

Source Variation in Physical and Chemical Properties of Coconut Coir Dust

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Abstract. Physical properties differed significantly among five Philippine-produced coconut (*Cocos nucifera* L.) coir dust sources. Bulk densities ranged from 0.04 to 0.08 g·cm⁻³. Air-filled pore space, water-filled pore space, and total pore space ranged from 9.5% to 12.6%, 73.0% to 80.0%, and 85.5% to 89.5% (v/v), respectively. Total solids accounted for 10.5% to 14.5% of total volume, and water-holding capacities ranged from 750% to 1100% of dry weight. Significant differences existed in particle size distribution, with the largest differences occurring for particle sizes <8.0 mm and 0.25 to 0.50 mm in diameter. Chemical properties were determined for 12 sources from the Philippines, Sri Lanka, or Indonesia. The pH and electrical conductivities ranged from 5.6 to 6.9 and 0.3 to 2.9 mS·cm⁻¹, respectively, and were significantly different among sources. No significant differences occurred among samples with respect to Fe, Mn, Zn, B, Cu, NH₄-N, and Mg concentrations. Coir dust samples contained Fe, Mn, Zn, B, and Cu at 0.01 to 0.07 mg·L⁻¹. The levels of NH₄-N and Mg were 0.1 to 0.2 and 1.0 to 7.4 mg·L⁻¹, respectively. Significant differences occurred between sources for Ca, Na, and NO₃-N, with levels (mg·L⁻¹) ranging from 1.0 to 24.3, from 22.3 to 88.3, and from 0.4 to 7.0, respectively. The widest ranges occurred in K (19 to 948 mg·L⁻¹) and Cl (26 to 1636 mg·L⁻¹). Sources differed with respect to cation exchange capacities, with values ranging from 38.9 to 60.0 meq/100 g.

Artificial substrates are used extensively in the production of containerized greenhouse and nursery crops and are usually composed of several components. Among these, peat is one of the most widely used materials. Environmental concerns (Barkham, 1993; Buckland, 1993; Robertson, 1993) and increasing prices have generated significant interest in the development of alternatives to peat.

Most research into the development of peat substitutes has focused on the use of municipal or agricultural wastes. However, some of these materials are proving to be unsuitable because of their high degree of variability and their likelihood of containing undesirable materials such as glass, metal fragments, lead, and mer-

cury. Other materials are not produced in volumes large enough to impact the market. Any potential peat substitute must have suitable physical and chemical properties, must be available in significant quantities, and must be uniform and economically compatible with the potential markets. One material that is purported to meet these requirements and is being marketed as a peat substitute is coconut coir dust (CD).

Although CD may be produced in any coconut-producing region, it is primarily produced in Sri Lanka, India, Philippines, Indonesia, Mexico, Costa Rica, and Guyana. The raw material for the production of CD is the mesocarp tissue, or husk, of the coconut fruit. The husk contains 60% to 70% pith tissue, with the remainder being fiber of varying lengths (F. Soriano, personal communication). After grinding the husk, the long fibers are removed and used for various industrial purposes, such as rope and mat making. The remaining material, composed of short and medium-length fibers as well as pith tissue, is commonly referred to as waste-grade coir. The waste-grade coir may be screened to remove part or all of the fiber, and the remaining product is referred to as CD.

Reports of physical and chemical properties of CD are limited to either commercial product labels or single sources (Handrek, 1993). The objective of this study was to determine the physical and chemical properties of CD from several sources and to determine the degree of variability that exists among them.

Commercially produced CD was collected from the Philippines by the authors or provided by cooperators from Sri Lanka and Indonesia. For each of 12 locations (Table 1), five random samples were collected. All samples collected were referred to and marketed as CD. Chemical properties of all samples were determined, but only sources A, B, C, D, and E were used for physical properties testing due to limitations of sample volumes.

Particle size distribution was determined by rehydrating and air-drying CD samples. After samples were dried, particles sizes were separated by sieving 100-g samples on a CSC Scientific (Fairfax, Va.) rotary shaker for 10 min using screens with pore diameters of 8.0, 6.3, 4.0, 2.0, 1.0, 0.5, and 0.25 mm. Five samples were screened for each coir source. The weight of the material collected in each screen was determined. The weights and standard errors were plotted against pore size.

