

IPM FOR SHRUB PRODUCTION



EDITED BY AMY FULCHER

• Preface •

This manual is dedicated to Mr. Mark Halcomb, retired University of Tennessee Area Nursery Extension Specialist, who worked tirelessly to assist nursery producers large and small. His endless devotion to the Tennessee nursery industry was the rising tide that lifted all ships.

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• CHAPTER 3 •

HYDRANGEAS



by Mark Halcomb,
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• Section 1 •

Highlights

1. Hydrangeas are some of the most popular, widely sold shrubs.
2. Hydrangea means "water loving".
3. *H. macrophylla* can have blue, pink, or white flowers
4. Some hydrangeas are remontant meaning they have a second bloom period.
5. Knowing when to prune is critical so that flower buds aren't removed.
6. Hydrangeas do not have many serious pests other than powdery mildew.



Unnamed oakleaf hydrangea crosses from Dr. Sandra Reed's breeding program in McMinnville, TN.

Introduction and Select Cultivars

Hydrangeas are summer-flowering shrubs that have experienced a tremendous surge in popularity during the past decade. In 2007, hydrangea sales were \$73,205,000 (USDA, 2009), a threefold increase since 1997. Hydrangeas were the second most popular deciduous shrub following rose in the census. Several species are cultivated worldwide, but the most popular in the U.S. are *Hydrangea*

macrophylla, *H. arborescens*, *H. paniculata*, and *H. quercifolia*.

The following tables feature descriptions and limited cultural information for some the most popular selections. Much of this information is applicable to the landscape.

Hydrangea arborescens, Smooth Hydrangea

Table 3.1. Smooth hydrangea selections.

NAME	DESCRIPTION
'Annabelle'	Corymbs are 8 inches across and are held more upright than some older selections. Flowers are white and mature to an apple green color. In spite of having stronger stems than some selections, the stems are not substantial enough especially during storms, and plants often must be staked even in production. 'Annabelle' blooms 2 weeks later than 'Grandiflora'.
'Grandiflora'	Corymbs are 6-8 inches across with mainly sterile, white flowers. The surface of the corymb is a somewhat knobby or globular, not uniform. 'Grandiflora' can sucker 10-20 feet across. 'Grandiflora' was found growing wild in Ohio in the late 1800s.
Incrediball®	Corymbs are globular shaped, 12 inches across, the largest of any readily available selection. Stems are quite sturdy and do not droop under wet, stormy conditions. Incrediball® has been extremely precocious in UT landscapes with plants as minimal as a single stalk supporting a gigantic corymb.
Invincibelle® Spirit	A recent release with 6" wide pink corymbs, one of the more commercially available pink selections of smooth hydrangea.



Incrediball® (left) and *Invincibelle® Spirit* (right). Photo credit: A. Pulte.

Smooth hydrangea *Incrediball®* (center and right)



Hydrangea macrophylla,
Lacecap form



Table 3.2. Lacecap bigleaf hydrangea selections.

NAME	DESCRIPTION
'Blaumeise'	Considered the hardiest of the "Teller Series" lacecaps. Sterile flowers are much larger and showier than in other lacecaps. Beautiful pure blue color in acidic soil. Other members of the Teller Series are 'Fasan', 'Libelle', 'Kardinal', and 'Taube'. These cultivars are often marketed as 'Teller Blue', 'Teller Red', 'Teller Pink', etc. Most Teller Series are not considered very cold hardy.
'Blue Bird'	Commonly available. Looks great planted at edge of woodland. Fairly reliable flowering.
'Blue Wave'	Commonly available. Performs very poorly following late spring freezes.
'Coerulea'	More tolerant to late spring freezes than most cultivars. Attractive flowers. May be difficult to find.
'Lady in Red'	'Lady in Red' has red stems. In Knoxville, considerable dieback, but plants were growing vigorously, covering the dead stems.
'Lemon Wave'	Green, yellow, and white variegated foliage. Attractive even without flowering.
'Mariesii Variegata'	Green and white variegated foliage. Attractive even when flowers are destroyed by cold weather. 1-25% of surface with mildew (Dirr, 2004).
'Sister Therese'	White-flowered cultivar. Not considered to be very cold-hardy.

Powdery mildew resistance from Dirr, M. 2004. *Hydrangeas for American Gardens*, Timber Press, Portland, OR



Hydrangea macrophylla, Mophead form



Table 3.3. Mophead bigleaf hydrangea selections.

NAME	DESCRIPTION
'All Summer Beauty'	One of the most reliable mophead cultivars. Continues to produce a few flowers throughout the summer. Good blue color in acidic soil. Very mildew susceptible (Dirr, 2004).
'Alpengluhen'	Also sold as 'Glowing Embers'. Attractive, dark green foliage. Thick, sturdy stems. Not suitable for low pH soils. Susceptible to damage from late spring freezes. Mildly mildew susceptible, 1-25% of leaf surface affected (Dirr, 2004).
'Blue Billow'	Small plant with coarse foliage. Leaves burn in sun. Blooms moderately well.
'Dooley'	Cultivar from the University of Georgia. Reported to flower well even following late spring freezes. Large blue mophead flowers. Very mildew susceptible (Dirr, 2004).
'Endless Summer'	Non-stop flowering, even after spring freezes. Small plant with mophead flowers.
'Lemon Zest'	Lime green foliage and pink mophead flowers. Unusual contrast. Attractive even without flowering.
'Mme Emile Mouillere'	White-flowered mophead. Large plant, slender stems. May re-flower in fall. Moderately mildew susceptible (Dirr, 2004).
'Nikko Blue'	Most commonly available cultivar. Large blue mophead flowers. One of the most reliably flowering cultivars. May re-flower in fall. Extremely mildew susceptible (Dirr, 2004).
'Penny Mac'	Reported to flower well even following spring freezes. Attractive blue- to pink-flowered mophead.
'Nigra'	Black stems. Light green foliage and large mophead flowers.
'Pia'	Rarely exceeds 2 feet in height. Produces small, bright pink mophead inflorescences throughout the summer. Very susceptible to cercospora leaf spot; mildly susceptible to powdery mildew, 1-25% of leaf surface affected (Dirr, 2004). Leaves scorch in sun. Should not be planted in low pH soil.
'Preziosa'	Putative <i>macrophylla</i> and subsp. <i>serrata</i> hybrid. Small mophead inflorescences open white then gradually age to bright fluorescent pink. Not very cold hardy, but very attractive and unusual. Very mildew susceptible (Dirr, 2004).

Hydrangea paniculata, Hardy Hydrangea



Limelight (Left), Little Lime™ (Center)



Quick Fire® (Right)

Table 3.4. Hardy hydrangea selections.

