Research Reports

Variability in the Physical and Chemical Properties of Retail Potting Media

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Summary. Popular press articles report that consumers often experience inconsistent results with retail potting media; however, few reports in the popular or scientific literature have quantified the variability in media properties. The purpose of this study was to assess the variability in physical and chemical properties among different brands of retail potting media and within certain brands. Twenty-four different packages of branded media, and multiple packages of five brands, were acquired from nine regional and national retail chain stores located in the Salt Lake City, Utah, area. Samples were analyzed for five physical and nine chemical properties. The coefficients of variation (CVs) among brands for initial gravimetric water content, bulk density, porosity, water retention, and air space were 85%, 74%, 21%, 59%, and 44%, respectively. The CVs among brands for saturated media (SM) pH, SM extract electrical conductivity (EC), nitrate-nitrogen (NO_3-N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), total carbon (C), total nitrogen (N), and C:N ratio were 18%, 81%, 132%, 153%, 96%, 78%, 71%, 36%, 45%, and 49%, respectively. Only one of the 24 brands met all published standards for chemical properties of premium media. Thirteen of the brands did not meet standards for NO_3-N; 12 did not meet standards for pH; and six did not meet standards for EC. There was more variation in physical and chemical properties among brands than within a brand of media. Label information describing media composition was not consistent with certain physical and chemical properties. No recommendations can be made which would allow consumers to select media that meets published standards. These results indicate better awareness of and/or adherence to standards is needed by the retail media industry to improve product quality and consistency.

Consumers can select from many different brands of potting media in retail stores. Labels on these media normally identify major components and additives, but provide little additional quantitative or objective quality assessment information on which consumers can base a purchasing decision. Label descriptors such as "premium," "professional grade," and "high quality" imply good performance; however, reports in popular press publications suggest consumers often experience inconsistent results with these media (Chaplin, 1999; McKinnon, 1980; Peterson, 2003; Pittenger, 1986).

Few studies have addressed variability among brands of retail potting media and none has addressed variability within a brand. Pittenger (1986) evaluated select physical and chemical properties of 15 different retail media brands. Considerable variability was found in physical properties such as air space and water retention, with even larger variations in chemical properties such as pH, EC, and nutrient content. Importantly, these media produced a wide range of tomato seed germination and early growth responses (Pittenger, 1986).

Recent efforts to improve the quality of planting media have resulted in the development of standards for "basic" and "premium" media [National Bark and Soil Producers Assn. (NBSPA), 1998; North Carolina State University (NCSU), 2004]. Physical properties such as water holding capacity, air space, and hydration index, and chemical properties such as pH, salinity, and soluble nutrient concentrations are part of the standards. Compliance with the standards is voluntary. It is not known how well retail potting media adhere to these standards. The objective of this study was to assess the variability in physical and chemical properties among 24 different brands of retail potting media and within selected brands of media. A secondary objective was to evaluate the extent to which retail media brands met published standards for chemical properties. Too many different brands of media exist to exhaustively sample all of them. Therefore, the intent of this study was to survey a subset of common branded media available to consumers for general-purpose use.

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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
0.01	%	$g \cdot g^{-1}$	100
0.0283	ft^3	m^3	35.3147
2.5400	inch(es)	cm	0.3937
0.0160	lb/ft^3	$g \cdot cm^{-3}$	62.4274
1	mmho/cm	$mS \cdot cm^{-1}$	1
1	ppm	$mg \cdot L^{-1}$	1
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

Materials and methods

Twenty-four different packages of branded media were acquired from nine regional and national retail chain stores located in the Salt Lake City, Utah, area. Additionally, multiple packages of five brands were purchased at different locations to assess variability within brands. Only one of the five brands identified different packages with a lot number. An A through X letter designation was used to reference the brands. Package volumes ranged from 0.2 to 2.8 ft^3. The contents of each package were passed through a 1-cm screen and mixed by hand in a 4-ft^3 plastic tub. Mixing was deemed necessary since, based on visual inspection, the contents of certain packages were segregated by particle size and density. Approximately 95% to 100% of the contents of each package passed through a 1-cm screen. Particles >1 cm in size consisting mainly of wood residues were discarded.

