PB 1840-A

# Hydrangea Production: Cultivar Selection and General Practices to Consider When Propagating and Growing Hydrangea

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This is one of two Extension publications that discusses hydrangea production. In this publication, general plant characteristics, species evaluations and general production practices are covered. Detailed information is also provided on propagation and diagnosing nutrient deficiencies. In the companion publication, "PB 1840-B Hydrangea Production: Species-Specific Production Guide," research-based production recommendations tailored by species are presented. Specific practices related to propagation, fertilization, blueing, irrigation, pruning, plant growth regulators and growth control are covered.


**Figure 1. Mophead type inflorescence of *H. macrophylla* 'Bailmer' Endless Summer.**

## INTRODUCTION

There are numerous species of deciduous and evergreen hydrangea shrubs, small trees or climbers, which include approximately 1,000 cultivars and hybrids. Many new selections are introduced annually worldwide. Hydrangea was the second most popular deciduous shrub across all horticultural markets in 2014 and was produced in more than 1,500 U.S. nurseries, with more than 10 million plants sold, accounting for 13.5 percent ($91.2 million) of total annual U.S. shrub sales ($676.6 million). Four hydrangea species are produced regularly in nursery cultivation in the southeastern and mid-Atlantic U.S. These deciduous shrub hydrangeas are selected for their showy inflorescence (flower), size, habit and disease resistance and are native to the U.S. or Asia. The species currently found in the U.S. trade includes *H. arborescens*, *H. macrophylla* (including var. *normalis* and subsp. *serrata*, which is used interchangeably with *H. serrata*), *H. paniculata*, and *H. quercifolia*.

The highly desirable floral display in hydrangea is achieved largely through abundant sterile florets that may be grouped into corymbs or panicles. Corymbs tend to be round and range from white to shades of pink, purple and blue (Figure 1). However, lacecap hydrangeas have flat to rounded inflorescences with inconspicuous fertile flowers surrounded by showy sterile florets (Figure 2). Conical panicles open from the base to the tip and continue to expand in length along the axis. Flowers are prized for their ability to change color as they age, often leading to an antiqued look. For example, *H. macrophylla* 'Blushing Bride' and *H. paniculata* Little Lime are selected for flowers that develop their color further as they mature on the plant (Figure 3). Remontant (re-flowering) selections of *H. macrophylla* bloom multiple times on the current season's growth and can be salable multiple times within a year. Most hydrangeas have soft-yellow or no fall foliage color, with the exception of *H. quercifolia* which provides a striking range of reds, oranges and deep maroon foliar hues in autumn.

**Figure 2. Lacecap type inflorescence, unknown *H. serrata* cultivar.**

**Figure 3. Little Lime hydrangea *(H. panicula-ta)* panicles open from the base and age with a pink to rose blush.**

## CULTIVAR TRIALS

A container-based plant trial of 47 *H. macrophylla* and *H. serrata* cultivars (Table 1) — as well as 18 *H. paniculata* cultivars (Table 2) — was conducted during the 2014 growing season at the Center for Applied Nursery Research in Dearing, Georgia (USDA zone 8b) (no *H. quercifolia* cultivars were trialed). The purpose of this trial was to determine the growth and flowering characteristics of commercially available hydrangea cultivars under commercial growing conditions. Five plants of each cultivar were obtained as liners, sheared to 2 inches, planted into #3 containers filled with 5/16" of aged pine bark, 2 lbs. lime/yd$^3$, 1 lb. gypsum/yd$^3$, Talstar (12 mo. Rate), 1 lb./yd$^3$ Micromax, and high rate Harrell's Custom 18-6-8 NPK+ minors fertilizer. The trial was initiated during the first week of April 2014, with first flowering data collected weekly and growth index [(Height + Width + Width / 3) – in cm$^3$] collected monthly. Foliage quality (1-5 scale [1 = disease free, healthy appearance, 2 = minor damage, but sellable appearance, 3 = moderate damage, borderline sellable condition, 4 = extensive damage, not sellable condition, 5 = all foliage is unhealthy and/or diseased]) and mortality were collected at the end of the season. No pesticides were applied to plants over the entirety of the study, and plants were irrigated with overhead impact sprinklers. *H. macrophylla* were grown under 40 percent shade.