NAME	DESCRIPTION
'Grandiflora'	Approximately 10 years ago, this was the primary selection in production. 'Grandiflora' inflorescence are massive, as large as 18 inches long and 12 wide at the base of the panicle. Panicles are composed nearly entirely of the large sterile flowers with sepals. Sepals often turn a pink to pinkish purple color as flowers age although that can be dependent on temperature.
'Limelight'	'Limelight' is probably the hardy hydrangea selection currently produced in the greatest quantity in Tennessee. 'Limelight' has a soft white inflorescence, primarily sterile flowers. Blooms not as large as some selections. Stems bow with the inflorescence during production in a graceful arch. Plants usually do not splay open under the weight of flowers during production. Plants can grow 6-10 feet tall and 4-5 feet wide in a mounded form. 'Limelight' shows well in a container; flowers are profuse and borne are young plants.
Little Lime™	Little Lime™ is a smaller version of 'Limelight'. Reported to not fill a small container as well or as attractively as 'Limelight' when a young plant (A. Pulte, personal communication). In our studies, 2 1/4 liners planted into a 3 gallon container finished by 4-5 months with medium rate controlled release fertilizer and daily irrigation when no rain.
'Phantom'	Poised to become the most popular <i>H. paniculata</i> . Huge inflorescence, bloom earlier, last longer than 'Limelight', stronger stems.
Quick Fire®	Blooms earlier than most hardy hydrangea, from mid to late May through late June in Middle Tennessee. Bloom period does overlap somewhat with 'Limelight'. Sepals open white, turn pink, and age to dark red. Inflorescence are open and airy with showy, large sepals, unlike the densely packed inflorescence of 'Limelight' or Little Lime™.

Hydrangea quercifolia, Oakleaf Hydrangea



unknown oakleaf hydrangea



'Snowflake' oakleaf hydrangea



Little Honey™ photo credit Jason Reeves



'Alice' oakleaf hydrangea

Table 3.5. Oakleaf hydrangea selections.

NAME	DESCRIPTION
'Alice'	Large plant, 12 feet by 12 feet. The inflorescence can be 10-14 inches and mature to a pink rose color. Fall foliage is a deep burgundy red. 'Alice' is a faster grower in container and field production than Snow Queen™ (R. Nunely, personal communication).
'Alison'	Slightly smaller than 'Alice' and with more upright panicles. Fall foliage turns a fluorescent burgundy red.
Little Honey™	Little Honey™ is a sport of 'Pee Wee' with golden, yellow-green leaves. Little Honey™ produces 4-5 inch long inflorescence early in the season but succumbs to heat. The foliage color can be used in dramatic combinations with other plants. Dirr reports the lime green color is lost in the shade. Orange-red fall color.
'Munchkin'	'Munchkin' oakleaf hydrangea is compact, growing to 3 feet tall and 4.5 feet wide after 9 years. Flowers are 6.5 inches long, stems support flowers upright, over the foliage. Like 'Ruby Slippers', fall color is a deep mahogany red. Breeder: Dr. Sandra Reed, USDA.
'Pee Wee'	Compact plant, only grows to 3 feet by 3 feet. Good plant for small gardens.
'Ruby Slippers'	'Ruby Slippers' is a smaller oakleaf hydrangea growing to 3.5 feet tall and 5 feet wide after 7 years. Flowers are 9 inches long and open white, turn to red. Fall color is a deep mahogany red. Bred in McMinnville, TN by Dr. Sandra Reed, USDA.
'Sikes Dwarf'	Compact plant, but probably will mature larger than 'Pee Wee'.
'Snowflake'	Double-flowered form. Long panicles often droop to the ground, more graceful than 'Roanoke' or 'Harmony'. Very attractive plant.
Snow Queen™	Probably the most popular cultivar. Panicles are 6-8 inches long and held upright. The sterile flowers are larger and more numerous, giving the inflorescence a more dense solid appearance. Flowers age to a medium pink. Leaves are dark green, turning dark red in the fall. Dirr (2009) reports Snow Queen™ tolerates full sun better than seedlings and no damage at -22F.

• Section 2 •

Highlights

1. Propagating hydrangea is generally easy by seed or cutting.
2. Softwood or semi-hardwood cuttings are best, depending on species.
3. Mist and rooting hormone generally improve rooting percentage or hasten rooting.
4. K-IBA became unavailable just prior to printing this document.
5. Propagators should experiment with safe K-IBA alternatives.



Oakleaf hydrangea propagation beds

Propagation

Seed Propagation

Seed propagation is desirable when looking for novel characteristics such as flower color. Seeds are collected in the late fall through winter by shaking the dried flower into a bag. No stratification is needed; remove chaff and sow. Seeds are sown on the surface of a seed germination medium that is maintained at 70 F.

Mist or otherwise keep evenly moist. Seeds germinate by 30 days. Will flower 1st or 2nd year (adapted from Dirr, 2004).

The chapter "Field Production of Deciduous Flowering Shrubs" has general information on cutting propagation. Table 3.6 contains cutting information for common hydrangea species.

Table 3.6. Cutting propagation of select *Hydrangea* species.

SCIENTIFIC NAME	COMMON NAME	DIFFICULTY ROOTING	TYPE OF CUTTING	ROOTING HORMONE	CONCENTRATION (PPM)	NOTES
<i>Hydrangea arborescens</i>	Smooth Hydrangea	Easy, 100% in 10-14 days ²	softwood ²	K-IBA ²	1000 ²	Has delicate leaves; extra care should be taken ⁷
<i>Hydrangea macrophylla</i>	Bigleaf Hydrangea	Easy, 10-14 days in 3 perlite:1 peat; nearly 100% without rooting hormone ²	softwood ²	K-IBA ²	1000 ²	6-8" long hardwood cuttings collected in January, direct stuck outdoors in pine bark substrate, rooted at 80% ⁷ ; 95% direct in vivo rooting with 5000 K-IBA, acclimatized and well-established <i>in vitro</i> plants produced in 3 weeks ⁶
		1, 2, and 3 node cuttings rooted at 88% ⁴	semi-hardwood ⁴	K-IBA ⁴	500-1500 5 second dip ⁴	
<i>Hydrangea paniculata</i>	Hardy Hydrangea	Root readily in sand:peat in 30-35 days ²	softwood ²	K-IBA quick-dip ²	1000 ² /5000 ⁷	Can root as late as September ²
<i>Hydrangea quercifolia</i>	Oakleaf Hydrangea	Easy to root, well-drained medium: 3 perlite:1 peat or 100% perlite ²	semi-hardwood ²	K-IBA ² /IBA ³	5000 ² /2500 ³	<i>in vitro</i> is used for some popular cultivars, <i>in vitro</i> increased branches, quality, symmetrical shape ⁵ ; too much moisture detrimental ² ; newly rooted cuttings may have trouble surviving the first winter.

General Notes: In general, collecting softwood cuttings earlier, May vs. July, yields more robust cuttings that grow larger faster, ready for transplanting sooner⁷. Single node cuttings are sufficient and allow for more cuttings per length of stem⁷. Cut leaves in half to reduce mist shadow.

All information from Hartmann and Kester's plant propagation: Principles and practices, 8th edition, Prentice Hall, unless otherwise noted.