Physical properties. Controversy exists over the preparation of disturbed media samples for physical analyses (Hanan et al., 1981). For example, various methods have been used to prepare potting media to measure bulk density, porosity, and air space (Bugbee and Frink, 1986; Buley, 1983; Hanan et al., 1981; Pittenger, 1986). Our intent in this report was not to compare absolute values of physical properties with previous research results or published standards, but rather to assess variability among and within brands of retail potting media. In this study, we employed methods that facilitated equal treatment of different media and that are reproducible with the descriptions given below. The methods used to characterize the physical properties of media in this study are different than the porometer method employed by NCSU (2004), so direct comparisons of media physical properties to NCSU standards could not be made.

Bulk density was measured on sub-samples of the media that had been previously oven-dried at 60 °C for 24 h. Oven drying was necessary since the media varied in initial gravimetric water content (Table 1, discussed later). Oven-dry media were placed in a 5-cm-diameter glass cylinder fitted with an end cover. The medium was lightly packed in the cylinder by adding three 2.5-cm increments, and tamping the cylinder three times on a lab bench from a height of 5 to 10 cm between additions. The final weight and volume of material in the cylinder were determined and the process repeated twice for each medium.

Porosity and water retention measurements used samples of each medium that had not been oven-dried. Total porosity was estimated by determining water content by volume in samples of the media wetted to saturation (Rhoades, 1982). Gravimetric water content in the saturated media was determined by oven drying at 105 °C (Gardner, 1986). The process was repeated twice for each sample. Water retention was estimated by filling 5-cm-diameter glass cylinders with media as described for the bulk density measurements. Cylinders were fitted with a screen to retain the media, and a cover to retain water. Water was added until a 5-cm layer was standing on the surface. The columns were allowed to saturate for 24 h at which time the end cap was removed and media allowed to drain for 24 h. During drainage a plastic sheet was placed on the top of the columns to reduce drying. Media volume was calculated based on the cylinder diameter and media column height after drainage. Drained media were then removed from the column and oven-dried at 105 °C to determine gravimetric water content (Gardner, 1986). The process was repeated for each sample.

Volume water content at saturation and after drainage was estimated by assuming the density of water is 1 $g \cdot cm^{-3}$. Volume water content was calculated by dividing the volume of water by the total volume of media in the sample. Air space was estimated as the difference in volume water content between saturation and drainage. The mean, SD, and coefficients of variation [CVs (SD expressed as a percentage of the mean)] among and within brands of media were calculated for each physical property.

Chemical properties. Media pH was measured with a glass combination electrode in duplicate samples of water-saturated media (Rhoades, 1982). Solution was extracted from the saturated media under vacuum through a Whatman #42 filter. Electrical conductivity of the extract was measured with a conductivity electrode. Nitrate-N was measured with an ion selective electrode after adjusting the ionic strength of samples and calibration standards with ammonium sulfate (Keeney and Nelson, 1982). Phosphorus was measured colorimetrically (Olsen and Sommers, 1982). Potassium, Ca, and Mg were measured by atomic absorption spectrometry. Total C and N were determined by dry combustion in a Leco carbon–hydrogen–nitrogen analyzer (Leco Corp., St. Joseph, Mich.). Values for the mean, SD, and CVs among and within brands of media were calculated for each chemical property.

Results and discussion

The samples obtained for this evaluation were brand name products sold as general-purpose potting media. None of the media were marketed for commercial greenhouse applications. Most package labels included a description of components; however, it was clear from visual inspections of the contents that certain media either did not contain the stated ingredients, or the amount was too low to be identifiable. Labels on two of the media (P and U) did not list components but, based on visual inspection, these media contained mainly organic components.

