Research Reports

Variability in Plant Growth in Retail Potting Media

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SUMMARY. There is extensive variability in physical and chemical properties among brands of retail potting media. The purpose of this study was to assess variability in seed germination and plant growth responses among and within brands. Twenty-four different brands of media, and multiple bags of five brands, were purchased at nine retail stores. Tomato (*Lycopersicon esculentum*) seeds were germinated in 11 different brands of media and in media from different bags of four of the same brands. Marigold (*Tagetes erecta*) and petunia (*Petunia ×hybrida*) were grown to flowering in 10 brands of media. Germination varied significantly among media brands and among bags of one of the brands. Plant performance also varied significantly, with several of the brands producing plants with few flowers, long times to flowering, and low shoot and root dry weights even though all treatments received uniform applications of a complete fertilizer solution three times per week. Few relationships could be discerned between individual physical and chemical properties of the media and plant performance. Results indicate improvements in quality among brands and quality control within brands are needed in the retail potting media industry. Quality assessment tools emphasizing plant performance could improve overall media quality.

Many different brands of potting media are sold in retail stores. Relatively little is known about the quality of, and variability among, retail media. Pittenger (1986) evaluated 15 different brands of retail media and found extensive variability in physical properties such as air space and water retention, and chemical properties such as saturated media (SM) pH and SM extract electrical conductivity (EC) and nutrient content. A recent study showed similar variability in physical and chemical properties among 24 different brands of retail media; variability among different bags of the same brand was lower than among brands for most of the properties tested (Wiberg et al., 2005).

Recent efforts to improve the quality of retail media have resulted in the development of suitability standards for "basic" and "premium" media based on a suite of physical and chemical properties [National Bark and Soil Producers Association (NBSPA), 1998; North Carolina State University (NCSU), 2005]. Only one of the 15 brands in the Pittenger (1986) study met all of the published standards for chemical properties of premium potting media. In the Wiberg et al. (2005) study, only one of the 24 brands met all of the standards for chemical properties of premium media. Physical properties could not be compared because the methods used were different than those cited in the standards.

Arguably the most important measure of retail media quality is plant performance. Popular press articles report that consumers commonly experience inconsistent and unsatisfactory results with retail media (Chaplin, 1999; McKinnon, 1980; Peterson, 2003). Media that meet suitability standards based on physical and chemical properties may not perform well if an important property is absent from the standards and deficient in the medium. As a result, media performance standards have also been developed (NBSPA, 2001). These standards involve a bioassay that assesses plant growth in media under a prescribed set of conditions and relative to a control medium. Compliance with both the suitability and performance standards is voluntary (NBSPA, 1998, 2001).

Few studies have assessed the variability in plant performance among brands of retail media, and none has evaluated variability within the same brand. Pittenger (1986) evaluated 'Bigset' tomato seed germination and early plant growth in 15 different retail potting media. The media produced a wide range of germination and growth

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.0283	ft^3	m^3	35.3147
3.7854	gal	L	0.2642
0.0160	lb/ft^3	$g \cdot cm^{-3}$	62.4274
1	mmho/cm	$mS \cdot cm^{-1}$	1
28.3495	oz	g	0.0353
1	ppm	$mg \cdot L^{-1}$	1
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

responses; four produced plants with a poor seedling vigor rating and two produced plants with an excellent rating based on color, height, and root development. Pittenger (1986) could discern no clear relationships between media performance and the ingredients stated on the label. In addition to recommending that manufacturers include more quantitative information on media labels, the author also recommended that consumers select retail media with a large proportion of bark, wood products, or sphagnum peat and vermiculite, leach the media thoroughly before use, and fertilize regularly.

The primary objective of this study was to assess variability in seed germination and plant growth among different brands of retail potting media. A secondary objective was to assess variability in seed germination within a brand of media. Too many brands of retail media exist to exhaustively sample them all. The intent of this study was to survey a subset of media brands available to consumers for general-purpose use.

Materials and methods

Single bags of 24 different brands of media were acquired from nine regional and national retail chain stores located in the Salt Lake City, Utah, area. Additionally, three to nine bags of five separate brands were purchased at different locations to assess variability within brands. Only one of the five brands identified bags with a lot number. Bag volumes ranged from 0.2 to 2.8 ft^3. An A through X letter designation was used to reference the brands, and numbers were used to reference separate bags of the same brand (e.g., B-1, B-2). Due to the limited amount of media available for these experiments, subsets of brands and bags within brands were used for the germination and growth studies, as noted below. The media were analyzed for various physical and chemical properties as described in Wiberg et al. (2005). Summary data for brands used in this study are reported in Table 1.