### *Table 1. Results of a container-based plant trial of 46* H. macrophylla *and* H. serrata *cultivars*

| Species/Cultivar | First Color | 50% Bloom | Panicle Size | Flower Color | May Growth Index* | June Growth Index* | July Growth Index* | September Growth Index* | End-of-season Height | Foliage Quality ** |
|---|---|---|---|---|---|---|---|---|---|---|
| *H. macrophylla* 'All Summer Beauty' | 5/9 | 7/15 | 15 x 17 | Soft Pink | 43.0 | 62.8 | 70.1 | 76.9 | 68.6 | 3 |
| *H. macrophylla* 'Angyo Shikizaki' | 4/29 | 5/27 | 20 x 19 | Pink | 30.7 | 52.4 | 58.9 | 65.9 | 55.4 | 4 |
| *H. macrophylla* 'Beaute Vendomoise' | 5/19 | 5/27 | 27 x 26 | Soft Pink | 23.6 | 49.2 | 60.9 | 67.0 | 60.8 | 3 |
| *H. macrophylla* Bloomstruck | 5/19 | 6/17 | 15 x 15 | Dark Pink | 22.9 | 54.7 | 73.3 | 76.5 | 56.6 | 2 |
| *H. serrata* 'Bluebird' | 5/26 | 6/17 | 11 x 7 | Soft Pink | 13.6 | 31.1 | 43.3 | 52.0 | 40.2 | 3 |
| *H. macrophylla* Forever & Ever Blue Heaven | 5/19 | 6/4 | 15 x 15 | Dark Pink | 18.2 | 38.6 | 49.6 | 51.7 | 50.5 | 4 |
| *H. macrophylla* 'Blue Wave' | N/A | N/A | N/A | N/A | 8.8 | 32.5 | 49.1 | 55.5 | 51.3 | 4 |
| *H. macrophylla* Blushing Bride | 5/19 | 6/3 | 20 x 17 | White/ Pink | 17.0 | 53.7 | 75.0 | 77.7 | 73.4 | 2 |
| *H. macrophylla* 'Compacta' | 5/19 | 6/3 | 14 x 13 | Dark Pink | 17.2 | 40.1 | 57.6 | 64.5 | 77.0 | 3 |
| *H. macrophylla* 'David Ramsey' | N/A | N/A | N/A | N/A | 11.6 | 36.1 | 58.2 | 68.2 | 58.2 | 3 |
| *H. macrophylla* Dooley | N/A | 7/4 | 23 x 23 | Purp/Pink | 32.1 | 61.2 | 76.1 | 83.8 | 72.0 | 3 |
| *H. macrophylla* Bailmer Endless Summer (The Original) | 5/19 | 5/26 | 22 x 18 | Soft Pink | 21.3 | 49.4 | 56.6 | 66.0 | 60.8 | 2 |
| *H. macrophylla* 'Eva Lyon Holmes' | 4/29 | 5/19 | 18 x 18 | Pink | 24.9 | 41.7 | 59.5 | 63.0 | 49.8 | 4 |
| *H. macrophylla* Everlasting Garnet | 5/27 | 6/7 | 18 x 16 | Dark Pink | 19.0 | 47.3 | 54.9 | 56.5 | 40.4 | 4 |
| *H. macrophylla* Everlasting Noblesse | 5/15 | 6/3 | 16 x 14 | White / Pink/ Green | 17.1 | 30.1 | 48.2 | 46.8 | 42.8 | 4 |
| *H. macrophylla* Everlasting Ocean | 5/26 | 6/7 | 19 x 18 | Soft Pink | 19.2 | 43.3 | 56.4 | 54.0 | 51.2 | 4 |
| *H. macrophylla* Everlasting Revolution | 5/26 | 6/17 | 13 x 10 | Pink | 18.8 | 37.3 | 45.2 | 48.9 | 39.6 | 3 |
| *H. macrophylla* Forever & Ever | N/A | 7/15 | 15 x 13 | Pink | 12.3 | 28.9 | 35.4 | 39.4 | 35.8 | 4 |
| *H. macrophylla* Forever & Ever Red | N/A | N/A | N/A | N/A | 7.6 | 21.2 | 29.7 | 31.1 | 24.4 | 4 |

| Species/Cultivar | First Color | 50% Bloom | Panicle Size | Flower Color | May Growth Index* | June Growth Index* | July Growth Index* | September Growth Index* | End-of-season Height | Foliage Quality ** |
|---|---|---|---|---|---|---|---|---|---|---|
| *H. macrophylla* Forever & Ever Summer Lace | 5/15 | 6/4 | 13 x 12 | White | 20.1 | 39.3 | 43.3 | 42.9 | 31.8 | 4 |
| *H. macrophylla* 'Fuji Waterfall' | 6/4 | 6/18 | 19 x 18 | Soft Pink | 7.4 | 25.6 | 44.7 | 52.1 | 42.8 | 3 |
| *H. serrata* 'Grayswood' | N/A | N/A | N/A | N/A | 7.9 | 29.1 | 43.8 | 66.7 | 59.0 | 4 |
| *H. macrophylla* 'Junihitoe' | 9/2 | 9/24 | 19 x 24 | Pink | 14.5 | 40.6 | 55.9 | 62.9 | 67.6 | 3 |
| *H. macrophylla* Lady in Red | N/A | N/A | N/A | N/A | 20.7 | 60.7 | 65.3 | 82.9 | 69.2 | 3 |
| *H. macrophylla* 'Lanarth White' | N/A | 9/24 | 14 x 12 | White/ Pink | 23.0 | 53.3 | 64.0 | 67.5 | 69.0 | 2 |
| *H. macrophylla* 'Lemon Zest' | N/A | N/A | N/A | N/A | 0.0 | 7.0 | 11.0 | 17.0 | 13.0 | 4 |
| *H. macrophylla* 'Lilacina' | N/A | 5/27 | 13 x 13 | White/ Pink | 25.5 | 48.5 | 65.7 | 70.5 | 54.2 | 3 |
| *H. macrophylla* 'Merritt's Supreme' | N/A | N/A | N/A | N/A | 7.3 | 25.8 | 42.2 | 46.6 | 43.0 | 4 |
| *H. macrophylla* Midnight Dutchess | N/A | N/A | N/A | N/A | 9.4 | 35.8 | 53.6 | 64.2 | 58.0 | 3 |
| *H. macrophylla* Mini Penny | 6/17 | 7/15 | 17 x 17 | Pink | 28.3 | 53.9 | 69.1 | 72.3 | 56.8 | 3 |
| *H. macrophylla* 'Nightingale' | 5/19 | 5/27 | 18 x 18 | Med Pink | 22.8 | 46.9 | 60.7 | 67.0 | 66.2 | 3 |
| *H. macrophylla* Nigra | N/A | N/A | N/A | N/A | 7.7 | 33.0 | 51.5 | 62.2 | 63.5 | 2 |
| *H. macrophylla* 'Nikko Blue' | 6/3 | 6/15 | 11 x 11 | N/A | 17.0 | 42.8 | 61.3 | 73.2 | 64.2 | 3 |
| *H. macrophylla* 'Oamacha Variegata' | 5/15 | 5/26 | 11 x 11 | Soft Pink | 32.8 | 58.1 | 66.9 | 76.7 | 71.6 | 2 |
| *H. serrata* 'Painter's Pallett' | 7/30 | 9/2 | 17 x 15 | Pink | 16.6 | 50.7 | 71.8 | 75.1 | 75.4 | 4 |
| *H. macrophylla* 'Penny Mac' | 5/19 | 5/26 | 25 x 18 | Soft Pink | 23.6 | 55.7 | 65.1 | 72.9 | 65.8 | 3 |
| *H. macrophylla* Forever & Ever Pepperment | 5/27 | 6/4 | 15 x 13 | White/ Pink | 24.1 | 35.1 | 38.6 | 34.7 | 26.6 | 4 |
| *H. serrata* 'Preziosa' | N/A | N/A | N/A | N/A | 8.7 | 31.1 | 47.1 | 56.7 | 52.8 | 4 |
| *H. macrophylla* 'Sister Theresa' | N/A | N/A | N/A | N/A | 7.4 | 29.8 | 40.9 | 48.1 | 36.8 | 3 |
| *H. macrophylla* 'Tokyo Delight' | 5/19 | 6/4 | 17 x 15 | Soft Pink | 23.5 | 54.5 | 73.8 | 86.1 | 94.0 | 2 |
| *H. macrophylla* Twist and Shout | 5/19 | 6/17 | 15 x 15 | Pink | 15.2 | 45.9 | 56.5 | 73.9 | 60.6 | 2 |
| *H. macrophylla* 'Veitchii' | 5/19 | 5/26 | 17 x 16 | Soft Pink | 34.1 | 57.4 | 69.9 | 72.9 | 59.4 | 2 |
| *H. macrophylla* Forever & Ever White Out | 6/18 | 7/15 | 13 x 15 | White | 13.9 | 28.1 | 37.7 | 41.3 | 32.6 | 4 |
| *H. macrophylla* 'White Swan' | N/A | N/A | N/A | N/A | 5.9 | 16.9 | 29.8 | 42.1 | 32.5 | 4 |
| *H. macrophylla* Zebra | 5/27 | 6/17 | 13 x 12 | White | 11.7 | 34.2 | 46.7 | 54.3 | 47.8 | 4 |
| *H. macrophylla* Zorro | 5/27 | 6/18 | 13 x 14 | Pink | 16.1 | 39.1 | 52.9 | 64.0 | 61.6 | 3 |

