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A Nutritional Survey of Sweet Cherry Orchards in Utah

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A NUTRITIONAL SURVEY OF SWEET CHERRY ORCHARDS IN UTAH

by

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INTRODUCTION

The sweet cherry crop has always been the number one fruit crop in Utah until the last three or four years when it shifted to second place due to severe spring frosts. However, the outlook for its continued success is still very good. Even though there are drawbacks such as virus infestations, spring frosts, nutritional disorders, cracking, doubling, and bird injury, new plantings are being made each year in each of the important fruit producing counties. Utah is also important in the national production of sweet cherries and is presently sixth in the nation.

A nutritional survey of sweet cheries in the United States has not been published to the author's knowledge. Preliminary information obtained from questionnaires sent to Utah growers showed a wide variation in the management of sweet cherries and a desire to learn more concerning the nutrition of sweet cherries for improved yields.

The primary objective of this research project was to conduct a nutritional survey of the sweet cherry trees in Utah and determine the general nutrient-element levels by means of leaf analyses and locate areas in the state where deficiencies occurred. A secondary objective was to study factors associated with the evaluation of the general nutrition of sweet cherries. In this connection the following

comparisons were studied: (1) the variation of nutrient-element levels between Bing and Lambert varieties; (2) the relationship between the nutritional status of a cherry orchard and the occurrence of the major virus diseases; (3) the seasonal trend of the nutrient-elements in cherry leaves; (4) the variation of the nutrient-elements due to the sampling position of the leaves on the tree; and (5) the effect of various washing procedures to remove contamination from the leaves. Comparisons were also made between nutrient-element levels according to the various management practices and conditions of the tree observed when collecting the samples.

REVIEW OF LITERATURE

Foliar analysis

Leaf analysis has been used extensively the past three decades to determine the nutritional status of perennial plants as well as annual crops. Wallace (1928 and 1931) worked with the leaves of gooseberry plants and several species of fruit trees. Batjer and Magness (1938) conducted a survey of several varieties of apples from several locations throughout the United States and analyzed the leaf tissue for potassium. From that time until the present, surveys and field plot work with various fertilizer treatments and combinations of treatments have been diagnosed by foliar analysis. Several excellent reviews (Childers, 1954; Emmert, 1959; Smith, 1962; Ulrich, 1948 and 1952) have been written which mention the enormous amount of work that has been done concerning foliar analysis on all kinds of plants.

Specific studies with surveys

During the past decade several surveys have been conducted on apples and peaches in various states (Beattie and Ellenwood, 1950; Emmert, 1955; Kenworthy, 1953; Smith and Taylor, 1952; Titus and Boynton, 1953; Walker and Mason, 1960; Walrath and Smith, 1952). Kenworthy (1953) made a nutritional survey of the principle fruit crops grown in

Michigan but did not include sweet cherries.

Sweet cherry nutritional studies

Nutritional studies with sweet cherries are lacking somewhat compared to other species of fruits. A few reports have been written concerning the levels of one or two nutrients in the leaves after specific treatments with those nutrient-elements, and a few articles have been written concerning the response of yield, fruit color, maturity, and other criteria to various fertilizer applications.

Overholser (1944) reviewed the literature pertaining to the fertilization of cherries. In general he summarized by saying: (1) nitrogen applications result in increased growth and production, and phosphorous and potassium applications have no effect; (2) potassium applications may interfere with the uniform coloring of sweet cherries; and (3) large nitrogen applications result in no significant size increase, possible soft fruit, a delay of fruit maturity, and a delay of the hardening processes occurring in the fall if applications are made in the summer. He recommended December to February applications of nitrogen at the rate of one pound for young bearing trees, two pounds for mature trees, and more for old and weak trees. He also reported that in certain areas cherry trees may benefit from soil applications of boric acid in August, and spray applications of zinc sulfate during the dormant season when boron and zinc are deficient.

Thorne and Stark (1946) discussed different cultural and fertilizer practices performed in sweet cherry orchards. They found that vetch planted as a cover crop in September and disced under the following June gave better yields than barley as a cover crop or clean cultivation. Their results indicated that nitrogen plus phosphorous gave better yields than either element applied alone.

Marshall (1954) indicated that the sour cherry trees may be expected to give a more striking response to nitrogen applications than the sweet cherry trees. He reported that nitrogen gave beneficial effects but that phosphorous and potassium had no benefit. He mentioned that manure applications on sour cherry plots in Colorado produced yields equivalent, if not better, than commercial applications of nitrogen.

In working with sweet cherries, Gerber and Williams (1958) reported that 500 pounds of barnyard manure plus one pound of nitrogen per tree gave higher yields over a ten year period than two pounds of commercial nitrogen. Their results showed that phosphorous had a slight effect on yield when applied with nitrogen but better yield could be obtained by doubling the nitrogen rate and applying no phosphorous.

Stanberry and Clore (1950) reported an increase in leaf nitrogen and phosphorous levels when combinations of the two elements were applied to field plots of sweet cherries. The average nitrogen values for the two years that leaf samples were collected increased from 2.7 to 3.0% for the various

treatments while phosphorous levels increased from .04 to .06%.

Wann (1954) also reviewed the literature concerning cherries which included origin, varieties, rootstocks, cultural practices, tissue composition of a few nutrient-elements, and physiological disorders. He reported that nitrogen applications are good on sweet and sour cherry trees but nitrogen plus phosphorous may be even better. No values were given for the nutrient-element composition in the leaf tissue of sweet cherries specifically but values for Montmorency cherries were given for potassium as .39 to 1.82% dry matter in deficient trees and 2.06 to 2.13% in normal ones. Manganese deficient leaves of sour cherries had about 12 ppm manganese while healthy leaves contained 43 ppm.

Woodbridge (1954 and 1955) reported close correlation between chemical leaf analysis and zinc and boron disorders in cherry trees. Benson, Batjer, and Chmelir (1957) did not find this idea to be always true in all kinds of fruit trees. In applying zinc chelates to trees showing zinc deficiency symptoms, zinc levels in the leaves increased in peach and sweet cherry but not in apple. The zinc levels in sweet cherry leaves ranged from 13.5 to 30.1 ppm.

Kenworthy (1961) proposed that standard nutrient-element values in the leaf should be the same for sweet cherries as for sour cherries. These values were 2.95% nitrogen, .25% phosphorous, 1.67% potassium, 2.09% calcium,

.68% magnesium, 150 ppm manganese, 203 ppm iron, 57 ppm copper, and 50 ppm boron.

Thorne and Wann (1950) described the nutrient deficiencies found in Utah orchards and their typical leaf symptoms. Richards and Cochran (1956) have discussed the virus diseases and the nutritional disorders that have been found in sweet cherries.

Interpretation of results

A number of standard chemical procedures can be followed to determine quantitatively the elements present in plant tissue. Procedures are available to measure soluble forms of nutrients in fresh plant tissue as well as total amounts of nutrient-elements in dry tissue. The results are expressed in units of dry weight, fresh weight, or the ash of the plants(Ulrich, 1948). Units that have been used include milliequivalents per 100 grams, ratios of elements to one another, and percentages. Per cent and parts per million of dry weight are the most common methods of expressing results from chemical analyses (Smith, 1962).

After the chemical analyses are complete, the results are interpreted to determine the sufficiency or deficiency of the nutrient-elements within the plant for optimum growth. Some workers have used critical nutrient levels for the interpretation of their results. These are determined by correlating the nutrient levels found in the plant with yield or growth and locating the level or narrow range for each element which

separates deficiency amounts, where plant performance begins to decrease, from adequate amounts, where plant performance has little or no increase. Other workers have based their interpretations upon the idea of a nutrient balance concept which considers the proportion of the nutrients to one another as well as the actual concentration. Values for the nutrient balance theory have been determined by growing plants with various nutrient levels and calculating the total quantity of nutrients found in the plant tissue as well as the ratios of one element to another which will give the highest yield or growth (Ulrich, 1952). Another method used especially for large perennial plants is by analyzing the tissue from healthy looking, good productive plants and using the results as the balanced or optimum values with the theory that "if the leaf concentrations are at optimum levels then it must follow that the intensity of nutrition and the nutrient-element balance also are optimum" (Smith and Taylor, 1952). Several workers have used this same basic idea for foliar diagnosis but may have used different terms.

Lagatu and Maume (1926) seemed to be the first to suggest equilibrium or balance among elements within the plant. Thomas (1929 and 1937) followed with the "intensity of nutrition" and the "quality of nutrition." Haddock (1961) used a quantity and quality factor to appraise the nutritional status of potatoes.

Shear, Crane, and Meyers (1946) explained that "maximum growth and yield occur only upon the concidence of optimum

intensity and balance." They further said that a plant may appear to be growing well and not show any deficiency symptoms if the elements are in proper balance yet not at optimum intensity. A plant could also appear to be growing well if the intensity of the nutrients are too high and out of balance; however, it would produce better if nutrients were brought into balance through proper fertilization.

Others leaning toward the balance theory proposed various levels. Smith and Taylor (1952) proposed optimum levels which were specific leaf concentrations "for each of the essential elements which is correlated with optimum response in terms of yield or other characteristics," and "these concentrations or optimum values hold over a wide range of soil types and under a variety of climatic conditions." They reported optimum levels would be more valuable than critical levels because critical levels indicate that deficiency symptoms would be expected to appear. They also recognized that there could be within the plant a level of luxury consumption where the nutrient level continued to increase but the response remained constant.

Goodall, Grant, and Slater (1955) stated that "in the case of most investigators who have referred to nutrient balance, no satisfactory definition is given; indeed there seems to be an aura of loose thinking around this concept."

Kenworthy (1961) also noted that there was no clear definition of balance and suggested that the term "standard values" be used. He made clear that these values were not

to be construed with critical values because the latter term denoted deficiency. Standard values were determined for each element by analyzing the leaf tissue of trees with good "horticultural characteristics." This term is quite broad and different nutrient levels may qualify under this statement. Kenworthy suggested five levels to describe the nutritional condition of a plant. Starting with the lowest zone or level, the levels were termed shortage, below normal, normal, above normal, and excess. The zones were represented on a chart by five colored vertical bands corresponding to the five zones and he called it a "Balance Chart." The concentration of each element in a sample was compared to the standard value and a balance index calculated for that element. A line was then drawn for that element across the chart which ended in one of the colored vertical bands. When all elements had been plotted, the chart indicated how far out of balance or in balance each element was with respect to the other elements and the normal. A circular chart called a "Balance Wheel" was previously used (Kenworthy, 1949) to describe essentially the same thing but later Kenworthy (1961) said that it had served its purpose and "is not believed to be as essential now as in the beginning."

Reuther and Smith (1954) used deficient, low, optimum, high and excess levels to evaluate the status of citrus trees.

Chapman (1941) was in favor of balanced nutrition within the plant until he started working with rubber plants and was somewhat surprised to find that the data could be more

satisfactorily explained on the basis of absolute quantities rather than on any theories of balance. However, he points out that he has been able to obtain results with the oil palm supporting both view points depending on the degree of nutritional deficiency existing in the plants.

Macy (1936) interpreted his results in terms of three levels of nutrient concentration. He explained that there was a zone of minimum percentage where yield increased but the nutrient level remained constant, a zone of poverty adjustment where the yield increased as the nutrient level increased, and a zone of luxury consumption where the nutrient level increased but the yield remained constant. The point between the zone of poverty adjustment and luxury consumption he termed critical percentage.

Dorsdoff (1954) believed there was a marginal range between a deficiency range and a luxury range. He also foresaw that there was a toxicity range beyond the luxury range.

Emmert (1955) considered the critical level of a nutrient-element as a narrow range of values between an optimum and sub-optimum nutrient condition and also as a narrow range of values between an optimum and hyper optimum nutrient condition.

Malavolta and Gomes (1961) idea of a critical level is one of economical importance. Their aim was to find "the level of a given element in the leaf beyond which the use of fertilizer is no longer economical." Dumenil (1961) also suggests this could be used as a definition for critical levels.

Prevot and Ollagnier (1961) found that the yield curve ends in a plateau when yield becomes indifferent to increasing doses of nutrients (luxury consumption) which is opposed to the notion of the necessity of strictly balanced mineral nutrition. They point out that "the plateau portion of the yield curve indicates there must be in the plant some kind of 'buffer systems' which enable the plant to maintain its mineral elements in different states and so to adapt itself to important variations in the composition of mineral solutions."

Figure 1 is a diagram designed by Smith (1962) to describe the variety of possible growth responses that a plant may show when the concentration of nutrient-elements are altered. Zone (a) may occur under conditions of extreme deficiency and is called the "Steenbjerg-effect" because of its description by Steenbjerg (1954) and shows an actual decrease in leaf concentration and an increase in growth following the application of a deficient nutrient. Zone (b) shows a growth response with little or no change in leaf concentration. In zone (c) leaf concentration and growth occur simultaneously until optimum growth is reached or the critical nutrient level. Zone (d) is the luxury range where leaf concentration increases and yield remains constant while zone (e) shows a toxicity range where a continued increase in mineral concentration causes a decrease in yield.

There are only two or three methods by which standard values are determined whether they are optimum values or

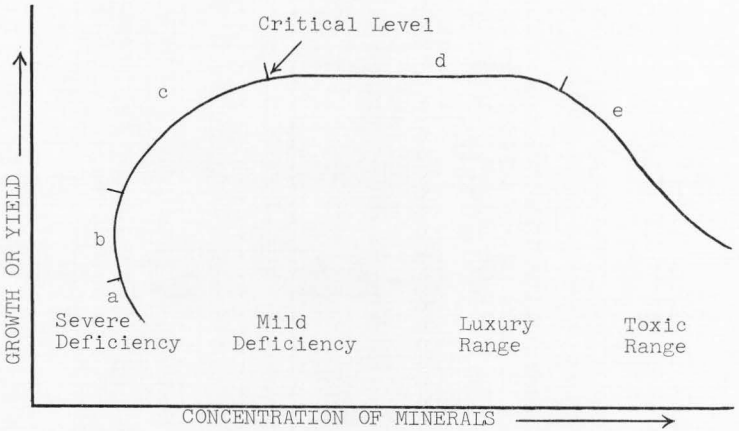

Figure 1. Diagram showing the relation of mineral composition of tissue to yield. See text for explanation of symbols.

critical values. One method is by sand or water culture. While this is very expensive for trees, it is used by a few plant nutritionists (Reuther and Smith, 1954). Here various combinations of elements may be added and response measured very early. Field experiments are used in many cases, but they require a long time to obtain results due to various soil factors (Thomas and Anthony, 1926; Reuther and Smith, 1954). Surveys have been used by some but the values found depend wholly on the nutrition of the trees or plants selected as the standards (Kenworthy, 1961; Smith and Taylor, 1952). Reuther and Smith (1954) state that surveys may provide a background for future work, or if the leaf concentrations are correlated with yield or growth some way, useful information may be obtained.

