THE INFLUENCE OF CERTAIN FACTORS ON THE ACIDITY AND SUGAR CONTENT OF THE JERSEY BLUEBERRY

by

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THE INFLUENCE OF CERTAIN FACTORS ON THE ACIDITY AND SUGAR CONTENT OF THE JERSEY BLUEBERRY

INTRODUCTION

While the fruit of the blueberry has been harvested from the wild since colonial times, the culture of this fruit as a crop dates back only to the early part of the present century. It began in New Jersey about forty years ago, and, a few years later, experimental plantings were made in Michigan. On the Pacific Coast, the first plantings were made after 1930 in both Oregon and Washington.

Today, blueberry culture is expanding rapidly in the United States wherever climate and cultural conditions are favorable. In the Pacific Northwest, this fruit gives promise of becoming an important adjunct to the small fruit industry, particularly in the areas west of the Cascade Mountains. Trial commercial plantings are also being made in the San Francisco Bay region of California.

Taxonomy of the Blueberry

Authorities generally recognize six important botanical species of the edible blueberry, all of which are indigenous to the United States. These belong to the genus *Vaccinium* as distinguished from the huckleberries which are usually grouped in the genus *Gaylussacia*. The six species are as follows:

V. membranaceum Dougl.---The Mountain Blueberry. Native of the high slopes of the Cascade mountains in Washington and Oregon.

V. ovatum Pursh.---The Evergreen Blueberry. Native along the coast from central California to British Columbia.

V. pallidum Ait.---The Dryland Blueberry. Native to the Ozarks and southern Appalachians and isolated areas as far north as New England.

V. ashei Reade --- The Rabbiteye Blueberry. Native to the river valleys and edges of woods in northern Florida, southern Georgia and southern Alabama.

V. australe Small (V.corymbosum L.) --- The Highbush Blueberry. Native from northern Florida to southern Maine and west to southern Michigan.

V. angustifolium Ait. --- The Lowbush Blueberry. Native of northern United States from Maine to Minnesota and south as far as Pennsylvania and West Virginia.

The named or cultivated varieties of blueberries are derived almost entirely from the highbush type. While a few of the varieties are selections originally made from the wild, most of them are the results of hybridization carried on by the United States Department of Agriculture and, to a lesser extent, by private hybridizers working mostly in the Pacific

Northwest. Among the best known commercial varieties are Jersey, Stanley, Dixie, Pemberton, Concord, Weymouth and Burlington. Of these varieties, Jersey is by far the most popular in Oregon, and for that reason it was the variety chosen for this study.

While the interest in the blueberry now centers largely around the cultivated types, large quantities of the fruit are still gathered from the wild plants of several species. In fact, the fruit of V. angustifolium gathered in Maine and neighboring states, still accounts for approximately 80 percent of all the blueberries utilized in the United States. As production from commercial plantings comes in, however, it is expected that the wild fruit will become less important in the future.

Purpose of the Study

Up to the time when this work was undertaken in 1953, practically no research had been done pertaining to the quality factors in the blueberry. Casual observations, however, had indicated that sweetness and sourness were in some way related to the size of the individual berries, and, size, appeared to be correlated with seed development. In this study, therefore, an attempt was made to determine to what extent size of berry is correlated with sugar and acid content, and to what extent size is related to seediness.

Other possible quality determiners considered in the study were the time of picking and the use of certain fertilizers or plant nutrients.

While the results obtained suggest fairly positive conclusions, the study must be regarded as being of a preliminary or exploratory nature.

REVIEW OF LITERATURE

Since the blueberry is a comparatively new fruit to the horticultural world, its literature is meager and incomplete. Particularly is this true of literature pertaining to the chemistry of the blueberry. The writer found it necessary, therefore, to review the literature of other small fruits such as the blackberry, raspberry, cranberry, strawberry, currant, and grape where research has been carried out correlating the composition of the berry with environmental and cultural factors.

The Relationship Between Seediness and Berry Size

Several investigators have found a relationship between seediness and berry size. In both blueberries and grapes the larger berries contained the most fully developed seeds, and seed weight seemed to correspond with berry size.

In 1932, Pearson (16, p. 171) at the University of California (Davis) investigated parthenocarpy and seed abortion in European Grapes (*Vitis vinifera*, variety Black Corinth). In testing eight clusters of grapes a definite relationship was found between seed development and berry size. A continuous increase in size of fruit was reported; the progression was from the seedless berries up to the berries in which seeds were apparently fully developed.

At the University of California in 1946, Olmo

(15, pp. 292, 295) investigated the correlation between seed and berry development of European grapes (V. vinifera). When comparing berries of the same variety, he found a comparatively high correlation between seed weight and berry weight. This correlation ranged from .780 to .931 in the six varieties tested.

While working on a pollination problem with blueberries, White and Clark (19, p. 308) at Whitesbog, New Jersey in 1935, found that the larger berries contained more seed than the smaller berries. They also noted that the larger berries contained more large seeds than did the smaller ones.

