reported that the blossoming period of the blueberry lasts 3 or more weeks and that the harvesting period is from 4 to 6 weeks

in length. Harvests are usually made at intervals of 10 to 14 days. He also has reported that the average total number of days from full bloom to first harvest is 51 to 60 days for 15 varieties. His study, extending over a period of 8 years, has shown that the total number of days vary from 7 to 25 days depending on the variety. More specifically both Rubel and Jersey varieties had an average of 54 days from full bloom to first harvest with a variation of 17 days for Jersey and 11 days for Rubel during the 8-year study.

Botanical information concerned with a morphological description about the genus Vaccinium is limited to a few publications. Schnarf (16) states that the inner epidermis becomes a protective layer for the embryo sac in the Ericaceae family. One primary archesporial cell becomes the megaspore mother cell. The embryo sac development follows that of the normal type. According to Schnarf (17) the normal type of embryo sac development is as follows: A megaspore mother cell undergoes five divisions before formation of the egg-cell and the embryosac originates from only one macrospore (megaspore). Further development consists of two phases: (1) leads to formation of a macrospore and consists of two successive divisions for the conversion of the diploid mother cell into monoploid macrospores and (2) usually carried out by one macrospore, the foundation for the fully developed embryo sac is laid down by 3 nuclear divisions. This stage is characterized by great growth and formation of the micropylar and chalaza poles. After first division of the macrospore nucleus, the embryo sac elongates and a large vacuole forms. At the chalaza end are 3 antipodal cells and one polar nuclei and at the micropyle are 2 synergids, one egg cell and one polar nuclei. The normal type shows great

variation in the second phase (embryo sac formation).

The endosperm is generally cellular throughout, one exception being V. corymbosum (16). Stevens (20) reported that endosperm development in V. corymbosum may begin by formation of cross walls following first primary endosperm division or by a period of free nuclear division . From the terminal endosperm cells are found endospermic haustoria, which are multinucleate at first and later having cross walls formed. Peltrisot (13--14), Artopoeus (1), Stevens (19--20), and Samuelsson (15) have found the two haustoria in 32 Ericaceae species.

Samuelsson (15) found hetertrope (amphitropous) ovules in V. myrtillus, V. uliginosum, and V. vitis idea while Hofmeister (10) finds a flattened, symetrical anatropous ovule in V. myrtillus and V. uliginosum. In speaking of the embryo sac development in V. microcarpum, V. myrtillus, V. uliginosum, and V. vitis idea Samuelsson (15) states that "the occurance of four tetrad cells muct be assumed to be typical. The embryo sac becomes developed within a single strong integument; the micropyle is very small as is the embryo sac. The egg apparatus lies in an enlargement above the tapeta zone." Hofmeister (10) describes V. uliginosum as "the endosperm arises out of repeated binary fission (dichotomy) of one individual the inferior two-thirds of the embryo sac occupies the cell." In V. myrtillus he found that "the embryo sac is first cut in half by a cross wall near the middle and later cross walls formed in each half and the micropylar end is cut off by a wall; thus the embryo sac is five superimposed cells without free nuclear division."

The cellular structure of the fruit is best described by Müller (12). Epidermal cells are square to rectangular with the outer wall thickened,

side walls are pitted. The mesocarp is made up of an outer 2 to 3 layers of collenchyma cells with parenchyma cells increasing in size towards the center of the berry. Intercellular spaces become larger towards the center.

Gleisberg (7) described the types of berry growth occurring in the cranberry (Vaccinium oxycoccus). The shape depends upon which direction growth is greatest from the center of the ovary when in the blossoming stage. Should the growth be equal in all diameters a spherical fruit would result but if the growth is greatest in the transverse diameter then a flattened fruit would result; likewise, should the growth be greatest opposite the calyx end a pear-shaped fruit would be formed. In this cranberry study all shapes of berries were found depending on which diameter or diameters growth was greatest. The fruits do not grow in the same diameter relationships throughout the season. Growth may prevail in one direction for a time then in another and so on until the fruit has reached maturity.

MATERIALS AND METHODS

The plants used in this study were growing on a Saugatuck sandy loam soil at the South Haven Experiment Station and the Triangle Blueberry Plantation, South Haven, Michigan where commercial pruning and fertilizing practices were carried on. With the exception of the Jersey variety used in 1948 all plants used were located at the Experiment Station. The soil in the Triangle Blueberry Plantation field adjoining the Experiment Station land was of a slightly higher organic matter and the Jersey plants were of higher vigor.

During the three years of the study, the driest growing season on record was recorded in 1946 and the growing seasons of 1947 and 1948 were below normal in rainfall. The following table gives in part the climatic conditions for the three years compared with the mean.

TABLE I--Total Monthly Rainfall and Monthly Mean Temperature for the Months of May, June, July, and August at South Haven Experiment Station

Rainfall (Inches)

	May	June	July	August	Departure from Mean for the Four Months
Mean	3.60	3.77	2.51	2.94	
1946	2.66	1.60	0.02	0.95	-6.49
1947	4.03	2.73	1.46	0.30	-4.30
1948	4.99	2.92	1.48	1.26	-2.17

Temperature (Degrees Fahrenheit)

	May	June	July	August
Mean	55.1	65.0	70.4	68.7
1946	55.4	65.9	71.6	66.4
1947	50.8	63.9	68.8	76.5
1948	51.2	63.4	72.8	70.9

Materials

The two varieties and species used were the varieties Rubel and Jersey both of which are *Vaccinium corymbosum* L. and a lowbush species, *Vaccinium angustifolium* Ait., selected from the northern part of Michigan and designated by Mr. Stanley Johnston as Lowbush No. 1. The Rubel plants were in their nineteenth growing season and the Jersey plants of the Triangle Blueberry Plantation were in their eighth growing season in 1948. During 1946 only Rubel was used while in 1947 and 1948 Rubel, Jersey, and Lowbush No. 1 were used for the study.

Typical blossoming clusters of berries as well as late blossoming clusters were studied. Those blossoms blooming in mass throughout the field are here known as typical blossoming clusters or berries. Late blossoming clusters are those which were found in full bloom 20 days after the blossoming period of the typical blossoming clusters. These late blossoming clusters or berries make up lass than one per cent of the entire crop.

For the three-year study 14,000 measurements were made on 457 individual berries from clusters selected at random throughout an area of uniform plants. In 1946, 30 Rubel berries had transverse and axial diameter measurements made from blossoming to fruit maturity. The berries were allowed to remain on the plant until fruit abscission occurred naturally or during the measurement operation. No regular harvesting schedule was used.

In 1947, five clusters (28 berries) of Rubel, ten clusters (61 berries) of Jersey and one cluster (5 berries) of Lowbush No. 1 were measured. Besides these typical blossoming berries, one late blossoming cluster each of Rubel (6 berries), Jersey (6 berries), and Lowbush No. 1 (4 berries) was measured. Only the transverse diameter measurements were used since the two diameter measurements made on Rubel the year before resulted in the same type of sigmoid curve even though the axial diameter is less than the transverse diameter. The fruits remained on the plant until natural abscission occurred. No regular harvesting operations were used on the measured fruits.

In 1948, six clusters (34 typical blossoming berries) of Rubel, twenty-eight Jersey clusters (199 typical blossoming berries), six late

blossoming clusters (24 berries) of Jersey, and four clusters (16 typical blossoming berries) of Lowbush No. 1 were measured by the transverse diameter. Of the 199 typical blossoming Jersey berries, 45 berries (five clusters) were measured by both the transverse and axial diameters. The berries used for the measurements in the 1948 season were harvested with the normal commercial harvesting operations. This is especially true for the Jersey variety as it was located in a commercial field. There were two harvests for the season, August 16 and 31 for Jersey and August 10 and 25 for Rubel.

Harvesting Operations

There are no set times for the harvesting of blueberries. The fruits mature over a period of about ten weeks and require several harvests since some berries of a cluster or even whole clusters are later in reaching maturity than others. The fruit in turning from a green to a blue or blue-black color passes through a very short period of red coloration. When the fruit has reached the blue or blue-black color, it is mature as far as the commercial producer is concerned and is ready to be harvested yet the fruit may not have reached its highest quality at the time of first appearance of the blue or blue-black color. After enough fruits have reached maturity a harvesting operation is made. A second and third or more harvests are made when enough fruits have matured to warrent another harvest. The number of harvests required is variable with the season and the grower.

Measurements

Measurements of the individual berries were made in the morning on Monday, Wednesday and Friday of each week from full bloom to maturity of the fruit by means of a vernier caliper and recorded in millimeters. All fruits received a transverse measurement and some fruits received in addition an axial measurement.

Calculations

Each of the diameter measurements were converted to volume (cubic millimeters) computed on the bases of a sphere or an oblate spheroid depending on whether transverse or both axial and transverse diameter measurements were made. In computing the oblate spheroid volume, the ratio between the two diameters is important. The formula used for finding the volume of an oblate spheroid is $4/3\pi a^2 b$ where a equals the major semi-axis diameter and b equals the minor semi-axis diameter. Turrel (23) using this formula has tabulated the volumes for oblate spheroids having diameters of 1.0 to 15.0 in 0.1 units which were used where both transverse and axial diameter measurements were made. When only the transverse diameter measurements were made the volume of a sphere ($4/3\pi b^3$) was used. These computed volumes for each berry on a given day were averaged to find the average berry size in cubic millimeters. Since the position of each berry in a cluster was known, the clusters were divided into three nearly equal portions so as to compare the terminal, medial, and basal portions. The berry volumes for each of the three portions were averaged in order that the mean berry size could be found on any one day that measurements were made. The data on Jersey collected in 1948 will be used in the figures of the text since the data is based on a larger number of measurements

and is similar to the Jersey data of the previous year.

RESULTS

Typical Development

The grand growth curve is of the normal sigmoid shape with three distinct periods of growth as found in many plants (Figure 1). Stage I, an accelerated rate of growth, has a duration of 28 days from full bloom for both early and late maturing varieties. The duration of Stage II, when little fruit size increase is evident, determines the time for fruit maturity; thus for a single plant the duration of this stage may vary as much as 42 days. Stage III, the second accelerated rate of growth, continues until maturity (blue or blue-black color) of the fruit. The rate of accelerated growth is shown by the steepness of the growth curve (Figure 1). The second period of accelerated growth is of a slightly lower rate than the first.

