Fifth I have not said much about hardening-off, for it is not a great problem with us. By the time the majority of our cuttings are ready to pot, the weather has cooled off and we have shut off the mist and have been hand-watering.

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Chairman Tichnor introduced Mr James S. Wells, James S Wells Nursery, Inc, Red Bank, New Jersey

MIST PROPAGATION — HARDENING-OFF TECHNIQUES

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Mist propagation has become such an integral part of almost any propagating nursery that it is interesting to recall that the first recorded instance of its use in plant propagation was in 1936, at Trinidad, British West Indies. By 1940, it was being tested in this country, and an excellent article in the *American Nurseryman,* May 1, 1941, by a nurseryman, Edward Gardner in Wisconsin, gave a long list of plants successfully propagated under mist. Then the war intervened, and most people lost sight of the method, although it was still in use at many of the state experiment stations. It was not until 1946-7 that practical work began once more. Mist, then, is a horticultural development of the first magnitude that has come into general use within the last 10 years.

As an essential preliminary to our discussion, we should first consider briefly some of the wider aspects of the misting techniques. I like to think of misting as being a better method of controlling water loss from cuttings, grafts, or transplanted seedlings. Most of the techniques the skilled plant propagator has used since his work began, have been directly toward the control of water loss from the plant materials with which he is working. A piece of a plant is arbitrarily removed from its natural water supply when it is taken as a cutting, and it is, therefore, in a precarious position It has no well-defined source of water, yet it has an undiminished ability to lose water through its leaves. Such a piece of plant material has to have quite careful attention day by day, even hour by hour, if it is not to die. It requires a special place — a greenhouse — plus the attention of the skilled propagator, and all these efforts are directed to the control of water loss. The syringing of greenhouse walls, the use of double glass or a polyethylene tent, the waxing of a graft union, or the use of mist are all part and parcel of the same thing, control of water loss. In this respect, misting has three distinct aspects. First is maintenance of an extremely high level of relative humidity inside the greenhouse. That is where fogging comes in. The standard humidifier is in this category, and for many cuttings this use of water is entirely adequate. Maintenance of humidity at 95 to 98% is sufficient to prevent undue water loss, particularly on cuttings that do

not wilt readily, such as conifers. For these and many more, this is the best type of "misting" to use, for such cuttings are damaged by the large amounts of water that are applied under direct misting. With this system, there is not much cooling of either the atmosphere or the plant tissues, an important effect to be found with other types of misting. Cooling of both the tissues of the plant material being propagated and the surrounding air follows application of excess water in mist form and the maintenance of a film of water on the leaves. This cooling has a very direct effect on water loss from the leaves, for if the leaves are cooled by the regular application of a small amount of water in the form of a fine mist, then not only is there ample water in the medium for the cutting to absorb, but furthermore, the tissues are kept at a slightly lower temperature than that of the surrounding air, and water loss by transpiration is negligible. The third, and perhaps most important, aspect of misting is the use of this cooling process to allow cuttings to be inserted and maintained in good condition in the open and in direct sunlight. Which brings us to one of the most important points in this question of hardening-off for there is a direct relation between the amount of light or energy being received by the cutting from the sun, and the frequency and quantity of water being applied to keep it cool. The two are interdependent, and this is important when we come to the problem of hardening-off, since shade can be used in place of mist to adjust the balance.

Let us now consider each of these three aspects of the use of mist, and discuss in a practical way how best to bring the propagated material back to normal conditions.

Where cuttings have been rooted under a relatively high humidity, but with little or no excess water, the problems are not so great, because the cuttings have been subjected to a fairly wide variation in air temperature and general conditions while rooting, which enables them to go without undue loss through a transition period from semi-controlled to uncontrolled conditions. The easiest way to achieve this successfully is, first, to increase slowly the air circulation in the propagating area by opening vents late in the evening and allowing them to remain open all night, closing them at a slightly later hour each morning. Otherwise, retain your normal system of humidification and modest venting, if temperatures are too high, during the hottest part of the day A slow extension of this ventilating over a two-week period should suffice.

We now come to cuttings rooted in the greenhouse under intermittent mist. First, we must consider a group of plants that fall naturally somewhere between the first and second groups. These plants will respond to intermittent misting and maintenance of a film of water on the leaves up to, but not beyond the point at which the cuttings commence to root. At that point, excess water becomes harmful and the plants will deteriorate rapidly, if water application is not drastically reduced Azaleas, when rooted in a greenhouse, are in this category, and so are Pyracanthas and some of the Prunus. Some conifers also are in this group, but in general, conifers prefer a somewhat drier condition than that provided by intermittent mist. The ideal method of hardening-off such cuttings is to maintain misting until rooting commences, and then switch to a condition of controlled humidity, which in turn

is slowly changed by shading and increased roof ventilation as the root system of the cuttings develop until the plants reach near normality

A cutting that is rooted in the open, under high light intensity and protected from desiccation by mist is one of the more difficult groups to harden up, because these are subjected to extremes of light and heat, which in turn require somewhat extreme measures of control It naturally follows that any slight deviation from the set pattern can produce a rapid change, and it is rapid change in any form that can be so disastrous to plant materials. Yet this method is an excellent one to use for certain plants, because it enables the cuttings to take full advantage of the high light intensity, and therefore to continue photosynthesis. In this way, cuttings that are poorly provided with chlorophyll, such as *Biota aurea nana,* can be rooted If such cuttings are put in a greenhouse under mist, or humidification, they will not root, or will root very indifferently But, put the same cuttings right out of doors in the full sun and protect them with a good intermittent mist system, and they root very well, indeed. This, I believe, is entirely due to the much greater light intensity, which enables the cuttings to manufacture excess food reserves for use in producing a root system.