In 1940 Darrow (7, p. 440) compared the seed size with the fruit size of the highbush blueberry (GM-37). He found that where the size was 256 berries per pint, the number of plump seeds per berry was approximately 2.1; where the size was 110 berries per pint, the number of plump seeds per berry was approximately 11.1; where the size was 75 berries per pint the number of plump seeds per berry was approximately 18.3 and where the size was 55 berries per pint, the number of plump seeds per berry was approximately 33.1. It can be readily seen from these figures that there is a positive correlation between seediness and berry size.

Working on a pollination problem with blueberries at Oregon State College in 1951, Cremins (6,pp.17-18,34) also noted that there was a correlation between seed weight and berry weight. He found that berry weight was directly related to the amount of fully developed seeds.

There was one reference in the literature which did not agree with the results of the other investigators. Merrill (13, pp. 15-16) reported in pollination experiments conducted at Michigan State College in 1936 that no relationship was found between size of berry and the number of seed per berry after testing four hundred open-pollinated Rubel blueberries for seed content and berry weight.

The Effects of Special Fertilizer Treatments on Sugar Content and Acidity

The experiments reported in the literature are not entirely consistent as to the effects of fertilizer treatments on the acid and sugar content of small fruit. No reports however, show any significant relationship.

At the Louisiana State University in 1930, Kimbrough (11, p. 184) tested the effects of certain factors on the quality of strawberries. He reported that the sugar content and the acidity were but little affected by various nitrogen, phosphorous and potassium fertilizer treatments.

Cochran and Webster (5, pp. 241-242), at Oklahoma Agriculture and Mining College, also studied the effects of various fertilizer treatments on the quality of strawberries. The treatments in this instance include fertilizers containing nitrogen, phosphorous, potassium, sulphur, and manganese. These workers reported that the various fertilizer treatments had no effect on the acid and sugar content of the berries. The same fertilizer treatments were given a different variety of strawberry, and in 1935, Cochran and Webster, working with Hart (9, p. 410) again tested the berries for sugar content and acidity. The results were identical to those obtained in 1931 with one exception. They noticed a slight increase in total sugars where the berries received the lower nitrogen treatments.

In 1930 at the Ohio Agricultural Experiment Station, Shoemaker and Greene (17, pp. 14-15) studied the effects of nitrogen fertilizers on the composition of strawberries. They reported that berries from plots not treated with nitrogen fertilizers consistently tested slightly higher in percent total sugars than the berries from the plots receiving nitrogen fertilizers. They also reported that berries from the plots not treated with nitrogen fertilizers were slightly more acid than the berries from the plots receiving the nitrogen fertilizer treatments. These results are somewhat in agreement with the second experiment of Cochran, Webster and Hart.

In experiments to test the effects of potash on grape yields, Larson, Kenworthy and Bell (12, p. 48) at Michigan State University in 1954, a relationship was found between potassium and sugar content. They reported that grapes treated with potassium chloride tested ten percent higher for percent soluble solids than grapes left untreated.

At the Research Station in Bristol, England in 1952, Kaiser, Pollard and Timberlake (10, pp. 166-168 Tables I-II) studied the effects of certain fertilizer treatments on the quality and chemical constituents of strawberries. The tested plots received various combinations of nitrogen, potassium, and phosphorous fertilizers. They reported a slight increase in both sugar and acid content of berries from plots receiving fertilizers containing potassium. Fertilizers containing only nitrogen and phosphorous did not affect the acid or sugar content of the fruit.

The Effects of Time of Picking on Sugar Content and Acidity

The results obtained by the various workers with regards to the relationship between time of picking and sugar and acid content again were not entirely consistant. Shoemaker and Greene (17, pp. 14-15) when testing the effects of fertilizers on strawberry composition also noted the effects of time of picking. Where the pickings were two days apart, they reported that the acidity went down between the first and third picking but rose again between the third and fifth picking. The percent of total sugar regularly increased between the first and fifth picking. Keiser, Pollard and Timberlake (10, pp. 169-170 Table III & IV) also studied the effects of time of picking on strawberry composition. Two tests were made in 1951 and 1952. In both tests they found that the acidity of the berries went down, though not regularly, between the first and sixth picking. During the first test the content rose irregularly between the first and sixth picking. During the second test, however, the sugar content decreased between the first and sixth picking.

METHODS AND MATERIALS

This study was made during the summer of 1953. Samples were taken from the fertilizer test plots at the Lewis Brown Farm near Corvallis. The bushes at the time of sampling were eight years old and had been bearing for the past six summers. (Figure 1)

The plots had been mulched with fir sawdust, and the depth at the time of sampling was about six inches. The fertilizer treatments were first applied during the spring of 1946, when the plants were one year old. There were nine different fertilizer treatments (two plots per treatment) applied at the following rates: 100 lbs. of N per acre (N); 50 lbs. of N per acre (urea); 0.2 lbs. of borax per acre, 2 lbs. of magnesium sulfate per acre, 1 lb. of manganese chloride per acre, 2 lbs. of zinc sulfate per acre and 1 lb. of copper sulfate per acre (minor); 10 lbs. of sulfur per acre (S); 100 lbs. of K_2O per acre (K); 100 lbs. of P_2O_5 per acre (P). The urea was applied two years later than the rest. Figure 2 shows how the test plots were laid out. The bushes were planted six feet apart in rows eight feet apart.

