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USING PLANT GROWTH REGULATORS ON HYDRANGEA SPECIES TO CONTROL PLANT SIZE AND INCREASE BRANCHING AND FLOWERING DURING NURSERY PRODUCTION

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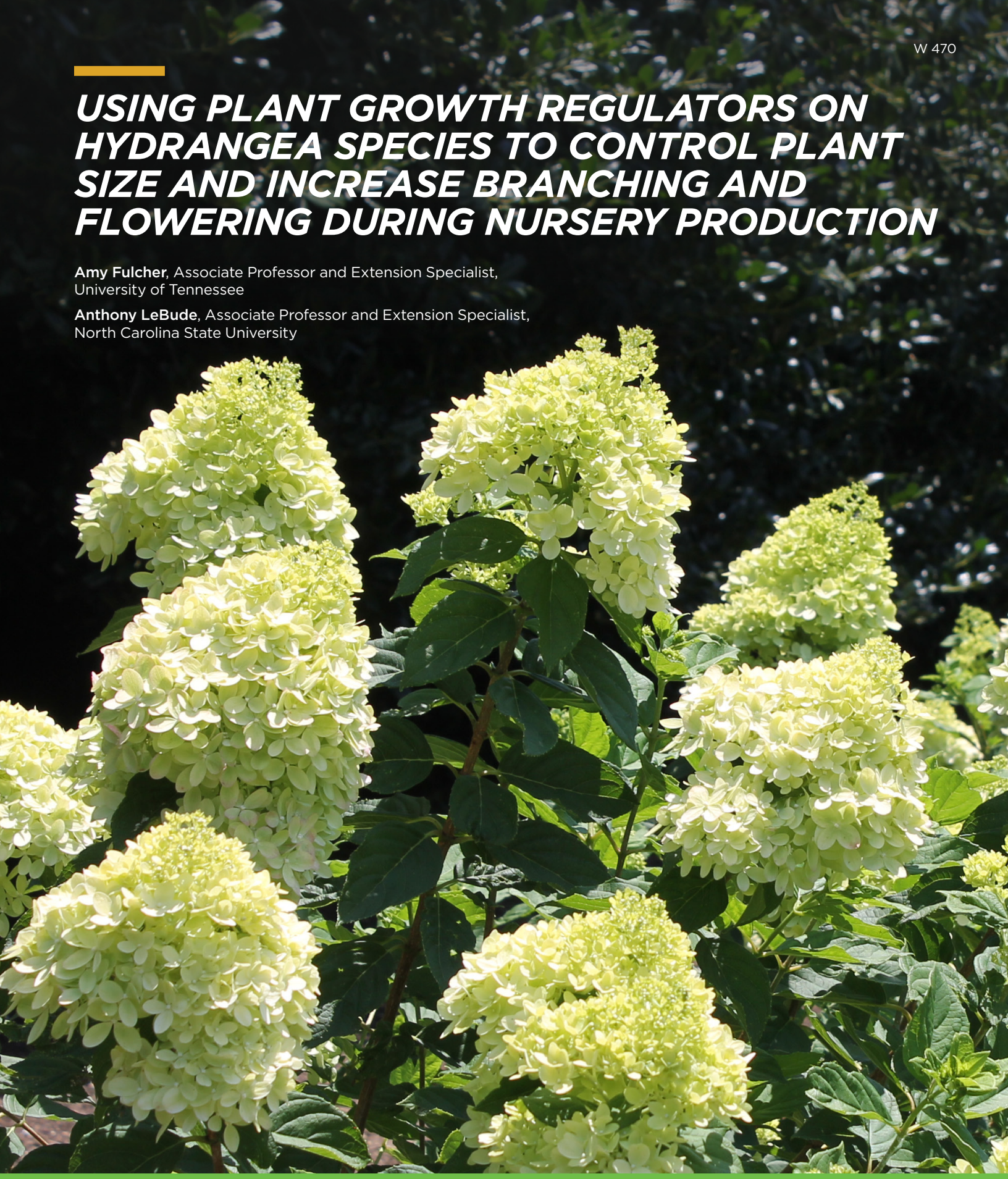