All measurements are listed in centimeters.
* Growth Index in cm = (Height + Width + Width) /3
**Foliage rating:
1 = clean
2 = minor problems, but sellable state
3 = moderate, borderline sellable state
4 = extensive, not sellable state
5 = no foliage left in good condition

In *Hydrangea macrophylla* and *H. serrata* cultivar trials (Table 1), one cultivar, 'Goliath,' had 100 percent mortality (data not shown). The first flowering date (visible color in blooms) ranged from April 29 to August 29, with 13 cultivars not flowering in the first growing season. The final (September) growth index ranged from 1.0 in ('Lemon Zest') to 5.3 in ('Tokyo Delight'). The majority of foliar disease was attributed to fungal leaf spot and powdery mildew, although ratings for individual diseases were not recorded. In *Hydrangea paniculata* cultivar trials (Table 2), the first flowering date ranged from May 14 ('Dharuma') to July 31 ('Strawberry Sundae'), with two cultivars not flowering in the first growing season ('Praecox' and 'Summer Snow'). The final (September) growth index ranged from 4.6 in ('Webb') to 6.6 in ('Phantom'). The majority of foliar disease was attributed to fungal leaf spot and downy mildew, although individual disease ratings were not recorded.

## *Table 2. Results of a container-based plant trial of 18* H. paniculata *cultivars*

| Species/Cultivar | First Color | 50% Bloom | Panicle Size | Flower Color | May Growth Index* | June Growth Index* | July Growth Index* | September Growth Index* | End-of-season Height | Foliage Quality ** | Survival |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *H. paniculata* Bombshell | 6/10 | 6/24 | 18 x 18 | White | 31.5 | 65.3 | 84.5 | 98.1 | 72.0 | 3 | 5 |
| *H. paniculata* 'Chantilly Lace' | 7/3 | 8/15 | 23 x 23 | White | 28.1 | 63.5 | 90.9 | 93.1 | 99.8 | 2 | 5 |
| *H. paniculata* 'Dharuma' | 5/14 | 6/5 | 11 x 11 | White | 33.8 | 59.5 | 72.9 | 74.7 | 77.2 | 3 | 5 |
| *H. paniculata* 'Floribunda' | 7/3 | 7/31 | 13 x 13 | White | 43.9 | 83.9 | 100.4 | 106.4 | 95.0 | 3 | 5 |
| *H. paniculata* Limelight | 6/23 | 7/31 | 21 x 21 | White/Green | 30.9 | 71.1 | 93.7 | 104.1 | 94.8 | 3 | 5 |
| *H. paniculata* Little Lamb | 6/10 | 6/23 | 20 x 20 | White | 26.0 | 53.4 | 68.8 | 66.9 | 38.4 | 4 | 5 |
| *H. paniculata* 'Phantom' | 6/23 | 8/12 | 22 x 22 | White | 41.2 | 83.1 | 100.3 | 107.4 | 90.2 | 4 | 5 |
| *H. paniculata* 'Pink Diamond' | 7/3 | 8/12 | 23 x 23 | White | 22.2 | 64.5 | 86.3 | 102.2 | 109.0 | 3 | 5 |
| *H. paniculata* Pinky Winky | 6/23 | 8/12 | 17 x 17 | White/Pink | 43.5 | 79.3 | 93.4 | 101.3 | 94.6 | 3 | 5 |
| *H. paniculata* 'Praecox' | N/A | N/A | N/A | N/A | 86.6 | 87.9 | 94.6 | 96.7 | 94.6 | 4 | 5 |
| *H. paniculata* Quick Fire | 6/23 | 7/31 | 19 x 19 | White/Green | 49.1 | 82.2 | 99.5 | 98.4 | 86.0 | 4 | 5 |
| *H. paniculata* 'Silver Dollar' | 6/23 | 7/31 | 22 x 22 | White | 41.1 | 69.3 | 77.1 | 77.9 | 51.6 | 3 | 5 |
| *H. paniculata* Strawberry Sundae | 7/31 | 9/5 | 17 x 17 | White/Pink | 19.2 | 59.9 | 94.1 | 125.6 | 85.0 | 2 | 3 |
| *H. paniculata* 'Summer Snow' | N/A | N/A | N/A | N/A | 48.1 | 84.9 | 100.4 | 102.2 | 98.0 | 4 | 5 |
| *H. paniculata* 'Tardiva' | 7/3 | 7/31 | 20 x 20 | White | 47.1 | 86.6 | 102.4 | 107.3 | 109.0 | 3 | 5 |
| *H. paniculata* 'Unique' | 7/3 | 7/31 | 15 x 15 | White | 42.0 | 76.4 | 93.0 | 102.0 | 85.8 | 3 | 5 |
| *H. paniculata* Vanilla Strawberry | 7/15 | 7/31 | 22 x 22 | White/Pink | 19.0 | 58.7 | 78.6 | 81.9 | 59.7 | 2 | 3 |
| *H. paniculata* 'Webb' | 7/15 | 7/31 | 14 x 14 | White | 44.3 | 73.4 | 75.7 | 74.6 | 39.8 | 3 | 5 |