The bushes were in better than average condition during the summer of 1953. The winter of 1953 was warmer than usual, and the temperature and moisture conditions during the blossoming period were normal. June was wetter and cooler than normal and the weather during the ripening

Figure 1. Blueberry fertilizer test plots at the Lewis Brown Farm. The row of small bushes (nearest to the road) are pollinizers.

Table I. Size Groups: Diameter and Average Weight Per Berry

Size Group	Diameter (mm)	Average Weight Per Berry (Grams)
A	16 - 17	1.83
B	15 - 16	1.54
C	14 - 15	1.30
D	13 - 14	1.05
E	12 - 13	.84
F	11 - 12	.69

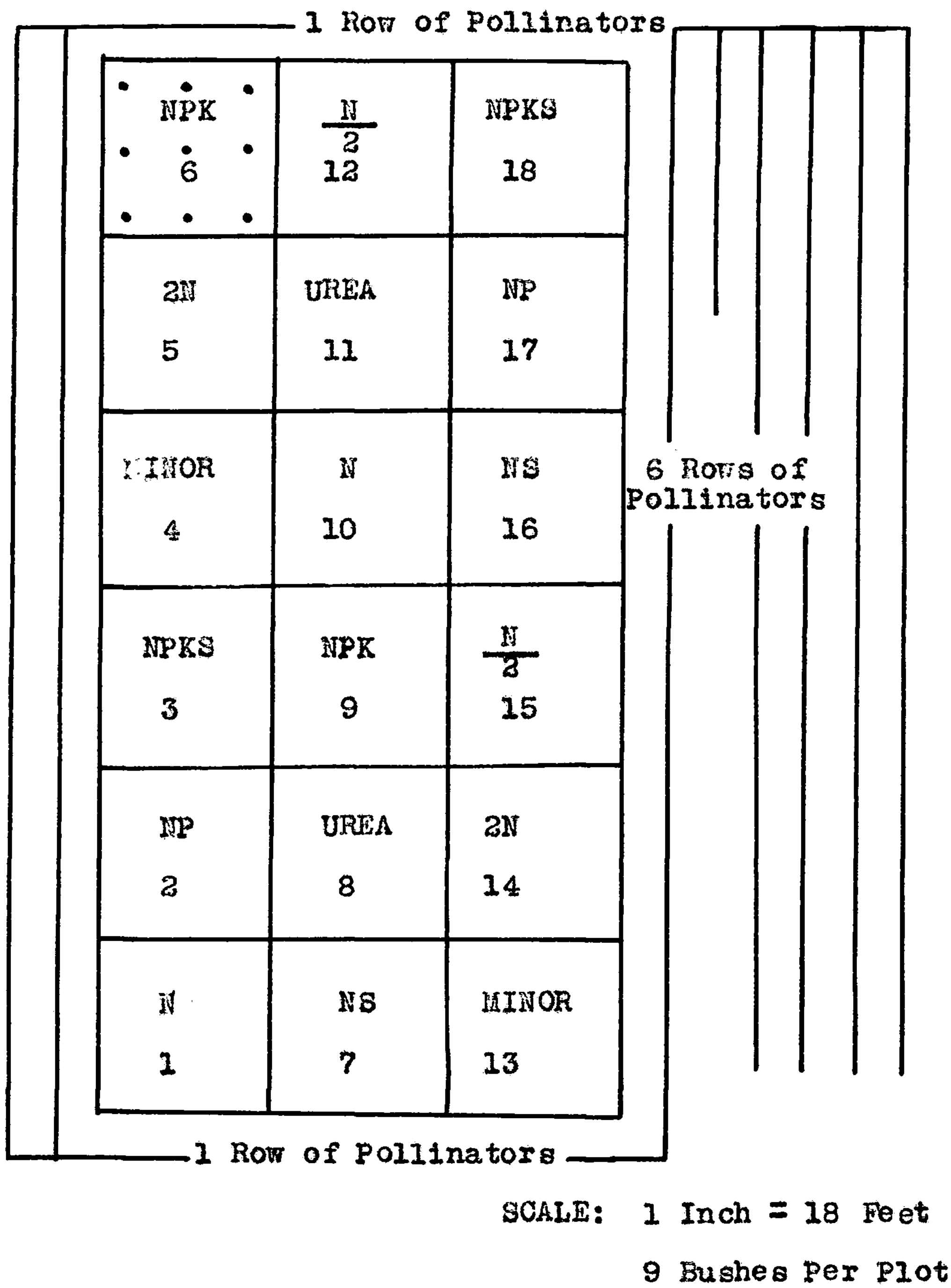


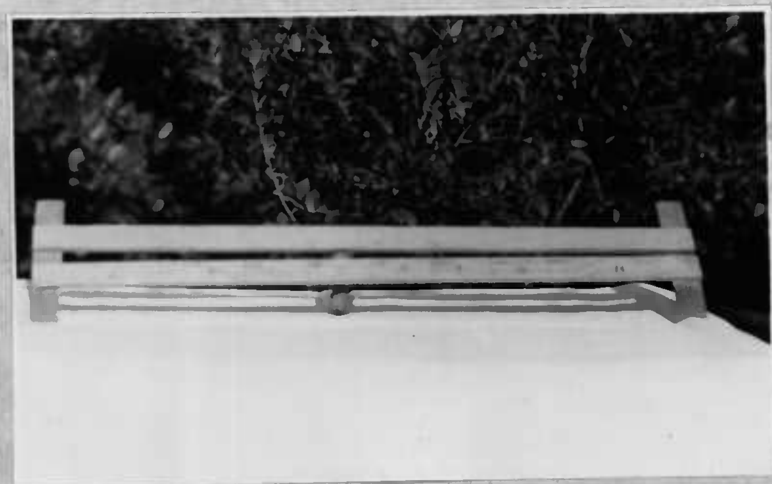
Figure 2. Plan of the blueberry test plots at the Lewis Brown Farm, showing location of the pollinizers and the plots (numbered) receiving the different fertilizer treatments.

period was also cooler than normal. It is believed that these weather conditions delayed ripening for about one week beyond the normal ripening time. The week preceding the third picking (28th August) was especially cool.

Time of Picking and Sampling

Samples were taken from all of the eighteen plots except #2 (NP), which was accidentally missed, during the first picking on the 28th July 1953. During the second and third picking, 12th and 28th of August respectively, samples were taken only from plot #9 (NPK). About three to four pints of berries were taken from each plot.

Each sample was further divided into five size groups, each containing 50 berries. A sizing device was constructed (Fig. 3) consisting of two fixed diverging strips of wood. The narrowest space was 11 mm. and the widest 17 mm. Marks were made at 12, 13, 14, 15, 16 mm. as well. The sizing device was placed over six containers, each $2\frac{1}{4}$ inches wide (labeled A to F), and the berries placed one by one by hand, rolling them toward the wider opening so that they fell through the portion of the slot corresponding to their average diameter. This procedure was continued until fifty berries were obtained for each size group. Table I shows the arrangement of the size groups and the diameter and average weight per berry in each size group.