Shear et al. (1960) proposed a new method for determining critical levels. In working with tung trees, the concentration of each element was plotted on a graph as it varied from the basal to terminal leaves of a branch. The concentration of a given element would increase or decrease and then revert back making a curve as analysis progressed from basal to terminal leaves. The concentration where the gradient changed direction was considered the critical level.

Those opposed to critical level values point out that an incomplete and misleading understanding of relationships between the many variable factors may be obtained when effects of one nutrient are studied at a time while holding

all other nutrients at a high and constant level (Dumenil, 1961).

Those against the balance theory doubt that all the elements would ever reach a specified intensity all at once to give maximum growth or yield even if all the environmental factors were simultaneously controlled (Smith, 1962). Ulrich (1952) states:

> While it appears logical to consider all fifteen elements (carbohydrates, etc., should be included also) as having a specific balance and proper intensity for maximum growth, nevertheless, the practical difficulty of demonstrating the uniqueness of a given balance is not easily attained experimentally. . . . It is not even possible at present to maintain a single nutrient at a specific concentration within a leaf, let alone a whole series of nutrient elements, for study at given concentrations.

Selection of sample and preparation

Obtaining a representative sample. Ulrich (1948) states that samples are generally "taken from an adequate number of plants which will represent a given condition." These conditions may be soil type, geographic area, cultural or fertilizer practice, stage of development of the crop, cropping history of the field, or others. In taking a survey, most workers have used a stratified random sampling plan in which some of these variables and others that might influence the nutrient content of the tissue are eliminated.

Emmert (1955) sampled orchards in Connecticut having permanent sod; the orchards were selected so there would not be a concentration in any one area in the state; trees sampled were selected and tagged, and none of the trees showed any

signs of having pathological disorders. There was no mention made as to the randomness of the selections made. Heeny and Hill (1961) selected mature McIntosh orchards over the major apple growing areas of southwestern Quebec which represented many variations in management and fertilizer practices. Walker and Mason (1960) obtained the names of apple growers in the four major fruit producing counties of North Carolina having a total of at least 500 trees of at least one of four main varieties. The trees of a given variety were subdivided into sampling units of ten trees each, and the units were then pooled within a county. A random sample of ten units was drawn for each variety in each county.

Tissue samples. Emmert (1959) and Shannon (1954) have compiled tables showing the various tissues that have been sampled. Some tissues have proven to be better for diagnostic purposes for some elements than others. For the analysis of several elements the whole leaf midway on the current season's growth has been selected by many investigators for their samples.

There is a wide variation in sampling schemes for surveys as well as field plot work. Walker and Mason (in press) compiled a table showing the variation in nutritional survey sampling schemes among investigators. The table shows that the leaves per tree varied from 5 to 30; the number of trees sampled varied from 3 to 10; the number of leaves per sample varied from 15 to 150, and the number of orchards sampled varied from 21 to 204. Walker and Mason further

showed that a small number of leaves per tree, more trees per sample, one analytical determination, and a large number of orchards sampled gave a higher precision for a given number of samples than collecting a large number of leaves from a few trees and a few orchards. Smith et al.(1954) reported that 30 mid-shoot leaves collected per sample per tree gave results comparable to that gained by using all the leaves on the tree amounting to several thousand. Steyn (1961) showed that 25 leaves per sample selected with great care in terms of age and position would adequately represent the status of most of the elements in a mature citrus tree.

Preparation. Leaf samples being assayed for total nutrients on a dry weight basis are generally stored in a cooler or refrigerator between 0 to 5 C if they cannot be taken directly to the laboratory for analysis (Reuther and Smith, 1954). If only analysis for the macro elements is done, washing is not necessary. However, if heavy metals are to be determined, especially iron or aluminum, it is essential that the leaves be washed (Smith and Reuther, 1950).

Previously it was thought that leaves would be cleaned sufficiently if wiped with a damp cloth (Kenworthy, 1953). One group of workers (Roach, 1949) made some buffing wheels to clean each leaf separately but later found that the cleaning was insufficient. Mason (1952) suggested that each leaf be submerged in a detergent solution for 10 seconds, scrubbed with a soft grade nylon toothbrush, rinsed in three changes of distilled water, shaken, air dried, wrapped in muslin, and

oven dried. This undoubtedly was a long process. Reuther and Smith (1954) suggested that the whole sample be placed in a 2 to 3 liter wide mouth glass jar with a screw top lid to which about 500 ml of 0.3 N HCl and 1 gram of detergent is added. The bottle should be shaken for two minutes, decanted and rinsed with four or five rinses of distilled water.

Taylor (1956) used five cleaning procedures and showed that a detergent plus chelate wash with several rinses was very effective in removing iron, and lead contamination. However, he found that there was no significant difference between cleaned and uncleaned leaves for levels of nitrogen, phosphorous, potassium, calcium, magnesium, manganese, copper, or boron. Taylor's data indicated that there was no leaching of even the most soluble elements when the leaves were immersed in the cleaning solutions. Tukey, Tukey, and Wittwer (1958) showed that there was a 4% loss of Ca, and a 3% loss of K in corn leaves that were soaked in water for two hours. He also found that nutrients were lost more readily from attached leaves than detached leaves. Smith, Reuther, and Specht (1950) reported no loss of any element when orange leaves were subjected to several cleaning treatments, including immersion in a detergent solution and scrubbing for as long as six minutes.

MATERIALS AND METHODS

Selection of the sample

Names and addresses of the sweet cherry growers in Box Elder, Davis, Salt Lake, Utah, Washington, and Weber counties were obtained through the help of the county agents. These six counties produce 99.2% of the sweet cherries grown in Utah according to the U. S. Bureau of the Census (1956). Two hundred and fifty-eight questionnaires were mailed to the growers to obtain information concerning the management and fertilization practices performed throughout the state. Ninety-three or 36% were returned. Valuable information was obtained, but it was impossible to select a sample from the returned questionnaires that would justly represent each county. Therefore, it was decided to arrange all the growers' names alphabetically for each town within each county and select every third name from which to collect a sample. The sampling was limited to Bing variety and to growers with at least 10 trees five years of age or over. If the orchard did not meet these qualifications, the next name on the list was selected. Bing cherry trees were identified by observing the absence of pubescence on the petiole of the leaf. Other commonly grown varieties contain pubescence in varying amounts. Few bark lenticels on Bing was another characteristic which was used to help identify

Bing from Lambert which has numerous bark lenticels. The use of this sampling scheme resulted in the collection of 15 samples from Box Elder county, 16 from Weber county, 14 from Davis county, 29 from Utah county, and 5 from Washington county to make a total of 79 samples for the state. Salt Lake county was eliminated because only two or three small orchards existed (Figure 2).

An attempt was made to collect the leaves just prior to harvest season. This time was chosen because the trees are sometimes damaged by the pickers. It has also been noticed by the author that some trees after harvest have become slightly wilted. A sudden loss of all the fruit may also be somewhat of a shock to the tree. It was thought that these factors may upset the metabolism of the plant and thus change the nutrient composition to some degree. Hence, the samples from Washington county were collected on May 20 and the remaining samples were collected between June 22 and June 29.

Each sample consisted of five clean, non damaged leaves collected from the middle portion of the current season's growth, four to seven feet high and from each of 10 trees selected at random throughout the orchard to make a total of 50 leaves. The leaves were placed in a polyethylene bag, labeled, and stored in a portable ice chest until they could be put in a refrigerator in the laboratory.

During the collection of each sample, notes were recorded as to the vigor, terminal growth, disease occurrence

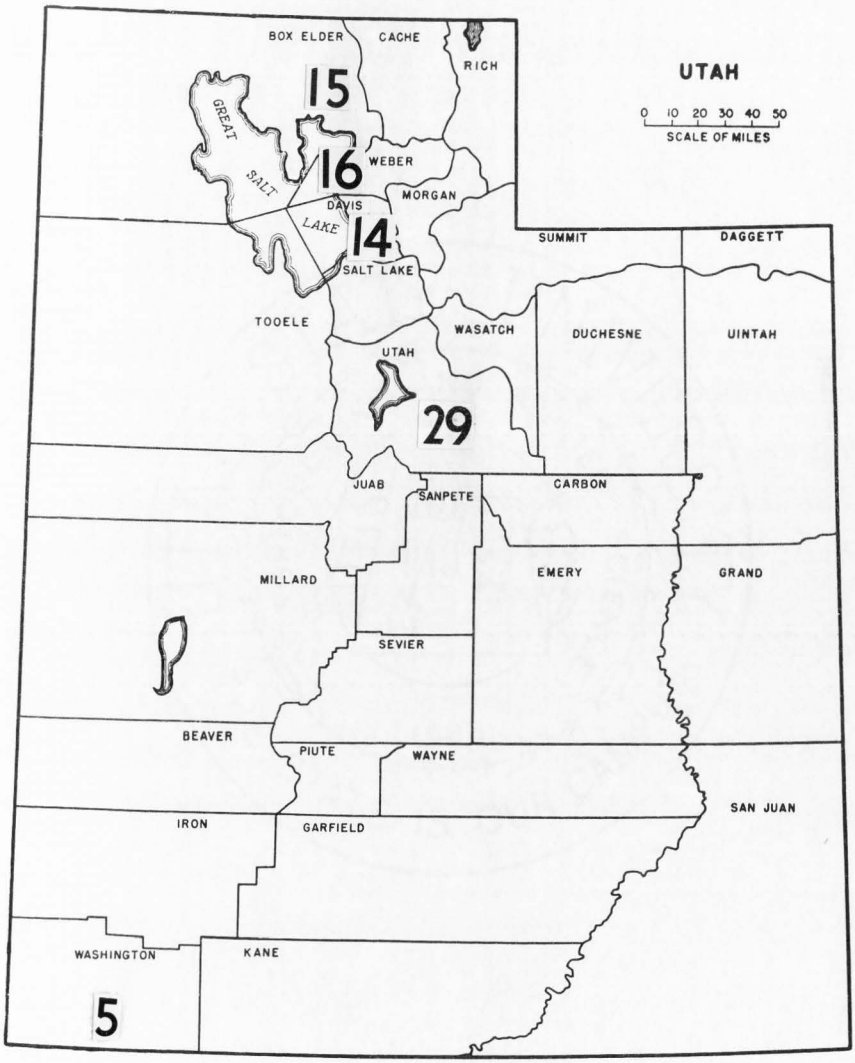

Figure 2. Number of Bing cherry leaf samples collected from the main fruit producing counties, 1961.

nutritional disorders, type of cultivation, age of tree, and size of crop with the idea in mind of correlating nutrient-element levels with the condition of the trees.

Additional samples were collected for the secondary objectives as follows: (1) To compare the nutrient-element variation between Bing and Lambert varieties, one sample consisting of 40 mid-shoot leaves from each of the five trees was collected for each variety. The trees were located on the same block of land and were the same age and had the same general appearance. (2) To determine if there was any correlation between the nutritional condition of a cherry tree and the occurrence of major virus diseases, samples were collected from uniform trees that had been inoculated with a specific virus. Attempts were made to obtain as many replications as possible, and approximately 35 to 40 leaves comprised a sample. The following treatments were sampled: (a) Five virus-free, three-year-old Bing trees which had been budded high on Mahaleb rootstock and growing consecutively in the row were each sampled to act as a control. (b) Three trees similar to the ones above had two or three scaffold branches inoculated with western X virus and were showing symptoms of the disease. One sample was selected from the infected portion of each tree. (c) The scaffold branches that were not inoculated under treatment (b) appeared normal. One sample was selected from the non-infected portions of each tree and compared with samples from the healthy portion of the same tree. (d) Four trees also similar to those

described under (a) had been inoculated with necrotic rusty mottle virus and were showing moderate symptoms. One sample was collected from each tree. (e) One sample was collected from each of two trees which were also similar to those under (a) but had been inoculated with rugose mosaic and were showing typical symptoms of the virus. (f) One sample was also taken from a ten year old Bing tree budded low on Mazzard rootstock which had no known virus. (3) To observe the seasonal trend of the nutrient-element levels within the foliage tissue, five Bing trees were selected in each of two orchards which represented two types of management practices. One orchard had permanent sod cover and was seldom irrigated, sprayed, or fertilized. The trees lacked vigor and averaged about 2 inches of terminal growth, and viruses and dieback were prevalent. The second orchard was clean cultivated, regularly irrigated, sprayed, and fertilized. The trees were very vigorous and had about 12-18 inches terminal growth during the season, and there were no visible diseases. A sample consisting of 40 mid-shoot leaves was collected from each tree on May 30, June 29, July 29, September 2, and September 26. The values obtained for each element were plotted for each sampling date and for the separate orchards so that samples collected at any time throughout the year could be compared to the values obtained in this study. (4) To determine the variation of the nutrient-elements due to the sampling position of the leaves on the trees, one sample of 40 mid-shoot leaves and one sample of 40 non-fruiting spur

leaves were collected from the periphery of each of five Bing trees growing under the same conditions. (5) To determine the effect of various cleaning techniques for the removal of contamination, 120 mid-shoot leaves were collected from the periphery of each of three Bing trees growing under the same conditions and equal in size, age, and vigor. Each tree sample was subdivided into lots of 30 leaves for the following treatments: (a) no wash; (b) one distilled water wash; (c) EDTA plus Alconox detergent wash, one tap water rinse, and two distilled water rinses; (d) EDTA plus Alconox detergent wash, one tap water rinse, two distilled water rinses, and one deionized water rinse (explained in detail under "Preparation of Samples").