All measurements are listed in centimeters.
*Growth Index in cm = (Height + Width + Width) /3
**Foliage rating:
1 = clean
2 = minor problems, but sellable state
3 = moderate, borderline sellable state
4 = extensive, not sellable state
5 = no foliage left in good condition


**Figure 4. Cultivar trials at the Center for Applied Nursery Research, located in Dearing, Georgia.**

## PROPAGATION

Hydrangea species are relatively easy to propagate by seed, although seeds can be exceptionally small, or sexually. Stem cuttings and tissue culture (micropropagation) are the most common methods of commercially propagating hydrangea. Each method has its advantages and disadvantages depending on the objective of the grower.

Some nurseries use micropropagation to produce large numbers of new releases quickly. Often, a separate commercial laboratory specializing in micropropagation provides tissue culture propagated liners for nurseries. Liners will be in one of three stages: Stage II unrooted stem cuttings, Stage III rooted plantlets, or Stage IV acclimatized plants. Both Stages II and III require a greenhouse to either root the stem cuttings or provide high humidity and mist to acclimatize plantlets to lower humidity and higher light levels. Stage IV plants may be ready to pot immediately, yet require some management to alleviate stress. If one chooses to pursue micropropagation or tissue culture in-house to produce plantlets, other specialty facilities are needed in addition to a greenhouse and will not be covered here. However, a detailed protocol for tissue culture of *H. macrophylla* is available (see Abou Dahab 2007 and Ruffoni et al., 2013 in the References and Additional Resources section).

Benefits to using liners produced in tissue culture include shorter internode lengths, more branches and a fuller canopy. Additionally, plants are more uniform in production since they all start at relatively equal size and have a more balanced root-to-shoot ratio. Greater survival after planting in production due to heavier root systems and more axillary buds is also reported. For example, plants of *H. quercifolia* 'Alice' produced from rooted stem cuttings are prone to asymmetrical growth, and plants are often sparse and consist only of a few rampantly growing shoots, which reduces shrub quality, but tissue cultured plants are more uniform.

When obtaining liners from tissue culture laboratories, scout for problems that include fragile plants not acclimatized to outdoor environments, fasciation (widening or flattening) of stems, and variation in cultivar characteristics due to tissue culture techniques. Plants produced from tissue culture had all nutrients provided during micropropagation and were grown in 100 percent humidity until plantlets were transferred to a greenhouse for acclimatization. Even though all plants may experience some stress postpropagation, tissue-cultured plantlets are still more fragile than similar plants rooted from stem cuttings using a traditional mist system. As a result, recently acquired plants produced from tissue culture and potted in production may require more shade, more frequent irrigation, and perhaps more nutrient monitoring to avoid excessive nutrients in the substrate to alleviate stress.

Fasciated stems are flat and wide and appear as if two stems were fused together. Although it does not occur often, fasciation results from the various hormones used in tissue culture. Plants containing fasciated stems should be culled and destroyed by the commercial laboratory prior to shipping. If they are present upon receipt, discard affected plants.

Most cultivars produced by tissue culture are propagated using axillary shoot proliferation. This regeneration method uses a small portion of stem and forces the axillary buds to elongate, thereby forming many shoots. These shoots are then rooted in tissue culture to form new plantlets of the desired cultivar. Axillary shoot proliferation is similar to the traditional method of collecting stem cuttings and rooting them in a greenhouse, only using much smaller shoot cuttings and rooting them under sterile conditions in a lab. Generation of shoots from undifferentiated tissue or callus could result in variation among resulting plantlets, and the true cultivar might not be present. A non-true-to-type variation does not occur often and is difficult to determine until late in production when the desired cultivar is grown within a block of plants, with individual plants exhibiting nonuniform growth or appearance. Ask the commercial laboratory what method they use to produce plantlets of the desired cultivar and gain some reassurance that they do not have many variations appearing after transplant.

**Figure 5. Tissue culture propagation at Microplant Nurseries Inc.**

*Seed propagation* is desirable when breeding or when looking for novel characteristics such as flower color or compact branching structure. Collect seeds in late fall or early winter, crush capsules and clean excess trash from the seeds. The seeds are small, so take care to sow evenly. Generally, moist prechilling (stratification) is not required for germination; however, 30-90 days of stratification may increase the speed of germination and uniformity. Sow seeds in flats on surface or medium and keep moist, preferably in a greenhouse or other high-humidity enclosure where the temperature can be controlled. Germination occurs within 10-30 days. The seeds of *H. arborescens* and *H. macrophylla* sown on milled sphagnum will germinate in two to three weeks. *Hydrangea paniculata* seeds require no pretreatment; plants will flower the same year seeds are sown. Similarly, fresh *H. quercifolia* seeds, sown directly after collection, germinate at high percentages two weeks later. For detailed seed propagation information, consult Dirr (2004).

*Vegetative propagation* is commonly used to mass propagate hydrangeas for nursery production. In general, softwood stem cuttings collected earlier in the season (May) will yield more robust, faster-growing plants than those collected later in the summer (July), but cuttings collected over that time frame all root readily. Single node cuttings are sufficient and allow for more subterminal cuttings per length of stem. Because stems can vary in thickness, even on the same plant, grade stem cuttings according to diameter to improve uniformity within a flat before setting into the substrate. Hydrangeas, especially *H. quercifolia*, have large leaves that can be cut by half or more to limit leaves from transpiring as well as from blocking mist during rooting.