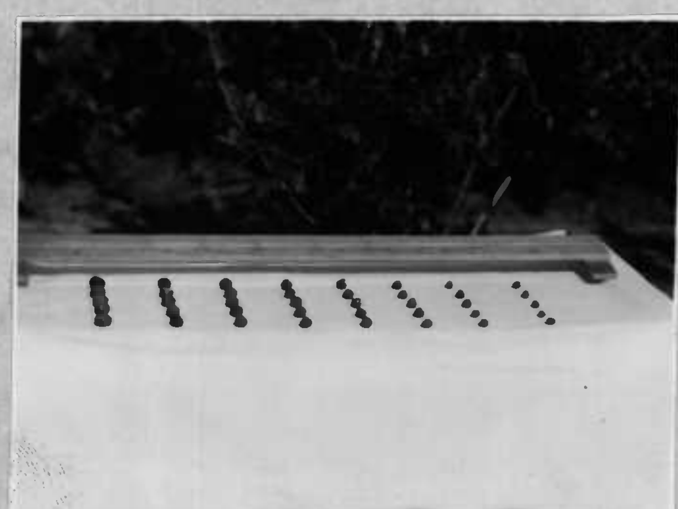


Figure 3. Device used for sizing blueberries. Smallest berries shown are less than 11 mm. in diameter. Diameters increase 1 mm. every $2\frac{1}{4}$ inches, moving from right to left.

After sizing, each group of fifty berries was placed in a polyethylene bag and stored at 34°F. None of the berries were out of refrigeration more than two days. The time under refrigeration, before running laboratory analysis varied from two to four weeks.

Laboratory Analysis

The approximate sugar content of the berries in these experiments was determined by testing for soluble solids with a hand refractometer, as outlined in Physical and Chemical Methods of Sugar Analysis by Browne and Zerban (3, pp. 78-79; 108-109). While soluble solids and actual sugar content are not synonymous terms, for practical purposes the percent of soluble solids is a close approximation of the sugar content, since the soluble solids other than sugar, constitute but a small fraction of the cell sap. As pointed out by Tingley, (18, p. 41) the sugar and soluble solids content of melons and squashes were found to be practically the same, in studies carried on at Cornell University. Other investigators report similar results with other horticultural products.

In using the hand refractometer, it is often found necessary to dilute the juice samples with water, since the pure juice of many fruits is too dense in color to permit a satisfactory reading. This was found to be true in the case of the blueberry, and, consequently, the juice samples were diluted with an equal amount of distilled water. As pointed out by Brown and Zerban, however, when the juice is diluted with water, the readings are from 0.61 to 0.75 percent higher than they are on the undiluted juice. However, since the purpose of this study was to compare samples rather than to make exact chemical determinations, it was felt that this error could be overlooked, particularly since the refractometer readings themselves are accurate only to the nearest 0.2 percent. Then, too, the same procedures were used on each and every sample, and the increases or decreases in soluble solids between samples should not be materially affected by this error.