SEED GERMINATION. Six-cell pack containers were filled with subsamples of each of 10 different potting media in August (Trial 1). Each cell pack was treated as one replicate of a medium. Two 'Better Boy' tomato seeds were sown in each cell (12 seeds total/medium-replication). Cell packs were placed on a greenhouse bench under intermittent mist for the duration of the germination trial. Greenhouse temperatures were 24/18 °C (venting/night temperature set points). The cell packs were monitored daily and date of germination was recorded for each seed. Germination was noted when seedlings were first visible above the medium surface. The experiment was terminated after 15 d. The experiment was repeated in early September using the same protocols described above (Trial 2). Due to the limited amount of some of the media brands, seven of the original 10 and four different brands (11 total) were used in Trial 2.

A separate germination trial was conducted in late September to assess variability within brands of media. This trial compared germination among different bags of four media brands identified as B, O, S, and T using the same protocols described above.

For each germination trial, cell packs were arranged in a randomized complete-block experiment design with four replications. Percent germination at 15 d was calculated for each cell pack. Since different media were used in each trial, trials were analyzed separately using conventional analysis of variance procedures. Means were compared using least significant difference (LSD) values calculated at the 0.05 level of significance. The coefficients of variation (CVs) also were calculated for germination among brands and among bags within a brand in each trial.

PLANT GROWTH. The performance of 'Antigua Gold' marigold and 'Supercascade Salmon' petunia was evaluated in subsets of 10 of the brands having a sufficient quantity of media remaining for the growth trials. Brands used to grow each plant are identified in Tables 2 and 3. Seeds were germinated in vermiculite under intermittent mist. At the first true leaf stage, uniform seedlings were transplanted into 0.6-L pots of media. At the beginning of the second week, plants were fertilized uniformly three times per week at irrigation with

Table 1. Variation in media bulk density, porosity, water retention, air space, saturated media (SM) pH, and SM extract electrical conductivity (EC) and nutrient concentrations among 14 retail potting media used in the germination and plant growth experiments.

Potting medium	Bulk density	Porosity	Water retention	Air space	pH	EC	Nitrate-N	Phosphorus	Potassium	Calcium	Magnesium
	(g·cm^{-3})[z]	------ (% by volume)	--------			(mS·cm^{-1})[y]	-------------------	[mg·L^{-1} (ppm)]	-------------------		
A	0.18	87	53	34	6.1	1.6	1.1	13.1	163	121	44
B-4[x]	0.27	79	20	59	6.3	3.5	8.0	15.3	353	221	69
C	0.29	92	68	25	6.7	1.5	2.5	0.4	108	154	38
E	0.25	61	24	37	7.3	2.9	0.2	1.3	305	83	31
H	0.33	79	69	10	6.2	1.7	1.1	1.3	88	73	40
I	0.48	72	49	23	7.2	12.5	0.7	3.1	522	191	70
J	0.28	71	30	40	6.2	3.2	1.4	28.8	439	137	88
K	1.18	34	13	21	7.2	4.8	5.2	1.3	245	512	186
O-1[x]	0.20	70	14	56	5.4	1.9	1.0	0.9	102	228	75
O-7[x]	0.24	73	15	58	6.1	1.6	1.0	4.4	163	147	44
P	0.68	58	53	5	6.4	3.2	3.8	0.0	30	772	89
Q	0.54	62	19	43	7.5	11.1	8.6	5.2	1315	178	99
T-3[x]	0.26	69	25	44	6.3	1.2	1.0	1.7	57	115	37
V	0.20	76	22	54	6.2	3.0	2.0	10.0	257	85	81

[z]1 g·cm^{-3} = 62.4274 lb/ft^3.
[y]1 mS·cm^{-1} = 1 mmho/cm.
[x]Multiple bags of brands purchased at different locations were given a number designation.

Table 2. Days to flower, total number of flowers per plant, and shoot and root dry weights of marigold grown in 10 different retail potting media.

