Engineering, Structures & Innovations

Benedict Posadas
Section Editor and Moderator

Evaluation of Hydrocks® as a Substrate Component for Horticulture Crops

Jeremy M. Pickens and Jeff L. Sibley
Auburn University, Department of Horticulture, Auburn, AL 36849
pickejm@auburn.edu

Index Words: propagation, cuttings, lime, IBA, rooting hormones, *Ficus benjamini*, carrier

Significance to Industry: Stem cuttings taken from *Ficus benjamini* 'Variegata' were stuck in various blends of Hydrocks® and lime, that had previously been soaked in 1000, 100, and 10 ppm IBA using a Dip N' Grow formulation. Lower concentrations of IBA soaked Hydrocks® resulted in a higher percentage of root tips when compared to conventional propagation methods. A reduction in human contact with IBA and a resulting higher number of root tips suggest that IBA presoaked Hydrocks® could provide a safe and efficient method of propagating stem cuttings of nursery crops.

Nature of Work: Hydrocks® is a fired clay with a porous nature which allows particles to absorb and retain water. A study of Hydrocks® physical properties revealed that aggregates have a potential to absorb 54 to 83 % of its own weight in water (Table 1). Using Hydrocks® as an auxin soaked substrate allows for a constant presence of hormone along the entire shaft of a stem cutting. The well drained, sterile nature combined with high moisture retention makes Hydrocks® ideal for a propagation substrate. Research has shown that organic substrates soaked in auxin can improve rooting response when compared to the industry standard quick dip. An auxin impregnated substrate also has been suggested to reduce human chemical contact and improve automation in a propagation environment (1).

There were two objectives to this study. The first was to determine if combinations of Hydrocks® and lime could be used as a rooting substrate. The second objective was to evaluate Hydrocks® as a potential carrier for indolebutyric acid (IBA) in propagation. Different particle sizes of Hydrocks® with different concentration levels of IBA were used to determine the most effective combination to be used in a propagation environment.

Treatments included three different Hydrocks® materials (3/16, 1/8, and crusher fines) which were evaluated alone or with combination with lime and three different concentrations of hormone (10 ppm, 100 ppm, and 1000 ppm IBA from the formulation of Dip N' Grow). Treatments with a quick dip of 100 ppm and 1000 ppm IBA with Fafard 3B as a substrate were used for controls to compare against Hydrocks® treatments. Hydrocks® materials were oven dried at 160°F for 48 hours prior to soaking. Hydrocks® treatments were soaked in appropriate hormone concentrations for 72 hours at room temperature and standard room air pressure. Variegated weeping fig (*Ficus benjamini* 'Variegata') stem cuttings were prepared with a minimum of 3 leaves per cutting and were placed under intermittent mist in a constant 72°F greenhouse at Paterson Greenhouse

Complex, Auburn University. A total of 20 treatments with 18 cuttings per treatment were evaluated in this study (Table 1). Cuttings were stuck in individual cells in appropriate treatments and were placed in a Randomized Complete Block Design with a total of 3 blocks. Each block contained a row of 6 cuttings per treatment. After two months of initial input the study was terminated. Data collected included rooting percent and a root quality rating based on a scale of 1 to 5. The root quality rating was based on structure and development of roots for each cutting, awarding 1 to cuttings with no roots and 5 for the best overall root system.

Results and Discussion: All 6 treatments containing concentrations of 1000 ppm IBA regardless of particle size or presence of lime were considered failures with rooting percentages ranging from 0 to 28%. No differences were observed between Fafard 3B control treatments containing 100 ppm and 1000 ppm IBA. Hydrocks® treatments presoaked in 10 ppm and 100 ppm had the highest rooting percent and scored higher on the root quality rating than the Fafard treatments (Table 2). Fafard treatments exhibited root development only at base of cutting, whereas, the Hydrocks® treatments exhibited root development along the entire shaft of the cutting. Hydrocks® treatments predominantly developed roots at the surface of the substrate and continued down the shaft of the cutting forming an upside down Christmas tree shape or a sporadic round shape in some cases. Hydrocks® treatments did not form roots at the basal end of the cuttings like the Fafard treatments. Despite the lack of roots at the bottom of the cutting, Hydrocks® treatments with 10 ppm and 100 ppm had a much higher number of root tips when compared to Fafard treatments. The higher number of root tips in Hydrocks® treatments could be attributed to the constant contact of hormone along the entire shaft of the cutting and the abrasive nature of the Hydrocks® aggregate. Successful Hydrocks® treatments resembled the type root systems formed when air root-pruning pots are used in container production and did not exhibit any visible circling of roots. Fafard treatments, however, had longer roots that did start circling the root ball after reaching the walls of the cell.