Answers obtained from the questionnaires were tabulated according to the different fertilizer practices and compared with the amount of foliar nitrogen. Some of the regular samples from the survey were included for the determination of the secondary objectives making a total of 172 separate samples collected for the entire project.

Preparation of samples

The samples were each washed vigorously by hand for 10 to 15 seconds in a pan containing 6 grams of ethylenediamine tetraacetic acid,[1] 2.5 grams of Alconox laboratory detergent,

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[1]Sequestrene--A.H. (99% EDTA). Supplied for this experiment by Geigy Agricultural Chemicals, Division of Geigy Chemical Corporation, Yonkers, New York.

and 3 liters of warm tap water (40 C). They were then transferred to a sink containing 20 to 25 liters of cool tap water for a 10 second rinse. Two successive rinses in distilled water of 15 liters each and one rinse in one liter of deionized water completed the washing procedure which took 40 to 50 seconds per sample. The detergent plus EDTA and the two distilled water rinses were changed after every fifth sample, but the tap water rinse and the deionized water rinse were changed for every sample (Figure 3). The leaves were shaken to remove the excess water, placed in a paper sack, and covered with a clean dish towel, and dried in a forced air draft oven at 70 C for 48 hours. A Wiley mill equipped with stainless steel blades and a 40 mesh screen was used to grind the samples into a fine powder which was collected directly into four ounce jars. The jars were sealed and stored until the analyses. A household vacuum with a converging spout on the end of the hose was used to clean the Wiley mill between each sample.

Chemical analyses and apparatus

The leaf samples were oven dried at 70 C before an aliquot was weighed and analyzed. The samples were analyzed for the total amounts of nitrogen, phosphorous, potassium, calcium, magnesium, iron, manganese, copper, and zinc.

Total nitrogen was determined by a modified Kjeldahl procedure for plant tissue used by the USDA Soil Conservation Service laboratory at Utah State University.

Figure 3. Leaf washing procedure showing the EDTA plus detergent wash, a tap water rinse, two distilled water rinses and one deionized water rinse.

To eliminate weighing and ashing an aliquot for the analysis of each element or just a few elements at a time, it was desirable to develop a single ashing procedure that would be satisfactory for the determination of all the remaining elements. This meant treating the one digestion with as much care as would be required for any of the elements needing special techniques or precautions. Therefore, deionized water was used throughout the experimental procedures, and other precautions were included that were necessary for certain elements but not for the other elements. All glassware was cleaned with 2 or 3 N hydrochloric acid, rinsed several times with tap water and twice with deionized water. Most analysts realize that micronutrient elements are retained in the silica when dry ashing procedures are carried out unless special laborious processes are included (Humphries, 1956; Mason, 1949; Mason and Whitfield, 1958; Ulrich and Johnson, 1959). Ulrich and Johnson (1959) point out that wet ashing procedures are "eminently superior" to dry ashing procedures in the determination for all elements except for boron and the halides. Two reasons in favor of wet ashing are (a) the digest cannot exceed the boiling points of the acids, and therefore, most of the elements are not lost; (b) the silica residue is completely dehydrated and left in a form where the adsorption of micronutrients is negligible. Therefore, a wet ashing procedure was developed by modifying the methods used by Ulrich and Johnson (1959, p. 33) and the USDA Agricultural Research Service crops laboratory at Utah State University.

The ground samples were oven dried at 70 C for six to eight hours, and one gram aliquots were weighed to the nearest milligram into 125 ml Phillips beakers. Ten ml of concentrated nitric acid were added and allowed to stand overnight or for five or six hours. The samples were then heated on a hot plate in a fume hood specially lined with ceramic and equipped with a water spray (to wash the walls periodically) for perchloric acid digestions. The rate of heating was controlled so that large amounts of nitric oxide fumes were not lost. After the plant material was dissolved and the volume had been reduced to 5 ml, the flasks were removed from the hot plate, and 4 ml of 70% perchloric acid were added. The heat was increased and the digestion continued until a total of 2 or 3 ml remained in the flasks. The total digestion time took two hours. Perchlorate crystals formed upon cooling which were dissolved by washing down the inside of the flask with about 15 ml of deionized water and gently warming in a water bath. The solution was then quantitatively transferred to a 50 ml volumetric flask and brought to volume with deionized water. The sample was transferred to a 50 ml centrifuge tube and centrifuged for 20 minutes to force the silica residue to the bottom of the tube. An aliquot of 25 ml was pipetted into a 100 ml tall form beaker for the analyses of the micronutrient elements--manganese, copper, iron, and zinc. The remainder of the solution was carefully decanted, so that the silica was not disturbed, into a test tube which was sealed with a rubber

stopper (cork stoppers became moldy after a time) and saved for the analyses of the macronutrient elements--phosphorous, potassium, calcium, and magnesium.

The micronutrient elements were separated with the use of an ion-exchange resin column and determined colorimetrically as described by Hunter and Coleman (1960). The resin columns[2] were made with a pyrex test tube at least 7/8 inch inside diameter and a capacity of 20 to 30 ml to form the reservoir. A hole was made in the bottom of the test tube and a piece of glass tubing 30 cm long and 5 mm inside diameter was sealed to bottom where the hole was. The opposite end of the tubing was drawn out and broken off to make a constriction so the resin would not fall out. A plug of fine glass wool was placed in the tapered end and the column was filled with a slurry of AG 1 X 8, 100-200 mesh anion exchange resin to make the resin column 27 cm long. Ground pyrex glass, fine enough to pass through a 105 micron screen was placed on top of the resin 1 cm deep to hold the resin in place and prevent drainage of the column and entry of air. The flow rate of the column averaged about 1 drop of water every 25 to 30 seconds and could be regulated by the amount of fine or course ground glass placed on the top of the resin. The ground glass that was too fine was separated by flotation from the courser glass (Figure 4).

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[2]Resin columns were constructed by Dr. A. H. Hunter, Ortho Chemical Division, Portland, Oregon.

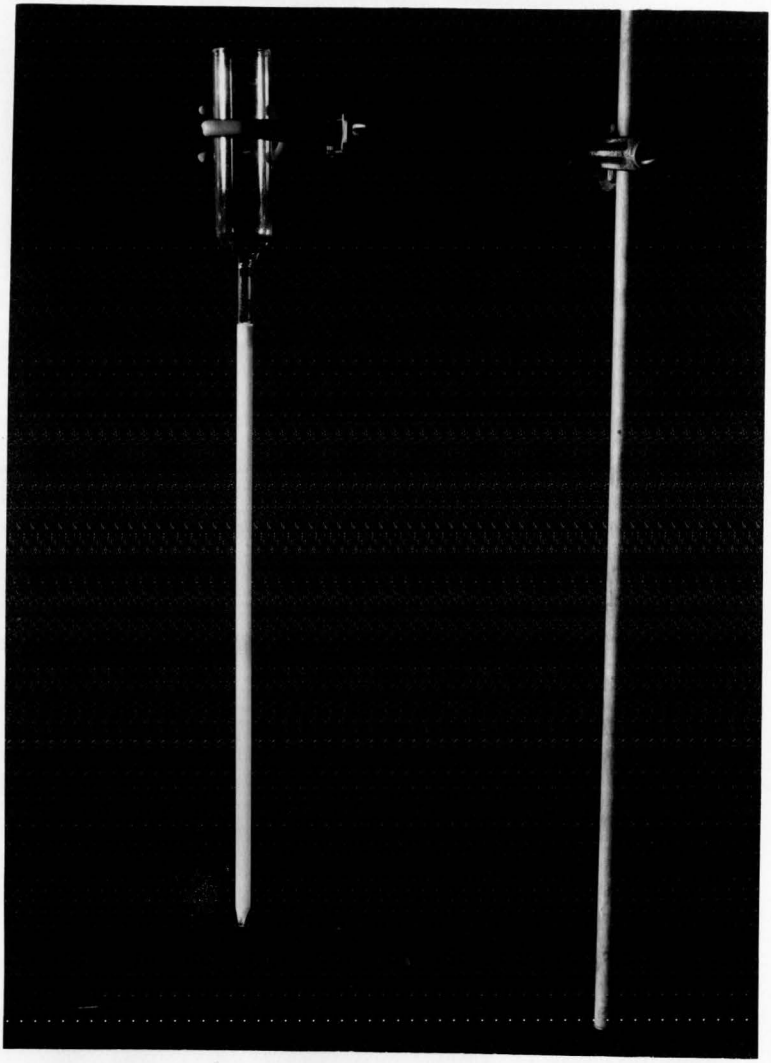

Figure 4. Resin column used for separating micronutrient elements.

According to Ulrich and Johnson (1959), perchloric acid used in wet digestion procedures interferes with the absorption of zinc on the resin. Therefore, the perchloric acid was reduced by adding one drop of concentrated sulfuric acid to the 25 ml aliquot for the micronutrient analysis, and the solution was taken to dryness in the ceramic fume hood. This was done rapidly at first and then very slowly during the last 3 or 4 ml to prevent the crystals from spattering out of the beaker. The heat was again turned to high to be certain that all of the fumes which had condensed on the side of the beaker were removed. This required about four hours. The fuming converts orthophosphate to pyrophosphate which forms an insoluble compound with zinc (Ulrich and Johnson, 1959). This was overcome by adding 5 ml of concentrated hydrochloric acid, covering with a watch glass, and heating gently for about 30 to 45 minutes or until all of the crystals were in solution. This decreased the volume to about 3 or 4 ml and the concentration of the acid to approximately 6 M (constant boiling hydrochloric acid is about 6 M). The hot solution was then transferred quantitatively to the resin columns.

Manganese moves gradually through the column if the resin is charged with 9 M hydrochloric acid and the plant sample is made up with the same molarity. Since the final solution was only approximately 6 M when ready to be placed on the column, manganese was partly lost before the first elution fraction was placed on the column. It was found

that by charging the resin column with 5 ml concentrated hydrochloric acid and also quantitatively washing the plant sample out of the beaker with two 1 to 2 ml aliquots of concentrated hydrochloric acid the molarity of the solution and the resin was sufficient to hold manganese if the volume was kept below 10 ml. Time was also a factor. It took approximately 42 seconds for 1 drop of concentrated acid to flow through the column which increased the time considerably if an excess of acid was put on the column the first time. Therefore, it was advantageous to keep the total volume of the original sample plus the washings to 7 or 8 ml or less.

When the excess solution from the plant sample plus washings had passed through the resin column, aluminum, nickel, and other unwanted ions were eluted and discarded. Various hydrochloric acid solutions were then added to the column in succession to elute the desired elements as indicated in Table 1. The entire run took about 12 hours and the different fractions were analyzed according to the procedures of Hunter and Coleman.

Table 1. Hydrochloric acid solutions used to elute the micronutrient elements from the resin columns and the methods used to determine their concentration.

Volume HCl(ml)	Molarity HCl	Element eluted	Method used for determination
8[a] (sample plus washings)	9[a]	Unwanted ions	Discarded
10	6	Manganese	Periodate
10	2.5	Copper	Zincon
10	0.5	Iron	Thioglycolic
15	0.005	Zinc	Zincon

[a]Estimated

Two stands holding 15 resin columns each were constructed so that 22 samples could be determined at once plus duplicates of 4 standard solutions to make a total of 30 columns operating simultaneously (Figure 5). When the columns were not in use they were stored in a 5 gallon plastic pail full of deionized water fitted with a lid constructed with holes in it to support the resin columns (Figure 6). A large plastic bag was put over the top of the columns to keep dust out and maintain a high humidity to prevent the resin from drying out.

A 5 gallon polyethylene carboy was used as a reservoir to hold a fresh supply of deionized water at all times (Figure 7). An automatic valve fitted in the top of the carboy was constructed to allow the water to run into the reservoir when the water level was low and shut the water off when the reservoir was full (Figure 8). The deionized water, with an electrical resistance reading greater than 250,000 ohms, was made by passing distilled water through a mixed bed resin column. Three all-plastic cylinders 7 inches long and 2 inches in diameter were constructed to hold the resin. Plastic plugs were cut to fit both ends of the cylinders snugly. One plug was sealed in with methyl cellulose solvent. The other plug was made water tight with a rubber gasket held tightly in place with two long stove bolts screwed tightly in the ends of a metal strap 3-1/8 x 1 x 1/8 inches on each end of the cylinder. A small hole was drilled in the center of each plug and a small piece of plastic

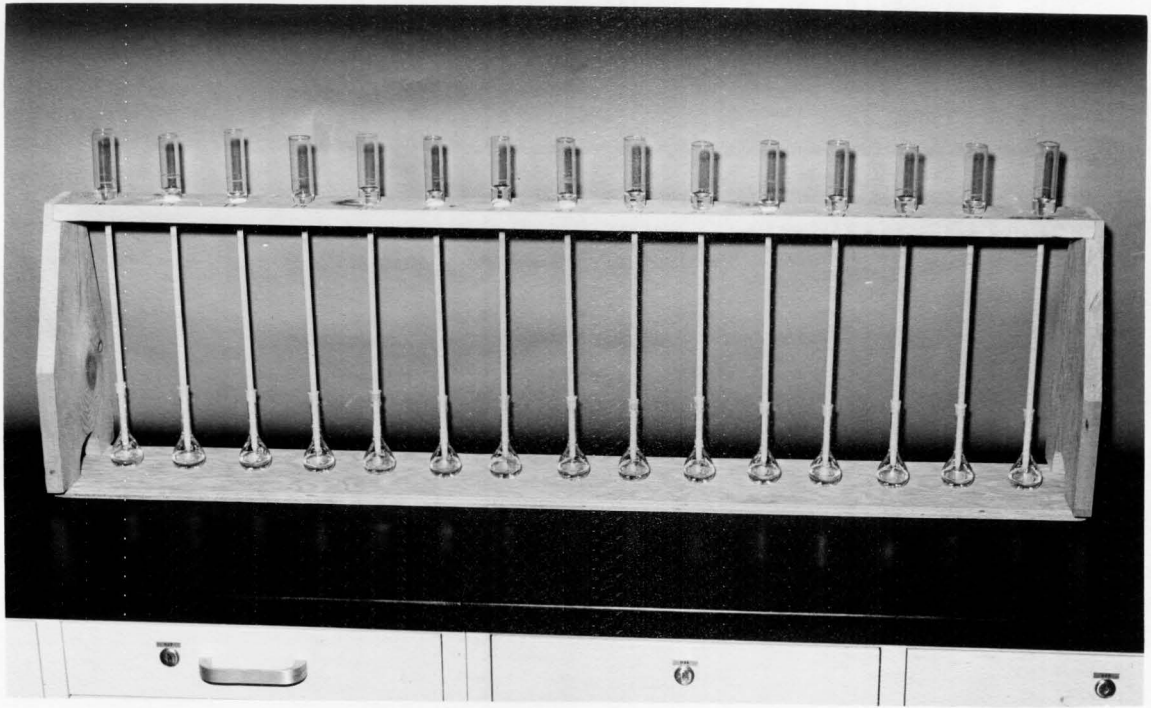

Figure 5. Stand holding 15 resin columns.