There remains much to be determined as to what occurs during Stage II, the period of retarded fruit growth. It is very possible that seed development occurs at this time as it does in other fruits. From free hand sections one observes that the increase in flesh size is due to an increase in cell size and not to increase in cell number.

A relationship exists between the computed volumes of the transverse and axial diameters (Figure 1). The transverse diameter volume gives the greater berry size and has a higher rate of accelerated growth (Stages I and III). Stage II is of a slightly longer duration when axial diameter measurements are made. Since these two diameter volumes (transverse and axial) show varying growth curve characteristics, a ratio of the major

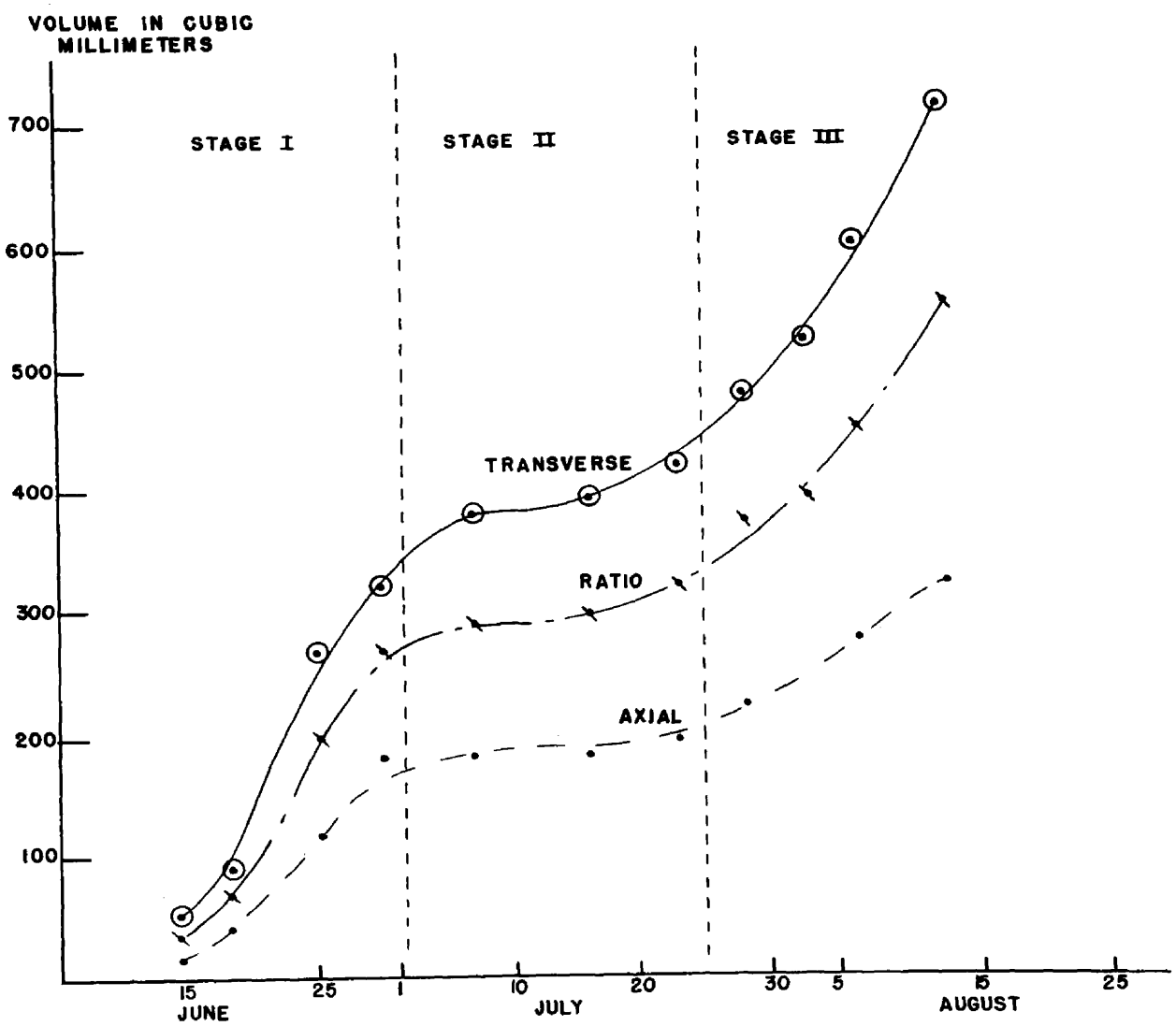

FIGURE 1--Fruit development for the first harvested fruits, volumes for transverse and axial diameters and ratio of the two diameters, taken from Table IX (Jersey 1948)

and minor axis, using the formula Volume = $4/3\,\pi\,a^2b$, where a is the major semi-axis and b is the minor semi-axis, can be used to reduce the differences of the two measurements and produce a more average growth curve.

From the data of the 1946 and 1947 seasons (Tables V, VI, VII, VIII, and XIV) when no formal harvesting operations were carried out on the berries being measured, the berries remained on the plant up to 17 days after first turning a blue color before dropping off the plant. The average time for fruits to remain on the plant after turning from the green to blue or mature color was 10 days for Rubel and 12 days for Jersey.

The cluster size ranges from 3 to 13 fruits per cluster in the case of the Jersey clusters studied. The Rubel variety had an average cluster size of 6.8 fruits based on the 10 clusters used in the measurement studies for 1947 and 1948. From these few clusters studied both varieties are essentially of the same size; namely, 7 fruits per cluster. The distribution data for Table II is based on 47 Jersey clusters and 10 Rubel clusters used in 1947 and 1948.

TABLE II--Cluster size distribution for Jersey and Rubel, 1947 and 1948

Number of Fruits Per Cluster	Frequency (Per Cent) Jersey	Rubel
2	0.0	0.0
3	4.3	0.0
4	8.5	10.0
5	17.0	20.0
6	8.5	10.0
7	23.4	20.0
8	12.8	20.0
9	17.0	20.0
10	2.1	0.0
11	2.1	0.0
12	2.1	0.0
13	2.1	0.0
14	0.0	0.0
Total	99.9	100.0

Typical Cluster Development

The average cluster size for Jersey in 1947 and 1948 was seven fruits. A representative cluster of eight fruits was chosen to show the individual fruit growth curves (Figure 2). The fruits were numbered 1 to 8 from terminal to basal position within the cluster.

One fruit was removed from the cluster at the time of the first harvest, five fruits were removed in the second harvest and two fruits remained in the cluster for the third harvest. The one fruit that reached maturity for the first harvest was located fourth from the terminal and had the smallest diameter (10.4 mm.) of all fruits at the time of maturity. This one fruit had turned to its mature color (blue or blue-black) three days before being harvested. The five fruits harvested at the time of the second harvesting operation were numbers 1, 2, 3, 5, and 7 in the cluster. They turned a blue color in the following order--1, 5, 3, 2, and 7. The sizes of these fruits at the time of their maturity (second harvesting date) varied considerably, 10.8, 11.1, 11.8, 11.9, and 10.6 mm. respectively for the five fruits. Fruits 6 and 8 were harvested in the third harvesting operation which took place after the measurement data had ceased. Their respective sizes at the time of the last measurement date (September 10) were 9.5 and 8.4 mm. Fruit 6 had turned blue on September 6 and fruit 8 was just starting to turn (red color) on September 10.

The largest fruit of the cluster is the first fruit to mature. Even after a harvesting operation this is true of the remaining fruits. The growth curves of all fruits in this one cluster during the first half of Stage I are the same. The growth started to vary at the end of Stage I and continued with increasing variability until maturity of the fruit.

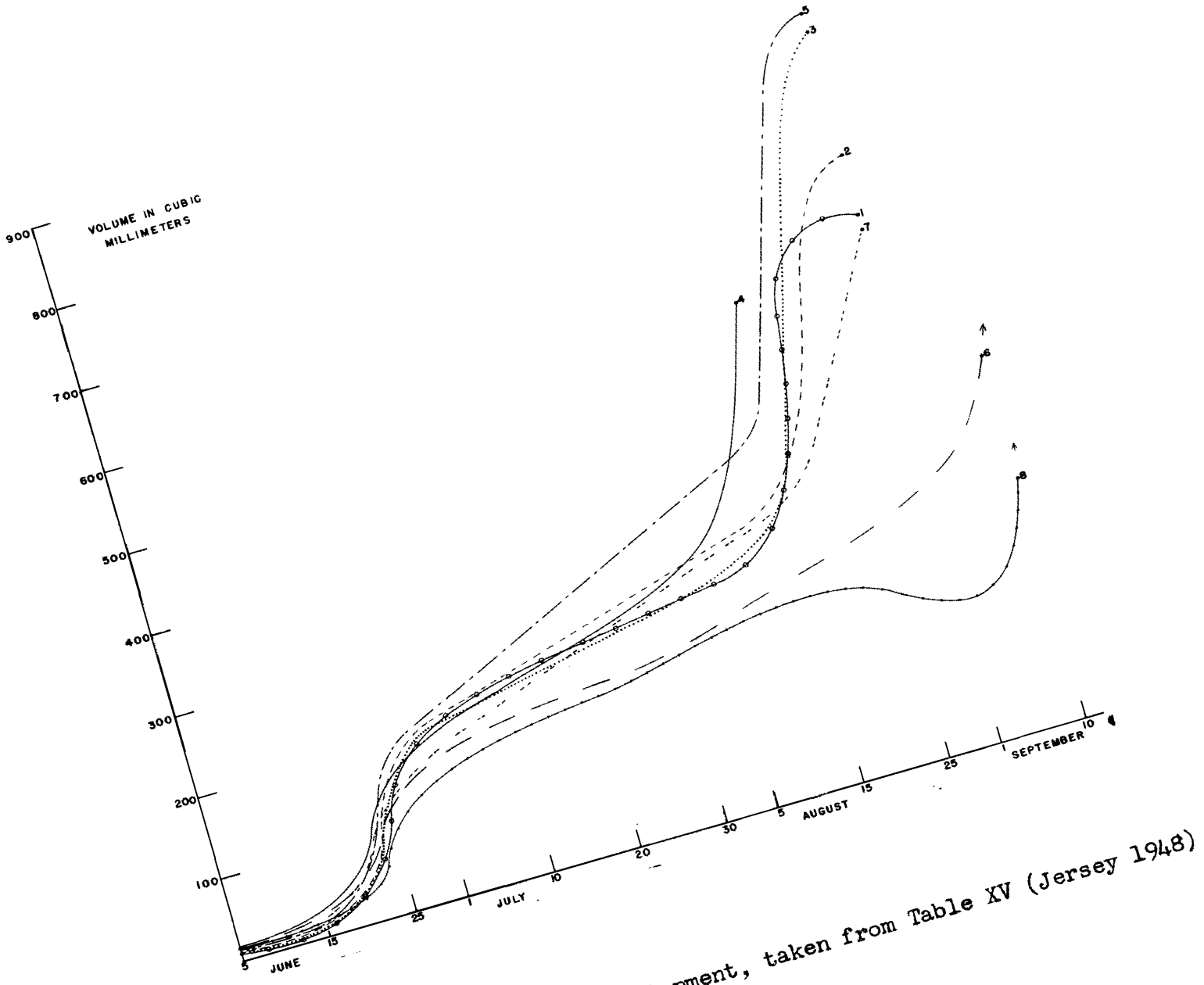

FIGURE 2--Typical cluster development, taken from Table XV (Jersey 1948)

