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Foliar Applied Rooting Solutions for Plant Propagation from Cuttings: Historical Background and Utility

Joel Kroin
Hortus USA Corp

Propagate plants from cuttings using foliar methods:

- Take leafy cuttings in the growing state.
- Apply aqueous IBA rooting solutions to the leaves.
- Sticking is done either before or after treatment depending upon the method.
- Roots are produced at the basal end of the cuttings.

Today foliar applied rooting solutions are successfully used to propagate leafy cuttings taken in the growing state. Fundamentals of the process seem obvious. It had been known for over a century that some substances were produced in leaves, causing plant growth regulation in other parts of the plant. These natural substances, called auxins, have been identified. The basic natural auxin, IAA, was found produced in leaves. Contained in aqueous solutions, auxins can be applied to leaves. These solutions can enter the vascular system of plants through pores in leaves called stomata. Inside the system, the auxins move by polar transport to the basal end of cuttings. Though physiological interactions, scientists believe that IAA becomes another natural auxin, IBA. Therefore, when IBA in aqueous solution is applied to leaves, it can enter the vascular system. IBA can be transported, with the leaf produced IAA, to the basal end. At the basal end, by processes still unknown by scientists, IAA and IBA induce cell division resulting in root formation.

HISTORICAL BACKGROUND

For more than a century, botanists debated how plants regulate growth. One of the mysterious phenomenon, root cells form in apparently normal plant tissue. Julius Sachs (1892) proposed specific substances act to form leaves, roots, or stems, moving with polarly in specific directions. His theory was that the root forming substance was formed in leaves and translocates to the lower parts of the plant, there stimulating root production.

The later generation scientist, Fritz Went was influenced by Sachs' ideas. Went's doctoral thesis (1928), developed the 'bio-assay' technique. Bio-assay is used to identify substances developed in tips of plants which translocate to lower portions of the plant for growth regulation. Using bio-assay, Went and Kenneth Thimann (1934) identified the plant growth regulator Indole acetic acid, IAA, as a natural substance produced in leaves. IAA has the ability to translocate within the plants' vascular system. Using IAA as a starting point, they identified other close compounds, 'auxins', which potentially have similar plant growth regulator activity.

Of the auxins, Indole butyric acid (IBA) and Naphthalene acetic acid (NAA) were found to have utility in plant growth regulation. Recently, IBA was found naturally occurring. After the discovery that auxins were important for root formation, it was well known, these natural substances were produced in inadequate amounts to initiate root formation on most plant cuttings. For those cuttings that cannot form roots on their own or are slow-to-root, external applications of auxins are required to achieve rooting.

After identification of the auxins, Went, Thimann, the Boyce Thompson Institute researchers, and other scientists, developed techniques to use them. Their research on root formation was limited to basal application, for intended root formation. They locally applied auxin dry powders, dilute solutions, or lanolin pastes to the basal end of cuttings. Positive root formation was observed.

Believed to be the first studies, foliar applied auxins were successfully used to root of carnation cuttings by D.W. Cheever (1967). The earliest published histology study on foliar applied aqueous IBA rooting solutions was Frederick Davies' PhD thesis (1978). Cuttings were taken in the growing state. Davies demonstrated root formation on Ficus pumila juvenile cuttings require lower IBA rates, with higher root numbers as compared to mature cuttings. *(Davies and Joiner's article on their research is in this book.)*

After the discovery of auxins, in Holland the Amsterdam Chinin Factory (ACF), established the Rhizopon company (1939). Rhizopon manufactures commercial plant rooting products, both dry dip powders and water soluble tablets to make rooting solutions. To improve use of the solution rooting products, Kees Eigenraam developed the first commercial foliar methods (1985). At the time, Eigenraam did not know the research by Davies. The first commercial users were Dutch growers propagating chrysanthemum cuttings. They found, foliar application reduced labor and improved the root formation of cuttings.

