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Foliar methods: Do's and Don'ts

Propagate plants from cuttings using foliar applied aqueous IBA rooting solutions.

Foliar methods: historical background

Foliar applied rooting solutions for plant propagation from cuttings: historical background and utility

History and methods to apply rooting solutions by basal and foliar methods

by Joel Kroin, Hortus USA Corp.

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Auxin application via foliar sprays

How Bailey Nurseries developed their program to foliar apply rooting solutions when propagating plants from cuttings

by Samuel Drahn, Bailey Nurseries

Label

Hortus IBA Water Soluble Salts

Propagate plants from cuttings using aqueous IBA rooting solutions by foliar and basal methods:

Basal	QUICK DIP
	LONG SOAK
Foliar	SPRAY DRIP DOWN
	TOTAL IMMERSE

Propagate plants from cuttings using foliar applied aqueous (*water based*) IBA Rooting Solutions. Tips: do's and don'ts

Today growers worldwide successfully propagate plants from cuttings using foliar applied aqueous (*water based*) IBA rooting solutions. They use the Spray Drip Down and Total Immerse Methods. Leafy cuttings are taken from annual, perennial, and woody plants in the growing season. Compared with other propagation methods, foliar application has significant labor and material cost savings. Cuttings are treated in bulk at low rates.

Basal methods are still very important when propagating plants from cuttings. Quick Dip especially, has a long successful use and should be considered along side foliar methods as appropriate for needs.

Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablet IBA Rooting Solutions are used for all basal and foliar methods.

A Brief History of Foliar Applied IBA Rooting Solutions

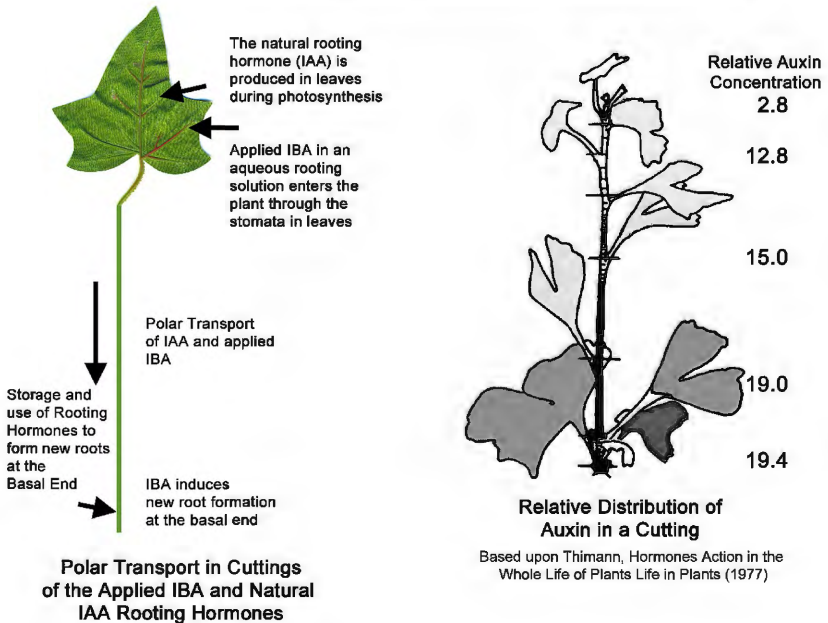
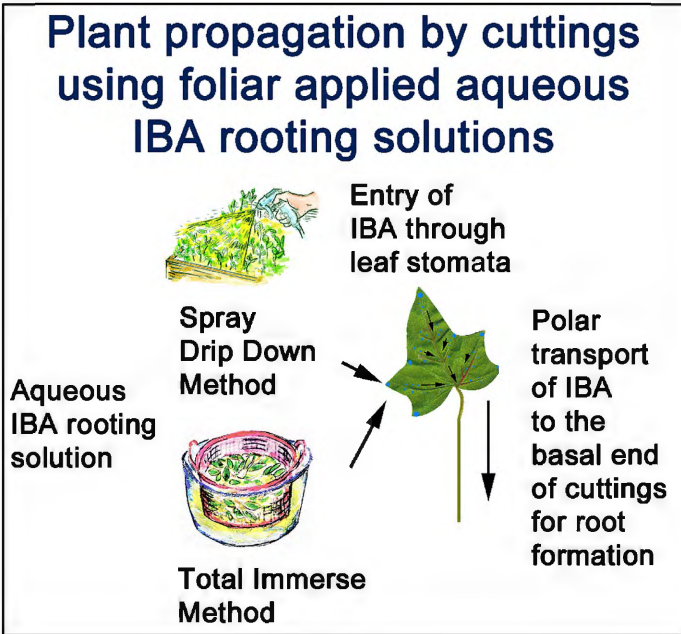
More than twenty-five years ago growers who wanted to propagate plants from cuttings by using rooting hormones were limited to basal application. Scientists had known plants produce growth substances (rooting hormones) in leaves. Charles Darwin, in his book 'The Power of Movement in Plants' (1880), described his study of the production and flow of these substances from the leaves to the lower portions of the plant. Scientists later identified the substances produced by plants. Commercial rooting hormones became available. As scientists and growers advanced procedures to propagate plants from cuttings they only focused on basal application of rooting hormones. They did not consider that foliar application of rooting hormones would naturally translocate to the basal end of cuttings where it can induce root formation.