All fruits except number 8 had increasing growth curves of various rates throughout the season. The growth curve of fruit 8 had a gradual declining curve during the latter part of Stage II and up to the time of the second harvest when five fruits of the cluster were removed. At this time fruit 8 had a rapidly increasing growth curve.

The one fruit maturing first (number 4) had the shortest duration of Stage II and the two fruits (numbers 6 and 8) maturing for the third harvest the longest duration of Stage II; the five fruits harvested at the time of the second harvest had essentially the same duration for Stage II. Of the eight fruits in the cluster four had nearly the same accelerated growth rate during Stage III.

Terminal, Medial, Basal Cluster Portion Development

The blossoming of the cluster in relation to the portion of the cluster is: basal first followed by medial, with the terminal the last blossoms to open. Contrary to what might be expected, the first fruits to mature are not basal. From the 199 Jersey berries measured in 1948, of the 30.7% that were harvested in the first harvesting operation, 9.7% were basal, 13.98% were medial, and only 6.98% were terminally borne berries (Table III).

TABLE III--Per Cent of Fruits Harvested in the Separate Harvesting Operations and Per Cent of Terminal, Medial, and Basal Fruits Harvested From 199 Jersey Berries (1948)

Harvest	Cluster Portion			Total
	Terminal	Medial	Basal	
First	6.98	13.98	9.70	30.66
Second	13.98	13.45	10.20	37.63
Third	10.75	9.70	11.30	31.75
Total	31.71	37.13	31.20	100.04

The different portions of the cluster (terminal, medial, and basal) develop differently (Figure 3). The rate of growth for all portions of the cluster remains equal for the first 10 days after full bloom, the berries having reached a diameter size of 4.3 mm. The medial portion of the cluster has the highest rate of growth with the terminal and basal portions of the cluster nearly equal at the end of Stage I, the average berry sizes being 7.7, 8.2, and 7.8 mm. for the terminal, medial and basal portions respectively. This relationship remains the same during the growth in Stage II and the early part of Stage III, the average increase being 1.1 mm. or approximately 14%. At the end of Stage III the medial growth rate is much greater than the basal and terminal portions, the average sizes being 9.5, 10.7, and 9.9 for the terminal, medial, and basal cluster portions. The growth of the berries after the first harvest is nearly the same as during Stage III of the first harvested berries with the rate of growth of the medial portion being much less yet the magnitude of the curve remains greater for the medial than for the terminal or basal portions at the time of the second harvest. The average diameter sizes at the end of Stage III of the second harvested fruits are 10.3, 10.5, and 9.6 mm. for the terminal, medial and basal portions of the cluster. The basal portion of the cluster has the greatest rate of growth near the end of the season (September or just before the third harvest) due mainly to fewer terminal and medial berries remaining in the cluster. The size cannot be given as their final stage of growth was incomplete when recording of data stopped on September 10.

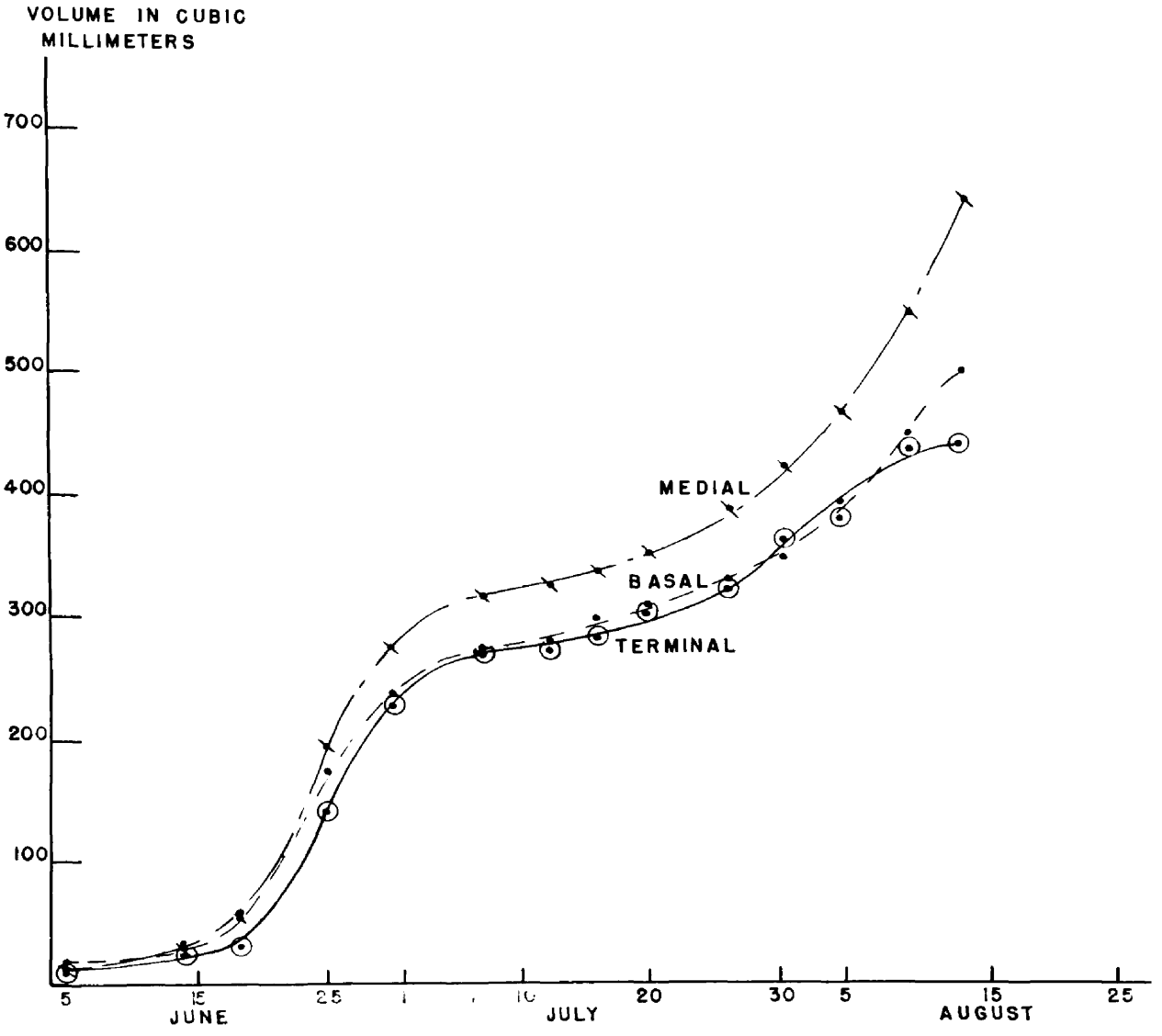

FIGURE 3--Fruit development for terminal, medial and basal cluster portions, taken from Table X (Jersey 1948)

Development of First, Second, and Third Harvested Berries

The duration of Stage II is directly correlated with the time of harvesting. The Jersey berries measured in 1948 had two commercial harvesting operations, August 16 and 31. Approximately 1/3 of the berries remained after the second harvest (Table III) and were not mature until after September 10 when the measuring data ceased. These berries are here regarded as the third harvest even though their growth was not yet completed.

The duration of Stage I is 28 to 30 days (Table IV) for all berries harvested. The rate of growth of the berries in this stage is the same for the first and second harvested fruits while those fruits of the third harvest have a much slower rate of growth (Figure 4). The average fruit diameter at the end of Stage I is 7.8, 8.1, and 6.7 mm. respectively for those berries of the first, second, and third harvesting operations.

The average berry size at the end of Stage II for the first, second, and third harvests is 8.3, 9.6, and 8.6 mm. respectively, while the duration of this stage for the first harvest is 14 days, for the second harvest is 36 days and the third harvest is 56 days.

The second period of accelerated growth continues to fruit maturity at a less accelerated rate than in Stage I. The berries of the three harvesting operations have the same rate of growth for Stage III. The average berry size at the time of harvesting is 10.1 and 11.6 mm. for the first and second harvests. The third harvest berry size cannot be given since their growth was incomplete. The average volume of the fruit is greatest for the second harvested berries.

