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Development and Application of Foliar Applied Rooting Solutions©

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INTRODUCTION

To propagate plants from cuttings, Kees Eigenraam told me about the 'foliar' (leaf) application of rooting solutions with Rhizopon products. That was in 1989 when I came to know Kees. Our introduction was associated with my company, Hortus USA, importing his Dutch Rhizopon plant rooting products into the USA.

In those pre-Goggle Scholar days, I did extensive book and journal reading about plant propagation. Nowhere could I find a reference to 'foliar' use. Before growers used foliar methods for applying rooting hormones, plant propagation from cuttings was limited to basal methods. While he had written information, few growers outside Kees' Dutch and European customers knew of foliar methods.

Foliar application of rooting solutions has a recent history. The earliest extensive study was Davies' histological and physiological research comparing root formation in juvenile and mature cuttings (1978, 1980, 1982). Davies and Joiner (1980) found foliar application of water base IBA rooting solutions to be effective to induce roots. Kees developed the first commercial foliar methods in 1985. At the time, Kees did not know the research by Davies. The first commercial users were Dutch growers propagating chrysanthemum cuttings.

SPRAY DRIP DOWN METHOD AND TOTAL IMMERSE METHOD

Lacking other names and basic information, I termed the 'Spray Drip Down Method' and the "Total Immerse Method". Over the years, Kees and I improved and documented the methods. Now, growers worldwide use the methods to propagate many types of plants from cuttings with water base indole-3-butyric acid (IBA) rooting solutions. IBA is the most useful rooting hormone. For plants suitable to be propagated from cuttings, growers apply the solutions to leafy cuttings of annual, perennial, and woody plants in the active growing state. Compared with other propagation methods, foliar methods have improved rooting quality, reduced misses, reduced labor cost, and lower rate application savings.

The Spray Drip Down Method is used by annual plant growers such as Dummen's Red Fox rooting stations and Yoder Chrysanthemums, perennial plant growers such as Aris Green Leaf Plants and Keepsake Plants, and woody plant growers such as Bailey Nurseries. The Total Immerse Method is used with tissue culture plantlet transplanting at the greenhouse stage. Total Immerse is also used on large homogenous crops such as *Hedera* (ivy) and pot roses (*Rosa*).

FOLIAR AND BASAL METHODS

I know of five foliar and basal methods to propagate plants from cuttings. I do not advocate use of foliar methods all the time. Depending upon the plant variety and season, basal methods are sometimes better. Some plant taxa, such as selected cultivars of chrysanthemums, are propagated by both foliar and basal methods in the same facility in parallel.

Basal Methods

Three methods are used to apply rooting hormones to the basal end of cuttings. The methods are used all year, on leafy and leafless cuttings, in the active growing and dormant states. The Basal Dry Dip Method use rooting hormone powders, and the Basal Quick Dip and Basal Long Soak Methods use rooting solutions.

Foliar Methods
Two methods are used to apply rooting hormones to the leaves of cuttings taken in the active growing state. The methods are not used on leafless or dormant cuttings. The Spray Drip Down and Total Immerse Methods use water base IBA rooting solutions.

Basic Foliar Practice
Growers take leafy cuttings from stock plants in the active growing state since there must be internal sap flow. Dormant cuttings are not used since there is limited metabolic activity and restricted sap flow and vascular uptake. Leafless cutting have no "leaf" entry points. A water base IBA solution is applied to leaves which enters the plant's vascular system through open pores in leaves via stomata. Stomata are open in a temperature range of 16-32°C (60-90°F), provided cuttings are well hydrated.

SCIENTIFIC STUDIES RELATING TO FOLIAR APPLICATION

Efficacy
Davies and Joiner's study (1980, 1982) demonstrated the efficacy of foliar application of water base IBA rooting solutions to induce rooting.

