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

RICHARD H. ZIMMERMAN
Department of Horticulture
Rutgers University
New Brunswick, New Jersey

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.

From 1900-1920, much research was done on plant nutrition and several additional elements were stated to be essential. However, it was not until the period 1920-1940 that essentiality was definitely ascertained for any other elements. In this period, five micronutrient elements were determined to be essential (4), ie., manganese (1922), boron (1926), zinc (1926), copper (1931) and molybdenum (1939). Since that time only chlorine, in 1954, has been established as essential, and this only for tomatoes.

The correlation of visual symptoms with a specific deficiency dates back at least to 1844 (1) Gris, in France, reported that chlorosis was caused by a deficiency of iron. Several years later, a German scientist, Salm-Horstmar, produced characteristic deficiency symptoms for all the macronutrient elements (and some of the micronutrients as well) on oats. Since that time, especially since 1900, symptoms have been described for all the major and minor elements on many plants.

The use of visual symptoms for diagnosing nutrient deficiencies is based on the fact that abnormal development of the plants occurs when nutrition is not satisfactory This abnormal development may take several forms, the most common of which are chlorosis and necrosis of the leaves. Chlorosis is a lack of chlorophyll, the green pigment of leaves, caused by any means and resulting in light green, yellow or white areas in the leaf. Necrosis is the death of cells in the leaf, usually used in reference to dead spots in the leaves, dying of the leaf margins and tips, etc. Quite often the symptoms of nutritional disorder are characteristic enough to be recognized with some certainty. Once deficiency symptoms for a given element on a given species have been determined experimentally, it is hoped that deficiencies under field conditions can be identified through comparison with the known symptoms. When a nutritional disorder in the field can be diagnosed on this basis, this method is obviously a rapid and inexpensive method of determining plant needs.

This method is not quite so simple as it may sound, however. The type of symptom may vary from species to species and even from variety to variety. It may be affected by the supply of other nutrients, e.g. there may be a deficiency of two or more elements or an oversupply of one nutrient may induce a deficiency of another. Further, deficiencies of different elements may give the same symptoms or the symptoms of a nutritional disorder may resemble those produced by insect injuries, virus and other diseases, drought, etc. Thus confirmation of the deficiency must be made by other techniques in some cases.

As mentioned earlier, another limitation of the method is that symptoms develop only when the deficiency becomes severe and this may be so late as to severely check the growth of the plant before remedial action can be taken. It has been found that nutritional deficiencies may cause diminutions in yield and growth without inducing any visible symptoms. This is known as incipient deficiency and it cannot be detected by visual symptoms

The use of indicator plants has been suggested to overcome this last difficulty. These are plants chosen because (1) they are particularly susceptible to given deficiencies, (i.e., they show symptoms in a short period of time), (2) the symptoms they produce are not easily confused with symptoms from other causes and (3) the deficiencies are especially pronounced.

Wallace (8) gives a rather extensive list of indicator plants to use for vegetable and fruit crops and perhaps some of these might be suitable for ornamental crops as well. Reeve et al. (7) have suggested several crops which are suitable as indicators of low boron contents in soil Turnip is an especially good indicator for boron deficiency under field conditions while sunflower is a good indicator for boron deficiency under greenhouse conditions. It has been suggested that symptoms appearing on common weeds may be used as an indication of a low level of nutrients in the soil which could lead to deficiencies in economic plants (2, 5).

Now that we know some of the background behind visual deficiency symptoms, let us consider the appearance of the symptoms on plants. These symptoms are discussed in several publications (1, 2, 3, 4, 6, 8).

NITROGEN

This is probably the most common deficiency on most crops. The growth of both tops and roots is restricted. Shoots are slender and short, with very few new breaks. The leaves are small and light green or yellow green. As the deficiency becomes more severe, the lower leaves turn yellow, then brown and drop off. Tints of red, orange, or even purple may appear, usually starting with the lower leaves and sometimes appearing in the petioles.

