

NUTRITIONAL CONDITIONS OF
MICHIGAN BLUEBERRY PLANTATIONS

By

WALTER ELMER BALLINGER

AN ABSTRACT

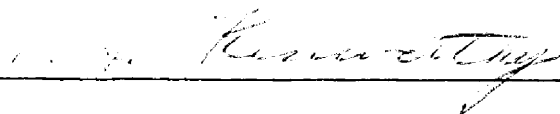
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State University of Agriculture and Applied Science
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DOCTOR OF PHILOSOPHY

Department of Horticulture

1957

Approved

A handwritten signature in cursive script, appearing to read "W. J. Kinnear", is written over a horizontal line.

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The highbush blueberry deviates quite markedly from other fruit crops in its soil and nutritional requirements. When grown on the proper soil, it is relatively free of nutritional disorders expressed as deficiency symptoms. Relatively little information is available concerning the nutritional requirements of the blueberry. Since its soil requirements differ from those of other fruit crops, the information available for the other fruit crops may not be applicable to the blueberry.

A survey was made in 1955 and 1956 to initiate a more extensive study of the blueberry in Michigan utilizing some of the more recent research tools, such as spectrographic leaf analysis and soil exchange analyses.

Approximately 55 blueberry plantings were used for the survey. Soil samples were analyzed for cation exchange capacity, exchangeable calcium, magnesium and potassium, and pH. Yield records were completed for approximately 33 of these plantings. Analyses were made of fruiting-shoot leaves during 1955 and 1956. Additional samples of blueberry fruit and sucker-shoot leaves were analyzed in 1956.

Fertilizer trials were initiated in 1956 on several plantings whose 1955 nutrient-element balance charts indicated a nutritional unbalance. Leaf analyses were obtained concurrently with the survey samples.

The survey revealed that ecological conditions such as excessive or deficient quantities of soil moisture, frost, and abnormal temperatures may seriously influence production.

Nitrogen, as percent dry weight of the fruiting-shoot leaves, was directly proportional to yield until a maximum level of approximately 2.10 percent was reached. Yield decreased when nitrogen exceeded 2.10 percent.

The percent of the soil cation exchange capacity occupied by calcium appeared to affect the vigor of the blueberry plant. Quantities above approximately eight percent were related to extremely poor growth. For those bushes where calcium on the soil exchange was below eight percent, nitrogen was apparently more influential.

There were some indications that the magnesium content (percent dry weight) of the fruiting-shoot leaves was related to fruit yield.

Linear correlations between any two of the three tissues analyzed (fruiting-shoot leaves, sucker-shoot leaves, and blueberry fruit) and multiple correlations suggested that manganese was highly mobile in this plant. Consequently, any one of these tissues may be used as an index of manganese content. Nitrogen, potassium, calcium and iron did not appear to be as mobile. Copper and zinc seemed to be highly immobile. For these nutrients leaves appear to be the desirable tissue for analysis.

By computing total nutrients removed from the soil by blueberry fruit and leaves, a fertilizer ratio of 4-1-2 was evolved. If this ratio is more appropriate, the excessive potassium in the 11-11-11 ratio being used may explain the occurrence of magnesium deficiency symptoms in scattered blueberry plantations.

Deficiency ranges for magnesium, manganese and iron in the leaves appeared to be less than 0.11, 0.0031 and 0.006 percent respectively.

Soluble solids readings were taken in 1955, but no relationship to other data was noted. Soil moisture and a multiplicity of other factors apparently preclude the use of soluble solids readings on blueberry fruit as an index of nutritional conditions.

The fact that the blueberry plant is shallow-rooted warrants the employment of soil cation exchange determinations as well as leaf analyses in determining the nutritional status of this crop. The soil analysis would indicate the presence of excessive supplies of calcium and would be useful as a pre-planting diagnosis. Leaf analysis would indicate the nutritional needs of the established bushes.

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A THESIS

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INTRODUCTION

Michigan is one of the leading States in the production of the high-bush blueberry (Vaccinium corymbosum L., or V. australe, Small). A current estimate of the State's annual yield exceeds twelve million pints. Assuming a conservative retail price to the consumer of twenty-nine cents per pint, the value of this crop would be approximately three and one-half million dollars per year. This value compares closely to that of the grape, which is valued at about four million dollars per year (Larsen, 1955).

Fertilizer recommendations for Michigan plantations include the use of a complete fertilizer. A 11-11-11 ratio fertilizer is utilized for mineral soils and 5-10-15 for organic soils. The fertilizer for the majority of the growers is purchased through the Michigan Blueberry Growers Association, which is conducive to a somewhat standard nutritional program. The method of placement, as well as the rate and time of application, however, are variable.

Since the blueberry, as well as other members of the Ericaceae family, deviates quite markedly in its soil and nutritional requirements from other fruit crops, a relatively small backlog of information concerning its nutrition is available. Research in Michigan has been limited to but a few workers, such as Johnston, Harmer, and Merrill.

The purpose of this investigation was to initiate a more extensive study of the blueberry in Michigan utilizing leaf and soil analyses to provide basic information and data upon which future recommendations and studies can be based.

REVIEW OF LITERATURE

Johnston (1951) stated that "the blueberry is more American than turkey for Thanksgiving, for it was in this country in great abundance and was highly prized by the Indians before the white settlers arrived". For nearly 300 years after the pilgrims landed very little improvement took place until 1906, when the late Dr. F. V. Coville initiated investigations on soil requirements and in breeding of the blueberry. Coville's work was the beginning of the development of the cultivated blueberry industry. Credit must also be given to Miss Elizabeth White of Whitesbog, New Jersey, who, in cooperation with Dr. Coville, established the first commercial plantings of hybrid blueberries. One of Miss White's selections, Rubel, is today one of the leading varieties grown commercially in Michigan.

Comparatively little information is available on the nutrition of the blueberry. Hitz and Scott (1953) confirm that research results are too meager and too conflicting to allow a very satisfactory understanding of the nutritional requirements of this crop. Coville was one of the first to show that the blueberry plant is very sensitive to soil conditions (Johnston, 1934). Beckwith and Coville (1931) stated that the best soil for blueberries was a mixture of peat and coarse sand for the topsoil, with a sand subsoil

underlain with a hardpan usually within three or four feet of the surface. Veatch and Partridge (1934) describe a soil found in the Berrien County area of Michigan as a "Saugatuck-type soil". It is characterized by a "rusty-colored, sandy hardpan underlaid by water-logged sand. Where the hardpan has a considerable thickness, it interferes with the movement of moisture through the soil, and in some instances appears to be impenetrable to the roots. These sandy soils are also generally acid".

Johnston (1942) described the soil most commonly used for commercial production of blueberries in Michigan as a sandy soil, very acid in reaction, and well supplied with moisture, except during very dry periods. The surface is composed of a dark-grey sand of 2 to 10 inch thickness. The soil is a light grey, nearly white sand beneath the surface. He also confirmed this soil as a Saugatuck type, which usually has a hardpan of rusty-brown or coffee colored sand found at a depth of 3 to 12 inches.

Bailey et al (1939) were of the opinion that an ideal blueberry soil should be fertile, have a plentiful and continuous water supply, well drained and aerated, well supplied with organic matter, and acid. Soils that dry out, even for short periods of time, were unsatisfactory. Conversely, excessive water during the growing season was also detrimental, although blueberries will tolerate standing water in Massachusetts from November to the first of April. The water table must be at least 14 inches below

the surface. Johnston (1934, 1948) particularly stressed that soil moisture should be optimum during the months of April, May and June to avoid serious effects upon growth and reproduction.

Many workers report that the blueberry needs an acid soil.

Johnston (1934) grew blueberry plants in soils ranging in pH from 3.4 to 6.8. Best growth occurred at pH 4.4. Harmer (1944) later established the optimum pH range for good growth and production at 4.5 to 4.8 on organic soils. As a result of such observations, many recommendations for blueberry cultures practically insist that the plantings be made on soils which have an initial or adjusted pH range of between 4.3 and 4.8 (Hitz and Scott, 1953).

Boller (1951), however, was of the opinion that pH is not the only important factor to consider. Many other factors may be more important, such as moisture, aeration, and fertility. These may be duplicated by artificial means, e.g., irrigation, use of sawdust, and liberal application of ammonium sulfate.

Blueberries can be grown on clay soils, as reported by Johnston (1951). Sufficient organic matter must be added, however. Subsoils underlying the Southwestern Michigan blueberry areas often crop out, resulting in poor growth and reduced yield of the involved blueberry plant. Johnston suggested that by increasing the organic matter of these areas by growth of cover crops, and the hauling-in of peat, the growth of the plants could be

improved. Growth was generally proportional to the amount of organic matter. In some controlled experiments, Johnston found that pH rather than percent clay was the determining factor (Johnston 1942).

Stene (1939) doubted that blueberries in all cases require a distinctly acid soil. They might grow well within a wide range of pH under certain conditions. Growth was dependent upon the availability of various nutrients under a given condition.

Merrill (1939) found that a soil may be too acid. He reported that plants growing in soil with a pH 3.2 were of poor growth and dying. The soil, compared to soil from normal plants, differed only in pH, calcium and potassium. Treatments set up in pots where limestone was withheld had leaf burning, beginning at the tips of terminal leaves and progressing subsequently across the entire leaf. This continued down into the older leaves until, in late August, the plants were practically defoliated. Applications of lime to raise the pH to 3.4 to 3.8 prevented leaf scorch and resulted in normal growth.

Chandler (1938), concurrently, found that the addition of lime may increase yield. As much as 18 tons of lime per acre added in three applications was not detrimental. Minton et al (1951) describe symptoms of calcium deficiency on leaves of the rabbit eye blueberry as follows: "both old and new leaves are scorched at the tips. Later, the leaves are cupped. Leaves are of medium size; plants make moderate growth".

A high calcium content of the soil may affect the uptake of various other nutrients from the soil. Reeve and Shive (1944) suggested that as the potassium of the substrate increased, there was a corresponding increase in boron content of the plant. An increase in the substrate calcium resulted in just the opposite effect. High calcium in the substrate inhibited boron uptake by the plant.

Hill (1956) was of the opinion that the optimum pH for blueberry soil should be about 4.8. However, blueberries could be produced on many soils with a higher pH if attention was given to the needs of the plant. For this he recommended a three- to four-inch layer of sawdust to be applied each year. On upland soils of a normally higher pH blueberries are quite susceptible to iron chlorosis. The plants are weak, dwarfed and unproductive. Hill corrected the chlorosis by the addition of 100 grams per plant of chelated iron compounds, which were evenly spread and worked into the soil about the base of a four-year-old plant. Within 30 days, the chlorosis began to disappear. The treated bushes showed vigorous shoot growth and normal foliage during the following season. The soils apparently were low in available iron, since Stewart and Leonard (1954) found that a chlorosis of the growing point is a universal symptom in all iron deficient plants.

deKock (1955) worked with mustard plants grown in nutrient solution at pH 7.8 with iron supplied as chloride, Versenate, Versen-ol, and Versenediol. He hypothesized that the high phosphorus content of chlorotic plants probably resulted from a metabolic unbalance in the cell, due to a deficiency of iron. The iron-phosphorus ratio may be an index of the iron status of plants. The higher the index, the more chlorosis appeared on the leaves.

Lindner and Harley (1944) studied lime induced chlorosis; they analyzed green and chlorotic leaves of pear, apple, peach, and cherry trees growing on high lime soils. The iron content was found to be no lower in chlorotic than in green leaves. Perhaps the excess potassium absorbed in high lime soils may be the cause and not the result of iron chlorosis. Potassium, according to these workers, may displace iron from enzymes involved in chlorophyll formation.

Chapman (1945), working with citrus, and using culture solutions having ample soluble iron, found that iron chlorosis was brought on by many conditions. A potassium deficiency brought on typical iron chlorosis of the leaves. Prolonged magnesium deficiency under similar conditions also produced iron chlorotic leaves. Slight excesses of copper and zinc in the nutrient solution resulted in iron chlorosis. In general, Chapman reported that nutritional disturbances of many kinds may influence iron availability.

Shear et al (1946) lend support to Chapman's theory on nutrient unbalance. Deficiency symptoms, according to these authors, are merely an expression of an unbalance. Calcium may do the same thing. An excess of phosphorus, zinc, copper, manganese, or too little potassium, magnesium or calcium, as well as a lack of availability of iron, may cause an iron deficiency.

Manganese deficiency symptoms may be due to an excessive accumulation of any one of the three major bases, and is most severe when all three are high in proportion to manganese, according to Shear et al (1946).

The deficiency and toxicity of boron is associated with an unbalanced ratio between boron and all three major bases, calcium, magnesium, and potassium. Low levels of the bases in relation to boron are conducive to a boron toxicity. High levels are associated with boron deficiency (Shear, et al., 1946).

Shear et al (1946) indicated that a magnesium "deficiency" may result from excess potassium accumulation in the leaves. Mikkelsen and Doehlert (1950) found that magnesium deficiency was more prevalent in sandy soils with low organic matter. Symptoms were expressed as: "Conspicuous marginal and interveinal coloration, which appear first in basal leaves of vigorous shoots. Chlorotic areas are pale green when the fruit

begins to ripen, then a yellowish olive green, followed by vivid orange and red in severe cases as the season progresses". Each spring the blueberry foliage on deficient plants develops in a normal manner. Symptoms appear only when the fruit begins to ripen.

