



Propagation of Plants from Cuttings Using Foliar Applied IBA in Aqueous Solutions at or after Sticking

When propagating plants from cuttings, plant hormones called auxins, can be applied to induce root formation. The auxin most used in plant propagation is Indole butyric acid (IBA). Basal application of auxins, done all year, has been done at the time of sticking using dry powders or solutions. Foliar application of auxin in aqueous solutions has been done in the growing season on leafy plant cuttings either before or after sticking. The applied auxin enters the plant's vascular system through open stomata. The auxin solutions travel with the natural auxin IAA, by polar transport, to the basal end of cuttings where they can induce root formation.

The present study is to find out if there is a difference in root numbers on cuttings of the annual plant *Begonia diera* ('red wing'), if an IBA in aqueous solution is foliar applied at time of sticking or several days later. Commercially, Yoder Green Leaf Plants, on perennials, and Bailey Nurseries, on woody ornamentals, both recommend an IBA in aqueous solution foliar treatment within the day after sticking. Using foliar applied IBA in aqueous solutions on the woody plant *Ficus pumila* (creeping Ficus) by Dr. Fred T. Davies, all treated cuttings, both mature and juvenile, had higher root numbers than un-treated cuttings.

The current study found IBA in aqueous solution foliar treatment to be effective on annual cuttings. Application can be done at time of sticking and up to several days after sticking. Higher root numbers occurred on cuttings when treatment was near the time of sticking. Root numbers diminished when treatment was done on later days.

Foliar Applied Rooting Hormones to Induce Root Formation on Cuttings

Since the late 1800's, scientists including Charles Darwin, believed substances produced in the leaves of the plants regulated other parts of the plant (Darwin 1880). "*In 1893 (Julius) Sachs' suggestion was that special stimulating and constructive substances are formed in the metabolic processes in leaves.*" (Reynolds-Green 1909). In 1934 Thimann and Went identified this substance as Indole acetic acid (IAA). Produced in the leaves during growth, they called it an 'auxin' or 'plant hormone'. They also identified the bio-simulators of IAA, Indole butyric acid (IBA) and Nathalene acetic acid (NAA), more stable then IAA yet producing similar effects. In their book, 'Phytohormones', they define "*a hormone is a substance which, being produced in any one part of the organism, is transferred to another part and thereby influences physiological responses.*" They found application of auxin to the leaves of plants had a positive effect on basal root formation. They also identified the route the auxin, from leaves to the basal end of cuttings, as polar (one way) transport. (Thimann 1937).

Auxins in aqueous solution can be applied to the foliage of plants in the growing season. They can enter through open stomata where the leaves capture the solutions under the stomata's guard cells in air spaces. After, they are polar transported to the basal end. (Sargent 1965, Franke 1967). At the basal end the auxins are stored then regulated by the plant to stimulate root initiation (Thimann 1937) (Epstein & Ludwig-Muller 1993).

Dr. Fred T. Davies foliar applied IBA in aqueous solutions in his rooting trials on cuttings of the woody plant *Ficus pumila*. In one of his trials, application was one time at the time of sticking.

Foliar treated cuttings all had higher root numbers compared to untreated control cuttings. Cuttings treated at the time of sticking had the highest numbers. Juvenile cuttings had higher root numbers than mature cuttings. (Davies 1980, 1982, 1984).

In Holland, Kees Eigenraam, the Senior Researcher of Rhizopon, in 1985 found that foliar applied IBA in aqueous solution improved root formation on chrysanthemum cuttings. Working with the growers at the Dutch company Lyraflor, their greenhouses began using robotic sprayers to apply IBA in aqueous solutions to cuttings soon after sticking (Eigenraam 2010).