PHOSPHORUS

The effects of phosphorus deficiency resemble those of nitrogen in many respects Top and root growth is restricted and shoots are short, spindly, and upright. Leaves are small and early defoliation occurs starting with the lower leaves. Leaves are a dull, dark green or bluish-green, often developing a purple or bronze coloration. Leaf margins may develop a brown scorched appearance and sometimes the lower leaves turn yellow before dropping

POTASSIUM

Symptoms vary considerably with the severity of the deficiency. Growth is restricted in mild cases and shoots may die back in severe cases. The leaf symptoms are striking and are usually characteristic for the different types of plants. Leaves may be a dull gray-green or blue-green and chlorosis will be evident. Interveinal chlorosis starts at the margins of the lower leaves and spreads inward on the leaf and up to other leaves on the shoot. Following the chlorosis will be tip burn, marginal leaf scorching and/or the development of brown spots, usually near the margins. The scorched margins quite often roll towards either the upper or lower surface of the leaf.

CALCIUM

Symptoms most commonly appear on the young leaves and near the growing points of shoots and roots. Young leaves deficient in calcium are severely distorted with the tips hooked back and the margins rolled. The margins are malformed and ragged, often with brown scorching or spotting. Tip leaves become chlorotic, only the veins and leaf tips remaining green and those too turn yellow in time. The terminal buds are often killed. Root systems are poorly developed.

MAGNESIUM

As would be expected since magnesium is part of the chlorophyll molecule, leaf chlorosis is one of the chief symptoms of a deficiency of this element. The interveinal chlorosis starts on the older leaves and progresses upward on the plant. Chlorotic areas may become a very pale yellow or even white. Leaf margins may curve upward or develop a puckering effect. Either necrotic spots or marginal scorching may appear with the leaves dying soon after. Defoliation becomes severe with the shoots bare save for a few leaves near the tip of each shoot.

SULFUR

Shoot growth is restricted and the stems are thin, stiff and erect. Leaf chlorosis starts on the new leaves, the whole leaf, including veins, turning yellow. The older leaves become affected gradualy and there is a gradation of color from newest to oldest in contrast to iron deficiency. All leaves are light green when the deficiency is severe but the lower leaves do not dry up and drop off as in nitrogen deficiency. Dead areas, purple in color, may appear at the base of the leaves.

IRON

The most important symptom here is the interveinal chlorosis of the new leaves which always occurs with this deficiency. As the deficiency becomes more acute, the leaves may become bleached almost white with the veins remaining green for a long time. In very severe cases, scorching of leaf tips and margins may occur. Die back of branches occurs in some cases.

MANGANESE

Leaf chlorosis is probably the commonest symptom of this deficiency. The chlorosis is checkered or mottled with the interveinal areas yellow while even the smallest veins remain green. Necrotic spots scattered over the leaf surface are often present. The chlorosis usually appears first on the new leaves though it may spread to the old leaves also in contrast with iron deficiency.

BORON

The most striking symptoms for boron deficiency are the effects on the growing points. The terminal bud may die and new leaves will show considerable distortion. Leaves are scorched and curled, thick, brittle and generally chlorotic. The tissue at the base of new leaves breaks down. Stems may be hollow and roughened. The stems and the petioles are brittle and frequently twigs and branches die back.

ZINC

Leaf chlorosis is the outstanding characteristic of zinc deficiency in herbaceous plants while abnormalities of twigs and leaves are more important in woody species though chlorosis is present here also. Leaves are small and malformed, quite often very narrow with crinkled margins Necrotic spots develop, usually starting near the tips or margins of the leaves. Foliage on the plant is sparse and leaves are rosetted about the terminal buds. Dieback of shoots and limbs may occur.

COPPER

An early symptom is a dark green color of the leaves, showing a high nitrogen concentration. Interveinal chlorosis of new leaves may occur with the chlorotic areas almost white. Chlorotic leaves may also show mottled green areas. Leaf margins are wavy irregular. As the severity of the deficiency increases, new leaves become small and distorted Defoliation occurs from the tip of the shoot back. Die back of the shoot occurs.

MOLYBDENUM

Symptoms are quite varied for different species. Some plants show a chlorosis or mottling of the leaf. Necrosis follows in most cases. Often leaves develop without a blade, giving the name of whiptail to this deficiency in many crops Frequently the deficiency appears first on the mid shoot leaves Affected leaves eventually drop.