Potting medium	Time to flower (d)	Flowers (no./plant)	Shoot dry wt (g)[z]	Root dry wt (g)[z]
		Trial #1		
B-4[y]	64 bc[x]	4 a	19.3 a	33.4 ab
C	65 abc	2 bc	20.2 a	24.6 abcd
E	70 ab	1 c	10.8 d	13.3 cd
H	68 ab	2 bc	17.1 ab	36.2 a
J	70 ab	1 c	11.4 d	14.3 cd
K	64 bc	2 bc	15.3 bc	15.1 bcd
O-1[y]	70 ab	1 c	11.0 d	15.2 bcd
P	64 bc	2 bc	12.3 cd	9.4 d
Q	60 c	3 ab	17.2 ab	41.1 a
T-3[y]	73 a	1 c	11.9 d	31.4 abc
		Trial #2		
B-4[y]	59 ab[y]	1	11.0 ab	10.5 a
C	53 bc	1	11.8 a	7.7 ab
E	64 a	1	4.5 de	2.6 cd
H	60 ab	1	8.5 c	7.5 ab
J	60 ab	1	6.3 d	3.8 cd
K	47 c	1	9.1 bc	5.3 bc
O-1[y]	69 a	1	1.1 de	3.8 cd
P	61 ab	1	2.4 e	0.7 d
Q	46 c	1	10.4 abc	8.4 ab
T-3[y]	67 a	1	5.6 d	5.0 bc

[z]1 g = 0.0353 oz.
[y]Multiple bags of brands purchased at different locations were given a number designation.
[x]Within a trial and column, means for a given parameter followed by the same letter are not significantly different according to Tukey's honest significance difference at the 0.05 level.

Table 3. Days to flower, total number of flowers per plant, and shoot and root dry weights of petunia grown in 10 different retail potting media.

Potting medium	Time to flower (d)	Flowers (no./plant)	Shoot dry wt (g)[z]	Root dry wt (g)[z]
		Trial #1		
A	37 abc[y]	5 de	5.4 ef	2.3 bcd
B-4[x]	26 de	20 ab	8.7 bc	3.6 a
C	25 e	22 a	8.8 b	2.5 abc
E	41 a	1 e	2.4 gh	0.1 ef
H	32 bc	10 cd	4.8 de	1.5 cde
J	39 a	4 de	4.0 fg	1.3 def
O-7[x]	38 abc	5 de	6.1 de	2.1 bcd
P	39 ab	1 e	1.1 i	0.3 f
Q	32 cd	14 bc	7.1 cd	3.2 ab
V	25 e	25 a	11.5 a	3.5 a
		Trial #2		
A	48 a[z]	13 de	6.6 d	1.8 ab
B-4[x]	35 c	31 ab	10.4 bc	4.0 ab
C	37 bc	33 a	11.5 ab	3.2 ab
E	51 a	3 f	2.0 e	0.9 b
H	39 bc	24 c	8.6 bcd	1.4 b
J	41 b	17 d	6.8 d	2.0 ab
O-7[x]	52 a	12 de	7.0 cd	1.4 b
P	52 a	5 f	1.9 e	0.1 b
Q	37 bc	25 bc	8.5 bcd	1.8 ab
V	34 c	33 a	14.2 a	7.3 a

[z]1 g = 0.0353 oz.
[y]Within a trial and column, means for a given parameter followed by the same letter are not significantly different according to Tukey's honest significance difference at the 0.05 level.
[x]Multiple bags of brands purchased at different locations were given a number designation.

100 mg·L^{-1} nitrogen (N) supplied from a 20N–4.4P–16.7K fertilizer (Peter's Peat-Lite Special; Scotts-Sierra Horticultural Products Co., Marysville, Ohio). Plants were grown in a greenhouse at 24/18 °C (venting/night temperature set points) under 16 h of supplemental light supplied by 400-W high-pressure sodium lamps.

Samples were collected from three replicates of each medium at the end of the third week of the trials and analyzed for SM pH. Date of first flower was recorded for each plant. After all plants had flowered, the total number of flowers on each plant was recorded. Shoots were removed and media washed from the roots. Shoot and root tissues were oven-dried at 85 °C for 48 h and weighed. The experiment was repeated once for each plant species. The first experiment was conducted from September to November and the second experiment from February to April. Each experiment was a randomized complete-block design with eight replications. Data were analyzed using conventional analysis of variance procedures. For each plant species, each trial was analyzed separately due to a statistical interaction between time and medium for plant performance data. Means were compared using Tukey's honest significant difference (HSD) calculated at the 0.05 level of significance. For each of the plant growth trials, a matrix of Pearson correlation coefficients and associated *P*-values for level of significance was developed for relationships between individual physical and chemical properties of the media and measures of plant performance (time to flower, flowers per plant, root and shoot dry weights).