The greatest number of fruits were picked in the second harvest (Table III). Forty-five per cent of the berries of the first harvest were growing

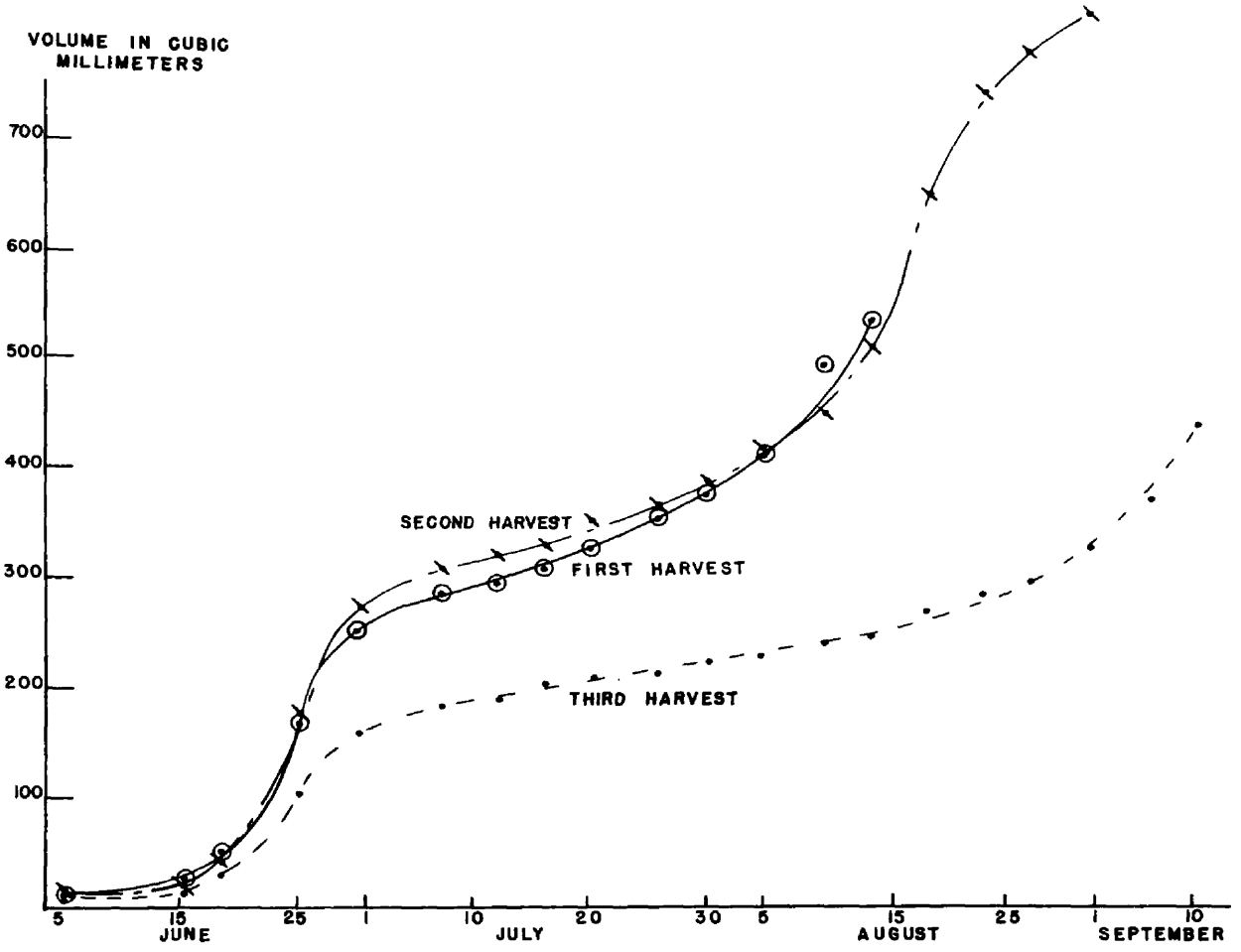

FIGURE 4—Fruit development for first and second harvests and remaining fruits, taken from Table XI (Jersey 1948)

on the medial portion of the cluster, twenty-three per cent were terminal and thirty-two per cent were basal fruits. The second harvest was made up of fairly equal portions of berries with thirty-seven per cent terminal, thirty-six per cent medial, and twenty-seven per cent basal. The third harvest would have had thirty-six percent of its fruits harvested from the basal portion followed closely by thirty-four per cent terminal and thirty per cent from the medial portion of the cluster.

Comparison of Late Blossoming With Typical Clusters

The first measurements for typical blossoming berries were made on June 5 with the blossoms in full bloom while the first measurements made for late blossoming berries were on June 25 when they were in full bloom. The same type of sigmoid growth curve (Figure 5) results for late blossoming fruits as for typical blossoming fruits of Jersey. The late blossoming clusters required only one harvesting operation made at the time of the second harvest for the typical blossoming fruits.

Stage I is essentially the same for both types of clusters. The end of Stage I is difficult to determine in the late blossoming berries since the curve is less abrupt than the typical berry curve. The average size of the fruit at the end of Stage I is 8.2 mm. for the typical berries and 8.6 mm. for the late blossoming fruits; thus the rate of growth is slightly higher for late blossoming fruit.

Stage II is more prolonged for late blossoming berries, being 24 days as compared to 14 days for typical fruits.

Stage III for both types of clusters has the same accelerated rate of growth. The late blossoming fruits have a longer duration of this stage; therefore, the average berry size is larger, 10.7 mm. as compared to 10.1

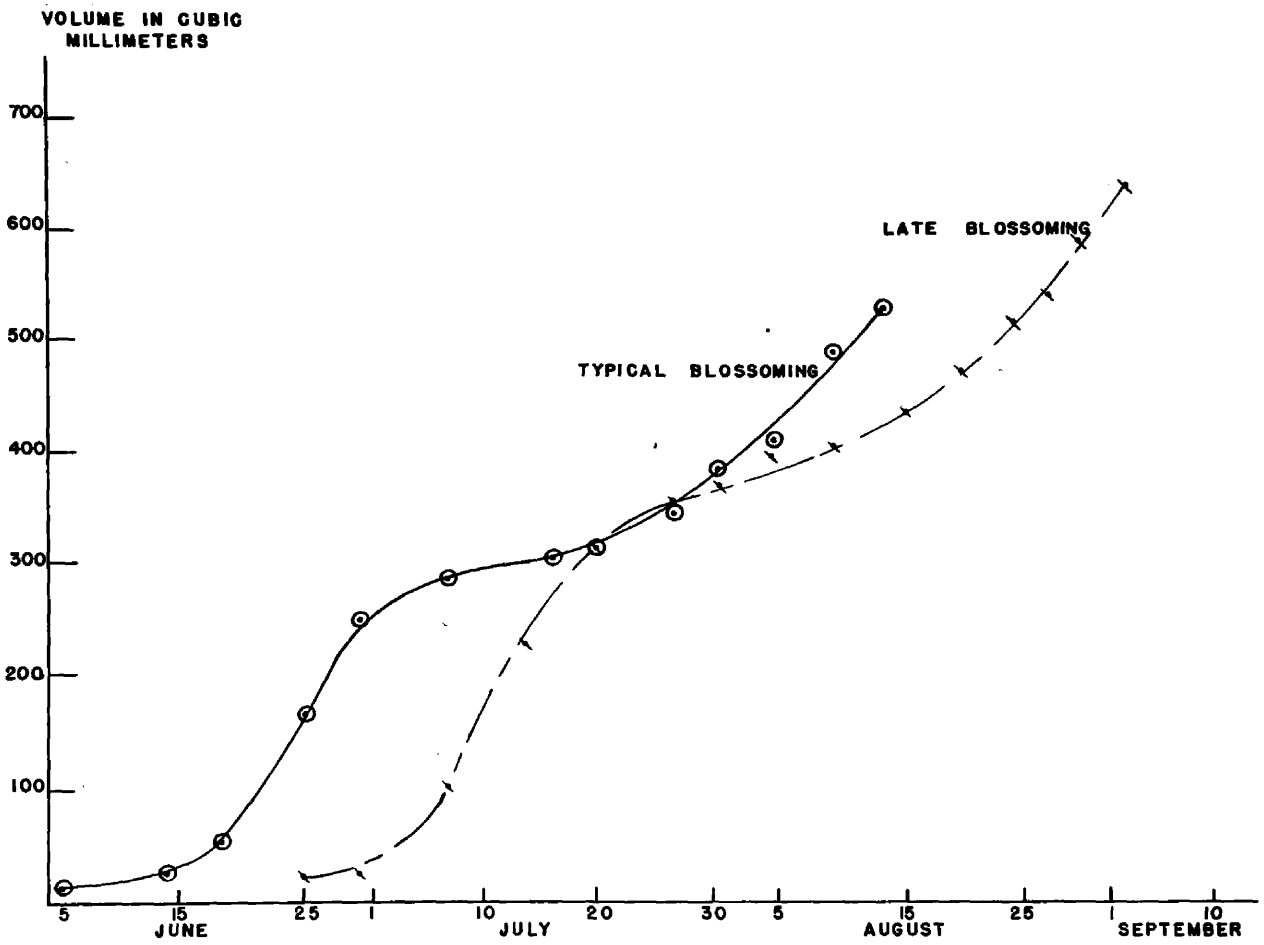

FIGURE 5--Fruit development for typical and late blossoming clusters, taken from Tables X and XII (Jersey 1948)

for typical fruits at maturity.

Development of Varieties and Species

So far the discussion has been limited to one variety, Jersey, in giving the various forms of growth curves. A comparison of Jersey (V. corymbosum) with Lowbush No. 1 (V. angustifolium), which matures its fruits three weeks ahead of Jersey shows that Stage II for Lowbush No. 1 is of a very short duration (Figure 6). In comparing the first harvest of each species, Lowbush No. 1 had a 5 day duration for Stage II while Jersey had 14 days (Table IV). The total number of days from full bloom to maturity (first harvest) is approximately 50 days for Lowbush No. 1 and 70 days for Jersey. The rate of growth for Lowbush No. 1 approaches that of a straight line. The fruit size is on the average considerably smaller than that of Jersey.