The results of the chemical analyses were analyzed statistically by using the analysis of variance procedure of Snedecor (1956) and least significant difference procedure of Cochran and Cox (1957). The standard deviation was calculated and subtracted from the state's mean values for each nutrient-element determined. The values determined by subtracting the standard deviation from the mean were used merely as a guide to determine which orchards were relatively low in the various nutrient-elements.

RESULTS AND DISCUSSION

The results of the analyses for nitrogen, phosphorous, potassium, manganese, copper, iron, and zinc in the foliage from the survey of 79 Bing cherry orchards in Utah are presented. Comparisons among the counties from which the orchards were chosen are made. Data concerning the additional samples collected for the determination of factors affecting the nutrient levels in sweet cherries are also discussed.

Survey

The mean values for the macronutrients in the state's Bing cherry orchards were approximately the same general levels as reported for other fruit crops in other areas. Nitrogen was 2.32%, phosphorous was .25%, and potassium was 1.42%. Foliar nutrient levels for optimum growth and production for sweet cherries are not well defined. Since optimum or critical levels were not available for comparison, the standard deviation was subtracted from the mean for a guide as to which orchards were relatively lower in the nutrient-elements than other orchards. The disadvantage of this procedure is that a certain percentage of the orchards will be below this level even though the actual amount may be adequate. Using this method, 11 to 20 per cent of the orchards were below the mean minus the standard deviation for the macro elements.

The mean micronutrient element values for the state were 39 ppm manganese, 10.8 ppm copper, 60.5 ppm iron, and 18.9 ppm zinc. When the standard deviation was subtracted from these values, 24, 16, 16, and 8 per cent of the orchards appeared to be relatively low in manganese, copper, iron, and zinc respectively. The coefficient of variation was 41 and 51 per cent for manganese and zinc which appeared rather high. However, this is conceivable when examining the wide ranges. A wide range would make the standard deviation high which in turn would cause a high coefficient of variation. Wide ranges of nutrient-elements in plants have been noted without any deficiency or toxicity symptoms appearing. Thorne and Wann (1948) reported that the concentration of manganese in non-deficient peach leaves was 24 ppm while the concentration in mild deficient leaves was 3.1 ppm. This indicates that the plant may contain much more of a nutrient-element than is needed for good plant growth; hence, wide ranges and great variations are possible. Wide ranges may also be due to analytical errors involved in measuring such minute quantities. A summary of the nutrient-element status of Bing cherry trees in Utah is given in Table 2.

The mean nutrient values for the state were all lower than the standard values proposed by Kenworthy (1961) for sour and sweet cherries combined except for phosphorous which was the same. Nitrogen and potassium were in the same general area but the micronutrients were more than three times lower than the proposed standard values. The mean values for Utah

Table 2. Nutritional status of Bing cherry trees. Foliar samples collected June 22-29, 1961.

Nutrient	High	Low	Mean	Std dev	Mean minus std dev	Coeff var	Samples below $\bar{X} - s$[b]	
	% dry wt					%	No.	%
N	3.00	1.77	2.32[a]	.30	2.02	13.0	15	19
P	.38	.15	.25	.06	.19	21.9	9	11
K	1.85	1.00	1.42	.18	1.24	12.8	16	20
	ppm dry wt							
Mn	111	11	39.0	16.0	23.0	41.0	19	24
Cu	18	6	10.8	2.4	8.4	21.7	13	16
Fe	120	42	60.5	13.9	46.6	23.0	13	16
Zn	68	5	18.9	9.6	9.8	51.0	6	8

[a]Mean of 79 samples.

[b]Samples below the mean minus the standard deviation.

and Kenworthy's proposed standard values are compared in Table 3.

Table 3. Mean nutrient-element levels of Utah Bing cherry leaves compared with Kenworthy's[a] standard values for cherries.

Nutrient	Utah means	Std values
	% dry wt	% dry wt
Nitrogen	2.32	2.95
Phosphorous	.25	.25
Potassium	1.42	1.67
	ppm dry wt	ppm dry wt
Manganese	39.0	150
Copper	10.8	57
Iron	60.5	203
Zinc	18.9	---

[a]Kenworthy, 1961.

The breakdown of the nutritional status of Bing cherry trees in Utah is given in Tables 4 through 10 for the individual counties from which samples were collected.

Table 4. Nitrogen content (% dry wt) of Bing cherry leaves collected June, 1961.

County	No. samples	Range High	Range Low	Mean	Samples below $\bar{x}$ - s No.	Samples below $\bar{x}$ - s %
Box Elder	15	2.77	1.77	2.22	3	20
Weber	16	2.65	1.82	2.21	6	38
Davis	14	3.00	1.77	2.40	2	14
Utah	29	2.95	1.82	2.42	3	10
Washington	5	2.41	1.93	2.24	1	20

Table 5. Phosphorous content (% dry wt) of Bing cherry leaves collected June, 1961.

County	No. samples	Range High	Range Low	Mean	Samples below $\bar{x}$ - s No.	Samples below $\bar{x}$ - s %
Box Elder	15	.38	.15	.23	2	13
Weber	16	.38	.16	.26	2	12
Davis	14	.35	.20	.27	0	0
Utah	29	.34	.17	.24	5	17
Washington	5	.26	.20	.22	0	0

Table 6. Potassium content (% dry wt) of Bing cherry leaves collected June, 1961.

County	No. samples	Range High	Range Low	Mean	Samples below $\bar{x}$ - s No.	Samples below $\bar{x}$ - s %
Box Elder	15	1.60	1.00	1.31	7	9
Weber	16	1.85	1.10	1.48	2	12
Davis	14	1.78	1.02	1.34	4	28
Utah	29	1.85	1.15	1.45	3	10
Washington	5	1.70	1.52	1.60	0	0

Table 7. Manganese content (ppm dry wt) of Bing cherry leaves collected June, 1961.

County	No. samples	Range High	Range Low	Mean	Samples below $\bar{x}$ - s No.	Samples below $\bar{x}$ - s %
Box Elder	15	111	28	51	0	0
Weber	16	57	23	36	1	6
Davis	14	75	19	48	1	7
Utah	29	72	11	28	16	55
Washington	5	65	19	46	1	20

Table 8. Copper content (ppm dry wt) of Bing cherry leaves collected June, 1961.

County	No. samples	Range High	Range Low	Mean	Samples below $\bar{x}$ - s No.	Samples below $\bar{x}$ - s %
Box Elder	15	14	7	10.2	3	20
Weber	16	14	8	10.6	3	19
Davis	14	18	6	10.5	6	43
Utah	29	14	6	11.0	1	3
Washington	5	17	10	12.8	0	0

Table 9. Iron content (ppm dry wt) of Bing cherry leaves collected June, 1961.

County	No. samples	Range High	Range Low	Mean	Samples below $\bar{x}$ - s No.	Samples below $\bar{x}$ - s %
Box Elder	15	120	52	72	0	0
Weber	16	96	48	61	0	0
Davis	14	112	52	67	0	0
Utah	29	68	42	54	8	28
Washington	5	44	42	43	5	100

Table 10. Zinc content (ppm dry wt) of Bing cherry leaves collected June, 1961.

County	No. samples	Range High	Range Low	Mean	Samples below $\bar{x}$ - s No.	Samples below $\bar{x}$ - s %
Box Elder	15	37	8	20.5	1	7
Weber	16	32	5	16.0	4	25
Davis	14	68	10	21.9	0	0
Utah	29	48	6	17.7	1	3
Washington	5	28	18	22.0	0	0

The t-test was used in measuring the differences in the nutrient status of the sweet cherry orchards among the counties. Since there were an unequal number in each county, the pair of extreme means for the northern four counties were used in computing the differences. By comparing the extreme means it was possible to determine whether or not there was significance among the counties for the various nutrient-elements. If significance occurred it is possible that other county means may be different also. However, if significance was not present for the extreme means, there was assurance that no differences would be expressed among any of the counties. Washington county was not compared with the other four counties since a much smaller proportion of the state's cherry production is in that county. Samples were collected in that area merely as supplementary information.

Utah county orchards were higher in foliar nitrogen than Weber county orchards. There were no differences among the county averages for phosphorous. Foliar potassium values were less in Box Elder county cherry orchards than Weber county orchards. Manganese and iron values were greater in Box Elder county than in Utah county orchards. Differences were not apparent for copper and zinc; however, there was some indication that Utah and Weber counties were lower in zinc than other counties. Table 11 shows the mean values for the nutrient-elements and the least significant difference between the counties compared.

Table 11. County means of the nutrient-elements in Bing cherry leaves, June, 1961.

County	% dry wt N	P	K	ppm dry wt Mn	Cu	Fe	Zn
Box Elder	2.22	.23 ·	1.31 ·	51 ·	10.2 ·	72 ·	20.5
Weber	2.21·	.26	1.48 ·	36	10.6	61	16.0 ·
Davis	2.40	.27 ·	1.34	48	10.5	67	21.9 ·
Utah	2.42·	.24	1.45	28 ·	11.0 ·	54 ·	17.7
Washington	2.24	.22	1.60	46	12.8	43	22.0
L.S.D.[a] .05	.18	N.S.	.14	10.9	N.S.	8.7	N.S.
.01	N.S.	---	N.S.	14.6	---	11.6	---

[a]Least significant difference determined with t-test for extreme means of the first four counties only. Dots indicate which values were compared.

Variety

Foliar nutrient levels were significantly different between Bing and Lambert sweet cherry varieties. The nutrient values for Bing cherry leaves were lower than Lambert leaves in nitrogen, phosphorous, and copper. However, Bing leaves were higher than Lambert leaves in zinc content. The data are presented in Table 12.

Table 12. Nutrient-elements of Bing and Lambert cherry leaves, June, 1961.

Variety	% dry wt N	P	K	ppm dry wt Mn	Cu	Fe	Zn
Bing	1.81[a]	.21	1.21	39.5	9.2	67.0	16.8
Lambert	2.36	.26	1.29	38.7	12.0	60.2	8.5
L.S.D. .05	.21	.04	N.S.	N.S.	2.3	N.S.	5.4
.01	.35	N.S.	---	---	N.S.	---	N.S.

[a]Values are the means of 5 samples.

Viruses

The nutrient-element levels of trees infected with western X virus were all generally higher than the untreated controls except for zinc, which was lower. Nitrogen and phosphorous were significantly higher in the diseased portions of the trees than the untreated controls.

The portions of the trees not infected with western X were approximately the same as the untreated controls for nitrogen, potassium, and copper. Phosphorous was higher in the non-infected portions than the untreated controls but not as high as the diseased portions of the trees. Manganese and iron values were higher for the non-infected portions than either the western X portions or the untreated controls. Zinc was lower in the non-infected portions than the untreated controls or the western X portions.

Trees affected with necrotic rusty mottle virus did not differ significantly from untreated trees in the nutrient elements measured. However, the mean nutrient values of the infected trees were slightly higher than the untreated trees except for nitrogen and zinc. Levels of nitrogen in the foliage of the virus infected trees was the same as the untreated trees, and zinc was lower in the foliar content of the virus infected trees than the untreated controls.

Cherry trees infected with rugose mosaic were higher in foliar nitrogen and phosphorous than the untreated trees. The trend for the remaining nutrient-element levels was higher for the diseased trees than the untreated controls but not significantly.

This experiment indicates that there is a difference in the nitrogen composition of trees infected with certain viruses. In general most all nutrient levels were higher among the virus infected trees compared with the non-infected trees. Zinc levels were exceptions which were lower in the foliage of the portions of the trees inoculated with western X, of the non-infected portions of the trees inoculated with western X, and of the trees infected with necrotic rusty mottle virus. Nitrogen and potassium were also low in the trees infected with necrotic rusty mottle.

The one Bing on Mazzard rootstock tree that had not been inoculated with any virus was very low in foliar nitrogen and copper and slightly lower in foliar iron and zinc compared to the untreated controls of Bing on Mahaleb rootstock. Potassium and manganese levels were very high and phosphorous was slightly higher in the foliage of Bing on Mazzard rootstock than untreated Bing controls. Since there was only one tree available of Bing on Mazzard and the age of the trees in the different treatments were very different, no statistical comparisons were made for the nutrient levels between the untreated controls and Bing on Mazzard rootstock. Table 13 shows the results of the effect of viruses on nutrient levels in the foliage of Bing cherry trees.

Table 13. Nutrient-element levels in the leaves of virus infected Bing cherry trees on Mahaleb and Mazzard rootstocks, July, 1961.