Substances Used
The natural occurring auxins, IAA and IBA, induce root formation. Endogenous IBA and IAA are both produced in shoot apices and young developing leaves. Through *B*-oxidation in the cutting, IBA is converted to IAA to enhance rooting (Hartmann et al., 2011). IAA is unstable in solution and sensitive to light. Hence, the more stable, water base IBA solutions are best used for foliar applications.

Carrier Needed
Water is the universal solvent in plants. Special formulations of IBA can be made into water base rooting solutions. Water base IBA solutions are suitable to apply by foliar methods. While IBA is insoluble in water, it is soluble in alcohol. The alcohol base solutions should not be used for foliar methods, alcohol can cause foliar burning or 'alcohol burn' which is detrimental to the cutting.

Entry Point of the Solution
The entry point of applied IBA into the plant is though stomata and also run-off accumulation at the base of the cutting. While mostly found on the underside of leaves, stomata can also be found on other plant parts including upper leaf surfaces, stems and specialized structures. Their function is to regulate interchange of gasses, including water vapor between the plant and the environment. The stomata have two principal parts, the internal pore and the surrounding guard cells. The guard cells regulate the size of the pores. For foliar application of rooting solutions to work successfully the pores must be open. Studies show stomata are open when cuttings are well hydrated and when temperatures and other factors are suitable for translocation of gas, vapor and liquid. Stomata close when cuttings are wilted.

Solution Movement within the Plant
The stomatal cavities contain air spaces and leaf mesophyll cells which can absorb fluids such as water base IBA solutions. Solution absorption is caused by pressure differentials between the relative humidity outside the leaf and the stomatal cavity, i.e. VPD — vapor pressure deficit (Hartmann et al., 2011). After the applied IBA solution enters the leaves, it is absorbed and enters vascular bundles (the phloem). The bundles facilitate translocation of fluids through the plant. Along with leaf produced IAA, the applied and natural IBA is translocated in a polar direction to the basal end of the cuttings — and adventitious roots are initiated and formed. One should avoid high auxin concentration which can cause phytotoxicity, foliar burning and necrosis of the cutting stem base.

Growers should trial at the lowest possible rates to avoid phytotoxicity.

FOLIAR METHODS

The Spray Drip Down Method

The Spray Drip Down Method can be used on many small production lots at one time. Growers first stick the cuttings into media. No personnel protection equipment (PPE) is required to stick untreated cuttings; thin gloves may be used solely for sanitary purposes. It is necessary for grower to use a water base IBA solution such as Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. A sprayer is selected for the best use in the facility. The solution is sprayed onto the leaves of the cuttings until there is a drip down. The drips are a visual indicator that an adequate amount of solution has been applied. Growers should try to treat both the top and bottom of cuttings. An excess application is best. The solution is used one time to avoid biological contamination between production lots. The typical application is about 10 m^2 liter (200 ft^2/gal). Misters can be turned on after about 30-45 min or until the solution dries on the leaves.

The Total Immerse Method

The Total Immerse Method can be used for large homogeneous plant lots that are clean and disease free. Large leaf cuttings benefit by having both sides of the leaves treated at one time. The method requires little setup and can be used on large or small production lots.

A simple tub and strainer basket are used to treat the cuttings. Growers use a water base IBA solution as above. Cuttings are dipped into the solution until the leaves are completely covered with liquid, about five seconds. When used to treat tissue culture plantlets, growers must take care not over fill the basket, thereby avoiding cutting breakage. Long immersion is not recommended to avoid adverse reactions. After dipping, growers stick the cuttings into media. Since biological materials from dipped cuttings enter the solution, it is best to dispose the solution between different production lots at the end of the work day.

Solutions Used by Foliar Methods

The US EPA prohibits un-registered or technical grade IBA products to be used by growers for propagation. Two US EPA registered products are allowed to be used to make water base IBA rooting solutions and are labeled for use by foliar application: Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets (Phytotronics, <www.phytotronics.com>).