**Figure 6. Vegetative propagation: Stem cuttings of *H. macrophylla* at Bailey Nurseries Inc.**

Treating stem cuttings with foliar applications of IBA has been as successful as traditional quick dips for rooting hydrangea. Applications can be made with a backpack sprayer containing the rooting hormone at the appropriate concentration. Spray cuttings to runoff, and then apply 1 liter of finished solution per 60 square feet. At Bailey's Nursery in Minnesota, all hydrangea cultivars are treated via overhead foliar application. Treating the foliage trades high labor costs for dipping cuttings for high chemical costs for spraying, but generally reduces exposure of employees to chemical contact. Additionally, the number of employees who handle and apply plant growth regulators (rooting hormones) decreases, which improves uniformity of application and growth. Mist frequency or volume does not change nor does the time of rooting or overall root quality compared to traditional quick dip methods. Since the hormone used is the potassium (K) salt of indole 3-butyric acid (IBA), or K-IBA, which is water-based, there is no phytotoxicity associated with other solvents like alcohol. When IBA was applied via foliar spray to stem cuttings of *H. paniculata* at 50 ppm K-IBA or 50 ppm K-IBA + 25 ppm naphthalene acetic acid (NAA), rooting percentage, root length and shoot length were similar to stem cuttings treated traditionally with a basal quick dip of either 1,000 ppm IBA or 1,000 ppm IBA + 500 ppm NAA.

*Preemergence weed control in propagation*
A trial was conducted to determine if preemergence herbicides applied to the rooting substrate would affect the rooting of stem cuttings of *H. macrophylla* 'Penny Mac.' The herbicides used were Ronstar (oxadiazon) and Snapshot (trifluralin + isoxaben) at 150 lbs. per acre, Marengo G (indaziflam) at 100 lbs. per acre, and Tower (dimethenamid-p) at 26.5 fl. oz. per acre. Containers approximately 4 inches square and 6 inches deep were filled with substrate (1 peat :1 perlite). Granular herbicides were applied with a shaker directly to moistened soil, and Tower was applied with a backpack sprayer. Two-node stem cuttings with leaves cut in half were dipped in 1,000 ppm K-IBA for three seconds and set directly through the herbicide into the substrate. The plants were watered afterward and set under mist for six weeks. The rooting percentage was not affected by preemergence herbicides in any of the treatments. The root dry weight was not affected either; however, roots in the Marengo treatment tended to grow toward the sides of the container and down rather than directly around the stem cuttings or below them. With the exception of Marengo, none of these chemicals are labeled for use in a covered structure. These results show there was no damage to rooting or root growth during the rooting of stem cuttings and no phytotoxicity was observed. Rooted plants were not potted up and grown further, so it is not known if the effect Marengo had on root system architecture affected either the root system or the canopy long term.

## GENERAL PRODUCTION

***Container.*** Rooted cuttings are typically transplanted into 1 gallon (#1; approximately 3.7 L) to 3 gallon (#3, approximately 11.4 L) containers to be sold in the fall or following spring. Containers are spaced to ensure adequate room for branch development and lateral growth. Typically, medium rates of controlled release fertilizers (CRF), incorporated or top-dressed, are sufficient; however, high CRF rates or starter nitrogen fertilizer, such as urea-formaldehyde, can be warranted for certain species such as *H. macrophylla*. Pruning twice a season and/or PGRs are typically used in an effort to increase branch number, flowers, and plant density and to control plant size for rack shipping and display for many cultivars.

***Field.*** Bareroot liners or #1 containers can be planted into a cultivated, preamended (lime, potash and phosphorus as indicated by soil test results) field on 36- or 48-inch centers in the spring or fall to be sold as finished balled and burlapped or bareroot shrubs that fall or in the fall of the following year, depending on initial liner size. Plants can be fertilized with nitrogen by broadcast or side-dressed, typically in spring and again in early summer, when soil temperatures are greater than 50 F and plants are actively growing.

**Figure 7. Recently lined out oakleaf hydrangeas at Walker Nursery Co.**

## Container Substrate and Soil Management

***Substrates***. A well-drained, aged pine bark passed through a ½" or ⅜" screen is commonly used to produce hydrangeas in the nursery industry in the southeastern U.S. Ideal physical properties would be approximately 80 percent (by vol.) total porosity, 55-65 percent (by vol.) water holding capacity, and 20-30 percent (by vol.) air space. Hydrangea that are high water users and sensitive to low soil moisture or drought may benefit from an addition of 15-30 percent (by vol.) Sphagnum peat moss to increase substrate water holding capacity. Little to no inorganic substrate additions (for example, perlite or pumice) are needed to maintain adequate air space unless plants are being direct stuck and/or staying in the container for long periods of time (greater than nine months), or the initial substrate supply has low air-space.

***Soil.*** Well-drained, moist soil, preferably a fertile sandy or silt loam with greater than 1 percent organic matter, is recommended for field planting. Nevertheless, hydrangea have been produced successfully in clay soils with proper water management.