Virus	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
a. Control	2.38[a]	.16	.80	27.7	12.0	62.7	28.0
b. Western X	2.79	.38	1.20	32.3	13.0	64.3	21.7
c. Western X on tree but not on limbs sampled	2.36	.22	.74	42.0	13.0	79.3	16.7
d. Necrotic rusty mottle	2.38	.17	.88	34.7	14.7	86.0	22.0
e. Rugose mosaic	2.64	.21	.96	28.0	16.0	72.0	43.0
f. Bing/ Mazzard[b]	1.87	.20	1.72	70.0	8.0	62.0	26.0
L.S.D. .05	.19	.04	N.S.	N.S.	N.S.	N.S.	N.S.
.01	.27	.05	---	---	---	---	---

[a]Each value represents the mean of 3 samples.

[b]Values for this treatment are from one sample only and are not included in the statistical analysis.

Seasonal trend

There was a significant decrease in the foliar level of nitrogen, phosphorous, and potassium on a percentage basis from the May to September sampling. Manganese increased significantly while iron, zinc, and copper remained approximately the same during the season. Most all nutrient-element levels in the foliage were the same for the June 29 and July 29 samplings, which would indicate a good time for sampling leaves. The nutrient values from the two Bing cherry orchards were combined for each sampling date for the seasonal trends. Figures 10 and 11 show the trend of the nutrient-

elements throughout the season, and Table 14 gives the nutrient-element levels determined for the various sampling dates.

Table 14. Seasonal trend of nutrient-elements in Bing cherry leaves, 1961.

Date sampled	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
May 30	2.42[a]	.30	1.40	29.7	10.5	62.2	22.5
June 29	1.90	.20	1.20	32.6	10.7	64.6	19.5
July 29	1.84	.20	1.01	31.8	11.8	60.4	18.5
Sept. 2	1.63	.18	.84	30.9	9.6	59.1	11.5
Sept. 26	1.62	.20	.70	35.4	12.6	71.0	18.5
L.S.D. .05	.15	.02	.09	3.1	N.S.	N.S.	N.S.
.01	.20	.03	.12	4.2	---	---	---

[a]Each value represents the mean of 5 samples from each of two orchards combined.

The individual nutrient values for the five sampling dates were combined for each orchard for comparison of the different management systems. Nitrogen, copper, and zinc were lower in the leaves of the trees from the clean cultivated orchard than the orchard with the cover crop. Phosphorous, potassium, manganese, and iron were all higher in the leaves of the trees in the clean cultivated orchard than the orchard with the cover crop. Table 15 gives the data for the two orchards.

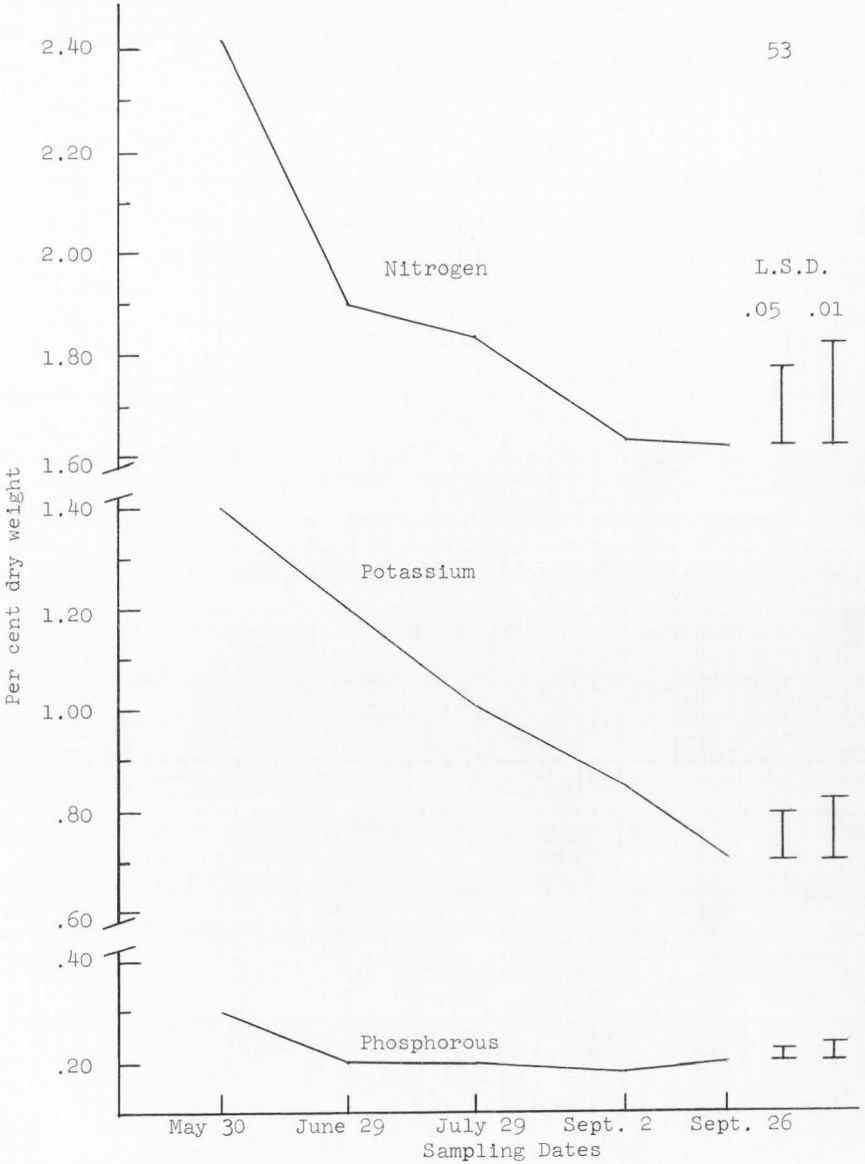

Figure 10. Seasonal trends of nitrogen, potassium, and phosphorous in Bing cherry leaves, 1961.

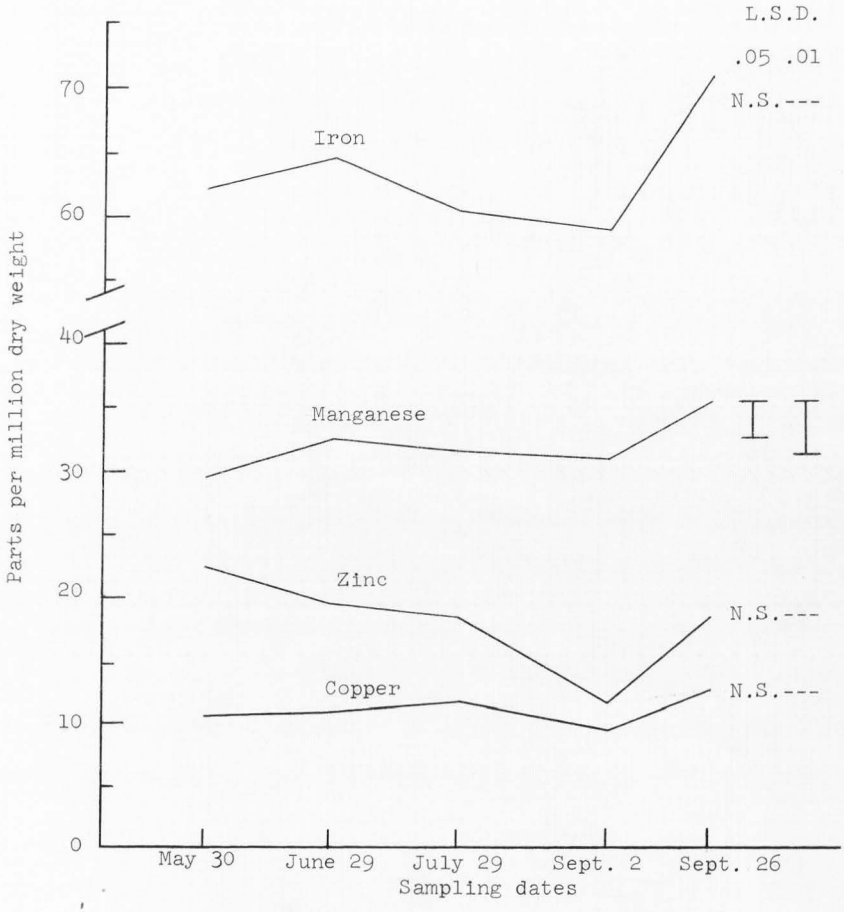

Figure 11. Seasonal trends of iron, manganese, zinc, and copper in Bing cherry leaves, 1961.

Table 15. Nutrient-elements of Bing cherry leaves under two different types of management, 1961.

Management	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
Clean cultivated	1.75[a]	.23	1.11	37.6	8.6	64.1	17.9
Cover crop	2.01	.20	.95	26.6	13.4	62.8	18.3
L.S.D. .05	.13	.02	.08	2.1	1.7	N.S.	N.S.
.01	.18	N.S.	.11	2.8	2.3	---	---

[a]Each value represents the mean of 25 samples collected throughout the season.

Sampling position

Nutrient levels were generally higher in leaf samples taken from the spur growth of Bing cherry trees compared with leaf samples taken from the middle of the current season's growth on the same trees. However, only phosphorous, manganese, and copper levels were significantly higher for the spur leaves than the mid-shoot leaves. The data are presented in Table 16.

Table 16. Nutrient-element content of spur leaves and mid-shoot leaves of Bing cherry trees, July, 1961.

Leaf location	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
Spur	2.16[a]	.21	1.18	66.8	12.4	79.9	7.6
Mid-shoot	2.09	.19	1.18	53.2	9.7	66.8	6.5
L.S.D. .05	N.S.	.02	N.S.	10.2	1.8	N.S.	N.S.
.01	---	N.S.	---	N.S.	N.S.	---	---

[a]Values are the means of 5 samples.

Washing procedure

The nutrient levels in Bing cherry leaves did not differ greatly except for iron and copper when treated with four different cleaning procedures. It appears that a distilled water rinse for the leaves was sufficient for the determination of the majority of the nutrient-elements. However, iron levels were lower when the leaves were washed in EDTA plus a detergent wash with tap and distilled water rinses than when washed with only distilled water. This indicates the need of a good washing procedure for leaves if iron is to be analyzed. The treatment which included a final rinse of deionized water seemed to be of little value when compared to the treatment without the deionized water rinse. However, if micronutrients are to be determined and there is a question as to the purity of distilled water, it may be justifiable, even though time consuming, to rinse the leaves with redistilled or deionized water. In this study the results for manganese and zinc were slightly lower when rinsed with deionized water than when not. Table 17 gives the data for the cleaning procedures.

From the foregoing studies it is apparent that variety, disease, time of season, sampling position, and washing procedures are all important and should be considered when selecting leaf samples for nutritional determinations.

In the questionnaires, information was asked concerning the amount and type of fertilizer that was applied to the

Table 17. The effect of four washing procedures on the nutrient-element content of Bing cherry leaves, September 2, 1961.

Cleaning procedures	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
a. Not cleaned	1.70[a]	.28	1.27	42.0	17.8	228.3	26.7
b. Distilled water	1.77	.28	1.30	40.0	10.8	89.3	13.7
c. EDTA plus detergent with tap and distilled water rinse	1.66	.28	1.32	40.8	8.5	65.7	20.0
d. Same as c plus one deionized water rinse	1.82	.29	1.26	39.7	11.3	67.7	12.3
L.S.D. .05	N.S.	N.S.	N.S.	N.S.	5.5	21.6	N.S.
.01	---	---	---	---	N.S.	32.6	---

[a]Values are the means of 3 samples and 2 determinations of each sample.

orchard. Questionnaires were received from 40 growers whose orchards were sampled. Fourteen growers applied only manure, 7 growers applied ammonium nitrate, 13 growers applied ammonium sulfate, 4 growers applied ammonium phosphate, and 2 growers applied a fertilizer containing nitrogen, phosphorous, and potassium. The growers applying nitrogen containing fertilizers were grouped according to the amount of actual nitrogen that was applied per tree and then compared with the nitrogen levels in the foliage of these orchards. Orchards that received no nitrogen were lower in foliar nitrogen than those that applied 0.5 to 2.0 pounds of nitrogen per tree. Orchards that received 4 pounds or more nitrogen per tree were the highest in foliar nitrogen but there were

only two orchards receiving this amount. A poor correlation occurred in comparing the amount of nitrogen applied between 0.5 and 3.0 pounds and the amount in the foliage. A number of factors may account for this, such as growers not being sure of amount applied, different amounts being applied annually and reserve nutrients being available, a small number of orchards being compared or that cherry trees do not respond to nitrogen fertilizer as generally regarded. Data from the foregoing discussion are presented in Table 18.

Table 18. Nitrogen applied by growers and the per cent nitrogen in the leaves, 1961.

Nitrogen applied per tree	Number Orchards	Foliar nitrogen
Pounds		% dry wt
0	14	2.21
0.5	3	2.43
1.0	16	2.31
2.0	3	2.41
3.0	3	2.19
4.0	2	2.52

SUMMARY

A nutritional survey was conducted on sweet cherries to determine the general nutritional condition of the sweet cherry orchards throughout Utah. Seventy-nine orchards were sampled and analyzed for nitrogen, phosphorous, potassium, manganese, copper, iron, and zinc. The mean values for the nutrient-elements were 2.32% nitrogen, .25% phosphorous, 1.42% potassium, 39 ppm manganese, 11 ppm copper, 61 ppm iron, and 19 ppm zinc. When the foliar nutrient levels for the Bing cherry orchards were compared among counties, Box Elder county orchards were low in nitrogen and potassium; Weber county orchards were low in nitrogen; Utah county orchards were low in manganese and iron; and Washington county orchards were low in iron.