Mikkelsen and Doehlert (1950) applied 70 and 200 pounds of MgO per acre as Epsom salts, or 300 pounds per acre as hydrated lime, in a fall application. Deficiency symptoms failed to appear the following season. Rapid foliar tests indicated a magnesium content of 350 ppm in normal leaves, and only 30 ppm in chlorotic leaves. The total mineral composition of leaves treated was not changed except in magnesium content. The increase in magnesium was not accompanied by an equivalent reciprocal replacement of potassium or calcium. The phosphorus, iron, and manganese composition was not changed appreciably.

Shear et al (1946), however, maintained that the elimination of visible symptoms does not mean that the nutrient balance and intensity in the plant has returned to an optimum for maximum growth and production. They summed up nutrient balance and intensity as follows: "All other factors being constant, plant growth is a function of two variables of nutrition, intensity, and balance, as they are reflected in the composition of leaves when the plants are in the same stages of growth or development. At any given level of nutritional intensity (total equivalent concentration of all

functional nutrient elements in the leaf) a multiplicity of ratios may exist between these elements. Maximum growth and yield occur only upon the coincidence of optimum intensity and balance".

Fertilizer recommendations vary and are often conflicting. Variations in soil types and conditions from one production area to another are undoubtedly a factor.

Complete fertilizers have not consistently been better than nitrogen alone for blueberry production in Maine. Dow et al (1950) reported best profits by application of nitrogen alone.

Johnston (1951) recommended the use of a complete fertilizer, i.e. an 8-8-8 for sandy soils, and a 3-9-18 for muck soils. Potash should be derived from sulfate of potash.

Bailey et al (1950) reported that several fertilizer mixtures have been successful in Massachusetts, particularly 7-7-7. On soils where nitrogen was lost easily by leaching or by absorption by weeds and on muck, split applications seemed advisable. Blueberries should not be grown on soils with a pH above 5.5, but where already established, the acidity can be increased by using ammonium sulfate. Then, phosphorus and potash can be provided by a 0-14-14 fertilizer. Bailey et al (1951) recommended that half the ammonium sulfate and all the 0-14-14 be applied in a first application and the other half of the ammonium in a later application.

Latimer and Smith (1938) recommended that manure or lime never be applied. For New Hampshire, the following fertilizer mixture was recommended:

Sodium nitrate	640 pounds
Concentrated tankage	640 pounds
Acid phosphate	300 pounds
Sulfate of potash	420 pounds

This mixture was to be applied at the rate of 500 to 600 pounds per acre (one-half pound per plant).

In New York, Slate and Collison (1942) reported that comparatively little experimental work had been done on fertilizers for blueberry. However, a safe recommendation for bearing plantations should be 300 to 400 pounds of superphosphate and 150 to 200 pounds of sodium nitrate or a little less ammonium sulfate per acre. A fertilizer such as 5-10-5 may be used; however, Slate and Collison (1942) agreed with Bailey et al (1950) in that attention should be given to the acid or alkaline reaction of the fertilizer; if the soil was not too acid, ammonium sulfate, ammonium nitrate, or urea were advised. Mixtures containing limestone as a filler were to be avoided.

Slate and Collison (1942) found that muriate of potash may severely injure or even kill blueberry bushes. They assumed that the chloride was responsible; the grower should ascertain the absence of chlorides in the fertilizer employed.

In Canada, Eaton et al (1950) reported that a special 4-8-7 fertilizer was used near the Kentville area; a 5-10-5 mixture was used later. These applications were often augmented by applications of nitrogen. During World War II, the standard brand of 9-5-7 recommended for apples was used. This gave strong growth of twigs and foliage and large yields of fruit. Since the blueberry fruit is produced on wood of the previous year, Eaton et al (1950) stressed the importance of maintaining vigorous annual growth to maintain production.

Doehlert (1944) presented a field-tested blueberry fertilizer which was very good for New Jersey conditions. It consisted of the following:

Sodium nitrate	300 pounds
Calcium nitrate	300 pounds
Tankage (7% N)	650 pounds
Rock phosphate	450 pounds
Sulfate of potash	300 pounds

Under wartime conditions, however, a 7-7-7 ratio was substituted and proved satisfactory; a 5-10-10 was not recommended since it could induce a magnesium deficiency. Bear (1948) indicated that magnesium added to the fertilizer would do no harm. Doehlert (1953) later recommended that bearing bushes receive four to five hundred pounds per acre of an 8-8-8 fertilizer containing two percent MgO.

Darrow et al (1951) recommended an application of 400 to 600 pounds per acre of a 5-10-5 mixture at the time of bud start in spring, followed by 150 pounds of sodium nitrate or calcium nitrate six weeks later if the soil was very acid. For soils not very acid, 110 pounds per acre of ammonium sulfate should be substituted, followed by one or two similar applications at intervals of six weeks. They strongly suggested that ammonium sulfate be used instead of sodium nitrate, if the foliage shows chlorosis or yellowing.

Cain (1952) suggested that ammonium nitrogen was preferable to the nitrate form, and may be associated with iron nutrition. Nitrates may even be detrimental to the plant. Conditions were favorable for the growth of nitrifying organisms in marginal, high pH soils; consequently, the organisms may effect a high concentration of nitrate therein. Ammonium nitrogen is quickly converted to nitrates under such conditions. Conversely, denitrifying bacteria thrive in a highly acid soil and readily convert nitrates to the ammonium form.

EXPERIMENTAL PROCEDURE

Survey

Soil and leaf samples were collected from 55 blueberry sites in 21 plantations in Southwestern Michigan. These represented a cross-section of the major blueberry area of the State, including, thereby, a variety of ecological conditions of climate, moisture and soil. The following counties were included: Muskegon, Ottawa, Allegan, and Van Buren. The sites were selected to provide plants of varying vigor and production; Figure 1 shows a comparison of plants arbitrarily judged as "good" and "poor".

From six to ten bushes were selected for sampling in each of the 55 plots. Leaf samples were taken from shoots one-half to one foot long, which arose from a branch containing blueberry fruit clusters. Two leaves were taken from each of a number of these shoots to provide about 200 leaves per plot (see Figure 2).

Each year the date of sampling was selected to coincide with the physiological development of the fruit. Samples were collected when the earliest fruit had fully developed prior to a development of anthocyanin in the fruit. This occurred generally during the first or second week in July. Leaves were taken from the south or west side of the bushes, depending upon the direction of row planting.

Additional leaf samples were collected at the same time during the second year, 1956, from basal "sucker" shoots. These leaves were large in area, compared to the other fruiting-shoot leaves, and not quite as mature.

Soil samples were taken on the west or south side of the bushes, as were the leaf samples. Many soil cores were taken with a soil tube which was pushed six to seven inches into the soil. These were thoroughly mixed and a one-half pint cardboard container was filled from the mixture. The samples were returned to the laboratory, and the container lid opened a crack to allow drying of the soil until later analysis was accomplished.

Yield records were obtained on all plots. However, due to frost injury, dry soil effects and other external factors, only thirty-three plots provided two-year yield data which were expressed as pounds per bush. The leaf and soil analyses data for these 33 plots were averaged and correlated with yield. Further, nine of the highest yielding plots were used in the preparation of leaf and soil standards.

Blueberry fruit was collected for analysis during the second year of the survey. A one-pint cardboard container was filled with fruit picked at the peak of the harvest, and frozen at -10°F for storage until analysis at a later date.

Figure 1. A comparison of blueberry bushes arbitrarily designated at the beginning of the survey as good, i. e., of vigorous, healthy growth (upper photograph); and poor, lacking in vigor, and abnormally small in size (lower photograph).





Figure 2. Position of the fruiting-shoot leaves on the blue-berry bush which were selected for leaf analysis.

Leaves were on shoots one-half to one foot long, which arose from a branch containing blueberry fruit clusters.

Tissue Analysis

The leaf and fruit samples were washed to remove dust, insecticide and other deposits. They were then dried and ground. The Department of Agricultural Chemistry made analyses spectrographically for phosphorus, calcium, magnesium, manganese, iron, copper, boron, and zinc. Nitrogen was determined by the standard Kjeldahl procedure. Potassium analysis entailed the use of a flame photometer.

Soil Analysis

The soil samples were tested for pH using a Beckman pH meter. The tests were made by the Experiment Station Soil Testing Laboratory.

Determination of the three main soil cations (calcium, magnesium and potassium) was made using a normal, neutral solution of ammonium acetate. The leachate was dried under heat lamps, fired in a furnace at 400°C, dissolved in one percent hydrochloric acid, filtered, and collected for quantitative analysis. Potassium was determined using a flame photometer. Calcium and magnesium were determined titratometrically using a standardized versenate solution, murexide, and Eriochrome black T (F241), developed by Kuang Lu Cheng and Roger H. Bray (1951).

Cation exchange capacity was determined by re-leaching the same soil sample with 95 percent ethyl alcohol, saturating the exchange complex

with sodium from a 10 percent sodium chloride solution, and then leaching the exchangeable sodium using the neutral normal ammonium acetate. The exchangeable sodium thus obtained was then determined using a flame photometer. The exchangeable calcium, magnesium, potassium, and cation exchange capacity were calculated as milli-equivalents per 100 gram dry soil. The saturation of the cation exchange capacity of the three soil cations was calculated on a percent basis.

Fertilizer Treatments

During the last week of April, 1956 fertilizer treatments were established in several plantations which, as indicated by the previous season's leaf analysis, portrayed indications of a nutritional unbalance of the plants. The plots were located as closely as possible to the survey plot for comparison. The treatments per bush were as follows:

- (1) 1 oz. MnSO_4
1/2 lb. 11-11-11 fertilizer
5 gm. borax
- (2) 4 oz. MgSO_4
5 gm. borax
- (3) 0.5 lb. hydrated dolomitic lime
5 gm. borax

Leaf samples were collected from the test plots at the time of the regular leaf sample collections in early July. During the harvest season, yield records were taken on those trial plots whose comparison-survey plots provided two-year yield records.

Soluble solids determinations were made on the berries during the 1955 season. Samples of 10 to 15 berries were taken at random from the picking containers after weighing for yield records. The berries were placed on a six-inch diameter milk filter pad, which was then folded and twisted until the berries were well squeezed and mixed. A small quantity of the juice was then forced through the filter pad onto a Zeiss-Opton hand refractometer for testing. Three to five samples were tested and averaged from each harvest period. Determinations were read directly in percent soluble solids, which was primarily sugar.

RESULTS

General Field Observations

The presence of standing water in many of the plantings was observed during a preliminary trip on June 15, 1955. Areas of more severe floodings within a given planting were generally associated with poor vigor of the bushes as judged by relative bush size. Drainage is one of the more serious problems with which the grower must contend (Johnston, 1948).

The wet spring in 1955 was associated with a severe frost in May (Elliott, 1955) that killed many of the early blossoms which normally were the first to mature.

Later, the season became dry due to an extremely abnormal lack of rainfall in conjunction with above-normal temperatures. The high temperatures caused early and rapid ripening of fruit, with many berries changing rapidly from a green to blue color instead of gradually turning from a green to red to deep blue. As an example of the temperature effect, the variety Rubel usually ripens before the Jersey variety. However, in 1955, the Jersey variety began to ripen before the harvest of Rubels could be completed.

Weather conditions during the following year, 1956, were quite different. The spring was quite late and cool. Standing water was not

much of a problem. Johnston (1957) reported that a period of heat and drought in 1956 injured the developing young fruits; the previous seasons record heat and drought effects augmented the extent of damage.

Frost damage was very slight in 1956; dry weather did not become a problem until later in the harvest season. August and September were unusually dry; however, during the time of sample collection in early July, seasonal conditions were near normal.

Vegetative growth seemed to be favored over reproductive growth during this second year, 1956. Many areas that appeared to be poor in vigor during the first year recovered during the second year. Conversely, yields were, in general, reduced as compared to the previous year, as previously explained by Johnston (1957). Thus, weather was a factor to be considered in the interpretations of this survey.

Pruning was not being practiced extensively and much appears to be desired in its proper procedure, particularly in the case of Stanley variety. A few growers left the bush-prunings in the field and machine shredded them in order to maintain the organic matter content of the soil. Many, however, removed the brush for burning. This practice would deplete the nutrient content of the soil. Many of the plantations were sown in cover crops each fall.

A complete fertilizer, at the rate of one-half to three-quarters pound per bush, was applied by most growers in April. The fertilizer formula consisted of a 11-11-11 for mineral soils, and 5-10-15 for sites of peat. The sulfate form of nitrogen and potassium was incorporated in the fertilizer. Applications were made by hand or a tractor-mounted spreader.

A cooperative insect control program by airplane was used by most growers. It consisted of (1) 5% methoxychlor at the rate of 40 pounds per acre, applied in two applications, June 1 and June 20; (2) 4% Malathion at the rate of 20 pounds per acre, applied June 10; and (3) 2 1/2% rotenone at the rate of 20 pounds per acre, applied in two applications, July 4 and July 14.