During the evaluation of the study, Hyrdocks® treatments retained an intact rootball when handled carefully but when shaken Hydrocks® treatments broke freely from the roots leaving an intact substrate-free root system. Bare root liner production is increasing as fuel and shipment cost continues to rise. The ease with which Hydrocks® was removed from roots suggests real potential for bare root liner production. Because Hydrocks® aggregates do not deteriorate over time, Hydrocks® materials could be re-used year after year in a bare root propagation situation and would alleviate cost associated with purchasing new substrate.

Following harvest, cuttings for all treatments were potted in 4 inch pots in Fafard 3B. Subsequently, no visible differences were observed between Hydrocks® and Fafard treatments after two months of growth. This study demonstrates that Hydrocks® can be used successfully as a rooting substrate, as a hormone carrier with low concentrations of hormone, and as a substrate for bare-root liner operations.

Literature Cited:

1. Blythe, E.K., J.L. Sibley, K.M. Tilt, and J.M. Ruter. 2004. Auxin application to stem cuttings of selected woody landscape plants by incorporation into a stabilized organic rooting substrate. J. Environ. Hort. 22:63-70.

Table 1. Physical Properties of Lightweight Aggregates.

	Weight as Received	Bulk Density[Z]	Fully Hydrated Weight	Absorption Capacity
Hydrocks® 3/16 inch	67.2	0.69 / 43.1	97.0	0.545
Hydrocks® 1/8 inch	70.5	0.68 / 42.5	105.3	0.835
Hydrocks® Crusher Fines	81.1	0.78 / 48.7	103.4	0.72

[Z]g/cm3 and Pounds per cubic foot

Table 2. Root Quality Rating[Z] and Rooting Percent for Variegated Weeping Fig Cuttings Using Hydrocks®.

	Treatment	Average Rating	Rooting Percent
1	900ml 3/16 Hydrocks + 300ml Lime + 1000ppm D&G	1.0	0%
2	900ml 3/16 Hydrocks + 300ml Lime + 100ppm D&G	3.7	72%
3	900ml 3/16 Hydrocks + 0ml Lime + 10ppm D&G	4.0	78%
4	900ml 3/16 Hydrocks + 0ml Lime + 1000ppm D&G	1.0	11%
5	900ml 3/16 Hydrocks + 0ml Lime + 100ppm D&G	4.0	78%
6	Fafard 3B + 0 ml Lime + Dip and Stick D&G 1000ppm	3.0	78%
7	300ml 3/16 Hydrocks + 100ml Lime + 10ppm D&G	3.0	33%
8	Fafard 3B + 0 ml Lime + Dip and Stick D&G 100ppm	3.0	78%
9	900ml 1/8 Hydrocks + 300ml Lime + 1000ppm D&G	1.0	11%
10	900ml 1/8 Hydrocks + 300ml Lime + 100ppm D&G	3.3	89%
11	900ml 1/8 Hydrocks + 0ml Lime + 10ppm D&G	3.3	94%
12	900ml 1/8 Hydrocks + 0ml Lime + 1000ppm D&G	1.3	28%
13	900ml 1/8 Hydrocks + 0ml Lime + 100ppm D&G	2.0	67%
14	250ml 1/8 Hydrocks + 83 ml Lime + 10ppm	2.0	17%
15	900ml Cr Hydrocks + 300ml Lime + 1000ppm D&G	1.0	0%
16	900ml Cr Hydrocks + 300ml Lime + 100ppm D&G	5.0	94%
17	300ml Cr Hydrocks + 0ml Lime + 10ppm D&G	3.0	83%
18	300ml Cr Hydrocks + 100ml Lime + 10ppm D&G	3.0	100%
19	900ml Cr Hydrocks + 0ml Lime + 1000ppm D&G	1.0	0%
20	900ml Cr Hydrocks + 0ml Lime + 100ppm D&G	4.7	78%

[Z]Rating scale is 1 = poor or no roots up to 5 = best root system.