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Dikegulac sodium can lead to short-term phytotoxicity, as shown on H. paniculata *'Phantom'. Photo Credit: Amy Fulcher, University of Tennessee*

Larger liners and refined fertilization and irrigation practices have allowed the nursery industry to turn crops faster than ever. The advent of quick-turn liners and reduced production times make it possible to finish a 3-gallon crop in less than a growing season. Given this trend, coupled with the extreme popularity of hydrangea species, an in-depth understanding of the plant growth regulators (PGRs) effective on hydrangeas may help produce a higher quality plant with greater efficiency and have wide-reaching implications for overall nursery productivity and profitability. Plant growth regulators can increase the number and size of blooms and accelerate bloom time compared to pruning. Also, PGRs can help develop a finished crop while controlling plant size and quality to meet the requirements for both rack shipping and retail display — all key to shortening your production cycle while maintaining the quality and blooms your customers demand. Pruning can't do that!

THE LINK BETWEEN THE NUMBER OF HYDRANGEA BRANCHES AND THEIR FLOWERS

Hydrangeas form terminal, determinate inflorescences (an inflorescence is a complete flower structure including peduncle, florets, petals, sepals and reproductive organs). This means that flowers develop on the tips of branches, bloom, then fade; new shoots develop from axillary buds just below an infloresence to produce new stems, and potentially another terminal infloresence, depending on the cultivar. Therefore, the greater the number of branches present, the greater the potential for flowers. Increased branches, however, can also increase the number of "blind shoots" present. Blind shoots are shoots that have no terminal flower due to time of year, high temperatures, long days or too much weak vegetative growth from increased nutrition and overwatering. Minimizing blind shoots is an added incentive to understand and maximize pruning, both independently and in conjunction with PGR use to increase the number of branches with inflorescences.

REMONTANT

The ability of a plant species to reflower is known as remontancy. Well-known remontant selections of *H. macrophylla* include Bloomstruck, Endless Summer, 'Nikko Blue' and 'Penny Mac.'

WHAT CONTROLS BRANCHING IN NATURE?

Branching is controlled by a balance between the naturally occurring plant hormones in the auxin and cytokinin classes. Auxins are produced in the terminal bud of a branch and move downward from the apical tip toward the soil where they promote root growth. On the way down, however, auxins suppress the growth of axillary buds, inhibiting lateral growth. Cytokinins are produced in the roots and move toward the canopy, activating axillary buds and promoting lateral growth. When the terminal bud is removed after pruning, auxin production is reduced and the balance shifts, favoring cytokinins. Without auxin present to repress growth, axillary buds begin to grow and branches develop. Thus, pruning favors branching along the stem. Also present is gibberellic acid, a plant hormone in the gibberellins class that increases bud break, cell division and growth; induces flowering; and promotes internode elongation. It is produced in many plant organs, particulary the inflorescences. The interplay of these three plant growth hormones as modulated by environmental conditions, plant genetics and production practices affects how densely branched a plant is, or alternatively, how tall and lanky or "stretched" it might become if not managed properly.

PLANT GROWTH REGULATORS CONTROL GROWTH

PGRs are compounds that can be sprayed, drenched or sprenched on plants to elicit a desired growth effect. They include synthetic compounds that mimic naturally occurring plant hormones like auxins and cytokinins, as well as chemical compounds that do not normally occur in nature. PGRs available for use on hydrangea in nurseries can be divided into three groups: branch inducers, chemical pinchers, and those that decrease internode length by inhibiting gibberellic acid production. Branch inducers include benzyladenine, a synthetic version of a naturally occurring cytokinin. These products aim to increase the cytokinin to auxin ratio, shifting the balance toward releasing axillary buds and forming branches. Chemical pinchers include those products that chemically "remove" (damage) the branch tips and decrease auxin, again shifting the balance to favor increased branching. Chemical pinchers elicit a response similar to pruning. Gibberellic acid inhibitors function as growth retardants by inhibiting stem elongation and internode length and have been mainstays of floriculture crops and greenhouse-grown hydrangeas and other crops to aid in producing plants that meet strict size guidelines for shipping.

