USEFULNESS OF VARIOUS DIAGNOSTIC METHODS IN DETERMINING NUTRITIONAL DISORDERS

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When the plant propagator sows seed or makes cuttings as the initial step in producing new plants, he consciously or sub-consciously wonders whether or not they will grow properly. He may be concerned with seed viability, breaking of seed dormancy, seed germination, or the selection of wood or plant parts for cuttings In the seed bed, propagation frame or nursery field, he concerns himself with soil texture, soil moisture, soil aeration, soil fungi, soil bacteria, soil insects, soil nematodes, etc. Sooner or later, he may become concerned with plant nutrients or soil fertility and wonder whether or not the plants will develop deficiency symptoms or show instances of toxicity while in the container or nursery row.

Years of experience has taught many of you the technique of preparing a seed bed, propagation frame or nursery field. You can prepare them in such a way as to insure most of the physical features desired for best plant performance. Obviously, we don't all do it the same way. We can visually judge soil condition as related to drainage, moisture holding capacity and aeration but it is next to impossible to visually judge the soil as regards fertility or nutrient supply. Characteristically peat, manures or other forms of organic matter are added to the soil or grown on the field and later incorporated into the soil to improve soil texture. However, manure is not always as good as it might be. Both manure and organic residues of crops are only as good as their source. For example, growing a cover crop on a field that is deficient in a particular nutrient is not likely to correct the deficiency unless the deficient nutrient is added.

In order to prevent nutrient disorders or to detect the development of a nutrient disorder, anyone working with plants needs certain diagnostic tools. We have the diagnostic tools necessary to control the nutritional status of our plants. Such tools are (1) deficiency symptoms, (2) soil tests, (3) soil analysis, (4) tissue tests, (5) leaf or plant analysis, and (6) field trials. These tools are useful However, they are useful only if they are used. (Even the car or tractor is not useful if not used.) Each of these diagnostic tools has its limitations and each has its advantages. We should consider these advantages and disadvantages in order to arrive at a logical approach to controlled plant nutrition.

DEFICIENCY SYMPTOMS

These are useful in determining severe or critical shortages of single, and sometimes double, nutrient-element deficiences. Usually when more than one nutrient-element is deficient there is no visible expression of the symptoms but the plant may not perform normally. Also, by the time deficiency symptoms have appeared, plant growth has already been drastically reduced. However, if the deficiency symptoms develop and are known, there is no other method of diagnosis that is *quicker, easier,* and *cheaper* than the use of such symptoms. Unfortunately, deficiency symptoms are not known for all nutrients for all crops. Still more unfortunately, the symptom for a particular nutrient deficiency may vary according to conditions under which it develops. For example, magnesium deficiency in blueberries show a red color in good light but yellow in poor light.

In addition to identifying a disorder, visual symptoms may distinguish between nutrition, insect and disease disorders. Mr. Zimmerman will show slides of plant nutrient deficiencies As he shows these slides, I would like for you to note the patterns. For the most part, the symptoms will show characteristic patterns as related to the margins or veins of the leaves. Also the pattern will be essentially the same from leaf to leaf for each deficiency. However, the pattern of brown, yellow, or red discoloration will not of necessity be the same for all species or varieties. Regardless of pattern, the symptom will be related to the veins of the leaf. As for insects and diseases, the characteristic pattern does not develop in relation to leaf veins. Insects and diseases do not have any particular regard to leaf veins and their invasion is not consistent from leaf to leaf. By keeping these factors in mind, we can divide our troubles and avoid calling a plant nutrition man when we need an entomologist or a plant pathologist.

SOIL TESTS

Soil tests are useful, mainly to determine or estimate the basic fertilizer applications prior to planting. They are useful, also, as a periodic check upon nutritional conditions during the growing season. Soil tests have had their greatest usefulness on annual or biennial crops that have relatively small or shallow root systems. Such tests have not been too satisfactory for woody perennials that have extensive root systems. Soil tests are rapid and inexpensive. They may be made in the field and necessary correction measures taken immediately.