Indole-3-butyric acid can be made into solutions in two ways. Specially formulated IBA can be dissolved in water to make rooting solutions. IBA "as produced" is water insoluble; it can be dissolved in solvents such as. There are other commercially produced, EPA-labeled auxin concentrate products that have an alcohol base that are mixed with water to form more dilute formulations. If applied to the leaves of cuttings, alcohol rapidly evaporates and dehydrates plant tissue and can burn tissue. In my studies, foliar applications to cuttings with solutions containing with as little as 5% alcohol content can cause phytoxicity and death.

When using foliar methods, I do not recommend use of wetting agents in solutions made using Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets. Trials show no differences using wetting agents.

Some growers prefer to measure and mix solutions rather than dry measure the Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets. Using the required number of grams or tablets, a concentrate solution can be made. The required portion of the concentrate is put in the production tank. Water is added to dilute to the required volume. Hortus IBA Water Soluble Salts solutions can be made to over 80,000 ppm IBA using water, which would be too high an auxin concentration for cuttings. Unless otherwise specified, thin waterproof gloves are adequate for handling water base rooting

solutions.

Water base IBA rooting solution products are used by both basal and foliar methods. These solutions replace any pre-mixed rooting solutions when used at the same IBA rate. In growing facilities where both basal and foliar methods are used, this eliminates the need to inventory different rooting solution products.

I have been told some growers have wanted to make rooting solutions using dry dip rooting hormone powders. These powders contain mostly insoluble talc and are not practical for foliar applications.

Temperature of the Solution and Cuttings

Growers can propagate in cool greenhouses or when cuttings are taken from coolers. Based upon my research, the standard foliar application temperature range for cuttings and solutions is 16-32°C (60-90°F), provided the cuttings are hydrated.

Time between Sticking and Spraying

I did trials to determine the effect of time between sticking and treatment by the Spray Drip Down Method. Davies and Joiner's studies (1980) indicated that there was a variation in rooting after several days between sticking and treatment, i.e. it is best to apply foliar auxin applications within the first 48-h of sticking. There was a decline in rooting after waiting more than a week to apply IBA. My trials determined that it is best to treat the same day as sticking. For PPE purposes, it is advantageous for the treatment person to do spraying at the end of the work day when other production workers are not in the greenhouse. In hot climates, where daytime temperatures are high, spraying is sometimes done early in the morning after sticking, when temperatures are lower.

Hydration and Misting

Growers should use well hydrated cuttings when using foliar methods. IBA in the rooting solution enters the leaf within a few minutes after application through open pores in stomata. Wilted cuttings have closed stomata, therefore the cuttings must be re-hydrated before treatment. With the Spray Drip Down Method, mist systems must be turned off before treatment to avoid diluting the rooting solution and restored about 30-45 min after treatment. With the IBA runoff accumulation, some of the auxin will also be taken up at the base of the cutting.

Keeping Solutions

As previously mentioned, it is best to keep unused solutions for no more than several weeks. Unknown biological substances from untreated pond water, wells, or city water, may cause the IBA to degrade. The Total Immerse Method requires sticking the cutting into the solution. The cuttings bring biological substances which can cause contamination if the solution is stored and not discarded after use. Hence, it is important to dispose the solution after use at the end of the work day. The Spray Drip Down Method uses the solution one time. Unused solutions can be kept, however, not for a very long time.

FOLIAR RATES

The same rates are used by the Spray Drip Down and Total Immerse Methods.

Annual Plant Cuttings

Some tender plant varieties and juvenile cuttings are treated at rates 80-100 ppm IBA. The normal trial range is from 80-200 ppm IBA. If leaf distortions occur, the rates need to be adjusted downward.

Perennial and Woody Plant Cuttings

Perennial and woody plant cuttings have similar rates. The selected trial rates are 500, 1000, and 1500 ppm IBA. Rates above 1500 ppm IBA are rarely needed except for some mature cuttings. Rates below 500 ppm IBA are sometimes needed for tender, juvenile

perennial cuttings.