Survey

The leaf composition for the nine highest yielding plots were compiled to obtain a standard with which the individual years fruiting-shoot leaves could be compared. Table 1 shows that a majority of the nutrients were higher in 1955 than in 1956. The potassium content of the leaves did not vary significantly from the first to the second year of the survey. Calcium and copper were higher during the second year. The two seasons standards were averaged to provide a tentative blueberry leaf standard for use in future determinations of the nutritional status of blueberry plantings.

The soil analyses from the same nine highest-yielding plots shown in Table 1 were compiled (Table 1) to provide soils standards. There was little difference in pH or cation exchange capacity from the first to the second year. Milliequivalents of calcium and potassium per 100 grams of soil were higher in 1955 than 1956. Conversely, magnesium was higher in 1956. Since the cation exchange capacity changed very little from year to year, the percentage of the cation exchange capacity occupied by these three cations followed the same pattern. There were greater amounts of the divalent cations calcium and magnesium on the soil cation exchange complex than the monovalent potassium.

The same nine most productive plots, on a two year average-yield basis, were used for the compilation of tentative standards for succulent sucker leaves and blueberry fruit. Analyses for two years, 1955 and 1956, were averaged to provide the fruiting-shoot standard. Analyses of sucker-leaves and blueberry fruit were available for only one year, 1956.

These standards are presented in Table 2. The nitrogen content of both types of leaves was approximately the same, namely, 1.98 percent for fruiting-shoot leaves, and 1.94 percent for the sucker leaves. The nitrogen content of the fruit was about one-third that of the leaves, e. g., 0.617 percent. The phosphorus content of the leaves was about the same in both cases, i. e., .15 and .16 percent; whereas, the fruit had about one-half

Table 1. Fruiting-Shoot Leaf and Soil Standards Prepared for the 1955 Season Compared to Those of the 1956 Season. Compiled from Averages of the Analyses of the Nine Highest-Yielding Blueberry Plantings.

A. <u>Fruiting-Shoot Leaf Standards</u>											
Year	Yield (lbs/bush)	Nutrient-Element (% Dry Weight)									
		N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
1955	20.86	2.13	.17	.532	.67	.33	.0174	.018	.0012	.0060	.0022
1956	<u>15.21</u>	<u>1.84</u>	<u>.14</u>	<u>.521</u>	<u>.80</u>	<u>.23</u>	<u>.0161</u>	<u>.013</u>	<u>.0019</u>	<u>.0039</u>	<u>.0017</u>
Ave.	18.04	1.98	.16	.527	.74	.28	.0168	.015	.0015	.0049	.0020

B. <u>Soil Standards</u>										
Year	pH	m.e./100 gm. soil			% cations on soil exchange complex					
		Cation exchange capacity			Ca	Mg	K	Ca	Mg	K
1955	4.0	22.96	1.88	0.52	0.87	8.17	2.26	3.79		
1956	<u>4.0</u>	<u>20.70</u>	<u>1.17</u>	<u>1.27</u>	<u>0.32</u>	<u>5.65</u>	<u>6.13</u>	<u>1.55</u>		
Ave.	4.0	21.87	1.53	0.90	0.60	6.91	4.20	2.67		

this amount, 0.07 percent. Potassium content was higher in the vigorously growing sucker leaves than in the more mature fruiting-shoot leaves. Potassium content of the blueberry fruit was near that of the fruiting-shoot leaves.

As was the case with phosphorus, the calcium content of the two types of leaves varied little, whereas the calcium content of the blueberry fruit was only one-half as great as that of the leaves. Of the remaining nutrients, zinc was higher in the fruit than in either of the two leaf types. The other elements, magnesium, manganese, iron, copper and boron, were much higher in the leaves than in the fruit.

Table 2 also presents the coefficients of variation calculated for use in the nutrient-element balance chart developed by Kenworthy (1949). The values for nitrogen and potassium varied but little in any of the three tissues sampled. Manganese, on the other hand, varied excessively with a coefficient of variation of 34.3 in the fruiting-shoot leaves, 67.5 in the sucker leaves, and 48.8 in the blueberry fruit. Boron in the blueberry fruit samples had a low coefficient of variation (10.6), but was more variable in the leaf samples. Zinc in the blueberry fruit samples varied greatly, with a coefficient of variation of 58.04. Coefficients of 40 or lower are satisfactory for use in nutrient-element balance chart interpretations.

Table 3 shows the correlations between the two types of leaves and blueberry fruit in respect to nutrient content. Manganese was the only

Table 2. Standard Values for Fruit and Leaf Composition. Survey of Blueberry Plantations, 1955 and 1956.

Nutrient	*Fruiting Shoot Leaves (Two year average)		**Sucker Leaves (1956 Analysis)		***Blueberry Fruit (1956 Analysis)	
	% Com- position	Coeff. Varia- tion	% Com- position	Coeff. Varia- tion	% Com- position	Coeff. Varia- tion
Nitrogen	1.98	9.0	1.94	7.1	0.617	9.9
Phosphorus	0.16	17.0	0.15	12.7	0.070	21.4
Potassium	0.527	9.1	0.805	5.0	0.526	10.3
Calcium	0.74	29.1	0.66	29.3	0.32	43.7
Magnesium	0.28	25.4	0.19	25.6	0.036	17.3
Manganese	0.0168	34.3	0.0110	67.5	0.0017	48.8
Iron	0.015	21.1	0.010	35.0	0.0025	16.7
Copper	0.0015	36.5	0.0017	14.7	0.00061	26.6
Boron	0.0049	44.3	0.0031	23.4	0.00067	10.6
Zinc	0.0020	27.0	0.0021	25.0	0.0046	58.04

*Leaves collected in mid-July from mid-position of fruiting shoots of good vigor and production.

**Leaves collected in mid-July from mid-position of lower, vigorously growing "sucker" shoots.

***Fruit collected in early August at peak of harvest season from bushes of good vigor and production.

Table 3. Summary of Correlation Determinations for Fruiting-Shoot Leaves, Sucker Leaves, and Fruit of the Blueberry.

Nutrient	Fruiting-Shoot		Fruiting-Shoot		Sucker-Leaves		Multiple Correlation Coefficient
	Leaves to:	Sucker Leaves	Leaves to:	Fruit	Leaves to:	Fruit	
<u>Linear Correlation Coefficient (32 D.F.)</u>							
Nitrogen	+0.835**		+0.392**		+0.344*		+0.155
Phosphorus	+0.136		+0.136		+0.561**		+0.318
Potassium	+0.517**		+0.525**		+0.472**		+0.330
Calcium	+0.330*		+0.319*		+0.394**		+0.196
Magnesium	+0.496**		+0.265		+0.320*		+0.117
Manganese	+0.777**		+0.775**		+0.704**		+0.628**
Iron	+0.548**		+0.561**		+0.463**		+0.349
Copper	(-) 0.057		+0.182		+0.073		+0.040
Zinc	(-) 0.035		+0.007		+0.012		+0.000
Boron	+0.640**		+0.254		+0.599**		+0.387*

*Significant at 5% level.

**Significant at 1% level.

element to show a highly significant multiple correlation among the three tissues. The boron multiple-correlation ratio was significant only at the 5 percent level. None of the multiple correlation ratios of the other eight nutrients were significant.

The correlation of potassium, manganese and iron between fruiting-shoot leaves and the sucker leaves, or the fruit; and between the sucker leaves and the fruit, were highly significant. Nitrogen and calcium showed significant correlations among the three plant samples. Copper and zinc showed no correlation among any of the tissues tested. Phosphorus showed a correlation between sucker leaves and fruit.

The soluble solids readings taken during the harvests of 1955 are recorded in Table 4. The soluble solids readings presented represent the average of the several determinations made during the various harvests of a given plot. Readings were not made on fruit of plots where yield records were not taken due to frost injury, dry weather effects and other miscellaneous abnormalities. This accounts for the missing plot numbers. The average soluble solids values ranged from 10.66 to 17.27 percent sugar. There appeared to be no relationship between soluble solids readings and yield.

About 35 of the original 55 blueberry plots provided yield records for the two-year period; the data for each of these sites were averaged for the two years, 1955 and 1956, in order to reduce the effects of seasonal and cul-

Table 4. A Comparison of Yield in Pounds of Blueberries per Bush with the 1955 Seasonal Averages of Percent Soluble Solids Determinations on Blueberry Fruit.

Plot No.	Yield (lbs. /bush)	Soluble Solids (%)	Plot No.	Yield (lbs. /bush)	Soluble Solids (%)
3	20.96	12.98	35	12.45	13.56
4	12.46	15.07	36	18.82	13.48
5	16.01	13.56	37	1.19	17.27
6	18.36	14.19	38	5.94	15.63
7	15.54	11.87	39	10.07	14.78
10	12.77	10.66	40	20.64	14.23
11	3.47	13.03	41	22.14	13.78
13	6.70	12.62	42	13.02	14.00
14	19.67	12.40	43	10.55	13.52
16	10.60	12.91	44	23.27	12.28
17	24.43	13.22	45	6.70	12.60
18	18.79	14.22	47	14.95	14.02
19	24.34	12.76	48	13.56	14.33
20	3.31	14.01	49	15.87	12.85
21	5.99	14.74	50	8.13	15.53
26	7.92	15.07	51	20.03	13.75
27	15.33	14.54	52	12.79	13.50

tural variations. These data are presented in toto in Tables 1 and 2 of the Appendix.

The degrees of correlation between the two year averages of yield and nutrient-elements of the fruiting-shoot leaves were determined. There was a highly significant correlation, 0.717, between yield in pounds of berries per bush and percent dry weight of nitrogen in the fruiting-shoot leaves; when leaf nitrogen was above 2.10 percent the correlation was negative rather than positive. As shown in Figure 3, a nitrogen content exceeding an optimum of approximately 2.10 percent resulted in a marked decrease in yield. Values for individual plots indicated that 60.1 percent of the plots had below optimum and 16.7 percent had above optimum concentrations of nitrogen in the fruiting-shoot leaves.

The correlation between yield and magnesium content of the fruiting-shoot leaves, 0.339, was significant at the five percent level. Scattered diagrams showed no apparent relationship between yield and leaf composition for the following nutrient-elements: manganese, potassium, phosphorus, calcium, zinc, copper, boron and iron.

The percentages of the cation exchange capacity of the soil in these 35 plots occupied by calcium, magnesium and potassium were grouped into four categories based on total cation exchange capacity, e. g. 0 to 5, 5 to 10, 10 to 20, and 20 to 50 milliequivalents per 100 grams of soil. Figure 4 shows

Figure 3. A comparison of the nitrogen content of fruiting-shoot leaves with the yield in pounds of blueberries harvested per bush.