Additional studies were conducted to determine the nutrient-element differences for varieties, the effect of viruses, seasonal trend, sampling position, and washing procedures. There were significant differences for some of the nutrient-elements among the treatments in the various studies. The foliar values for Bing variety were lower than Lambert variety in nitrogen, phosphorous, potassium, and copper but higher in manganese, iron, and zinc. Except for zinc nutrient values were generally higher for trees infected with

viruses. Nitrogen, phosphorous, and potassium levels decreased in the foliage on a percentage basis as the season progressed while manganese increased slightly. Copper, iron, and zinc levels varied throughout the season. Nutrient-element levels in spur leaves were higher than in mid-shoot leaves of the sample of Bing cherry trees. The washing procedure including the EDTA plus detergent wash with several rinses of deionized water appeared to be the most effective washing treatment for leaves in preparation for iron analysis. Otherwise, a distilled water rinse of the leaves appears to be sufficient.

LITERATURE CITED

Batjer, L. P., and J. R. Magness. 1938. Potassium content of leaves from commercial apple orchards. Proc. Am. Soc. Hort. Sci. 36:197-201.

Beattie, J. M., and C. W. Ellenwood. 1950. A survey of the nutrient status of Ohio apple trees. Proc. Am. Soc. Hort. Sci. 55:47-50.

Benson, N. R., L. P. Batjer, and I. C. Chmelir. 1957. Response of some deciduous fruit trees to zinc chelates. Soil Sci. 84:63-75.

Chapman, G. W. 1941. Leaf analysis and plant nutrition. Soil Sci. 52:63-81.

Childers, N. F. 1954. Fruit nutrition. Hort. Publ., Rutgers Univ., New Brunswick, N. J. 907 p.

Cochran, W. G., and Gertrude M. Cox. 1957. Experimental designs. 2nd ed. John Wiley and Sons, Inc., New York. 611 p.

Drosdoff, M. 1954. Role of fertilization of tung trees, p. 181-190. In H. Lundegardh, ed. Plant analysis and fertilizer problems. Inst. de Recherches pour les Huiles et Oleagineux, Paris.

Dumenil, L. 1961. Nitrogen and phosphorous composition of corn leaves and corn yields in relation to critical levels and nutrient balance. Soil Sci. Soc. Am. Proc. 25:295-298.

Emmert, F. H. 1955. Foliar analysis results from forty Connecticut orchards. Conn. Agr. Expt. Sta. Bull. 317.

Emmert, F. H. 1959. Chemical analysis of tissue as a means of determining nutrient requirements of deciduous fruit plants. Proc. Am. Soc. Hort. Sci. 73:521-547.

Gerber, R. K., and M. W. Williams. 1958. Increase yields of peaches and cherries with nitrogen and phosphate fertilizers. Farm and Home Sci. 19(1):16-17.

Goodall, D., L. A. Grant, and W. Slater. 1955. Nutrient interactions and deficiency diagnosis in the lettuce. I. Nutritional interaction and growth. Australian J. Biol. Sci. 8:301-329.

Haddock, J. L. 1961. The influence of irrigation regime on yield and quality of potato tubers and nutritional status of plants. Am. Pot. J. 38:423-434.

Heeney, H. B., and H. Hill. 1961. The use of foliage analyses to determine fertilizer requirements for apple orchards and some vegetable crops, p. 16-27. In W. Reuther, ed. Plant analysis and fertilizer problems. Publ. 8, Am. Inst. Biol. Sci., Washington, D. C.

Humphries, E. C. 1956. Mineral components and ash analysis, p. 456-504. In K. Paech and M. V. Tracy, ed. Modern methods of plant analysis, Springer-Verlag, Berlin.

Hunter, A. H., and N. T. Coleman. 1960. Ion-exchange separation in the determination of some polyvalent metal ions in plant tissue. Soil Sci. 90(4):214-218.

Kenworthy, A. L. 1949. Wheels of nutrition--a method demonstrating nutrient-element balance. Proc. Am. Soc. Hort. Sci. 54:47-52.

Kenworthy, A. L. 1953. Nutritional condition of Michigan orchards. A survey of soil analyses and leaf composition. Mich. Agr. Expt. Sta. Tech. Bull. 237.

Kenworthy, A. L. 1961. Interpreting the balance of nutrient-elements in leaves of fruit trees, p. 28-43. In W. Reuther, ed. Plant analysis and fertilizer problems. Publ. 8, Am. Inst. Biol. Sci., Washington, D. C.

Lagatu, H., and L. Maume. 1926. Diagnostic de l'alimentation d'un vegetal par l'evolution chimique d'une feuille convenablement choisie. Comp. Rend. Ac. Sc. Paris 182:653-655.

Macy, P. 1936. The quantitative mineral nutrient requirements of plants. Plant Physiol. 11:749-764.

Malavolta, E., and F. P. Gomes. 1961. Foliar diagnosis in Brazil, p. 180-189. In W. Reuther, ed. Plant analysis and fertilizer problems. Publ. 8, Am. Inst. Biol. Sci., Washington, D. C.

Marshall, R. E. 1954. Cherries and cherry products. Interscience Publishers, Inc., New York. 283 p.

Mason, A. C. 1949. The estimation of phosphorous, potassium, calcium, magnesium, iron, manganese and nitrogen in plant material. Rep. E. Malling Res. Sta. p. 111-115.

Mason, A. C. 1952. The cleaning of leaves prior to analysis. Rep. E. Malling Res. Sta. p. 104-107.

Mason, A. C., and A. B. Whitfield. 1958. A progress report on the mineral composition of leaves from selected apple orchards in the eastern counties of England. Rep. E. Malling Res. Sta. p. 86-88.

Overhosler, E. L. 1944. Review of literature pertaining to fertilizing cherries. Proc. Wash. State. Hort. Assoc. 40:93-101.

Prevot, P., and M. Ollagnier. 1961. Law of the minimum and balanced mineral nutrition, p. 257-277. In W. Reuther, ed. Plant analysis and fertilizer problems. Publ. 8, Am. Inst. Biol. Sci., Washington, D. C.

Reuther, W., and P. F. Smith. 1954. Leaf Analysis of citrus, p. 254-297. In N. F. Childers, ed. Fruit nutrition. Hort. Publ. Rutgers Univ., New Brunswick, N. J.

Richards, B. L., and L. C. Cochran. 1956. Virus and virus-like diseases of stone fruits in Utah. Utah State Agr. Expt. Sta. Bull. 384.

Roach, W. A. 1949. Biochemistry. Rep. E. Malling Res. Sta. p. 36.

Shannon, L. M. 1954. Mineral content of fruit plants, p. 835-867. In N. F. Childers, ed. Fruit nutrition. Hort. Publ., Rutgers Univ., New Brunswick.

Shear, C. B., H. L. Barrows, M. S. Neff, B. G. Sitton, and W. W. Kilby. 1960. Determining critical ranges in leaf contents of nutrient elements from changes in gradients along the axes of one-year-old tung trees. Proc. Am. Soc. Hort. Sci. 76:310-322.

Shear, C. B., H. L. Crane, and A. T. Myers. 1946. Nutrient-element balance: A fundamental concept in plant nutrition. Proc. Am. Soc. Hort. Sci. 47:239-248.

Smith, C. B., and G. A. Taylor. 1952. Tentative optimum leaf concentrations of several elements for Elberta peach and Staymen apple in Pennsylvania orchards. Proc. Am. Soc. Hort. Sci. 60:33-41.

Smith, P. F. 1962. Mineral analysis of plant tissues. Ann. Rev. Plant Physiol. 13:81-108.

Smith, P. F., and W. Reuther. 1950. Seasonal changes in Valencia orange trees. I. Changes in dry weight, ash, and macro-nutrient elements. Proc. Am. Soc. Hort. Sci. 55:61-72.

Smith, P. F., W. Reuther, and A W. Specht. 1950. Mineral composition of chlorotic orange leaves and some observations on the relation of sample preparation technique to the interpretation of results. Plant Physiol. 25: 496-506.

Smith, P. F., W. Reuther, A. W. Specht, and G. Hrnciar. 1954. Effect of differential nitrogen, potassium, and magnesium supply to young Valencia orange trees in sand culture on mineral composition especially of leaves and fibrous roots. Plant Physiol. 29:349-355.

Snedecor, G. W. 1956. Statistical methods. 5th ed. Iowa State College Press, Ames, Iowa. 534 p.

Stanberry, C. O., and W. J. Clore. 1950. The effect of nitrogen and phosphorous fertilizers on the composition and keeping qualities of Bing cherries. Proc. Am. Soc. Hort. Sci. 56:40-45.

Steenbjerg, F. 1954. Manuring and plant production, p. 31-34. In H. Lundegardh, ed. Plant analysis and fertilizer problems. Inst. de Recherches pour les Huiles et Oleagineux, Paris.

Steyn, W. J. A. 1961. The errors involved in the sampling of citrus and pineapple plants for leaf analysis purposes, p. 409-430. In W. Reuther, ed. Plant analysis and fertilizer problems. Publ. 8, Am. Inst. Biol. Sci., Washington, D. C.

Taylor, G. A. 1956. The effectiveness of five cleaning procedures in the preparation of apple leaf samples for analysis. Proc. Am. Soc. Hort. Sci. 67:5-9.

Thomas, W. 1929. Balanced fertilizers and Liebig's law of the minimum. Science 70:382-384.

Thomas, W. 1937. Foliar diagnosis: Principles and practice. Plant Physiol. 12:571-600.

Thomas, W., and R. D. Anthony. 1926. Eliminating some of the variables in apple fertilizer experiments. Proc. Am. Soc. Hort. Sci. 23:81-87.

Thorne, D. W., and A. L. Stark. 1946. The management of sweet cherry orchard soils. Farm and Home Sci. 7(4): 3, 14-15.

Thorne, D. W., and F. B. Wann. 1948. Manganese deficiency: A new plant nutrient problem in Utah. Farm and Home Sci. 9(3):5, 11, 12.

Thorne, D. W., and F. B. Wann. 1950. Nutrient deficiencies in Utah orchards. Utah Agr. Expt. Sta. Bull. 338.

Titus, J. S., and D. Boynton. 1953. The relationship between soil analysis and leaf analysis in eighty New York McIntosh apple orchards. Proc. Am. Soc. Hort. Sci. 61:6-26.

Tukey, H. B., Jr., H. B. Tukey, and S. H. Wittwer. 1958. Loss of nutrients by foliar leaching as determined by radioisotopes. Proc. Am. Soc. Hort. Sci. 71:496-506.

U. S. Bureau of the Census. 1956. United States census of agriculture. 1954. Vol. I, counties and state economic areas, part 31. U. S. Govt. Printing Office, Washington, D. C.

U. S. Department of Agriculture. 1961. Agricultural statistics. U. S. Govt. Printing Office, Washington, D. C. 624 p.

Ulrich, A. 1948. Plant analysis--methods and interpretation of results, p. 157-198. In H. B. Kitchen, ed. Diagnostic techniques for soils and crops. Am. Potash Inst., Washington, D. C.

Ulrich, A. 1952. Physiological bases for assessing the nutritional requirements of plants. Ann. Rev. Plant Physiol. 3:207-228.

Ulrich, A., and C. M. Johnson. 1959. Plant analysis and analytical methods. Calif. Agr. Exp. Sta. Bull. 766.

Walker, D. R., and D. D. Mason. 1960. Nutritional status of apple orchards in North Carolina. Proc. Am. Soc. Hort. Sci. 75:22-31.

Walker, D. R., and D. D. Mason. (In press.) Nutrient-element variability of apple leaf samples and precision estimate derivations for nutritional field experimental and survey studies with apple trees.

Wallace, T. 1928. Investigations on chlorosis of fruit trees: III. A chlorosis of plums due to potassium deficiency. J. Pomology and Hort. Sci. 7:184-198.

Wallace, T. 1931. Chemical investigations relating to potassium deficiency of fruit trees. J. Pomology and Hort. Sci. 9:111-121.

Walrath, E. K., and R. C. Smith. 1952. Survey of forty apple orchards. Proc. Am. Soc. Hort. Sci. 60:22-32.

Wann, F. B. 1954. Cherry nutrition. In N. F. Childers, ed. Fruit nutrition. Hort. Publ., Rutgers Univ., New Brunswick, N. J.

Woodbridge, C. G. 1954. Zinc deficiency in fruit trees in the Okanogan Valley, British Columbia. Canad. J. Agr. Sci. 34:345-351.

Woodbridge, C. G. 1955. The boron requirements of stone fruits. Canad. J. Agr. Sci. 35:282-286.

APPENDIX

Table 19. Average production and value of fruit in Utah between 1944 and 1958 (U.S. Department of Agriculture, 1961).

Fruit	Quantity produced	Total value
Peaches	498,000 bushels	$1,055,760
Sweet cherries	3,464 tons	1,028,808
Apples	392,000 bushels	807,520
Pears	232,000 bushels	549,840
Apricots	5,090 tons	514,090
Sour cherries	2,095 tons	316,345

Table 20. Average sweet cherry production in the leading states between 1949 and 1958 (U.S. Department of Agriculture, 1961).

State	Quantity produced (tons)
California	29,590
Oregon	22,560
Washington	18,920
Michigan	9,400
New York	4,370
Utah	3,464
Idaho	2,522
Montana	1,331
Pennsylvania	1,160
Colorado	625
Ohio	355

Table 21. Analytical procedures used for the determination of the essential nutrient-elements.