Dr. Frederick Davies did histological and physiological studies on the foliar application of aqueous IBA rooting solutions (1978). IBA is a well used root promoting substance. The studies were concurrent with his propagation work comparing root formation in juvenile and mature cuttings.

In 1985 Kees Eigenraam, the technical advisor at Rhizopon, introduced to Dutch growers the foliar application of IBA rooting solutions to propagate plants from cuttings. At the time, Kees did not know the research by Dr. Davies. Kees and Joel Kroin began to formalize the foliar techniques later named **the Spray Drip Down** and **Total Immerse Methods**. By the early 1990's they introduced these techniques to US growers. Initially growers of **annual plants** adopted

the methods. Soon after, growers at Yoder (now Aris) Green Leaf Plants and Keepsake Plants began using the Spray Drip Down Method on their many **perennial plant** varieties. They also developed a foliar program on their Yoder brand chrysanthemums.

After 2000, Sam Drahn's studies at Bailey Nurseries led to their extensive use of the Spray Drip Down Method on **woody ornamental plant** cuttings.



Methods to Propagate Plants from Cuttings

Currently five methods are used to propagate plants from cuttings. No one method is best for all plant varieties under all situations. Use the optimum foliar and/or basal methods as needed for the plants and operation of the facility.

Basal Methods

Three methods are used to apply rooting hormones to the basal end of cuttings. The methods are used all year depending upon the condition of the cuttings.

Using dry powder rooting hormones ready for use:

- **Basal Dry Dip Method**

Using rooting solutions:

- **Basal Quick Dip Method**
- **Basal Long Soak Method**

Foliar Methods

Two methods are used to apply rooting solutions to the leaves of cuttings. The methods are used on leafy cuttings taken from during the growing season. They are not used on leafless or dormant cuttings.

Using aqueous (water based) IBA rooting solutions:

- **Spray Drip Down Method**
- **Total Immerse Method**

How Does Foliar Application Work?