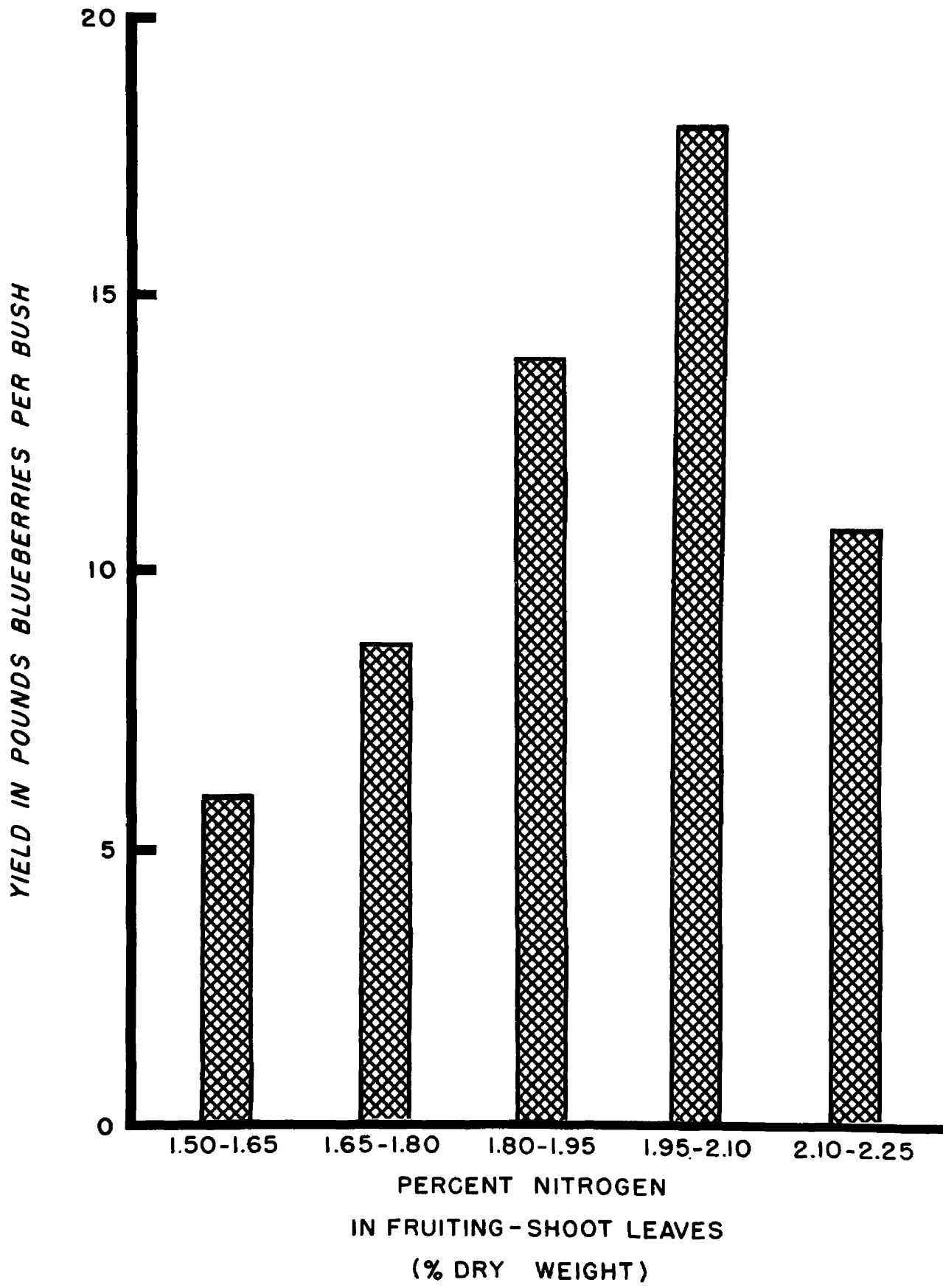
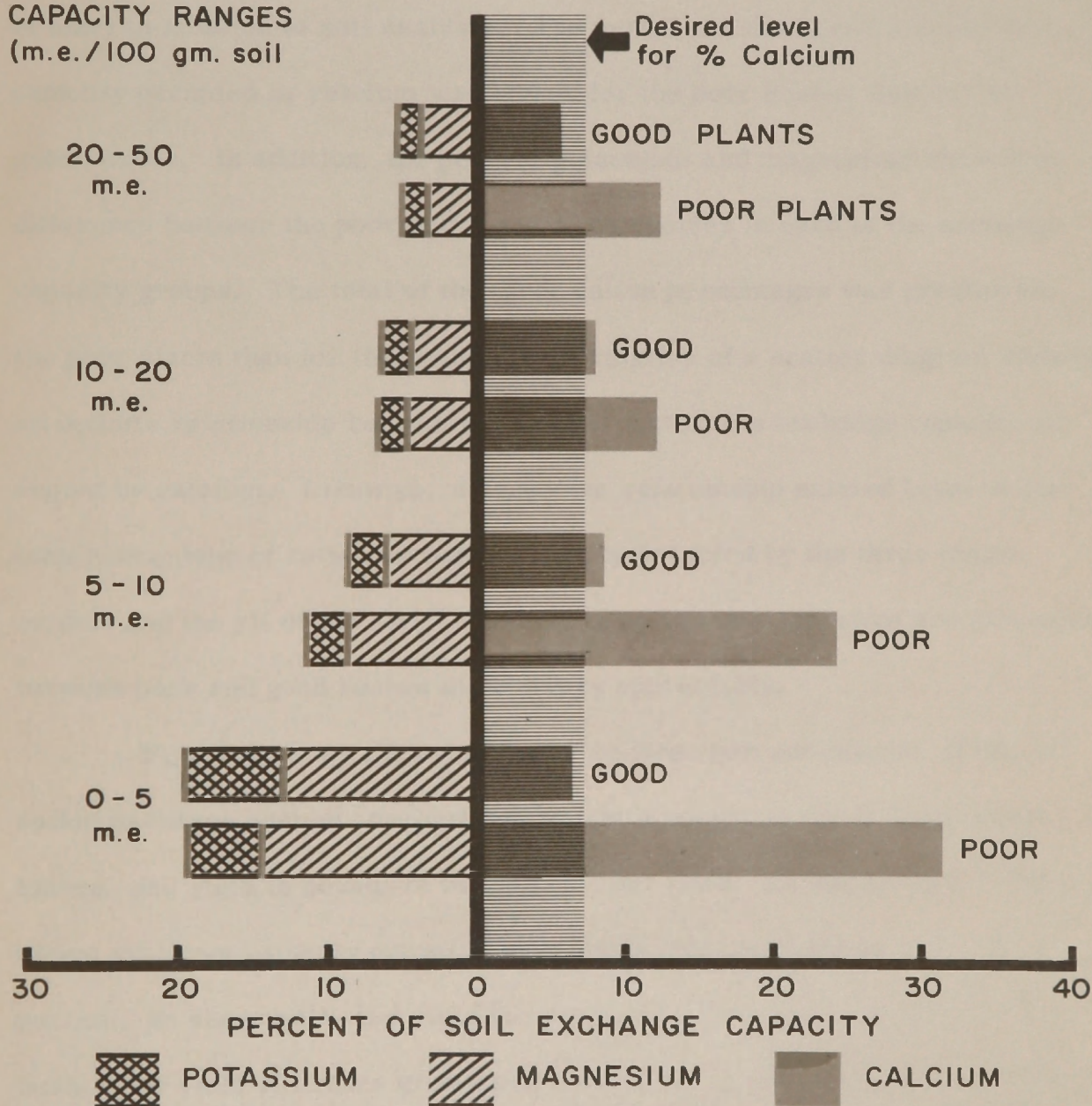


Figure 4. The effect of the percent of the soil cation exchange capacity occupied by calcium, magnesium and potassium on the general vigor of the blueberry plant. The averages of bushes designated as "good" in vigor are compared to those of "poor" vigor at each of five soil cation exchange capacity ranges.

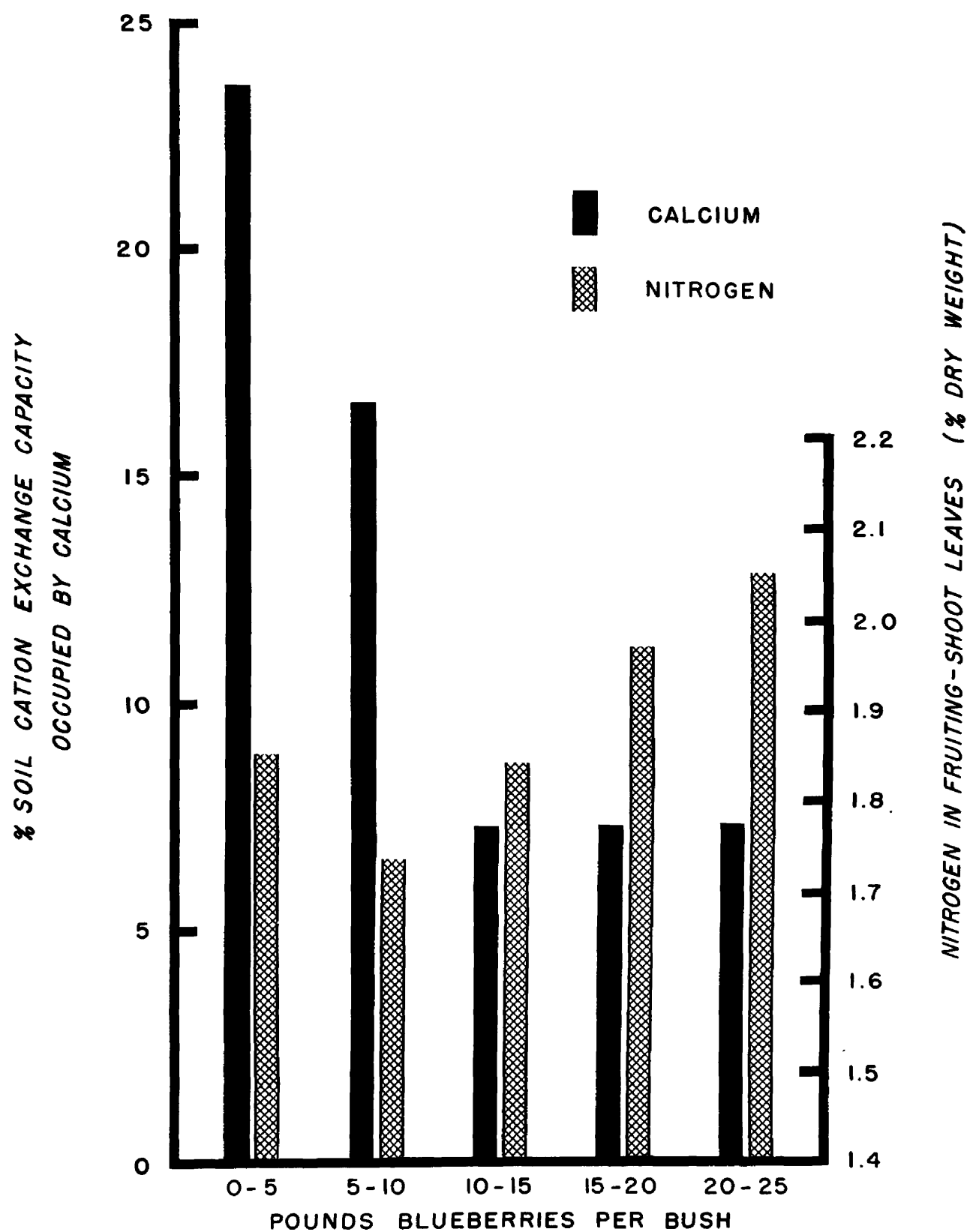
**SOIL EXCHANGE
CAPACITY RANGES**
(m.e./100 gm. soil)



a comparison of the bushes designated at the beginning of the survey as good (of vigorous, healthy growth) and poor (lacking in vigor, abnormally small in size) in relation to soil analysis. The percent of the total cation exchange capacity occupied by calcium was higher for the poor bushes than for the good bushes. In addition, the percent potassium and magnesium showed no difference between the poor and the good categories in each of the exchange capacity groups. The total of the three cation percentages was greater for the poor plants than for the good. The formation of a scatter diagram showed no definite relationship between pH and percent cation exchange capacity occupied by calcium. Likewise, no apparent relationship existed between the total percentage of cation exchange capacity occupied by the three major cations and the pH of the soil. The average percent magnesium and potassium between poor and good bushes did not vary appreciably.

Figure 5 shows the relationship between percent calcium of the soil cation exchange system, percent dry weight nitrogen in the fruiting-shoot leaves, and yield in pounds of blueberries per bush. As the percent of the cation exchange capacity occupied by calcium increased above eight to ten percent, an abnormally low yield resulted, i. e., less than ten pounds per bush. The yield of bushes growing in a soil of less than eight to ten percent calcium on the soil exchange was apparently limited, mainly by a low-nitrogen content. However, bushes with a yield of five to ten pounds each were

Figure 5. The percent of the soil cation exchange capacity occupied by calcium compared to the nitrogen content (percent dry weight) of the fruiting-shoot leaves; averages are presented according to ranges of yield in pounds of blueberries per bush.



affected both by a low nitrogen content and a high percent calcium on the soil exchange system. Bushes with the lowest yields were mainly affected by an excessively high soil calcium; the nitrogen content of leaves from these bushes was quite variable.

Fertilizer Trials

Certain plots were selected for fertilizer trials to study the influence of supplying manganese, boron and magnesium where the 1955 analyses indicated a shortage of any of these elements.

Treatment (1) which consisted of one ounce of manganese sulfate, eight ounces of a 11-11-11 blueberry fertilizer, plus five grams of borax per bush, caused marked responses. Green leaf color was intensified as a result of treatment, but new shoot growth was not appreciably affected. Analyses of fruiting-shoot and sucker leaves are presented in Table 5, together with fruit yields. Manganese and boron contents in both types of leaves were increased markedly. Fruit analyses of the treated bushes were not obtained. However, the fruit of the untreated plants contained only 0.0005 percent manganese as compared to a standard value of 0.0017 percent. The boron content of the fruit from the untreated bushes was nearly identical to that of the fruit standard value.

The most important response observed was an increase in yield. The initial yield, taken on August 2, was increased 96 percent, and that of

Table 5. Results of the Application of One Ounce of MnSO_4 , Five Grams of Borax, and Eight Ounces of 11-11-11 Blueberry Fertilizer to the Soil of Nine-Year-Old Blueberry Bushes (Treatment No. 1).

Analysis of Fruiting-Shoot Leaves

(% Dry Weight)

Nutrient Element	Fruiting-Shoot Leaves		Sucker Leaves	
	Untreated	Treated	Untreated	Treated
N	1.68	1.68	1.66	1.83
P	.15	.14	.12	.14
K	.476	.470	1.04	.794
Mg	.27	.23	.20	.19
Ca	.55	.72	1.03	.91
Fe	.009	.011	.007	.010
Mn	.0056	.0110	.0063	.0117
Cu	.0013	.0014	.0020	.0018
B	.0027	.0080	.0035	.0085
Zn	.0019	.0015	.0025	.0027

Yield in Pounds Per Bush

<u>Date of Harvest</u>	<u>August 2</u>	<u>August 14</u>	<u>September 3</u>	<u>Total</u>
Untreated	1.96	3.44	2.38	7.78
Treated	3.84	4.04	2.13	10.01

the second harvest, on August 14, was increased 17.5 percent; yield at the third harvest of September 3, 1956 was not increased. The total yield was increased from 7.78 on the untreated plants to 10.01 pounds per bush on the treated ones. This gave a net increase of 2.23 pounds of blueberries per bush or an increase of more than one ton per acre when calculated on a basis of 1000 bushes per acre.

Soil treatments with five grams of borax per bush also increased, appreciably, the leaf content of boron in other bushes. Treatment (2), in which five grams of borax and four ounces of magnesium sulfate were applied to the soil, increased the fruiting-shoot leaf content of boron from .0029 to .0251 percent dry weight. The magnesium content was increased from .14 to .23 percent (Table 6). Yield, however, was not increased.