Joel Kroin, of Hortus USA, got together with Eigenraam in 1989. They discussed the foliar methods that were newly used. Other than Rhizopon's data sheets, Kroin could not find anything written about foliar methods. Literature of the time indicated plant propagation from cuttings was limited to basal methods. Lacking foliar nomenclature and other basic information, Kroin termed the ‘Spray Drip Down Method‘ and ‘Total Immerse Method’. Over the years, Eigenraam and Kroin improved and documented the methods.

For use of foliar and basal methods, Hortus USA, introduced US growers to Rhizopon AA Water Soluble Tablets (measured by counting tablets) (1993). Tablets, when dissolved in water, make IBA solutions. Among the first US foliar method users were the Yoder chrysanthemum propagators in Florida. Soon after, Yoder established their perennial propagation facility, Green Leaf Plants, in Lancaster PA. There they began using the foliar Spray Drip Down Method. Keeping concise records, they established rates for thousands of named plant varieties. Their cuttings are taken from juvenile stock plants, resulting in rooting uniformity. Significant for propagators of high volume annual and perennial plants, found the foliar methods save labor. Cuttings are treated in bulk rather than individually. Low solution rates result in low material cost. Hortus USA developed Hortus IBA Water Soluble Salts, measured by weighting powder, to meet the aqueous (water based) IBA solution needs of large scale production.

A few years later, Bailey Nurseries’ research director Sam Drahn, started to use the Spray Drip Down Method to root woody ornamental cuttings. Based upon his data, it became apparent that the rates for woody ornamental plant cuttings were similar to those obtained by Dr. Davies’ juvenile cuttings, and the perennial cuttings of Green Leaf Plants.

Using this information, rates were established for two basic groups of cutting rates for juvenile leafy cuttings that are in the growing state. Rates for mature leafy cuttings are higher than the rates for juvenile cuttings.

Cuttings of annual plants require very low rates; the midpoint trial rate about 125 ppm IBA using Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets.

Cuttings of perennial and woody ornamental plants require the same rates; the midpoint trial rate about 1000 ppm IBA using Hortus IBA Water Soluble Salts. (*Drahn’s article on his research is in this book.)*

The technology of foliar application of aqueous (water based) IBA rooting solutions are based upon plant physiology. Water is the natural fluid carrier in the plant’s vascular system. As described above, it has been found that both IAA and IBA are naturally produced by plants. IAA produced in leaves is usually inadequate for root initiation. IAA is unstable. It decays rapidly due to biological factors, light, and heat. Whereas, IBA is stable when needed for root initiation. Compared to IAA, IBA has greater ability to initiate roots. Various studies indicate IBA may be a very simple ‘conjugate’ of IAA and must be converted to IAA by b-oxidation. As such, either IAA or IBA may be the substance that induces cell division and root initiation. The plant can use the applied IBA as a booster where natural IAA is not sufficient for root formation. It has also been shown, auxins translocate from the apical to basal portions of the plant section.

The foliar entry point of applied aqueous (water based) IBA solution into the plant is though the structure called ‘stomata’. 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. 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 allow translocation of gas, vapor and liquid. Stomata close when cuttings are wilted.

Stomatal cavities contain air spaces and leaf mesophyll cells which can absorb fluids such as aqueous (water based) IBA solutions. Solution absorption is caused by pressure differentials between the relative humidity outside the leaf and the stomatal cavity, (for example, VPD ‘vapor pressure deficit‘). 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; adventitious roots are initiated and formed. If an excess of IBA is foliar applied, it may be possible for it to return, by non-polar transport, to upper portions of the cutting. If so, herbaceous cuttings may exhibit leaf curls or spotting. If the excess was not too high, the cuttings will still produce proper rooting and growth. Lowest possible IBA rates avoid such phytotoxicity.

METHODS

Three basal and two basal methods are successfully used to propagate plants from cuttings.