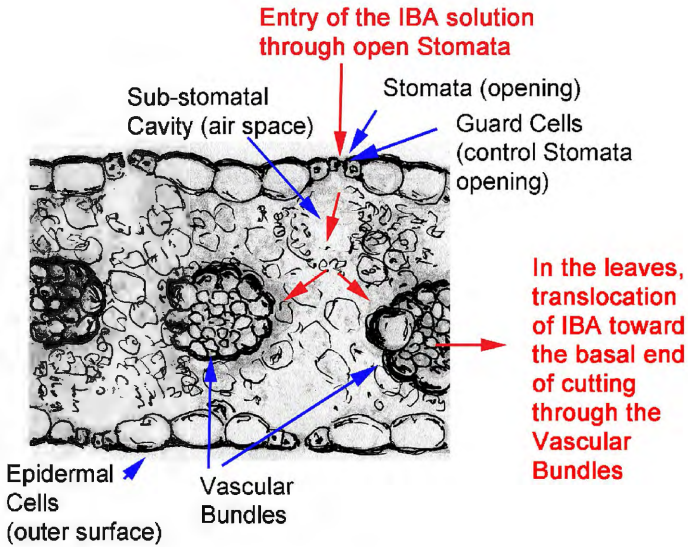
- Leafy cuttings are taken from stock plants in the growing season. Leafless or dormant cuttings are not used.
- The leaves of plant cuttings are treated with aqueous (water based) IBA solutions. IBA can enter the vascular system through open pores in the stomata. Stomata are open in a temperature range from about 60-90°F (15-33°C) and when cuttings are well hydrated before treatment.
- The IBA translocates through the plant's vascular system, by polar (one way) transport, to the basal end of the cuttings.
- At the basal end the IBA induces root formation.

We can look at the IBA flow like a "Ferryboat Carrier Model", a traditional model of biological transport:

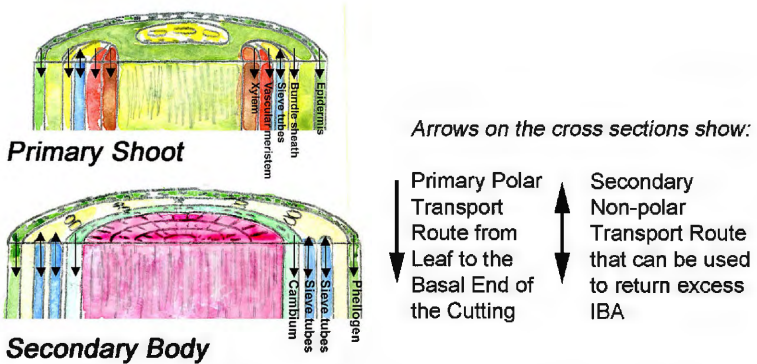
Ferryboats pickup an ever increasing number of passengers on the departure side. They are transported across the river to a small arrival loading dock. The loading dock fills to capacity, then, some passengers are thrown into the river.

A large amount of IBA is applied to the leaves where it enters the plant's system. IBA is polar transported through in the phloem to the basal end where it accumulates. The needed amount of IBA at the basal end initiates new roots. Excess IBA is returned, in the non-polar route, to

the leaves. Returned IBA may cause tender leaves to show some deformities. When return flow stops, new leaves will form normally. Quality roots will form as expected.



**Leaf Cross Section:
Entry of IBA through open Stomata
and Translocation toward the Basal End**



**Free IBA Transport from Leaves to the
Basal End of cuttings through the
Primary Shoots and Secondary Bodies**

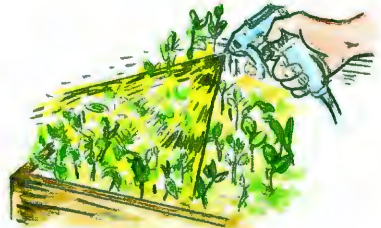
Foliar Methods

Foliar methods are simple.

- Apply aqueous (water based) IBA rooting solutions to leafy cuttings taken in the growing season.
- Labor saving: cuttings are processed in bulk.
- Low rates: low material cost.

Spray Drip Down™ Method

- Stick the cuttings into media.
- Use the selected sprayer.
- **Spray the solution onto the leaves of the cuttings until there is a drip down.**
- Excess application is best.
- The solution gets sucked by capillary action into the plant's subsystem. Wait about 3/4 hour or until the solution dries on the leaves, then turn on misters.