¹Raulston, J.C. 1995. Propagation guide for woody plants in the NCSU Arboretum. NCSU Arboretum, Raleigh, NC.

²Dirr, M. 2009. Manual of woody landscape plants. Stipes, Champaign, IL.

³The International Plant Propagators' Society combined proceedings, various years.

⁴Paul, T.M. and A.Q. Jhon. Influence of node number and IBA treatments on rooting of *Hydrangea macrophylla* (Thunb.) cuttings. 1992. Advances in Plant Sciences. 5:619-622.

⁵Fulcher, A. 2008. Effect of plant growth regulators on growth of tissue culture and cutting-produced *Hydrangea quercifolia* 'Alice'. Proc. International Plant Propagators' Society. 58:175-181.

⁶Ruffoni, B., S. Ermanno, and M. Savona. 2013. In vitro propagation of *Hydrangea* spp. Methods in Molecular Biology. 11013:231-44. DOI: 10.1007/978-1-62703-074-8_18.

⁷Dirr, M. 2004. Hydrangeas for American gardens. Timber Press. Portland, OR.

[†]Note: K-IBA became unavailable just prior to printing this document. Propagators should experiment with substitutes to identify the type and concentration that best replaces K-IBA in their propagation system.

• Section 3 •

Highlights

1. Hydrangeas are generally easy to grow.
2. PGRs or multiple prunings are required during production and must be carefully timed to ensure plants are in flower when marketed.
3. To produce bigleaf hydrangea with blue flowers (sepals) aluminum sulfate must be added to container crops as a drench or substrate amendment.
4. Overwatering hydrangea is possible. Oakleaf hydrangea is the least tolerant of these 4 species to excess moisture.



Production

Hydrangea arborescens — Smooth Hydrangea

Smooth hydrangea is native to deciduous woodland of the Eastern U.S. and into Canada. It is hardy from USDA hardiness zone 3 to 9. In natural stands smooth hydrangea can form

thickets from suckering outward. In maintained landscapes it has a mounded growth habit, 3 to 5 feet in height and spread. The stems are often not branched and can be stiff but weak and insufficient to support the large, heavy flowers, called corymbs. Smooth hydrangea will grow well in full sun, especially further north, with ample moisture but does best in partial shade. It



Hydrangea grow fastest with ample moisture and may require irrigation.

is more tolerant of alkaline soils than *H. macrophylla* but like *H. macrophylla* prefers consistent moisture and a soil enriched with organic matter (Dirr, 2004). Unlike *H. macrophylla*, it reliably flowers from Florida to Canada. Leaves (immature and mature) are more frost tolerant than those of *H. macrophylla* and *H. serrata* (Dirr, 2004). Fall color is often brown but some years a clear yellow.

Smooth hydrangea bears large, white corymbs at the shoot terminals in mid-June for 6-8 weeks. Inflorescences of native populations consist primarily of small fertile flowers with a few large sterile flowers and thus may not be ideal for breeding stock. Flowers can be so large that they often must be staked to support them during wind and rain.



'Annabelle' staked during production to support flowers; PGR applications may have prevented the need to stake.

Container Production

Rooted cuttings can go in a 1 or 3 gallon container. Containers should be well spaced to support branch development and lateral growth. Placing 3 gallon plants on 2 ft spacing is appropriate. A 3 gallon container can be bumped to a 5 gallon, which is about the largest size of hydrangea that is typically marketed.

Daminozide (B-Nine®) at 5,000-7,000 ppm is used during the production of Invincibelle® Spirit¹. A minimum of three foliar applications approximately 10-20 days apart are typically applied beginning when the plants are small. Drenches are not recommended. Plants that are already at the market dictated

¹Adapted from. Anonymous. 2010. How to apply PGRs to the Invincibelle® Spirit hydrangea. Spring Meadow Nursery. Grand Haven, MI.

height are not good candidates for PGRs. It is not advised to prune before application. When the leaves in the apical meristem begin to point upward, the plants are growing out of the application. When the leaves lay flat, the PGR is active. As with all PGR applications, the environmental and cultural conditions: fertilizer levels, light, humidity, and temperature can impact the efficacy of the PGR.

Hydrangea macrophylla - Bigleaf Hydrangea

Bigleaf hydrangea is native to Japan and Korea. Plants usually grow to 3 to 6 feet in height, but can grow to 10 feet with width becoming equal to or greater than plant height. There are over 500 named cultivars reported in existence. Bigleaf hydrangea is considered hardy in USDA Hardiness Zones 6 to 9. Many cultivars are not hardy, and thus, cultivar selection must be made carefully. Nearly all are considered to have the ability to change bloom color based on soil pH. There are also a few white-flowered cultivars whose flowers may turn very pale pink or blue as they age. Plants are grown for the landscape and florist markets and are generally produced in containers. Commercial greenhouse growers force *H. macrophylla* into bloom for Easter and Mother's Day in Tennessee.

Two botanical groups of *H. macrophylla* are recognized. Mopheads or hortensias have large round corymbs consisting primarily of large, sterile flowers. Lacecaps have inflorescence consisting of an outer ring of large sterile flowers and an inner ring of small fertile flowers.

H. serrata, mountain hydrangea, was previously listed as a subspecies of *H. macrophylla*. Members of this subspecies have smaller leaves and flowers than *H. macrophylla* cultivars, and foliage may develop some red coloration in fall. Their inflorescences are generally of the lacecap type. Mountain hydrangea is reported to be more susceptible to powdery mildew than bigleaf hydrangea. Dirr (2009) reports it as less vigorous than bigleaf hydrangea in Georgia plantings.

Cold injury to the flower buds and improper pruning are the usual reasons for flower failure. These hydrangeas form flower buds during the fall months. Because they bloom on last year's wood, they are very susceptible to low temperature injury. When they freeze back, the blooms are lost for the year and the only benefit is the foliage. In Tennessee and Kentucky, wildly fluctuating temperatures in fall and spring probably do more damage to *H. macrophylla* floral display than do low winter temperatures. Reduced flower initiation was linked to root restriction in container production (Yeh and Chiang, 2001). Some selections may continue to produce flowers throughout the growing season. Remontant is the term used to denote a plant that has a repeat bloom period.

H. macrophylla require a lot of water and are generally sensitive to herbicides. In a study with a variety of mulches (geotextile discs, coco discs, plastic discs, hazelnut shells, sawdust, Biotop, and crumb rubber) applied to container grown plants to control weeds and reduce substrate evaporation, there was no appreciable differences in water use of mulched and non-mulched 'Fasan' and 'Endless Summer' (Altland and Lanthier, 2007). However,

hydrangea growth quality and foliar color were better when fertilizer was placed under the mulch. Drenches of synthetic ABA increased the days between irrigation before wilting and increased with increasing concentration to 1000 ppm (van Iersel et al., 2009).