After weighing and dilution, each sample was placed in a Waring Blendor and agitated at a slow rate of speed until all of the seeds had separated from the pulp. The length of the agitation time depended on the size of the berries. Thirty seconds was found to be sufficient for the smallest berries with an additional five seconds for each one millimeter increase in berry diameter. Leaving the berries in the blendor too long resulted in the skin being torn into small fragments which made separation of the seed difficult later on.

The acid content of the various samples was determined by neutralizing the diluted juice with a 0.2 N solution of sodium hydroxide, according to the methods specified in

Official Methods of Analysis, A.O.A.C. (14, p.20.32:20.33). The percent total acid was calculated from the results of the titrations.

Determination of Seed Weight

After the acid and sugar content of the juice was determined the seed was separated from the skin and pulp. This was accomplished by a series of decantings (pouring from a large beaker into a sieve) and finally washing into a cone of filter paper shaped into a funnel. This method has been used for many years and has now been recommended in an article by Morrow, Darrow, and Scott (14, p. 265). The resulting product was all of the mature seeds, most of the undeveloped ones and the placentas. The almost microscopic undeveloped seeds could not be saved by this method. The seed was dried in an electric oven for 48 hours at 50° C and weighed immediately after removal. In determining the actual seed weight a correction had to be made for the placentas. Each berry contained ten placentas and the weight of these placentas was the same in all berries - regardless of size. It was, therefore, necessary only to subtract the weight of 500 dried placenta from the gross weight of seed in each 50 berry sample to obtain the actual seed weight.

PRESENTATION OF DATA

The Relationship Between Berry Size and Sugar Content

As seen from Table II, the data appear to show that there is a definite positive relationship between berry size and sugar content. The smallest berries (average weight per berry 0.69 grams) tested 10.5% soluble solids. The largest berries (average weight per berry 1.83 grams) tested 15.0% soluble solids. Upon close inspection of the data it can also be seen that percent soluble solids appreciably increased each time the berries tested were taken from the next larger size group. The berries of the largest size group averaged 165.2% larger (a little more than 2½ times larger) by weight than the berries of the smallest size group. The over all increase in percent soluble solids, between the smallest and largest size group, was 42.9%.

The Relationship Between Seediness and Sugar Content

There was also a definite relationship between seediness and sugar content. From the data in Table II, it can be seen that the average percent soluble solids of the berries in size group F (size group containing the smallest amount of seed per berry) was 10.5%; where as, the average percent soluble solids of the berries in size group A (the size group containing the largest amount of seed per berry) was 15.0%. In every size group tested the greater the amount of seed per berry the greater was the average percent soluble solids. The overall increase in percent soluble solids, moving from the least seedy to the seediest, was 42.9%.

The Relationship Between Certain Fertilizer Treatments and Sugar Content

The complete data for this portion of the problem is presented in Table V. A close inspection of this table shows that the berries tested from the plots receiving the minor elements and the plots receiving nitrogen and phosphorous in combination were slightly sweeter than berries tested from the other plots. The average percent soluble solids for all the size groups of the minor element plots was 12.9%. The average percent soluble solids for all the size groups of the NP plots was slightly higher than 12.7%. The berries from the plots receiving N/2 and N treatments tested the lowest. The average percent soluble solids for all the size groups of the N/2 treatment plots was slightly less than 12.1%. The average percent soluble solids for all the size groups of the N plots was 11.9%. The average percent soluble solids for all the size groups of the other fertilizer test plots tested from 12.1% to slightly less than 12.7%.

The Relationship Between Time of Picking and Sugar Content

The sugar content increased, in every size group, between the first and second picking (Table IV). The average percent soluble solids of the berries of the first and second pickings was 12.4% and 14.2% respectively. However, in every size group, the sugar content went down between the second and third pickings. The average percent soluble solids of the berries of the third picking was 13.4%. In size group A the sugar content of the berries was even lower in the third picking (14.6% soluble solids) than in the first picking (15.2%). However, in all the other size groups the sugar content of the third picking still remained higher than the sugar content of the first picking.

The Relationship Between Berry Size and Acidity

There was a definite negative relationship between berry size and acidity. The data for this relationship is presented in Table II. The smallest berries (average weight per berry was 0.69 grams) tested 3.61% total acid; whereas, the largest berries (average weight per berry was 1.83 grams) tested 1.06% total acid. Upon closer inspection of the data it can be seen that the percent total acid decreased appreciably each time the berries tested were taken from the next larger size group. The overall decrease in percent total acid, moving from the smallest to the largest berries, was 70.6%

The Relationship Between Seediness and Acidity

A definite negative relationship was also found to exist between seediness and acidity. (Table II) The berries containing the smallest amount of seed tested 3.61% total acids; whereas, the berries containing the largest amount of seeds tested 1.06% total acids. There was an appreciable decrease in percent total acids each time the berries tested were selected from the next seediest group. Going from the least seedy to the seediest berries, the overall decrease in percent total acid was 70.6%