Physical properties. The initial gravimetric water content of samples taken directly from the packages ranged from 0.08 to 4.41 $g \cdot g^{-1}$ dry media (Table 2). Bulk density, porosity, water retention and air space also varied among brands, though less than initial gravimetric water content (Table 1). Most media were organic-based, with bulk densities less than 0.5 $g \cdot cm^{-3}$ (Table 1). Two of the media (K and L) had relatively high bulk densities, identified sand as a component on the label and, based on visual inspection, clearly contained a large percentage of sand. However, four other media (C, E, N, and Q) also identified sand as a component, but had bulk densities similar to media that did not contain sand.

Porosity ranged from 34% to 92% by volume and had a lower CV among media than other physical parameters (Table 1). Porosity was related to bulk density ($y = -42x + 87$, $r = 0.82$, $n = 24$, $P < 0.001$), a finding similar to that of other media studies (Bunt, 1976; Hanan et al., 1981). Water retention ranged from 2% to 71% (Table 1) but was not related to bulk density ($r = 0.22$, $P > 0.10$). Media K and L, with high bulk densities and a large proportion of sand, had expectedly low water retentions. However, other media with low bulk densities and composed mainly of organic materials (D, G, Q, U, and X) also had relatively low water retention. These low water-retaining media were also among the lowest in initial gravimetric water content (Table 1), suggesting that these media were not easily rewetted during 24 h of saturation. This was supported by a linear relationship between initial gravimetric water content and water retention (y = 0.17x + 13, r = 0.84, n = 24, $P < 0.001$). Bunt (1976) noted the difficulty in rewetting dry peat-based potting media, and suggested it would be nearly impossible to do so once media are placed in a container. Bunt (1976) recommended the addition of wetting agents or surfactants to facilitate rewetting. According to package labels, nine of the media contained wetting agents (E, G, L, O, R, S, T, V, and W), but these did not result in higher average water retention (31%) than the other 15 media (33%). The wetting agents were either absent (contrary to the label statement), ineffective, or improperly mixed with the media.

Air space ranged from 5% to 75% by volume (Table 1). Air space was weakly correlated with bulk density (y = –27x + 49, r = 0.44, $P < 0.05$). Outliers were evident in the correlation between air space and bulk density. For example, medium P had moderate porosity (58%) and relatively high water retention (53%), which resulted in a low estimate of air space (5%). Medium U had relatively high porosity (77%) based on SM water content, but low water retention (2%) due to an inability to be wetted in the column as previously described. Collectively, these resulted in the highest estimate of air space for medium U (75%).

Within five of the brands, initial gravimetric water content (Table 2) was less variable than among brands (Table 1). Coefficients of variation for bulk density and porosity were also lower within than between brands. Coefficients of variation for water retention were higher among bags of media S and T (Table 2) than among different brands (Table 1), and the CV for air space was higher within brand S than among brands. Two bags of brand S had unusually high water retention values in excess of 75%, and correspondingly low air space estimates of less than 10%. After excluding these bags of media as outliers, initial gravimetric water content was linearly related to water retention within brands (y = 0.32x – 1.4, r = 0.96, n = 25, $P < 0.001$).

Physical properties such as water retention, drainage, and aeration are important in potting media (Hershey, 1990; Shumack, 1978; Swanson,

Table 1. Variation in water content, bulk density, porosity, water retention, and air space among 24 different brands of retail potting media.