In 1994, Kees Eigenraam and I visited the Yoder Brothers chrysanthemum propagation facilities in Florida, introducing foliar applied IBA in aqueous solution. Since they had large homogenous plant lots, we suggested that they use the Total Immerse Method. By 1996, Yoder Green Leaf Plants greenhouses in Pennsylvania began using foliar application on perennials. They have small production lots; the Spray Drip Down Method was more suitable since they did not want to have cross-contamination between lots. They recommend: *“apply hormone within 24 hours of stick for best results.”* (Green Leaf 2010). After 2002, Bailey Nurseries began using foliar applied IBA in aqueous solution on their woody ornamental plant cuttings. *“Our results have shown when making these applications within 24 h of sticking is critical for our success.”* (Drahn 2007). Dr. Davis said *“We would typically apply at dusk at Gainesville, Florida, with the mist turned off for the evening.”* (Davies, corresp.).

Kees Eigenraam and I have refined two methods to foliar apply auxin in aqueous solutions to leafy cuttings in the growing season. We call these the Spray Drip Down and Total Immerse Methods. Rates of application are similar. Application is to be done when the temperature permits stomata to be open. If application is made in cold or hot temperature the stomata would be closed and will not accept the solution. When day temperatures are high then treatment is done early, on cool mornings. Some plants, such as clematis have their stomata on the bottom of leaves. To assure adequate treatment we found it is best to spray the solution on both sides of the leaves or use the Total Immerse Method.

Spray Drip Down Method

The Spray Drip Down Method is used after sticking. The solution is used one time resulting in no cross contamination between plant lots. The solution is kept in a tank that does not have cuttings dipped in. Foliar treatments can be made one time or many times on the same lot. Secondary application can be done on cuttings that had a primary treatment by any other basal or foliar method such as quick dip, basal long soak, or dry dip.

- Stick the cuttings.
- Spray leaves of cutting with the solution until drip down.
- After treatment, they can resume misting within 30-45 minutes.

Total Immerse Method

The Total Immerse Method is used one time on cuttings before sticking. The cuttings are dipped in a production tank where multiple lots can be processed. It is suitable where cuttings come from a homogenous lot where cross contamination of a used solution is not a problem. The method is useful when getting good coverage of leaves by spray is difficult, such as treating large leaves.

- Totally immerse the cuttings in the solution for about five seconds then drain.
- Stick the cuttings.
- After treatment, misting can be resumed within 30-45 minutes.

Plants can be divided into three relative foliar rate groups:

annual like plant cuttings	@80-250 ppm IBA
perennial like plant cuttings	@250-1500 ppm IBA
woody ornamental like plant cuttings	@500-1500 ppm IBA

Growers have asked me if a surfactant (wetting agent) should or could be used with foliar applied solutions made with Hortus IBA Water Soluble Salts. I have never heard of any commercial growers that have added them. In Dr. Davies' studies he added a surfactant to his solutions. It could be the Hortus IBA Water Soluble Salts solution does not need a surfactant due to the composition of the Salts. I plan to do a study find out if surface tension of IBA aqueous solutions is a critical factor in root formation. I want to find out if droplets have a low enough surface tension to enter open stomata.

Present study

The present study was conducted on cuttings of the annual plant *Begonia diera*. IBA in aqueous solutions was foliar applied by the Spray Drip Down Method. The study was to find out differences in root number formed between un-treated and one treatment at time of sticking, at the third, fifth or seventh day after sticking.

Methods and materials:

Annual plant *Begonia diera* (*B. ludicra*) "red wing" cuttings were used. All cuttings were taken from one mother plant kept in bright daylight for several days. Stem cuttings had 3-5 full leaves. The media was 50% perlite: 50% peat. Treatment was by the Spray Drip Down Method. The solution was 200 ppm IBA in aqueous solution using Hortus IBA Water Soluble Salts (1.0 gm Salts per liter water). Fifteen cuttings were in each of five blocks: un-treated control cuttings, treated after one hour after sticking, or at three, five or seven days after sticking. Application was made at 80F to assure the stomata were open to accept the solution. Cuttings were kept in a propagation tunnel at close to 100% humidity for the trial period. Bright sunlight was supplemented with artificial light for sixteen hours.