The Relationship Between Certain Fertilizer Treatments and Acidity

On the basis of the data presented in Table V, the berries tested from the plots receiving nitrogen (N) and the plots receiving both nitrogen and sulphur (NS) were considerably more acid than the berries tested from the other fertilizer plots. The average percent total acids for all the size groups of the (N) plots and (NS) plots was 2.49%, and 2.52% respectively. The berries from the plots receiving nitrogen, phosphorous and potassium (NPK) and the minor elements (minor) tested the lowest; a little higher than .79% in the former treatment and a little lower than 1.92% in the latter. The average percent total acids of the berries from all the other fertilizer test plots tested from slightly higher than 1.91% to slightly lower than 2.23%

The Relationship Between Time of Picking and Acidity

The influence of time of picking on acidity, as noted in Table IV, was quite pronounced. The acidity of the berries decreased between the first and second pickings and also between the second and third pickings. The average percent total acids of the berries of the first, second and third pickings was 1.90%, 1.74% and 1.14% respectively. On an individual size group basis, in sizes C, D, and E, the acidity decreased between the first and second pickings; whereas, in the two largest size groups, sizes A and B, the acidity increased. There was a considerable decrease in the acidity of the berries between the second and third pickings. In the two smallest size groups (D and E) the acidity of the berries of the third picking was half that of the berries of the second picking. Contrasting with this was the fact that in the largest size group (A) the percent total acid did not change between the second and third pickings.

The Relationship Between Berry Size and Seediness

There definitely appears to be a positive relationship between berry size and seediness. (Table II). The average seed weight per berry of size group F (the smallest size group tested) was 0.0185 grams; whereas, the average seed weight per berry of size group A (the size group containing the largest berries) was 0.0253 grams.

In every plot tested, the larger the berries the greater was the average seed weight per berry. The overall increase in average seed weight per berry (going from the smallest to the largest size group) was 36.8%.

Table II. The Relationships Among Seediness, Berry Size, Sugar Content and Acidity

	Average Weight of Berries in grams	Average Percent Soluble Solids of Berries	Average Percent Total Acid of Berries	Average Seed Weight per Berry
F	.69	10.5	3.61	.0185
E	.84	10.8	3.12	.0200
D	1.05	11.7	2.47	.0216
C	1.30	12.6	1.66	.0225
B	1.54	13.8	1.23	.0240
A	1.83	15.0	1.06	.0253

Table III. The Relationships Among Berry Size, Sugar Content, Acidity and Seediness of Immature Berries

Size Group	Average Weight of Berries in Grams	Average Percent Soluble Solids of Berries	Average Percent Total Acid of Berries	Average Seed Weight per Berry in Grams
C	1.09	11.0	5.05	.0239
D	.99	10.8	4.87	.0213
E	.80	10.4	4.53	.0189
F	.64	10.2	4.60	.0168

Table IV. The Relationship Between Time of Picking, Sugar Content and Acidity

Size Group	Average Weight Per Berry in Grams			Average Percent Soluble Solids of Berries			Average Percent Total Acid of Berries		
	First Pick	Second Pick	Third Pick	First Pick	Second Pick	Third Pick	First Pick	Second Pick	Third Pick
E	0.82	0.82	0.80	10.6	12.8	12.6	3.10	2.34	1.04
D	1.00	1.07	1.04	12.0	13.0	12.8	2.60	1.90	0.95
C	1.33	1.30	1.28	11.2	14.0	13.2	1.88	1.60	1.26
B	1.54	1.49	1.48	13.2	14.8	13.8	1.06	1.66	1.13
A	1.86	1.71	1.80	15.2	16.4	14.6	0.88	1.30	1.30
Mean	1.31	1.28	1.28	12.4	14.2	13.4	1.90	1.74	1.14

Table V. The Effects of Various Fertilizer Treatments on Sugar Content and Acidity

Fertilizer Treatments	Size Group F	E	D	C	B	A	Mean
(Average Weight per berry in gms)							
Minor	.74	.90	1.10	1.35	1.56	1.79	
Urea	----	.84	1.02	1.26	1.50	1.78	
N/2	----	.79	1.04	1.26	1.50	1.92	
N	.74	.86	1.06	1.37	1.61	1.82	
2N	.77	.88	1.12	1.35	1.60	1.87	
NS	----	.84	1.03	1.30	1.51	1.87	
NP	.61	.80	1.04	1.27	1.54	----	
NPK	----	.85	1.04	1.33	1.57	1.81	
NPKS	.73	.86	1.11	1.36	1.58	1.77	
(Average percent soluble solids							
Minor	11.1	11.0	12.3	13.6	14.7	15.0	12.9
Urea	----	11.0	11.7	12.6	13.4	14.8	12.7-
N/2	----	10.5	10.9	11.7	12.9	14.4	12.1-
N	10.0	9.8	11.5	12.7	12.7	14.9	11.9
2N	10.8	10.9	11.7	13.1	14.5	14.2	12.5
NS	----	10.9	11.3	11.9	13.6	15.4	12.6-
NP	11.0	11.2	12.6	13.8	14.8	----	12.7
NPK	----	10.7	11.6	12.0	13.4	15.0	12.5-
NPKS	10.0	10.9	11.2	12.0	13.7	14.7	12.1
(Average percent total acids)							
Minor	3.27	2.54	1.42	1.22	1.17	----	1.92-
Urea	----	3.03	2.63	1.80	1.21	.89	1.91
N/2	----	----	----	----	----	----	----
N	4.26	3.50	2.82	1.94	1.45	.96	2.49
2N	3.68	2.93	1.99	1.40	1.17	----	2.23-
NS	----	4.11	3.15	2.29	1.57	1.47	2.52
NP	----	----	----	----	----	----	----
NPK	----	2.87	2.52	1.46	1.02	1.07	1.79
NPKS	3.24	2.74	2.16	1.34	1.05	----	2.11-