Potting medium	Initial water content ($g \cdot g^{-1}$ dry media)[z]	Bulk density ($g \cdot cm^{-3}$)[y]	Porosity (% by volume)	Water retention (% by volume)	Air space (% by volume)
A	2.95	0.18	87	53	34
B[x]	0.90	0.31	82	27	55
C	2.33	0.29	92	68	25
D	0.63	0.24	62	15	47
E	0.98	0.25	61	24	37
F	0.78	0.42	64	33	31
G	0.85	0.16	81	14	68
H	2.36	0.33	79	69	10
I	1.02	0.48	72	49	23
J	1.08	0.28	71	30	40
K	0.11	1.18	34	13	21
L	0.08	1.25	37	10	27
M	1.16	0.23	65	27	38
N	0.70	0.33	66	23	43
O[x]	0.82	0.28	79	24	55
P	1.83	0.68	58	53	5
Q	0.62	0.54	62	19	43
R	0.36	0.34	87	30	57
S[x]	0.88	0.29	77	48	29
T[x]	1.23	0.28	78	35	43
U	0.14	0.13	77	2	75
V	1.08	0.20	76	22	54
W	4.41	0.16	91	71	20
X[x]	0.62	0.37	65	19	46
Mean	1.16	0.39	71	32	39
Standard deviation	0.99	0.29	15	19	17
CV (%)	85	74	21	59	44

[z]1 $g \cdot g^{-1}$ dry media = 100% water by weight.
[y]1 $g \cdot cm^{-3}$ = 62.4274 lb/ft^3.
[x]Multiple bags of the same brand purchased at different locations were analyzed separately. Data in the table are averages of the multiple bags of these media.

Table 2. Variation in water content, bulk density, porosity, water retention, and air space within five brands of potting media.

Medium (n = no. of entries)	Initial water content ($g \cdot g^{-1}$ dry media)[z]	Bulk density ($g \cdot cm^{-3}$)[y]	Porosity (% by volume)	Water retention (% by volume)	Air space (% by volume)
B (n = 9)					
Mean	0.90	0.31	82	27	55
Range	0.14 – 1.86	0.27–0.35	69–96	4–52	32–65
SD	0.49	0.03	8	15	11
CV (%)	54	10	10	56	20
O (n = 7)					
Mean	0.82	0.28	79	24	55
Range	0.50–1.30	0.20–0.35	70–92	14–40	48–58
SD	0.25	0.05	8	9	4
CV (%)	30	18	10	38	7
S (n = 5)					
Mean	0.88	0.29	77	48	29
Range	0.58–1.16	0.22–0.36	63–87	17–82	4–56
SD	0.21	0.05	12	30	33
CV (%)	24	17	16	63	114
T (n = 3)					
Mean	1.23	0.28	78	35	43
Range	0.51–2.12	0.26–0.32	69–95	13–68	27–57
SD	0.82	0.03	15	29	15
CV (%)	67	11	19	83	35
X (n = 3)					
Mean	0.62	0.37	65	19	46
Range	0.59–0.82	0.36–0.37	54–73	17–22	36–52
SD	0.15	0.01	10	3	9
CV (%)	24	3	15	16	20

[z]1 $g \cdot g^{-1}$ dry media = 100% water by weight.
[y]1 $g \cdot cm^{-3}$ = 62.4274 lb/ft^3.

1989). It has been suggested that the most common reason for potted plant decline is overwatering and lack of aeration (Crockett, 1972; Hanan et al., 1981; Wright, 1974). Critical minimum media air space volumes of 5% to 10% have been cited for good plant performance (Bugbee and Frink, 1986; Hershey, 1990). Most media in the present study greatly exceeded these minimums, although some appeared to have excessively high air space at the expense of water retention properties.

Chemical properties. As with physical properties, chemical properties were variable both among and within brands. Media pH was the most consistent property with the lowest CV among samples. Concentrations of NO_3-N and P tended to have the highest CVs both among (Table 3) and within (Table 4) brands. Variability in chemical properties within brands (Table 4) was generally less than among brands (Table 3), as indicated by lower CVs.

Since a standard saturated media extract procedure was used to assess chemical properties, results were compared to the NCSU standards (NCSU, 2004) for premium potting media (Tables 3 and 4). Media pH ranged from 4.0 to 7.5, with only 12 of the 24 media in the optimum pH range of 5.5 to 7.0. Eighteen of the 24 media had EC levels between the NCSU standards of 1.0 to 5.5 $mS \cdot cm^{-1}$, but two of the media had EC values in excess of 10 $mS \cdot cm^{-1}$.