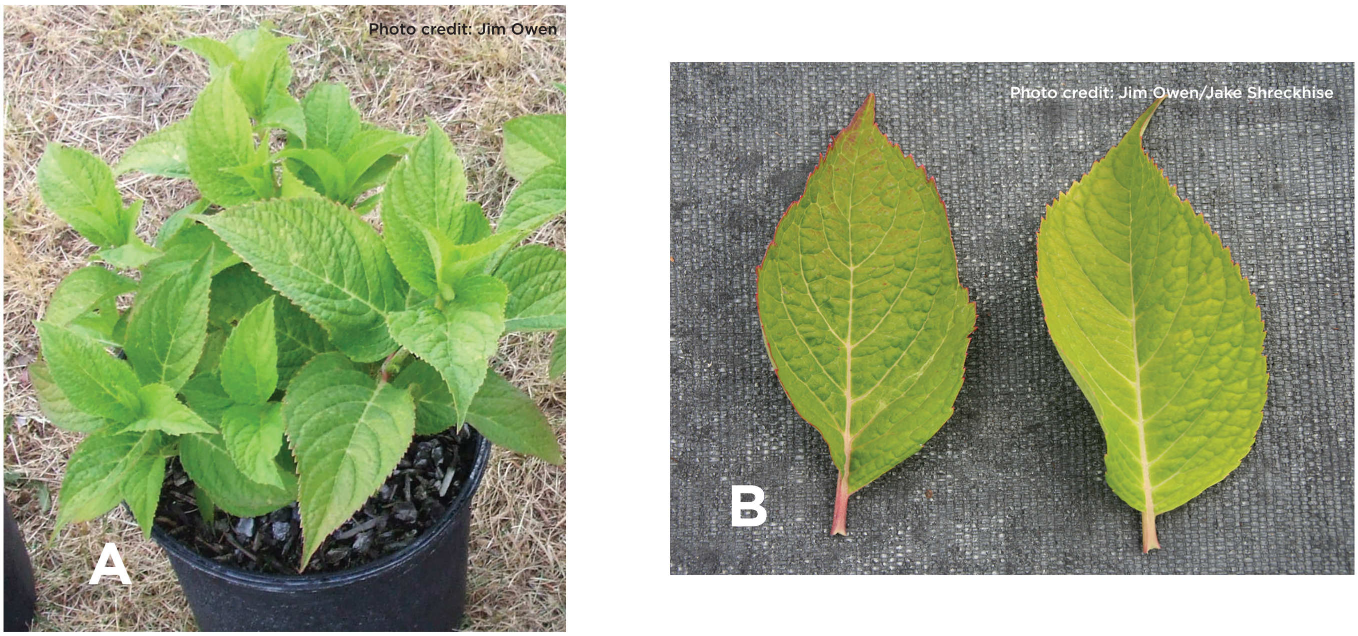
## Nutrient Management

***Container.*** Hydrangeas grow best with a soil or substrate pH of 5.5–6.5, with some species preferring or tolerating alkaline soils or substrates near or above pH 7.0. In containers, dolomite [$CaMg(CO_3)_2$] is used to supply calcium and magnesium to the plant and is amended to the substrate to have the desired pH. Micronutrients in addition to sulfur are also added. Gypsum ($CaSO_4$) can be used as an alternative to dolomite to supply calcium if no pH adjustment is desired. Typically, a medium to high rate of CRF is incorporated or top-dressed, applied to the surface of substrate at the time of planting and again the following summer, depending on production cycle and fertilizer longevity. Many fast-growing hydrangeas can begin to show yellow foliage (chlorosis) or grow slowly during the lag phase of release for some CRFs (for 15 to 30 days after application); therefore, growers can incorporate a relatively safe and quick release nitrogen source, such as urea-formaldehyde, at the time of potting to ensure adequate nitrogen and subsequent electrical conductivity for the plant to get a quick start. Growers may decide to fertigate for better control of growth or to supplement CRF to maintain a desired electrical conductivity at different crop production phases. Additionally, growers can apply foliar urea in the fall, prior to leaf drop, to increase plant nitrogen content prior to dormancy and subsequent bud break in the spring. Urea is adsorbed as ammonium but can be lost via evaporation or volatilization up to 72 hours after application before being taken up by the plant. Foliar applications with excessive urea concentration can result in necrosis and premature leaf drop; however, this response is species- and cultivar-specific. Iron deficiency, observed as interveinal chlorosis on newer foliage, has been reported to be addressed with regular foliar application or drenches of iron sulfate or iron chelate; however, there are few published reports on this topic. Substrate pH management, specifically, maintaining a pH < 6.0, is the easiest way to ensure iron is readily available for crop uptake. Specialty fertilizers are available to aid in the bluing of bigleaf hydrangeas (see Flower Color Management below).

***Field.*** For field production, test soil early enough so that any lime, phosphate or potash can be broadcast and incorporated prior to planting. Signs of iron and, to a lesser extent, boron, deficiency may develop at pH > 7.0. A typical recommendation for all shrubs is no more than 50 pounds of actual N per acre (agricultural-grade nitrogen) applied in the spring when soil temperatures maintain greater than 50 F consistently and again approximately three to five months later. Broadcasting fertilizer after the crop is planted is not always economical. The per acre rate can be used for side dressing, whether done by machine or hand. Excessive nitrogen rates will often promote growth foliage while reducing the number and size of inflorescences. Fertilizer should be applied when foliage is dry to minimize the chance of damage to leaves, flowers and buds.

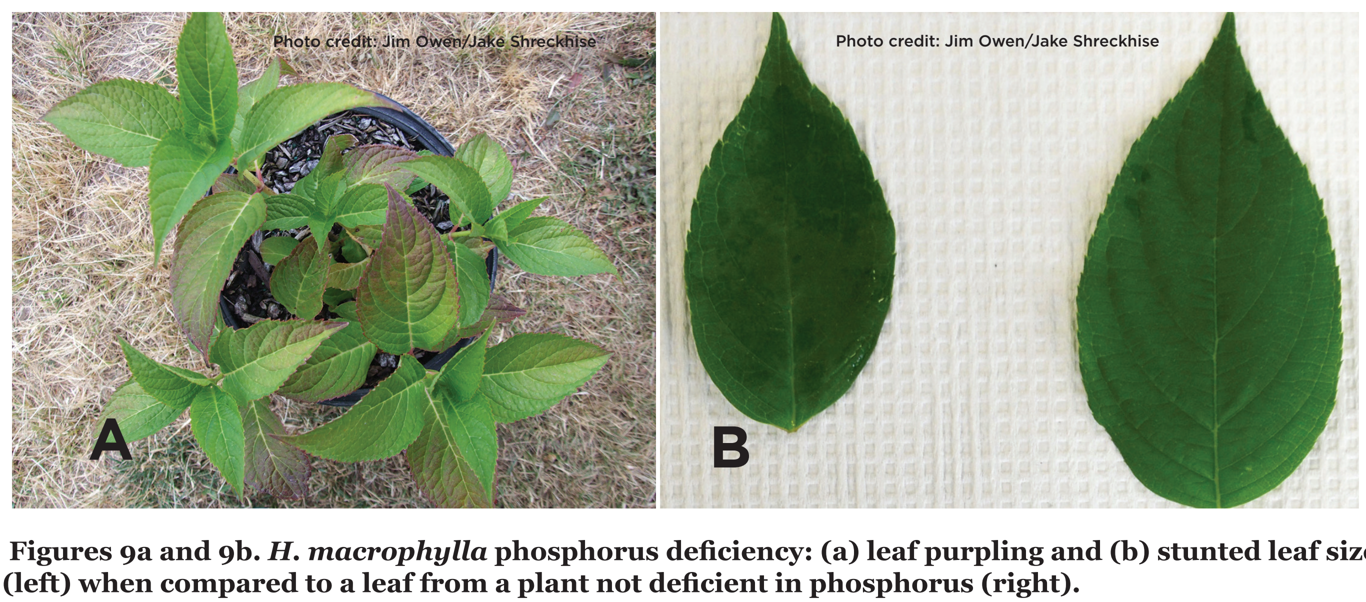
***Nutrient Deficiencies.*** Mineral nutrient deficiencies differ across taxa, and specific nutrient symptomology is lacking for the many hydrangea cultivars and hybrids now available in the industry. Below is a general guide to common nutrient deficiencies observed in *Hydrangea* sp. Mineral nutrient deficiencies are categorized into mobile (nitrogen, phosphorus, potassium, magnesium), partially mobile (sulfur), or immobile mineral nutrients (calcium, iron, manganese), referring to their ability to be translocated or moved within the plant once taken up from the soil or substrate. For example, mobile mineral nutrients can move from leaf to leaf via the phloem, whereas immobile mineral nutrients move primarily via water within the xylem. Deficiencies of mobile, partially mobile or immobile mineral nutrients are usually observed either at the base of the plant where older growth occurs, throughout the whole plant, or at the top of the plant where there is new growth, respectively. Symptoms of deficient nutrient levels are described below.