This question of light intensity in the rooting of cuttings of all kinds and under all situations, is of great importance, and I would like to digress a little from the theme of hardening-up cuttings under mist to tell you something that happened to me last winter, in the rooting of Rhododendrons that I attribute directly to lack of light. Last year, our sash-type propagating house was used for summer cuttings and was shaded with 50% Saran shade cloth. When the summer crops were finished, the house was cleaned, sterilized, and prepared for Rhododendrons. I am sorry to admit that we just forgot the shade cloth tacked to the outside of the greenhouse Early in September, we began to insert the Rhododendron cuttings. They looked very well at the beginning, and, in fact, after about 8 weeks some began to root This was about the first of November Then, however, the cuttings began to deteriorate rapidly. First, the base of the cuttings began to rot, and then some of the leaves dropped off Sometimes a cutting would root again above the rotted base, and this in turn would rot. Finally, of course, the cutting died. We had these tested for fungus diseases, but all that were found could definitely be stated to be secondary: no primary fungus diseases were present.

The situation became quite serious, and, for want of a better answer, I attributed the problem to some unknown condition of the wood. About that time, I attended the Plant Propagators meeting in Philadelphia, where I heard a discussion given by Dr. Stuart H. Nelson from Ottawa, Canada, in which he described some experiments that were conducted on rooting a wide range of plants in a propagation house under mist. These tests covered deciduous shrubs, conifers and broad-leaved evergreens In the first year's tests, cuttings of all kinds rooted with an average of just over 90% under mist, with each treated with the appropriate hormone. The tests were repeated a second year, but with a drastic drop in over-all rooting (to just over 20%). This violent drop could not be explained by any obvious change in method, for plants,

greenhouse, bench, medium, hormone treatment — even the man doing the job — were the same. The only difference was that a permanent lath shade had been constructed over the top of the house a few months before the second set It seemed that this had to be the cause of the trouble. It was torn down, and the experiment was repeated for a third time The results immediately returned to the original high (90%) level.

I returned from the meeting determined to see just how much light I had in my greenhouse, but I was fortunate to have Dr. Nelson and Dr. William Snyder from Rutgers come for a visit I showed them my dying cuttings, and they confirmed my opinion that the light was insufficient Dr. Snyder said that a minimum of 450 foot-candles of light is required to maintain a leafy cutting in good condition, if the bench temperature is 70° F. I called the local light company, who came with a good light meter to test the light, and I was astonished and mortified to find that at mid-day on a reasonably bright winter day, the light intensity was only a little more than 200 foot-candles We immediately stripped off the shade cloth, washed the glass with lye, and cleaned everything up as much as possible, and it seemed to me that the cuttings looked brighter, almost overnight. More light was getting in, so they should. but they looked brighter in themselves. Be that as it may, the situation did change, for the leaves stopped dropping off, and the cuttings began to root. Later batches, put into the house at this time, rooted very well, indeed. Since then, I have had confirmation of the problem and the remedy from two or three sources. I believe we should use, at all times, the maximum amount of light that can be applied without damaging the cuttings.

To return now to our mist system, the quantity of light that can be used is much greater when we are applying mist than when we are not Light usually means heat, and therefore, increased water loss, but where we have the cooling of a mist system, light (and therefore energy) can be applied in much greater quantities without incurring the liability of rapid water loss and ultimate desiccation. Under such conditions, many cuttings can be rooted quickly and successfully. We find that we can take extremely soft cuttings of many plants and maintain them in excellent condition under a mist which, would be quite impossible in any other way Such "butter soft" cuttings can be kept turgid only by the use of mist, and such cuttings usually root with amazing speed

But when we use such soft cuttings, keep them in the open, and maintain their condition by misting. It is obvious that the greatest possible care is needed when we change these conditions in any way to slowly bring the newly rooted plants back to normality. From what I have said, it should be clear that there is an important interplay between misting and light intensity, and, conversely, the lack of light — shade. One can be substituted for the other to a fairly wide degree, especially once the cuttings have begun to root, and I believe that shade is of vital importance in hardening cuttings rooted in this way.