With treatment (3), in which one-half pound of hydrated dolomitic limestone was applied in conjunction with five grams of borax to the soil, the boron content of the fruiting-shoot leaves was increased from .0029 to .0138 percent dry weight (Table 6). The magnesium content was increased from .14 to .18 percent. In this test the presence of calcium in the lime may have reduced the uptake of boron and magnesium as compared to treatment (2) where the source of magnesium was Epsom salts. Visible leaf symptoms of a magnesium deficiency were not noted at the time of sampling in early July on either the treated or untreated plots. Yield was not increased by this treatment.

Table 6. A Comparison of the Leaf Analysis of Untreated Bushes (Check) with those Whose Soils were Treated with Magnesium in the Form of Hydrated Dolomitic Lime, Plus Borax; and Magnesium in the Form of Epsom Salts ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), Plus Borax.

Nutrient	Fruit-Shoot Leaf Composition (% Dry Weight)		
	Check	150 lbs. MgO/acre (as hydr. Dolo-lime) and 5 gm. borax/bush	70 lbs. MgO/acre (as $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) and 5 gm. borax/bush
		(Treatment 3)	(Treatment 2)
Nitrogen	1.83	1.78	1.81
Phosphorus	.13	.14	.15
Potassium	.561	.567	.580
Calcium	1.08	.91	.88
Magnesium	.14	.18	.23
Manganese	.0171	.0132	.0122
Iron	.014	.010	.012
Copper	.0015	.0014	.0013
Boron	.0029	.0138	.0251
Zinc	.0015	.0016	.0016

Deficiency Levels

During the routine sampling in the present survey, bushes in several areas were observed to have deficiency symptoms on the leaves. Some of these leaves were collected for analysis to possibly provide some information concerning deficient levels of nutrients in the fruiting-shoot leaves. The data indicated that symptoms may be altered by shortages of more than one nutrient-element.

Figure 6 shows a picture of chlorotic leaves on bushes grown on an upland soil of pH 5.2 that had 48.41 percent calcium on the soil cation exchange system. Interveinal chlorosis as well as complete yellowing of some leaves was apparent. Complete yellowing of the leaves was an advanced stage of the deficiency symptom. The accompanying nutrient balance chart (Kenworthy, 1949) shows that iron, manganese and magnesium were excessively low. The leaf contained .006 percent iron, .0031 percent manganese, and 0.11 percent magnesium. This sample, therefore, gives possible deficiency levels of these three elements.

Figure 7 shows symptoms not as advanced as those of Figure 6. These leaves came from bushes grown on highly acid soil of pH 3.6; the percent calcium on the soil exchange was 2.38 percent. The accompanying nutrient-element balance chart shows that the manganese content was

Figure 6. A nutrient-element balance chart (Kenworthy, 1949) constructed from the analyses of fruiting-shoot leaves of a blueberry bush shown in the accompanying photograph. The upland soil on which it was grown had a pH of 5.2, with 48.41 percent calcium on the soil cation exchange system.

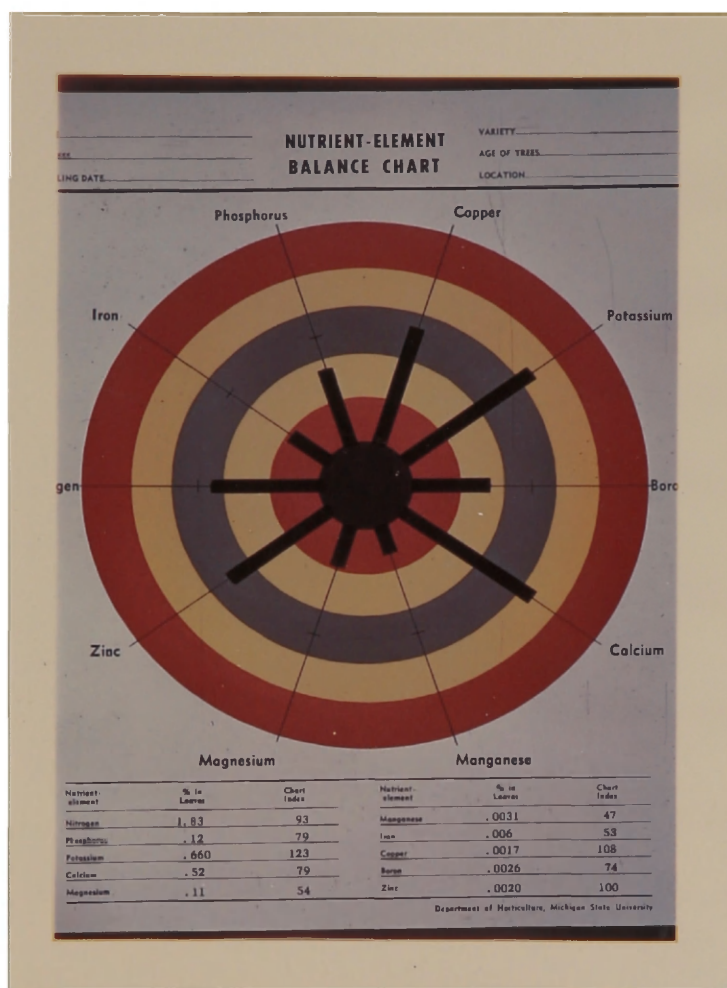
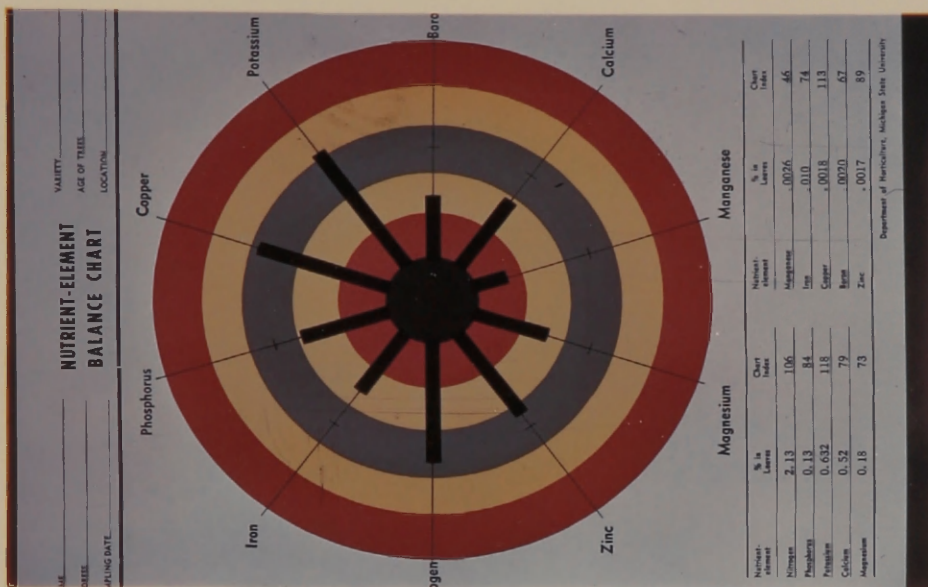


Figure 7. Blueberry leaves exhibiting symptoms not as advanced as those in Figure 6.

The accompanying nutrient-element balance chart shows that manganese was dangerously low. Below-normal levels of iron, magnesium and boron are also present, however.



dangerously low (.0028 percent). Below-normal levels of iron, magnesium and boron may have influenced the symptom expression, however.

Another deficiency symptom may be seen in Figure 8. The leaves contained only .0023 percent manganese, and the nutrient-element balance chart shows this level to be dangerously low.

Figure 9 shows lower leaves of a basal shoot exhibiting typical magnesium deficiency symptoms as described by Mikkelsen and Doehlert (1950). This photograph was taken in early September. The accompanying nutrient-element balance chart shows an exceedingly low content of magnesium. These leaves contained .04 percent magnesium on a dry weight basis.

Figure 8. Blueberry leaves exhibiting symptoms somewhat typical of manganese deficiency. The leaves contained only .0023 percent manganese, and the nutrient-element balance chart shows this level to be dangerously low.

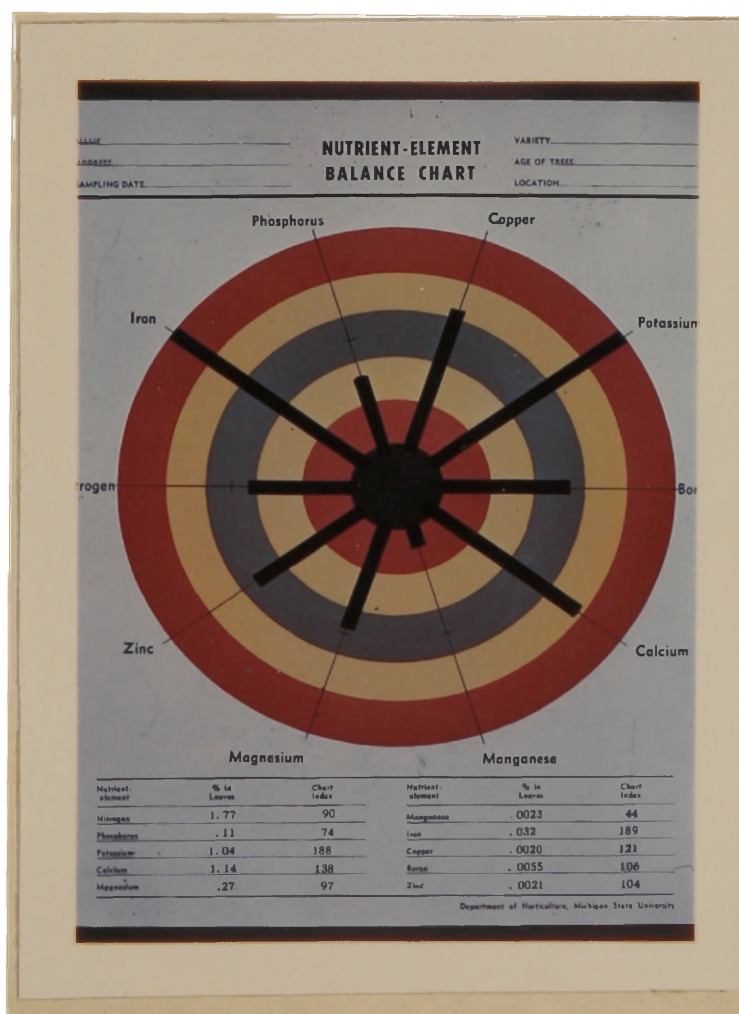
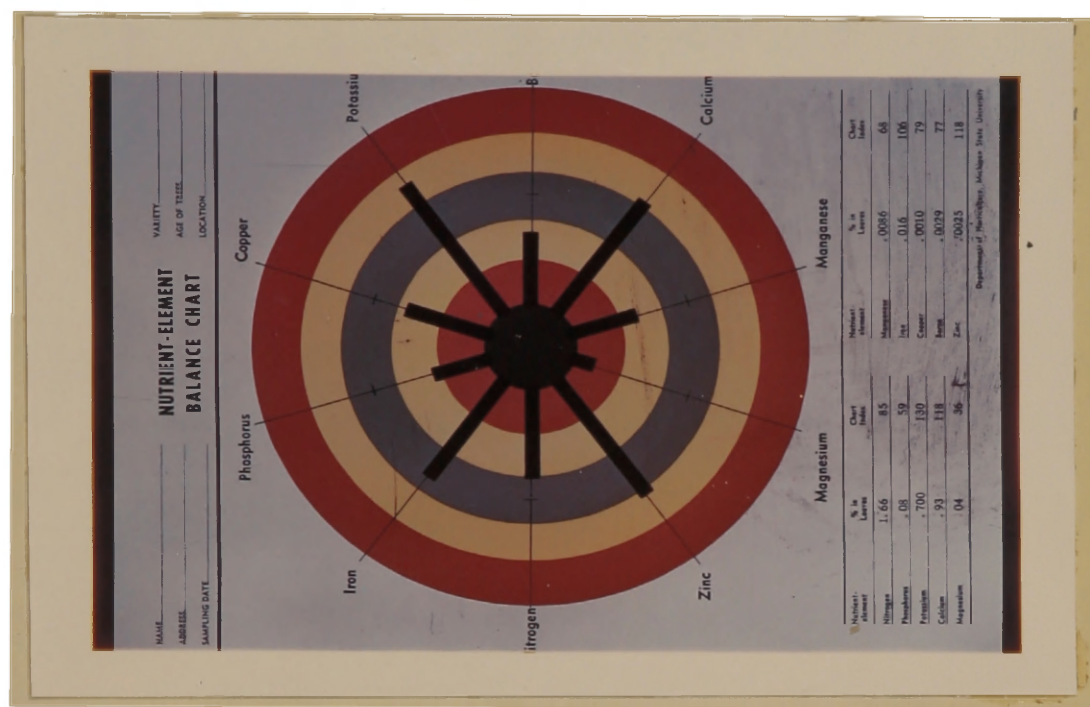


Figure 9. Basal leaves of a sucker shoot of a blueberry bush exhibiting typical magnesium deficiency symptoms. The accompanying nutrient-element balance chart (Kenworthy, 1949) shows an exceedingly low content of magnesium.