LITERATURE CITED

1. Bear, F. E. 1948 Diagnostic techniques for soils and crops. Amer Potash Institute, Washington.
2. Bear, F. E 1949. Hunger signs in crops — a Symposium. Amer Soc. Agron and Nat Fert. Assn., Washington.
3. Duke University. 1959. Mineral nutrition of trees — a Symposium. School of Forestry, Duke University, Durham, N.C
4. Gilbert, F. A. 1957 Mineral nutrition and the balance of life University of Oklahoma Press. Norman, Oklahoma.
5. Goodall, D. W., and F. G. Gregory. 1947. Chemical composition of plants as an index of their nutritional status. Imperial Bureau of Horticulture and Plantation Crops. East Malling.
6. Orr, H. P, T. Furuta and C. W. Bell. 1957 Azalea fertilization. Ala. Agric. Expt. Sta Circ. 118. Auburn. 15 p
7. Reeve, E., A. L. Prince, and F. E. Bear. 1944. The boron needs of New Jersey soils. N J. Agric. Expt. Sta. Bul. 709 26 p.
8. Wallace, T. 1951. The diagnosis of mineral deficiencies in plants by visual symptoms His Majesty's Stationery Office. London.

*   *   *   *   *

MODERATOR CHADWICK: Thank you, Mr Zimmerman, for that very fine discussion and those excellent slides I think they told the story very well.

We are going to follow much the same procedure this afternoon as we did this morning relative to the panel and general discussions. The panel members are the same as we had this morning, so we have no need to introduce them again at this time We will hear first from Bob De Wilde on maintaining proper fertility levels in containers

MR. BOB DE WILDE: I feel that you could use any system to determine nutrient levels and get correlation, providing you are consistent in your method of analysis. We use the LaMotte soil test system. It is a colorimetric means of determination for most of the elements. We worked with LaMotte and modified some of the tests to get more accuracy in reading the test. They will be glad to provide you with any of the information and help you establish a system.

We have established some figures, based upon intelligent guesses, as to the nutrient requirements of a plant during a specific growing season. These limits have been set at 100 pounds of available nitrogen, 75 pounds of available phosphorus and 125 pounds of available potassium. We attempt to maintain these levels throughout our growing season, which is from May until the end of August.

We must pick a starting point in the fertilization cycle, so I will start in May. We test our soil according to variety and age of the plant in the container. Our one-year plants, as you will remember, should already have good soil fertility because we added our nutrients at the time we prepared our potting mix. We will therefore start with our two-year old stock. We will first go in and take one combined soil sample from all of our junipers, one combined sample from all of our yews, from all our hollies, et cetera, down our list of families in the various age groups. Since we are on a more or less three-year production schedule, we will have three age groups to test from.

After the tests are completed, we will fertilize, using commercial ratios. This is done through the irrigation system, our primary fertilizer is a 20-20-20, and we apply this mix at approximately two week intervals in small dosages to maintain our standard of 100 pounds of available nitrogen, 75 pounds of available phosphorous and 125 pounds of available potassium. We find this gives us excellent results One of the things that you might attribute this to is our pH which we try to maintain at 6.2.

We don't have to worry about an occasional September frost because we are located in the woods area which gives us a modified climate and the plants are prepared for winter. As they are grouped, each one receives a heaping tablespoon of Uramite to carry it through the winter. Tests with Uramite have proved there is apparently better wintering because of its use. It is a fact that in the springtime this nitrogen will be available to the plant as it starts to grow. We have completed our cycle and will test our soil again in May to carry the plant through its season of rapid growth. Thank you.

MODERATOR CHADWICK: We will go directly to Jack Hill for his comments.

MR. HILL: I really feel there is very little I can add to these two splendid illustrated talks we had earlier. This matter of detecting nutritional disorders is a very difficult thing, as Bob just finished pointing out. They are so frequently disguised and confused that I have lost all confidence in the amateur looking at a plant and saying, "Oh, this is a magnesium deficiency," or "boron deficiency."

Because of the high percentage of peat moss in the mix which we are using we are not believers in micro-element deficiencies The reason we feel that way is that peat moss, after all, came from a living plant, and if that sphagnum had not had pretty reasonable balance, it probably wouldn't have grown well enough to have developed into peat moss.

Most of the micro-elements tend to be in the heavy metal class and as such don't tend to leach readily. We feel we are not likely to run into micro-element deficiencies in our system for maintaining overall nutrient balance.

Currently, we have our feeding program which is entirely liquid, tied in with our frequency of irrigation We are feeding every time that it becomes necessary to irrigate for the third time. By this I mean we irrigate with clear water twice and the third time it is with an application of a soluble fertilizer.

We make up and mix our own solutions We have three basic formulae we are using. No. 1 is a complete fertilizer of approximately 20-10-15, the second one is 20-10-30, and the third one is 10-40-15.