Economic Impact of Technology Adoption Among Horticulture Firms

B.C. Posadas, P.R. Knight, R.Y. Coker, C.H. Coker and S.A. Langlois
Mississippi State University, Coastal Research and Extension Center,
1815 Popps Ferry Road, Biloxi, MS 39532
benp@ext.msstate.edu

Index Words: Mechanization, Automation, Greenhouse and Nursery, Northern Gulf of Mexico

Significance to the Industry: Sustaining the growth of the nursery and greenhouse industry requires a steady supply of reliable workforce capable of performing several horticultural tasks including planting, cultivating, harvesting, and transplanting plants. In order to achieve higher labor productivity and a satisfactory work environment, nurseries and greenhouses can strive to automate or mechanize their operations fully or partially, depending on their own individual circumstances. The results of the survey were used to show the differences in production levels and sales attributable to the differences in the levels of automation in the major tasks performed in nursery and greenhouse operations in the region. It is expected that with this information, growers can make informed decisions regarding nursery and greenhouse automation that would be beneficial to the nursery business and to its workforce.

Nature of Work: This socioeconomic (SEC) project is a part of a research program currently being undertaken by the Mississippi Agricultural and Forestry Experiment Station and the U.S. Department of Labor entitled Enhancing Labor Performance of the Green Industry in the Gulf South (1). The overall goal of this SEC project is to develop a socioeconomic profile of horticulture workers and to evaluate the impact of automation or mechanization on their employment, earnings, safety, skill-levels, and retention rates (1). The nursery automation index could be defined as a measure of the average level of automation or mechanization (AVELOAM) currently being practiced in each nursery or greenhouse included in the regional survey (2). It shows the extent to which nurseries have currently automated or mechanized the various tasks involved in the production of horticulture products. In this paper, the AVELOAM (0-100 percent scale) was estimated from the individual percentage scales reported in each of the tasks performed by each participating nursery or greenhouse. In order to evaluate the impact of mechanization or automation on the annual output of horticulture products, workers' employment, earnings, safety, skill-levels, and retention rates, the following empirical models were used:

Annual gross sales as a proxy to annual output of horticulture products:
salesyr3 c aveloam fte acreprod year2 nuronly ghonly peracreuse Eqn. 1
Annual employment:
manhr c aveloam acreprod year2 nuronly ghonly peracreuse Eqn. 2
Annual workers' earnings:
totlabcst c aveloam fte acreprod year2 nuronly ghonly peracreuse Eqn. 3

Workers' skills:
workskill c aveloam fte acreprod year2 nuronly ghonly peracreuse Eqn. 4
Workers' safety:
manhrlost c aveloam fte acreprod year2 nuronly ghonly peracreuse Eqn. 5
Workers' retention rates:
powreturn c fte aveloam fte acreprod year2 nuronly ghonly peracreuse Eqn. 6.
where: salesyr3 = mid-point of the annual gross sales group reported ($/year), fte = full-time equivalent workers (no./year), totlabcst = labor costs ($/year), workskill = percent of new workers hired with basic horticultural skills (%), manhrlost = number of man-hours lost due to work-related injuries (h/year), powreturn = percent of workers who were employed in the same firm last year (%), c = constant term, acreprod = number of acres under production, year2 = number of years since establishment, nuronly = dummy variable representing nursery only, and ghonly = dummy variable representing greenhouse only. Equations 1-6 were estimated by using the Tobit method due to the limited range of values of some of the variables used in estimation (3, 4).