**Nitrogen (N, mobile):** Older, mature or lower leaves may be chlorotic, uniformly light green or yellow, and may have brown/black or dying (necrotic) tips. New or young leaves may be smaller, have red margins (leaf edge), and edges and stems or bud scales could have a purple tint. Growth will appear reduced as a result of reduced shoot elongation and fewer developing buds.




**Figures 8a and 8b. *H. macrophylla* nitrogen deficiency: (a) Chlorosis and (b) red leaf margins and smaller leaf (left) compared with a leaf from a plant not deficient in nitrogen (right).**

**Phosphorus (P, mobile):** Older, mature or lower leaves may be slightly chlorotic, uniformly yellow and may have purple margins (leaf edge). Plants will have a stunted appearance as a result of shorter internodes and potentially decreased flower buds. New or young leaves may be smaller than normal and have a dark green or even blue-green coloration.




**Figures 9a and 9b. *H. macrophylla* phosphorus deficiency: (a) leaf purpling and (b) stunted leaf size (left) when compared to a leaf from a plant not deficient in phosphorus (right).**

**Potassium (K, mobile):** Recently expanded or young leaves may be dark green, lustrous (shiny) and narrower than expected. Shoots may have a rosette appearance due to being compact or having shorter internodes (distance between branches). Older, mature or lower leaves may first appear chlorotic (yellow), followed by rapid necrosis (brown/black or dying tissue) along old leaf blades or as speckling.

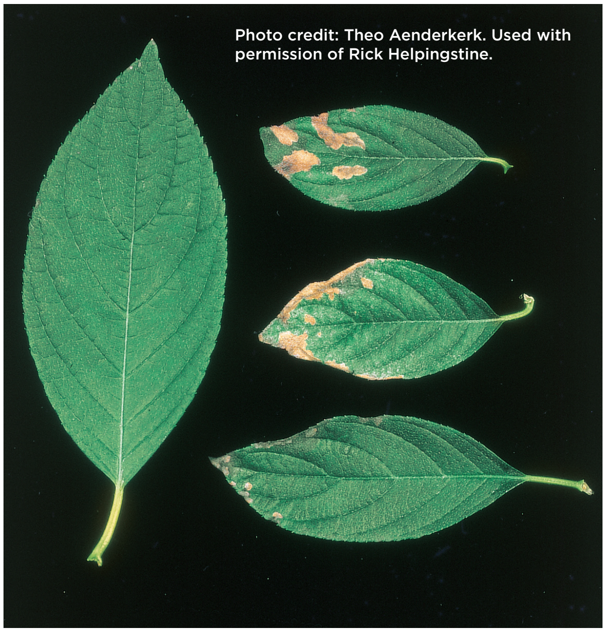



**Figure 10. *H. paniculata* potassium deficiency: Leaf necrosis (top right) and narrower leaf blade with dark green tint (bottom right) when compared to healthy leaf (left).**

**Magnesium (Mg, mobile):** Lower or older leaves may have interveinal chlorosis (yellow leaf and green veins) and possibly red margins (leaf edge). Leaf margin can curl under (hooding) as deficiency worsens. Root growth may be reduced or shallow but appear healthy.

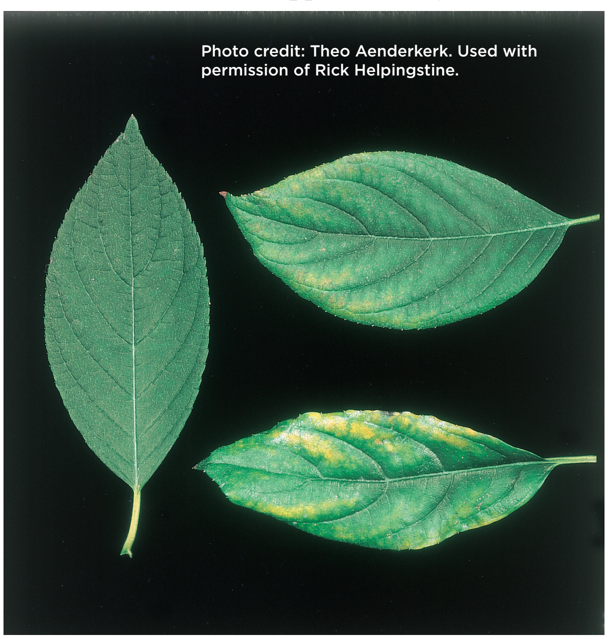



**Figure 11. *H. paniculata* magnesium deficiency: Interveinal chlorosis (top right) giving way to leaf hooding (bottom right) when compared to a healthy leaf (left).**

**Sulfur (S, partially mobile):** Recently expanded or young leaves may be chlorotic (yellow), which can be pronounced on the leaf margins (edges). Growth will appear reduced as a result of reduced shoot elongation and shorter internodes (distance between branches). Severe sulfur deficiency can lead to defoliation or leaf drop. Sulfur deficiency can be confused easily with nitrogen deficiency (no photo).