DISCUSSION AND CONCLUSIONS

Factors Affecting the Sugar Content

Size

The results, rather strongly, indicate that the larger berries are the sweetest. This positive relationship between size and sugar content was quite pronounced. Similar results were obtained in every test. It is interesting to note that this relationship between size and sugar content also held true even when immature fruit was tested. A sample of berries still showing a faint tinge of red through the overall blue color were divided into four size groups. These groups were tested for percent soluble solids and percent total acid, and showed the same relationship as was found to exist in the mature fruit.

In endeavoring to explain this relationship between berry size and sugar content, it should be pointed out that under the present methods of harvesting blueberries, where berries are picked by running the fingers lightly through the clusters and gathering those that fall, there is a possibility that in a box of berries there might exist quite a range of maturity among the individual berries. If this difference does exist, perhaps the larger berries are more mature than are the smaller ones. Their advanced state of maturity might account for their testing higher for sugar. However, this relationship between size and sugar content was true for immature fruit and it was true for fruit of the first, second and third pickings. This would indicate, then that the size-sugar relationship is independent of the maturity of the fruit.

Seediness

There also existed a positive relationship between seediness and sugar content. This was to be expected, since there also existed a positive relationship between size and seediness. The increase in average seed weight as the berries increased in size can be explained by the larger number of fully developed seeds in the larger berries as opposed to a greater number of undeveloped seeds in the smaller berries. These results, therefore, demonstrate that large size in blueberries is dependent on the maturing of the many ovules contained in the fruit. The development of sugar content in blueberries follows the completed development of the fruit, viz. the development of seeds. It was observed that the largest berries were found to be seediest in immature as well as mature fruit.

Fertilizers

The various fertilizer treatments did not seem to significantly effect the sugar content of the berries. These results parallel most of the results obtained by other investigators working with strawberries and grapes. Some experiments indicated that potassium increases the sugar content slightly. However, the results obtained in this study did not indicate any relationship between potassium and sugar content.

Shoemaker and Greene (17) working with strawberries, noticed that berries receiving lower nitrogen treatments resulted in a very slight increase in percent soluble solids. Again there was nothing in the results of the present study to indicate this relationship. It is interesting to note, however, that the plot receiving no nitrogen, but minor elements instead, tested higher than any other fertilizer plots for percent soluble solids. The berries taken from the same plot also tested low in percent total acid. This relationship could result from the absence of nitrogen in the treatment or the effects of one or more of the minor elements. However, the plots receiving nitrogen and phosphorous in combination also tested higher for sugar content.

It is felt that the data on the fertilizer effects are too incomplete and the number of replications insufficient for one to draw any definite conclusions. It is believed that this problem should be isolated and given more extensive and careful study.

Time of Picking

The results obtained from this study seem to indicate that the sugar content of blueberries is affected by the time of picking, despite the fact that the percent soluble solids decreased between the second and third picking. It was indeed unfortunate that the test was interrupted by the abnormally cool weather the week before the third picking. There is no doubt that this cool weather prevented the berries from developing more sugar. It would be best, therefore, to disregard the data on sugar content obtained during the third picking. Nevertheless, the results do show the effect of weather on sugar development in berries. There was, however, a definite rise in sugar content in every size group between the first and second picking. One, therefore, might assume that there is a trend in the direction of a relationship between sugar content and time of picking. It is probable that if the weather had been normal the sugar content would have continued to rise. It seems reasonable to expect that the berries left on the bush have a better chance to come nearer to reaching the maximum possible sugar content.

Factors Affecting the Acidity

Size

As there was a direct relationship between size and sugar content, there was an inverse, relationship between size and acidity. In explaining this relationship, what was said with regard to the maturity of the fruit under "Factors

Affecting the Sugar Content" (p. 28) can of course be said here. However, there is one difference. When immature berries were tested, the larger berries were slightly more acid than the smaller ones. (Table III) If more extensive research is undertaken with regards to sugar-size relationship it would be well to cover the acid-size relationships at the same time.

Seediness

There was also an inverse relationship between seediness and acidity. The berries with the most developed seeds were the least acid. This might be explained on the theory that the development of seeds is related to the complete development of the fruit. The results indicated as mentioned earlier, that complete development results in larger fruit, and, in every case the larger the fruit the lower the acidity.