FLOWER INITIATION

Hydrangea species begin to form flower buds at different times, which is one reason why relying on pruning to control growth is challenging. *Hydrangea arborescens* and *H. paniculata* flower on the current season's growth, so pruning in the spring or summer before blooming has the potential to remove developing flower buds invisible to the unaided eye. *Hydrangea macrophylla* and *H. quercifolia* begin to develop flower buds in the previous year, so pruning anytime from late summer to bloom risks removing the flowering tissue.

SPRENCH

Sprench is a combination of the words "spray" and "drench." It is a foliar application applied heavily enough to cover the leaves but also penetrates the top portion of the substrate. As with drenching, sprenching is used with products that can be absorbed by roots. However, there is no defined volume of solution per production area or container for sprenching, like those established for drenches and sprays. In contrast with sprays, a sprench is usually applied when a moderate, somewhat long-lasting response is desired, but not as strong or long-lasting as a response from a drench.

While the container nursery industry commonly relies on pruning as a way to stimulate branching and control growth, stem removal creates several complications in the production of hydrangeas, as well as other flowering shrubs. For example, pruning can remove terminal tissue containing flower buds and therefore delay or eliminate flowering, while simultaneously increasing the time needed for the plant canopy to regain a natural appearance. An additional complication is that pruning does not always stimulate branching. Sometimes a branch is pruned and a single branch replaces it — there is no increase in branch number. In numerous studies at the UT Institute of Agriculture, hydrangeas that were pruned had the same number of branches as water-sprayed "control" plants that were not pruned. In comparison, some PGRs caused hydrangeas to have a two to threefold increase in branching and flowering without pruning. Pruning can usually be used to control height and often stimulates branching, but if stimulating branching can be done in a way that preserves flowering tissue and eliminates delays in flowering and canopy recovery time, that is an improvement and a big step toward greater efficiency. Because hydrangea inflorescences occur on terminal branch tips, simply spraying PGRs during production without pruning may increase the number of branches and flowers.

TABLE 1. *Effect of plant growth regulator application, rate and/or pruning on growth and flowering characteristics of select hydrangea species and cultivars. Experiments were conducted outside unless otherwise indicated.*

	CHEMICAL	METHOD AND RATE	PRUNED (1 time)	OUTCOME	REFERENCE
H. paniculata 'Limelight'	None applied	--	Yes	Fewer, smaller flowers than not pruning (or applying PGRs).	Cochran et al. 2013. HortTechnology 23:836-842.
	dikegulac sodium	One foliar spray at 800 or 1,600 ppm	PGR was applied to pruned and nonpruned plants	Increased branch number compared to nontreated plants, regardless if pruned or not pruned.	Cochran et al. 2013. HortTechnology 23:836-842.
'Little Lime'	None applied	--	Yes	Pruning either increased branching slightly compared to ethephon or decreased it compared to dikegulac sodium; pruning reduced flower number 76% compared to three other PGRs.	Cochran and Fulcher. 2013. HortTechnology 23:306-311.
	benzyladenine	Two foliar sprays 1 week apart at 300 or 600 ppm	No	At either rate, did not affect branching compared to nontreated plants; at 600 ppm comparable branching to pruned plant; greater flower number than pruned but no different from nontreated plants.	Cochran and Fulcher. 2013. HortTechnology 23:306-311.
	dikegulac sodium	One foliar spray at 800 or 1,600 ppm	No	Increased branch number compared to water controls (2x to 4x) and pruned plants (1.5x or more); increased flower number compared to pruned plants but not better than nontreated plants. Improved plant symmetry compared to nontreated plants. Phytotoxicity occurred 2-4 weeks after treatment, but was gone by sale date.	Cochran and Fulcher. 2013. HortTechnology 23:306-311.
	ethephon	One spray, foliar application at 500 or 1,000 ppm	No	At 1,000 ppm, branching comparable to pruning, at 500 and 1,000 increased flower number compared to pruning but not better than nontreated plants.	Cochran and Fulcher. 2013. HortTechnology 23:306-311.