Three basal methods, the Dry Dip, Basal Long Soak and Quick Dip Methods, have been used since discovery of auxins. Cuttings of active growing or dormant annuals, perennials, and woody plants can be used.

The Dry Drip Method uses dry powder rooting hormones. Basal ends of the cuttings are dipped into the powder then stuck. The Basal Long Soak Method, was well used through 1950's. The method uses rooting solutions. Basal ends of the cuttings are soaked into the solution for several hours then stuck. The Quick Dip Method uses rooting solutions.

Basal ends of the cuttings are dipped into the solution for a few seconds then stuck.

Two foliar methods, the Spray Drip Down and Total Immerse Methods have recent use. Cuttings of actively growing or dormant annuals, perennials, and woody plants can be used. The methods use aqueous (water based) IBA rooting solutions made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. The Spray Drip Down Method is used on cuttings that are first stuck. The rooting solution is sprayed onto the leaves until liquid drops are seen to drip down. The Total Immerse Method has cuttings totally immersed in the rooting solution for a few seconds then stuck.

Compared to basal methods, foliar methods have improved rooting quality, reduced misses, reduced labor cost, and material cost savings. Basal methods can be used on cuttings taken all year. Foliar methods can be used on cuttings taken growing state. Selection of the method to be used for particular cuttings should be based upon facility needs, direct and in direct cost, the plant variety, and growing state. In the same facility, some plant taxa, such as selected cultivars of Chrysanthemums or Roses, are sometimes propagated in parallel using either foliar or basal methods.

ROOTING STATIONS USE FOLIAR METHODS

The Spray Drip Down Method is used by annual plant growers including Dummen's Red Fox rooting stations and Yoder Chrysanthemums. Some perennial plant grower users are Aris Green Leaf Plants and Keepsake Plants. Many woody plant growers also use it including Bailey Nurseries. The Total Immerse Method is used with tissue culture plantlet transplanting at the greenhouse stage. Total Immerse is also used on crops such as some phlox, dianthus, and hedera (ivy).

FOLIAR METHODS

THE TOTAL IMMERSE METHOD

The Total Immerse Method is used on cuttings taken in the growing state. Small or large homogeneous plant lots and be used. To avoid cross contamination between production lots, cuttings must that are clean and disease free. Cuttings are treated then stuck. Rooting solutions are made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets.

Cuttings are dipped into the rooting solution until the leaves are completely covered with liquid for about five seconds. The result is, leaves have treatment on both their tops and bottoms. After draining, the cuttings are stuck into media. A simple tub and strainer basket are used to treat the cuttings. It is important not to over-load baskets to avoid cutting breakage. Dipped cuttings bring biological materials into the solution. It is best to dispose of the solution between dissimilar cutting lots. When homogenous lots are treated, the solution should be disposed at the end of the production day or period. Personnel protection equipment (PPE) is required as stated on the product labels.

THE SPRAY DRIP DOWN METHOD

The Spray Drip Down Method can be used on small or large plant lots. If kept separate, cuttings of different types can be treated together. Cuttings are stuck then treated. Rooting solutions are made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets.

After sticking cuttings, the rooting solution is sprayed onto the leaves until there is a drip down. The drips are a visual indicators of the adequate amount of applied solution. Leaf treatment should be both their top and bottom. An excess application is best. After spray treatment, misters can be turned on after about 30-45 minutes or until the solution dries on the leaves. Typical spray application uses about 10 m^2/ liters (190-220 ft^2/gal). Various types of sprayers are used such as backpack, hydraulic, boom, or custom made. The solution is used one time. Since the unused solution is kept in the sprayer tank, there is no possible solution contamination between production lots. No personnel protection equipment (PPE) is required to stick untreated cuttings. Thin gloves may be used solely for sanitary purposes.