DISCUSSION

Variations in weather and other growing conditions are pertinent factors to be considered in the production of blueberries and must be taken into consideration when interpreting data collected during a survey. The two seasons represented in this survey showed several extremes in climate. Averaging the data for two years would tend to minimize variations due to climatic factors, such as rainfall and temperatures.

Nitrogen played an important role in the production of blueberries. It was the only element known to be deficient in blueberry plantings on mineral soils in Oregon (Boller, 1951). Bailey (1956) conducted a nutritional survey of blueberries in Massachusetts, and reported that only nitrogen was outstandingly deficient.

The results of the present survey revealed a similar trend. The nitrogen content of leaves was found to be proportional to yield until an optimum concentration of about 2.10 percent was reached. A majority of the plantings sampled were apparently receiving sub-optimal amounts of nitrogen.

It is generally known that nitrogen is one of the first nutrients to become deficient in a soil which has been in production for a number of years and that native blueberries are found in a soil that is high in organic

matter and rich in nitrogen. Clearing of such land and subsequent clean cultivation are conducive to an increased oxidation and depletion of organic matter and a decrease in nitrogen. Marginal soil types, such as the light, sandy types utilized for some blueberry plantings, were originally low in organic matter and nitrogen.

Romaine (1940) reported that reasons for soil depletion should include the removal of plant food by crops. Reduced yield and quality of crops have been identified as nutrient deficiency symptoms, which is an indication that the soils are becoming depleted of their fertility. Generally, Romaine stated that "the longer soils are farmed, and the lighter the soil, the more fertilizer usage tends to approach the crop content of all three main nutrients. In Europe, fertilizer usage is often based entirely on the plant foods contained in the crop".

Accordingly, the quantity of nutrients removed by blueberry fruit should afford a clue as to the quantity removed from the soil with various yields. The size of yields, naturally, will influence the amount of nutrients removed from the soils.

Table 7 shows the pounds of nitrogen, phosphorus and potassium removed on an acre basis by various yields of fruit, using the standard values in Table 2 for fruit analysis. Pounds of fertilizer carrier needed for the replacement of these nutrients are also shown. Table 7 indicates

Table 7. Nutrients Removed by Blueberry Fruit per Acre, and the Pounds of Carrier of 11-11-11 Fertilizer Required to Replace Them, Assuming a One Hundred Percent Recovery from Soil Applications.

Blueberry yield lbs. per bush	tons per acre*	Nutrients removed per acre (lbs)**			Pounds of carrier need- ed for replacement			Pounds per acre of 11-11-11 fertilizer required for re- placement		
		N	P	K	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
5	2 1/2	4.18	0.48	3.55	4.18	1.10	4.28	38.00	10.00	38.91
10	5	8.35	0.95	7.10	8.35	2.18	8.55	75.54	19.82	77.72
15	7 1/2	12.53	1.43	10.42	12.53	3.28	12.55	113.90	29.82	114.08
20	10	16.70	1.90	14.20	16.70	4.35	17.11	151.80	39.54	155.53
25	12 1/2	20.88	2.38	17.75	20.88	5.45	21.38	189.80	49.54	194.34
30	15	25.05	2.85	21.30	25.05	6.53	25.66	227.70	59.36	233.25

* Based on 1000 bushes per acre.

** Assuming fruit to be 14 percent dry weight, using blueberry fruit standards compiled in 1956.

that a 4-1-4 ratio would be required if only the nutrients removed by the harvested fruit were replenished.

The leaves of the bushes also contain elements which may not be completely returned to the soil. Winds may transport them from the plantation; they may be raked out with pruning-brush. It would seem logical to donate the leaves to replace some of the organic matter and nutrients which are lost annually from the soil by leaching and oxidation.

Table 8 provides data on the quantity of nutrients removed by the leaves of blueberry plants. These data were calculated using the standard values for fruiting-shoot leaves presented in Table 2. It is apparent that the nutrients, on a fertilizer carrier basis, are no longer in the ratio of 4-1-4 as was the case with the fruit. The ratio is now about 6-1-2. This ratio may explain the phenomenon that many blueberry plantings are becoming deficient in nitrogen. Since relatively more nitrogen is being removed per acre by leaves and fruits than phosphorus or potassium, it is logical that nitrogen is more apt to be the first nutrient to become limiting.

Assuming that a high yield of twenty pounds of berries is harvested per bush, and the bushes, being of medium size, contain eight pounds of leaves, then according to Tables 7 and 8, 64.2 pounds of nitrogen, 13.2 pounds of P_2O_5 , and 32.3 pounds of K_2O will be needed to replace the nitrogen, phosphorus and potassium removed. This would require 584 pounds of 11-11-11

Table 8. Nutrients Removed by Blueberry Leaves per Acre, and the Pounds of Carrier of 11-11-11 Fertilizer Required to Replace Them, Assuming a One Hundred Percent Recovery from Soil Applications.

Pounds of leaves per bush	Tons of leaves per acre*	Pounds nutrients removed per acre			Pounds fertilizer carrier required for replacement			Pounds 11-11-11 fertilizer needed for replacement		
		N	P	K	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
2	1.0	11.88	0.96	3.16	11.88	2.20	3.81	107.88	20.00	34.63
4	2.0	23.76	1.92	6.32	23.76	4.40	7.61	215.98	40.00	69.17
6	3.0	35.64	2.88	9.48	35.64	6.60	11.42	323.97	60.00	103.81
8	4.0	47.52	3.84	12.64	47.52	8.80	15.23	431.87	80.00	138.44
10	5.0	59.40	4.80	15.80	59.40	11.00	19.03	539.95	100.00	172.98

*Based on 1000 bushes per acre.

fertilizer per acre to replace the nitrogen, only 119.5 pounds to replace the phosphorus, and 293.97 pounds to replace the potassium. The average grower applies about 500 pounds of 11-11-11 fertilizer. This may supply sufficient nitrogen, but an excess of phosphorus and potassium. A fertilizer ratio approaching 4-1-2 would be more in line with plant requirements and should be more economical in terms of fertilizer materials as well as grower costs.

In addition, nutrients are also stored in the wood of the bush. Some nutrients are removed as pruning brush, transported away from the planting, and thereby constitute a direct loss. These nutrients may be returned for active usage by the plant only if correct pruning is practiced and the brush chipped or chopped and returned to the soil. If such is the case, the ratio of fertilizer as previously calculated, 4:1:2, would still be a valid one. In confirmation, Doehlert and Shive (1936) found that the best response of blueberries in sand culture experiments was from a culture solution high in nitrogen and low in phosphorus and potassium.

The excess potassium added in the 11-11-11 fertilizer being used may contribute to the low magnesium which was indicated by the significant correlation between magnesium content of the leaves and yield. Bear (1948) offered this explanation to the New Jersey growers. The continued use of large quantities of potassium on other crops has often resulted in the appearance of magnesium deficiency. In addition, the fact that potassium deficiency

under field conditions has not been reported for blueberries would question the validity of a 1-1-1 ratio fertilizer.

The soils of many of the plantings are low in cation exchange capacity; their ability to "hold" cations in the soil at any one given time, therefore, is limited. Considering the large quantity of fertilizer previously calculated as essential for maintaining a moderately vigorous and productive bush, growers possessing such soils may profit by applying fertilizer in more than one application. The use of smaller applications at desired intervals would reduce losses due to leaching and provide a more continuous supply of nutrients. Doehlert (1948), in the New Jersey Agricultural Experiment Station's 16th Annual Blueberry Open House report, stated that he has become convinced that two applications of fertilizers in the spring are better than only one. Three applications in the spring, however, show no advantage over two. He stated that plants not in a thrifty condition should benefit from a third application in the fall, consisting of one-third of the yearly requirement.

Soils with more than eight percent calcium on the cation exchange were associated with reduced blueberry production. Figure 4 showed that whenever the percent calcium exceeded this figure, poor growth occurred. Concurrently, the total of the three main cations (in percentage saturation) on the soil exchange was also much higher for poor-vigor plants. This

information should be quite helpful in selecting soil locations for the establishment of new plantations. Plantations already established on such high calcium soils may be modified, perhaps, to give better growth and vigor to plants thereon. Boller (1951) has found mulching to be highly beneficial on soils not ideal for blueberry growing. The poorer the soil, the greater was the benefit.

Mulching material, preferably weathered sawdust, or even peat, improves soil moisture conditions, allows for an improved growth of fibrous roots, and increases the organic matter content of the soil. The latter attribute seems to be one of the most important, since it increases, thereby, the cation exchange capacity of the soil. Since the quantity of calcium remains somewhat constant, the percent calcium of the total cation exchange would be reduced. The ability of the soil to retain nutrients applied in fertilizer would also be improved. Johnston (1951) reported that blueberries could be grown on clay soil if sufficient organic matter is added.

These marginal soils may also be improved by the application of sulfur, if the soil pH is above 5.1. Soil bacteria oxidize the sulfur to form sulfate which combines with the calcium, forming calcium sulfate. Since calcium sulfate is relatively insoluble, the quantity of active calcium would be reduced. Cain (1952) recommends that the ammonia form of nitrogen be applied to marginal soils. Nitrates may actually be harmful. The addition

of ammonium sulfate will tend to decrease the soil pH, thus reducing the population of nitrifying soil bacteria which convert ammonium to nitrate. Extra ammonium sulfate should be applied to sawdust mulches (Boller, 1951) for use by bacteria which are slowly converting the sawdust to humus.

The total base content of the root medium of another Ericaceous plant, Azalea, was found to be inversely proportional to good growth and foliage color by Colgrove and Roberts (1956). Best growth and foliage color occurred when the total base content of the nutrient solutions was reduced to a low level. The same phenomenon was observed by Amling (1957) during sand culture studies with blueberries. One-half the concentration of a trial culture-solution resulted in a marked response of increased vigor.

Kramer and Schroeder (1945) conducted experiments with blueberries in which they indicated that this plant has exacting moisture and oxygen requirements, but more important, a high anion and low cation requirement. They state that the blueberry has a shallow root system and grows in a "... high soil acidity where oxidation rather than reduction process prevails. Since such soils are low in calcium and other exchangeable bases, a low cation requirement is necessary for plants to exist in such an environment.....". Accordingly, as shown in Figure 4, such conditions may be causing reduced growth in some Michigan blueberry soils, which are low in organic matter and relatively dry. This would support the suggestion

made previously that several integral applications of fertilizer should be made instead of a single application. This method reduces the possibility of getting too great a concentration of bases in the soil at any one time.

Relatively few, if any, cases of potassium deficiency symptoms of blueberry under field conditions have been reported in the literature, although it is possible to induce them in sand cultures, as reported by Kramer and Schroeder (1942). Marginal scorching and necrotic spots over the entire surface of the leaf appeared on the older leaves while interveinal chlorosis appeared on new axillary-bud growth. This may be related to the postulations of Mehlich and Drake (1955), and Drake et al (1951) that the exchange capacity of root colloids influences the absorption of mono- or divalent cations at low levels of soil fertility. Since the blueberry is adapted to a relatively low-fertility soil, this phenomenon may be of importance in a discussion of its cation absorption.

According to Dunham (1954), plants with a low root exchange capacity are able to accumulate more potassium from low potassium in a nutrient solution than those of a higher root exchange capacity. Drake et al (1951) found that plants possessing a low root cation exchange capacity have difficulty absorbing divalent cations such as magnesium and calcium. Since acute deficiencies of potassium have not been observed in blueberries, the blueberry plant roots may have low cation exchange capacity. Further, since

magnesium deficiencies have been reported in numerous plantations, Mikkelsen and Doehlert (1950) and Bailey and Drake (1954), the divalent cations may be more difficultly absorbed by the roots. Blueberries have such a small calcium requirement that calcium is seldom a limiting factor. However, it may produce antagonistic effects on the uptake of the other major divalent cations in the soil, i. e. magnesium.

The effect of excessive soil calcium on the exchange complex may also be one which influences the anion-cation relationship. Kramer and Schroeder (1945) hypothesize that the differential absorption of anions may be explained by the fact that amphoteric proteins in blueberry leaves act as cations.

The analyses of fruiting-shoot leaves, presented in Table 2 as standards, compare very closely to those given by Bailey et al (1949) for Massachusetts plantings except for the calcium level. The Massachusetts plantings showed a desirable calcium range of 0.25 to 0.38 percent dry weight in leaves, as compared to 0.74 percent reported in Table 2.

Cain and Galletta (1954) summarized the available literature and presented estimated deficiency ranges for several nutrients. They established calcium at 0.30 percent in leaves. The calcium value in Table 2 for Michigan was 0.74 percent, or more than double that reported elsewhere.

From data in Figures 6 and 7, deficiency symptoms may appear when manganese is less than .0031 percent; iron is below .0060 percent; and magnesium is less than .11 percent. These values are in close agreement with those suggested by Cain and Galletta (1954).

Parups (1955), working with Montmorency cherry trees, found that calcium absorption was depressed significantly by the presence of large quantities of sulfate. The absorption of magnesium was depressed by increasing amounts of sulfates. It was interesting to note that the supply of this anion also seemed to reduce the influence of potassium and calcium upon the absorption of magnesium.