	CHEMICAL	METHOD AND RATE	PRUNED (1 time)	OUTCOME	REFERENCE
'Phantom'	None applied	--	Yes	Time to first flower delayed 6 weeks compared with dikegulac sodium; delayed 5 weeks compared to flurprimidol and benzyladenine.	Fulcher unpublished data
	dikegulac sodium or flurprimidol	One foliar spray at 800 ppm or 200 ppm	No	Time to first flower not affected compared to nontreated plants.	Fulcher unpublished data
	dikegulac sodium	One heavy foliar spray at 800 ppm; (heavy = approximately double the application volume)	No	At the end of the season of application, plants had 32 branches compared with 17 for pruned plants and 5 for nontreated plants. Doubled flowers present the following June.	Fulcher unpublished data
H. quercifolia 'Alice'	benzyladenine	Two foliar sprays 4 weeks apart at 500 ppm	No	Did not affect branching compared to nontreated or pruned plants. No phytotoxicity symptoms occurred.	Cochran et al. 2014. J. Environ. Hort. 32:182-188.
	cyclanilide	One foliar spray at 100 ppm or two foliar sprays 4 weeks apart at 100 ppm	No	Two applications increased total branch number compared to nonpruned plants. No phytotoxicity symptoms were visible by time of sale.	Cochran et al. 2014. J. Environ. Hort. 32:182-188.
H. quercifolia 'Alice' or 'Pee Wee'	ancymidol	One foliar spray at 25, 50 or 100 ppm; or one drench application at 1, 2 or 4 ppm	No	From 2 to 16 weeks after treatment, did not reduce height or width of plants compared to pruned plants or nontreated plants with very few exceptions.	Cole et al. 2013. HortTechnology 23:339-346.
	uniconazole	One foliar spray at 12.5, 25 or 50 ppm; or one drench at 1, 2 or 4 ppm	No	From 2 to 16 weeks after treatment, did not reduce height or width of plants compared to pruned or nontreated plants with very few exceptions.	Cole et al. 2013. HortTechnology 23:339-346.
H. quercifolia [1] (no cultivar specified)	benzyladenine, or benzyladenine + GA_{4+7}	Two foliar sprays 2 weeks apart at 100 ppm	No	Did not increase branching, but had no phytotoxic effects.	Courtesy of IR-4 (Gibson 2006)
	cyclanilide	One or two foliar sprays 2 weeks apart at 100 ppm	No	Two applications doubled branch numbers, but decreased quality to unsaleable by end of season.	Courtesy of IR-4 (Gibson 2006)

[1]*These results are from experiments conducted in a greenhouse, not a nursery.*

	CHEMICAL	METHOD AND RATE	PRUNED (1 time)	OUTCOME	REFERENCE
H. arborescens **Invincibelle Spirit**	daminozide	Three foliar applications at 5,000-7,000 ppm; 10-20 days apart when plants are small; do not drench	No	Controls height. Do not prune before application. Daminozide did not influence the number of flowers or the number of stems, but the stem length was shortened and the leaf color was darker.	Protocol courtesy of Tim Wood, Spring Meadow Nursery Inc.
H. macrophylla **'Nikko Blue' or 'Merritt's Supreme'**	benzyladenine	One or two foliar sprays at 300 ppm or 600 ppm	No	Neither rate improved branching; in some experiments reduced it compared to pinched, nontreated plants.	Hester et al. 2013. J. Environ. Hort. 31:27-29.
H. macrophylla **'Nikko Blue'**	dikegulac sodium	One foliar spray at 800 or 1,600 ppm	No	800 ppm reduced branching, while 1,600 ppm did not affect branching compared to pinching.	Hester et al. 2013. J. Environ. Hort. 31:27-29.
H. macrophylla **'Merritt's Supreme'**	dikegulac sodium	One foliar spray at 800 or 1600 ppm	No	At 800 ppm, greater branch number than pinched plants in 2/3 of trials. At 1,600 ppm increased branch number (46-253%) in all 3 trials.	Hester et al. 2013. J. Environ. Hort. 31:27-29.
	dikegulac sodium	One foliar spray at 400 or 800 ppm	PGR applied to pinched and unpinched plants	400 ppm and pinching increased branch number; 800 ppm and pinching increased the number of flowers compared to nonpinched controls.	Sun et al. 2015. HortTechnology 25:306-312.
H. macrophylla **'Nikko Blue' or 'Merritt's Supreme'**	ethephon	One foliar spray at 500 or 1,000 ppm	No	Either did not affect branching or reduced it slightly compared to pinched plants.	Hester et al. 2013. J. Environ. Hort. 31:27-29.