TABLE IV--Average Duration in Days for the Stages of Fruit Development

Variety		Stages I	Stages II	Stages III	Total Days
Jersey	Fruits of First Harvest	30	14	26	70
	Fruits of Second Harvest	28	36	20	84
	Fruits Remaining (Sept. 10)	28	56	18+	92+
Rubel	Fruits of First Harvest	30	15	20	65
Lowbush No. 1	Fruits of First Harvest	29	5	16	50

The grand growth curve for Rubel (Tables V, VI, and XIII) is comparable to that for Jersey except that it is of a higher magnitude as the calculated volume was computed as a sphere for transverse diameters instead of an oblate spheroid as in the case of Jersey (1948). On the average Rubel had a smaller berry than did Jersey (Figure 6). The Rubel

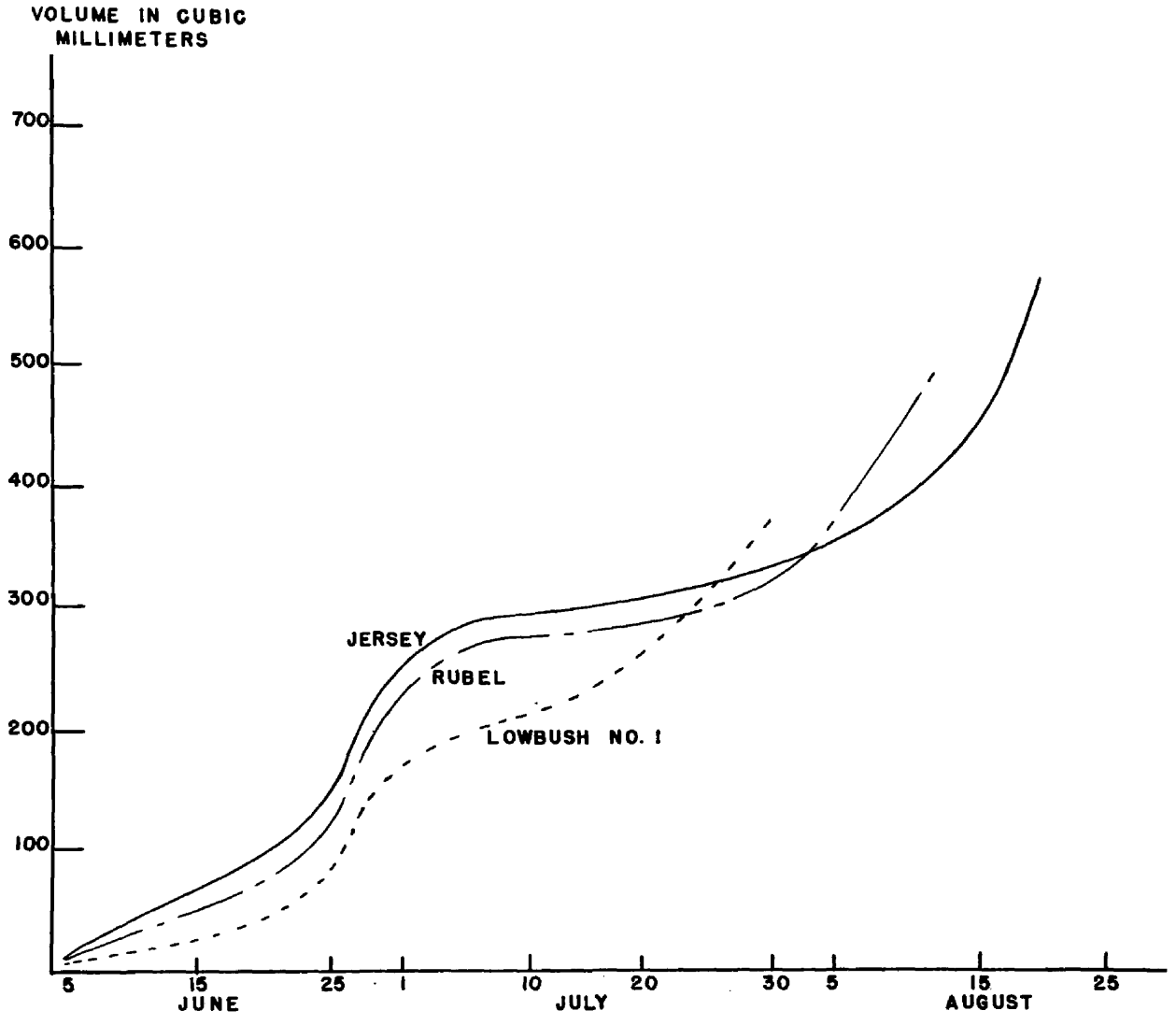

FIGURE 6--Average fruit development for Lowbush No. 1, Rubel and Jersey for 1946, 1947 and 1948

fruits in the 1948 season grew like those of Jersey in relation to position of the fruit within the cluster, the medial portion producing the largest fruit. The duration of Stage I remains the same as for Jersey and Lowbush No. 1, 30 days, but the duration of Stage II for the first harvested fruits is 15 days for Rubel in comparison to 14 days for Jersey and 5 days for Lowbush No. 1. Stage III tends to be somewhat longer for Jersey than for Rubel as Jersey ripens about a week later.

There is a definite correlation between time of blossoming and maturity of the fruits. Early varieties such as Cabot, June, and Rancoccus, and Lowbush No. 1, blossom several days ahead of Rubel and Jersey. The maturity for these early varieties is as much as two to three weeks ahead of Rubel and Jersey. The number of days difference for blossoming between Jersey and the early varieties is much less than the difference existing at maturity of the fruits.

The late blossoming Rubel berries (Table VIII) grew similarly to those of the late blossoming Jersey. The Rubel berries have a more distinct period for Stage II lasting 20 days than do the typical Rubel fruits. The magnitude of the curve is greater for late blossoming fruits than for the typical blossoming Rubel fruits at the time of fruit maturity. The two accelerated rates of growth (Stage I and Stage III) were higher for the late blossoming than the typical blossoming fruits.

The late blossoming fruits of Lowbush No. 1 (Table VIII) had a shorter duration of Stage II than the typical blossoming Lowbush No. 1. The growth rate was somewhat higher in the case of the late blossoming fruits. A comparison of the Lowbush No. 1 with Jersey revealed that the rate of growth was more rapid for Stages I and III while the duration of Stage II was less

than 5 days as compared with 14 days for the typical Jersey fruit.

Seasonal Development

The typical growth curve for the Jersey variety of 1948 (Figure 1) was of a slightly lower magnitude than for the 1947 season (Table VII) due to the manner of computing the volume. The duration of each of the three stages of growth was the same for both years but the rate of growth for Stages I and III was of a more accelerated rate for the 1947 seasonal curve. Full bloom for 1948 was five days ahead of that for the 1947 season and the time of maturity was of the same variation.

A variation in growth for the different portions of the Jersey cluster occurred for the two seasons. The medial portion curve in 1948 (Figure 3) was of the highest magnitude throughout the season while in 1947 (Table VII) the basal portion curve had the highest magnitude of growth from blossoming to the end of Stage II at which time the medial portion surpassed the basal portion and continued to be of the highest magnitude for the remainder of the growing season.

The late blossoming fruits of Jersey in 1947 (Table VIII) had a higher accelerated rate of growth for Stages I and III than the typical blossoming fruits. For this reason the berry size at the start of Stage II and at maturity was greater for the late blossoming fruits.

Little if any variation occurred for the two seasons growth in the case of Lowbush No. 1 (Table XIV) for the typical blossoming fruits other than for the size of the fruit at the time of fruit maturity. The 1947 curve had the highest magnitude due to having a more steadily increasing curve. One variation cannot be said to be more typical than another since only 25 berries were measured for the two seasons.

The typical fruit growth for the Rubel variety was similar for the three seasons of study (Tables V, VI, and XIII). The rate of growth in Stage I for 1947 remained low for the first 20 days following blossoming after which a very accelerated rate of growth occurred and continued to the end of Stage I. The accelerated rate of growth (Stage I) started immediately after blossoming for the 1948 season. The second accelerated rate of growth (Stage III) was less accelerated in 1947 than in the 1948 season, but neither was as accelerated as the growth of Stage I. The magnitude of the Rubel fruit growth curves for the three seasons showed the influence of the weather conditions very markedly. The berry size being smallest in 1946 and largest in 1948 when the rainfall was least and greatest respectively.

The three cluster portions (terminal, medial and basal) for Rubel in 1947 and 1948 (Tables VI and XIII) had variable growth curves. The curves were essentially the same with the exception that the terminal portion for 1948 produced the smallest fruits and in the 1947 season produced the largest fruits of the cluster.

Cluster Location

The rows of plants from which all berries were measured run in an east-west direction. Clusters of fruit studied were located on the north and south sides of the plants. The clusters could be exposed to the sunlight or shaded by the plant foliage.

The growth of the fruits showed a slight variation depending on which side of the plant the berry was located. The fruit on the south side tended to be larger throughout most of the growing season than did those located on the north side (Figure 7). The fruit size difference