Fertilizer Treatments

It was mentioned previously that the berries from the plot receiving the minor elements tested fairly low for percent total acid. The explanation of this relationship is not known. It was suggested that the relationship between minor elements and sugar content was worthy of further research. It would of course be logical to include the minor elements - acidity relationship as well in these experiments.

There is one more significant point that can be made with regards to the effects of the various fertilizer treatments on the percent total acid of blueberries. In the case of the plots receiving elemental sulphur combined with nitrogen (NS), the acidity of the berries was considerably higher than in any other fertilizer test plots. Though this fertilizer treatment did not affect the sugar content of the berries, the affect on the acidity was quite pronounced. This affect on acidity, however, was not noted when sulphur was added in combination with potassium, phosphorous and nitrogen. It is believed that the results with sulphur present an excellent problem for further experimentation. It was also noted that the plots receiving the treatment of minor elements tested rather low for acidity. This is interesting in view of the fact that the minor plots tested rather high for sugar (p. 20). These results certainly indicate that further investigation as to the affects of minor elements on composition would be well worth while.

Time of Picking

Time of picking also affected the acidity of blueberries. Between the first and second pickings the average percent total acid of all the size groups decreased considerably. The percent total acid decreased in every size group tested. except the two largest sizes (A and B).

This deviation cannot be accounted for except in size group A where there was a decrease in the average weight per berry between the first and second pickings. It has been suggested earlier that there is a relationship between size and acidity which could account for the resulting increase in acidity.

The average percent total acid of all the size groups tested also decreased considerably between the second and third pickings. It is interesting to note that this decrease in succeding pickings was greatest with the smallest sizes (D and E). This seems to indicate that perhaps the chemical breakdown of acids in the larger berries occurs earlier and faster; whereas, with the small fruit later and slower. The abnormal weather conditions prior to the third picking did not seem to affect the acidity of the berries.

Because of the manner in which the blueberry plots are laid out at the Lewis Brown Farm (Figure 2), there are no suitable replications. It is not possible, therefore, to establish the significance of the results statistically. The results are so striking, however, that it is apparent from casual observation of the data that a high degree of correlation exists between berry size and sugar content, acidity, and seediness. It was possible, however, to obtain correlations from the data presented in Table II. The correlations obtained, based on averages, demonstrate rather markedly the definite relationship existing between size and sugar content, acidity, and seediness. The coefficients of correlation were as follows:

1. between size and average percent soluble solids - 0.98
2. between size and average percent total acid-minus 0.98
3. between size and average seed weight per berry - 0.99

Recommendations

It can be definitely concluded from the results of these experiments that larger berries are sweeter and less acid than are the smaller ones. It might possibly be a good idea, therefore, for some growers to sort berries into two sizes. The larger sizes, which would have a higher sugar content, could be sold fresh and the smaller sizes, which would be more acid, could go to the processors. Fresh fruit consumers are definitely attracted to the large berries and prefer the sweeter berries. Processors are not so much concerned with size but do prefer the more acid berries. This might be one way to please the processors and at the same time increase the popularity of the blueberry as a fresh fruit. Growers might even receive a premium for large, uniform berries when sold for fresh consumption.

Sizing the fruit would be relatively easy and would only necessitate an extra step in handling. The berries could be picked in bulk in the field and gently shaken through a sieve that would separate them into two sizes. The berries for the fresh market could then be placed in the usual pint baskets and the berries for processing packed in suitably, larger containers.

SUMMARY OF RESULTS

1. There is a definite positive relationship between berry size and sugar content. In every plot tested the larger berries consistently tested higher for percent soluble solids. The overall increase in percent soluble solids, between the smallest and largest berries, was 42.9%.
2. A definite relationship exists between berry size and acidity. In every plot tested the larger berries consistently tested lower for percent total acid. The overall difference in percent total acid, between the smallest and largest berries, was 70.6%.
3. The more seeds a Jersey blueberry contains the larger it is. It was found that in every test the larger berries were the seediest. The overall increase in average seed weight per berry, going from the smallest to the largest size group, was 36.8%.
4. The various fertilizer treatments did not influence significantly the sugar content of the berries. However, berries selected from plots receiving the minor elements and nitrogen and phosphorous in combination did test slightly higher for sugar content than berries selected from any of the other fertilizer plots. Berries selected from plots receiving half-nitrogen (N/2) tested slightly lower than the rest.

5. There were no significant relationships between any of the fertilizer treatments and acidity except where berries were selected from the plots receiving nitrogen and nitrogen and sulphur in combination. These berries tested considerably higher for acidity than the berries selected from any of the other fertilizer plots. The berries from the plots receiving the treatment containing the minor elements and nitrogen, phosphorous and potassium in combination tested the lowest.
6. The data dealing with the influence of time of picking on sugar content was incomplete. The results, notwithstanding, did indicate a trend towards berries harvested late in the season being sweeter.
7. The berries picked towards the end of the season were less acid than those picked at the beginning of the season.

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