H. paniculata *'Phantom' (from left to right): water control, pruned, dikegulac sodium at 800 ppm, two benzyladenine applications four weeks apart (900 ppm), and flurprimidol (200 ppm). Dikegulac sodium-treated plants had as many or more, but smaller flowers and three times more branches, than any other PGR treatment. Branch number of dikegulac sodium-treated plants was equivalent to or greater than pruned plants with no reduction in flower number. Photo Credit: Quinn Cypher, formerly University of Tennessee*

Pinching (light tip pruning to new growth) in combination with PGR application can lead to desired branching of Hydrangea macrophylla *'Merritt's Supreme'. From left to right: dikegulac sodium applied once at 0, 400, 800 or 1600 ppm. Back row pinched, front row not pinched. Photo Credit: Guihong Bi, Mississippi State University*

TRIAL RESULTS FOR PGRS APPLIED TO HYDRANGEAS DURING CONTAINER NURSERY PRODUCTION

Treatments (Table 1): pruning or PGR applications, were made four weeks after potting (mid-June). The branch number of *H. paniculata* 'Limelight' or Little Lime in 3-gallon containers was similar whether plants were pruned or not, and pruned plants generally had fewer and smaller flowers than either PGR-treated plants or no treatment (Table 1). This highlights a need for an alternative to pruning to stimulate branch development for this species. In fact, pruning Little Lime reduced flower number by at least 78 percent compared with PGR treatments: benzyladenine (300 or 600 ppm), ethephon (500 or 1,000 ppm), or dikegulac sodium (800 and 1,600 ppm). Dikegulac sodium (either rate) was the only treatment that increased branching and plant quality without reducing the floral display of Little Lime. Time to first flower was not recorded for 'Limelight' or Little Lime. In limited trials on *H. paniculata* 'Phantom', time to first flower for 3-gallon plants was slightly accelerated by dikegulac sodium application; however, pruned plants required five to six weeks to achieve the same level of flowering as those treated with dikegulac sodium, benzyladenine, or flurprimidol, or nontreated plants.

Hydrangea quercifolia, oakleaf hydrangea, can be lanky and asymmetrical during container production and has been reported as susceptible to dieback caused by aerial rhizoctonia after shearing, especially during wet conditions. Therefore, using PGRs might control plant size while avoiding dieback. In experiments testing market potential, two foliar applications of cyclanilide four weeks apart at 100 ppm increased branch number compared to nonpruned plants (Table 1). Unfortunately, ancymidol (25, 50 or 100 ppm foliar application and 1, 2 or 4 ppm drench application) or uniconazole (12.5, 25 or 50 ppm foliar application and 1, 2 or 4 ppm drench application) applied to 'Pee Wee' or 'Alice' oakleaf hydrangea did not reduce overall size compared to pruned plants at 12 to 16 weeks after treatment. Cyclanilide was not brought to market as a product for controlling growth in ornamentals, but these results indicate its effect on reducing labor and height without pruning.

To control growth of *H. arborescens* Invincibelle Spirit, Spring Meadow Nursery recommends applying daminozide at 5,000-7,000 ppm during production. They recommended a minimum of three foliar applications approximately 10-20 days apart be applied beginning when the plants are small. Drenches are not recommended because daminozide is broken down rapidly in the container substrate. Plants already at the market-dictated height are not good candidates for PGRs. Pruning is not advised before application. The following visual indicators can be used to assess activity and application timing: when the leaves in the apical meristem begin to point upward, the plants will grow out of the application. When the leaves lay flat, the PGR is active.