After 24 days (TABLE 1)

- Compared with the un-treated control cuttings, all cuttings treated with foliar applied IBA in aqueous solution had higher root numbers.
- Cuttings treated one hour after sticking had the best side root formation.
- Both the un-treated control cuttings and those treated one hour after sticking had new leaf shoot formation; un-treated controls had more shoots than those treated after sticking.
- Cuttings treated at 3, 5, or 7 days had some leaf loss and no new leaf shoot formation.
- The numbers of rooted cuttings in blocks varied from 92 to 95% (not statistically significant).

Basic findings:

The present study found, auxins applied to leaves translocated to the basal end at the expense of leaf formation. The un-treated control cuttings had more leaf shoot formation compared with cuttings treated within an hour. For the un-treated control cuttings this was at the expense of root formation. The study found an advantage to treat within the first hour after sticking and perhaps within the same day. (TABLE 1)

Discussion

Rate determination

Begonia's require very low foliar rates, usually 80-200 ppm IBA. A high a rate on tender annual cuttings may cause leaf curl or leaf spotting where the liquid touches the leaves. Despite these problems, the cuttings develop a good root system with new normal leaves. I have observed the new leaf growth to be normal and the cuttings develop a strong rooting system. The *Ficus pumila* in Dr. Davies' trials used a high rate, 1000 ppm IBA for juvenile and 3000 ppm for mature cuttings. For this specific variety Davies said: "Optimum concentrations for the juvenile and mature *Ficus* were, respectively, 1000-1500, and 2000-3000 ppm K-IBA" (Davies, corresp.). Other *Ficus* family plants require other rates. In our trials on *Ficus benjamina*, found 500 ppm IBA to be suitable. I had never heard of other plants that had useful rates higher than 1500 ppm IBA.

Rooting Quality

The present study, on annual Begonia's, showed the best root quality are on cuttings treated soon after foliar treatment. The Davies' studies had similar results.

Effects of High Rate

Occasionally I have seen cuttings, such as acers and rhododendrons, that have received too high a foliar treatment rate. Woody plant cuttings may accumulate the auxin at the basal end. The auxins, having no place to go but accumulate at the basal end. This may cause heavier than normal callus formation, and may inhibit root initiation. Growers made the problem more severe when they made a second or third application at the same high rate.

Third Day Observations

I can't identify why in all the trials there was a slight decrease in root number formation on cuttings treated on the third day after sticking. These cuttings still had more root numbers than the un-treated controls. The root numbers increased on fifth day treated cuttings. I had seen this effect in prior trials using cuttings from the same Begonia *diera* mother plant and on *Ficus benjamina*. My initial response was that there were problems with the experiments on the third day. Apparently the trials were accurate.

Secondary Treatment

In another study, Dr. Davies did two foliar applications on *Ficus pumila*. All treated cuttings were given a treatment at time of sticking. The second application was given on one of several days. The two rates were the same. Juvenile cuttings had more root formation when treated on the third day, for mature cuttings on the ninth day. His study suggests a first application at the time of sticking with a second application a few days later give improved root numbers and quality (Davies 1980).

Kees Eigenraam did research at Dutch commercial growers of herbaceous plants. He found using a foliar application of rooting solution at the time of sticking, then a second application a week or so later, gave improved root formation. For the grower, the crop is leveled; it may reduce the need for grading (Eigenraam corresp.).

Juvenility

Juvenile cuttings appear to benefit most from foliar application. Dr. Davies found juvenile cuttings of *Ficus pumila* had higher root numbers than mature cuttings. Growers like Yoder, in commercial propagation of perennials and crops like chrysanthemums, regenerate their stock plants, by taking cuttings from cuttings to make new stock plants. These juvenile cuttings root well when using foliar applied IBA in aqueous solutions.

