NUTRITIONAL EVALUATION OF SELECTED *TAXUS MEDIA HICKSI*

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Richard N. Boonstra

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By

RICHARD N. BOONSTRA

A THESIS

Submitted to the School for Advanced Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
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MASTER OF SCIENCE

Department of Horticulture

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RICHARD N. BOONSTRA ABSTRACT

This investigation was designed to determine the nutrient status of Taxus media hicksi, growing at selected locations in southern Michigan. Leaf analysis was employed to establish actual or incipient deficiencies or toxicities, and to establish standard levels for each element. The assessments of nutrient status from soil analyses were compared to those determined from leaf analyses.

Samples were collected over the growing season at East Lansing to establish seasonal variation in nutrient levels for these plants, and to determine the validity of sampling in summer. Samples were collected in July from both good and poor plants growing on six representative sites in southern Michigan.

Leaves were analyzed for nitrogen by the Kjeldahl method, for potassium by flame photometer, for phosphorous, calcium, magnesium, iron, manganese, copper, zinc, and boron by spectrographic analysis.

Soil samples were obtained at each site and analyzed by the Spurway method, using active soil extracts. Total exchangeable bases were determined, using a versenate titration for calcium and magnesium, and flame photometer for potassium.

Nitrogen was found to be satisfactory on all sites sampled. Phosphorous was found to be below normal on one-half of the sites. Potassium deficiency was found on several sites, associated with higher pH, and the use of potassium on low pH soils had not caused any deficiencies of calcium and magnesium, although levels of these two elements were generally below normal in plants on these soils.

Early spring appeared to be the best time to sample this crop. Copper and zinc determinations were unreliable in July. Boron and magnesium levels were changing in the tissues at this time.

Soil tests in which active extracts were used did not appear to be a reliable method of determining the nutrient status of Taxus. The versenate titrations of calcium and magnesium showed a high correlation with the levels of these two elements in the leaves.

The average composition of the better plants found in the survey was used as the proposed standard for the interpretation of leaf analyses of Taxus media hicksi. Expressed as percent of dry weight, the average composition was: nitrogen, 2.15; phosphorous, 0.49; potassium, 1.96; calcium, 0.54; magnesium, 0.36; iron, 0.012; manganese, 0.0241; copper, 0.0012; zinc, 0.0029; and boron, 0.0056.

It was concluded that after the reliability of these proposed standards was determined by sampling in at least two more seasons, and the significance of departures from normal for each element was investigated, leaf analysis would provide a very useful aid in the diagnosis of nutrient deficiencies for this crop.

The thesis is supplemented by five tables and nine figures.

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LEAF ANALYSIS AS A DIAGNOSTIC TECHNIQUE

The law of the minimum, the law of dimishing returns, the zones of nutrition, and nutrient element balance are important principles which have been evolved to relate the composition of the leaf to the nutrition of the plant (Blackman, 1905; Mitscherlich, 1909; Macy, 1936; Shear et al., 1946).

Blackman (1905) proposed the law of limiting factors, in which plant growth was limited by "that" factor in least supply. He felt that increasing "that" factor, whether it was the level of an essential element or some environmental or soil factor, should result in increased growth up to the point where some other factor became limiting.

In contrast to the law of the minimum, in which a linear relation between the yield and the amount of nutrient given was expected (Goodall and Gregory, 1947), Mitscherlich (1909) believed that the curve relating the two should be a hyperbola, approaching a maximum value with maximum gradient at low nutrient levels. When a single nutrient element was increased in the presence of an excess of all other factors, Goodall and Gregory (1947) believed that both field and pot culture experiments confirmed this law of diminishing returns.

Macy (1936) related the nutrient concentration and yield response of plants to three zones of nutrition: a zone of "minimum percentage" in which the nutrient concentration remained constant and the yields increased; a zone of "poverty adjustment" in which the nutrient concentration and yields increased simultaneously; and a zone of "luxury consumption" in which the nutrient concentrations increased and the yields were constant. The "critical percentage" separated sharply the zone of "luxury consumption" from the zone of "poverty adjustment".

Shear, et al. (1946) emphasized and elaborated the importance of nutrient balance concept in the evaluation of the nutritional status of plants. They stated that maximum growth and yield were possible only as a result of the coincidence of optimum intensity and balance of all nutrient elements. They believed that as one element varied from optimum, maximum growth was possible only when all elements were brought into balance with the intensity of that element.

In addition to these basic concepts, the comments of various other workers were of interest.

Kenworthy (1949) stated that leaf or plant analyses had shown that the level of one nutrient element might vary considerably. The amount present in the material analyzed varied from a very low to a very high value. He observed that at very low values visible deficiency symptoms were often present, while at very high values a visible symptom of excess or a deficiency symptom for some other element often occurred.

He mentioned that somewhere between the values for optimum growth and the value where deficiency symptoms might occur, there was a range in plant composition in which the plant would respond to nutrient element applications. This range he called "hidden hunger" or "hidden deficiency". There was also a range in composition somewhere between the optimum values and the values where visible "excess" symptoms might occur, in which additions of a nutrient element resulted in a reduction in plant growth. This range he called "hidden excess" or "approaching excess".

Working with rubber trees, Chapman (1941) demonstrated that the relation between leaf composition and growth rate was often linear.

Ulrich (1943) defined critical concentration of a nutrient as a level at or below which the growth and yield of a plant decreased. He believed that there should be no increase in yield by raising the level of an element above the critical percentage, and that these critical levels were fairly constant for a given crop (Ulrich, 1948).

Lundegardh (1951) pointed out that practical standards of leaf composition were not absolute values, but that relative concentrations of other nutrients had to be considered. His conception was that the essential elements could interact, not only with each other, but also with non-essential elements, and with such environmental factors as light, temperature, and moisture supply in influencing plant growth.

Reuther and Smith (1954) concluded that neither soil nor climate appreciably influenced the fundamental nutrient requirements of citrus.

Thomas (1937) presented a method of interpretation which considered both intensity and balance of nutrition. His work dealt with the analysis of extracts of plant tissue and has been highly developed as a method labeled "foliar diagnosis". The sum of the percentages of nitrogen-phosphorous-potassium and calcium-magnesium-potassium was regarded as an intensity factor and the ratio of the milliequivalents of each to the sum of the milliequivalents in the group was regarded as a balance factor. However, Goodall and Gregory (1947) pointed out that the use of ratios tended to obscure other relationships which might have been of equal or greater importance in interpretation.

Lundegardh (1943) in explaining why leaf analysis is considered an index of the nutrient status of the plant and the soil pointed out that the absorbing power of the roots in part regulated the concentration of salts in the leaves, and that the nutrient salt transformations taking place in the green, assimilating leaves controlled the growth of the plant. He believed that leaf analysis not only gave a summation of the extraction of salts from the soil during a period of several weeks, but in addition presented a picture of soil saturation at the time of sampling. This conclusion was based on the fact that the vegetative parts of the plant were still vigorous, although fully grown when the samples were taken. Several workers typified the concentration of nutrient elements in the leaves as the summation of all of the factors affecting plant nutrition (Goodall and Gregory, 1947; Ulrich, 1943).

Reuther and Smith (1954) stated that the leaves were regarded not only as the seat of carbon assimilation by the plant, but also as organs sensitive to, and exerting an influence on other fundamental processes in the whole plant. In addition, leaves functioned as a part of the plants mineral and carbohydrate storage resevoir. Thus, concentrations of mineral nutrients in leaves not only influenced the efficiency of the photosynthetic machinery within the leaf, but also reflected nutrient conditions influencing the vigor and fruitfulness of the whole plant. They mentioned that tissues other than leaves also reflected the nutrient status of plants, and had been used for diagnostic purposes to some extent with certain crops. Generally, leaves were found to be a practical, sensitive, and convenient index of the nutrient status of citrus trees (Reuther and Smith, 1954).

Thomas (1944) concluded that the experimental evidence showed that the growth and yield of plants were regulated by the amounts of nutrient salts present in the green, assimilating parts of the plant.

Goodall and Gregory (1947) pointed out that nutrition could affect the growth and yield of the plant in many other ways than by direct effects on assimilation. They concluded that, even where an unsatisfactory nutritional condition affected the yield by reducing the assimilation, the analysis of some other part, or of the plant as a whole, could provide a more sensitive index of the nutrition than would analysis of the leaf itself.

They also mentioned that the optimum time to sample might not be independent of the varying external conditions. Since changes in light, temperature, and water supply affected the distribution of nutrients among plant parts, one part might provide a more reliable type of sample in one year, another plant part in the following year.

In diagnosing boron deficiency in apples, Askew and Thomson (1937) preferred an analysis of the fruit. Christ and Ulrich (1954) found in the case of the grape vine, that both the potassium and nitrate concentrations changed more in the petioles than in the leaf-blades with the varying nutritional conditions; and moreover, that these differences were more highly significant.

The importance of the physiological age of samples was pointed out by many workers (Goodall and Gregory, 1947; Reuther and Smith, 1954; Ulrich, 1948; Wood, 1947; Lundegardh, 1951; Thomas, 1945; Boynton and Compton, 1945). Levels of nutrients in a leaf changed as that leaf grew, matured, and became senescent. Leaves would thus have different normal compositions, depending on the stage of development at which they were analyzed. Particular stages of development were shown to best indicate deficiencies of particular elements. Certain stages of development were to be avoided because of rapid fluctuations in the level of an element at that time.

Conclusions differed as to the proper stage of development at which to sample, depending on the crop and element in question. Tamm (1954), having found levels of nutrients to be too variable in summer, sampled forest trees in the fall. July and August were recommended as the best times to sample by workers in orchard trees (Kenworthy, 1953; Reuther and Boynton, 1940; Lilleland and Brown, 1942; Chapman and Brown, 1950).

