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MODERATOR COGGESHALL: Thank you very much, Jim.

We will now go on to the next speaker, Dr. Sidney Waxman, University of Connecticut, Storrs, Connecticut, who will speak on the subject of Physiology of Evergreen Cuttings from Collection Through Rooting. Dr. Waxman!

DR. SIDNEY WAXMAN: I, too, do not like to read from a paper, but I have a feeling I will be sticking my neck out on some of these statements I am going to make and I would rather be confined to those statements than any I might make beyond that.

THE PHYSIOLOGY OF AN EVERGREEN CUTTING FROM THE TIME IT'S TAKEN UNTIL THE TIME IT IS ROOTED

SIDNEY WAXMAN
Plant Science Department
Storrs Agricultural Experiment Station
University of Connecticut

To thoroughly cover such a topic as this, the physiology of evergreen cuttings from time of taking to time of rooting would, of course, take considerably more time than 20 minutes. When I accepted the request of our program chairman to give this talk, I didn't realize just how difficult it would be merely to decide on *how* to present it. Also, John was clever enough to make this request well in advance of the meeting. Six months seemed so far in the future that it was very easy to agree.

However, I've decided to present this talk by discussing the status of growth of the cutting at the time it's taken and how it may have some bearing on its ability to initiate roots.

Concerning the physiology of the cutting itself, the ideal situation for rapid root initiation would be one in which the following conditions exist:

1. The presence in the stem of young cells that can quickly be induced to become meristematic.

As you have heard from Bill Snyder's presentation, it is necessary that certain cells near the base of the cutting become meristematic, and start dividing as the first step in the construction of an organized root.

2. The second condition is the need for a reserve of carbohydrates. The process of growth which includes cell division and enlargement can proceed only if there is a constant source of energy. The source of energy is derived from the oxidation of sugars that are synthesized by the leaves. If the supply of these carbohydrates is limited, rooting will also be limited.

3. The third condition is: *The presence of a balance of all the substances necessary for rooting to occur.*

In 1934 it was demonstrated by Went (1934) that auxin was highly effective in controlling root initiation.

More recently it was found that not only auxin, but other materials produced by the leaves were also required. Among these were certain vitamins and some organic nitrogen compounds. Hess (1961) working with English Ivy has shown evidence of four additional cofactors, all of which apparently have to be present for root initiation to occur. The lack, or inbalance of one or more of these substances could prevent or delay rooting.

To put it all in fairly simple terms, rooting occurs as a result of the following course of events:

Substances made in the leaves and buds flow down and accumulate near the base of the cuttings, where they cause certain cells or group of cells, to start dividing. The energy necessary for all this work to occur is derived from the reserve of carbohydrates originally synthesized in the leaves and translocated to the place where the roots are being initiated. Unfortunately, it is only rarely that we find all of these conditions operating at the same time and at an optimal level.

In spite of the fact that at a particular time one of these conditions may be below the desired level, it is still possible to encourage rooting. This can be accomplished by the appropriate treatment of the cutting and by controlling the environment during rooting. Actually it is really not this simple. We know of the considerable variability that exists among different species, not to mention differences among varieties within a given species. We also know that even within a clone the degree of rooting will vary according to the time of the year, the age of the plant, the age of the cutting, the selection of juvenile or mature wood, the position on the plant, the nutrition of the plant, etc. It becomes necessary to be familiar with the characteristics of the plant we are working with in order to develop the most effective method of propagating it, and this, of course, is where experience really helps.

Generally speaking, the time of the year, and the temperatures and daylengths that correspond with it, appears to have the most consistent controlling influence on the physiology of the plant. When selecting cuttings to be rooted, we certainly must consider this and how it may effect rooting.

Perhaps it would be more accurate to consider the stage of growth of the stock plant rather than the time of the year, since many evergreens start their vegatative growth at various times and often at repeated intervals.

I've grouped the various stages of growth into four categories according to their physiolgical and anatomical status.

The first category, to which I refer as the *active growth stage*, concerns the period during which growth in length is occurring. Cuttings taken of these shoots are composed of tender stem tissue with thin leaves. There is a high rate of meristematic activity, the cells are actively dividing and elongating, hormone production is at a relatively high level, and the cells at the base of the stem are young enough to be quickly reactivated, i. e. to become meristematic ones again and to divide and produce masses of cells that will eventually develop into roots. Internally, they appear to be ideally suited to initiate roots in a fairly short period of time.

However, at this very early stage of growth, there is a low supply of reserve foods. Considerable energy is needed for the development of the new shoot. This is derived from both the stored carbohydrates of the stock plant and from the leaves of the new shoot that are capable of photosynthesizing, although at a relatively low rate. Also, the new shoot with its thin and not fully expanded leaves has not been in existence long enough to synthesize a surplus of sugars.

In other words, most of the carbohydrate entering the new stem via translocation and by photosynthesis is most likely used up as a source of energy needed for the growth of the stem. The net result is a low reserve of foods.