While PGRs are applied routinely in the production of florist hydrangeas, results in the nursery can vary, and, yet, pinching may not be a better solution, especially where flower development is affected. Applications of dikegulac sodium caused phytotoxicity initially but increased the number of branches and flowers on container-grown *H. macrophylla* 'Merritt's Supreme'. Dikegulac sodium plus pinching increased branching at 400 ppm in one location of the study, while 800 ppm plus pinching increased the number of flowers compared to unpinched controls at both locations (Table 1). Pinching plants was only successful at increasing branching compared with untreated controls in one location of the study. Dikegulac sodium (800 and 1,600 ppm) did not significantly increase

branching compared to untreated *H. macrophylla* 'Nikko Blue'. Benzyladenine (300 ppm and 600 ppm) and ethephon (500 and 1,000 ppm) were not effective at inducing branching on either 'Merritt's Supreme' or 'Nikko Blue'.

Care should be taken when using PGRs as residual effects can occur on florist and landscape hydrangeas the following season. Summer PGR applications the year before spring forcing have reduced flower size and plant height of *H. macrophylla* 'Böttstein'. This could have been due to increased branching that reduced height and produced more, but smaller, flowers. Alternatively, a residual effect can be a value-added asset. For example, *H. paniculata* 'Phantom' treated with heavy (approximately double the volume) applications of dikegulac sodium at the labeled rate of 800 ppm had more flowers (approximately double) the season following application. Most residual effects wear off after the next season. Habituation, however, generally occurs after long exposure to high concentrations of PGRs, which causes some plants to respond as if the PGR is still being applied. This phenomenon is known to occur when plants are propagated by tissue culture. After long periods of exposure to cell proliferation and then branch-inducing chemicals, plants can continue branching more after acclimatization to greenhouse conditions compared to traditional cuttings. This is important to note when purchasing cultivars from tissue culture producers. While known to occur as a result of exposure to growth hormones during tissue culture, habituation has the potential to occur from repeated PGR applications to plants during production. Additionally, the effect of exposure to growth hormones during tissue culture propagation followed by the use of PGRs during production has not been thoroughly studied.

HABITUATION

Habituation is a phenonmenon that occurs during tissue culture, following repeated exposure to a growth hormone, in which cells no longer require the hormone to be applied for the intended response in growth to occur. Habituation is considered relatively long-lasting and heritable, yet is also considered to be reversible.

TRIAL ON A SMALL SCALE

Conducting a trial of a PGR on a small scale to assess the extent and duration of any phytotoxic responses, general effectiveness and longevity is recommended. In order to more fully and accurately evaluate the difference a PGR application makes, take a uniform block of plants that have been subjected to identical production practices, and treat some plants with the PGR that you are testing. Prune others according to your normal practices, and do not prune or apply PGRs to the rest. Clearly label the plants. Periodically assess their growth and health.

Consistency with PGRs can be elusive from year to year at the same location and within a year at different locations across the country. Their benefits of increased branching, flowering and time to market, however, outweigh the time it might take to develop a safe and effective protocol.

PHYTOTOXICITY

The term "phytotoxicity" refers to a compound being visibly damaging to plants. Properly selected, mixed and applied PGRs can diminish the visual aesthetics of a crop initially, but plants generally recover within the production cycle so as not to affect sales. However, longer lasting, undesirable effects on plant appearance and more serious damage that impairs plant health are possible, in particular when products are not used correctly.

LABELS

Product labels and the availability of plant growth regulators change periodically based on patents and demand by growers. For example, cyclanilide, one of the two most active PGRs for hydrangeas in nursery production, may not be available. The pursuit of these and other PGRs for nursery production is possible if PGR manufacturers recognize the potential of the market and support their use for ornamentals. Nurseries can have an influence over this process by communicating their needs and gaps in availability and labeling to manufacturers, their sales representatives and Extension specialists.

DISCLAIMER

Use of trade or brand names in this publication is for clarity and information; it does not imply approval of the product to the exclusion of others that may be of similar, suitable composition, nor does it guarantee or warrant the standard of the product. The author(s), the University of Tennessee Institute of Agriculture, University of Tennessee Extension, and the NC State University Agriculture Research Service assume no liability resulting from the use of these recommendations.

This publication contains recommendations that are subject to change at any time. The recommendations are provided only as a guide. It is always the applicator's responsibility, by law, to read and follow all current label directions for the specific product being used. The label always takes precedence over the recommendations found in this publication. Always refer to the product label for specific information on proper product use, tank mix compatibility and crop tolerance. Contact your local Extension agent for support when trying new products.

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