Goodall and Gregory (1947) commented that the optimum time for sampling might be expected to differ for different nutrient elements, so that a single sampling time could not be optimal for all elements. In respect to time of sampling, they hoped that the technique adopted would fall within a fairly wide range around the optimum.

Many workers found recently matured tissue to be the best indication of nutrient status (Chapman and Fullmer, 1951; Lundegardh, 1943; Ulrich, 1948; Reuther and Smith, 1954). Levels were generally more constant at this time than during periods of rapid growth. Redistribution of minerals was not great in recently matured tissue, and dry weights were more constant.

Differences in the nutrient content of leaves as a result of their positions on the plant were mentioned by many investigators (Goodall and Gregory, 1947; Ulrich, 1943; Shear et al., 1946), all of whom believed that samples should be from the same morphological position on the plant.

Leaf analysis often has been found to better indicate nutritional conditions than an analysis of the soil. For grapes, field crops, and grains it has been concluded that chemical analysis of soil was of limited value in determining fertilizer requirements as compared with leaf analysis (Ulrich, 1948; Lundegardh, 1951).

Christ and Ulrich (1954) mentioned that one of the limitations of leaf analysis of grapes was that the analysis could not tell the vineyardist the exact amount of fertilizer to apply to overcome a deficiency. Once fertilizers had been applied, however, their adequacy or inadequacy could be determined by the analysis of plant samples collected later in the season or during the following year.

Scarseth (1943) believed that since only the nutrients that entered the plant were effective, it was important to know whether or not the plant was absorbing the nutrient.

After finding differences in corn yields on six plots, Lynd, Turk, and Cook (1949) demonstrated that chemical soil tests could not account for the differences. They found a positive correlation of total nitrogen by leaf analysis with the corn yields.

Reuther and Smith (1954) stated that the soil analysis method rested on the assumptions that roots would extract nutrients from the soil in a manner comparable to chemical soil extractants, and that there was a simple, direct relation between the extractable concentration of ions in the soil and uptake by plants. There was ample evidence that these assumptions were not entirely justified. They considered that ion antagonism, time, and vital processes were of considerable importance in regulating the uptake of nutrients by plants. They believed that these phenomena could not be adequately evaluated by means of soil analysis. Such factors as soil aeration, soil moisture supply, soil temperature, and amount of food supplied by the top influenced uptake of ions by roots, and were not measured by soil analysis.

Reuther and Smith (1954) mentioned a further limitation of soil analysis--the difficulty in obtaining a sample which adequately would reflect the soil explored by the root system, especially in perennial crops. They believed that the concentration of nutrients in leaves in a comparable number of samplings would integrate more adequately the effects of these dynamic substrate factors on uptake by the plant. They concluded that soil analysis data could provide valuable supplementary information concerning the probable nutrient status of a citrus orchard. They pointed out that cation exchange capacity, pH, salinity, reserves of nutrients, and degree of fixation of added nutrients might not be directly indicated by leaf analysis. They concluded that an evaluation of some of these factors by soil analysis might be valuable for the intelligent formulation of a practical fertilizer program for tree crops

Boynton and Compton (1945) concluded that leaf analysis for nitrogen, phosphorus, and potassium, could not take the place of careful observations of tree behaviour and appearance, of the development of visible leaf or fruit symptoms, or of past climatic and management conditions, but that chemical analyses of leaves, coupled with these observations might make possible a positive diagnosis that no single one would have permitted.

The factors influencing the intake of any given nutrient by a plant were so numerous, according to Salter and Ames (1928), that they precluded the hope of using plant composition as a guide to soil requirements unless steps were taken either to control or measure the influence of the factors. Hall (1905) in finding greater yearly variation in leaf composition than any variation between differentially fertilized plots, indicated that it was impossible to diagnose soil conditions through plant composition. Goodall and Gregory (1947) believed these objections were not valid when the status of the crop, and not the soil, was of prime concern.

Although in no way interfering with the use of plant analysis, Carolus (1938) pointed out that fertilizer applications might make it difficult to secure a representative soil sample.

In 1947, Goodall and Gregory mentioned that more attention had been given for a longer period of time to the development of methods of soil analysis and to their standardization against field trials, than to the same development and standardization of plant analysis. They also stated that soil analysis for the trace elements had not been developed and that plant analysis should be of importance in this diagnosis.

They further mentioned that a useful method of combining the techniques of soil and plant analysis would be the use of soil analysis as a means of determining what basal fertilizer dressing to apply before a crop was planted, using the results of subsequent periodical plant analyses to determine whether that basal dressing was taken up by the crop, whether it was adequate, and whether additional top or side dressings were to be recommended.

Many workers agreed that the reliability of the diagnostic use of leaf analysis rested on the reliability of the standards (Shear, et al., 1946; Chapman, 1945; Goodall and Gregory, 1947; Ulrich, 1943) and according to Ulrich (1943) and Reuther and Smith (1954) the ultimate test to which standards had to be subjected was a system of properly controlled field plot-fertilizer experiments.

The possibility of error in expressing the nutrient content on a percentage dry weight basis was pointed out by Reuther and Smith (1954). Although their data showed a maximum range of only 2.5 to 8.7 percent in carbohydrate content for citrus, they stated that changes in carbohydrate levels might seriously affect the dry weight of leaf tissues and thus influence percent composition of the mineral elements. Ulrich (1948) believed that errors due to changes in dry weight could be largely overcome by using tissue of the same physiological age.

Chapman (1945) stated that the development of reliable methods was a matter of carrying out sufficient experimental work to establish proper standards, and to determine the significance of departures from these standards in terms of yield and quality of plant product

Reuther and Smith (1954) warned that their leaf standards and interpretations all presumed that the root systems of the trees sampled were not handicapped or damaged by poor aeration. They stated that this common difficulty rendered the soil unfavorable for vigorous root development and tended to reduce the capacity of the feeder roots in taking up nutrients. They suggested that any other factor which caused appreciable damage to the root system was likely to cause apparent deficiencies of those elements in scant, but normally adequate supply. They emphasized that conclusions based on leaf analysis alone could lead to an erroneous diagnosis of a problem unless disease, pest, soil tilth, and soil drainage factors were evaluated. They wisely concluded that leaf analysis interpretation could never be a substitute for a wide horticultural knowledge of the plant. It was only a guide useful for improving the mineral nutrition factor in crop production. Boynton and Compton (1945), Scarseth (1943), Cain and Galletta (1954), Ulrich (1943), and Goodall and Gregory (1947) also stressed these possibilities.

While her preliminary data did not demonstrate losses sufficient to cause any great errors, Mes (1954) mentioned the possibility that losses of nutrients through leaching of the leaves by rain, dew, and irrigation water might affect the reliability of leaf analysis.

Reuther and Smith (1954) stated that most plants had a remarkable inherent capacity for adapting themselves to a wide range of supply of the nutrient elements, provided none were in the deficient range. They concluded that from the standpoint of practical crop production, the optimum ranges of concentration and balance were fairly broad and that it was practical to develop and apply empirical standards of leaf composition which provided very useful, but not entirely infallible, guides for evaluating the nutritional status of citrus trees.

Kenworthy (1949) mentioned that plant analyses had shown that optimum growth and production might occur when the analysis for any one nutrient element varied considerably. As a result of this, he suggested that there appeared to be a range of values in plant composition at which optimum growth, visible deficiency or excess symptoms, and "hidden deficiency" or "hidden excess" might occur.

PROCEDURE

The purpose of this work was to investigate the nutrient status of an ornamental crop, Taxus media hicksi, growing at selected locations in southern Michigan. The investigation was designed: (1) to determine whether actual or incipient deficiencies or toxicities of each nutrient element existed; (2) to establish standard levels for each of the elements considered; and (3) to compare the assessments of nutrient status from soil analysis to those determined from leaf analysis.

It was observed that Taxus had two yearly periods of growth. The spring flush of growth was terminated in July, at which time the plants remained more or less quiescent until adequate rainfall caused a second period of growth in August and September. The cessation of growth in July was characterized by a "hardening" of the new growth. This seemed to satisfy the requirements for a recognizable, definite sampling stage.

New, terminal growth was used as the plant part to be sampled. These plants were commonly sheared in the field to promote compactness which made old tissue less available. New terminal growth was abundantly available in July. Sampling at this time followed the practice of using recently "matured" tissue, which had been found to generally give the best results (Chapman and Fullmer, 1951; Lundegardh, 1943; Ulrich, 1948; Reuther and Smith, 1954).

The cultivar hicksi is an upright form of Taxus media, and samples were collected by removing the terminal three inches of several of the most vigorous shoots from the tops of at least thirty plants in the group to be sampled. After washing, samples were placed in paper bags. The group of plants to be sampled was chosen on the basis of vigor and uniformity.

Because the investigation was confined to a single season, the stage of development for sampling had to be pre-determined. Rapid changes might take place in the levels of an element over a short period of time, and if such changes were occurring during the sampling period, the accuracy of the results would be reduced.

To determine the validity of the sampling period and to follow these changes in nutrient concentrations with development over the growing season, samples were collected at East Lansing from a commercial field grown plot at monthly intervals, for seven months beginning March 15, 1955. There were marked differences in the length of terminal shoots, apparently all lengths falling either well above, or well below an average value. Consequently, two samples were collected each month, one from the previous season's vigorous terminal growth, and one from the less vigorous growth. This was continued until June, when differences were no longer apparent, and the sampling procedure consisted of one sample of current growth each month.

On the night of May 8th, a minimum temperature of 30° F. (U. S. Department of Commerce, Weather Bureau, local climatological data, East Lansing, Michigan, May, 1955) completely killed all new growth on the plants being sampled. This dead tissue was separated from the May 15 samples and analyzed independently.

By July 16, subsequent growth was less rapid and the shoots were less succulent. On July 25, 26, and 27, samples were collected from five other sites in Michigan in an attempt to determine any variation in normal nutrient levels as a result of location. The samples were from plants 4 to 6 years from cuttings growing in field plots at commercial nurseries at Monroe, Bay City, Vicksburg, Allegan, and Stevensville (Figure 1). The plants growing on each site were not at the same stage of development because the retarding effect of the Great Lakes had delayed the growth in the Bay City, Monroe, and Stevensville areas.