Some benefits:

- No PPE is required for sticking untreated cuttings.
- The Spray Drip Down Method can be used on many small production lots at one time.
- The solutions are used one time. There can be no cross contamination between production lots due to biological matter being dragged into the solution.



Total Immerse Method

- Use a tub and strainer basket.
- **Dip the cuttings in the solution until the leaves are completely covered with liquid, about five seconds.**
- Drain.
- Stick the cuttings into media.



Some benefits:

- Simple equipment is used.
- The Total Immerse Method can be used for large homogeneous plant lots that are clean and free of diseases.
- The method requires little setup. It can be used on small lots.
- Can be used to treat large leaves that may be difficult to spray uniformly.

Rooting Solutions for Foliar Methods

Foliar methods use aqueous (water based) IBA solutions.

- Water is the natural fluid in plants that is used to translocate natural rooting substances.

The US EPA requires registration of IBA rooting products. There are only two registered products used to make water-based IBA rooting solutions and labeled for foliar application. These products are:

Hortus IBA Water Soluble Salts

- WEIGH THE SALTS
- Mix into water



Rhizopon AA Water Soluble Tablets

- COUNT TABLETS
- Mix into water



Only Use Water Based IBA Solutions

Do NOT use alcohol base IBA rooting solutions when using foliar application. Alcohol dehydrates plant tissue and causes cutting fatality called 'Alcohol burns'.

Dry powder rooting hormone products, like Rhizopon AA #1, #2 and #3, are not used by foliar application. These products are **INSOLUBLE** in water.

Make Concentrate Rooting Solutions

It is sometimes easier to measure and mix solutions rather than dry measure the Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets for many production tanks. In those cases make up a solution concentrate at the required number of grams or tablets, then, decant the solution into the production tank. Add water to bring the tank to the required volume. Warm water helps to dissolve the Salts and Tablets.

Foliar Rates

- **Annual Cuttings**

Annual cuttings require low rates. Some tender plant varieties and juvenile cuttings are treated at rates 80-100 ppm IBA. If rates are slightly too high there may be some leaf distortion; the roots may form well and new leaves will be normal. Leaf distortion may not be evident on mature cuttings.

- **Perennial and Woody Ornamental Plant Cuttings**

Perennial and woody plant cuttings have a similar range of 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 juvenile tender perennial cuttings.

- **Tissue Culture Plantlets**

Use the Total Immerse Method on tissue culture plantlets when transplanting at the third to fifth stages.

- Blueberry example: use two Rhizopon AA Water Soluble Tablets per liter water. Other typical rates are 1-3 Tablets/liter water.

Trial Foliar Application Rates			
using Hortus IBA Water Soluble Salts & Rhizopon AA Water Soluble Tablets			
Cutting Type	Hortus IBA Water Soluble Salts (as ppm IBA)	Initial Trial Rates ▼	Rhizopon AA Water Soluble Tablets (tablets per liter water)
Annuals and tender Perennials	50-250 ppm IBA	125 ppm IBA	1-5 tablet/liter
Perennials	250-1500 ppm IBA	1000 ppm IBA	5-30 tablets/liter
Woody Ornamental	300-1500 ppm IBA		6-30 tablets/liter
TC plantlets at 3rd to 5th stage transplants			1-3 tablets/liter

- Juvenile cuttings require lower rates than mature cuttings.
- **Do not use the same rates for foliar application as used by the Basal Quick Dip Method, they are usually too high.**

Use the Proper Equipment

Spray Drip Down™ Method

Use appropriate equipment for the job for labor saving and effectiveness.

Typical sprayers: hand back pack, hydraulic, site specific sprayer, and automated robots.