Unfortunately, soil tests are limited in nutrient coverage. Most soil tests will report only pH, phosphorus, and potassium. If desired, they may include magnesium, calcium, manganese, iron, sulfate, chlorides and total salts Also, soil test values have not been standardized for each crop. For example, we may be able, from soil tests, to suggest safe levels at which no further additions of nutrients are needed. However, the level below which we cannot go and at which nutrient additions should be made is not the same for all crops. Those values prescribed for corn, wheat, oats and alfalfa may not be economically sound on the Horticultural crops we are interested in. Also, it may not be economically sound to maintain a continuous maximum supply of nutrients.

A third handicap for soil tests would be the lack of standardization between methods. As an illustration — it is not possible to compare soil test results with anyone else unless he is using the same soil testing method. Thus, soil test results in Michigan may be different from those obtained in Wisconsin, Iowa, Illinois, Indiana, New Jersey, and other states The difference being due to methods used. Until, soil tests are standardized so we can compare and use results of our associates, there will be much confusion in this method For the present we must each develop our own standards and put them into use Just think of the advantage you would have if you could exchange such information with your associates.

SOIL ANALYSIS

Soil analysis differs from soil tests only in that it is a more precise procedure. It is more precise because the suggested fertilizer additions are based upon the soils ability to hold the nutrients — as measured by exchange capacity. With a known exchange capacity, the amount of necessary fertilizer may be varied accordingly. However, this is only a mathematical calculation and does not need to be as precise as often reported It may seem accurate and precise to calculate fertilizer needs to the nearest pound per acre or gram per container but our methods of application and the plants themselves are not that accurate.

One of the principle advantages of soil analysis is that the laboratory methods are fairly well standardized and comparable results can be obtained by different laboratories. The main attempt to place soil analysis into field operation has been developed in Missouri. This method is used by certain commercial laboratories. However, before we invest an undue amount of time and money in soil analysis, we should consider that the handicaps are the same as for soil tests. Chiefly, we do not have the necessary information for making recommendations specific to the crop in question.

TISSUE TESTS

These tests are primarily useful on plants of a succulent nature. They have not been found to be useful for woody plants. The very nature of tissue tests would indicate a good reason for their failure to be satisfactory on woody plants. Tissue tests are based upon the extraction of plant sap (and woody plants are not very juicy). The leaves and other tissues of woody plants is of such a nature that extraction of the sap is extremely difficult. In addition, the presence of large amounts of tannic substances often interferes with the color expressions on which tissue tests are based

The coverage of nutrients by use of tissue tests is limited mainly to nitrogen, phosphorus, potassium, and magnesium. Chloride excess may be also be detected. For woody plants, a special potassium tissue test may be used when standardized for the crop in question. Most woody plants do not contain nitrate nitrogen and, therefore, the nitrate test is not usable. However, should nitrates be present in woody plants, there may be reason to suspect molybdenum deficiency. Chloride excess may be detected by tissue test on the more succulent tissues by use of a silver nitrate solution. This possibility of testing for chlorides can bear some study, especially where excess salts are likely to accumulate as a result of frequent watering.

LEAF OR PLANT ANALYSIS

Leaf or plant analysis is useful for both succulent and woody plants. As the name implies, an accurate chemical or spectrographic analysis of the composition of the leaf or plant part is obtained. At the present time, leaf or plant analysis is being used for diagnostic purposes for nearly all agricultural crops. Leaf or plant analysis is considered to be the best diagnostic tool for woody plants

What can leaf analysis do for us? Leaf or plant analysis has been used to provide information that identified a nutrient disorder for the first time. They are used to demonstrate nutrient shortages prior to visible symptoms. Plant analyses may correct an erroneous diagnosis of nutrient disorders. Also they may detect the development of nutrient disorders before they become critical.