The air-filled pore space at container capacity [percent by volume (% v/v)], water-filled pore space at container capacity (% v/v), total pore space (% v/v), total solids (% v/v), water-holding capacity at container capacity [percent by weight (% w/w)], and bulk density (g·cm⁻³) were determined using loose-packed cores and methods adapted from Byrne and Carty (1989). However, we used 7.5 (height) × 7.5-cm (inside diameter) cylinders with volumes of 345 mL.

Substrate nutrient status was determined using the saturated media extract method as outlined by the North Central Regional Committee for Soil and Plant Analysis (Warncke, 1988). Electrical conductivity (EC) was determined using a Beckman (Cedar Grove, N.J.) solu-bridge (measured as mS·cm⁻¹), and the pH was determined using an Orion (Cambridge, Mass.) pH meter. Nitrate N concentration was determined using the copperized cadmium reduction procedure (Keeney and Nelson, 1982) and ammonium was determined by the nitroprusside-salicylate procedure (Wall et al., 1975). The Cl concentration was estimated by the mercury thiocyanate procedure (Fixen et al., 1988). For P, K, Ca, Mg, B, Fe, Mn, Zn, Cu, and Na, we used the filtered

Table 1. Source of coir dust samples.

Source code	Sample source or location
A	Davao City, Mindano, Philippines
B	North of Davao City, Mindano, Philippines
C	San Pablo City, Luzon, Philippines
D	Laguna province, Luzon, Philippines ^z
E	Laguna province, Luzon, Philippines ^z
F	Laguna province, Luzon, Philippines ^z
G	Commercial sample, Sri Lanka ^y
H	Commercial sample, Sri Lanka ^y
I	Commercial sample, Sri Lanka ^y
J	Raiugkas Bitung, Java, Indonesia
K	Lampung, Sumatra, Indonesia
L	Tasik, Java, Indonesia

^zSamples were collected from several coir dust factories in Laguna province.

^ySamples were commercial products provided by various suppliers.

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extract for simultaneous inductively coupled argon plasma emission spectrometry (Jones, 1977; Munter and Grande, 1981). Cation exchange capacity (CEC) was determined using the ammonium saturation/displacement method (Brown and Warncke, 1988).

Five replications were tested for each source. An analysis of variance was conducted to determine if source significantly affected a physical or chemical property. Where significant differences existed, a LSD mean separation test ($\alpha = 0.05$) was conducted to establish significant differences between means.

Results and Discussion

All physical properties tested differed significantly among sources. Bulk density ranged from 0.04 to 0.08 g·cm⁻³ (Table 2). Air-filled pore space and water-filled pore space at container capacity ranged from 9.5% to 12.5% and 73.0% to 80.0% (v/v), respectively. Total pore space ranged from 85.5% to 89.5% (v/v), while solids accounted for 10.5% to 14.5% of total volume. Physical properties of CD generally were in ranges similar to what would be expected of sphagnum peat (Abad et al., 1989; Puustjarvi and Robertson, 1975). However, water-holding capacities of CD samples ranged from 750% to 1100% of dry weight. Depending on degree of decomposition, sphagnum peat generally holds 400% to 800% of its weight in water (Puustjarvi and Robertson, 1975). This result confirms unpublished anecdotal reports that CD has a higher water-holding capacity than sphagnum peat.

Most of the particles in the CD sources were from pith tissue (particles <8 mm) and were between 0.5 and 2.0 mm in diameter (Fig. 1). There were significant differences among sources with respect to the amount of very fine particles (0.25 to 0.50 mm) and the amount of fiber (>8 mm).

Source B had a higher average bulk density, water-filled pore space, total pore space, and water-holding capacity than any of the other samples. Source B also had the lowest air-filled pore space. Source D had the lowest average bulk density, water-filled pore space, total pore space, and water-holding capacity. Source D also had the highest air-filled pore space. Differences in physical properties might be accounted for because of the differences in particles sizes between the sources (Table 2). Source B contained little fiber (<8 mm), while it contained the highest percentage of its weight as particles with diameters in the range of 0.25 to 0.5 mm. Source D contained significantly more fiber than the other samples. Increasing the particle size increases the number of noncapillary pores, increases air-filled pore space, and reduces water-holding capacity in peat (Puustjarvi and Robertson, 1975). Tilt et al. (1987) found that increasing the number of fine particles in a substrate increased the number of micropores and increased water-holding capacity of the substrate. It is therefore logical to assume that CD with high proportions of fiber and large particles will have larger air-filled pore spaces and reduced water-holding capacities as compared to CD

Table 2. Physical properties of coir dust from various sources.