Constant levels of each element would minimize the effects of differences in stages of maturity. With this in mind, samples were obtained at weekly intervals from the 16th to the 30th of July at the East Lansing plot.

Soil samples were obtained by means of a standard soil sampling tube. This was inserted ten inches into the ground at twelve points along the row of plants The samples were mixed, and a half-pint of this soil mixture was used for analysis (Spurway and Lawton, 1949)

LOCATION OF SAMPLING SITES

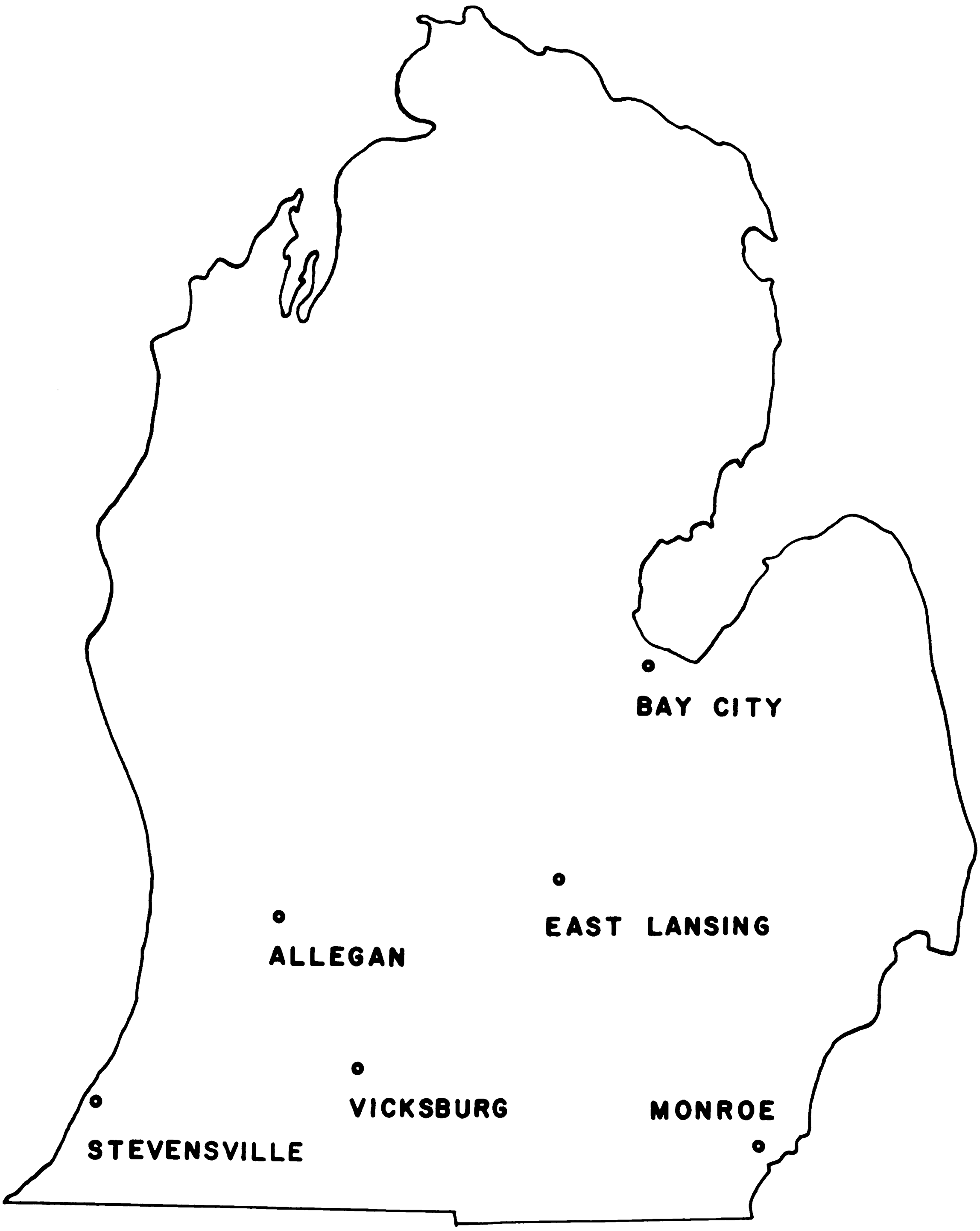


FIGURE I

At the time freezing injury occurred in East Lansing, the current season's growth was prolific, a uniform light green color, and about one inch long. The growth occurring on last season's less vigorous terminals was much less prolific, a uniform light green color, and about one-half inch long. Subsequent new growth was irregular in length, chlorotic, and frequency of shoots did not occur with its former uniform distribution. Since some new growth on each shoot had regained a light green color, the samples collected on June 15 were a mixture of old and new tissue, chlorotic and non-chlorotic. By July 16, all new growth was similar.

In sampling plants from the various locations, it was found that all sites had not been equally damaged by low temperature. Damage varied from "none", in which terminal shoots were as long as 18 inches (Monroe and Allegan); to "partial" in which a few shoots were longer than 14 inches, while the majority were 1/2 to 9 inches long (Stevensville); to "complete", in which all shoots were 4 to 10 inches long (East Lansing and Vicksburg).

The nutrient status of Taxus expresses itself in amount of growth. Two good measures of vigor of growth would be maximum, minimum, and average length of shoots, or total length of all new shoots Since these lengths obviously were affected variably by the frost, no such measure of vigor was attempted. No comparisons were drawn between plants on which complete loss of new growth had occurred, because it was believed that soil moisture would be too variable between locations during the month and a half of subsequent growth. Effects on nutrition were evidenced by the completely changed character of the growth occurring before and after the frost at East Lansing.

Often there were wide differences in the apparent vigor, especially when it was expressed in the height and width of the plants Since all plants were of about the same age, size of the plants was used as a measure of optimum or sub-optimum nutrition. Unfortunately, this was the only basis of evaluation available. No deficiency symptoms were recognizable.

Accordingly, the average composition of those plants which apparently had been making satisfactory growth was used as a standard level of nutrition.

Leaf samples were washed to remove spray residues, dried, ground in a Wiley mill, and stored in stoppered bottles. Prior to analysis, they were oven dried at 100° C. Nitrogen was determined by the Kjeldahl method, and potassium by flame photometer. Analysis for eight other elements was made spectrographically, using D. C. arc for zinc, and A. C. spark for phosphorous, calcium, magnesium, iron, copper, manganese, and boron.

Soil samples were analyzed for nitrate, phosphate, potassium, magnesium, manganese, iron, calcium, chloride, and sulphate by the Spurway method (Spurway and Lawton, 1949), using active soil extracts. They were analyzed for cation exchange capacity by leaching with . 1 N ammonium acetate, adding 10% sodium chloride solution after an alcohol wash, then leaching with ammonium acetate after another alcohol wash. Sodium in the extract, a measure of cation exchange capacity, was determined by flame photometer. Soil samples were further analyzed for total exchangeable calcium and magnesium by a versenate titration method adapted from Cheng and Bray (1951), and for total exchangeable potassium by flame photometer.

Kenworthy illustrated the use of a nutrient-element balance chart in 1949. Later he demonstrated the use of the coefficient of variation of the standard values for each element in a chart presentation (Kenworthy, 1953). This procedure involved relating the specific concentration of an element mathematically to the optimum level of that element, then correcting the fraction obtained for the coefficient of variation found in determining the standards. In effect, the result lowered all values above optimum (1.00), and raised all those below optimum. It also decreased to some degree the apparent difference from optimum which had no nutritional significance, but was the result of optimum values being a range of concentrations and not a specific value. The charts were further divided into the following zones of nutrition: 0.00-0.52 of optimum--a deficient zone; 0. 52-0. 84--a zone of hidden deficiency (reduced growth and yield with no deficiency sumptoms); 0. 84-1. 00--a zone approaching optimum; 1. 00-1. 16--a zone above optimum; 1. 16-1. 48--a zone approaching excess; and 1. 48 and above--a zone of excess. His figures were based on vast experience with tree-fruit crops, which had shown that his data could be interpreted accurately in this way. Norman (1955) observed that the minimum percentage of an element is frequently less than half the critical percentage (optimum).

Although these figures for the various zones did not necessarily apply directly to Taxus, they were used in the present investigation in order to present a graphical picture of nutrient balance and intensity in the plants.

This method of presentation might avoid placing too much emphasis on a low value obtained for an element that has a wide range of "normal" composition values, since its value would be raised considerably because of the high coefficient of variation. Goodall and Gregory (1947), tabulated data on normal ranges of some elements in a variety of crops which showed an overlap between the range in which deficiency symptoms occurred and the range found in normal plants.

It was recognized that when high values for the coefficient of variation were found, values which fell in the deficient range on the chart could not be obtained. It was believed, however, that balance between elements was, nevertheless, still sufficiently well presented so that interpretations could be made showing probable deleterious effects of the level shown.

RESULTS

PRESENTATION AND DISCUSSION

In this section the following items are presented and discussed: (1) the variation in the levels of the nutrients over the growing season, (2) an evaluation of the sampling period, (3) frost effects, (4) fertilizer use, (5) intensity-balance charts, (6) standard values, and (7) fertility levels as revealed by leaf and soil analyses.

The variations in the level of the nutrients over the growing season are presented in Figures II and III. The levels of potassium, calcium, magnesium, zinc, and manganese increased in the new tissue during the spring flush of growth, while the levels of nitrogen, phosphorous, iron, copper, zinc, and boron decreased. The results for potassium, manganese, zinc, and boron, were opposite to those found by Reuther and Smith (1954) for citrus.