Results and discussion

The samples obtained for this study were brand name products sold as general purpose potting media. None of the media were marketed for commercial greenhouse applications. A summary of physical and chemical properties of the media is reported in Table 1 (adapted from Wiberg et al., 2005).

Tomato seed germination. At the end of 15 d, tomato seed germination ranged from 30% to 90% among brands in the first trial and 60% to 90% among brands in the second trial (Fig. 1). Medium K resulted in fewer seeds germinated than any of the other media in the first trial. Due to a limited amount of this medium, K was not included in the second trial. Media H, P, and Q resulted in fewer seeds germinated than medium J in the first trial, and fewer than both I and J in the second trial.

Temperature and misting frequency were constant among media. Therefore, differences in germination were likely due to either differences in water retention or chemical properties of the media. Medium K contained a large amount of sand and had the highest bulk density and lowest water retention of all media evaluated in the germination trials (Table 1). This medium clearly had problems retaining water during the germination trial. Media H and P had the lowest air space of the media evaluated, and medium Q had one of the highest SM extract

ECs, of the media evaluated (Table 1). Similar to Q, however, medium I had a high EC but significantly higher germination than Q. Pittenger (1986) also found that tomato seed germination varied among media and that media with high levels of soluble salts did not necessarily result in lower germination. Apparently, soluble salts are readily leached from media (Bunt, 1976; Handreck and Black, 2002) and may not inhibit germination in an open container system. Soluble salts could be a problem in a closed container or if salts are not leached before planting.

Within brands, only medium S-4 resulted in significantly lower germination at the end of 15 d than other bags of brand S (Fig. 2). Medium S-4 had relatively low air space (7% by volume), but so did S-5 (4%), which had a 15 d germination percentage similar to the other bags of medium S (Fig. 2). Medium S-4 had higher nitrate-N (NO_3-N) and calcium (Ca), and lower P and K, concentrations than S-5 (data not presented). It is unlikely these differences in chemical properties would result in lower germination in S-4, but indicate other differences may have existed between S-4 and S-5.

With the exception of medium S, CVS among brands (Fig. 1) were lower than within brands (Fig. 2). This suggests that there is less variability in germination performance within a brand than among brands. Physical and chemical properties were also less variable within a brand than among brands of retail potting media (Wiberg et al., 2005).

PLANT GROWTH. In the first 3 weeks, plants growing in several of the media showed symptoms of nutrient imbalance. Media used in this study had a broad pH range (5.4 to 7.5; Table 1). Marigolds are prone to iron and manganese toxicity and may develop necrotic spots and a bronze appearance when media pH is below 6.0 (Fisher et al., 2001). Petunias are prone to iron deficiency and may develop chlorosis symptoms in new foliage when media pH is above 6.2 (Fisher et al., 2002). Both visual symptoms were apparent early in the trials with certain media, but became less pronounced as the trials progressed. Media pH at the end of the third week averaged 7.3 among brands in Trial 1 and 7.2 in Trial 2, compared to an initial average media pH of 6.5 (Table 1). The irrigation water used in this study was alkaline