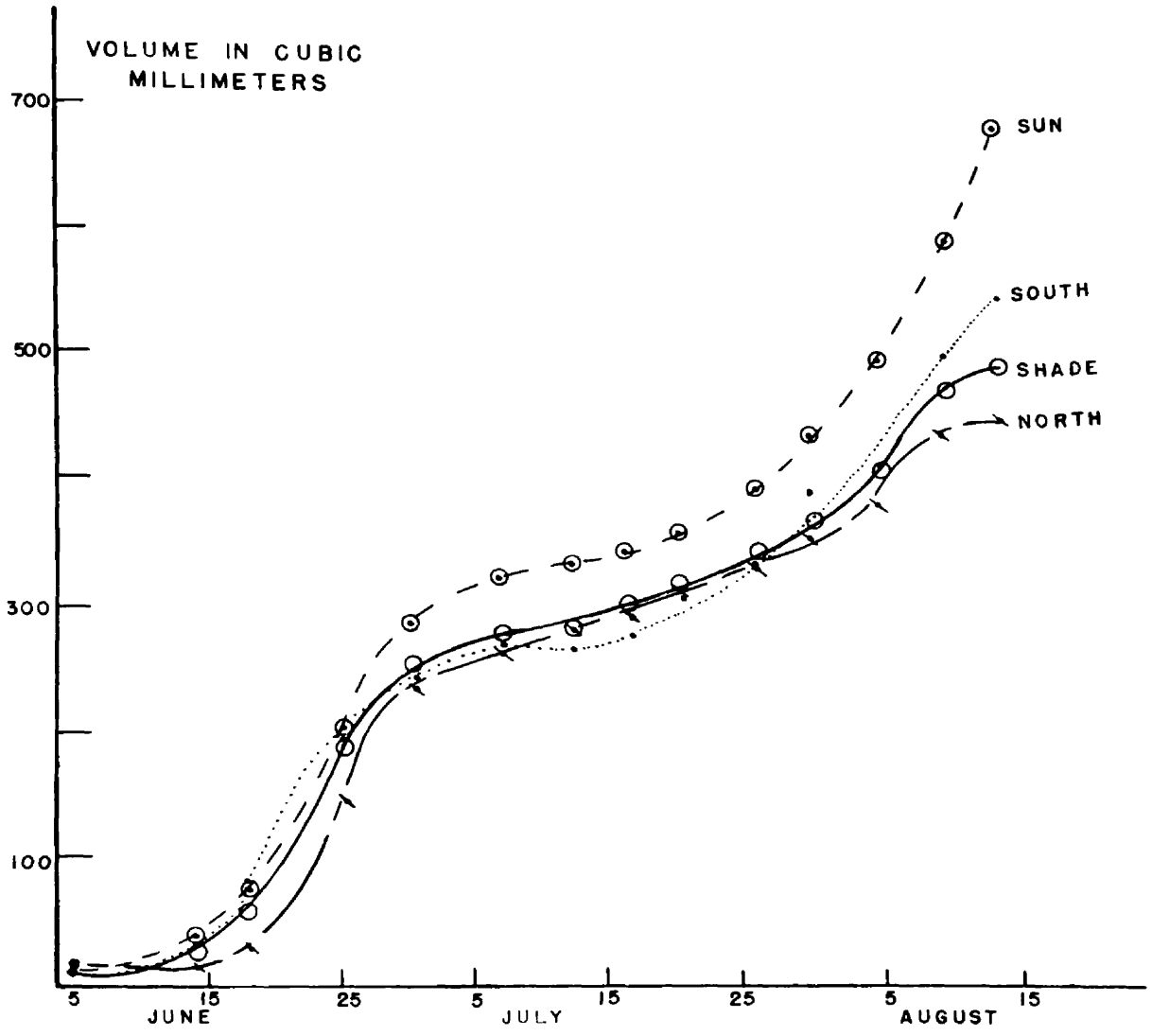

FIGURE 7--Fruit development as to position on plant--north and south exposure and direct and indirect sunlight, taken from Table XVI (Jersey 1948)

at the time of the first harvest was 0.7 mm. with the fruits on the south side having attained the largest size.

Sunlight had a greater influence on the fruit size than did direction exposure (Figure 7). Little difference in growth occurred during the early part of Stage I but by the end of Stage I the fruits exposed to the sunlight had reached a diameter size of 7.3 mm. as compared to 7.2 for shaded fruits. During Stage II the variation remained the same between the berries. The size of the fruits exposed to the sunlight averaged 10.9 mm. as compared to 9.9 mm. for shaded fruits at the time of their maturity.

DISCUSSION

Data were collected during three seasons having below normal rainfall. During some of the extremely dry weather, particularly noticeable during the final stage of growth (Stage III), shriveling of the berries occurred. In the 1946 season the berries did not regain their turgidity as was the case of most shrivelled fruits in the 1947 season. This was due to the more prolonged drought conditions of the 1946 season. Some blueberry growers practice irrigation to some extent but usually too late to be of full benefit for the final swell (Stage III) of all fruits. From the data, for irrigation to be effective for all fruits, it must be used during any dry period occurring in Stage III. For most locations in Michigan some irrigation would be to the advantage of the grower in that fruit size and quality should be better when optimum water relationships are maintained in the plant throughout the growing season.

The fruits of the late blossoming clusters were larger and matured more evenly throughout the cluster than the typical blossoming clusters.

These late blossoming clusters always required at least one less harvest for the removal of all fruits. With the harvesting operations being the most expensive to the grower it might well be profitable to delay blossoming two to three weeks by possible application of some growth regulating materials, thus reducing the number of harvests required for the removal of all fruits from the plant and also increasing the fruit size.

Fertilizer applied so as to be of benefit for Stages I and III would be of value in attaining better growth of plant and increasing fruit size and quality with a good nutritional balance of the elements essential for good plant growth.

The position of the cluster on the plant is important. Those clusters exposed to the sun matured their fruit before those clusters found in the inside of the plant and shaded from direct sunlight. Pruning of the plant with the thought in mind of having all the bearing surface towards the outside of the plant in contact with direct sunlight would help in maturing the crop more evenly and thus possibly reduce the number of harvesting operations.

SUMMARY

Development of the fruit of the blueberry is similar to that for such fruits as the peach, cherry, and fig. There are three distinct stages of growth namely: an accelerated rate of growth following fertilization and lasting about 29 days in the case of the blueberry, a period of retarded growth for the pericarp, and a second accelerated rate of growth of the pericarp or the final swell of the fruit. Fruit maturity depends upon the duration of the retarded period of growth which varies from 14 to 56 days. Fruits will tend to remain on the plant after

reaching maturity (blue color) for 12 days in the case of Jersey and 10 days for the Rubel variety. The average cluster size for Jersey is 7 berries and for Rubel 6.8 berries.

The growth of the individual fruits of an average sized Jersey cluster are variable after Stage I. There is no definite order of development of the fruits in the cluster nor can a definite relationship of size be made since all portions have some large and small fruits reaching maturity for the first or the last harvesting operations. The largest berry in the cluster matures first. When it is harvested the largest of the remaining fruits is then first to reach maturity and so on until all fruits are mature.

A variation exists between the terminal, medial, and basal portions of the cluster. While each portion contributes a third of the entire crop, the medial portion produces the bulk of the first harvest. For the second harvesting operation the three cluster portions (terminal, medial and basal) contribute 14%, 13%, and 10% of the total crop. The third harvest consists mostly of basally positioned fruits followed closely by terminal with the medial portion contributing the least.

The berries harvested in the first harvesting operation have the shortest duration of Stage II while those of the third harvest have the longest duration of the period of Retarded growth. The two accelerated stages of growth (I and III) for the fruits of the three harvesting operations are of the same acceleration and duration.

A comparison of the growth curves for Lowbush No. 1, Rubel, and Jersey shows that Jersey produces the largest fruit followed by Rubel and then Lowbush No. 1. The growth curves are the same general shape.

The rate of growth for the two varieties (Jersey and Rubel) and the two species (V. corymbosum and V. angustifolium) for the first and third stages of growth are essentially the same but their times of maturity are different. Lowbush No. 1 is the first to reach maturity due to the short duration of Stage II while Jersey matures last with Rubel intermediate.

Late blossoming clusters which are in blossom 28 days after the typical blossoming clusters mature their first fruits about 28 days after the first fruits of the typical blossoming clusters are matured regardless of whether they are of an early or a late maturing variety.

The amount of rainfall determins to a large extent the magnitude of the growth curves from season to season. The rainfall does not seem to have any influence to any degree upon the length of Stage II for the growth of the blueberry fruit.

Sunlight has a greater influence on berry size than does the exposure direction. Fruits exposed to direct sunlight have a larger transverse diameter than do shaded fruits. Fruits with southern exposure are somewhat larger than those on the north side of the plant due to the amount of sunlight.

EXPLANATION OF TABLES

All volume averages and volumes are recorded in cubic millimeters.

The data presented in Tables IX to XI have the volumes calculated on the basis of an oblate spheroid while Tables VI, VII, VIII, XII, XIII, and XIV have the calculated volumes based on a perfect sphere. Tables V and IX have the volumes calculated by both methods.

The variation existing between the number of berries used for determining the average volumes for terminal, medial, and basal portions of the cluster and the total number used in finding the grand average volume is due to not using one cluster for the terminal, medial, and basal portions that was included in the grand average as the cluster was broken off early in the season. This occurs in Tables VI and VII.

The number of berries used in calculating the average volume decreases as the berries reach maturity and abscission takes place or they are harvested.

Regular harvesting operations for berries measured in 1946 and 1947 were not carried out. The Jersey and Rubel varieties used in 1948 were harvested as in a commercial field. These harvests occurred on August 16 and 31 for Jersey and August 10 and 25 for Rubel.

In Tables XIII and XIV (1948) the number of berries being measured was increased on July 12 to replace a cluster which had been previously broken off in the cultivation operations.

The relationship between volume in cubic millimeters and its diameter in inches and millimeters is shown by the following:

Volume	Diameter	
Cubic Millimeters	Millimeters	Inches
100	5.8	0.225
200	7.3	0.300
400	9.1	0.375
600	10.5	0.420
800	11.5	0.450

TABLE V--Average Computed Volumes for Transverse and Axial Diameters Based on a Sphere and Ratio Volume Based on an Oblate Spheroid (Typical Blossoming Rubel 1946)

Date		Transverse Diameter	Transverse Volume	Axial Diameter	Axial Volume	Ratio Volume	Number of Berries
July	13	7.9	258	5.8	102	190	29
	15	7.9	258	5.6	92	183	
	17	7.9	258	5.7	97	186	
	22	8.3	299	6.0	113	216	
	24	8.3	299	5.9	108	213	
	26	8.4	310	6.3	131	233	
	29	8.2	289	6.4	137	225	27
	31	8.1	278	5.9	108	203	24
August	2	8.3	299	6.2	125	224	23
	5	8.3	299	6.2	125	224	
	7	8.5	322	6.5	144	246	21
	9	8.8	357	6.6	151	268	18
	14	9.1	395	7.2	195	312	9
	16	9.5	449	7.5	221	354	7
	18	9.8	493	7.9	258	397	5
	19	9.9	508	7.8	248	400	
	21	9.9	508	7.9	258	405	
	23	9.7	478	7.4	212	365	
	26	10.0	524	7.5	221	393	4
	28	10.1	539	7.4	212	395	3
	31	9.0	382	7.6	230	322	2

TABLE VI--Volume for the Grand Average, Terminal, Medial and Basal Cluster portions of Rubel (1947)