Source	Bulk density (g·cm ⁻³)	Air-filled pore space at container capacity [v/v (%)]	Water-filled pore space at container capacity [v/v (%)]	Total pore space [v/v (%)]	Total solids [v/v (%)]	Water-holding capacity [w/w (%)]
A	0.05	11.5	74.9	86.4	13.6	910
B	0.08	9.5	80.0	89.5	10.5	1100
C	0.06	11.0	75.7	86.7	13.3	900
D	0.04	12.5	73.0	85.5	14.5	750
E	0.06	11.5	76.3	87.8	12.2	950
P > F	**	*	*	*	*	*
LSD ($\alpha = 0.05$)	0.02	2.0	6.4	3.5	3.0	125

ns, *, **Nonsignificant or significant at $P < 0.01$ or 0.001, respectively.

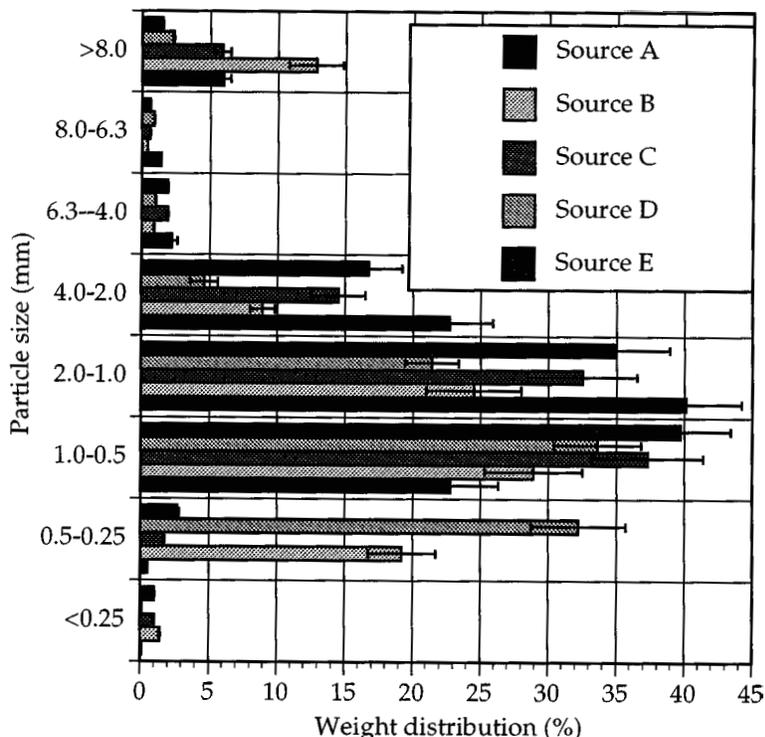


Fig. 1. Particle size distribution and standard errors for five sources of commercial coir dust.

with a larger proportion of small particles. Although coconut husks may vary in the proportion of pith and fiber tissue, the major factor that is likely to affect the relative proportions of particle sizes in processed CD will be factors associated with grinding the husk and screening the CD. Varying either the degree of grinding, the screen size, or the screening time may impact the relative proportions of particle sizes in the product and thus the physical properties of the CD.

The pH and electrical conductivities differed significantly among CD samples, with pH and electrical conductivities ranging from 5.6 to 6.9 and 0.3 to 2.9 mS·cm⁻¹, respectively (Table 3). All CD samples contained Fe, Mn, Zn, B, and Cu at 0.01 to 0.07 mg·L⁻¹ (detailed data not shown), with none of the differences being significant. The levels of NH₄-N and Mg were 0.1 to 0.2 and 1.0 to 7.4 mg·L⁻¹, respectively, and were similar for all sources (Table 3). Calcium, Na, P, and NO₃-N concentrations (in mg·L⁻¹) differed significantly among sources, ranging from 1.0 to 24, 22 to 88, 1.3 to 66, and 0.4 to 7.0, respectively (Table 3).

The ranges (in mg·L⁻¹) were higher for K and Cl, ranging from 19 to 948 and 26 to 1636, respectively (Table 3).