Typical Backpack Sprayer

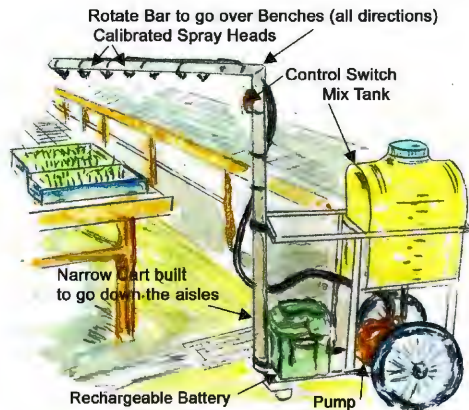


Hydraulic Sprayer
Spray Drip Down Method
(Bailey Nurseries)



Robotic Sprayer
Spray Drip Down Method
on Chrysanthemum (Holland)

This sketch shows a custom spray cart used at Aris Green Leaf Plants in Lancaster PA.



Total Immerse Method

Use a basket for dipping into the solution tank.

- Do not overload the baskets to avoid cutting breakage.
- Do not use a basket or tank made from materials that can corrode.

The top photo shows a large hedera (ivy) greenhouse in the Netherlands. Workers in the back do sticking after Total Immerse treatment in the tank shown.



The bottom photo shows Total Immerse treatment of blueberry Tissue Culture plantlets. Few cuttings are in the basket to prevent damage.



The Cuttings

Cutting Types

- For foliar methods, use leafy cuttings in the growing season; do not take dormant or leafless cuttings. For those cuttings use the basal Dry Dip, Basal Long Soak, or Basal Quick Dip Methods.
- Cutting Maturity
 - Do not use hard woody or old mature cuttings.
 - **Juvenile cuttings** are easier to propagate from cuttings compared to those which are mature. When possible, take cuttings from cuttings. Juvenile cuttings require lower IBA rooting solution rates than mature cuttings.
- Bad cuttings cannot be revived.

FOR ALL PROPAGATION METHODS

Cutting Nodes

- Use cuttings that do not have nodes or buds at the basal end.

Do Not Cut Leaf Tips

In old-school for propagation by other methods, some growers cut the tips of large leaf cuttings to obtain more cuttings in a propagation tray.

There are reasons NOT to cut the tips:

- The cut causes a wound that is open to infection.
- The cuttings have reduced natural rooting substance IAA formed at a usual place, the tips of leaves. The natural IAA works with the applied IBA to induce roots. With the tips cut, there is less IAA available.
- With a wound present, the cuttings use valuable resources to heal, rather than induce root formation.
- Growing compact stock plants allow taking cuttings from an earlier stage where the preferred leaves are smaller.



Not acceptable
bud or node

Acceptable with
no bud or node



Use cuttings without
cutting tips

Importance of the Stomata

Stomata are located on outside surfaces of plants. When stomata pores open they allow fluid, vapor and gas exchanges between the plant and it's environment. Stomata on some plant varieties are more numerous, larger, and on the underside of leaves. In some varieties there are more stomata on the underside.

- Stomata
 - **open** when cuttings are well hydrated.
 - **open** when temperatures and other factors are suitable for translocation of fluids and air.
 - **close** when cuttings are wilted.
 - **close** when protecting the plant from exchanges under harsh environmental conditions.
 - **close** in the dark and open in the light.



Typical winter leaf curl on Rhododendron

Sometimes identifying the primary stomata side is easy. Leaf curl means the plant is under stress leading to closed stomata interior to the curl. *The photo shows leaf curl due to bottom closed stomata, protecting against harsh winter environment.*

Foliar Method considerations:

- The Total Immerse Method gets the IBA solution on both sides of leaves.
- Spray Drip Down Method should be used to spray leaves both top and bottom.
- Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets solutions are made to have free IBA entry into the plant's vascular system.

Coverage by the Spray Drip Down Method

The person doing spraying must see the solution drip down from the leaves. This is a visual indicator that an adequate amount of solution has been applied. The top and bottom of cuttings should be treated.

Foliar Spray Solution Utilization

Using the Spray Drip Down Method, the amount of solution needed to cover an area varies. Typical solution use is about 200 sf/gallon (10 sq meter/liter).