Results and Discussion: A total of 87 nursery automation survey forms were completed from personal interviews with horticulture firms randomly selected in Mississippi, Louisiana and Alabama between Dec. 2003 and Dec. 2005. The 87 nurseries included in the survey reported a total of 1,804 acres or an average of 21 acres per nursery. Preliminary Tobit regression results suggested some insights on the size and direction (enhancing, limiting or neutral effects) of the influences exerted by the level of mechanization or automation on the key variables under consideration. The annual gross sales (as a proxy to the output of horticulture products) reported by nurseries and greenhouses seemed to have significant direct association with the average level of mechanization or automation, the number of full-time equivalent workers and the number of acres under production (Table 1). These results imply that a one percent improvement in the level of mechanization or automation, the hiring of an additional FTE worker, and the use of one more acre in production could be associated to an increase in annual sales or production by $3,384..73, $69,513.70 and $1,207.53/year, respectively. An increase in annual employment (0.13 fte/year) was required for every additional acre placed under production. It seemed that annual employment was lower among firms which were operated either as a nursery only (5.76 FTE/year less) or as a greenhouses only (2.78 FTE/year less). The level of mechanization or automation exerted a neutral effect on annual employment. The expected increase in annual workers' earnings ($/year) as a result of a percentage improvement in the level of mechanization or automation, the hiring of an additional FTE worker, and the use of one more acre in production were $1,629.51, $18,455.90 and $842.11/year, respectively.

The percent of new workers with basic horticultural skills were higher among firms which were operated either as a nursery only (56.44%) or as a greenhouse only (49.60%). A neutral association was observed between the level of mechanization or automation and percent of new workers with basic horticultural skills (Table 2). A lower percent of new workers with basic horticultural skills (1.30% less) was observed among firms with higher acreage under production. More man-hours were lost due to work-related injuries among firms with more FTE workers (9.80 h/year), larger production acreage (0.36 h/year), and operated as a nursery only (74.34 h/year). There were no significant effects (neutral) of the average level of mechanization or automation on either workers' safety or workers' retention rates.

Literature Cited:

1. Posadas, B.C., G.B. Fain, C.H. Coker, P.R. Knight, C. D.Veal, and R.Y. Coker. 2004. Socioeconomic survey of nursery automation. Proc. SNA. Res. Conf. 49: 306-309.
2. Posadas, B.C., P.R. Knight, C.H. Coker, R.Y. Coker, S.A. Langlois, and C.D. Veal. 2005. Levels of technology adoption among horticulture firms in the northern Gulf of Mexico. Proc. SNA. Res. Conf. 50: 365-368.
3. Long, J.S. 1997. Regression models for categorical and limited dependent variables. Sage Publ., Thousand Oaks, Calif.
4. Maddala, G.S. 1983. Limited-dependent and qualitative variables in econometrics. Cambridge Univ. Press, NY.

Table 1. Tobit results of annual gross sales, annual employment and annual workers' earnings in nurseries and greenhouses in northern Gulf of Mexico, Dec. 2003-Dec. 2005.

Independent variable	Annual gross sales	Annual employment	Annual workers' earnings
Constant term	-72,526.86	4.62 **	-30,966.04
Mechanization or automation level	3,384.73 *	0.01	1,629.51 *
Full-time equivalent workers	69,513.70 ***	-	18,455.90 **
Production acres	1,207.53 **	0.13 *	842.11 ***
Years since establishment	1,254.98	0.04	-639.96
Nursery only	67,916.82	-5.76 *	-7,453.90
Greenhouse only	56,472.47	-2.78 *	-14,114.33
Percent of land use	116,579.90	1.21	19,769.10
Number of observations included	75.00	78.00	56.00
R-squared	0.92	0.45	0.94
S.E. of regression	224,227.90	7.04	60,213.49

***, ** and * - Significant at P #0.10, 0.05, and 0.01, respectively.

Table 2. Tobit results of workers' skills, workers' safety and workers retention rates in nurseries and greenhouses in northern Gulf of Mexico, Dec. 2003-Dec. 2005.