H. macrophylla growth can become rank and require multiple prunings per season (Midcap, 2004). PGRs are often used in nursery production to control growth and are nearly always used in florist hydrangea production. PGR efficacy can vary with production system and environmental conditions and often varies by plant selection. Care should be taken when using PGRs as residual effects may be seen on florist type hydrangea the following season. Bailey and Clark (1992) tested three PGRs and found that summer PGR applications the year before spring forcing reduced flower size and plant height.

Low phosphorus levels have the potential to prevent excessive algae growth in reclaimed water and have the added benefit of conserving a natural resource. Phosphorus levels of just 0.29 pounds P_2O_5/yd^3 were sufficient to produce desired growth and quality. Rates as high as 0.53 P_2O_5/yd^3 are commonly used and appear to be excessive. See Flower Color Management Section.

Yellow foliage, chlorosis, and weak root systems commonly occur during nursery production of *H. macrophylla*, particularly in midsummer. This problem has been attributed to overwatering, root rot, and low iron uptake (Midcap 2004; Midcap and Bilderback, 2002). A composted bark, mini nugget substrate with

desirable physical properties (air space 39%, container capacity 53%, available water 21%, unavailable water 32%, bulk density 0.2 g/cm^3 , and cation exchange 8.1) produced the best growth of five different substrates tested for 1 and 3 gallon plants (Midcap and Bilderback, 2002). The 9:1 bark to kaolin clay substrate supported the least growth.

Flower Color Management

Bigleaf hydrangea is popular in part because some cultivars have blue flowers (sepals), and flower color can be manipulated to produce a range of colors from pink to lavender to blue. A few cultivars do not produce blue flowers, regardless of pH. Both pink and blue flowers have market appeal. The color is determined by aluminum availability, which in turn is based on the soil pH. When the soil/substrate pH is acidic (4.5 – 5.5), the color can be expected to be blue because aluminum is generally highly available in a low pH. A soil/substrate pH of 6.5 to 7.0 results in a pink flower color. When the soil/substrate pH ranges from 5.5 to 6.5, flowers may be pink, blue or lavender, or a mixture of pink and blue flowers may be present on the same plant.

The flower color is not permanent. The color will ultimately be dependent on the soil pH of the landscape into which they are eventually planted. There are a few cultivars, such as 'Pia', 'Masja' (McNiel et al., 2007), 'Alpengluhen' ('Glowing Embers'), and 'Todi', which do not turn blue or have several colors on an individual inflorescence. At a low pH, these flowers may turn an unattractive muddy-red.

Flower Color Management in Containers:

Nursery growers report they sell on average 10 blue hydrangeas for every pink one, so controlling the color is crucial. To produce a blue flowered bigleaf hydrangea in containers, the pH must be managed very closely to ensure Al remains available as there are several variables that can influence substrate pH. Potential variables that must be considered in managing substrate pH include substrate components, amount of lime in the substrate, how long ago the plants were potted, the quality of irrigation water, the amount of rainfall and irrigation to which the plants have been exposed, and the source and rate of fertilizer. Testing the water supply is necessary to gain the necessary information on pH and alkalinity. The Virginia Tech Extraction Method is a monitoring technique that growers can use to ensure that their plants are growing at the necessary pH to produce the desired flower color (Yeager et al., 2000); a step-by-step illustrated guide is at the following link (LeBude and Bilderback, 2009). <http://www.nurserycropscience.info/nutrition/equipment-to-monitor-fertility/containers/ag-717wawa.pdf/view>

The addition of aluminum sulfate to the substrate is likely required as soilless substrates have little or no aluminum. Sulfate lowers the pH, making the aluminum in the aluminum sulfate available. If the substrate pH is higher than 5.5, apply aluminum sulfate before the flower buds form in order to increase the blueness of the flower color. Too much aluminum can damage or kill roots resulting in plant stunting, leaves dropping, and smaller flowers aborting. Plant death can also occur, therefore use of aluminum sulfate must be done carefully and on a small scale until the grower becomes

familiar with how the plants will respond in their individual production system.

Blom and Piott (1992) examined flower color of *H. macrophylla* forced into bloom in greenhouse production and determined that 13.3 g or approximately 0.5 ounce of aluminum sulfate per 6" diameter container was needed. As a rough guide of application rates to begin with when experimenting with aluminum sulfate, apply 1 tablespoon of aluminum sulfate per #3 container. Make applications in early May and again 2 weeks later. Repeated drenches are a common strategy to deliver Al but are labor intensive. Drenches must be repeated because the container substrate will not retain the Al. Too much phosphorus can make the aluminum less available.

Not only can too much aluminum damage crops but so can too low of pH. Alternatives to drenching with aluminum sulfate exist and may be less labor intensive. Handreck (1997) found that including 10% (v/v) Kaolite, a calcined clay mineral, in the potting substrate increased Al and sepal blueness. Plants grown in 10-20% Zeolite precharged with Al as the only source of Al produced blue sepals (Opena and Williams, 2002). Growth was reduced at 30-40% Zeolite. Calcined clay may provide a mechanism for delivering Al to the crop with less risk of subjecting plants to an extremely low pH. Adding pozzolan clay, a calcined clay, and aluminum sulfate supported blue sepals even at higher pHs (Stoven and Owen, 2008). Increasing levels of pozzolan and aluminum increased blue color and consumer desirability ratings, both of which were best when aluminum sulfate and pozzolan were used in combination.

Field Production

Most Tennessee producers buy their liners from propagators rather than root their own. They will be 4-6 inches tall when lined out.

Bigleaf hydrangeas can be grown on less than the best soils. Select a site where water never stands. Hydrangea benefit from supplemental water during dry periods and from shade. When the temperature is in the high 80s or higher, plants in full sun can wilt, even when provided with adequate moisture.

Flower Color Management in Field Production:

As opposed to soilless substrates used in container production, mineral soils normally have sufficient levels of aluminum. Therefore, elemental sulfur rather than aluminum sulfate is recommended. The sulfur is necessary to lower the pH to 4.5-5.5 so that the naturally occurring aluminum is available to plants. Because aluminum can become toxic at a low pH, additional aluminum as would be supplied by aluminum sulfate is not desirable. Before planting any crop or adjusting the pH, a soil test is necessary. Field-grown bigleaf hydrangeas can be induced to bloom blue by lowering the soil pH with 90% sulfur several months in advance of bud set (6 months if the pH is high). However, lowering the pH rapidly with a large amount of sulfur can cause the soil pH to go below 4. Roots can be damaged or die at a pH of 4.

Hydrangea paniculata — Hardy Hydrangea

Hardy hydrangea is native to Japan and eastern and southern China. It is cold hardy to USDA hardiness zone 4, making it one of the most cold hardy hydrangea species. Hardy hydrangea can grow

to 10 to 20 feet in height and spread and can even be trained as a small tree. Some selections have a very coarse texture making them somewhat difficult to place in the landscape but very easy to grow. Most newer cultivars do not grow as large as the species and have a more refined texture. With the introduction of the cultivar 'Limelight', hardy hydrangea became an even more popular landscape plant.