Dilley (1957), working with cherry, apple, peach and grape plants, reported results similar to those of Parups (1955). Calcium was decreased in cherry, apple and peach by higher levels of sulfate in the nutrient solutions. Also, high levels of chloride decreased the uptake of potassium. Mikkelsen and Doehlert (1950), however, found no equivalent reciprocal replacement of potassium or calcium by the blueberry when magnesium sulfate was applied to the soil, although the leaves tended to accumulate more of all the cations when the magnesium sulfate was applied.

In the current study, magnesium added to the soil in the form of either dolomitic limestone or Epsom salts did not increase the total of calcium, magnesium and potassium in the leaves (see Table 6). However,

magnesium sulfate plus borax reduced leaf calcium more than domomitic lime plus borax. Leaf magnesium was not increased as much as leaf calcium was reduced. The sulfate form, however, was accompanied by the greater increase in magnesium.

Current fertilizer recommendation for blueberries contain potassium in the sulfate form. Muriate of potash is not recommended. It is interesting to compare this field-tested response of the blueberry to the results obtained by Parups (1955) and Dilley (1957). This indicates that the blueberry will tolerate very little chloride anion and that the sulfate anion may be required to regulate excessive absorption of calcium. A further study of the effects of these two anions on blueberries would be well warranted.

Little information is available concerning the nutrient content of blueberry fruit. Chandler (1944) reported that this fruit contains more manganese than 120 other foods except wheat-bran, a fair amount of calcium, and a relatively large amount of iron. Chandler presented the analyses on a fresh weight basis; however, the percent moisture was also given. From these figures, the percent dry weights were calculated and compared to the standard values determined in the present survey on a percent dry weight basis:

<u>Source</u>	<u>Nutrient-element (%)</u>					
	N	P	K	Ca	Mg	Mn
Chandler	0.600	.135	.721	.17	.102	.0068
Present survey	.617	.070	.526	.32	.036	.0017

It is apparent that there is a fairly close agreement between the two analyses with nitrogen, potassium, calcium, and magnesium. Analyses of phosphorus, and manganese are not in agreement.

Table 3, in which linear correlation coefficients are given, indicates that manganese is apparently highly mobile in the blueberry plant, since there was a highly significant multiple correlation for this element in each of the two types of leaves and the fruit. This indicates that an analysis of any of these three tissues studied would provide an index of the manganese content of a given blueberry bush. The lower coefficient of variation for fruiting-shoot leaves suggests that they may be preferred.

Nitrogen, potassium, calcium and iron did not appear to be as mobile as manganese; copper and zinc seemed to be highly immobile in the blueberry plant since there was practically a zero correlation between any two of the three tissues analyzed. Larsen (1955) found no consistent pattern with copper in a similar survey of the Concord grape in Michigan.

In many cases, dry weather and lack of moisture in the soil in

1955 resulted in the development of small berries that were rather hard and firm. In such cases, this small size was accompanied by a soluble solids reading of 16 to 18 percent sugar, which was much above normal. In those plantations supplied with irrigation, the berries generally attained a fair size, but excessive heat seemed to ripen them prematurely. These prematurely ripened berries, upon tasting, were rather bland and lacking in flavor, apparently due to a curtailed or abnormal development of acids, tannins or some other organic constituent. These extreme variations, although exceedingly abnormal during the season, indicated that there is a multiplicity of factors influencing the soluble solids content of the blueberry fruit which deny it significance.

SUMMARY

A survey of Michigan blueberry plantations conducted in 1955 and 1956 revealed that soil moisture, either as standing water in the spring or as a deficiency of moisture later in the growing season, was one of the more important factors influencing the vigor of the plants. In a large number of plantations vigor was also being curtailed by a lack of proper pruning practices.

Nitrogen, as percent dry weight of the fruiting-shoot leaves, was directly proportional to yield up to a maximum of approximately 2.10 percent, above which the yield decreased.

The percent of the soil cation exchange capacity occupied by calcium appeared to affect the vigor of the blueberry plant. Quantities above approximately 8 percent were related to extremely poor growth. For those bushes with quantities of calcium on the soil exchange below 8 percent, nitrogen was apparently the limiting factor.

There were some indications that the magnesium content (percent dry weight) of the fruiting-shoot leaves was related to yield. However, few instances of magnesium deficiency were found.

By computing total nutrients removed from the soil by blueberry fruit and leaves, a fertilizer ratio of 4-1-2 was evolved. If it is assumed

that this is an appropriate ratio, then the excessive potassium in the 11-11-11 fertilizer ratio being used today may explain the occurrence of magnesium deficiency symptoms in certain blueberry plantations. This proposed ratio also indicates the need for a larger supply of nitrogen which was reflected in the apparently sub-optimal content of nitrogen in the leaves of many of the blueberry plantings.

Magnesium, manganese and iron deficiencies were associated with a leaf composition of less than 0.11, 0.0031, and 0.006 percent respectively.

Soil moisture and a multiplicity of other factors apparently preclude the use of soluble solids readings on blueberry fruit in interpretations.

The fact that the blueberry plant is shallow-rooted warrants the employment of soil cation exchange determinations, as well as leaf analysis, in determining the nutritional status of this crop. Soil analysis would be primarily useful to determine exchangeable calcium and leaf analysis useful to determine the supply of other nutrients.

Analyses of additional tissues, e. g. sucker-shoot leaves and blueberry fruit, were made in 1956. Linear correlations between any two tissues and multiple correlations suggested that manganese is highly mobile in this plant. Nitrogen, potassium, calcium and iron did not appear to be as mobile as manganese; copper and zinc seemed to be highly immobile.

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APPENDIX

Appendix Table 1. ANALYSES OF SOILS FROM BLUEBERRY PLANTINGS FROM WHICH TWO YEAR
YIELD DATA WERE AVAILABLE.

Location Number	Year	Yield (lbs. / bush)	pH	Soil Analysis - m.e./100 gm. soil			
				Total Cation exch. capacity	Ca	Mg	K
1	1955	9.52	4.1	9.83	0.66	0.18	0.19
	1956	12.21	4.2	11.47	0.48	0.88	0.28
	Average	10.87	4.2	10.65	0.57	0.53	0.24
3	1955	20.96	4.6	11.81	1.01	0.25	0.14
	1956	4.24	4.6	18.37	0.52	0.95	0.24
	Average	12.60	4.6	15.09	0.77	0.60	0.19
4	1955	12.46	4.3	6.68	0.63	0.14	0.16
	1956	4.42	4.7	8.97	0.16	0.64	0.11
	Average	8.44	4.5	7.83	0.40	0.39	0.14
5	1955	16.01	4.6	14.38	1.42	0.48	0.15
	1956	4.75	4.3	24.95	1.10	1.02	0.21
	Average	10.38	4.4	19.67	1.26	0.75	0.18
6	1955	18.36	4.7	23.12	1.33	0.18	0.13
	1956	8.25	4.7	16.85	0.92	0.85	0.19
	Average	13.31	4.7	19.99	1.13	0.52	0.16

Appendix Table 1 - continued

Location Number	Year	Yield (lbs. / bush)	pH	Soil Analysis - m. e. /100 gm. soil			
				Total Cation exch. capacity	Ca	Mg	K
7	1955	15.54	3.9	135.22	7.81	5.11	0.43
	1956	7.42	3.9	121.96	4.28	6.11	0.67
	Average	11.48	3.9	128.59	6.05	5.61	0.55
12	1955	4.70	3.9	141.14	10.28	1.29	0.46
	1956	4.50	4.0	131.09	13.22	3.79	0.31
	Average	4.60	4.0	136.12	11.75	2.54	0.39
14	1955	19.67	4.8	26.28	3.85	0.91	0.49
	1956	12.63	4.7	26.90	1.45	2.21	0.68
	Average	16.15	4.8	26.59	2.65	1.56	0.59
17	1955	24.43	4.3	6.69	0.84	0.22	0.17
	1956	22.83	4.0	10.44	0.13	0.59	0.22
	Average	23.63	4.1	8.57	0.49	0.41	0.39
18	1955	18.79	3.8	39.92	2.61	0.87	0.33
	1956	16.62	4.1	36.41	1.61	1.07	0.23
	Average	17.71	3.9	38.17	2.11	0.97	0.28
19	1955	24.34	4.0	47.83	2.24	0.46	0.23
	1956	9.92	4.1	35.00	1.41	3.03	0.26
	Average	17.13	4.1	41.43	1.83	1.75	0.25

Appendix Table 1 - continued

Location Number	Year	Yield (lbs. / bush)	pH	Soil Analysis - m. e. /100 gm. soil				
				Total Cation exch. capacity	Ca	Mg	K	
20	1955	3.31	4.1	6.15	1.38	0.43	0.13	
	1956	1.00	4.2	7.61	0.91	1.02	0.20	
	Average	2.16	4.2	6.88	1.15	0.73	0.17	
21	1955	5.99	4.9	16.62	3.35	0.47	0.26	
	1956	2.50	4.5	10.49	2.23	1.08	0.36	
	Average	4.25	4.7	13.56	2.79	0.78	0.31	
26	1955	7.92	4.9	27.65	5.72	0.45	0.16	
	1956	4.52	5.0	30.98	2.34	1.40	0.21	
	Average	6.22	5.0	29.32	4.03	0.93	0.19	
27	1955	15.33	4.5	7.96	1.34	0.18	0.07	
	1956	11.97	4.8	13.94	1.73	0.75	0.11	
	Average	13.65	4.6	10.95	1.54	0.47	0.09	
35	1955	19.17	3.9	7.46	0.90	0.16	0.18	
	1956	12.67	3.8	7.01	0.27	0.90	0.31	
	Average	15.92	3.9	7.24	0.59	0.53	0.25	
36	1955	18.82	3.6	3.30	0.31	0.18	0.27	
	1956	7.65	4.0	4.02	0.17	0.73	0.24	
	Average	13.24	3.8	3.66	0.24	0.46	0.26	

Appendix Table 1 - continued

Location Number	Year	Yield (lbs./ bush)	pH	Soil Analysis - m. e. /100 gm. soil			
				Total Cation exch. capacity	Ca	Mg	K
37	1955	1.19	5.2	9.15	4.98	0.41	0.11
	1956	0.90	4.6	7.17	2.92	1.28	0.24
	Average	1.05	4.8	8.16	3.95	0.85	0.18
38	1955	5.94	4.4	11.38	2.74	0.20	0.17
	1956	7.06	4.3	8.21	0.77	0.67	0.26
	Average	6.50	4.4	9.80	1.76	0.44	0.22
39	1955	10.07	4.3	10.87	2.20	0.57	0.11
	1956	7.89	4.4	12.66	0.97	0.70	0.15
	Average	8.98	4.4	11.77	1.59	0.64	0.13
40	1955	20.64	4.1	29.83	2.59	0.39	0.28
	1956	6.82	4.4	26.79	1.31	0.81	0.27
	Average	13.73	4.2	28.31	1.95	0.60	0.28
41	1955	22.14	3.8	13.93	0.51	0.40	0.10
	1956	15.22	3.7	12.07	0.14	0.60	0.15
	Average	18.68	3.8	13.00	0.33	0.50	0.13
42	1955	13.02	3.6	17.78	0.68	0.25	0.11
	1956	10.97	3.9	6.52	0.08	0.61	0.14
	Average	12.00	3.7	12.15	0.38	0.43	0.13

Appendix Table 1 - continued

Location Number	Year	Yield (lb. / bush)	pH	Soil Analysis - m. e. /100 gm. soil				
				Total Cation exch. capacity	Ca	Mg	K	
43	1955	10.55	3.7	57.21	8.12	1.15	0.78	
	1956	11.01	4.0	51.27	4.00	2.07	0.73	
	Average	10.78	3.8	54.24	6.06	1.61	0.76	
44	1955	23.27	3.9	47.68	4.27	1.13	0.29	
	1956	18.48	4.0	43.85	4.00	2.08	0.70	
	Average	20.88	4.0	45.77	4.14	1.61	0.50	
45	1955	6.70	4.5	6.68	1.76	0.25	0.04	
	1956	7.21	4.7	7.61	1.81	0.97	0.09	
	Average	6.96	4.6	14.29	1.79	0.61	0.07	
46	1955	6.70	3.9	9.54	0.82	0.31	0.03	
	1956	5.36	3.9	7.94	1.73	0.99	0.09	
	Average	6.33	3.9	8.74	1.28	0.65	0.06	
47	1955	14.95	4.0	10.24	0.81	0.59	0.14	
	1956	9.45	4.1	7.34	0.27	0.70	0.21	
	Average	12.20	4.1	8.79	0.54	0.65	0.18	
48	1955	13.56	4.3	8.74	0.95	0.19	0.10	
	1956	5.08	4.4	9.13	0.69	0.87	0.25	
	Average	9.32	4.4	8.94	0.82	0.53	0.18	

Appendix Table 1 - continued

Location Number	Year	Yield (lbs./ bush)	pH	Soil Analysis - m. e./100 gm. soil				
				Total Cation exch. capacity	Ca	Mg	K	
49	1955	15.87	3.8	10.46	0.78	0.04	0.08	
	1956	15.60	4.3	5.65	0.63	0.40	0.13	
	Average	15.74	4.0	8.06	0.71	0.22	0.11	
50	1955	8.13	4.3	3.00	1.18	0.22	0.05	
	1956	6.23	4.6	3.70	0.91	0.67	0.11	
	Average	7.18	4.4	3.35	1.05	0.45	0.08	
51	1955	20.03	3.7	6.38	0.92	0.52	0.09	
	1956	12.95	4.0	8.97	0.90	0.57	0.17	
	Average	16.49	3.8	7.68	0.91	0.55	0.13	
52	1955	12.79	3.4	48.37	1.69	0.90	0.28	
	1956	15.42	3.6	43.97	0.33	1.45	0.50	
	Average	14.11	3.5	46.17	1.01	1.18	0.39	

Appendix Table 2. FRUITING-SHOOT ANALYSES FROM BLUEBERRY PLANTINGS FROM WHICH TWO YEARS YIELD DATA WERE AVAILABLE.