We have reduced the number of soil tests that we made three or four years ago when we were running tests as frequently as one every two weeks. We have now cut it back this last year so I don't think we ran more than three sets of samples through the whole growing season. We feed right up until the water is about to freeze in the pipes We believe in feeding that plant right up to the onset of winter. The reason for that is we feel that the season of growth in our latitude is controlled not at all by available nutrients but rather by daylight, provided that the plant has been held at a level of good nutrition throughout the entire season. Thank you

MODERATOR CHADWICK: Thank you, Jack. We will go on to John Mahlstede for his comments:

DR. MAHLSTEDE: Probably more work has been done with the maintenance of fertility levels in containers than with all other phases of container production combined. Each and every nurseryman has what he believes to be a good fertilizer program, and this is as it should be. When deficiency or toxicity symptoms show up in container grown stock, usually considerable growth is lost during the insuing months or years This is why a grower must experiment and know what a particular fertilization program will do under his specific conditions.

It is almost a must for growers producing any quantity of stock in containers to use a regular and systematic program of soil testing. Spurway type tests should be used to maintain the fertility within the following limits: nitrates 25-75 ppm, potassium one-half the nitrates, phosphorus 2-5, calcium 100-200, chlorides below 50, sulfates below 200, pH 5.5-7.2 depending on the crop, and soluble salts (10-5) 50 to 100 ppm in a 1 to 2 distilled water suspension. With leachate extracts the following ratios are advised: nitrates 100-200, potassium one-half the nitrogen, phosphorus 1-5, soluble salts 100-150, chlorides below 100, calcium 50-100 and sulfates below 200.

Starter solutions for soil mixtures vary from state to state. Rapidly growing, succulent plants generally respond better to these solutions than the slower growing broadleaved and narrowleaved evergreens. One such solution is prepared by stirring the following in 10 gallons of water at 70-90° F.: 1 ounce of 15 per cent wettable parathion, 1 ounce of potassium nitrate and 1 ounce of ferbam. Water once and then add the starter solution until leaching starts.

To maintain soil nutrients in the optimum range, the grower can use either dry or weak solution mixtures of the essential mineral elements, or combinations thereof. Again, general maintenance solutions vary in composition, depending on the medium, and location of the nursery. One such mixture applied weekly or at least twice a month to all growing plants in a soil mix so that each pot is filled twice is as follows: for each 10 gallons, 1 ounce potassium nitrate, ½ ounce (food grade) urea, ¼ ounce of ammonium phosphate, and ¼ ounce of magnesium sulfate. It is essential to use regular soil tests with these recommendations, or for that matter, for any program of this nature.

In the plunge and tile system of culture we have found that satisfactory growth is maintained by banding a complete fertilizer in the furrow under the container before placement or by mixing with the soil at the base of the tile before filling. Actually if the soil has been properly cared for before culture and is of high fertility, no additional fertilizer program is required to maintain proper growth rates.

For plants growing in a 50-50 peat perlite mixture in containers on top of the ground, experiments using uramite and a 0-20-20 fertilizer have been quite successful. For young stock transplanted into 6 inch containers in Jiffy pots, a mixture of 1½ pounds of Uramite and 1½ pounds of 0-20-20 per cubic yard of mix has given good results. The fertilizer should be added to the growing medium immediately prior to use; it should not stand around longer than a week prior to use. As the plants grow during the late spring and early summer it may be necessary to supplement this fertilization program by the addition of one level teaspoon each of Uramite and 0-20-20 in the late summer or early fall or as tests indicate. Two year stock and older can be fed with two full teaspoons of Uramite and 0-20-20 applied to the surface of the container in the spring. These latter observations are based on our experience to date, and are by no means final.

MODERATOR CHADWICK: What have you to say on this subject Ken?

DR. REISCH: I want to make some general comments first relating to general fertilization. Recommendations for fertilization will vary according to the medium that is used, irrigation techniques, amount of rainfall, and many other factors. Any specific recommendation that is given for one area would certainly have to be adopted to yours even if you are using this particular type of culture The methods of analysis would be similar as far as the levels you want to maintain, either in the plant or the soil.

We have conducted a few studies on fertilization practices and up to a couple of years ago we felt that using fertilizers every two weeks was sufficient on container stock. Since then we have changed our mind radically and have come to the conclusion that probably the use of soluble fertilizers as frequently as every watering, possibly at least once a week, is much better to maintain adequate levels of fertilizers in the containers and in the plants.