Hardy hydrangea can grow under full sun to light shade, is pH adaptable, but prefers good drainage. It can tolerate urban environments and drier soil conditions (once established) better than most other major hydrangeas included in this document but will wilt during drought and high temperatures (Dirr, 2004).

Hardy hydrangea flowers in mid-to late-summer, usually in beginning in mid-July in Tennessee and can last until September. The inflorescence are large panicles, 6 to 18 inches long, that contain both fertile and sterile flowers. The flowers often cause the branches to bow over in a graceful arch when in container production (Dirr, 2004). Flowers open white and often age to a pale to medium pink; however, the change to pink is more consistent in cooler climates and even cultivars that promote aging to pinkish purple colors may not do so in Tennessee. Weather conditions greatly impact the life of the inflorescence. Dirr (2004) reports inflorescence being longer lasting and sepals not browning as rapidly in cooler climates. Irrigation can lead to earlier flowering by about 10 days for those cultivars that responded to irrigation: 'Kyushu', 'Tardiva', and 'White Moth' (Dunwell et al., 2001) and pruning practices can increase affect flower size (Dirr,

2004), although in replicated studies, hand pruned 'Limelight' and Little Lime™ in 3 gallon containers had fewer and smaller flowers than water and PGR-treated plants (Cochran and Fulcher, 2013; Cochran et al., 2013). The difference between these results and those observed in the landscape may be the greater carbohydrate reserves in the established landscape plants compared to a young, container-grown plant.

Container Production

Hardy hydrangea is the most vigorous species discussed in this document. Medium rates of fertilizer are sufficient. A 2 1/4 inch liner will finish a 3 gallon container by 4-5 months. Minimal care is needed while in production. Pruning twice a season and/or PGRs are typically used in an effort to increase branch number, flowers, and plant density – see section on use of PGRs. Hardy hydrangea requires ample water while in container production. In a non-scientific study, consumers preferred more but smaller flowers when compared to plants with fewer but much larger inflorescence. It can be produced in full sun in Tennessee.

Hydrangea quercifolia — Oakleaf Hydrangea

Oakleaf hydrangea is native to southeastern US and is hardy to USDA cold hardiness zone 5. Most cultivars reach 6 to 8 feet in height. Plant spread is greater than height as plants sucker from roots. Like most hydrangeas, oakleaf hydrangea benefits from light shade in the landscape but will tolerate full sun if given ample moisture. They are subject to root rot if placed in poorly drained soil or over-irrigated during production. Oakleaf hydrangea

flowers early to mid-summer. Flowers are large, white to cream-colored panicles that turn pink to rose as they age. Inflorescences are composed of a mixture of large sterile and small fertile flowers.

Container Production of Oakleaf Hydrangea

Oakleaf hydrangea is not easy to grow in a container. The following production schedule has been used successfully: Plant seeds into trays in September-November. Transplant into 36 inch cell pack/flats when the seedlings develop the second pair of true leaves (use a small, dull knife blade to lift the seedlings tenderly). Keep seedlings on the dry side. Transplant seedlings into jumbo 5" pots; pinch the top two nodes to force branching. Transplant to #3 containers when the roots fill the containers. Prune any vigorous lateral branches that are stimulated after the pinching.

The above procedure will produce plants that will be attractive in a #3 container by April 20 but will not be large enough to sell. Number 1 containers could be ready to sell by late April if the seedlings go into #1's from the 36 cell pack and if they are grown with heat in a greenhouse all winter. It is not suggested to transplant the seedling straight into a #1 container or the 36-cell pack straight to a #3 because the small plants can stay too wet and develop root rot.

In studies at the UT campus in Knoxville, 4 inch 'Alice' liners (rooted cuttings) transplanted into a 3 gallon container were ready for retail sales by 4 months. Plants tolerate full sun in production.

Cole et al. (2013) report dieback after shearing, and this has been observed in Tennessee. It was not clear if dieback was because the plants were using much less water than other plants in the irrigation zone and were over watered or some other cause. Oakleaf hydrangea appears to be the least “water loving” hydrangea species commonly grown. Growers sometimes use air pruning containers on this species to try to ensure plants do not stay overly wet. This can be an especially helpful technique when oakleaf hydrangea must be grouped in an irrigation zone with other plants that require more water. To conserve water, plants are produced in the same irrigation zone as plants with similar water needs or in their own zone.

General Production and Harvesting

Fertility

Hydrangeas grow best with a soil pH of 5.0 – 6.5. A medium level of phosphorus and potassium is generally desirable. However, for *H. macropylla*, lower phosphorus is desirable as it ties up aluminum even at lower pHs. Specialty fertilizers are available from Harrell’s and other companies for blue hydrangeas. Soil test early enough so that any lime, phosphate, or potash can be broadcast prior to planting. Signs of iron deficiency may show at a higher pH. If so, soil test. Contact the UT Soil, Plant, and Pest Center or a nursery specialist with the Cooperative Extension Service to determine the best course of action.

The normal UT Extension recommendation for all shrubs is no more than 50 pounds of actual nitrogen per acre applied in late February and again in late June. It is not always economical to broadcast fertilizer after the crop is planted. The per acre rate can be used for sidedressing, whether done by machine or hand. See Table 3.7 to determine the pounds of fertilizer required to achieve 50 pounds of actual nitrogen for different fertilizers.

During container production, medium to high rates of fertilizer are often used. Be careful of excessively high rates of nitrogen, which can lead to excessive foliage at the expense of flowers.

Table 3.7. Fertilizer weight corresponding to 50 pounds of actual nitrogen per acre of root zone.

POUNDS OF FERTILIZER	FERTILIZER ANALYSIS
150	34-0-0
250	20-10-10
333	15-15-15
385	13-13-13

¹Nursery crops generally use a 3-1-2 ratio of nitrogen, phosphorus and potassium. Using a high phosphorus rate over-applies phosphorus and can prevent aluminum uptake. This wastes phosphorus and may interfere with development of blue sepals. Currently, phosphorus mines are expected to be depleted in as little as 50 years.

Field Spacing

Spacing examples of plants on 1 solid acre are shown in Table 3.8.

Table 3.8. Plant populations on a solid acre, no roads.

3 x 4 = 3,630	3.5 x 4 = 3,112	4 x 4 = 2,723
3 x 4.5 = 3,227	3.5 x 4.5 = 2,766	4 x 4.5 = 2,420
3 x 5 = 2,904	3.5 x 5 = 2,489	4 x 5 = 2,178
3 x 5.5 = 2,640	3.5 x 5.5 = 2,281	4 x 5.5 = 1,980
3 x 6 = 2,420	3.5 x 6 = 2,074	4 x 6 = 1,615
3 x 7 = 2,074	3.5 x 7 = 1,778	4 x 7 = 1,556

Carefully consider the number of rows per block as the more rows there are the more difficult it may be for pesticide applications to penetrate the interior of the block. Use water sensitive paper to verify adequate spray penetration. Remember to leave a 12 to 20 foot roadway between blocks from which to load and spray with an air-assisted sprayer.

