Comparison of Substrate Amendments for the Adjustment of Hydrangea (*Hydrangea macrophylla* (THUNB.) SER 'Bailmer', Endless Summer®) Flower Color

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Significance to the Industry: Results demonstrated that pozzolan clay can be used as a soilless substrate amendment that results in enhanced blue sepal color in container produced hydrangeas. With the addition of clay to a Douglas-fir bark substrate, blue flowers occur at higher pH levels than with aluminum sulfate alone. Nursery growers who observe poor growth from low substrate pH or have difficulty achieving blue sepals could use a clay amendment to alleviate these issues.

Nature of Work: As hydrangeas gain popularity and new cultivars are developed, it is essential for growers to have the ability to produce quality containerized plants with the desired, marketable flower color. The availability of aluminum (Al) causes hydrangea sepal color to change between varying shades of pink and blue. Research by Takeda et al. (8) showed that Al causes blue flowers by interacting with anthocyanin and quinic ester pigments within the sepals. The amount of Al available in a soilless substrate is directly related to substrate Al content and pH. Commonly, Al is not available in adequate concentrations in soilless substrates. Altland and Buamscha (1) found that when adjusting the pH of Douglas-fir bark (DFB) with $CaCO_3$, the DTPA extraction of (Al) went from 22.9 mg/L at a pH of 4.9 to an availability of 5.5 mg/L at a pH of 6.5. Therefore, it has been traditionally recommended for the greenhouse and nursery industry to grow pink flowering hydrangeas at a substrate pH of 6.5, and blue hydrangeas at a substrate pH of 5.5 (2). To achieve these low pH values while providing proper Al, aluminum sulfate ($AlSO_4$) drenches or amendments have been used as the industry standard to produce blue sepals in hydrangea production.

Various clay containing minerals have been used as soilless substrate components either to increase bulk density (3,5), or to improve water and nutrient holding capacities (6). Additional studies have been done using (aluminosilicates) clays as a substitute for aluminum sulfate replacement. Handreck (4) mixed a 10% kaolite clay amendment to a pine bark based substrate and was able to produce blue hydrangea sepals when the pH remained below 4.9. Using Al charged zelolite clay at rates from 10-40% in a peat and perlite mix, Opena and Williams (7) were able to produce blue hydrangea flowers in the pH range of 3.7-4.0.

To assess the ability of pozzolan clay [diatomaceous calcined clay containing 10% (by wt.) aluminosilicate] to produce blue hydrangea flowers at an elevated pH, an experiment was initiated on 1 June 2007 at the North Willamette Research and Extension Center, Aurora, OR. The experiment was a 3 x 3 factorial design (Al rate x substrate amendment) organized in a completely randomized design with nine treatments each replicated 10 times. *Hydrangea macrophylla* (THUNB.) SER 'Bailmer' (PP15,298), Endless Summer® was potted into three bark based substrates with different amendments in trade #2 containers. Douglas-fir [Pseudotsuga menziesii (Mirb.)] bark of a fine and course textures (screened to 0.9 or 2.2 cm) was used as the primary component of all substrates (Marr Bros. Monmouth, OR.). The substrates were as follows: 9:1 (by vol.) DFB:pozzolan clay (Western Pozzolan Corp., Doyle, CA.), 7:3 (by vol.) DFB:sphagnum peat moss (Sun Gro Horticulture Canada Ltd., LAVAL, Quebec), and 3:2 (by vol.) coarse DFB:fine DFB. Three rates of $AlSO_4$ (GEO Specialty Chemicals, Baltimore, MD.) were added to the three substrates: the industry standard of 7.4 $kg{\cdot}m^{-3}$ (12.5 lb yd^{-3}); high rate, $kg{\cdot}m^{-3}$ (6.3 lb yd^{-3}); medium rate or no $AlSO_4$. A requisite amount of dolomite lime was added to each of the treatments to equalize pH across treatments. Dolomitic lime (Chemical Lime Co., Fort Worth, TX) was incorporated at a rate of 4.8, 3.6, 2.4 $kg{\cdot}m^{-3}$ for the high, medium, and control $AlSO_4$ treatments, respectively. Micromax (The Scotts Company, Marysville, OH) was incorporated [0.88 $kg{\cdot}m^{-3}$ (1.5 lb yd^{-3})] into the substrate for all treatments. Hydrangeas were topdressed with 60 g of 15N-9P-12K Osmocote Plus (5-6) mo. product (The Scotts Company, Marysville, OH) and were overhead irrigated following industry standards.