Thirteen of the media had concentrations of NO_3-N below NCSU standards, and five had levels as low as 0.2 $mg \cdot L^{-1}$ (Table 3). All but three of the media exceeded the NCSU minimum standards for P and K, and all exceeded standards for Ca and Mg. Concentrations of P, K, Ca, and Mg were, however, highly variable among brands with CVs ranging from 71 to 153%. The CVs for total C, total N, and C:N ratio were lower than for other chemical properties except pH. Media that contained a large proportion of sand and had high bulk densities (K and L; Table 2) had expectedly low total C and N concentrations (Table 3).

Some disagreement was apparent between measured chemical properties (Table 3) and composition stated on the label. For example, according to the label, 21 of the media (all but A, J, Q) contained sphagnum peat moss or peat and five (F, S, V, W, and X) contained lime; however, neither component had any clear relationship to pH. Labels on four media (A, O, R, and V) identified fertilizer as a component, though this did not result in consistently higher nutrient levels than media that did not include fertilizer.

While CVs for chemical properties were generally lower within (Table 4) than among (Table 3) brands, values for certain chemical properties were still highly variable within three of the five brands. Medium O had high CVs for NO_3-N, P, and K (Table 4). Medium O listed fertilizer as a component on the label. This variation in nutrient content suggests that fertilizer may not have been uniformly distributed

Table 3. Variation in saturated media (SM) pH, SM extract electrical conductivity (EC) and nutrient concentrations, total carbon (C) and nitrogen (N) concentrations, and C:N ratio among 24 different brands of retail potting media.

Potting medium	pH	EC	Nitrate-N (NO_3-N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Total C	Total N	C:N ratio
		(mS·cm^{-1})[z]	[mg·L^{-1} (ppm)]					(%)		
A	6.1	1.6	1.1	13.1	163	121	44	38	0.81	47
B[y]	6.0	4.3	3.8	15.3	388	296	98	29	0.90	32
C	6.7	1.5	2.5	0.4	108	154	38	18	0.17	105
D	4.5	5.9	14.2	97.8	273	423	302	34	1.34	26
E	7.3	2.9	0.2	1.3	305	83	31	38	1.13	34
F	6.8	2.1	0.2	8.3	248	64	35	27	0.52	53
G	5.4	1.9	3.2	17.9	173	122	47	39	0.74	54
H	6.2	1.7	1.1	1.3	88	73	40	16	0.65	25
I	7.2	12.5	0.7	3.1	522	191	70	24	0.58	41
J	6.2	3.2	1.4	28.8	439	137	88	35	0.51	68
K	7.2	4.8	5.2	1.3	245	512	186	3	0.19	16
L	7.4	3.8	1.4	1.7	303	329	104	2	0.13	17
M	4.0	5.0	11.7	45.0	247	321	82	40	0.96	42
N	6.5	3.9	0.2	9.6	342	313	124	37	0.52	72
O[y]	4.9	3.4	6.8	12.2	205	305	91	27	0.60	45
P	6.4	3.2	3.8	0.0	30	772	89	23	1.30	18
Q	7.5	11.1	8.6	5.2	1315	178	99	24	0.88	27
R	4.2	6.6	18.1	4.4	370	564	178	29	0.98	30
S[y]	4.8	1.4	2.9	22.7	94	128	39	32	0.80	40
T[y]	6.0	0.9	0.2	1.3	48	76	24	27	0.41	66
U	5.0	0.6	0.2	1.7	10	68	40	33	0.86	38
V	6.2	3.0	2.0	10.0	257	85	81	38	0.93	41
W	5.5	1.2	1.8	16.2	147	148	104	37	0.93	40
X[y]	6.8	1.1	0.5	18.8	120	40	28	35	0.70	45
Mean	6.0	3.7	3.8	14.0	274	237	89	28	0.73	43
SD	1.1	3.0	5.0	21.4	263	186	63	10	0.33	21
CV (%)	18	81	132	153	96	78	71	36	45	49
NCSU Standards[x]	5.5–7.0	1.0–5.5	2.3–45.2	≥1.3	≥21	≥30	≥10			

[z]1 mS·cm^{-1} = 1 mmho/cm.
[y]Multiple bags of the same brand purchased at different locations were analyzed separately. Data in the table are averages of the multiple bags of these media.
[x]North Carolina State University standards for premium potting media (North Carolina State University, 2004).

among packages of this brand. Similar variability was found among packages of media S and X (Table 4), although these brands did not identify fertilizer as a component.