Timing

Commercial growers must plan their production day to take into account the time of sticking and the time of treatment. The Total Immerse Method has treatment in line with sticking. The Spray Down Method can be done at time of sticking or at a later time. Yoder and Bailey say they have best results when then treat within the day after sticking. To accommodate scheduling, the present study and the Davies studies suggest that after sticking, treatment after a few days produces positive root formation. And, rooting numbers are best when treatment is made soon after sticking. I intend to do future studies narrowing the treatment to half days in the first five days after sticking. (TABLE 1, 2. GRAPH 1).

Discussing his *Ficus pumila* trials, Dr. Davies said: *“In terms of our aqueous applications of IBA on juvenile and mature Ficus pumila, the earlier we applied the auxin, the better the response.”* *“Auxins were applied at days 3, 5, 7 for the juvenile and days 3, 9, 15 for the mature since the process of adventitious root formation occurs more rapidly in the juvenile material.”* *“When we delayed applying IBA to the easier-to-root juvenile Ficus from days 3, 5 or 7, there was no significant difference in adventitious root formation, including root quality. When we delayed applying IBA to the more difficult-to-root mature Ficus from days 3, 9 to 15, there was no significant difference in adventitious root formation, including root quality at day 3 or 9, but there was a significant reduction in day 15.”* (Davies, corresp.).

Conclusion

Auxins, natural substances produced primarily in plant leaves, translocate to the basal part of cuttings to induce root formation. IBA, a bio-simulator of the natural auxin, when applied in an aqueous solution by foliar means can be used to propagate plants from leafy plant cuttings in the growing season. The applied auxin solution enters the leaf's stomata and translocates with the natural auxin to the basal end. The plant self regulates auxin use to produce new roots. Application can be done on annual, perennial and woody plant cuttings. One time application can be done by the Total Immerse Method. One time, or multiple time applications, can be done by the Spray Drip Down Method. Studies used IBA in aqueous solutions. Woody plant *Ficus* studies found, compared with un-treated control cuttings, juvenile cuttings develop the highest root numbers followed by mature cuttings. The present study on *Begonia*, an annual plant, compared un-treated control cuttings with foliar treated cuttings. The highest root numbers were on cuttings treated close to the time of sticking. Positive root numbers were on cuttings treated three, five and seven 7 days after sticking. Other studies, by Davies, on slower to root cuttings have shown positive root numbers when treated beyond seven days after sticking. Auxins accumulate at the basal end. Root formation is at the expense of leaf formation. Leaf growth resumes after root formation. Cuttings that are foliar treated with IBA in aqueous solution anytime in the trial period have higher root numbers than untreated control cuttings.

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Contacts for personal correspondence:

Fred T. Davies, Ph.D., CPH
Professor & TAES Faculty Fellow
Dept of Horticultural Sciences
Texas A&M University
College Station, Texas 77843-2133
Phone: 979-845-4524
fdavies@ag.tamu.edu

Kees Eigneraam
President
Rhizoapon bv
Postbus 336
2400 AH Alphen ann den Rijn
Holland
keeseigenraam@rhizoapon.com

TABLE 1

Present study: Number of roots formed on cuttings by day 24

Plant Variety: *Begonia diera* ('red wing')
 Treatment: The Spray Drip Down Method
 Solution: @200 ppm IBA in aqueous solution
 using Hortus IBA Water Soluble Salts 1.0 gm Salts/liter water).

	Number of Roots Formed (Averages)				Root Quality	Observation
	Avg. per cutting	Avg. at basal cut	Avg. at sides	Avg. at nodes		
Un-treated Control	▼ 18.9	12.3	4.1	2.5	Good	New leaf shoots.
Treat at 1 hour	▲ 27.2	3.9	19.7	3.6	Good	New leaf shoots.
Treat at 3 days	20.7	5.5	8.3	6.9	Poor	Original leaf loss. No new leaf shoots.
Treat at 5 days	22.0	12.4	2.9	6.7	Poor	Original leaf loss. No new leaf shoots.
Treat at 7 days	22.1	6.0	12.4	3.7	Poor	Original leaf loss. No new leaf shoots.