Growth index [(height + mean width)/2] and flower color were recorded 21May 2008 when the plant was determined to be at a saleable stage. At this time substrate solution pH was measured via the pour-through nutrient extraction procedure (9). Flower color and customer appeal were evaluated independently by 8 individuals. Hydrangeas were rated 1 to 5; 5 being most blue and highest customer appeal, respectively. The rating results were arcsin transformed to ensure normal distribution. Data was analyzed by analysis of variance using the General Linear Models Procedure (SAS Institute, Cary, NC). Means were separated with Fisher's Protected Least Significant Difference, $P = 0.05$ when appropriate. Simple Effects were used to test significant interactions.

Results and Discussion: Substrate and $AlSO_4$ had a significant effect on ratings for sepal color and customer appeal (Table 1). Increasing aluminum sulfate and pozzolan clay amounts increased the blue color rating of hydrangea sepals. At each $AlSO_4$ concentration, the highest color ratings for all substrates occurred in combination with clay. The addition of the peat amendment did not significantly affect flower color compared to the unamended treatment. When the flowers were ranked for customer appeal, blue flowers were preferred (Table 1). As $AlSO_4$ rates increased, the flower color was rated as more blue and consequently appeal ratings also increased. The same effect was also seen when the $AlSO_4$ rate was 0, the addition of clay produced blue flowers which were rated higher for appeal than the flowers from the peat and none substrates. The clay amendment treatments had the highest color and appeal ratings, with the clay + high $AlSO_4$ rated highest overall.

Substrate and $AlSO_4$ had a significant effect on soilless substrate solution pH (Table 2). We hypothesize the differences in soilless substrate solution pH were due to discrepancies in the dolomite and aluminum sulfate rates. However, the variability of substrate pH, at 6.63 – 7.02, was not great and likely did not affect flower color or growth. The mean height (55.0 cm ± 0.9 SE), mean width (66.5 cm ± 0.7 SE) and mean growth index (90.8 cm ±0.6 SE) was not significantly different between treatments (data not shown).

The incorporation of pozzolan clay in addition to $AlSO_4$ in the substrate assists in blueing of hydrangea sepals even at high pH levels without negatively affecting growth. This will give growers more leeway in the production of blue hydrangeas, allowing for the desired flower color without the complications of maintaining a low pH.

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Table 1. Effect of substrate amendment and aluminum sulfate ($AlSO_4$) rate on flower color and customer appeal.

Substrate Amendment	$AlSO_4$ (kg·m^{-3}) 0		3.7		7.4		Significance	
	color	appeal	color	appeal	color	appeal	color	appeal
Clay	3.7^{v}a^{z}	3.7^{w}a	4.4a	3.7	4.7a	4.0	**^{x}	ns
Peat	1.0b4	1.0b	3.3b	2.8	3.9b	3.3	**	**
None	1.2b	1.3b	2.9b	2.7	4.2b	3.5	**	**
Significance	**^{y}	**	**	ns	**	ns		

^{z}Means within a column and variable not followed by the same letter are significantly different as determined by Fishers Protected LSD P = 0.05.
^{y}Significnce for color and customer appeal within row
^{x}Significnce for color and customer appeal within column
^{w}Customer appeal of the flower color rated on a scale from 1-5, 5 being most blue.
^{v}Color of the flower rated on a scale from 1-5, 5 being most blue
^{ns,} ** Nonsignificant or significant at $P \leq 0.01$, respectively.

Table 2. Effect of substrate amendment and aluminum sulfate ($AlSO_4$) rate on pH at experiment completion on 22 May 2008.

Substrate Amendment	$AlSO_4$ (kg·m^{-3}) 0	3.7	7.4	Significance
Clay	6.95	7.01 a^{z}	6.86	ns^{y}
Peat	6.89	6.63 b	7.02	**
None	6.72	6.81 b	6.84	ns
Significance	ns	**	ns	

^{z}Means within a column and variable not followed by the same letter are significantly different as determined by Fishers Protected LSD P = 0.05.
^{y}Significance within row
^{x}Significance within column
^{ns,} ** Nonsignificant or significant at $P \leq 0.01$, respectively.