In a retail potting media evaluation conducted by Pittenger (1986), eight of 15 brands met the NCSU premium standards for pH and EC; three met the standards for NO_3-N; all of the brands met the standards for P and K. In the present study, three of 24 brands met the NCSU standards for pH, EC, and NO_3-N; only one met all of the standards for chemical properties. These results do not indicate improvement as measured against published standards for potting media chemical properties. This could mean that the standards are not widely known in the industry or that retail potting media producers are not actively striving to meet these voluntary standards.

Pittenger (1986) recommended that, for best performance, consumers select media high in bark, wood products, peat moss, and vermiculite. Due to the large amount of variability among and within brands of media, and the apparent inconsistencies between stated media composition and certain physical and chemical properties, no recommendations can be made from the present study which would allow consumers to consistently select high quality media based on label information. The failure to meet published standards coupled with the large amount of variation among and within brands suggests a need for retail media manufacturers to improve quality and quality control practices.

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Table 4. Variation in saturated media (SM) pH, SM extract electrical conductivity (EC) and nutrient concentrations, total carbon (C) and nitrogen (N) concentrations, and C:N ratio within five brands of potting media.

Medium (n = no. of entries)	pH	EC	Nitrate-N (NO_3-N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Total C	Total N	C:N ratio
		(mS·cm^{-1})[z]	[mg·L^{-1} (ppm)]					(%)		
B (n = 9)										
Mean	6.0	4.3	3.8	15.3	388	296	98	29	0.90	33
Range	5.3–6.4	2.2–5.4	0.2–8.4	8.7–19.2	233–448	147–494	45–149	23–31	0.65–1.10	27–53
SD	0.4	1.0	2.9	3.5	73	112	39	4	0.10	9
CV (%)	7	23	76	23	19	38	40	14	11	27
O (n = 7)										
Mean	4.9	3.4	6.8	12.2	205	305	91	27	0.60	45
Range	4.0–6.1	1.3–5.6	0.2–13.5	0.4–53.3	102–357	121–481	41–141	21–37	0.45–0.66	35–82
SD	1.0	1.8	6.3	19.2	96	144	40	5	0.10	17
CV (%)	20	53	93	157	47	47	44	19	17	31
S (n = 5)										
Mean	4.8	1.4	2.9	22.7	94	128	39	32	0.80	40
Range	4.2–5.7	0.8–2.0	1.4–5.2	2.6–43.2	66–159	27–359	14–77	19–45	0.30–1.29	21–83
SD	0.6	0.6	1.8	17.9	38	143	26	10	0.40	25
CV (%)	13	43	62	79	41	112	67	31	50	49
T (n = 3)										
Mean	6.0	0.9	0.2	1.3	48	76	24	27	0.41	66
Range	5.4–6.3	0.6–1.2	0.0	0.9–1.7	43–57	13–115	5–37	24–29	0.37–0.43	55–79
SD	0.5	0.3	0.0	0.4	8	55	17	3	0.00	12
CV (%)	8	33	0	31	16	72	71	11	0	18
X (n = 3)										
Mean	6.8	1.1	0.5	18.8	120	40	28	35	0.70	45
Range	6.7–7.0	1.0–1.3	0.0–1.1	13.5–23.1	117–123	31–49	21–38	31–37	0.73–0.77	43–48
SD	0.2	0.2	0.7	4.8	3	9	9	3	0.00	3
CV (%)	3	18	150	26	3	23	32	9	0	7

[z]1 mS·cm^{-1} = 1 mmho/cm.

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