Nitrogen

Reagents

1. Concentrated sulfuric acid.
2. Saturated sodium hydroxide. Dissolve 1 g NaOH per 1 ml distilled water.
3. Digestion mixture. Mix thoroughly 500 g Na_2SO_4, 50 g $CuSO_4 \cdot 5H_2O$, and 5 g powdered selenium.
4. Indicator solution. Dissolve 350 mg of brome cresol green in 10 ml of 95% ethyl alcohol in a 250 ml volumetric. Add 1 ml of 0.5 N NaOH and about 200 ml of distilled water. Add 22.1 ml of an aqueous 1% solution of new coccine and then add 750 mg of p-nitro phenol which has been dissolved in a few milliliters of 95% ethyl alcohol. This coccine solution should be mixed separately in a 250 ml graduate and finally diluted to the mark with distilled water. Test a few drops of the indicator in an acetate or pthalate buffer at pH 4.6. If the light gray color is not completely neutral as seen by the type of light to be used in subsequent titrations add small amounts of new coccine solution or brome cresol green solution, as the case may be, to one ml portions of the solution and retest with the buffer. When the color is neutral gray correct the bulk of the indicator by a proportionate amount of either the brome cresol green or the new coccine solution. This indicator is added directly to the stock solution of boric acid to avoid the necessity of individual sample additions during the analysis. The amount to be used depends upon the color desired by the analyst. Usually 75 to 100 ml of this mixed indicator is used per 18 liters of 2% boric acid solution.
5. Boric acid solution 2%. Dissolve 360 g H_3BO_3 in 18 liters of water. Add indicator solution.
6. Standard sulfuric acid solution, exactly 0.0714 N. Add 37-1/2 ml of concentrated H_2SO_4 to an 18 liter bottle. Dilute to 18 liter and mix thoroughly. Standardize using 0.1 N NaOH and phenolphthalein solution. After exact normality is known, calculate amount of water needed to make normality exactly 0.0714. Add this amount and mix thoroughly. Titrate again to check normality and add water or acid as needed to make the normality exact.
7. Granular zinc, 20 mesh.

Procedure

1. Weigh 1.00 g oven-dry plant material to nearest 2 mg into tared ashless filter paper.
2. Wrap sample up in filter paper and drop into the bottom of an 800 ml Kjeldahl flask.
3. Add 1 teaspoonful (10 grams) of digestion mixture.

Table 21. Continued.

Nitrogen continued

4. Add 25 ml concentrated sulfuric acid.
5. Add 3 or 4 glass beads.
6. Digest on Kjeldahl apparatus until the solution becomes clear green (20 to 30 minutes). Continue for 10 to 15 minutes to insure complete conversion of organic nitrogen to ammonium sulfate.
7. Cool.
8. Add 30 ml of distilled water.
9. Add about 0.5 g of 20 mesh granular Zn.
10. Transfer 50 ml of boric acid solution containing the indicator into a 250 ml Erlenmeyer flask and place under the delivery tube of the Kjeldahl distilling apparatus. The end of the delivery tube should extend below the surface of the boric acid solution.
11. Slowly add, down the side wall of the Kjeldahl flask, 60 ml of saturated sodium hydroxide.
12. Connect the flask securely to the distilling head.
13. Mix by swirling and seat the flask on the hot heater.
14. Continue boiling until a total of 100-125 ml have distilled over into the Erlenmeyer flasks.
15. Move Erlenmeyer flasks forward to lower shelf so that the delivery tubes are out of the solution.
16. Continue to boil for 2 minutes to rinse tubes.
17. Cool and allow tubes to drain several minutes.
18. Titrate with standard 0.0714 N H_2SO_4 to the neutral gray color established for the indicator.
19. A blank should be carried through the procedure once each day and when new reagents are used.
20. Calculate % N on a dry weight basis:

$$\% \text{ N} = \frac{\text{ml acid (sample)} - \text{ml acid (blank)}}{10}$$

Phosphorous

Reagents

1. Ammonium meta-vanadate--ammonium molybdate--nitric acid reagent.
   Solution 1. Dissolve 45.0 g ammonium molybdate in 800 ml distilled water.
   Solution 2. Dissolve 2.50 g ammonium meta-vanadate in 600 ml boiling distilled water. Cool. Add 500 ml mitric acid. Pour solution 1 into solution 2 and dilute to two liters.
2. Standard phosphorous solution, 1000 ppm. Dissolve 4.396 g KH_2PO_4 (dried to constant weight at 105 C) in distilled water and dilute to one liter.

Table 21. Continued.

Phosphorous continued

Procedure

1. Pipet 5 ml of the digested plant material (represents 0.10 g of plant tissue) into a 50 ml volumetric flask.
2. Add 10 ml reagent.
3. Make up to volume with distilled water and shake. Let stand for thirty minutes to allow full color to develop.
4. Determine absorbance with a Beckman Model B Spectrophotometer at 440 mu.
5. Determine ppm phosphorous by comparing against standard solutions containing 0, 50, 100, 250, and 500 ppm phosphorous which have been run through the digestion and analysis procedures simultaneously with the plant samples.
6. Calculate the per cent phosphorous in the sample:

$$\%P = \frac{\text{ppm P in solution}}{10^3}.$$

Potassium

Reagents

Standard potassium solution, 100 ppm. Dissolve 0.1907 g KCl in distilled water and dilute to one liter. Dilute to make stock solutions of 10, 20, 30, 40, 50, and 70 ppm K.

Procedure

1. Pipet 5 ml of the digested plant material (represents 0.10 g plant tissue) into a 50 ml volumetric flask.
2. Make to volume with distilled water and shake.
3. Set Perkin-Elmer, model 146, direct reading flame photometer on 766.5 mu.
4. Adjust flame photometer with carefully prepared standard stock solutions to desired sensitivity.
5. Read directly from the flame photometer the ppm potassium in the solution.
6. Calculate the per cent potassium in the sample:

$$\%K = \frac{\text{ppm K in solution X 5}}{100}.$$

Calcium and Magnesium

Apparatus

1. Two 10 ml graduated microburets graduated at intervals of 0.02 ml.
2. Adjustable light source. Ordinary gooseneck lamp is suitable.

Table 21. Continued.

Calcium and Magnesium continued

Reagents

1. Deionized water or a good quality distilled water.
2. Buffer of pH 12. Dissolve 80 g of NaOH in one liter of water, cool and add 10 g of NaCN or KCN.
3. Buffer of pH 10. Dissolve 67.5 g of NH_4Cl in 570 ml of concentrated NH_4OH; add 10 g of NaCN or KCN and dilute to 1 liter.
4. Standard calcium solution, 0.01 N. Dissolve 0.5000 g pure dried $CaCO_3$ in 30 ml of approximately 1 N HCl and dilute to one liter. One ml of the solution contains 0.01 meq or 0.2 mg calcium.
5. Dye of Patton and Reeder (HHSNN). Grind 1 g of the dye with 200 g of pure powdered K_2SO_4 or anhydrous Na_2SO_4. Grind in a porcelain mortar until a uniform color is obtained. Store in a brown container.
6. Erichrome Black T indicator. Dissolve 0.5 g of Eriochrome Black T and 4.5 g of hydroxylamine hydrochloride in 10 ml of 95% ethanol or methanol. Prepare fresh at monthly intervals.
7. EDTA solution, 0.01 N. Dissolve 3.723 grams of disodium dihydrogen ethylenediamine tetraacetate dihydrate in water and dilute to 2 liters. Standardize against the standard calcium solution.
8. Triethanolamine. For a 50% aqueous solution, mix equal parts of triethanolamine and water.
9. Magnesium EDTA. Make up saturated solution of Mg-EDTA.

Standardization of EDTA

1. Pipet a 5 ml aliquot of standard calcium solution into a 250 ml Erlenmeyer flask.
2. Add 2 ml of 50% triethanolamine. Stir.
3. Add 5 ml of pH 12 buffer. Stir.
4. Add 50 mg of Dye of Patton and Reeder.
5. Titrate with EDTA to exact blue point.
6. Titrate blanks using water instead of standard calcium solution.
7. Calculate exact normality of EDTA:

Normality of EDTA =

$$\frac{(\text{ml std Ca})(\text{N std Ca})}{\text{ml EDTA used corrected for blank titration}} .$$

Procedure for the determination of calcium

1. Pipet 5 ml (0.1 g plant tissue) of the digested plant material into a 250 ml Erlenmeyer flask.
2. Add 2 ml 50% triethanolamine. Stir.
3. Add 5 ml of pH 12 buffer. Stir.

Table 21. Continued.

Calcium and Magnesium continued

4. Add 50 mg of Dye of Patton and Reeder just before the titration of each individual sample. Stir.
5. Titrate with EDTA to blue point.
6. Add in excess 0.5 to 1.0 ml EDTA and stir one minute to insure blue point.
7. Back titrate with calcium solution to red point.
8. Titrate with EDTA to exact blue point.
9. Record the ml of calcium used and the total ml of EDTA used.
10. Calculate the per cent calcium in the sample:

$$\text{Meq Ca} = [\text{total ml EDTA (corrected for blank)} \times \text{N EDTA}] - [\text{ml std Ca} \times \text{N std Ca}]$$

$$\% \text{ Ca} = \frac{\text{Meq Ca} \times 20.04 \times 100}{\text{mg sample in aliquot}}.$$

Procedure for the determination of magnesium

The total amount of calcium plus magnesium is determined by this procedure. The amount of magnesium is determined by the difference in this titration and the previous titration for calcium only. The same size aliquot of the digested plant material must be used for both determinations.

1. Pipet 5 ml (0.1 g plant tissue) of the digested plant material into a 250 ml Erlenmeyer flask.
2. Add 2 drops saturated Mg-EDTA.
3. Add 2 ml 50% trienthanolamine. Stir.
4. Add 9 ml of pH 10 buffer. Stir.
5. Add 5 drops Eriochrome Black T just before the titration of each individual sample. Stir.
6. Titrate with EDTA to blue point.
7. Add in excess 1 ml EDTA and stir for one minute to insure persistance of blue color.
8. Back titrate with calcium solution to red end point.
9. Titrate with EDTA to exact blue point.
10. Record the ml of calcium used and the total ml of EDTA used.
11. Run blank determinations the same way using water instead of the sample.
12. Calculate the per cent magnesium in the sample:

$$\text{Meq Ca + Mg} = [\text{total ml EDTA (corrected for blank)} \times \text{N EDTA}] - [\text{ml std Ca} \times \text{N std Ca}]$$

$$\text{Meq Mg} = \text{Meq Ca + Mg} - \text{Meq Ca}$$

$$\% \text{ Mg} = \frac{\text{Meq Mg} \times 12.16 \times 100}{\text{mg sample in aliquot}}.$$

Table 21. Continued.

Manganese

Reagents

1. Use deionized water throughout procedure.
2. Composite solution. Dilute 65 ml concentrated HNO_3, 135 ml concentrated H_3PO_4, and 1.3 g trisodium para periodate to one liter.
3. Sodium hydroxide solution, 20%. Dissolve 200 g NaOH in 800 ml water.
4. Standard manganese solution, 100 ppm. Dissolve 0.2878 g dry $KMNO_4$ in 300 ml water and 20 ml concentrated H_2SO_4. Add enough solid sodium sulfite to dispell color. Boil gently to remove excess sulfur dioxide. Cool. Dilute to one liter.

Procedure

1. Collect the 10 ml, 6 M HCl fraction containing the manganese in a 100 ml beaker.
2. Evaporate carefully to dryness on a hot plate.
3. Remove from hot plate and add 15 ml composite solution. Allow to stand a few minutes.
4. Add 10 ml 20% NaOH.
5. Allow to stand for two hours for color development.
6. Determine absorbance at 525 mu.
7. Determine ppm manganese by comparing against standard solutions containing 0, 10, 20, and 50 ppm manganese which have been run through the digestion and analysis procedures simultaneously with the plant samples.
8. Multiply by two to correct for dilution.

Copper

Reagents

1. Use deionized water throughout procedure.
2. Buffer, pH 9.0. Dissolve and dilute 8.52 g NaOH and 30.92 g H_3BO_3 to one liter.
3. Zincon solution. Dissolve 0.13 g Zincon (2-carboxy-2'-hydroxy-5'-sulfaformazylbenzine) in 2 ml N NaOH and dilute to 100 ml. Prepare fresh weekly.
4. Composite solution. Mix 5 ml buffer, 3 ml Zincon solution, and 17 ml water for each sample.
5. Standard copper solution, 100 ppm. Dissolve 0.393 g $CuSO_4 \cdot 5H_2O$ with water in a one liter flask. Add 5 ml concentrated H_2SO_4. Dilute to volume.

Procedure

1. Collect the 10 ml, 2.5 M HCl fraction containing the copper in a 50 ml beaker.
2. Evaporate carefully to dryness on a hot plate.
3. Remove from hot plate and add 25 ml composite solution.

Table 21. Continued.

Copper continued

4. Determine absorbance at 600 mu.
5. Determine ppm copper by comparing against standard solutions containing 0, 10, 20, and 50 ppm copper which have been run through the digestion and analysis procedures simultaneously with the plant samples.
6. Multiply by two to correct for dilution.

Iron

Reagents

1. Use deionized water throughout procedure.
2. Thioglycolic acid, purified reagent.
3. Ammonium hydroxide solution. Dilute 370 ml concentrated NH_4OH to one liter.
4. Standard iron solution, 100 ppm. Dissolve 0.7024 g ferrous ammonium sulfate ($FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$) in 50 ml of water and 10 ml of concentrated H_2SO_4. Dilute to one liter.

Procedure

1. Collect the 10 ml, 0.5 M HCl fraction containing the iron in a 25 ml volumetric flask.
2. Add 0.1 ml (2 drops) thioglycolic acid. Mix.
3. Add 5 ml NH_4OH solution. Mix.
4. Dilute to the mark.
5. Mix and allow to stand 5 minutes.
6. Determine absorbance at 535 mu.
7. Determine ppm iron by comparing against standard solutions containing 0, 20, 50, and 100 ppm iron which have been run through the digestion and analysis procedures simultaneously with the plant samples.
8. Multiply by two to correct for dilution.

Zinc

Reagents

1. Use deionized water throughout procedure.
2. Sodium hydroxide solution, 1 N. Dilute 40.01 g NaOH to one liter.
3. Buffer, pH 9.0. Same as for copper determination.
4. Zincon solution. Same as for copper determination.
5. Hydrochloric acid solutions, 2 N. Dilute 167 ml concentrated HCl to one liter.
6. Standard zinc solution, 100 ppm. Dissolve 0.4398 g $ZnSO_4$ ($ZnSO_4 \cdot 7H_2O$) in 2 N HCl and dilute to one liter with 2 N HCl.

Table 21. Continued.