We have used one ounce of a 15-30-15 soluble fertilizer to 16 gallons of water every watering. The leaf analysis records indicated that with a rate of one ounce to 16 gallons every watering we maintained a higher and more constant level of nitrogen.

As concerns the dry feed we found that the surface application produced a better and faster rate of growth than when mixed in the medium. I think that is probably all I have to say

MODERATOR CHADWICK: We suggest you confine your questions to nutrition on this particular part of the program. Leslie Hancock has his hand up first.

MR. LESLIE HANCOCK (Cooksville, Ont.): I would like to ask Jack Hill if he would care to comment on sources of nutrition from organic versus inorganic components.

MR. HILL: My present feeling is that organic fertilizers are far too expensive for what is in them. Because rates of breakdown are largely beyond your control when you are making applications of reasonable size, and because of the labor factor involved you pretty much lose control when you put that teaspoonful of fish meal or hoof and horn in the top of the can

MODERATOR CHADWICK Any other comments from the panel members on it? Does that answer your question, Leslie, or do you think you had better pin them down a little more?

MR. HANCOCK: I don't know anything about it, although I have always had the idea that it is more difficult for the plant to assimilate organic forms than inorganic.

MR. DE WILDE: I would like to say that we feel it is very important to have both. You need definitely a mineral or inorganic type of fertilizer for rapid availability For carry over, particularly during the winter months and during that early spring season when you get your flush of growth we feel it is definitely important to have some source of organic plant food to carry that plant through. This latter period occurs when you do not have sufficient time to analyze your soil and take care of those plants because of other nursery work We use Uramite.

DR KENWORTHY. This comparison of organic *versus* inorganic sources of nutrients I feel is largely a consideration of the rate of release. You need your inorganic for immediate release and it would be nice to have your organic sources around or have your inorganic tied into your soil so that the release is more slow.

We must keep in mind in all of this that a plant, if you will pardon the expression, is a selective glutton. It will absorb and take into its system almost all the soil nutrients in the solution. If too much is in there, you have toxicity. The organic can more or less diminish this toxicity.

MR. HILL: This is a question from the panel to Dr. Kenworthy. If the determination of organic versus inorganic is to be made on the basis of rate of release why do you want something released slowly? Why not have positive control, since you are irrigating in this container stock on a frequency of four or five times a week during the growing season. Why not utilize something which is available immediately? Why do we want anything which is slow?

I don't agree that you need fertilizer at all in the winter time. True, we need it early in the spring, but I do not think we need it during the winter itself.

DR. KENWORTHY: I think you have answered your own question in a sense. You want control one way or another. If you can't do it by spoon-feeding as you do a baby, though irrigation systems, you need to do it some other way. By and large, when you have plants in a restricted or rather limited environment, it can't forage very much. You have to treat it like a small baby and give it a feeding. We, ourselves, only eat three meals a day and probably would feel better if we would limit that to one or two, but a baby needs five or six The same thing applies to plants.

MR. JIM WELLS: I would like to make a comment and then ask a question regarding this organic and inorganic controversy. I have for years been an organic man, and yet, all reason says that you ought to be able to produce something out of a bag and put it in water, which is short-circuiting the digestive processes in the soil and presenting it in immediate available form to the plant. I have tried to slowly drive myself to accept that theory, with a little help from Jack Hill. Anyway, there was a time about five years ago when a foreman under my control came to me and said, "I want a load of leaf mold." I said, "What for?" He said, "I have to pot my azalea understocks in a soil mixture containing at least half oak-leaf mold."

Now here was an old-time propagator requiring this material with which I was completely in sympathy, but I said, "I am sure you can get just the same results with Michigan peat and a little fertilizer." "No, you cannot," he said. So I set out to prove him wrong. We had the mixture with leaf mold very carefully analyzed. We then made up a mixture from Michigan peat soil and fertilizer, analzyed it and we reproduced the leaf mold analysis exactly. We potted two groups of plants in these two mixtures and they grew beautifully.

They were then grafted by the same man and put into the grafting bench. The group in the synthetic soil, if you like, failed completely and the other took beautifully

Now so much for that My question is about biuret, a by product in the manufacture of some of these slow release nitrogen fertilizers. I understand that it results in serious problems when used on certain plants, particularly ericaceous materials. Does anyone or a member of the panel have anything worthwhile on this?