Total Immerse Method Timing

Using the Total Immerse Method dip cuttings in the solution until the leaves are completely covered with liquid, about five seconds.

Foliar Spray Drip Down™ Method for Multiple Applications and Transplanting

When plant cuttings utilize applied rooting solutions and rooting hormone powders, some cuttings apparently need a steady flow of the IBA. If one time application is inadequate, daily **sequential Spray Drip Down Method** solution application induces root cell division during time based cell activity.

Where cuttings are known slow-to-root or have low percentage rooting, sequential Spray Drip Down Method may be an option. Then, where high IBA rates had been used unsuccessfully, lower sequential IBA rates may result in better rooting performance. Using the Spray Drip Down Method on transplants gives an extra boost for root cell regeneration.

The trial rates listed previously in this article use the Spray Drip Down Method using solutions made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets.

Sequential Three Day Treatment

After sticking, many growers increase root formation and root mass when applying the rooting solution by the Spray Drip Down Method, in a three day sequence, at the same initial rate.

Leveling Crops

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.

Annual cuttings

Trial Range

100-150 ppm IBA

Improving Rooting of 'Slow-to-Root' Cuttings

Secondary Spray Drip Down Method foliar applications can be used on slow to root cuttings in the active growing state using the same initial rate. For cuttings first treated by another rooting method use the Spray Drip Down rate recommendations.

Spray Time of the Day

Sometimes spray is done early the morning following the day of sticking. Where ambient temperatures are high, early morning treatment at cool temperatures has benefit; leaf stomata are open.

Treatment of Transplants and Divisions

When rooted cuttings and plant divisions are transplanted they require stimulation to regenerate and make new root cells. Use the Spray Drip Down Method on planted cuttings and divisions.

	<i>Trial Ranges</i>
Grass divisions & annual rooted cuttings:	100-150 ppm IBA
Perennial rooted cuttings:	750-1000 ppm IBA
Woody ornamental rooted cuttings:	750-1000 ppm IBA

Labor Saving

Growers find foliar methods require less labor than basal methods.

- It is faster to stick cuttings when they are batch treated as compared with individual basal treatment.

Hybrid Propagation Systems and Solution Product Inventory

- Many growers use a hybrid system of both basal and foliar applications in the same facility. By season, foliar methods may be used with some crops, dry powder rooting hormones or basal quick dip for others.
- When using aqueous IBA rooting solutions you can use the same product for both basal and foliar application solution needs. There is no need to stock more than one product.

Foliar Application Temperature

- For foliar methods do not apply when the cuttings and solutions are at low or high ambient temperatures. Use foliar application when the temperature of both the solution and cuttings are at about 60-90°F (15-33°C).

Sticking and Treatment Timing

- Apply by the Spray Drip Down Method within the day of sticking.
- For cuttings kept in a hot climate, such as southern Florida, cuttings are stuck during the day and treated early the following morning.

Cutting Hydration and Misting

Well hydrate cuttings before foliar treatment:

- Hydrate cuttings before treating to assure the stomata are open. This will allow the IBA solution to enter the vascular system.
- Wilted cuttings have closed stomata. The cuttings must be fully hydrated before treatment.

Well hydrate cuttings after foliar treatment:

- When using the Total Immerse Method, misters can be turned on any time after sticking. There is always a lag time between treatment and sticking.
- When using the Spray Drip Down Method, wait to turn on misters about 3/4 hour or until the solution dries on the leaves.
- Some growers of chrysanthemum find they get better rooting when they let the cuttings lose turgor before turning on misters.

Use Appropriate PPE

- Use the most effective PPE that complies with the product label. Unless otherwise specified, thin waterproof gloves are adequate for handling aqueous (water based) IBA rooting solutions.
- No chemicals are handled by sticking personal when using the Spray Drip Down Method, therefore no gloves or other PPE are needed. Thin gloves may be used solely for sanitary purposes.