Zinc continued

Procedure

1. Collect the 15 ml 0.005 M HCl fraction containing the zinc in a 50 ml volumetric flask.
2. Add about 1 ml N NaOH to make solution slightly alkaline.
3. Add 5 ml pH 9.0 buffer.
4. Add 3 ml Zincon solution.
5. Mix and dilute to volume.
6. Determine absorbance at 620 mu.
7. Determine ppm zinc by comparing against standard solutions containing 0, 20, 50, and 100 ppm zinc which have been run through the digestion and analysis procedures simultaneously with the plant samples.
8. Multiply by two to correct for dilution.

Table 22. Nutrient-element levels in leaves of sweet cherry trees from 79 Utah orchards.

Name	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
Box Elder County							
D. C. Barker	2.00	.31	1.38	54	12	56	17
R. Beecher	2.59	.18	1.35	111	11	88	8
C. Hansen	2.10	.23	1.22	29	14	62	10
R. Hirschi	1.77	.38	1.42	48	7	60	18
J. F. Leggett	2.38	.25	1.00	35	9	62	16
O. M. Lemon	1.82	.25	1.60	34	8	91	27
G. A. Nielsen, Jr.	2.20	.20	1.25	49	7	68	30
G. A. Nielsen, Jr. (Up. Orch.)	2.32	.20	1.10	51	10	60	11
W. Osman	2.77	.15	1.30	73	10	110	28
E. W. Payne	2.44	.25	1.15	28	12	120	26
J. W. Perry	2.31	.21	1.48	84	12	68	19
G. Pettingill	2.49	.22	1.50	49	11	66	37
A. Tolman	2.09	.23	1.48	38	11	52	21
R. White	1.80	.21	1.21	40	9	67	17
E. D. Young	2.27	.24	1.18	42	10	55	22
Weber County							
V. Barker	1.96	.20	1.30	44	10	50	16
E. Bingham	2.41	.28	1.48	28	11	49	8
H. Chandler	2.20	.29	1.40	38	9	78	26
E. A. Chatlain	2.51	.21	1.38	42	11	96	10
W. Cragun	1.87	.18	1.48	57	10	73	17
G. I. Eames	2.65	.35	1.75	29	14	64	10
Howell Field Station	2.00	.20	1.18	26	12	62	22
B. Jensen	2.51	.28	1.50	42	10	60	32
K. MacFarlane	1.95	.27	1.85	24	14	49	14
D. Perry (Indust. School)	2.10	.34	1.75	38	8	70	32
M. E. Purdy	2.33	.33	1.70	23	9	48	8
L. Randall	2.59	.16	1.10	39	12	60	11
K. Storey	1.88	.38	1.60	37	8	54	8
F. Taylor	2.03	.26	1.40	46	8	56	19
F. Warner	1.82	.28	1.50	32	11	53	18
M. Woodfield	2.48	.20	1.40	32	12	56	5

Table 22. Continued.

Name	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
Davis County							
F. Barkdull	2.24	.32	1.02	56	8	58	21
E. R Behling	2.52	.20	1.42	71	6	58	10
L. Burningham	1.77	.22	1.22	29	12	68	16
C. Butcher	2.90	.30	1.48	64	7	62	11
I. Egbert	2.51	.35	1.78	28	17	56	18
J. N. Ford	2.09	.29	1.25	36	6	56	19
G. Lloyd	2.62	.23	1.38	32	18	52	12
G. Manning	2.68	.26	1.25	67	12	82	11
L. S. Rice	1.81	.26	1.22	53	10	64	21
G. Rosetta	2.65	.31	1.55	19	12	52	29
R. Springer	3.00	.25	1.30	75	7	70	24
L. Stettler	2.12	.26	1.38	33	12	56	19
K. Walton	2.04	.26	1.30	58	7	96	68
E. Wilson	2.63	.22	1.15	58	13	112	28
Utah County							
G. Anderson	1.82	.18	1.85	35	6	42	18
T. Antonio	2.58	.19	1.18	18	13	68	18
B. Boyce	2.19	.22	1.35	21	12	56	24
D. Burr	2.78	.21	1.45	72	12	60	20
J. Carnesecca	2.10	.23	1.30	16	9	59	11
S. Crandall	2.08	.31	1.40	25	13	63	12
East Sharon Stake	2.95	.23	1.30	21	12	51	28
C. Fullmer	2.60	.28	1.42	21	10	58	10
R. Gappmayer	2.91	.28	1.38	46	12	64	32
J. Gilman	2.36	.22	1.40	23	12	50	19
R. Glazier	1.98	.17	1.15	41	10	46	48
C. Harper	2.38	.20	1.52	25	10	58	10
G. E. Johnson	2.44	.23	1.50	21	11	45	24
C. Lunceford	2.57	.19	1.58	15	10	46	11
J. Medved	2.76	.29	1.42	21	10	52	12
J. Muhlstein	2.51	.20	1.15	15	12	50	22
R. Park	2.65	.31	1.55	19	12	52	29
F. Patten	2.42	.25	1.40	28	12	42	12
C. Pulham	2.23	.34	1.65	22	14	63	14
T. Reese	2.33	.25	1.60	23	11	66	6
L. Revoir	1.97	.33	1.68	21	9	44	13
F. C. Robertson	2.38	.25	1.32	27	10	46	16
G. Seal	2.66	.28	1.50	21	10	58	11
G. Seal	2.62	.24	1.42	11	12	50	18
E. Smith	2.22	.20	1.32	27	10	47	17
J. Stratton	2.19	.24	1.28	36	13	52	20
V. Stratton	2.49	.25	1.35	30	12	62	11
C. Wadley	2.55	.20	1.80	37	10	45	15
C. Wadley	2.59	.18	1.75	60	10	68	12

Table 22. Continued.

Name	% dry wt			ppm dry wt			
	N	P	K	Mn	Cu	Fe	Zn
			Washington County				
B. Isom	2.17	.21	1.58	54	12	42	22
F. Judd	2.35	.20	1.52	47	17	43	22
B. Slack	2.41	.24	1.55	19	12	44	28
A. Stout	2.34	.20	1.70	65	13	42	18
R. Webb	1.93	.26	1.65	43	10	44	20

U T A H S T A T E U N I V E R S I T Y

HORTICULTURE DEPARTMENT

Logan, Utah

Dear Fruit Growers:

I am a graduate student at Utah State University working on my master's degree. As a project for my thesis I am going to conduct a nutritional survey of the sweet cherry orchards in Utah in hopes that better recommendations and help can be given to the growers and thereby increase production to make sweet cherries a better crop in Utah. My survey procedures will be done by taking 50 to 200 leaves depending on the size of the orchard and analyzing them in the laboratory for nutrient-elements essential for plant growth.

I will not be able to take samples from every orchard in the state, but if yours is selected, would you be willing to cooperate and allow me to take these few leaves for the survey? (Please answer "Yes" or "No" on the questionnaire.) Also, if yours is selected, I will return the data to you so you may know the nutritional status of your own orchard.

If you would please fill out the enclosed questionnaire and return it immediately in the addressed and stamped envelope, I would appreciate it very much. You may be assured that this information will be kept strictly confidential and the data obtained will be used only to help me in sampling procedures.

Yours truly,

M. Dale Christensen

MDC/mgb

QUESTIONNAIRE FOR NUTRITIONAL SURVEY OF SWEET CHERRY ORCHARDS

(Please fill in the appropriate spaces as accurately as possible.)

1. Name _____ County _____

2. Would you be willing to have leaf samples taken from your orchard? Yes ____ No ____.

3. Number of acres of sweet cherries? _____.

4. Please fill in the approximate number of trees:

VARIETY

	1 to 10 yrs	11 to 20 yrs	21 to 35 yrs	36 & older
BING				
LAMBERT				
OTHERS:				

5. Do you keep your orchard clean cultivated year around? Yes ____ No ____.

6. Do you have a cover crop (sod) in your orchard year around? Yes ____ No ____.

7. Do you have a cover crop in your orchard only during the late summer and winter? Yes ____ No ____.

8. Do you fertilize your orchard once every year? Yes___ No___. Once every two years? Yes___ No___. If neither of these, how often? _____.

9. Do you fertilize in the Fall?___ Winter?____ Spring?____.

10. Do you use commercial fertilizer? _____ Or manure? _____ Or both fertilizer and manure? _____.

11. If you use commercial fertilizer, do you use:

a. A complete fertilizer (Nitrogen, phosphorous, and potassium)?_____.
b. Only nitrogen and phosphorous? _____
c. Only nitrogen? _____.
d. Only phosphorous? _____.

12. What kind of fertilizer do you use such as ammonium nitrate, ammonium sulfate, ammonium phosphate, treble super phosphate, single super phosphate, etc.?_____
_____

13. Approximately how much fertilizer do you apply to your mature trees? (Please designate amount per tree or amount per acre.) _____.

14. Do you prune your trees every year?____ Once every two years? _____ Once every five years or less? _____.

15. Do you use sprinkler irrigation? _____ Furrow irrigation? _____ Or other? (Specify.) _____.

16. Do you ordinarily irrigate: 0 to 2 times a year? _____ 3 to 5 times a year? _____ 6 to 8 times a year _____ 9 times or more a year? _____.

17. What is the planting distance? _____.

18. What type of soil is your orchard on? (sandy, loam, clay, etc.) _____.

19. What spray materials have you used on your sweet cherry trees this year? _____
_____

20. Do you use a mechanical device to protect your orchard against frost damage? Yes _____ No _____. If so, do you have orchard (oil) heaters? _____ wind machines? _____
_____ or other? (Specify.)_____
_____.

E. A. Chatlain	8-10	Severe	V. lt.	8	Clean	2	W	M		3	9-10	20	Loam clay	O,LS	No
W. Cragun	0-4	V.severe	None	20	Cover						0-1				
G. I. Eames	0-4		Full	30	Clean							20			
Howell Field Sta.	0-2	V.severe	None	15	Cover	1	W	AN	1.5	3	3-4	30	Loam	P	No
B. Jensen	4-8	Slight	Medium	20	Clean										
K. MacFarlane	0-8	Moderate	V. lt.	30	Clean							20			
D. Perry	4-8	Slight	Medium	25	Clean								Rocky		
M. E. Purdy	4-8	Moderate	None	20	Clean	3	F			3	9-10	30	Black loam	O,P, S,L	No
L. Randall	4-8	Moderate	Medium	12	Clean	3	F	M			6-8	24	Clay, loam, rocky		No
K. Storey	0-4	Moderate	Medium	20	Clean	2	S	M		3	9-10	20	Gravel clay	O	No
F. Taylor	0-2	Severe	None	20	Clean										
F. Warner	4-8		Light	10	Clean										
M. Woodfield	0-4	Moderate	Medium	30	Clean								Rocky		

Davis County

F. Barkdull	0-4	V.severe	Full	20	Clean	1	S	AS	1	0	0	28	Sandy loam, clay	TEPP	No
E. R. Behling	4-6	Severe	Medium	10	Clean	1	W	AS,AP	1	3	9-10	28	Clay loam	LS	No
L. Burningham	4-8	Slight	Medium												
C. Butcher	8-12		Medium	10	Cover	1	W	NPK	1.5	1	9-10		Sandy loam	LS, TEPP	No
I. Egbert	4-6		Full	30	Clean	1	W	M,AS	2&1	2	9-10	25	Sandy loam, clay	LS,O	Yes
J. N. Ford	4-8	Moderate	Medium	25											
G. Lloyd	12-18	None	None	7	Clean	1	W	AP	1	2	6-8s	24	Sandy, clay	LS,O	Yes
G. Manning	0-4		Full	20	Clean	1	F	AS	1	2	9-10s	22	Gravel loam,	Ma, LS,O	Yes
L. S. Rice	0-2	Slight	Full												
G. Rosetta	0-4	Slight	Full	12	C & C	1	W	AS	1	1	9-10	28	Sandy, gravel	LS,O	No

C. Lunceford	10-12		Medium	15											
J. Medved	0-4	Severe	Medium	35	Cover										
J. Muhlstein	0-2	Moderate	None	20	Cover										
R. Park	2-4	None	Light	25	Clean	1	W&S	M	1	1	9-10		Black silt, rocky	LS	Yes
F. Patten	12-16			20											
C. Pulham	0	Moderate	None	20	Cover	1	S	AS	3	1	9-10	20	Rocky, loam, clay	Ma	Yes
T. Reese	2-6		Light												
L. Revoir	0	V.severe	None	30	Cover										
F. C. Robertson	4-8		Medium	20	Cover	1	F	AS	1	3	3-5	20	Loam, rocky	S,G, P	Yes
G. Seal	0-4	Moderate	None	20	C & C	2	S	AN,AS,AP		1	9-10	36	Sandy loam	Ma,O	Yes
E. Smith	10-12		Medium	20	C & C	2		M			9-10		Clay	Ma,O, Gu	
J. Stratton	4-8		Medium	20	C & C	1	S	AS	1	2	9-10	25	Gravel, loam	None	No
V. Stratton	12-16		Light	12	Cover	1	W	AS	0.5	3	9-10	22	Gravel, clay	None	No
C. Wadley	4-6	None	Light	20	Clean										
Washington County															
B. Isom			Medium	15	Cover	3	S	AN	Trace	2	6-8	30	Clay		
F. Judd			Light	10	C & C	1	S	AN	2-8	2	6-8	24	Clay		
B. Slack			Medium	30	Cover	1	S	AN,AP, TSP	1.5	3	9-10	25	Sandy loam		
A. Stout			None	5											
R. Webb			Medium	15	Cover	3	W	M		3	9-10	30	Loam	None	No

[a] C & C = Clean cultivated during the spring and cover cropped during the fall.

[b] 1= Operation performed every year; 2= Operation performed once every two years; 3 = Operation performed every three years or less.

[c] M= Manure; AS = Ammonium sulfate; AN = Ammonium nitrate; AP = Ammonium phosphate; NPK = Complete; TSP = Treble super phosphate.

[d] = Number of irrigations per year; s = sprinkler irrigated.

[e] O= Oil; P = Parathion; L = Lead; K = Kelthane; LS = Lime sulfur; Ma = Malathion; G = Genite; S = Sulfur; Gu = Guthion.