SOLUTIONS USED BY FOLIAR METHODS

Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets are US EPA registered. Mixed with ordinary water, they are used to make aqueous (water based) IBA rooting solutions. Their labels approve use by basal and foliar methods. When used by foliar methods, it is not necessary to use of wetting agents with their solutions. Where foliar and basal methods are used in the same facility, it is only necessary to inventory one or both products for any method.

A gram scale is used to weight Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. Tablets can be counted. The Salts or Tablets are dissolved in water. If a concentrate is made, it can be added to the production tank; water is added to bring to the required liquid volume. For ease of handling, concentrate Hortus IBA Water Soluble Salts solutions can be made to over 80,000 ppm IBA using water.

Solutions should be made soon before use. Unused rooting solutions can be kept a short period. Solutions that have cuttings dipped-in should be discarded soon after use.

RATES: Refer to the rate tables in other parts of this book.

RATES: CUTTINGS. The Spray Drip Down and Total Immerse Methods use similar rates for cuttings. Rates used by the Basal Quick Dip Method are usually too high for foliar methods. Juvenile cuttings require lower rates than mature cuttings. Plants growers generally know which of their cuttings are seasonally easy or hard-to-root and adjust their rates. Where leaf distortions occur, the rates are to be adjusted downward.

Annual and tender plant cuttings, and some juvenile cuttings, selected rates at about 80 to 200 ppm IBA using solutions made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. The midpoint trial rate at about 125 ppm IBA.

Perennial and woody ornamental cuttings require similar rates. Selected rates at about 500, 1000, and 1500 ppm IBA using solutions made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. The midpoint trial rate is about 1000 ppm IBA. Except for some mature cuttings, rates above 1500 ppm IBA are rarely used. Juvenile and tender cuttings, rates below 500 ppm IBA are used.

RATES: DIVISIONS AND CUTTING TRANSPLANTS. The Spray Drip Down Method is used to treat divisions and young rooted cutting transplants after transplanting. Cutting transplants require the same rates as if they are unrooted. Ornamental grasses transplant divisions require rates as if they were annual cuttings.

RATES: TC TRANSPLANTS. When transplanting tissue culture plantlets, the Total Immerse Method is used with Rhizopon AA Water Soluble Tablets at about 1 to 3 tablets, or lower, per liter of water. The rate for cultivated highbush blueberry TC transplants at about 2 Rhizopon AA Water Soluble Tablets per liter of water.

THE CUTTINGS

Leafy cuttings are taken from stock plants in the active growing state. There must be internal sap flow. Dormant cuttings are not used; there are limited metabolic activities and restricted sap flow and vascular uptake. Leafless cuttings have no ‘leaf’ entry points. Aqueous (water based) IBA solutions, using Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets, are applied to leaves. The solution enters the plant's vascular system through open pores in leaves through ‘stomata’ structures. Stomata are open in a temperature range about

60-90°F (16-32°C), provided cuttings are well hydrated. After entry into the vascular system, the IBA translocates to the basal end where it helps to initiate roots.

The rules for taking annual, perennial and woody plant cuttings are simple. Take leafy cuttings in the active growing state. Juvenile cuttings have better rooting capability compared to mature cuttings. Also, Juvenile cutting rates are lower than for mature cutting. To maintain juvenality, it is always best to use ‘cuttings from cuttings’ when possible. For foliar methods, dormant or leafless cuttings, these are propagated by basal methods. Generally, cuttings that have nodes at the basal end do not root as well versus cuttings with inter-nodes. Some plant 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.

FAVORABLE PROCEDURES

TEMPERATURE. When using foliar methods it is important not to apply in cold propagation areas or use cold solutions. Cuttings taken from coolers must be brought up in temperature before treatment. The standard foliar application temperature range for cuttings and solutions should be about 60-90°F (16-32°C), provided the cuttings are hydrated.

When propagation is done in locations where day temperatures are high, spraying is done early in the morning after sticking when temperatures are cool. In south Florida, sticking is done during the hot time of day, with workers cooled under mist. Spraying is done early the day after sticking when temperatures are cool.