Harvesting

Hydrangeas are commonly sold when they are 24-48 inches tall. Field-grown hydrangeas are generally a 3 year crop, depending on species, soil type, fertility, moisture, growth rate, pruning, etc.

Digging the Correct Size Ball

The American Standard for Nursery Stock ANSI code was written by the American Nursery & Landscape Association (ANLA). The standards establish techniques for measuring plants and minimum

rootball sizes for particular plant sizes and different plant types. A copy of the standards may be viewed and printed from this link for free: <http://www.anla.org/docs/About%20ANLA/Industry%20Resources/ANLAStandard2004.pdf>.

Producers are not legally bound to follow the ANLA standards, but it is a good business practice and reduces miscommunication and dissatisfied customers.

A portion of the ANSI code is presented below in Table 3.9. Refer to the standards for complete information. Intermediate type 2 deciduous shrubs are defined on page 26 as plants that typically mature at a height or spread from 3 feet up to 7 feet.

Table 3.9. Minimum ball sizes of type 2 deciduous shrubs.

HEIGHT (FEET)	MINIMUM DIAMETER BALL (INCHES)
3	14
4	18
5	24

• Section 4 •

Highlights

1. Hydrangeas are relatively pest free plants but powdery mildew, a disease, can be a severe problem.
2. Growing resistant plants is a basic step in IPM.
3. Consider growing selections that are resistant to powdery mildew when possible.
4. A new pest that has been spotted on *H. paniculata* is redheaded flea beetle.
5. Creating cultural conditions that favor plant growth and hinder pest growth will help keep plants stress and pest free.

Integrated Pest Management (IPM)

IPM helps prevent, detect, and manage pest problems before they cause extensive economic damage and/or plant loss while avoiding the economic costs and human and environmental health risks of frequent calendar-based pesticide applications. IPM is a way of managing pests that allocates time and resources toward controlling destructive pests only. The basic steps in an IPM program follow:

1. Prevention: Inspect and quarantine new plants, use proper sanitation, rotate crops,



A leaf spot disease on oakleaf hydrangea.

- preserve biological diversity, select plants with pest resistance, proper site selection.
2. Monitor: Frequently scout for pests on plants, monitor insect traps, monitor crop nutrient and pH levels.
3. Pest Identification: Identify the pest, understand its biology and life cycle.
4. Determine if the action threshold has been met--critical number of pests are present.
5. Control: Implement the most appropriate control, start with the least toxic option such as

biological controls and low toxicity pesticides before utilizing more toxic pesticides.

By using IPM, human and environmental risks can be minimized, pesticide costs reduced, plant quality increased, culls reduced, and money saved (Fulcher, 2012).

Hydrangea Pests

Hydrangeas are generally pest resistant plants. Powdery mildew and fungal leaf spots are the most common pests. See the tables in chapter 1 for more information about pest resistant selections.

Aphids

These are usually only a problem in greenhouses, shade houses, and on lush new growth where the aphids can distort and stunt new growth. Do not apply excess nitrogen fertilizer. Aphids are easily killed by insecticidal soap, and just being outdoors where biological control organisms occur naturally will reduce the population level. They are not a serious problem.

Bacterial blight

This disease can be a problem. Irrigate in the morning so foliage can dry. Discard dead, diseased leaves. Avoid cross contamination with shears by regular sanitization.

Botrytis blight

Occurs mainly in overwintering houses and in greenhouses. Avoid

overhead irrigation late in the day, evening, and night when flowers can remain wet.

Deer

Perdomo et al. (2004) report that deer occasionally severely damage all four species covered in this chapter. Varies with location. Others report *H. macrophylla* being regularly destroyed by deer.

Japanese beetle

Can feed on *H. paniculata* and *H. quercifolia*. It is not usually serious.

Leaf spots

These can be fungal or bacterial. It is fairly common on *H. macrophylla* and *H. quercifolia*. Diligently removing and destroying diseased leaves can help. Avoid overhead irrigation and irrigation late in the day that can permit foliage to remain wet for extended periods. *Cercospora hydrangeae* commonly mars foliage of *H. macrophylla* and is most severe in full sun.

Powdery mildew

See the Field Production of Deciduous Flowering Shrubs chapter for general powdery mildew information. The new, tender growth that is developing is most susceptible. Therefore, practices that stimulate new growth such as pruning and heavy nitrogen fertilization can encourage powdery mildew as can conditions that are conducive to pathogen proliferation such as greenhouse environments. Also, densely pruned plants and closely spaced

plants will have reduced air and light penetration into the canopy, which creates a humid microclimate within in the plant. A humid environment will favor powdery mildew development. Some *H. macrophylla* selections are highly susceptible. Look for powdery mildew resistance when selecting new cultivars. Some of the most powdery mildew resistant *H. macrophylla* include 'Veitchii', 'Lilacina', 'Lady in Red', and 'White Wave' (Dirr, 2009). See tables in section 1 of this chapter for more powdery mildew resistance information based on Dirr, 2004. Researchers in Tennessee examined 69 *H. macrophylla* and 18 *H. serrata* for disease resistance while growing under 63% shade and irrigated by spray stakes (Windham et al., 2011). Only 'Veitchii' was resistant at high levels for all 3 years.

Phytophthora root rot

Symptoms include poor growth, sudden wilting, yellowing and/or dropping leaves. Examine plants for brown roots. *H. quercifolia* is susceptible to this root rot in container production. This is the least water loving of the hydrangea species discussed in this chapter. Do not overwater and use a well-drained substrate; it is ideal to keep evenly moist but not saturated. Consider air pruning containers or a separate irrigation zone. Ensure pots are not sitting in puddles.

Rust

Rust can be a problem on *H. arborescens*, particularly 'Annabelle'. Angular, yellow lesions appear on the upper leaf surface. Yellow orange pustules are visible on the lower leaf surface. Rust can lead

to severe defoliation. Rust is generally managed with fungicide sprays.

Slugs

These are a common problem in moist, shady areas. Methiocarb and metaldehyde can be effective along with changing the production environment to make it less suitable for slugs.

Twospotted spider mite

This pest proliferates in hot, dry weather and is a problem on plants that remain in hot overwintering houses, greenhouses, or during extended dry periods outdoors. When dry conditions persist, scout in dusty areas and rows next to roadways first.

Virus

Hydrangea are susceptible to several ring spot viruses and other viruses. A relatively new virus, hydrangea chlorotic mottle virus (HCMV) causes a variety of symptoms on *H. macrophylla*. Infected leaves may be light green, have upturned tips, and become misshapen. HCMV may be spread by aphids, by pruning, and of course during propagation.