Rooting Solution Disposal

See page 17 of this book

No Wetting Agents

- Using foliar methods there is no need to use wetting agents in solutions made with Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets.

Overcoming Problems

Trials are Essential

- **Always do trials on small lots before doing production.** Evaluate a range of rates and methods.

Typical Deformities on Tender Plant Cuttings

Leaf curl and spotting are sometimes due to too high an IBA rate, but reversible.

- When IBA is applied to the leaves of cuttings, it is absorbed into the vascular system then translocated to the basal end by polar transport. At the basal end the IBA is accumulated. If there is an IBA excess, it will move back to the leaves causing leaf deformities such curl or spotting.
- Despite initial leaf irregularities, the cuttings will usually form normal roots and normal new leaves.



Leaf Curl



Leaf Spotting

Consider Plant Variations

For any successful method of propagation there sometimes may be unexpected results. “The” method or rate may be considered the culprit even though there was not knowingly change to the rate, method, timing, product, or other factors.

A common problem when using foliar application of rooting solutions is selection of juvenile vs mature cuttings. With excessive rates, juvenile cutting may exhibit distortions in leaves. Juvenile cuttings require lower rates than mature cuttings.

Some of many things to consider:

- Genetic variations of the cuttings: different stock plants.
- Quality of the cuttings.
- Deviations in the growing area such as changes in the environmental control systems and facility.
- Cuttings taken from a different part of the stock area, location, or plantation.
- Timing of taking cuttings from previous.
- Seasonal variations from the norm.

Conclusions

Foliar applied rooting solutions by the Spray Drip Down and Total Immerse Methods are useful for propagating plants from leafy cuttings in the growing season. Opposite to foliar application, there are times when basal applied rooting powders and rooting solutions are more useful.

Consider:

- The plants being propagated.
- The time of the year that propagation is being done.
- The quality of roots produced on the cuttings.
- The facility advantages and setup cost.
- Labor factors including time saved or lost in the process and training.
- Material cost.
- Always do trials on small lots before doing production.
- Evaluate a range of rates and methods.
- Try different methods on a variety of plants when propagating from cuttings. All the methods have proven useful under appropriate conditions: the basal Quick Dip, Basal Long Soak, Dry Dip Methods, and the foliar Spray Drip Down and Total Immerse Methods.
- Consider a hybrid system. To produce an optimum crop it may be beneficial to use several methods concurrently. Basal methods may be used on a crop at one time of the year and foliar methods at another time.

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

Joel Kroin, Hortus USA Corp., support@hortus.com, rootinghormones.com

INTRODUCTION

The propagation of plants from cuttings using foliar methods is easy:

- Take leafy cuttings in the growing state.
- Apply aqueous (water based) IBA rooting solutions to the leaves by spray or total immerse dip.
- 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 aqueous IBA 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 an IBA in aqueous rooting 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.

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 based dry powders (rooting hormone powders), auxin solutions, (rooting solutions), or auxin containing lanolin pastes to the basal end of cuttings. Positive root formation was observed.

Believed to be the first studies, foliar applied auxin solutions 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) first produced commercial auxins under their Rhizopon division (1940). Rhizopon manufactures commercial plant rooting products, both dry dip powders and water soluble tablets to make rooting solutions. To improve use of the rooting solution products, the Rhizopon scientist 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. These growers found, foliar application reduced labor and improved the root formation of cuttings.

Joel Kroin, of Hortus USA, first met 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 said 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, Kroin and Eigenraam improved and documented foliar 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 aqueous (water based) IBA rooting solutions. Among the first US foliar method users were the Yoder chrysanthemum propagators in Florida. Soon after, Yoder established their perennial propagation facility, now called Aris 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, foliar methods save labor. Cuttings are treated in bulk rather than individually. Low rooting 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 rooting solution needs of plant propagators.

Soon after, 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, the rates for woody ornamental plant cuttings are 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 perennial and woody ornamental plants require the same rates; the midpoint trial rate is about 1000 ppm IBA using Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. (Drahn's article on his research is in this book.)