DR. REISCH: I understand the original material that came out with this by product in it was withdrawn from the market. Actually, I don't believe the material on the market today has any in it.

DR. KENWORTHY: Again, I am going to bring in a little information from an orchard that I think will also work in the nursery row. We can, without exception, tell whether a cherry grower has sprayed his plants with urea or not merely by looking. We don't have to ask him. We get the nicest little yellow margin when urea sprays have been used. On sandy soils the use of urea in any form will also give us this margin on sour cherries. On apple we get no effects. I will not say that this is caused by biuret or not.

DR. JAMES R. KAMP (Urbana, Illinois): I didn't get up to supplement Dr. Kenworthy's discussion here on the effect of urea on plants but we did have some experience in foliar feeding, particularly on roses. We found that whenever we used urea we also got this marginal yellowing on greenhouse roses However, we found that if we sprayed the roses grown out of doors with the same thing we wouldn't get the marginal yellowing. Therefore you can't make a general statement but rather have to refer to a particular plant grown under a specific set of conditions.

What I came up here for was to ask Ken Reisch his feeling about the phosphorus level in his 15-30-15 fertilizer mix. Are you beginning to feel that phosphorus is required by the plant only in relatively low amounts?

DR. REISCH: That is correct.

DR. KAMP: I know we have sort of interpreted it this way. In most of our fertilizer experiments we got such a wide range of satisfactory growth at different prosphorus levels that we have gotten so we don't even bother about phosphorus any more.

DR. REISCH: I think in container production that nitrogen is the critical factor. You have to have an ample supply of nitrogen, and nitrogen seems to be one of the limiting factors.

DR. KAMP: What are you planning to change your analysis to for future work?

DR. REISCH: That is a good question. We haven't decided, but I would say probably one high in nitrogen, low in phosphorus and medium in potassium. What that would be I can't say at the moment. There are plenty on the market with that approximate analysis.

One comment, Chad, in relation to the use of organics versus inorganics. I have mixed feelings on the subject I think there is some merit to the use of organic fertilizers as concerns the rate of release. There are thousands of producers, however, that have never used organic fertilizers who are making money in the florist, nursery and farm crop business.

MODERATOR CHADWICK: Who has the next question?

DR. NELSON: In work at Ottawa this year we found that concentrations of the various salts necessary to support growth in container stock was quite different. For example, *Chamaecyparis* would be killed by concentrations of one quarter the normal rate. By the same token, in arborvitae we got that same spread. Some would thrive on four times the concentration of salts that would kill another type. Little Gem, for example, was killed at a very, very low concentration of salts. What are you doing with the segregation of your stock? In other words, do you have a different feeding program for different types of plant materials?

MR. HILL: I am not sure that I can answer that entirely except to point out that the very basis of the system which we are attempting to follow relates to optimum levels of N-P-K, calcium and magnesium, to the water-holding capacity of the mix. That is based upon the recognition of the fact that a level of total soluble salts which would be lethal in sand or lethal in my class of marbles, if you please, would be a starvation diet in pure peat. Therefore, some place along there you should be able to plot that relation if it is a straight line. Therefore, measuring the moisture-holding capacity in terms of percentage based on dry weight you should be able to come up with optimum levels.

I, too, have observed the very thing you are talking about, where there are huge differences in the tolerances of plants. Unfortunately, I don't think there has been definite work done on ornamentals. There has been some on cereal crops and fiber crops and grass crops.

MR. PETER VERMEULEN: Jack, I believe you fertilize right up to the approach of winter. Bob, you said that you cut your fertilizer applications off at the end of the active growing season. I have a question on this, which perhaps can explain the difference in your response by the difference in temperatures or your seasons. Do you, Jack, in Dundee, have a gradual approach in the winter or do you experience, as we do here on the east coast, sudden drops of temperature and then warm periods and then another drop, where we would have soft growth resulting from continued application of fertilizer damaged by these cold snaps?

MR. HILL: I do not think our climate in Dundee has the same temperatures or the same humidities, but I think it is about the same in that we frequently get cold spells. This year, for example, all sorts of temperature records were broken. Our whole philosophy is built around the theory that plant growth is controlled by the available nutrients in the mix at the onset of winter, provided the plant has had sufficient throughout summer. They stop growing whether you feed or not. In fact, our tests have indicated clearly that if the plant is fed up to the onset of winter it will be better than one that is deliberately checked and starved before winter sets in.