There was no apparent growth in August and September. Terminal buds were not visible and slow elongation of the shoots might have occurred. Nitrogen, calcium, magnesium, iron, and manganese accumulated during this time; zinc and potassium decreased; while phosphorous, copper, and boron remained constant

In the previous season's growth, all elements except nitrogen,

SEASONAL VARIATION IN LEVELS OF NUTRIENT ELEMENTS IN <u>TAXUS MEDIA HICKSI</u>

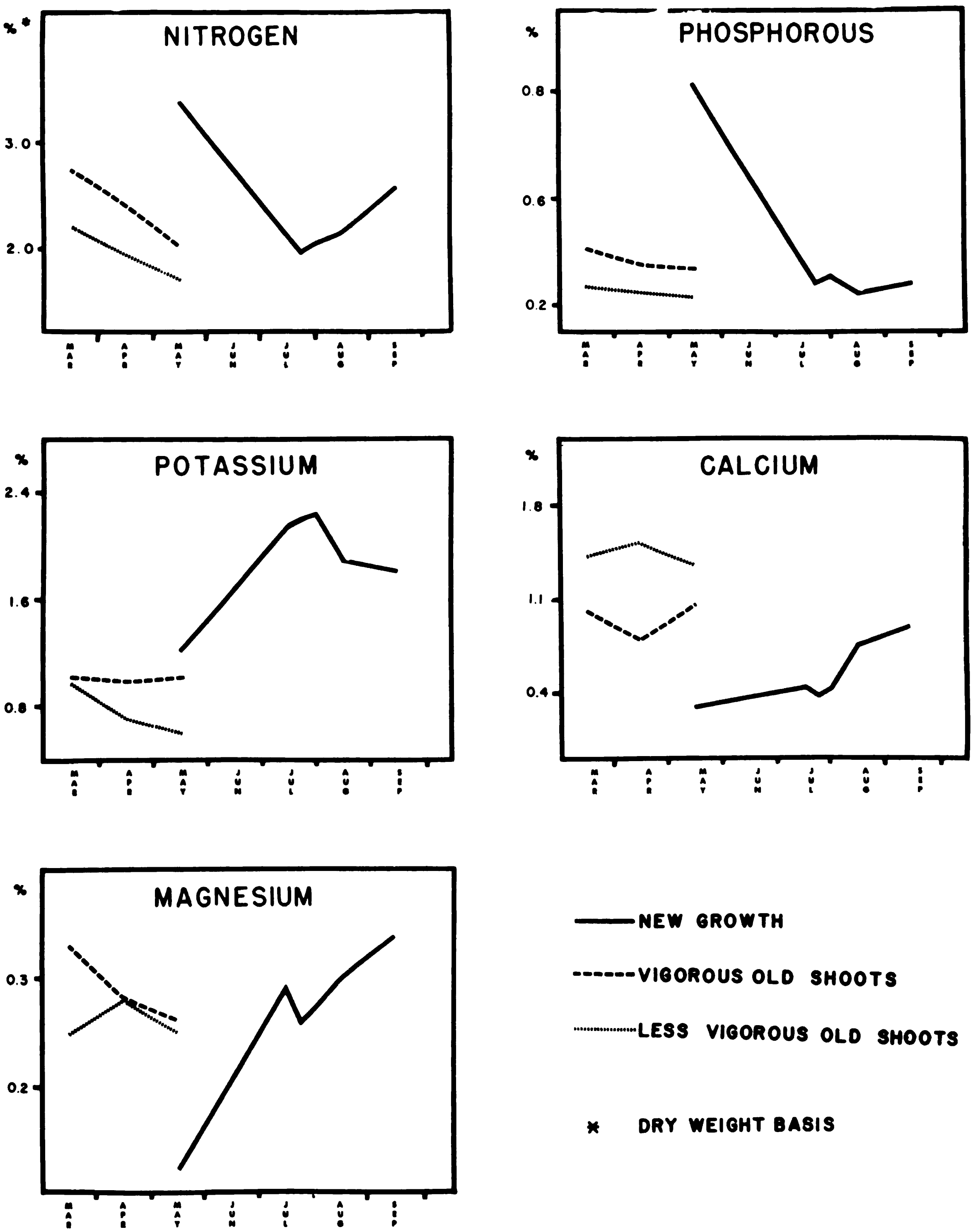


FIGURE II

SEASONAL VARIATION IN LEVELS OF NUTRIENT ELEMENTS IN *TAXUS MEDIA HICKSI*

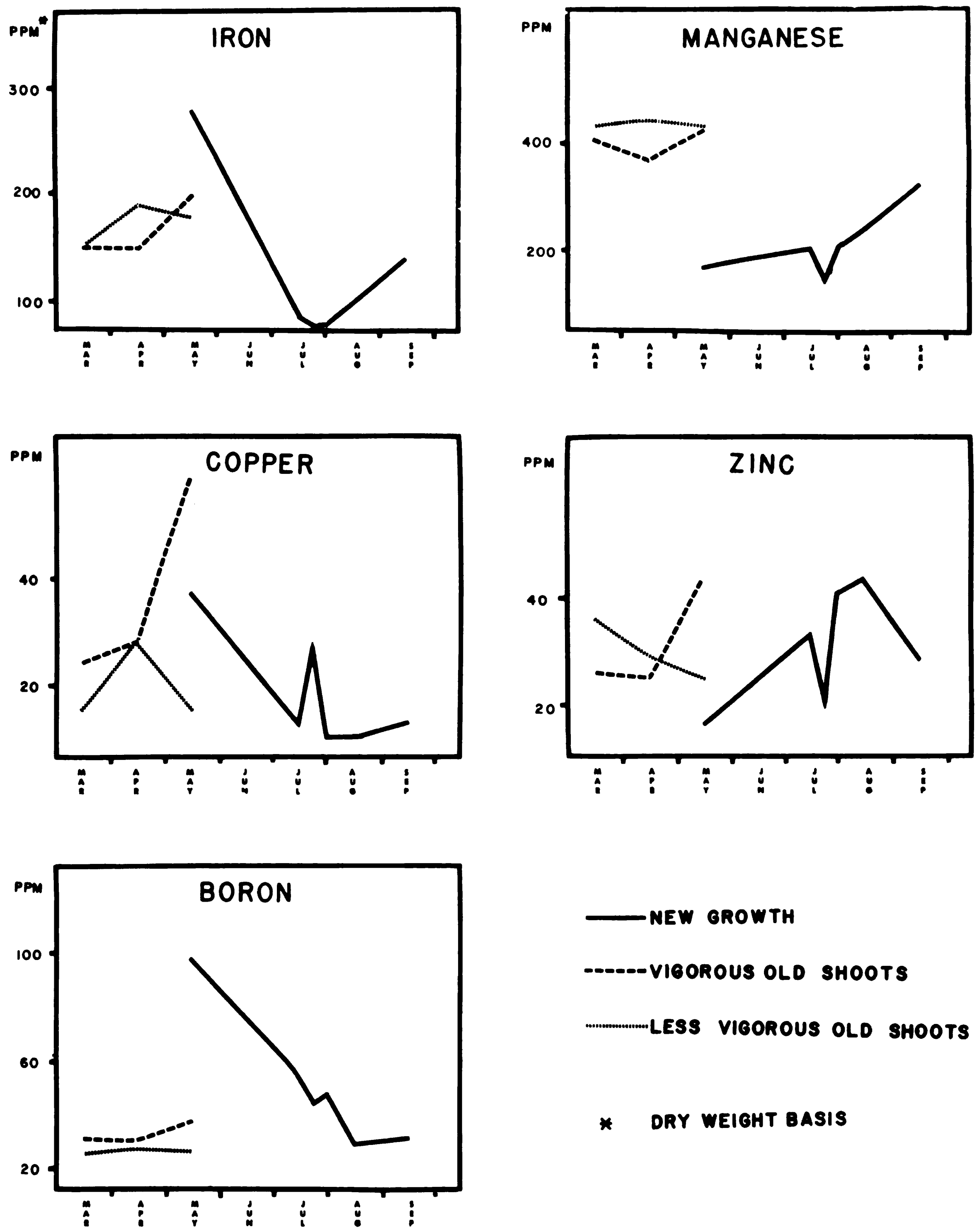


FIGURE III

calcium, and magnesium were fairly constant until April 15, at which time rapid changes occurred. Nitrogen, calcium, and magnesium decreased between March 15 and April 15.

The amount of nitrogen, phosphorous, iron, boron, and, to a lesser extent, potassium was higher in the new growth than in the old tissue from which the new growth was derived. The other elements were lower in the new tissue than in old tissue when new growth first appeared.

The differences in trends over the growth period and initial levels in the new growth cannot be explained on the basis of ion mobility in the plant, since both mobile and non-mobile ions showed the same characteristics.

All plants sampled were not at the same stage of maturity. Constant levels of elements in the leaves as they approach and reach maturity would minimize errors caused by differences in maturity, and thus, variations during the three week period in July, during which weekly samples were obtained at East Lansing, are of interest. Nitrogen, phosphorous, potassium, calcium, and, to a lesser extent, manganese were constant for this period of sampling. As shown for copper and zinc, the sampling plus analytical error at any one time was probably high because the wide fluctuations indicated in this data probably did not actually exist. Boron was decreasing and magnesium increasing during this period, which should be reflected in higher boron and lower magnesium contents in the "normal" plants that were retarded in development by their proximity to the Great Lakes. Actually there were no such relationships apparent, but the possibility is still present that boron levels are lower and magnesium levels higher for the Stevensville, Monroe, and Bay City sites than analysis indicated. Because of the apparent errors in copper and zinc determinations, such trends would be obscured.

Since the levels of all but three elements were fairly constant in early spring, this period would appear to be a more favorable time to obtain samples for diagnostic purposes. Although no samples of poor plants were obtained in early spring, there should be differences in composition between normal and poor plants at this time which would permit diagnosis of shortages. Standard values would, of course, be different for this sampling period than for samples obtained from new growth.