Independent variable	Workers' skills	Workers' safety	Workers retention rates
Constant term	65.63 *	-159.65 *	83.87 ***
Mechanization or automation level	-0.70	-0.80	0.28
Full-time equivalent workers	2.18	9.80 ***	-0.03
Production acres	-1.30 *	0.36 *	-0.05
Years since establishment	-0.73	-1.60	-0.22
Nursery only	56.44 *	74.34 *	3.12
Greenhouse only	49.60 *	47.86	-4.11
Percent of land use	-50.47	-1.43	7.68
Number of observations included	59.00	74.00	73.00
R-squared	0.34	0.92	0.06
S.E. of regression	41.73	19.15	23.68

*** and * - Significant at P #0.10 and 0.01, respectively.

Aquatic Phytoremediation Containment System Evaluation

Laurie J. Fox, Jeremy Beech and Bonnie L. Appleton
Virginia Polytechnic Institute and State University,
Hampton Roads Agricultural Research and Extension Center,
1444 Diamond Springs Rd., Virginia Beach, VA 23455
ljfox@vt.edu

Index Words: water hyacinth, *Eichhornia crassipes*, water quality, nutrient runoff, bio-filtration, storm water retention ponds

Significance to the Industry: Water quality is a concern in every part of the green industry, and nutrients and sediments in storm water runoff are the primary pollutants which degrade water quality (1). Phytoremediation is the use of plants to remove contaminants. A phytoremediation system which uses aquatic plants to remove nutrients from storm water ponds has many benefits. The key components in a successful system are plants that are efficient biofilters and a containment system to keep those plants located where they will intercept the most nutrient polluted runoff, and to keep those plants from escaping and becoming weeds. An economic and site-adaptable system can be used in any type of pond; aesthetic, recreational, irrigation, in any location; residential, industrial, agricultural, nursery, and golf course. Algae blooms and subsequent algaecide applications would be reduced, in turn reducing the chances for copper resistant algae. Excessive growth of other aquatic vegetation and subsequent herbicide applications would also be reduced. Pond life expectancy (time before dredging) would be lengthened. Water quality would be improved in the pond prior to release back into the natural system. In nursery irrigation ponds, the aquatic plants could become an additional crop using previously unproductive space. Excess aquatic plants could be harvested, composted and added to potting substrate or back into the landscape, or bagged and sold as a soil amendment.

Nature of Work: Research has already been conducted on the use of wetland plants as filters in buffer zones and constructed wetlands (2, 3, 4). In a similar manner aquatic plants could be used as water filters to improve water quality in retention and irrigation ponds at nurseries, golf courses, and residential, municipal, and industrial sites. Floating water hyacinth (*Eichhornia crassipes*) is an effective biofilter for removing excess nutrients from water, which has been documented in both ornamental ponds and waste water systems. The characteristics that make water hyacinth a good biofilter also make the plant a weed. An inexpensive, site adaptable containment system is necessary. The hyacinths must be kept at the location(s) where the most nutrient polluted runoff is coming into the pond in order to intercept and filter the nutrients effectively. The hyacinths must also be contained so they do not escape into the aquatic ecosystem and become an invasive weed. Containment corrals were constructed and evaluated for this purpose.

At Bayville Golf Club, Virginia Beach, VA pond five hole 5 was selected as the site for a containment study in January 2004. Floating water hyacinth (*Eichhornia crassipes*) was selected for the containment system evaluation.

Twelve containment corrals were constructed of white 10.16 cm (4 in) schedule 40 coextruded cellular poly vinyl chloride (PVC) no-pressure pipe (Fig. 1). The PVC pipe came in 6 m (20 ft.) lengths which were cut into 1.2 m (4 ft) lengths. To create a square containment corral with final dimensions of 11.18 m^2 (4.3 ft^2), four lengths of PVC pipe 1.2 m (4 ft) and four 90º PVC elbows were glued together using PVC cement. Black Durethene polyethylene netting (formerly ADPI Enterprises, now Conwed Plastics) was attached to the bottom of each corral with 83.8 cm (33 in) Fastenal Industrial plastic cable ties. Six corrals had netting with a diamond mesh size of 1.9 cm (.75 in) and six with 4.4 cm (1.75 in). This was to prevent hyacinths from escaping underneath the PVC due to any rocking motion. Three corrals from each group then had 20.3 cm (8 in) of netting (same mesh size as on the bottom of the corral) attached around the corral perimeter to form a 'containment guard' above the floating PVC pipe. Again this was to prevent hyacinth escape over the top of the PVC due to any rocking motion. The four treatments included small mesh with and without guard and large mesh with and without guard. Corrals with guards cost $49.58, and corrals without the guard cost $45.55.