Weed Management

Several common preemergence herbicides were tested on containerized *H. macrophylla* 'Nikko Blue' (Czarnota, 2003). Barricade, Gallery, and Dimension caused the worse injury. Surflan reduced growth. Granular Ronstar was the safest but caused a reduction in plant height. Pennant was the second safest

product. The highest labeled rates were used. Overhead irrigation was turned on within 60 minutes of the application. In this trial herbicide application was linked to increased powdery mildew.

Fusilade T/O is labeled on *H. paniculata* and *H. quercifolia* but not *H. macrophylla*. Segment (formerly Vantage) is labeled for *H. macrophylla*. Envoy Plus is not labeled for any hydrangea. These herbicides are intended to kill tender, green grass.

Derr reports Broadstar, simazone (Princep), and isoxaben (Gallery, Snapshot, Showcase) can damage hydrangea.

Derksen et al. (2012) found that various over-the-top applications made to hardy hydrangea 'DVP Winky', Pinky Winky™ were blocked by the canopy with only 5-10% of the spray reaching the substrate surface.

Pesticide Recommendations

For chemical controls for insects, mites, and disease-causing pathogens, refer to the UT Insect and Plant Disease Control Manual (Redbook) <https://ag.tennessee.edu/EPP/Pages/TFS.aspx> or download the app developed by UT in collaboration with other southern universities: IPMPro at http://wiki.bugwood.org/IPMPro_app. Refer to Tables A and B: Preemergence and Postemergence-Nursery Crops under the Weed Control heading at <http://www.utextension.utk.edu/mtnpi/handouts.html> for a complete list of labeled pre and postemergence herbicides for most common woody ornamentals. For pest identification contact your

county extension office or the UT Soil, Plant, and Pest Center <http://soilplantandpest.utk.edu>. For cultural information on these and more pests, consult <http://utknurseryipm.utk.edu>.

• Section 5 •

Highlights

1. Always consider time to sale and time to bloom following pruning before removing any growth.
2. Consider whether PGRs or pruning will be more effective.
3. Remember hydrangeas bloom on the tips of branches, the more branches, the more potential for blooms.
4. Deadheading following bloom has been reported by some to enhance growth during field production.



'Hayes Starburst'

Hydrangea Pruning Guide

Pruning in the Landscape

How to prune hydrangea is one of the most common questions that arises in caring for hydrangeas in the landscape. To know when to prune, first determine on what wood the flowers

form--last year's growth or growth that will take place in the current growing season. Knowing this will help avoid pruning flowering shrubs at the wrong time of year and inadvertently removing flower buds. See also Hydrangeas as Woody Cut Stems section.

Table 3.10. Overview of hydrangea characteristics and pruning.

SCIENTIFIC & COMMON NAME	COMMON SELECTIONS	TYPICAL FLOWER COLOR	BLOOM PERIOD	GROWTH BEARING BLOOMS	WHEN TO PRUNE: PRODUCTION ¹	WHEN TO PRUNE: LANDSCAPE
<i>H. arborescens</i> Smooth Hydrangea	'Annabelle', Incrediball [®] , Invincibelle [®] Spirit	White, less commonly pink, ages to apple green	Mid-June for 6-8 weeks	New growth	Prune repeatedly to develop full growth until the spring of sales.	Pruning in winter or early spring will yield flowers the following season; if pruned immediately after flowering may re bloom.
<i>H. macrophylla</i> Bigleaf Hydrangea	Numerous	Blue, pink, less commonly white	Early-mid June, some remontant ²	Old growth, unless remontant ²	Pruning recommendations vary if container or field production (see text). Use of PGRs is common to enhance branch quality without removing flowers.	Pruning not needed except to control size. Prune right after flowering.
<i>H. paniculata</i> Hardy Hydrangea	'Limelight', Little Lime [™] , 'Phantom'	White aging to rose	Late June	New growth	Pruning during container production has led to smaller & fewer flowers, inconsistent branch response. Consider PGRs.	Pruning in winter or early spring will still yield flowers the following season.
<i>H. quercifolia</i> Oakleaf Hydrangea	Alice', Little Honey [™] , 'Munchkin', 'Ruby Slippers', Snow Queen [™]	White aging to rose	Early May-June	Old growth	Some growers deadhead to produce more vegetative growth. Prune 2-3 times a year until fall before sale.	Pruning not needed except to control size. Prune right after flowering.

¹Times given are those that are anticipated to maximize floral display. Each production system is different. Always consider time to sale and time to bloom following pruning before removing any growth. ²remontant means reblooming

Hydrangea arborescens

As alluded to by its ability to flower as far north as Alberta, Canada, smooth hydrangea flowers on new wood. Therefore, if it needs pruned, it should be pruned in late winter to early spring before it breaks dormancy. Plants may produce a second flush of flowers, if they are pruned (Birr, 2000), fertilized, and watered after the initial flowering. The flowers on the second flush are smaller. Plants do not have to be pruned, but it may make for a tidier plant. However, leaving overwintering stems or an outer ring of overwintering stems leads to thicker, stronger stems and may reduce the need for staking (Reese and Reeves, No Date). Conventional rejuvenation pruning, removing 1/3 of the older stems at ground level, can stimulate new growth increasing the floral display. Plants may flower from new growth on overwintering stems. These flowers tend to be smaller than if the previous year's stems are pruned to ground level (Dirr, 2004).

Hydrangea macrophylla

This species generally flowers on old wood, so it should not be pruned after bud set in late fall through bloom the following season or the buds will be pruned away. If drastic pruning is needed such as to reduce size do it right after flowering. Once a plant is established, it is safest to remove 1/3 of the oldest stems each year to keep the plant rejuvenated if pruning is needed at all. Remontant bloomers, those that bloom throughout the season on new growth, have more flexibility concerning pruning.

Hydrangea paniculata

Hardy hydrangea flowers on new wood so it can be pruned in winter or early spring. It doesn't have to be pruned, but pruning may lead to a tidier plant as well as more new growth and therefore more flowers. Pruning to the ground can encourage longer stems on established plants (Bir, 2000). Reece and Reeves (No Date) as well as Dirr (2004) report much larger flowers in seasons following hard pruning (and ample water and fertilization). Results differ for pruning plants in container production. Plants can be pruned immediately following blooming and may bloom again (Bir, 2000). Rejuvenation pruning, removing 1/3 of the oldest stems to ground level, can help stimulate new growth.

Hydrangea quercifolia

Oakleaf hydrangea flowers on old wood so should be pruned after flowering, if necessary. Pruning late fall through bloom time the following year will remove the buds. Oakleaf hydrangea develops an attractive peeling bark that is noticeable in the winter. Cutting 1/3 of the older stems to ground can help stimulate suckering and new growth, rejuvenating the plant.

Pruning and Other Branch-Enhancing Practices During Production

Pruning

Hydrangea arborescens

Smooth hydrangea will need pruned multiple times each season during production to produce full, densely branched plants that ultimately produce many blooms. Avoid pruning in the spring, the season of sale, as that will remove or at least delay significantly the floral display.