In addition to variations during the sampling period there were several other factors which probably had an influence on leaf composition.

One of these factors was the frost damage which occurred in May The composition of those "normal" plants from the two sites on which there apparently had been frost damage compared to the two sites on which no apparent frost damage occurred is presented in Table 1. It may be significant that the composition of all elements except phosphorous was consistently either above or below normal on the non-damaged plants. These plants were above normal in their contents of nitrogen, calcium,

TABLE 1

Composition of the Normal Plants Affected and Not Affected by Frost

Range in composition found	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
East Lansing, Vicksburg	1.86	.30	1.41	.39	.26	.008	.0149	.0007	.0020	.0043
Damaged by frost	2.18	.86	2.22	.68	.46	.013	.0478	.0027	.0040	.0071
Standard value	2.15	.49	1.96	.54	.36	.012	.0241	.0012	.0029	.0056
Monroe, Allegan	2.39	.29	1.52	.54	.39	.012	.0100	.0012	.0025	.0035
Not damaged by frost	2.51	.57	1.77	.67	.40	.019	.0200	.0008	.0027	.0040

Note: all figures expressed as percent dry weight magnesium, and iron, and below normal in potassium, manganese, copper, zinc and boron. Since the standard values for these elements were an average of the composition of all normal plants, the standards for the first group of elements might have been higher. Similarly, the standards for the second group might have been lower if the frost had not occurred.

This effect might be explained on the basis of the shorter growing season for the frost damaged plants. Where the initial flush of growth was not killed by frost, growth took place over a longer period than on sites where the first flush of growth was killed by frost.

The other factor having an influence on plant composition was the use of fertilizer (Table 2). The application of each of the major nutrient elements could be expected to have an effect on the levels of each of the major elements. The three major bases, potassium, calcium, and magnesium, could be expected to have an antagonistic effect on each other, and applications of any of the major bases could be expected to depress the availability of the heavy metals (Lundegardh, 1951; Drake and Scarseth, 1939; Ulrich, 1948; Shear, et al., 1948; Chapman, 1941).

Potassium was the only one of the major bases added on these sites, and the correlation coefficient for potassium-calcium levels was -.724, significant at the 1% level, and for potassium-magnesium levels was -.467, significant at the 5% level. The correlation for levels of calcium and

TABLE 2

Use of Fertilizer on Sites Investigated

Monroe

1952 - 64-24-24
1953 - 64-48-48, 4000 gal/A sewage
1954 - 64-80-80, 4000 gal/A sewage
1955 - 88-120-120

Bay City

1952 - heavy application of manure
1953 - none
1954 - heavy application of manure, Rapid-Gro in irrigation water
1955 - none

East Lansing

1954 - 60-60-60
1955 - 30-30-30, 2-2-2 in irrigation system

Vicksburg

1952 - 20-80-80

Allegan

Sawdust, manure, fertilizer each year

Stevensville

1953 - manure
1954 - 35-35-35
1955 - 62-0-0

Note: figures are rates of application expressed as pounds per acre of nitrogen P_2O_5-K_2O

phosphorous was -.574, significant at the 1% level.

The other significant correlations found were between levels of calcium and iron, and calcium and boron, both significant positive correlations. There were no significant correlations between the levels of the major nutrient elements, nitrogen, phosphorous, and potassium.

Thus, the use of complete nitrogen-phosphorous-potassium fertilizers had some effect on the levels of other nutrients in plants on these sites. These effects were especially important in arriving at an estimate of whether proper rates of fertilizer were being applied on each site.

The analyses of plants at each location are presented on intensity-balance charts in Figures IV through VII. Charts 1 and 2 represent plants sampled at Allegan. There were great differences in growth between the two groups. The smaller plants, Chart 1, had received no fertilizer or irrigation, while the larger plants, Chart 2, had received applications of sawdust, manure, fertilizer, and water. The difference in intensity and balance between the two could not account for the extreme differences in growth. Water may have been the factor limiting the growth of the poorer plants.

The plants represented by Charts 1, 3, and 4 were the best plants found. The levels of all elements were not in the normal range. Although the vigor of these plants appeared satisfactory, a correction of the lower levels of certain nutrients may result in better growth. Thus, the plants

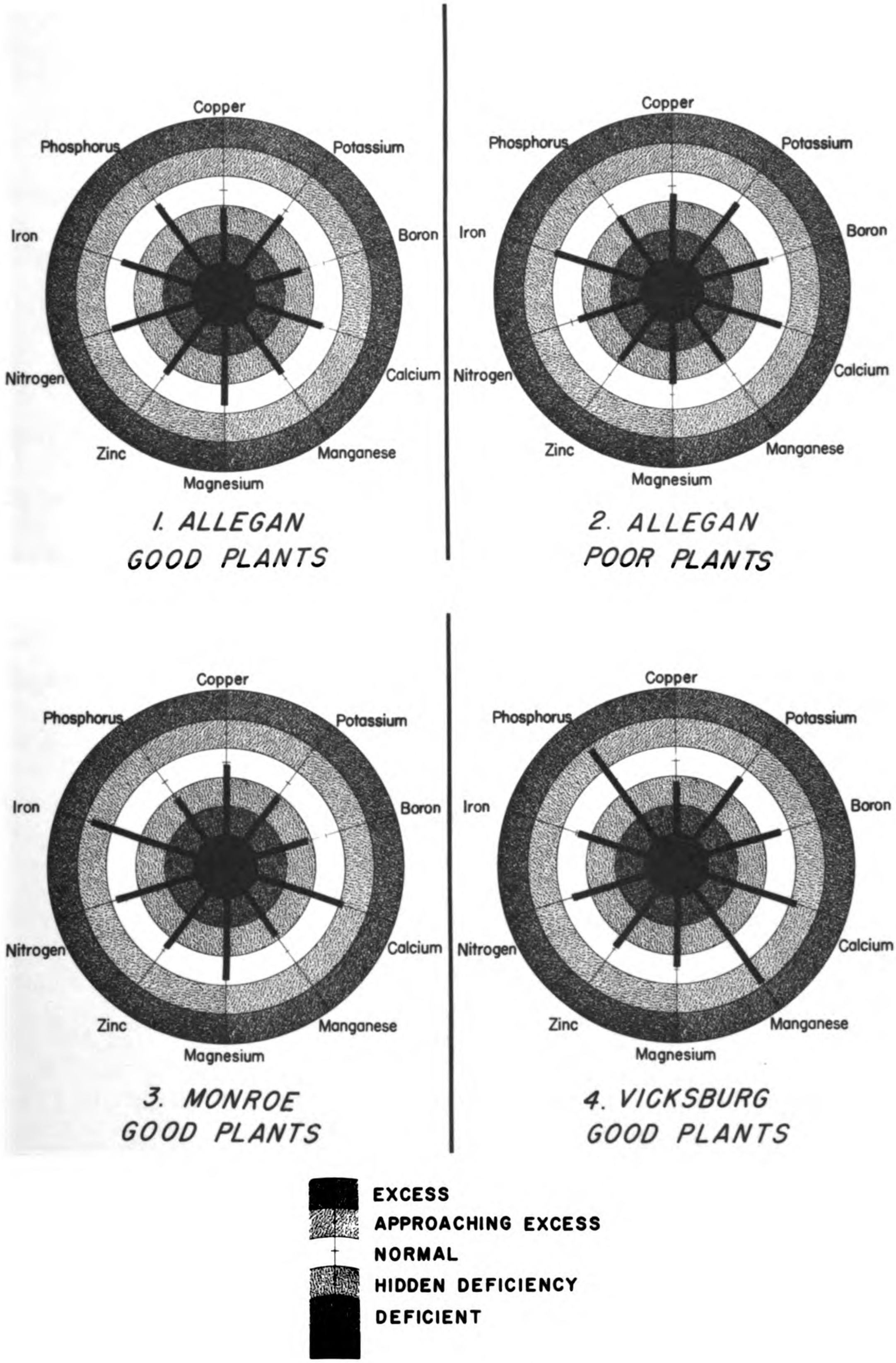
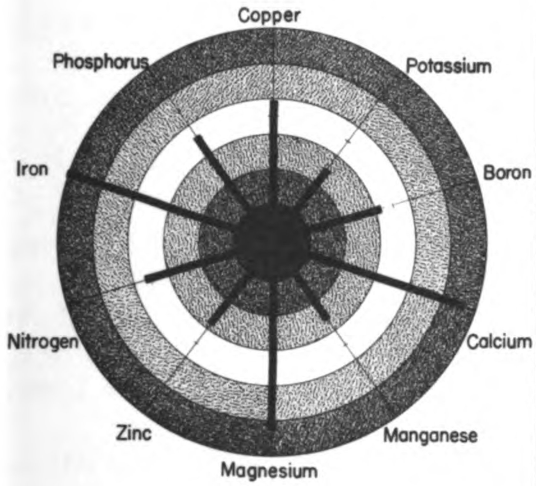

Copper
Potassium
Boron
Calcium
Manganese
Magnesium
Zinc
Nitrogen
Iron
Phosphorus
1. ALLEGAN
GOOD PLANTS
2. ALLEGAN
POOR PLANTS
3. MONROE
GOOD PLANTS
4. VICKSBURG
GOOD PLANTS
EXCESS
APPROACHING EXCESS
NORMAL
HIDDEN DEFICIENCY
DEFICIENT

FIGURE IV

at Allegan (Chart 1) may respond to additions of boron. The plants at Monroe (Chart 3) may respond to additions of phosphorous, potassium, boron, and manganese. No additional phosphorous should be applied at Vicksburg (Chart 4) if the plants were side-dressed with fertilizer.