We often consider leaf or plant composition as a relatively new diagnostic tool. However, it is older than often believed. In fact, the concept from which the use of plant analysis is based was proposed by the great chemist Leibig in 1840 — 119 years ago. During the last 30 years, since 1920, the use of plant analysis has developed very rapidly. Although there are many reasons for this great increase in the use of plant analysis since 1920, some of the more important are:

1. An increased recognition of the importance of trace element deficiencies.
2. An increase in the attention given to Horticultural crops by Agricultural chemists and research workers.
3. The development of analytical methods that would permit the analysis of a large number of samples for nearly all of the essential nutrients.

It would be difficult to decide which of these factors is most important. The choice may well be the development of analytical methods. If we only reflect upon this briefly we can more fully realize the importance of this development. The determination of potassium, for example, used to be one of the more complex methods of analysis. With the introduction of flame photometry the determination of potassium has become one of the more simple determinations.

Spectrographic analysis has been widely discussed during the last ten years. Some of the first uses of the spectrograph for plant analysis was in Sweden and other European countries in 1939. However, in this country, the use of the spectrograph for plant analysis has developed mainly since 1949. The spectrograph permitted the analysis of plant samples for more nutrients in less time. Spectrographic analysis has been approximately ten times faster than chemical methods. More recently, we have drawn upon the experiences of steel, aluminum and other metallurgical plants to make the analysis even more rapid. With the use of a direct-reading spectrograph (known as a photoelectric spectrometer) it will be possible to obtain the analysis for ten elements within five minutes after ashing of the sample. We have just installed such a unit in our plant analysis laboratory at Michigan State University This new unit will permit us to complete the analysis for 12 elements on 60 samples each day using three technicians. Such analysis would require more than 12 competent chemists if chemical methods were used.

Let me further illustrate the importance of flame photometry and spectrographic methods. During the last 12 years the leaf analysis program in the Department of Horticulture at Michigan State University has increased from 600 determinations to 23,100 determinations annually. An increase of 40 times in 12 years without increased personnel.

When a leaf or plant sample is analyzed, what do we get? First, we obtain data on the amount of nutrients the plant has been able to absorb. Such data is obtained on nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, copper, boron, zinc, and molybdenum. These eleven elements may be deficient and additions may be required in the form of fertilizers or other methods. It does not require a great deal of effort to determine the limiting nutritional factor after the analysis has been obtained.

Perhaps unfortunately, standardized values are not available for many of the crops of interest to plant propagators. Such research is underway and will gain momentum. Dr. Harold Davidson, at Michigan State University, for example, has just completed the initial investigation on seven important species. He has data, for the first time, on nine elements that represents the composition of good plants for these seven species. Using these data, he can now initiate trials on diagnosis of nutrient disorders. He, also, has data indicating the level at which potassium deficiency may occur in seven species. This sort of information is being gathered by many research groups, more rapidly than is possible to report, and soon the stage will be set for the use of leaf analysis on all ornamental plants for diagnostic purposes. There is much work to be done on sampling, collection of data useful for diagnostic purposes, and interpretation of the results. However, this can and will be done in much less time than necessary previously.

FIELD TRIALS

Field trials are a necessary part of diagnosing nutritional needs regardless of what other diagnostic tool is used. The use of field trials remains the oldest diagnostic tool. Regardless of the method used to determine nutrient needs, field trials should be used to confirm such results. Unless absolutely certain of the diagnosis, a field trial should be established to prove the need for the suggested fertilizer. The size of such a trial should be based upon your confidence in the diagnosis. If you are confident of the diagnosis leave only a few untreated plants. If you are doubtful of the diagnosis, then treat only a few plants.

If there is difficulty in prescribing a correction measure, different methods should be tried. Only a few plants would be needed for each method. There is much to be learned in the application of essential nutrients. For some nutrients, soil applications are not too efficient. Nutrient sprays applied early in the season, during the season and on dormant plants have been effective and efficient methods for applying certain trace elements. Concentrations of such sprays need confirmation when used on another species.