Containment corrals were deployed into pond 5 in early May 2004. Each corral was anchored in place .9 m (3 ft) from shore by two 20.3 cm (8 in) cinder blocks. Each block was sunk an then attached with 1.2 m (4 ft) of .6 cm (.24 in) nylon rope and a carabiner to two (opposite) sides of each corral. Each corral was connected to the adjacent corral with a carabiner to prevent lateral movement and to form a line of floating corrals paralleling the shoreline greens complex of hole 5.

Ten water hyacinths were placed in each corral on May 7, 2004. The study was observed for eight weeks. A 100 square grid equal in size to the corrals was constructed using pressure treated wood for the frame and pink nylon cord for the grid. Each week the grid was placed over each corral and photographed. Percent canopy coverage was assessed by counting the number of grid squares containing foliage. Hyacinth fresh and dry weights were collected at the end of eight weeks. Observations were also made on corral UV light stability, hyacinth containment, float integrity, anchoring, and ease of corral deployment and removal from the pond. In addition, water temperature, pH, dissolved oxygen, and electrical conductivity were monitored weekly.

The study design was a randomized complete block with four treatments and three replications. Data were analyzed using SAS (SAS version 8.1, Cary, NC). A repeated measures analysis was performed on the canopy coverage data. Other data were analyzed using Duncan's multiple range test. The level of significance was $P = 0.05$.

Results and Discussion: At the end of eight weeks, no differences in canopy coverage were observed. The corrals did not adversely influence hyacinth reproduction. The hyacinths were contained effectively regardless of corral mesh size or guard feature. Corrals remained UV stable, buoyant, and anchored. They were easy to maneuver in the pond and could be readily adjusted to the site if necessary, or added onto if more filtration was desired. The corrals were also cost efficient relative to other prototypes as the supplies were locally available, uncomplicated to assemble, and easy to transport.

Initial concern existed about hyacinth and corral removal from the pond due to the amount and weight of the biomass. If this was a problem at the end of eight weeks, then it certainly would be for the user at the end of a growing season. The most efficient method was to remove the anchor blocks then float the full corrals to an access point where they were lifted out of the pond with a forklift and loaded onto a pickup truck to be hauled to the composting site. Once the water had drained, two people could easily lift the corrals off the truck for dumping. Manual removal of the hyacinths and corrals from the pond was labor and time prohibitive. Several corrals were left in the pond after the eight week study due to equipment and weather issues. At ten weeks, the hyacinth biomass was so large and buoyant that the cinderblock no longer anchored the corrals and they floated across the pond. The stress of buoyancy versus weight of the cinderblock caused the PVC on several corrals to crack and fill with water, allowing hyacinths to excape. Surprisingly though, the corrals remained afloat until removed at twelve weeks. For a large scale phytoremediation containment system, the use of turbidity barriers with curtains (similar to what is used to contain oil spills) is a possibility.

Literature Cited:

1. Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecol. Appl. 8(3):559-568.
2. Cole, J.T., J.H. Baird, N.T. Basta, R.L. Huhnke, D.E. Storm, G.V. Johnson, M.E. Payton, M.D. Smolen, D.L. Martin, and J.C. Cole. 1997. Influence of buffers on pesticide and nutrient runoff from bermudagrass turf. J. Environ. Qual. 26(6):1589-1598.
3. Cooper, C.M. and S.S. Knight. 1990. Nutrient trapping efficiency of a small sediment detention reservoir. Agr. Water Mgt. 18(2):149-158.
4. Kohler, E.A., V.L. Poole, Z.T. Reicher, and R.F. Turco. 2004. Nutrient, metal, and pesticide removal during storm and nonstorm events by a constructed wetland on an urban golf course. Ecol. Eng. 23:285-298.

Figure 1. PVC frame (1), mesh underlay (2), mesh guard (3), carabiner on rope around corral (4), nylon rope (5), cinderblock anchor (6), grid overlay frame (7), 100 count grid (8).