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

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 previously described, 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 with IAA, IBA has greater ability to initiate roots. Various studies suggest IBA may be a very simple 'conjugate' of IAA and must be converted to IAA by β -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 rooting solution into the plant is through 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 gases, 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 that can absorb fluids such as aqueous (water based) IBA solutions. Rooting 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 rooting 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 were not too high, the cuttings will still produce proper rooting and growth. Lowest possible IBA rates avoid such phytotoxicity.

METHODS

Three basal and two foliar 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 Dip 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 rooting solution for several hours then stuck. The Quick Dip Method uses rooting solutions. Basal ends of the cuttings are dipped into the rooting solution for a few seconds then stuck.

Two foliar methods, the Spray Drip Down and Total Immerse Methods have been in use as described previously. Cuttings of actively growing or dormant annuals, perennials, and woody plants are 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. Drop formation on the top and bottom of the leaves is preferred. The Total Immerse Method has cuttings totally immersed in the rooting solution for a few seconds then stuck. Rates for the two Methods are similar.

Compared with 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 indirect 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 AND LINER PROPAGATORS 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. Total Immerse is extensively used on crops such as many perennials, and other plants such as phlox, dianthus, and heder (ivy). The Total Immerse Method is also used on tissue culture plantlets when transplanting in the greenhouse stage.

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 can be used. To avoid cross contamination between production lots, cuttings must be 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. Disposing of the rooting solution between dissimilar cutting lots is best. When homogeneous lots are treated, the rooting 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. 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 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 3/4 hour or until the rooting solution dries on the leaves. Typical application

uses about 10 m²/ liter (190-220 ft²/gallon). Various types of sprayers are used such as backpack, hydraulic, boom, or custom made. The rooting solution is used one time. Since the unused rooting solution is kept in the sprayer tank, there is no possible rooting 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 large quantities of Rhizopon AA Water Soluble Tablets. Or, 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. Warm water, at hand washing temperature, makes dissolving easier than when using cold water. For ease of handling, concentrate Hortus IBA Water Soluble Salts aqueous IBA rooting solutions can be made to over 80,000 ppm IBA. 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 (See page 30-38)

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 is 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. Mature cutting 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 one to three tablets/liter solution. As a guideline for TC rate selection, the rate for cultivated highbush blueberry TC transplants is about two Rhizopon AA Water Soluble Tablets/liter solutions (One tablet/liter solution was shown inadequate and three tablets/liter solution formed callus mis-formation.)

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 rooting 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. For root formation, juvenile cutting require lower Rooting Solution rates than for mature cutting. To maintain juvenality, 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) showed 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.

Many growers have found root formation increase when, after sticking, using three day sequential Spray Drip Down Method at the same rate each day. Perennial and woody ornamental develop improved roots when treated at about 750-1000 ppm IBA using Hortus IBA Water Soluble Salts solutions.

PERSONAL PROTECTIVE EQUIPMENT.

(Reference the product label for specific PPE)

When using the Spray Drip Down Method, treatment workers doing spraying must use appropriate PPE. It is best 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 rooting 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 3/4 hour or until the rooting 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.

To level crops, secondary weekly Spray Drip Down Method foliar applications are used on leafy cuttings in the active growing state, at rates similar to the first initial rate. First application may be any method.

For sequential day application, in this book see the article "Propagate Plants from Cuttings Using Foliar Applied Aqueous IBA Rooting Solutions. Tips: Do's and Don'ts", section "Sequential Treatment".

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. At the same or other times in the same facility, the Dry Dip Method (using dip rooting hormones) are used on some varieties; the Spray Drip Down Method (using rooting solutions) are used on other varieties.

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 the high rate basal Quick Dip Method.
- 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: there are no misses. Spray Drip Down Meth treatment is done by skilled workers. Total Immerse Method is done in bulk.
- 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 rooting solution is handled.
- 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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