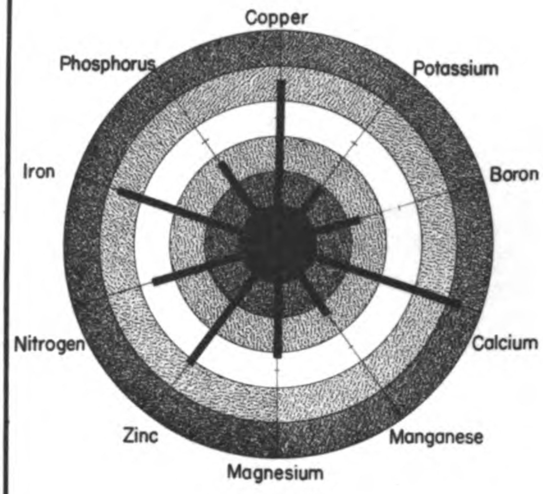
The analyses of samples from the poorer plants are presented in Charts 5 through 8. Chart 5 represents a sample from a poor row in the block at Monroe. Potassium deficiency was apparent, since not only was the potassium level below normal, but magnesium and calcium levels were in the excess range. Analysis of the better plants on this site indicated that additional phosphorous might be needed. If phosphates were increased, the high iron level in this analysis would probably decrease and calcium levels may also decrease. This chart also revealed levels of manganese and zinc to be below normal, indicating that there may be some response to additions of these elements. If the level of the three major bases were corrected, complex interactions could be expected. This might cause a change in the levels of all the minor elements

In the samples obtained at Bay City (Chart 6), potassium deficiency was again apparent. Additions of potassium should reduce the levels of both calcium and magnesium, but here the level of magnesium was normal. Thus, additions of potassium should be accompanied by additions of magnesium. Rate of application of phosphorous should also be increased, which should not only raise the level of phosphorous, but also decrease the high



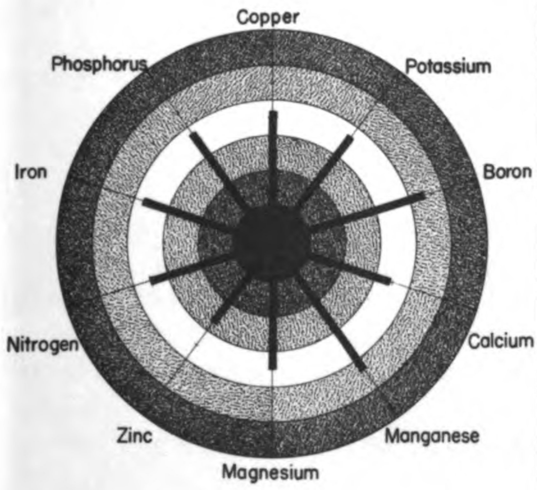
5. MONROE

POOR PLANTS



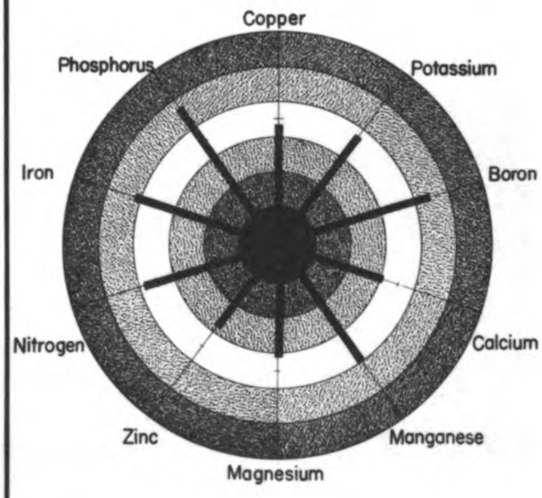
6. BAY CITY

POOR PLANTS



7. STEVENSVILLE

POOR PLANTS



8. STEVENSVILLE

POOR PLANTS

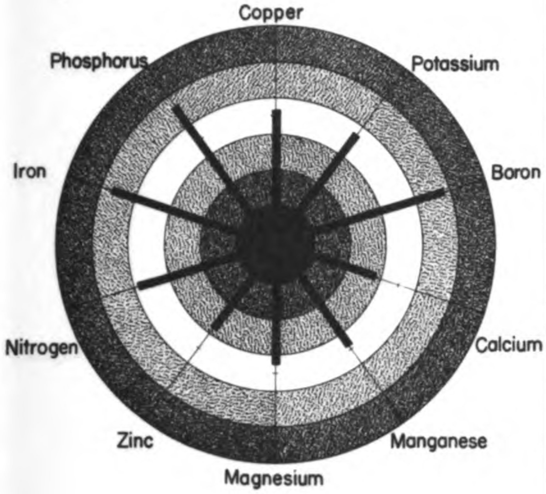
FIGURE V

calcium level. Once these two corrections were made, there might be responses to applications of manganese and boron, although these recommendations should be determined by subsequent leaf analysis.

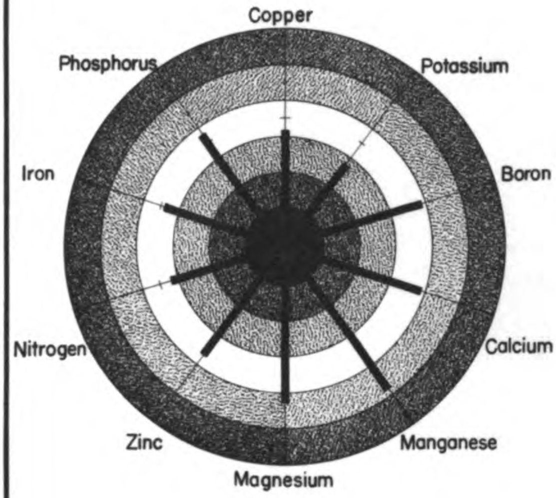
In Charts 7 and 8 the analyses of samples of the poorer plants at Stevensville are presented. The analysis of samples for the better plants sampled on that site are presented in Chart 9. Plants represented by Chart 7 were growing within the good row, although they were much smaller than the normal plants in the row. Those represented by Chart 8 occurred in a row that was uniformly poor. Some factor other than nutrition must have caused the reduction in growth. Leaf analysis did indicate that there might be some response to additions of calcium and magnesium and that the rate of additions of nitrogen, phosphorous, and potassium could be reduced. In the case of potassium, additions should be reduced to prevent calcium and magnesium deficiencies.

Older, normal plants at East Lansing were also sampled (Charts 10, 11, 12). The 20-year-old plants represented by Chart 10 were less vigorous than the 10- and 8-year-old plants (Charts 11 and 12), and leaf analysis showed a slight deficiency of potassium.

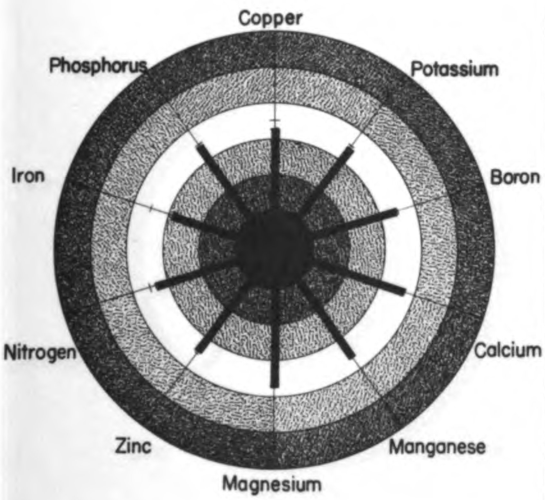
The analyses of the three samples obtained on July 16, 23 and 30 at East Lansing are presented in Charts 13, 14, and 15 These charts show the extreme variation in copper and zinc levels discussed previously. Although these plants were making satisfactory growth, they were slightly