The first procedure should be to reduce the cycle of misting and replace the mist with a fairly heavy shade. What do I mean by a fairly heavy shade? I would say, under extreme conditions, at least 75%

shade, produced perhaps by placing two 50% lath shades, one above the other, with some gap between, or by using a 75% Saran shade cloth. Misting could, then, be reduced by about half, either by increasing the interval between misting or reducing the duration of the misting period. But even then, the cuttings should be watched carefully, particularly after making the first change, to see that it is having the desired effect. It might well be that the interval should not be reduced so drastically for the first two or three days, but, once the cuttings have begun to harden up, the interval between mistings can be slowly increased and shade equally, slowly reduced until the cuttings have come to a nearly normal state. This transition period requires that the skill and detailed attention of the propagator be exercised to the full. Let me emphasize that modern techniques and equipment do not in any way eliminate the need for careful day-by-day attention by the plant propagator. We may have fine, mist lines, percentage timers, electronic leaves, hormone powders and whatnot, but they still require the skill of the practiced plantsman to operate them successfully.

Some very successful propagators are rooting cuttings in flats in a mist area and then removing the flats, once the cuttings are rooted, to a semi-controlled area, such as a lath house, in which there may be a few jets, where a relatively high humidity can be maintained and the cuttings moved in bulk from one place to the other to be hardened-off This excellent arrangement works well where the equipment is set up in a proper manner Which brings us to the question of controls. I have used a number of forms of the electronic leaf. There is no question that in theory this is the best means of controlling a mist system, but in practice, I have found it to be somewhat temperamental and unpredictable. For this reason, I still hesitate to place a valuable batch of cuttings under its control I have an electrician friend, who is developing a new version, transistor-powered, with a variable sensitivity control. It has promise, but is still not entirely satisfactory. I, therefore, rely on the Watco timer, which has a 24-hour clock for turning the mist on and off, and a six-minute clock for the misting cycle By adjustment, this will give any number of 10-second squirts that I may think necessary.

To summarize, I believe that the best method of hardening-off all types of cuttings that have been rooted under some method of controlled water supply is to substitute heavy shade for some part of the mist period, and then to adjust both shade and mist until mist is eliminated and shade is the only protection given the batch of cuttings Then, in turn, the shade can be reduced until the cuttings are well-hardened up and have returned to completely normal conditions.

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CHAIRMAN HERB FOWLER: How do you get deciduous Azaleas to break dormancy after being rooted?

MR. WELLS: The rooting of deciduous Azaleas is now fairly well established. Cuttings have to be taken when very soft, early in the spring, in late April and early May There is a rapid decrease in the ability to root from mid-May to mid-June. I am quoting dates from my locality The cuttings will take quite a strong treatment with a hormone powder, up to 2% IBA. They will take from 2 to 2½ months to root, during which time they have to be kept under intermittent mist. The problem is to get them to grow. There are two ways to do this. One is to give supplementary light Once the cuttings have been rooted, give them longer daylengths with supplementary light The other way is to store them at about 35 degrees, but not allowing them to freeze. There is enough cold accumulating through the winter so that the natural dormancy of the plant is broken by spring.

CHAIRMAN TICHNOR. What is the diameter of the copper tubing in your mist system?

MR WELLS: The tubing is half inch, o.d., and a half-inch solenoid. I am only using 8 jets at 60 to 80 pounds pressure. I would dearly love to have all mist systems operate at 600 to 800 pounds. I think that would be by far the best.

CHAIRMAN TICHNOR. What are Florida jets?

MR WELLS: It has a threaded base and various collars and units that fit together Water comes out of an orifice, hits a stainless steel baffle and gives a flat spray in all directions The spray is horizontal, and that, to me is it's greatest value.

Mr Westgate sells Monajets and I have used them. If you have low water pressure, 25 pounds, the Monajet is the best in my opinion, because it is designed to operate well at that pressure. But when the pressure gets much above 25 pounds, then the angle of the mist rises and coverage is not as good. The Monajet is an excellent jet. But if your water pressure is above 25 or 30 pounds, than I think the Florida jets will do a better job.

CHAIRMAN TICHNOR. Can water at 250 pounds pressure be used for a mist?

MR. WELLS. Oh, yes, I think that is perfectly splendid. You should use a stainless steel orifice at that pressure, otherwise you will get worn-out nozzles if you use a brass orifice. At much above a hundred pounds pressure, the nozzles do not last long, so I am told.

MR PHIL BARKER: Would you compare the T-jet nozzle with the Monarch nozzle?

MR. WELLS: Well, I have seen and just tested very briefly the T-jets, so I can't really compare them accurately Some people are using them. I am partial to Monarch, because I began with Monarch. I think they are very good.

MR. CURTIS: Well, I use a Monarch jet and I have a galvinized line right down the middle of the bench. I have just about come to

the conclusion that if you have a 4-foot bench, you should use a jet giving a 5-foot diameter mist. You get a little bit better coverage on the edges of your bench My water pressure varies. In the winter time, I maintain about a 35 or 40 pound pressure. In the summer, I have 60 pounds pressure, but the Monarch works all right with either pressure.

MR. WELLS: Now, I would like to say this. We have been ranging over misting and if any of you have the chance, you should go to see Harvey Templeton's setup in Winchester, Tennessee. He has brought together and is applying, in the most practical manner, all these various facets of propagation under mist, that we are talking about.

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