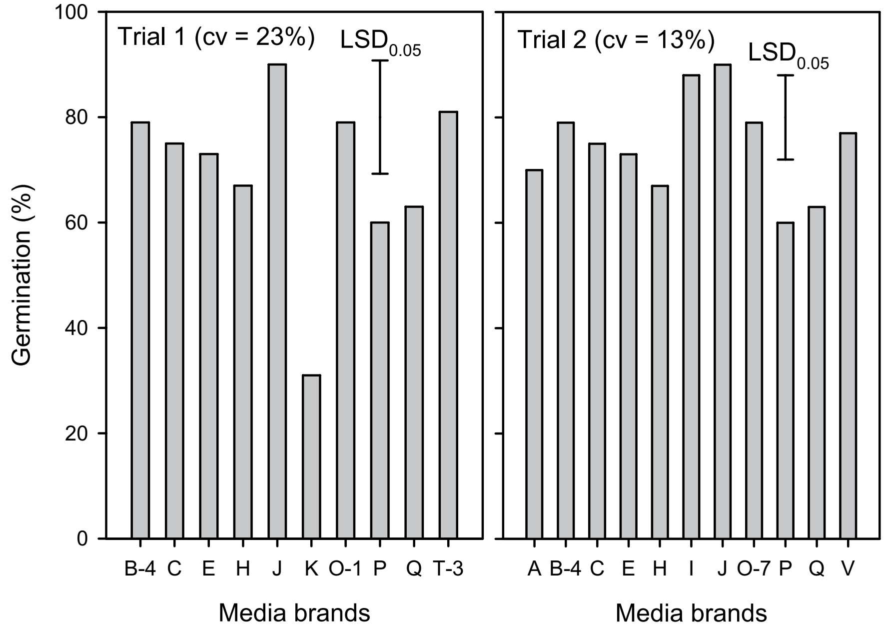

Fig. 1. The influence of retail media brands on percent tomato seed germination after 15 d under intermittent mist. Different media brands are identified by capital letter designation. Number designations identify separate bags of a medium brand. Least significant difference values were calculated at the 0.05 level ($LSD_{0.05}$) for germination comparisons made at 15 d among media within a trial. CV = coefficient of variation for average 15 d germination among brands.

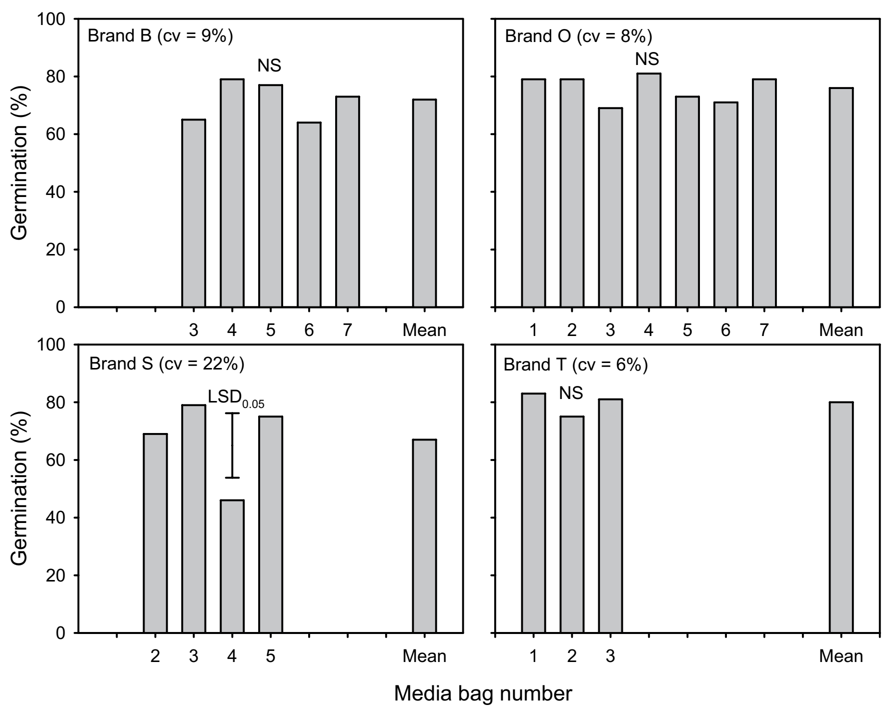

Fig. 2. The influence of separate bags of the same brands of four different media on percent tomato seed germination after 15 d under intermittent mist. NS = no significant difference in germination among bags of that medium. The least significant difference value was calculated at the 0.05 level ($LSD_{0.05}$) for germination comparisons made at 15 d among bags of medium S. The "mean" bar represents the average tomato seed germination for a brand. CV = coefficient of variation for average 15 d germination among bags within a brand.

(pH range 7.8 to 8.1) and apparently increased average media pH over time. An increase in media pH would explain the improvement in marigold appearance but would have aggravated petunia symptoms. We cannot explain why petunia symptoms became less pronounced as the trials progressed. Plants growing in certain media also continued to exhibit symptoms such as a light green color, senescence of lower leaves, and purple coloration for the duration of the study even though all media were fertilized uniformly three times per week beginning at week two with a solution containing N, P, and K.