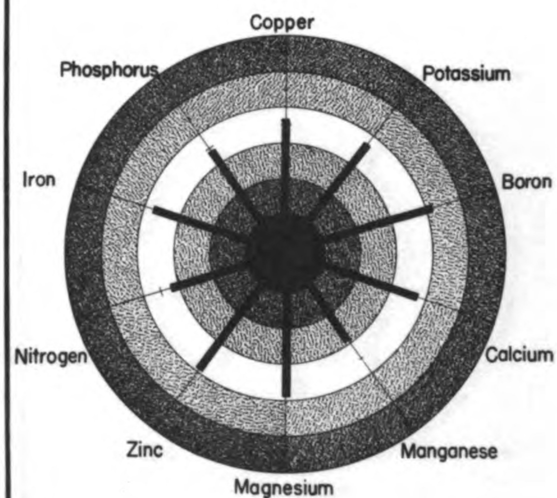
9. STEVENSVILLE
GOOD PLANTS



10. EAST LANSING
20 YEAR OLD PLANTS

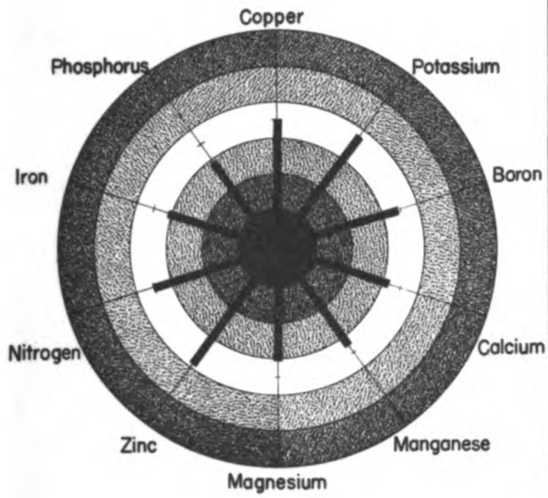


11. EAST LANSING
10 YEAR OLD PLANTS

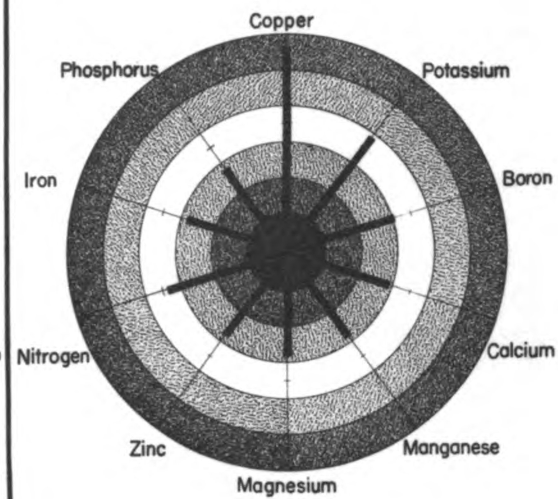


12. EAST LANSING
8 YEAR OLD PLANTS

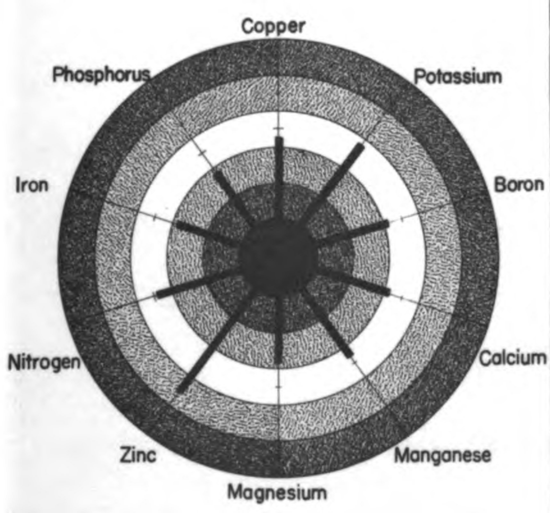
FIGURE VI



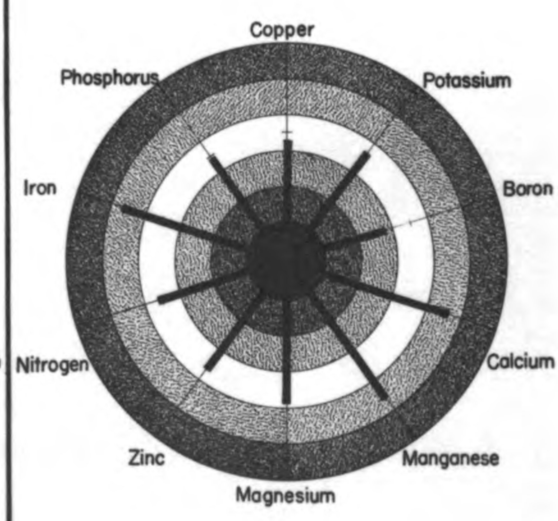
13. EAST LANSING
JULY 16



14. EAST LANSING
JULY 23



15. EAST LANSING
JULY 30



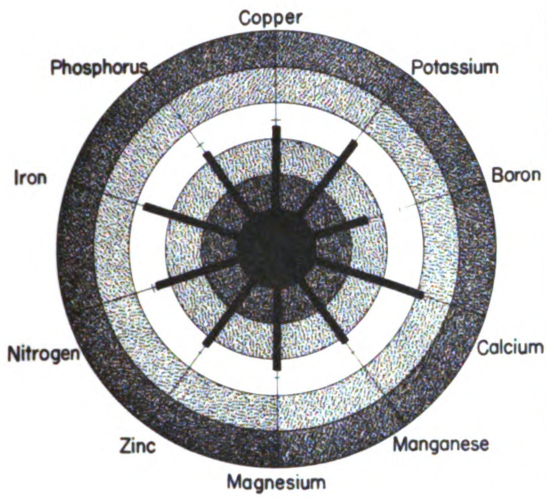
16. TAXUS CUSPIDATA INTERMEDIA
GOOD PLANTS

FIGURE VII

less vigorous than the plants at Monroe, Vicksburg, and Allegan. The charts indicated that these plants should respond to additions of phosphorous, calcium, and magnesium. There may be response to added iron, but iron levels would change as a result of additions of the previous three elements. On this site, additions of potassium were too heavy for the existing calcium and magnesium levels in the soil, and a continuation of the fertilizer program would probably result in a deficiency of calcium or magnesium.

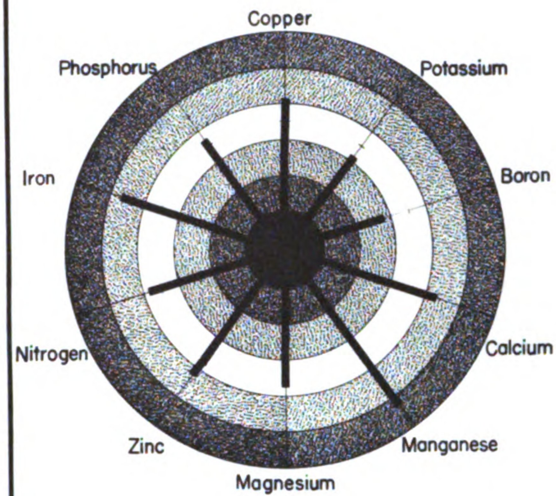
Several conclusions were drawn from the above analyses. Potassium deficiency was associated with a pH in the range 6.5-7.0 (Monroe, Bay City, Allegan). Levels of manganese and boron which were below normal also occurred on these soils. These were the soils on which large applications of organic matter were made (Table 2). Although no low levels were found, calcium and magnesium tended to be lower where soil pH ranged between 4.8 and 5.5 (East Lansing, Vicksburg, and Stevensville). Phosphorous levels were below normal and in the range of "hidden deficiency" on half of the sites. Nitrogen levels were always satisfactory.

Other species and cultivars of Taxus were sampled and the analyses are presented in Charts 16 through 20, using the standard values obtained for the cultivar hicksi. All plants were growing in the same blocks as the cultivar hicksi at East Lansing and Stevensville. Using these standards, the cultivars T. cuspidata intermedia and T. media halloran could be diagnosed correctly as being satisfactory. At East Lansing a very poor,



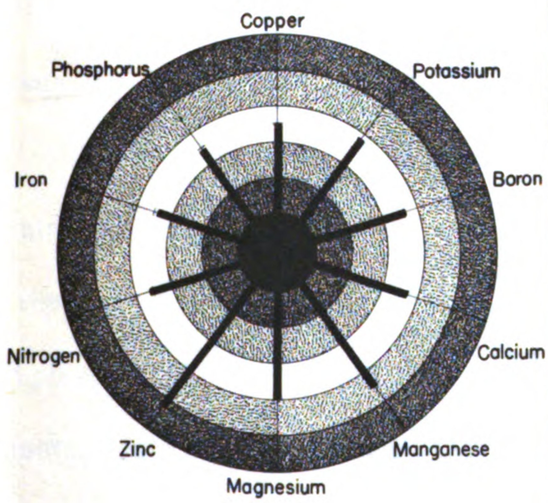
17. TAXUS MEDIA HALLORAN

GOOD PLANTS



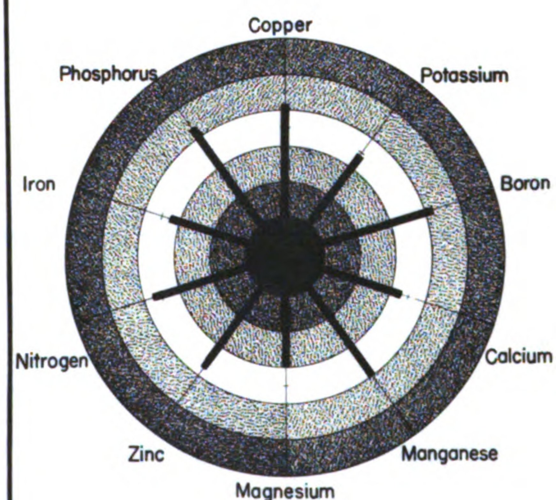
18. TAXUS CUSPIDATA

POOR PLANTS



19. TAXUS CUSPIDATA EXPANSA

POOR PLANTS



20. TAXUS CUSPIDATA EXPANSA

GOOD PLANTS

FIGURE VIII

chlorotic group of the species T. cuspidata was found (Chart 18). Excess manganese was indicated by the analysis, thus this species was able to extract manganese from the soil more efficiently than the other kinds growing on this site. The excess manganese may not be the cause of the reduced growth. The species may have different nutrient requirements or normal levels which could result in any of the elements shown actually having been in the deficient range.

The cultivar, T. cuspidata expansa was found to contain large amounts of zinc and manganese. The differences in the levels of these two elements between the group of plants at East Lansing, which was poor (Chart 19), and those at Stevensville, which were satisfactory (Chart 20) could not account for the differences in growth. Thus, it would appear that there is a difference in normal composition between the species of Taxus, especially for the element manganese and possibly for zinc.

The composition of the ten "normal" plant samples used in determining the standards are presented in Table 3. There are some variations in the size of these plants, but the plants evaluated as poor were much smaller (Figure IX). The three samples obtained at weekly intervals in July at East Lansing from good plants were included so that the coefficient of variation would include some measure of variations during July.

Previous analyses of Pinus, Picea, and Abies needles showed similar results for nitrogen and phosphorous (Tamm, 1954), and for iron (Mitchell, 1954).