Tissue Culture Plantlets
When transplanting tissue culture plantlets, the Total Immerse Method can be used with Rhizopon AA Water Soluble Tablets at 1-3 tablets per liter of water. For blueberry, two Rhizopon AA Water Soluble Tablets per liter are used.

Transplanting Divisions
The Spray Drip Down Method is used when transplanting decorative grass divisions. Rates are similar to those used for annual cuttings. Juvenile cuttings require lower rates than mature cuttings. Growers generally know which of their cuttings are seasonally easy or hard-to-root and adjust their rates. The basal quick-dip rates are usually too high a concentration for foliar application.

Cuttings
The rules for taking annual, perennial and woody plant cuttings are simple. Take leafy cuttings in the active growing state. It is always best to use cuttings-from-cuttings when possible. It is important not to take dormant or leafless cuttings which are better propagated by basal methods. Do not cut leaf tips. Some growers cut the tips of large leaf cuttings to obtain more cuttings in a propagation tray. The cut causes a wound that is open to infection. Wounds in the tip area create competing 'sinks', which ties up valuable resources (metabolites) to heal the leaf wound, rather than induce root formation at the basal end.

Secondary and Transplant Applications
A post, second Spray Drip Down Method foliar application can be used on leafy cuttings in the active growing state that were first treated by any auxin application method. The second application helps to improve root formation on slow-to-root cuttings. Applications can be done weekly or as required. Rates are similar those used for first foliar application for cutting type and species.

One of the major ways to use the Spray Drip Down Method is to treat divisions and young rooted cutting transplants. Growers of ornamental grasses use this method on transplant divisions at rates as if they were annual cuttings.

Labor Savings, Quality Control, and Material Cost
Foliar methods have reduced labor cost, with better control, compared with basal methods. It is faster to stick cuttings when foliar batch treating. There are no 'misses' as may happen with traditional quick-dip basal methods. Foliar methods, at low rates, have lower material cost than high rate basal methods.

Trials are Necessary
Before conversion of production to foliar application, growers should conduct initial trials. Growers should do trials on small lots, keeping accurate records of methods, rates, time of the year and varieties tested. The review of results should also consider the facility advantages, and labor and setup costs for each method.

Hybrid System
In the same growing facility, a hybrid system with both basal and foliar methods is often used at the same time on cuttings propagated in the active growing state. Selection of methods and rates depend upon the species and cultivars.

ADVANTAGES OF FOLIAR PROPAGATION METHODS
- Foliar bulk treated cuttings are uniformly treated and avoid quick-dip basal treatment skips.
- Foliar methods use about one-third the labor compared with individual treated basal

methods.

- Foliar methods have low material cost due to the reduced rates.
- The Spray Drip Down Method minimizes cross contaminate diseases and pathogens since solutions are used once.
- The Spray Drip Down Method's well-trained application person is the only worker needing PPE.
- Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets have zero hour restricted entry interval (REI).
- What was learned in school may be out dated: The latest edition of *Hartmann and Kester's Plant Propagation: Principles and Practices* (Hartmann et al., 2011) discusses commercial foliar methods.
- The number of growers using foliar methods has rapidly increased as they bring their knowledge of foliar method success when changing jobs.
- For cost savings and efficiency: foliar propagation methods can save money, improve quality, save time, and reduce labor.

SUMMARY

Foliar methods are easy to understand and use:

- Growers select cuttings from plants that are propagated from cuttings using rooting hormones.
- Growers can propagate annual, perennial, and woody plants from cuttings.
- Leafy cuttings are used.
- Cuttings are to be in an active growth stage, hence, dormant and leafless cuttings are not used.
- Water base IBA rooting solutions are used.
- Cuttings are to be well hydrated before and after treatment; Application is to be made at temperatures from about 16-32°C (60-90°F).

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