The second category is the *summer dormant stage*. During this period the rate of cellular activity has declined and growth in length has come to a halt while photosynthesis goes on at a high level.

The great demand of energy for cell growth has subsided and, consequently, the content of carbohydrate within the stem increases with time. During this period the plant catches up with itself, cell walls become thicker and both the leaves and stems increase in thickness and in rigidity. A layer of cutin is gradually being deposited over the leaves and, on the whole, the shoot is beginning to harden off.

The terminal and lateral buds appear to be dormant at this time, but with many evergreens this is only temporary. Additional spurts of growth may occur during mid and late summer.

The third category is the *winter rest stage;* here, all active growth in length has come to a halt. The leaves are thicker, and have a heavy layer of cutin. The stems are more rigid and of greater diameter. There is a relatively low rate of cellular activity.

The terminal and lateral buds are in winter rest and usually will not grow unless given a period of low temperature or long photoperiods. Hormone production is approaching its lowest level while certain growth inhibiting materials are at their highest level. Because of the cessation of growth the need for energy has decreased, and, as a consequence, the carbohydrate supply is at its highest level.

The fourth stage of growth referred to as the *revival stage* for lack of a better name, is one in which the cuttings are dormant but have been exposed to low temperatures.

Anatomically there appear to be no differences existing between cuttings of the *winter rest stage* and those of the *revival stage.* Physiologically, however, there have been changes brought about in the buds by exposure to the low temperatures.

In comparing the physiological and anatomical status of these four categories, we find that insofar as rooting is concerned, there are both favorable and unfavorable factors with each one. It is necessary that we first consider the various stages of growth mentioned and the anatomical and physiological status associated with them. We must then make a decision on how to handle such cuttings to make up, somehow, for the lack of one or more of the conditions necessary for rooting to occur.

In propagating cuttings during the *active growth stage,* we have a sort of dilemma. On one hand we have tissue that appears to be perfect for the rapid initiation of roots, i. e. relatively high concentration of rooting factors, and cells young enough to quickly be induced to initiate roots, but we do not, on the other hand, have a sufficient storage of foods to serve as a source of energy for this to occur. It becomes necessary, therefore, to expose the leaves to bright sunlight to manufacture these foods, but this brings up a problem concerning moisture. Shoots as tender as these will lose water from the leaves in bright light faster than it can be replaced through the stem.

The leaf has not as yet developed the wax-like protective layer of cutin over its surface. The cells have not begun to form the secondary walls that would aid in supporting both the stem and the leaf. Cuttings taken at this stage of growth would very quickly wilt. It would be necessary to place them under a fairly heavy shade to slow down their loss of water. However, this would be detrimental, because the degree of shade necessary to keep the cuttings moist would be so dense as to permit too low an intensity of light for the leaves to use as a source of energy for a sufficent rate of photosynthesis. As a result under these low light conditions, the level of carbohydrates would soon be depleted and the cutting would collapse.

The solution of these two problems inherent in the rooting of tender cuttings came about through the development of mist propagation. Under mist, the cuttings are kept cool and wet, and in these conditions they do not wilt but remain turgid in spite of being exposed to high intensities of sunlight. Because no heavy shade is required, the cuttings can synthesize sugars that can be used as a constant source of energy necessary for the production of roots. The addition of synthetic auxins here would depend on the species involved. Although there is a peak of auxin production during this stage, the quantity necessary to induce rooting may within certain species be greater than what has accumulated at the base of the stem

Cuttings during *winter rest* present an entirely different problem. Two factors that may play a part in delaying rooting are:

1. The decreased production of auxin and other rooting co factors that correspond with decreased cellular activity in the buds and leaves and,

2. The relatively high level of inhibiting substances that are present at this stage of growth. The advantages of taking cuttings at this time are that the reserves of carbohydrates are at a high level and the ability of the leaf to lose excessive water is reduced.

Mist propagation at this stage is, therefore, not a necessity. A plastic tent, double glass, or a cold frame, could be used. The shading necessary for all of these methods could be applied without seriously causing a depletion of carbohydrates. To offset these factors that may delay or prevent rooting, we can apply synthetic auxins and bottom heat as well as wound it as a means of inducing the "dormant" cells at the base of the stem to become meristematic once again. Another thing that we can give them is time, and according to the rooting response of certain evergreen species, this becomes a necessity.

The *summer dormancy* stage of growth presents a situation that is intermediate of the *active* and the *winter rest stage* both physiologically and structurally.

Determining the most effective method of handling cuttings taken at any particular time during this stage would require some experience with the species used.

Perhaps the most important factor to be concerned with in deciding whether to root them under mist or plastic is their carbohydrate reserves. Cuttings high in reserves can be rooted under higher temperatures and lower light intensities as you would have in a plastic tent. Cuttings that appear to be low in reserves would have a better chance if they were rooted under higher intensities and at cooler leaf temperatures.