Hydrangea macrophylla

Field: Cut back to within 6 inches of ground in February-March after first growing season and after second growing season if not sold. Do not prune the last spring prior to harvest in order to leave the flower buds.

Container:

In a study that examined pruning at 2-3 inches above ground level (rejuvenation pruning), pruning halfway back, i.e., to the previous years' growth, and no pruning, 3 gallon bigleaf hydrangea had more blooms when pruned halfway back, 29% more than when the plants weren't pruned (Conwell et al., 2002). Bloom number for renewal pruning was not different from unpruned controls.

Hydrangea paniculata

Pruning practices can increase flower size (Dirr, 2004); although, in replicated studies hand pruned 'Limelight' and Little Lime™ in 3 gallon containers had fewer and smaller flowers than water and PGR-treated plants (Cochran and Fulcher, 2013; Cochran et al., 2013). The difference between these results and those observed in the landscape may be the greater carbohydrate reserves in the established landscape plants.

Training a Standard Form:

Panicle hydrangeas can be trained to a tree form, unlike other hydrangeas. Typically, large cultivars are selected for standard forms. This training should begin at an early age in the nursery and will require a stake. Allowing small branches to temporarily remain on the trunk will help develop caliper. Be sure to remove temporary branches regularly, before they exceed pencil size diameter. To develop the tree form, select and stake a single strong stem and remove all other competing growth. Once the stem reaches the desired height, cut it back using a heading back cut to stimulate branching. Prune out the tips of new growth repetitively to develop a dense, bushy canopy. This can be done by cutting all top growth back to the same height or pruning the topmost branches back to slightly different heights allowing the branches to emerge from a short section of the trunk rather than one point. While more time consuming, a stronger standard can be produced by the latter technique (Gilman, 2012). To maintain the tree form, remove branches that develop from the trunk several times throughout the year and cut the canopy back periodically to preserve the dense, rounded shape.

Hydrangea quercifolia

Oakleaf hydrangea can have a very undesirable, asymmetrical growth habit, with most branches lying over the side of the container. This branch architecture is highly undesirable as it takes up more space in production and transportation and doesn't display well in garden centers. In a study comparing tissue culture and cutting propagation, 'Alice' oakleaf hydrangea plants propagated by tissue culture generally had greater quality rating and more branches without pruning (Fulcher, 2008). Cutting-propagated plants needed to be pruned to achieve the same quality. As with all hydrangeas, keep plants well spaced.

Plant Growth Regulators (PGRs) and Other Branch Enhancing Techniques

PGRs typically used to induce branching among nursery crops are either ethephon, an ethylene generator, chemical pinching agents such as dikegulac sodium, DNA synthesis inhibitor, or cytokinin, a branch promoter. Other PGRs that function as growth retardants are used on florist type *H. macrophylla*.

Hydrangea macrophylla

PGRs are regularly used in the production of *H. macrophylla*. Augeo (800 and 1600 ppm) significantly increased branching compared to untreated pots of florist type *H. macrophylla* 'Merritt's Supreme' but not landscape type *H. macrophylla* 'Nikko Blue' (Hester et al., 2013). However, results were not consistent across all locations underscoring the need to conduct trials on a small scale before initiating a PGR program on a large number of plants. Benzyladenine and ethephon were not effective at inducing

branching on either cultivar. 'Leuchtfeuer' produced in white peat:composted bark (10-15 mm), 2:3 mix and subjected to a water limiting irrigation regime had reduced leaf area, height, and flower size, but quality and compactness were increased (Morel, 2001).

Hydrangea paniculata

In replicated studies, hand pruned 'Limelight' and Little Lime™ in 3 gallon containers had no different branch number compared to water controls and had fewer and smaller flowers than water and PGR-treated plants (Cochran and Fulcher, 2013; Cochran et al., 2013). In fact, pruning Little Lime™ reduced flower number by at least 78% compared with PGR treatments: benzyladenine at 300 or 600 ppm, ethephon at 500 or 1000 ppm, or dikegulac sodium (800 and 1600 ppm). Dikegulac sodium (either rate) was the only treatment that increased branch number and plant quality without reducing floral display of Little Lime™. Dikegulac sodium can cause phytotoxicity but when applied in the spring, is typically not apparent when the plants are marketed, i.e., late summer/early fall.

Hydrangea quercifolia

Gibson and Groninger (2007) found that cyclanilide¹, a chemical pinching agent, increased total branch number on seed propagated oakleaf hydrangea but it did not induce branching on 'Alice' (Fulcher, 2008). 'Ellen Huff' oakleaf hydrangea had more branches with increasing concentrations of foliar applied cyclanilide up to 200 ppm (Holland et al., 2007); quality was not enhanced at any rate. Fulcher (2008) found that in vitro propagation led to more branches and higher quality than cutting

¹The manufacturer of cyclanilide decided not to market it for this use due to inconsistent results on ornamentals.

propagation of 'Alice' and improved plant architecture and quality.

Hydrangeas as Woody Cut Stems

The large, showy inflorescence and long, rigid stems of *H. paniculata* including 'Boskoop', 'Pink Diamond', 'Unique', 'Kyushu', 'Tardiva', and 'Pee Wee' are generally well-suited to the cut flower industry. 'White Moth' was determined unsuitable as a cut flower because pruned, non-irrigated plants did not produce any blooms (Dunwell et al., 2001b). Dirr (2004) reports more *H. paniculata* flowers when plants are in full sun.

Mophead-type *H. macrophylla* are more desirable as cut flowers than lacecaps, but be aware that trends in cut flowers can vary considerably from season to season. In a Kentucky study, *H. macrophylla* pruned in the spring versus fall had more flowers (Bale et al., 2002) as did plants mulched in the fall with wood chips compared to no mulching or mulching with straw.

In a 2 year study including *H. arborescens* 'Annabelle', *H. quercifolia* 'Alice', and several *H. paniculata* cultivars, irrigated plants generally bloomed earlier or in a few cases at the same time as plants without irrigation (Dunwell et al., 2001a). 'Annabelle' was one of only two hydrangea taxa that didn't respond to rejuvenation pruning (stems removed to ground level) with more stems, longer stems, and larger inflorescence (Dunwell et al., 2001b).

A vase-life study showed that hardy hydrangea flowers will last 6 days and can tolerate long shipping periods under typical dry refrigeration conditions (Bale et al., 2002). 'Tardiva' and *H. arborescens* 'Annabelle' have a vase-life of 18 and 10 days, respectively, when no preservative is used (Leeson et al., 2008a, Leeson et al., 2008b). While not all cultivars have an extended shelf life, the authors noted that many uses for these large flowers are single day events that do not require a long shelf life such as weddings, funerals, and parties. With the use of several cultivars and pruning techniques, hardy hydrangea can be harvested from mid-July to September. Smooth hydrangea 'Annabelle' makes an excellent dried flower (Dirr, 2009).

• Section 6 •

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