MR. DE WILDE: Actually, when we have completed our last fertilization, the level is quite high. It is not toxicity high, but let's say the plant has plenty to feast on throughout the winter. Since it is not growing, we feel it doesn't need any nutrients any more. That is the primary reason we stop feeding. Definitely the nutrient level will drop off during the month of September, but it will still leave the plant with an optimum amount of plant food to last throughout the winter and give it that initial start during the spring, particularly with an added teaspoonful of uramite in each can.

Actually, we feel additional applications of fertilizer after this month would be useless.

MR PETER VERMEULEN: Bob, do you feel that an additional application would not only be useless but might be detrimental?

MR. DE WILDE: Yes. I am afraid to take that chance and push them too much. I think our level is high enough so there isn't any detrimental effect.

MODERATOR CHADWICK: I would certainly back Jack Hill 100 per cent on this matter of fertilization as he is practicing it. While this example doesn't apply to canned production, we have modified our whole outdoor plant fertilization program in the last several years on the basis of results that we have obtained For instance, in our rose garden at the University, we continue fertilizing our roses right on up through the middle of October or even to the first of November. The results over the past years have certainly indicated that those plants come through just as good or even better as where the fertilization is stopped in August or the first of September.

MR. HILL: We have come a long way since those days when it was felt necessary to put a fish in each hill of corn.

DR. KAMP: I would like to make a comment here because I think there may be a difference in what you are getting due to the treatment that you are giving prior to this fall feeding.

I think if you run one of these up and down, kind of fertilizer programs and the fertility level is down, when you put fertilizer on in the fall, you are apt to encourage a flush of growth which will suffer winter injury. On the other hand, if you have been giving these plants a good solid fertilizer supply all during the season and you continue that into the fall, then you are not encouraging a fall flush of growth, you are merely giving the plant sufficient fertilizer to continue its maturation processes. I think the important thing is not whether you put on this fertilizer in October or November, but what you did prior to that date.

MODERATOR CHADWICK: What period are you referring to as a fall application that will cause late growth?

DR. KAMP: I was thinking of the application of fertilizer, say in October. If we allow nutrients to become low and then apply a good fertilizer application in October with the Indian summer weather that we get and rains at that time, we would get a flush of new growth which is easily injured.

MODERATOR CHADWICK: On what types of plants?

DR. KAMP. Outdoor roses and a lot of our shrubs, are included. In our outdoor roses if we have not let the fertility level go down and then we put on an application of fertilizer in October there is no noticeable change in growth rate of the plant. It is just keeping on at a reasonable rate of development. But, as I say, if we let it go down and then put on an application you will see a lot of new growth coming out. When you have a sudden drop in temperature to zero there isn't much of this new growth that is going to survive very long. I think the reason that Jack is able to carry on his fertilizer program that late with good results is that this is just a smooth continuation of what he has been doing all the time.

MR. FLEMER: We see in our nursery quite frequently and Dr. Chadwick, you have probably seen it a lot in other nurseries growing forsythia, California privet and weigela, where we have an extremely wet September and an extremely severe winter. Young yearling plants in the field that had been heavily fertilized and pushed along in the summer would freeze right to the ground where the old stock would bud out in the spring right up to the tip of the plant.

MODERATOR CHADWICK: I don't know as I can answer that but I have seen just the opposite happen. Not so many years ago when we had a very severe winter in Ohio it was all of the old underfed *Kolkwitzia* that froze to the ground where the good growing plants that were fertilized in the fall came back.

I think it comes back to the carbohydrate-nitrogen relationship in the plant at the time you get that drop in temperature.

MR. FLEMER: The more you fertilize the more nitrogen you get and the less carbohydrates.

MODERATOR CHADWICK. Not necessarily. By the addition of the nitrogen you have also built up the carbohydrate content in that plant.

We now come to the unscheduled part of this program. I don't know whether the Secretary of the Plant Propagators Society is just modest but when it came to his part of this discussion he left it off. This doesn't let him out of a job, however. So we want to turn now to the final phase of this discussion of container production of nursery stock and consider the point of hardiness and winter protection.

Dr. Reisch of Ohio State is going to lead off the discussion and then we will come back with the panel members. Ken!

DR. REISCH: I tried hard to get out of the job, as Chad said, but it didn't work, so I am here.

Dr. Reisch discussed the subject of winter protection as it is related to the successful overwintering of container grown plants. (Applause)