Field trials can be useful in diagnosing the nutrient need. Different forms of fertilizer, different nutrients and time or amount to apply may supply the necessary information. We should not forget the time proven system of plant injection as a diagnostic method. The suspected nutrient may be injected into the stem, petiole or leaf by use of various techniques and identify or confirm a suspected nutrient disorder. Plant injections may only require a single leaf or a single branch and much can be learned from such studies Equipment may include a soda straw, piece of thread and the solution. Such a study may prove to be of considerable value if the original diagnosis should be in error or if diagnosis cannot be obtained by other means.

APPROACHING THE PROBLEM

To properly control the nutrient supply to our plants we should make full utilization of all diagnostic tools — deficiency symptoms, soil tests, leaf or plant analysis, and field trials but appreciate their limitations.

A constant check for the development of deficiency symptoms should be made. A periodic examinations of the leaves or growing tips may reveal a nutrient disorder not detected in the usual inspection of a nursery field, seed bed or propagation frame. Soil tests should be used to make sure that proper or safe levels of certain nutrients are present. For a more precise contol of nutritional conditions, plant or leaf analysis should be used.

One diagnostic method should not be the only basis for controlling nutritional needs. Often the combination of soil tests with plant analysis is useful. For example, if soil tests in a cherry orchard shows an ample supply of potash and plant analysis shows below normal or deficient level, the grower may suspect nematodes, soil insects, soil diseases or other soil conditions as being the source of trouble.

I would like to refer back to a statement made earlier. One of the reasons given for the rapid expansion in the use of plant analysis in recent years was — "the increased attention given to Horticultural crops by Agricultural chemists and research workers" This is important to you and to your industry. Unless each of you do all you can to create and maintain this interest in your crops and your problems, the Agricultural Experiment Station, and other research groups, will feel that your problems have been solved. With your encouragement and support, it will be possible to advance the field of nutrition of ornamental and nursery crops much more rapidly than previously. The potential is here but industry must help the research workers and keep everyone informed about the importance of its problems. By doing so, your soil fertility or nutritional problems will receive more immediate attention. As a result you will have better plants, happier customers and, of equal importance, more profits.

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MODERATOR CHADWICK: Thank you, Dr. Kenworthy, for that very interesting paper on methods and techniques available to us for determining nutritional deficiencies.

Very closely allied with the methods, of course, will be symptoms that we can use to determine nutritional deficiencies. At this time I would like to call on Mr Richard H. Zimmerman, Department of Horticulture at Rutgers University to discuss that phase of the subject. Mr. Zimmerman.

Mr Zimmerman presented his paper on visual symptoms for detecting nutrient deficiencies in plants, which was also illustrated by colored slides. (Applause)

VISUAL SYMPTOMS OF PLANT NUTRIENT DEFICIENCIES

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A perennial problem in agriculture is the determination of the mineral needs of plants. In attempting to solve this problem, research workers have developed several different methods along the following lines (8):

(1) Soil analysis — in order to determine the supply of minerals in the soil.
(2) Plant analysis — in order to determine needed levels in plant tissue.
(3) Field and pot culture experiments — to compare effects of different fertilization rates.
(4) Direct treatment of the plant, by spraying or injection, in order to induce a growth response.
(5) Diagnosis of nutrient deficiencies by visual symptoms.

When a mineral nutrient element deficiency in a plant is shown by visual symptoms, the deficiency is quite severe. It has been established that low levels of mineral elements can cause a reduction in plant growth without the appearance of visual symptoms.

Before expanding this topic, let us briefly review our knowledge about the essentiality of the nutrient elements. Prior to 1900, ten elements were known to be essential for plant growth. Of these, carbon, hydrogen and oxygen were obtained from the carbon dioxide of the air and from the water in the soil. Six of the remaining seven elements, (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) have become known as "major" or macronutrient elements because they are needed by the plant in large quantities relative to the other essential mineral elements. The seventh element, iron was the first of the "minor" or micronutrient elements known to be essential. These micronutrient or "trace" elements are needed in very small quantities by the plant.