The time to flower, total number of flowers per plant, and shoot and root dry weights of marigold were clearly affected by media brands (Table 2). In Trial 1, marigolds growing in media B-4, C, H, and Q flowered earlier and produced more flowers with higher shoot and root dry weights than the other media. Marigolds growing in media E, J, O-1, P, and T-3 did not perform as well, requiring more days to flower, and producing fewer flowers with lower shoot and root dry weights than plants growing in the other media. Similar trends were observed in the second marigold trial (Table 2), although the time to flower, number of flowers per plant and shoot and root dry weights were lower than in Trial 1. Similar to marigold, differences among media were observed in petunia performance (Table 3). Petunia performance was relatively good in media B-4, C, and V, and poor in media A, E, J, O-7, and P. Plants growing in media E and P, in particular, produced very few flowers and had exceptionally low shoot and root dry weights.

The relatively poor performance of plants growing in media E, O-1, P and T-3 could be attributed to individual physical and chemical properties. For example, compared to other media medium E had a relatively low concentration of nitrate-N (NO_3-N), O-1 a low pH, P a low percent air space and phosphorus concentration, and T-3 a low potassium concentration (Table 1). Comparatively, medium J did not have any obvious chemical or physical properties that might explain the relatively poor performance of plants growing in this medium. Also, among media with good plant performance (B-4, C, H, Q, and V), C had a relatively low phosphorus concentration, H had a low percent air space, and Q had high salinity and pH (Table 1). Since many different physical and chemical properties of potting media affect plant growth one would not expect performance to be related to a single property of the media. In fact, few correlations between individual physical and chemical properties of the media and plant performance were significant. Saturated media extract EC and NO_3-N concentration were negatively correlated ($P < 0.05$) with days to flower in both marigold trials, while NO_3-N was positively correlated ($P < 0.05$) with shoot and root dry weights in both trials, and with the number of flowers per plant in Trial 1. These correlations occurred even though all media were fertilized uniformly with a 100 $mg·L^{-1}$ nitrogen solution. No physical property was correlated with marigold performance. There were no significant correlations between individual physical or chemical properties of the media and petunia performance (data not presented).

Tomato seed germination in media K and Q was significantly lower than in medium J (Fig. 1); however, overall plant performance in media K and Q in the marigold trial, and medium Q in the petunia trial (medium K was not included in the petunia trial), was better than in medium J. Pittenger (1986) also found that media with poor seed germination could produce satisfactory plants and media with good germination could produce poor plants, indicating that optimum media properties for germination and plant growth are not necessarily the same. There was more consistency in the performance of certain media between the marigold and petunia trials. For both plant species, plants growing in media B-4 and C performed well, while plants in media E, J, and P performed poorly.

Popular press articles recommend consumers choose media with high quality components and well-known, name brands (Chaplin, 1999; Peterson, 2003; Pittenger, 1986). However, the majority of media used in this study were well-known brands with quality components stated on the label. Brand name and label components alone may not be sufficient to gauge quality in retail potting media. Price per unit volume was also not a good indicator of media performance since some media with relatively low price (C and Q; \$3.68/ft^3 to \$3.96/ft^3) performed well in the growth trials while other, more expensive media (J, O-1, and T-3; \$5.94/ft^3 to \$9.06/ft^3) did not. Based on the results of this comparative study few recommendations can be made to consumers regarding the selection of a quality retail potting medium. Results from the present germination trials (Figs. 1 and 2) and physical and chemical analyses previously reported (Wiberg et al., 2005) indicate there is less variability within a brand of media than between brands. Therefore, when consumers identify a brand with acceptable performance, they are more likely to obtain consistent results by purchasing additional bags of the same brand than by purchasing a different brand.

Results of this study are similar to those of Pittenger (1986) in that few relationships between measured physical and chemical properties and plant performance could be discerned. Of the media evaluated in this study, only brand B met all of the published suitability standards (NBSPA, 2001; NCSU, 2005) for chemical properties of premium media. The performance of plants growing in medium B was better than in many of the other media; however, other media that did not meet all of the suitability standards for chemical properties still performed as well as brand B. Apparently, media may perform well even if they do not meet all of the published suitability standards. It is also possible that media that meet suitability standards may not perform well if an important property is absent from the standards and also deficient in the media.

The large amount of variation among and within brands of retail media suggests opportunities for manufacturers to improve overall quality and quality control practices. Significant variation in plant growth response to media with diverse properties means it may not be possible to evaluate media performance based solely on analyses of certain physical and chemical properties. Standards emphasizing plant performance in addition to, or in place of, measured physical and chemical properties may be necessary to ensure acceptable and more consistent performance of plants growing in retail potting media. These standards exist (NBSPA, 2001), but apparently are not widely used by the retail media industry.

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