Location Number	Year	Percent Dry Weight Nutrient-Elements in Fruiting-Shoot Leaves									
		N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
1	1955	2.16	0.19	0.468	0.64	0.29	0.0176	0.013	0.0010	0.0071	0.0018
	1956	2.41	0.16	0.549	0.55	0.20	0.0323	0.017	0.0020	0.0046	0.0017
	Average	2.29	0.18	0.509	0.60	0.25	0.0250	0.015	0.0015	0.0059	0.0018
3	1955	2.20	0.20	0.468	0.76	0.37	0.0283	0.015	0.0014	0.0067	0.0032
	1956	2.16	0.15	0.549	0.61	0.20	0.0325	0.014	0.0020	0.0047	0.0016
	Average	2.18	0.18	0.509	0.69	0.29	0.0304	0.015	0.0017	0.0057	0.0024
4	1955	2.35	0.20	0.628	0.66	0.28	0.0289	0.014	0.0014	0.0067	0.0029
	1956	1.99	0.14	0.504	0.52	0.19	0.0317	0.012	0.0018	0.0035	0.0018
	Average	2.17	0.17	0.566	0.59	0.24	0.0303	0.013	0.0016	0.0051	0.0024
5	1955	2.23	0.14	0.567	0.57	0.25	0.0118	0.051	0.0007	0.0048	0.0022
	1956	2.26	0.14	0.594	0.59	0.23	0.0140	0.033	0.0018	0.0033	0.0023
	Average	2.25	0.14	0.581	0.58	0.24	0.0129	0.042	0.0013	0.0041	0.0023
6	1955	1.92	0.13	0.420	0.60	0.30	0.0084	0.029	0.0007	0.0033	0.0031
	1956	1.83	0.14	0.447	0.57	0.24	0.0074	0.029	0.0018	0.0027	0.0021
	Average	1.88	0.14	0.434	0.59	0.27	0.0079	0.029	0.0013	0.0030	0.0026
7	1955	2.23	0.18	0.458	0.55	0.42	0.0129	0.012	0.0013	0.0060	0.0023
	1956	2.02	0.15	0.500	0.63	0.29	0.0242	0.015	0.0016	0.0061	0.0022
	Average	2.13	0.12	0.479	0.59	0.36	0.0186	0.014	0.0015	0.0061	0.0023

Appendix Table 2 - continued

Location Number	Year	Percent Dry Weight Nutrient-Elements in Fruiting-Shoot Leaves									
		N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
12	1955	1.72	0.21	0.473	0.62	0.34	0.0094	0.017	0.0010	0.0067	0.0021
	1956	1.68	0.15	0.366	0.60	0.29	0.0162	0.010	0.0014	0.0052	0.0020
	Average	1.70	0.18	0.420	0.61	0.32	0.0128	0.014	0.0012	0.0060	0.0021
14	1955	2.11	0.17	0.558	0.77	0.33	0.0186	0.019	0.0020	0.0121	0.0027
	1956	1.85	0.10	0.539	0.59	0.17	0.0172	0.013	0.0018	0.0064	0.0017
	Average	1.98	0.14	0.549	0.68	0.25	0.0179	0.016	0.0020	0.0093	0.0022
17	1955	2.20	0.15	0.520	0.69	0.30	0.0088	0.018	0.0010	0.0046	0.0022
	1956	1.97	0.13	0.440	0.57	0.23	0.0143	0.014	0.0018	0.0031	0.0015
	Average	2.09	0.14	0.480	0.63	0.27	0.0116	0.016	0.0014	0.0039	0.0019
18	1955	1.98	0.19	0.636	0.59	0.39	0.0139	0.014	0.0011	0.0069	0.0029
	1956	1.81	0.14	0.590	0.57	0.26	0.0120	0.013	0.0018	0.0042	0.0012
	Average	1.90	0.17	0.613	0.58	0.33	0.0130	0.014	0.0015	0.0056	0.0021
19	1955	1.94	0.20	0.559	0.78	0.46	0.0176	0.020	0.0008	0.0044	0.0021
	1956	1.68	0.14	0.552	0.50	0.25	0.0180	0.012	0.0016	0.0027	0.0014
	Average	1.81	0.17	0.556	0.64	0.36	0.0178	0.016	0.0012	0.0036	0.0018
20	1955	2.06	0.19	0.655	0.72	0.29	0.0206	0.020	0.0012	0.0022	0.0017
	1956	2.19	0.12	0.640	0.60	0.16	0.0257	0.014	0.0017	0.0014	0.0025
	Average	2.13	0.16	0.648	0.66	0.23	0.0232	0.017	0.0015	0.0018	0.0021

Appendix Table 2 - continued

Location Number	Year	Percent Dry Weight Nutrient-Elements in Fruiting-Shoot Leaves									
		N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
21	1955	1.97	0.13	0.618	0.71	0.23	0.0109	0.017	0.0009	0.0088	0.0020
	1956	1.94	0.11	0.686	0.48	0.15	0.0106	0.010	0.0017	0.0020	0.0013
	Average	1.96	0.12	0.652	0.60	0.19	0.0108	0.014	0.0013	0.0054	0.0017
26	1955	1.80	0.16	0.450	0.72	0.32	0.0161	0.015	0.0010	0.0025	0.0021
	1956	1.60	0.15	0.524	0.53	0.26	0.0210	0.015	0.0019	0.0017	0.0011
	Average	1.70	0.16	0.487	0.63	0.29	0.0186	0.015	0.0015	0.0021	0.0016
27	1955	1.99	0.18	0.466	0.85	0.34	0.0161	0.016	0.0011	0.0035	0.0021
	1956	1.71	0.16	0.476	0.57	0.28	0.0244	0.015	0.0017	0.0022	0.0026
	Average	1.85	0.17	0.471	0.71	0.31	0.0230	0.016	0.0014	0.0029	0.0024
35	1955	2.25	0.19	0.522	0.74	0.28	0.0117	0.020	0.0011	0.0038	0.0022
	1956	1.85	0.14	0.560	0.65	0.18	0.0080	0.009	0.0012	0.0022	0.0021
	Average	2.05	0.17	0.541	0.70	0.23	0.0099	0.015	0.0012	0.0030	0.0022
36	1955	2.04	0.16	0.590	0.55	0.19	0.0112	0.020	0.0008	0.0026	0.0020
	1956	1.84	0.15	0.510	0.76	0.18	0.0090	0.010	0.0014	0.0022	0.0019
	Average	1.94	0.16	0.555	0.66	0.19	0.0101	0.015	0.0011	0.0024	0.0020
37	1955	1.61	0.11	0.443	1.00	0.22	0.0079	0.014	0.0006	0.0045	0.0027
	1956	1.56	0.11	0.354	0.91	0.14	0.0042	0.007	0.0012	0.0018	0.0026
	Average	1.59	0.11	0.399	0.96	0.18	0.0061	0.011	0.0014	0.0032	0.0027

Appendix Table 2 - continued

Location Number	Year	Percent Dry Weight Nutrient-Elements in Fruiting-Shoot Leaves									
		N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
38	1955	1.80	0.15	0.446	0.75	0.29	0.0080	0.019	0.0010	0.0053	0.0032
	1956	1.56	0.13	0.455	0.68	0.15	0.0050	0.010	0.0012	0.0020	0.0009
	Average	1.68	0.14	0.451	0.72	0.22	0.0065	0.015	0.0011	0.0037	0.0021
39	1955	1.63	0.13	0.431	0.73	0.35	0.0076	0.013	0.0011	0.0039	0.0021
	1956	1.68	0.15	0.476	0.55	0.27	0.0056	0.009	0.0013	0.0027	0.0029
	Average	1.66	0.14	0.454	0.64	0.31	0.0066	0.011	0.0012	0.0033	0.0025
40	1955	1.73	0.13	0.416	0.73	0.36	0.0128	0.014	0.0009	0.0048	0.0025
	1956	1.73	0.15	0.484	0.76	0.30	0.0190	0.014	0.0015	0.0052	0.0023
	Average	1.73	0.14	0.450	0.75	0.33	0.0159	0.014	0.0012	0.0050	0.0024
41	1955	2.18	0.15	0.511	0.65	0.27	0.0245	0.016	0.0009	0.0045	0.0022
	1956	1.91	0.15	0.551	0.95	0.19	0.0167	0.011	0.0016	0.0032	0.0019
	Average	2.05	0.15	0.531	0.80	0.23	0.0206	0.014	0.0013	0.0039	0.0021
42	1955	1.96	0.15	0.584	0.65	0.18	0.0158	0.013	0.0008	0.0035	0.0022
	1956	1.83	0.13	0.561	1.08	0.14	0.0171	0.014	0.0015	0.0029	0.0015
	Average	1.90	0.14	0.573	0.87	0.16	0.0165	0.014	0.0012	0.0032	0.0019
43	1955	2.05	0.17	0.501	0.65	0.31	0.0257	0.013	0.0013	0.0070	0.0028
	1956	1.74	0.15	0.512	0.79	0.26	0.0290	0.013	0.0012	0.0047	0.0022
	Average	1.90	0.16	0.552	0.72	0.29	0.0274	0.013	0.0013	0.0059	0.0025

Appendix Table 2 - continued

Location Number	Year	Percent Dry Weight Nutrient-Elements in Fruiting-Shoot Leaves									
		N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
44	1955	2.19	0.16	0.491	0.70	0.30	0.0275	0.018	0.0011	0.0068	0.0020
	1956	1.81	0.13	0.504	1.29	0.25	0.0305	0.015	0.0020	0.0043	0.0028
	Average	2.00	0.15	0.498	1.00	0.28	0.0290	0.017	0.0016	0.0056	0.0024
45	1955	1.68	0.12	0.373	0.91	0.32	0.0224	0.010	0.0015	0.0087	0.0028
	1956	1.49	0.10	0.376	0.98	0.12	0.0045	0.020	0.0025	0.0033	0.0025
	Average	1.59	0.11	0.375	0.95	0.22	0.0135	0.015	0.0020	0.0060	0.0027
46	1955	1.68	0.15	0.352	0.78	0.32	0.0130	0.035	0.0018	0.0110	0.0024
	1956	1.36	0.11	0.300	0.68	0.18	0.0071	0.012	0.0020	0.0065	0.0011
	Average	1.52	0.13	0.326	0.73	0.25	0.0101	0.024	0.0019	0.0088	0.0018
47	1955	1.91	0.15	0.508	0.75	0.26	0.0106	0.032	0.0016	0.0082	0.0020
	1956	1.49	0.12	0.457	0.58	0.15	0.0056	0.022	0.0019	0.0035	0.0018
	Average	1.70	0.14	0.483	0.67	0.21	0.0081	0.027	0.0018	0.0059	0.0019
48	1955	1.65	0.17	0.440	0.69	0.29	0.0152	0.022	0.0017	0.0055	0.0023
	1956	1.56	0.14	0.425	0.75	0.26	0.0120	0.035	0.0018	0.0049	0.0022
	Average	1.61	0.16	0.433	0.72	0.28	0.0136	0.029	0.0018	0.0052	0.0023
49	1955	2.16	0.15	0.467	0.55	0.27	0.0133	0.015	0.0013	0.0046	0.0020
	1956	1.92	0.17	0.494	0.94	0.27	0.0116	0.016	0.0028	0.0045	0.0008
	Average	2.04	0.16	0.481	0.75	0.27	0.0125	0.016	0.0021	0.0046	0.0014

Appendix Table 2 - continued

Location Number	Year	Percent Dry Weight Nutrient-Elements in Fruiting-Shoot Leaves									
		N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
50	1955	2.04	0.16	0.552	0.51	0.24	0.0141	0.018	0.0015	0.0041	0.0020
	1956	1.74	0.12	0.545	1.00	0.18	0.0143	0.010	0.0021	0.0032	0.0019
	Average	1.89	0.14	0.549	0.76	0.21	0.0142	0.014	0.0018	0.0037	0.0020
51	1955	2.16	0.20	0.528	0.57	0.33	0.0206	0.018	0.0012	0.0061	0.0015
	1956	1.74	0.13	0.458	1.13	0.25	0.0169	0.013	0.0023	0.0041	0.0020
	Average	1.95	0.17	0.493	0.85	0.29	0.0188	0.016	0.0018	0.0051	0.0018
52	1955	1.87	0.17	0.559	0.65	0.37	0.0113	0.019	0.0012	0.0056	0.0021
	1956	1.80	0.17	0.440	0.45	0.34	0.0154	0.010	0.0020	0.0046	0.0022
	Average	1.84	0.17	0.500	0.55	0.36	0.0134	0.015	0.0016	0.0051	0.0022