**Calcium (Ca, immobile):** Recently expanded or young leaves appear light green, yellow to translucent. Additionally, new growth can be necrotic, deformed or distorted. Roots may be short, densely branched and thick.


**Figure 12. *H. paniculata* calcium deficiency: Chlorosis (right) when compared to a healthy leaf (left).**

**Iron (Fe, immobile):** Interveinal chlorosis (yellowing) that clears to yellow or white, occurring on recently expanded or young leaves, and may have necrotic leaf areas along leaf margins (leaf edge). Can be confused with manganese (Mn) deficiency.

**Figure 13. *H. macrophylla* 'Merritt's Beauty' iron deficiency: Interveinal chlorosis.**

**Manganese (Mn, immobile):** Interveinal chlorosis, yellow with green veins, may occur on recently expanded or young leaves and may result in tan flecks on the leaf. Manganese deficiency can be confused easily with iron deficiency.


**Figure 14. *H. paniculata* manganese deficiency: Interveinal chlorosis (right) when compared to a healthy leaf (left).**

## Irrigation

***Container.*** Hydrangeas are considered high water users, with *H. macrophylla* and *H. quercifolia* grown in #2 containers using approximately 7 to 8 oz. per day or approximately 8 to 10 gallons over a six-month production cycle; however, water use varies among species and cultivars. Alternatively, hydrangea has been produced successfully when holding the substrate moisture content at approximately 20-30 percent volumetric water content. Maintaining the container substrate at too high of a moisture level, or "growing too wet," leads to stretching (stem elongation), potentially shallow root development, and/or increased root disease incidence. Substrate moisture and irrigation can be managed to produce plants on the dry side, resulting in increased quality and compactness, but it also can reduce leaf area, height and flower size. During hot summer days when plants are wilted or heat-stressed, cultivars of *H. macrophylla* benefit from wetting the foliage (syringing). Partial shade decreases irradiance; thus, plant water use decreases. Fine (e.g., sawdust) or nonpermeable mulches (e.g., weed disc) in addition to other substrate-separate types of weed barriers (e.g., coir or fabric disc) reduced daily water loss further. Drenches up to 1,000 ppm s-ABA (Contego Pro, Valent Biosciences, Inc.) decreased water use and delayed wilting and irrigation frequency for *H. macrophylla*. However, foliar spray applications up to 2,000 ppm s-ABA did not delay wilting compared to applying only water to foliage of *H. macrophylla* 'Bailmer' Endless Summer. Several experiments have been conducted in recent years that help quantify how much water hydrangea species need. The data from these studies can be helpful in refining irrigation scheduling for hydrangea.

***Field.*** Field-produced hydrangea can receive supplemental irrigation via overhead (e.g., hand-line, solid set or travelling gun) or drip irrigation as needed. Overhead irrigation application rate and volume should be determined by the infiltration rate of soil type, field slope, field water holding capacity and root depth of crop. A drip irrigation line should cross the root ball of each plant, and emitter spacing should be based on soil texture, being closer in sandy soils than in clay soils. The water application rate when using drip irrigation is determined by soil water holding capacity and the root depth of the crop. Soil-specific information can be found via Web Soil Survey (WSS — websoilsurvey.sc.egov.usda.gov). Contact an irrigation professional and/or local Extension agent or Extension specialist when designing or installing new irrigation.

***Water quality.*** High alkalinity (>1 meq/L) in irrigation water can increase substrate pH over the course of production; therefore, the lime rate should be adjusted accordingly or acid should be injected to correct irrigation water pH. When producing *H. macrophylla*, acid choice can influence flower color (see Flower Color Management). Free chlorine concentrations $\leq$ 2.5 ppm in irrigation water should not result in plant injury or impact crop growth; however, this concentration will vary by species and even cultivar and is subject to influence by other water quality characteristics. Chlorine damage in *H. paniculata* exhibits as early or unexplained leaf drop, but also may result in marginal necrosis in other taxa. Irrigation with reclaimed water with a salt level of 5.65 $dS \cdot m^{-1}$ resulted in smaller flowers and leaves and overall smaller plants of *H. macrophylla*. Additionally, plants receiving reclaimed water had delayed flowering and altered flower color. The reclaimed water also caused marginal necrosis that rendered the plants unmarketable.

## Plant Growth Regulators (PGRs) to Control Size and Enhance Branching

Plant growth regulators are typically used to induce branching among nursery crops and include ethephon, an ethylene generator; chemical pinching agents such as dikegulac sodium, a DNA synthesis inhibitor; or cytokinin, a synthetic compound that supplements naturally occurring growth hormones that promote branching. Other PGRs that function as growth retardants (e.g., gibberellic acid inhibitors) are used commonly on *H. macrophylla*. In Europe, where significant hydrangea breeding occurs, many PGRs have been declared unsafe for workers and are no longer used in the trade. PGRCALC, a web application, part of the GROCALC tools, can be used to calculate plant growth regulator mixing rates (extension.unh.edu/Grower-Tools/Web-Based).

In summary, choose species and cultivars that grow best in your production system and flower at different times of year to increase marketability. "Antiqued" inflorescence, fall color and foliage texture are also good marketing points after plants stop producing flowers. Monitor irrigation (frequency and volume) for many benefits: to improve growth and plant quality, control plant size for shipping, reduce leaching, and limit root rot outbreaks. Lastly, use this guide to train employees on production basics. Hydrangea species are flexible and adaptable crops that can be produced easily and quickly with proper culture.

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