Date		Grand Average	Number of Berries	Terminal Average	Number of Berries	Medial Average	Number of Berries	Basal Average	Number of Berries
June	10	16.2	28	16.1	7	13.2	9	20.8	7
	16	16.5		14.5		15.9		20.0	
	18	20.7		16.5		22.7		25.6	
	20	23.5		16.5		24.2		28.7	
	22	30.7		25.6		32.9		40.8	
	24	39.6		30.3		46.3		51.0	
	26	75.5		60.6		81.5		105.1	
	28	118.5		106.7		134.3		114.9	
	30	141.7		163.8		169.3		174.3	
July	2	189.3	27	203.3		219.1	8	200.5	
	4	204.9		230.4		227.6		207.9	
	7	224.8		254.9		249.4		227.3	
	9	252.4	25	258.5		251.7		250.6	
	11	251.0		267.4		245.0		241.3	
	14	282.2		299.8		276.5		279.1	
	16	290.5		316.6		278.9		281.4	
	18	291.3		321.0		284.0		274.0	
	21	304.0	22	338.4		287.3		291.8	
	25	322.7	21	391.0	6	298.5		291.8	
	28	336.7		406.6		311.8		305.3	
	30	344.9		426.2		324.3		298.7	
August	1	351.5	20	452.8	5	344.3		298.7	
	4	366.8		475.0		345.3		314.2	
	6	390.3		512.6		369.9		326.4	
	8	420.2		598.6		385.1		333.1	
	11	461.6		667.0		419.7		362.7	
	13	481.0		693.4		434.4		382.5	
	15	486.9	19	756.2	3	444.1		394.5	
	18	497.2		784.6		447.6		389.6	
	20	593.1	12	1066.0	2	560.7	5	436.3	5
	22	591.6		1066.0		555.2		438.3	
	25	615.5		1118.0		577.2		455.0	
	27	642.8		1140.0		608.2		478.6	
	29	672.0		1148.0		626.3		527.4	
September	1	526.0	8	860.0	1	468.5	3	465.5	4
	3	486.4	6		0	459.4		513.5	3
	5	521.0				509.5		532.5	
	8	604.5				539.9		669.1	
	10	621.4				573.8		669.1	
	12	641.7				614.3		669.1	
	15	551.3	5			590.4		492.5	2
	17	590.6				632.1		528.4	

TABLE VII--Volume for Grand Average, Terminal, Medial and Basal Cluster Portions for Jersey (1947)

Date		Grand Average	Number of Berries	Terminal Average	Number of Berries	Medial Average	Number of Berries	Basal Average	Number of Berries
June	10	17.6	60	16.4	18	18.6	18	18.1	18
	16	24.8		22.9		23.6		27.2	
	18	30.4		26.7		27.9		29.9	
	20	32.5		27.9		32.4		35.2	
	22	40.0		29.5		41.9		49.8	
	24	71.5		50.5		78.4		95.3	
	26	125.1		95.3		141.8		162.3	
	28	192.9		146.2		318.0		237.6	
	30	250.7	59	194.5		268.1		297.2	
July	2	304.5		248.5		315.8		344.9	
	4	339.3		395.0		339.7		373.0	
	7	370.8	57	339.1	17	366.4		393.2	
	9	379.8		349.8		382.1		396.4	
	11	383.4		347.5		386.1		403.8	
	14	392.6	52	362.4	16	393.6		418.5	
	16	393.3		370.7		395.9		419.7	
	18	404.4		377.8		408.4		423.9	
	21	406.7		392.4		414.6		428.5	
	25	419.9	51	398.6		429.3		431.1	17
	28	441.2		415.9		455.3		450.1	
	30	442.9		417.4		456.6		452.2	
August	1	448.9		417.4		478.3		453.3	
	4	495.7	50	473.2		526.5		489.6	16
	6	494.0		464.6		540.5		458.4	
	8	562.5	49	529.3		639.8	17	521.3	
	11	630.8	48	580.7		752.1	16	558.8	
	13	651.7	47	598.7		786.9		563.9	15
	15	701.6		638.8		841.2		619.6	
	18	760.9		694.2		885.5		699.1	
	20	779.5	46	713.7		891.8	15	688.5	
	22	753.5	44	724.5		856.6	14	684.0	14
	25	772.4	42	772.6	15	860.6		696.5	13
	27	778.1	39	811.4	14	873.7	12	663.5	
	29	664.5	29	761.9	11	626.5	8	587.7	10
September	1	584.4	20	493.2	7	674.6	6	598.2	7
	3	653.9	19	328.6	6	678.0		623.5	
	5	542.8	16	397.7		596.9	4	651.8	6
	8	505.3	13	341.0	5	461.7	3	695.7	5
	10	514.4	12	368.8		455.5		740.6	4
	12	540.0	11	412.4		385.0	2	776.9	
	15	452.0	9	406.8		422.5		427.2	2
	17	453.8		441.5		438.1		527.2	

TABLE VIII--Volume for Late Blossoming Clusters for Rubel, Jersey and Lowbush No. 1 (1947)

Date		Jersey Grand Average	Number of Berries	Rubel Grand Average	Number of Berries	Lowbush Grand Average	Number of Berries
June	28	22.4	6	14.1	6	12.9	4
	30	28.7		19.6		25.2	
July	2	37.0		22.0		40.1	
	4	54.1		32.2		54.9	
	7	127.1		71.7		84.5	
	9	200.6		106.0		91.3	
	11	285.3		140.5		105.2	
	14	391.2		228.8		109.6	
	16	499.3		279.2		175.6	
	18	511.8		293.6		184.7	3
	21	517.0		302.7		184.7	
	23	565.8		325.1		184.7	
	25	565.8		325.1		207.3	
	28	575.7		331.5		285.7	
	30	584.4		337.0		330.7	
August	1	591.0		343.7		393.8	
	4	620.3		356.0		479.3	
	6	559.5		339.7		571.6	
	8	612.8		370.9		601.9	
	11	636.8		390.9		647.6	
	13	587.6		398.7		668.1	
	15	691.9		446.3		707.6	
	18	664.5		512.0		675.2	
	20	677.3		549.7		690.3	
	22	683.6		575.4		671.0	
	25	655.5		648.9		656.7	
	27	837.5		657.0			0
	29	723.1	4	713.4			
September	1	622.3	2	711.9			
	3	729.6		758.2	5		
	5	755.0		798.3			
	8	874.7		605.8	1		
	10	874.7		696.6			
	12	850.1		676.6			

TABLE IX--Average Computed Volumes for the Transverse and Axial Diameters Based on a Sphere and Ratio Volumes Based on an Oblate Spheroid (Jersey 1948)

Date		Transverse Diameter	Transverse Volume	Axial Diameter	Axial Volume	Ratio Volume	Number of Berries
June	14	4.56	51.0	3.29	18.8	36.6	45
	16	5.06	69.5	3.94	33.5	51.1	
	18	5.51	87.1	4.28	41.6	68.1	
	23	7.36	212.0	5.75	102.0	164.0	
	25	7.79	268.0	6.14	119.0	198.0	
	28	8.03	268.0	6.35	134.0	211.0	
	30	8.47	322.0	6.99	180.0	269.0	
July	2	8.62	333.0	6.97	180.0	267.0	
	7	8.89	382.0	6.96	180.0	290.0	
	9	8.86	382.0	6.88	172.0	286.0	
	12	8.93	382.0	6.99	180.0	290.0	
	14	8.91	382.0	6.94	172.0	286.0	
	16	9.06	395.0	7.05	183.0	297.0	
	23	9.32	421.0	7.22	195.0	326.0	44
	26	9.53	449.0	7.36	212.0	340.0	43
	28	9.67	478.0	7.46	221.0	374.0	41
	30	9.82	493.0	7.55	226.0	377.0	
August	2	9.98	524.0	7.63	230.0	390.0	
	4	10.28	572.0	7.84	248.0	439.0	40
	6	10.46	606.0	8.06	278.0	453.0	39
	9	10.68	641.0	8.22	289.0	477.0	
	13	11.10	716.0	8.56	326.0	555.0	
	16	10.95	697.0	8.48	322.0	523.0	33
	18	9.61	463.0	7.41	212.0	357.0	20
	20	9.81	493.0	7.59	230.0	382.0	
	23	9.95	516.0	7.55	230.0	390.0	18
	25	9.86	508.0	7.09	187.0	380.0	17
	27	10.15	564.0	7.69	239.0	406.0	
	30	10.19	556.0	7.25	204.0	419.0	
September	1	9.76	493.0	7.68	239.0	377.0	14
	3	9.29	421.0	7.04	182.0	317.0	8
	6	9.30	421.0	7.23	195.0	326.0	
	10	9.47	449.0	7.54	221.0	359.0	

TABLE X--Volume for the Grand Average, Terminal, Medial, and Basal Cluster Portions (Jersey 1948)

Date		Grand Average	Number of Berries	Terminal Average	Number of Berries	Medial Average	Number of Berries	Basal Average	Number of Berries
June	5	11.4	199	14.7	63	12.0	73	11.5	63
	14	27.3		21.4		28.6		28.4	
	16	40.7		30.9		43.6		43.9	
	18	53.8		39.7		55.8		56.8	
	23	135.1		107.5		140.3		139.8	
	25	168.1		146.2		194.7		171.7	
	28	226.7		208.1		253.7		212.3	
	30	251.4		227.7		276.3		240.9	
July	2	260.9		236.6		288.6		251.0	
	7	287.4	194	267.8	60	318.9	72	272.2	62
	9	281.8		265.4		309.9		270.4	
	12	297.0	193	274.5		326.4		283.0	61
	14	297.0		277.7		325.0		282.1	
	16	307.5		285.6		337.3		296.6	
	20	330.9		307.1		353.2		312.8	
	23	337.7	192	304.5		376.2	71	327.6	
	26	351.5	190	323.3	59	387.6		325.9	60
	28	364.8	188	338.1		411.4	69	341.5	
	30	383.8	187	366.7	58	425.6		349.8	
August	2	388.9		356.1		438.7		353.5	
	4	415.1	185	380.9		568.6	68	393.2	59
	6	450.7	184	410.5	57	499.9		416.0	
	9	497.0		440.3		547.8		451.5	
	13	538.8	174	441.8	53	638.0	65	499.2	56
	16	533.8	163	399.5	50	655.9	60	509.5	53
	18	484.4	129	443.4	48	580.0	42	403.7	39
	20	482.7	125	460.0	47	557.8	39	433.5	
	23	523.6	123	495.8	45	611.4		466.8	
	25	516.0	119	509.7		582.3	37	484.6	37
	27	544.5	118	538.4		605.0	36	493.2	
	30	550.5	116	552.5	44	591.0	35	510.8	
September	1	546.3	105	566.9	40	604.9	32	460.0	33
	3	341.0	58	315.5	20	368.7	17	336.6	21
	6	370.0		351.3		402.8		361.9	
	10	433.0	51	400.4	16	453.6	14	451.6	

TABLE XI--Grand Average Volume for First and Second Harvests and Berries Remaining on Plant on September 10 (Jersey 1948)