NOTE:

Begonias form new roots on various parts of the cutting. How counts were made for the "Average number of roots"

"Avg. at basal cut": roots formed at the cut line of the basal end

"Avg. at sides": roots formed on the stem between basal cut and nodes or between nodes

"Avg. at nodes": roots formed directly over a node

TABLE 2

Study Comparison: Timing of Foliar Auxin Sprays for Rooting of *Begonia diera* and *Ficus pumila* Cuttings.

Plant Variety: Present study *Begonia diera* ('red wing')

Davies studies: *Ficus pumila*

Treatment: The Spray Drip Down Method

Solution: ppm IBA in aqueous solution

	<i>Begonia diera</i>		<i>Ficus pumila</i> Study (Davies & Joiner, 1980)				
	@200 ppm IBA		Juvenile @1000 ppm IBA		Mature @3000 ppm IBA		
Day Treated	Avg. # of roots formed per cutting	Root Quality	Avg. # of roots formed per cutting	Root Quality	Day Treated	Avg. # of roots formed per cutting	Root Quality
Un-treated Control	▼ 18.9	Good	▼ 0.8	Poor	Un-treated Control	▼ 1.5	Poor
Treat at sticking	▲ 27.2	Good	▲ 11.9	Good	Treat at sticking	▲ 13.3	Good
Treat at 3 days	20.7	Poor	9.5	Good	Treat at 3 days	13.1	Good
Treat at 5 days	22.0	Poor	11.0	Good	Treat at 9 days	8.6	Good
Treat at 7 days	22.1	Poor	10.3	Good	Treat at 15 days	2.7	Poor (See Note 2 below)

▼ Lowest value in the column

▲ Highest value in the column

Root quality note:

1) For root quality, in this table I have given a subjective value.

Dr. Davies gives a numeric value where I have assigned: 1 = poor, 2 = fair, 3 = good

2) "application at day 15 was beyond the "optimum application window", and there was a deterioration of percentage rooting, root numbers, root length and root quality." (Davies corresp)