TABLE 3

Proposed Standards for Taxus media Hicksi

Samples from good plants	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
East Lansing:										
July 16	2.15	.33	2.16	.45	.29	.009	.0200	.0012	.0033	.0054
July 23	1.99	.28	2.21	.39	.26	.008	.0146	.0027	.0020	.0043
July 30	2.07	.30	2.22	.45	.27	.008	.0203	.0010	.0040	.0046
20-year-old plants	1.86	.56	1.41	.63	.46	.011	.0447	.0009	.0031	.0067
10-year-old plants	1.96	.48	1.87	.60	.39	.008	.0268	.0010	.0028	.0056
8-year-old plants	1.90	.47	2.13	.60	.42	.013	.0149	.0013	.0034	.0071
Monroe	2.39	.29	1.52	.67	.40	.019	.0100	.0012	.0027	.0040
Vicksburg	2.18	.86	2.15	.68	.34	.011	.0478	.0007	.0027	.0061
Allegan	2.51	.57	1.77	.54	.39	.012	.0200	.0008	.0025	.0035
Stevensville	2.46	.79	2.11	.40	.32	.018	.0217	.0013	.0021	.0090
Average - standard value	2.15	.49	1.96	.54	.36	.012	.0241	.0012	.0029	.0056
Coefficient of variation - %	20.0	42.5	15.2	20.4	18.7	34.2	52.2	46.5	21.3	28.0

Note: all figures expressed as percent dry weight

GOOD PLANT

POOR PLANTS

VARIATION FOUND IN GOOD PLANTS

FIGURE IX

A comparison of fertility levels as revealed by leaf and soil analysis is presented in Table 4. Soil tests, using Spurway active extracts, for nitrates, phosphates, iron, and manganese did not accurately reflect the amount of these elements in the plants. Soil nitrates were measured as 4 lbs/A at East Lansing, 80 lbs/A at Monroe, and 0 lbs/A at other sites, and yet leaf nitrogen was within the normal range in all the plants. Phosphates tested from 1 to 7 lbs/A, which constituted a very low test, and yet phosphorous was above normal in the plants at Vicksburg and Stevensville on soils testing 1 lb/A phosphates. Soil tests indicated no iron in the active extracts of any of the soils. Manganese tested normal (16 lbs/A) for the soil from Vicksburg, while leaf analysis showed the level in the plants to be approaching excess. On the other sites, soil tests for manganese were blank and manganese ranged from below normal to normal in the plants. It would appear that if the soil test for manganese was to be employed, optimum levels should be set lower for Taxus than the 16 lbs/A used for field crops (Spurway and Lawton, 1949).

An examination of the results for the three major bases, potassium, calcium, and magnesium, indicated that analysis of soil extracts was not reliable for Taxus.

At Monroe, soil tests showed an excess of magnesium with a normal amount of calcium and potassium, while leaf analysis showed a deficiency of potassium in respect to both calcium and magnesium. Soil tests indicated

TABLE 4

Evaluation of Fertility Levels - Soil and Leaf Analysis

	Monroe		Bay City		East Lansing		Vicksburg		Allegan		Stevensville	
	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf
N	3	3	0	3	2	3	0	3	0	3	0	3
P	1	2	1	2	1	2	1	4	1	3	1	4
K	3	2	3	1	3	3	3	3	3	3	3	3
Ca	3	4	1	5	1	3	1	4	1	3	1	2
Mg	4	3	2	3	0	2	0	3	3	3	1	3
Fe	0	5	0	4	0	2	3	4	0	3	0	3
Mn	0	2	0	2	0	3	3	4	0	3	0	3

Evaluation	Soil analysis*	Leaf analysis
0	blank test	
1	very low	deficient
2	low	hidden dificiency
3	optimum	normal
4	above optimum	approaching excess
5	high test	excess

*interpreted according to Spurway and Lawton (1949) that potassium and calcium would be needed to bring about a balance of the three major bases, but leaf analysis showed that only potassium would be needed.

At Bay City, the soil was low in magnesium and calcium and normal in potassium, indicating that dolomitic limestone should be applied to correct the poor growth. Leaf tests showed that it was potassium which was low and that any additions of calcium or magnesium would probably result in further unbalance and reduced growth.

Soil tests at Vicksburg again indicated a need for potassium and magnesium. The leaves contained normal amounts of potassium and magnesium, with a slight excess of calcium. Here again applications of magnesium would probably result in reduced growth.

At Stevensville, the soil tests indicated a need for lime applications. Such applications should not reduce growth, since calcium was shown by leaf analysis to be slightly below normal. The soil test indicated a need for magnesium even though the leaves contained a normal amount of this element.

At Allegan, calcium was deficient in the soil, although all three bases were normal in the leaves.

The need for liming with dolomitic limestone was again indicated by soil tests at East Lansing. The leaves were slightly below normal for magnesium.

The one example of normal manganese in the soil was associated with an excess in the plants This might be the result of the use of survey data to establish the standard for an element. The standard proposed in this example might be too low as a result of a general deficiency of manganese in the area. The possibility of this error was a criticism of the use of the average composition of plants over an area to represent optimum nutrient levels. If there was a general manganese deficiency in the area represented by this survey, all plants sampled except those at Vicksburg (Chart 4) should show a response to added manganese.

Determination of total exchangeable bases, as recorded in Table 5, showed better agreement with leaf analyses. Although there was no correlation between leaf and soil potassium, the correlation coefficient for magnesium was .645 (significant at the 5% level) and for calcium was .593 (significant at the 5% level). Even at these correlations it was interesting to note that when leaf magnesium was .39 to .41 percent, the percent magnesium saturation ranged from .57 to 9.28 Leaf magnesium ranged from .31 to .62 percent dry weight and soil magnesium saturation ranged from .35 to 9.28 percent. The highest leaf values were associated with 7.23 percent magnesium saturation, and the lowest at .79 percent.

TABLE 5

Total Exchangeable Potassium, Calcium, Magnesium; Base Saturation; pH; and Exchangeable Capacity of Soils

Sample	Potassium		Calcium		Magnesium		CEC	pH
	me/100g	% sat	me/100g	% sat	me/100g	% sat	me/100g	
1	0.30	2.0	4.10	28.0	1.54	10.5	14.64	6.5
2	0.68	6.0	5.75	50.9	1.03	9.1	11.30	6.8
3	1.34	5.2	18.93	73.8	9.28	36.2	25.65	6.8
4	0.58	6.1	2.21	23.1	0.75	7.8	9.57	5.1
5	1.12	3.5	20.88	65.8	7.23	22.8	31.74	7.0
6	0.16	2.7	4.06	68.7	0.35	5.9	5.91	6.8
8	0.53	4.8	1.69	15.3	0.55	4.9	11.05	4.8
9	0.56	5.3	1.62	15.4	0.54	5.1	10.54	4.9
15	0.60	7.1	4.70	55.7	0.79	9.4	8.44	5.2
18	0.44	8.0	4.63	84.0	0.63	11.4	5.51	5.5

Note: samples listed by Chart number, Figures IV to VIII.

INTERPRETATION OF RESULTS

Nutrient levels were found to vary during the growing season The direction and extent of the changes were not comparable to the variations found in citrus by Reuther and Smith (1954).

Early spring appeared to be a favorable time for the sampling of Taxus media hicksi Zinc and copper determinations were unreliable and magnesium and boron levels were in a state of change in July, while levels of other elements were fairly constant.

Although rates of application of nitrogen varied, nitrogen was within the normal range in all plants sampled Potassium deficiency was the only general, definite deficiency found and it was associated with a pH of 6. 5-7 0. Incipient deficiency of manganese and boron was associated with the same range in pH and with heavy additions of organic matter. On soils of lower pH (4 8-5. 5), use of potassium fertilizers had not caused calcium or magnesium deficiency. Phosphorous levels were below normal on one-half of the sites investigated Zinc levels were below normal in all but one of the poorer groups of plants. Iron levels varied widely in both the poorer and better plants

The proposed standard levels of nutrients for Taxus media hicksi are presented in Table 3. Because of frost damage on some sites, the standards for nitrogen, calcium, magnesium, and iron should be slightly higher, and the standards for potassium, manganese, copper, zinc, and boron slightly lower. There were differences in normal composition between the species _media_ and _cuspidata_.

Active soil tests were not reliable for assessing the fertility status of this crop, and were shown to lead to erroneous conclusions on most sites. The versenate titration method for determining total exchangeable calcium and magnesium in the soil was quite reliable in predicting the leaf composition of those two elements.

SUMMARY

This investigation was designed to determine the nutrient status of *Taxus media hicksi* growing at selected locations in southern Michigan. Leaf analysis was employed to establish actual or incipient deficiencies or toxicities, and to establish standard levels for each element. The assessments of nutrient status from soil analyses were compared to those determined from leaf analyses.

Samples were collected over the growing season at East Lansing to establish seasonal variation in nutrient levels for these plants, and to determine the validity of sampling in summer. Samples were collected in July from both good and poor plants growing on six representative sites in southern Michigan.

Leaves were analyzed for nitrogen by the Kjeldahl method, for potassium by flame photometer, for phosphorous, calcium, magnesium, iron, manganese, copper, zinc, and boron by spectrographic analysis.

Soil samples were obtained at each site and analyzed by the Spurway method, using active soil extracts. Total exchangeable bases were determined, using a versenate titration for calcium and magnesium, and flame photometer for potassium.

Nitrogen was found to be satisfactory on all sites sampled. Phosphorous was found to be below normal on one-half of the sites. Potassium

deficiency was found on several sites, associated with higher pH, and the use of potassium on low pH soils had not caused any deficiencies of calcium and magnesium, although levels of these two elements were generally below normal in plants on these soils.

Early spring appeared to be the best time to sample this crop. Copper and zinc determinations were unreliable in July. Boron and magnesium levels were changing in the tissues at this time.

Soil tests in which active extracts were used did not appear to be a reliable method of determining the nutrient status of Taxus. The versenate titrations of calcium and magnesium showed a high correlation with the levels of these two elements in the leaves.

The average composition of the better plants found in the survey was used as the proposed standards for the interpretation of leaf analyses of Taxus media hicksi. Expressed as percent of dry weight, the average composition was: nitrogen, 2.147; phosphorous, .487; potassium, 1.955; calcium, .541; magnesium, .360; iron, .0117; manganese, .0241; copper, .0012; zinc, .0029; and boron, .0056.

It was concluded that after the reliability of these proposed standards was determined by sampling in at least two more seasons, and the significance of departures from normal for each element was investigated, leaf analysis would provide a very useful aid in the diagnosis of nutrient deficiencies for this crop.

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