Date		First Harvest	Number of Berries	Second Harvest	Number of Berries	Remaining Berries	Number of Berries
June	5	11.4	72	12.1	69	7.6	58
	14	27.3		21.8		17.1	
	18	53.8		44.9		30.3	
	25	168.1		175.1		104.2	
	30	251.4		278.6		159.6	
July	7	287.4	68	315.6		186.1	
	12	297.0	66	322.7		193.5	
	16	307.5		332.5		201.2	
	20	330.9		354.4		213.2	
	26	351.5	63	368.8		217.1	
	30	383.8	61	391.0		226.3	
August	4	415.1	52	416.4		232.2	
	9	497.0	47	454.6		239.2	
	13	538.8	32	508.0		246.7	
	18		0	655.3		272.2	
	23			744.6	64	284.8	
	27			777.9	60	298.0	
September	1			810.6	47	326.5	
	6				0	370.0	
	10					433.0	51

TABLE XII--Grand Average Volume for Late blossoming Clusters (Jersey 1948)

Date		Average Volume	Number of Berries
June	25	20.5	24
	28	23.3	12
	30	23.3	24
July	7	104.6	
	9	138.1	
	12	199.4	
	14	231.9	
	16	275.0	
	20	319.4	
	23	349.1	
	26	361.4	
	28	373.5	
	30	378.4	
August	2	381.9	
	4	400.9	
	6	404.9	
	9	411.2	
	13	433.7	
	16	442.3	
	18	457.8	
	20	479.1	
	23	497.9	
	25	516.3	
	27	542.0	
	30	596.0	
September	1	628.5	
	3	648.5	23
	6	664.6	21
	10	630.0	19

TABLE XIII--Volume for Grand Average, Terminal, Medial and Basal Cluster Portions (Rubel 1948)

Date		Grand Average	Number of Berries	Terminal Average	Number of Berries	Medial Average	Number of Berries	Basal Average	Number of Berries
June	5	34.3	34	21.3	11	44.4	12	36.3	11
	14	114.1		60.4		157.3		120.4	
	16	140.1		76.6		192.2		155.1	
	18	177.6		99.5		227.2		201.2	
	23	265.2		198.8		320.4		271.3	
	25	302.0		232.1		361.8		306.6	
	28	359.3		304.7		408.8		360.1	
	30	368.2		318.0		310.5		372.3	
July	2	385.4		338.7		428.3		385.3	
	7	425.3	26	384.8	8	462.4	10	419.6	8
	9	429.4	25	381.9		460.1		439.7	7
	12	446.0	32	405.9	10	471.3	12	455.7	10
	14	440.4		395.7		463.0		471.0	
	16	467.6	31	413.7		482.1	11	505.6	
	20	489.9	29	437.7	9	521.6		503.2	9
	23	538.6		469.6		570.3		568.3	
	26	566.2	28	459.9		619.4		612.6	8
	28	617.0	26	486.0		680.1		697.7	6
	30	665.2	25	489.9		756.9	10	775.5	
August	2	724.0	23	511.0		887.9	9	762.3	5
	4	779.2	20	584.6	8	976.5		700.8	3
	6	847.2		651.1		1032.8		772.8	
	9	901.9		717.0		1080.3		824.0	
	13	623.5	6	638.0	3	524.0	1	651.5	2
	16	734.8	5	606.0	2	697.0		882.5	
	18	905.0		786.0		998.0		977.5	
	20	1018.8		872.0		1050.0		1150.0	
	23	1059.0	4	928.0		1150.0		1230.0	1
	25		0		0		0		0

TABLE XIV--Grand Average Volume for Lowbush No. 1 for 1947 and 1948

1947 Date		1947 Grand Average	Number of Berries	1948 Date		1948 Grand Average	Number of Berries
June	11	46.7	5	June	5	48.9	9
	13	46.7			14	87.1	16
	16	66.6			16	104.1	
	18	69.4			18	111.1	
	20	69.4			23	117.4	15
	22	75.7			25	140.9	
	24	106.1			28	178.3	14
	26	107.3			30	174.3	13
	28	104.3		July	2	203.5	
	30	112.0			7	161.1	9
July	2	129.1			9	200.7	
	4	152.9			12	236.5	15
	7	200.3			14	269.4	
	9	163.6			16	290.7	
	11	191.9			20	391.6	14
	14	105.9	2		23	441.0	
	16	127.2			26	458.2	
	18	146.3			28	470.7	
	21	146.3			30	492.5	
	23	202.9		August	2	484.9	
	25	212.7			4	479.8	
	28	324.6			6	493.9	
	30	324.6			9	517.4	8
August	1	363.4			13	484.7	6
	4	363.4			16	505.9	
	6	363.4			18	531.3	5
	8	224.9			20	466.4	4
	11	409.3			23	473.9	
	13		0		25	480.1	
					27	441.0	
					30	469.1	
				September	1	428.4	
					3	417.9	3
					6	451.3	
					10	331.8	2

TABLE XV--Calculated Volume for a Typical Cluster, Fruits Numbered 1 to 8 from Terminal to Basal (Jersey 1948)

Date		Fruit Number							
		1	2	3	4	5	6	7	8
June	5	8	8	14	14	14	8	8	8
	14	8	8	14	14	14	23	14	23
	18	24	24	24	43	28	35	35	35
	23	83	83	83	120	108	93	108	51
	25	108	108	108	152	152	126	138	108
	30	201	218	201	201	201	155	201	141
July	7	222	222	222	222	269	165	204	151
	12	222	231	222	204	250	188	204	151
	16	246	246	227	201	286	185	246	185
	20	246	246	246	256	297	201	246	185
	26	264	284	254	284	340	208	264	191
	30	264	306	264	306	340	216	284	191
August	4	280	312	280	312	398	231	312	213
	9	331	355	308	393	393	246	331	208
	13	297	367	331	539	433	246	355	227
	18	450	450	450	-	644	268	382	238
	23	630	578	667		870	280	468	231
	27	606	716	861		861	276	539	209
September	6	-	-	-		-	374	-	198
	10						447		297

TABLE XVI--Average Volume of fruits for North and South Exposure and for Fruits Exposed and Shaded to Direct Sunlight (Jersey 1948)

Date		South	North	Exposed	Shaded
June	5	10.5	13.8	12.1	10.5
	14	37.3	17.1	38.7	29.6
	18	79.6	29.7	75.4	59.0
	25	200.6	148.7	204.3	192.2
	30	247.6	240.6	286.9	254.8
July	7	272.2	267.9	323.6	280.6
	12	270.6	286.9	332.6	284.2
	16	280.7	296.9	344.8	300.7
	20	310.4	316.9	364.4	320.4
	26	331.8	331.7	394.8	348.9
	30	395.7	359.7	439.6	367.9
August	4	417.5	386.0	498.3	412.5
	9	503.0	443.8	593.5	476.6
	13	551.4	452.2	683.0	491.0

LITERATURE CITED

1. Artopoeus, A. Uber den Bau und die Offnungsweiss der Antheren und die Entwicklung der Samen bei den Ericaceen. Flora 92: 309--345. 1903.

2. Anderson, A. P. The Grand Peroid of Growth in a Fruit of Cucurbita pepo Determined by Weight. Minn. Bot. Studies 1: 238--279. 1895.

3. Bailey, J. S. Development Time from Bloom to Maturity in Cultivated Blueberries. Amer. Soc. Hort. Sci. 49: 193--195. 1947.

4. Camp, W. A. The North American Blueberries with Notes on Other Groups of Vacciniaceae. Brittonia 5: 203--275. 1945.

5. Conners, C. H. Growth of Fruits of Peach. New Jersey Agric. Exp. Sta. Ann. Rpt. 1919: 82--88. 1919.

6. Crane, J. C. Fruit Growth of Four Fig Varieties as Measured by Diameter and Fresh Weight. Amer. Soc. Hort. Sci. 52: 237--244. 1948.

7. Gleisberg, W. Vergleichende Bluten und Fruchtanatomie der Vaccinium oxycoccus - Typen. Deutchen Bot. Gesellschaft Birichte 40: 202--211. 1922.

8. Gray, A. Manual of Botany. American Book Co. New York. 1889.

9. Gustafson, F. G. Growth Studies on Fruits. Plant Physiol. 1: 265--272. 1926.

10. Hofmeister, W. Neure Beobachtungen uber Embryobildung der Phanerogamen. Jahrb. Wiss. Bot. 1: 82--188. 1858.

11. Koch, L. Die Entwicklung des Samens von Monotropa hypopitys. Jahrb. Wiss. Bot. 13: 202--252. 1882.

12. Muller, u Blau. Fructus mrytilli. Weiner Pharm. Woch. 35:461. 1902.

13. Peltrisot, M. Development et Structure de la Graine de quelques Ericaceae. Jour. de Bot. 18: 234--244. 1904.

14. _____ Developpment et Structure de la Graine chez les Ericaceae. Jour. de Bot. 18: 309--367. 1904.

15. Samuelsson, G. Studien uber die Entwicklungsgeschichte einigu Bicornes Typen. Svensk. Bot. Tidskr. 7: 97--188. 1913.

16. Schnarf, K. Vergleichende Embryologie der Angiospermen. Verlag von Gebruder Borntraege . Berlin. page 160. 1931.

17. Schnarf, K. Contemporary Understanding of Embryo Sac Development Among Angiosperms. Bot. Rev. 2:565--585. 1936.

18. Sinnot, E. W. The Relation of Growth to Size in Cucurbit Fruits. Amer. Jour. Bot. 32: 439--446. 1945.

19. Stevens, N. E. Dioecism in the Trailing Arbutus with Notes on the Morphology of the Seed. Torr. Bot. Club Bull. 38: 531--543. 1911.

20. _____, The Development of the Endosperm in Vaccinium corymbosum. Torr. Bot. Club Bull. 46: 465--468. 1919.

21. Tukey, H. B. Embryo Abortion in Early Ripening Varieties of Prunus avium . Bot. Gaz. 44: 433--468. 1933.

22. _____, Growth of the Embryo, Seed and Pericarp of the Sour Cherry Prunus cerasus in Relation to Season of Fruit Ripening. Amer. Soc. Hort. Sci. 31: 125--144. 1934.

23. Turrell, F. M. Surface and Volume Tables for Oblate and Prolate Spheroids and Spheres. Univ. Cal. Press. Berkeley, Cal. 1945.