GRAPH 1

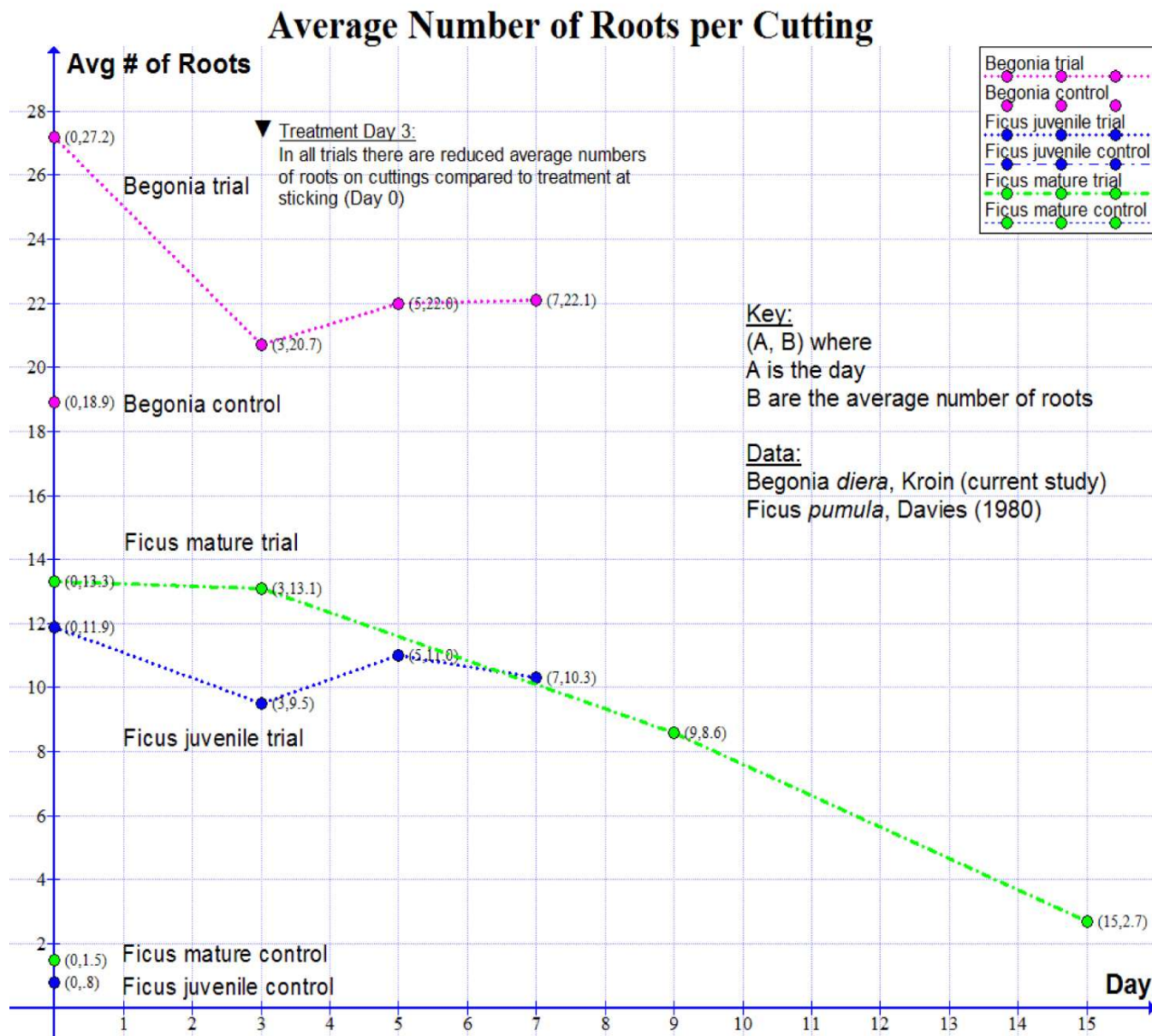
Study Comparison: Average Number of Roots per Cutting by Day of Application. Foliar Auxin Sprays for Rooting of *Begonia diera* and *Ficus pumila* Cuttings.

Plant variety: Present study *Begonia diera* ('red wing')

Davies studies: *Ficus pumila*

Treatment: The Spray Drip Down Method

Solution: ppm IBA in aqueous solution



Rooting of Plant Cuttings by Foliar Application of IBA by the Spray Drip Down Method
One Treatment made at time of sticking, after 3 days, 5 days, and 7 days



Control
 Avg # of roots/cutting rooted: 18.9
 Leaf formation: shoots



(a) Treat at 1 hr. after sticking
 Avg # of roots/cutting rooted: 27.2
 Leaf formation: shoots



(b) Treat at 3 days after sticking
 Avg # of roots/cutting rooted: 20.7
 Leaf formation: some leaf loss, no shoots



(c) Treat at 5 days after sticking
 Avg # of roots/cutting rooted: 22.0
 Leaf formation: some leaf loss, no shoots



(d) Treat at 7 days after sticking
 Avg # of roots/cutting rooted: 22.1
 Leaf formation: some leaf loss, no shoots

Dates: April 23-May 17, 2010. Photos taken at Day 24

Variety: *Begonia diera* (*B. ludicra*) "Red Wing".

Media: 50-50 perlite: peat

IBA Treatment: 200 ppm IBA solution using Hortus IBA Water Soluble Salts by the Spray Drip Down Method (spray until solution drips off leaf)

Lots: Control. One treatment: (a) at 1 hour after sticking, (b) at 3 days, (c) at 5 days, (d) at 7 days