TIMING 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. For example, it is best to use foliar auxin applications within the first 48 hours of sticking. There was a decline in rooting after waiting more than a week to treat with IBA rooting solutions. Hortus USA’s trials determined that it is best to treat the same day, or the following morning, after sticking.

PERSONAL PROTECTIVE EQUIPMENT. When using the Spray Drip Down Method, treatment workers doing spraying must use appropriate PPE. It may be beneficial to spray while other workers are not in the production area. This may be done at the end of the work day when other workers are away. Workers who only stick do not require PPE since cuttings are untreated.

HYDRATION. Cuttings should use well hydrated cuttings when using foliar methods. Wilted cuttings have closed stomata. The rooting solution must enter the leaf through open pores in the stomata. Solutions entry is within a few minutes after solution application. Some European chrysanthemum propagators advise successful Spray Drip Down Method on slightly limp leaf cuttings. When using the Spray Drip Down Method, mist systems must be turned off before spraying. This reduces dilution of the rooting solution. After spray treatment, misters can be resumed after about 30-45 min or until the solution dries on the leaves

LABOR SAVINGS AND CONTROL. Foliar methods have reduced labor cost; sticking batch treating cuttings is faster than individual hand sticking of cuttings by basal methods. Foliar methods have no 'misses' as may happen with basal dip methods. Foliar methods use lower rates, and reduced material cost, as compared with basal methods.

LEVELING CROPS BY SECONDARY APPLICATION. Secondary Spray Drip Down Method foliar applications can be used on leafy cuttings in the active growing state no matter how they were first treated by any rooting method. The second application may help to improve root formation on slow-to-root cuttings. Applications may be done weekly or as required to improve the leveling of crops. Some plant growers use this method on all their production, whether or not the rooting is considered slow. Rates are similar to those used for first foliar application.

HYBRID PROPAGATION SYSTEMS. Cuttings may be treated at time of sticking by any basal (Quick Dip, Long Soak, Dry Dip) or foliar (Spray Drip Down, Total Immerse) method. Then, the Spray Drip Down Method is used for second or third treatment; application will level crops.

Often growers will use either the Quick Dip, Long Soak, Dry Dip, Spray Drip Down, or Total Immerse Method to propagate some crops. Then, in parallel, use other method for other crops. Selection of the method can be dependant upon the plant variety, time of the year, or facility factors. In a chrysanthemum propagation facility, it is common to hybrid operations. Simultaneously, dry dip rooting hormones used on some varieties and solutions are used by the Spray Drip Down Method.

TRIALS. Before conversion of production to foliar application, plant 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. Where juvenile cuttings are taken, they will likely produce better rooting yields at lower rates as compared to mature cuttings. Review of results should also consider the facility advantages, and labor and setup costs for each method.

ADVANTAGES OF FOLIAR APPLIED AQUEOUS (WATER BASED) IBA ROOTING SOLUTIONS:

- Quality: Foliar methods produce high rooting quality due to uniform treatment.
- Low material cost: Foliar methods use low rooting solution rates and reduced material cost compared with high rate basal methods.
- Low labor cost: Sticking by foliar methods use on third the labor of basal treated cuttings. Foliar methods have bulk treated cuttings. Basal methods have individually treated cuttings.
- Uniform rooting results: Cuttings are uniformly treated. Sometimes basal treatment has treatment ‘skips’.
- No cross contamination: The Spray Drip Down Method reduces cross contamination of diseases and pathogens; solutions are used one time.
- Reduced Personal Protective equipment: PPE is not required by workers doing sticking by the Spray Drip Down Method; no solution is handled. Only at time treatments does the applicator worker require PPE.
- REI: Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets have zero hour Restricted Entry Interval (REI).
- Crops can be leveled: secondary spray application of the rooting solutions to planted crops can level crops.

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