The extent of the accumulation of these carbohydrates depends on the length of time that elapsed since growth in length stopped as well as the conditions under which the stock plant had grown.

The taking of cuttings in the *revival stage* should be limited to those species known to initiate roots more rapidly at that time than at any other period. Because the rest within the buds has been overcome, the terminals will hasten to grow once they are exposed to warm temperatures.

Taxus cuttings taken at this time would very quickly make a top growth usually at the expense of the roots. The taking of Taxus cuttings should be carried out before the rest in the buds has been completely broken. The Umbrella Pine, on the other hand, will initiate roots more readily during this stage than at any other.

The possibility exists that substances effective in promoting rooting are produced by the buds after exposure to a long period of low temperature. Also, growth inhibitors, known to be present in buds during the winter, are usually destroyed by early spring. Rooting may come about as a result of both of these occurrences.

The rooting of cuttings in this stage of growth might best be accomplished by mist with the addition of bottom heat to encourage the roots to develop before the top does.

To summarize, I've discussed the status of the evergreen at four different stages of growth. In the first, the *active growth stage*: A high level of auxins and possibly other root-inducing substances is associated with active cell multiplication in the terminal buds and leaves. During this period the cells within the newly developed tissues are of a primary type, i. e. they can quickly become meristematic and proceed to develop into an organized root system. The carbohydrate content at this point is, however, at its lowest level and, because of this, rooting may not be possible. The recommendation for rooting such cuttings is to place them under mist with little or no shade.

The second category, the *summer dormant stage,* is one in which the rate of cell multiplication in the terminal buds has come to a temporary or permanent halt for that season. Associated with this is the decrease in the production of auxins and other rooting factors. Anatomically the cutting at this stage is intermediate to those of the *active growth* and the *winter rest stages.* Carbohydrate reserves are greater here than during *active growth*, but less than if they were in *winter rest.*

The third category, that of *winter rest* is one in which growth of the terminal bud has stopped. Associated with this is the auxin content which is at its lowest level. Also at this time inhibiting substances present in the buds and leaves are at their highest level. The tissue cells at the base of the stem is composed mostly of older secondary cells that are more difficult to re-activate. However, the carbohydrate reserve is at its highest level and would serve as a good source of energy needed for the relatively long period of time required for rooting to occur at this stage.

Rooting of such cuttings could be accomplished under plastic or mist. The application of auxins, bottom heat and wounding are recommended.

Finally, the *revival stage* is similar to the *winter rest stage* except that the buds have been exposed to a long period of low temperature and as a result are now devoid of growth inhibitors and are ready to resume growth as well as produce a relatively high level of auxins and possibly other rooting substances.

Taking cuttings at this time is recommended only on a trial basis for certain evergreens that will not root at other stages of growth. Cool air temperatures, mist, bottom heat, and wounding are recommended in this instance.

In presenting this talk I referred to evergreens only in general terms. I fully realize that some evergreen species vary in their physiology and therefore demand specific conditions as a prerequisite for rooting. All I could attempt to do during this brief talk was to discuss in general what may occur within the cuttings at the time it is severed and to suggest some treatments that would be appropriate.

MODERATOR COGGESHALL: Thank you very much Dr. Waxman.

The final speaker on the panel this morning is Mr. Edwin Kubo, Oki Nursery, Inc., Sacramento, California, who will speak on Care and Management of Cuttings from Collection Through Rooting. Mr. Kubo.

CARE AND MANAGEMENT OF CUTTINGS FROM COLLECTION THROUGH ROOTING

EDWIN KUBO
Oki Nursery, Inc.
Sacramento, California

Before discussing my subject, "Care and Management of Cuttings From Collection Through Rooting," I would like to give you a brief resume of Oki Nursery. Located in Sacramento, Oki Nursery, one of the largest container nurseries in California, was founded by Mr. M. Oki in 1907. The approximate production acreage of the Nursery is 56 acres and the annual production is in the excess of 2 million container grown plants. Our production is based on the U.C. system in which the use of clean soil, clean stock, sanitation, standardization, systemization and mechanization plays an important role.

To increase the efficiency of our production program, we have emphasized careful planning of our production through the use of good record keeping. Our annual production projection schedule plays an important part in determining the varieties and quantities to produce for the year. The Seeding schedule and Cutting schedule are used as a guide before executing production. Once in production a careful set of records is kept for each item for future reference.

In our completed record for cuttings we have the following information:

1. Date, number of cuttings stuck, and location.
2. Date, number of liners planted, and location.
3. Date, number of gallons planted, and location.
4. Source of Wood
5. Treatments. (Dip and Drench)
6. Type of growth regulator or hormone.
7. Type of medium used in rooting.
8. Percentage of rooting.
9. Percentage take of liners
10. Remarks. (Used for evaluation)

We have standardized and systemized all procedures from the collection of the cutting through the rooting process as follows:

Cutting Wood Collection and Treatment