In some coir factories, raw coconut husks are soaked in water before grinding. In some locations, this water may be saline and thus contribute to the high levels of K, Na, and Cl in the resulting CD. However, several of the samples in the study were from locations where husks were not soaked in water before grinding and contained high levels of K and Cl, possibly because coconut plantation managers fertilize with KCl or NaCl (Menon and Pandalai, 1958; F. Soriano, personal communication). Coconuts are semi-halophytes and absorb salts and transport these to the developing fruit (Jeganathan, 1992). Since the Cl levels in the endosperm of coconut can be correlated with the level of KCl or NaCl applied to the tree (Remison et al., 1988), the Na, K, and Cl levels in the mature husk may be affected by applying KCl and NaCl to the trees. Other chemical constituents also may vary based on fertilization practices. Therefore, the mineral elements in CD and the

Table 3. Chemical properties of coir dust from various sources.^z

Variable	Source													P > F	LSD
	A	B	C	D	E	F	G	H	I	J	K	L			
pH	6.6	6.2	6.2	6.3	5.9	6.5	6.3	6.2	5.6	6.0	6.9	5.8	***	0.2	
EC ^y	0.8	1.6	1.2	1.9	2.5	1.3	1.4	2.9	0.3	0.9	1.0	2.5	***	0.5	
CEC ^x	39	48	45	55	60	46	43	50	49	45	50	57	***	19.0	
NH ₄ -N ^w	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	NS	---	
NO ₃ -N ^w	0.5	0.9	0.4	1.2	1.9	0.5	0.7	3.2	7.0	2.0	1.0	1.0	**	0.9	
P ^w	30	46	30	52	66	38	40	18	17	1.3	4.0	3.7	***	10.4	
K ^w	236	596	434	698	810	351	388	948	19	221	209	327	***	136	
Ca ^w	1.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	24	4.0	4.0	5.0	***	0.4	
Mg ^w	1.5	2.8	2.3	1.6	2.5	1.0	7.4	4.4	1.0	2.0	4.0	6.7	NS	---	
Cl ^w	183	435	300	560	721	377	337	843	26	517	512	1636	***	167	
Na ^w	31	22	25	42	32	48	32	37	34	31	88	30	**	21.5	

^zSee Table 1 for sources.

^yElectrical conductivity (EC) reported as mS·cm⁻³.

^xCation exchange capacity (CEC) reported as meq/100 g.

^wReported as mg·L⁻¹ in saturated medium extract.

NS, **, *** Nonsignificant or significant at $P < 0.01$ or 0.001 , respectively.

degree of variability in those elements may be a function of not only how the material is processed, but of the conditions under which the raw material was produced.

CEC ranged from 39 to 60 meq/100 g. This range is lower than that reported for sphagnum peat at 90 to 140 meq/100 g (Puustjarvi and Robertson, 1975) as well as the CEC reported on commercial labels (100 to 200 meq/100 g). The discrepancy may be a result of CD age. Large stocks of CD exist. The stocks are composed of CD that may be 20 years old or older (F. Soriano, personal communication) overlaid with recently added CD. Materials used in our study were from the surfaces of stock piles. Nelson (1991) and Puustjarvi and Robertson (1975) reported that the process of decomposition increases the CEC of organic materials. Therefore, the CEC of CD may depend on its age.

Although significant differences existed among sources with respect to chemical properties, most mineral elements were within ranges reported for sphagnum peats (Bunt, 1988) and considered acceptable for substrates to be used in most horticultural applications (Bunt, 1988; Peterson et al., 1989). The exceptions were pH, P, K, Na, and Cl. The higher pH of CD would negate the need to incorporate lime to raise substrate pH—a common practice when using peat in substrates—and the P and K found in CD may serve as a source of these mineral elements. However, Na and Cl levels may present problems when CD is used in substrates. Most sources indicate that Na and Cl levels of 75 mg·L⁻¹ or less are desirable in irrigation water (Bunt, 1988). Although only one sample had Na levels that exceeded this level, only one CD sample had Cl levels within the desirable range. It is unclear, however, whether Na and Cl in substrates are directly damaging to potted crops or whether the major effect is that of increasing the electrical conductivity of the substrate (Bunt, 1988).

Significant differences were observed among sources with respect to physical and chemical properties. Although the variability of most of these properties would not be of significant practical concern, others (i.e., Na and Cl) could be problematic with respect to using CD in substrates. The variability observed may originate from variability that exists in the raw husk as well as from variation in processing. An understanding of how husk source, degree of grinding, screen size, degree of screening, and CD age affect physical and chemical properties is needed so that a consistent product with acceptable characteristics can be produced.

Literature Cited

- Abad, M., V. Noguera, M.D. Martinez-Herrero, F. Fornes, and J. Martinez-Corts. 1989. Physical and chemical properties of sedge peat-based media and their relation to plant growth. *Acta Hort.* 238:45–56.
- Barkham, J.P. 1993. For peat's sake: Conservation or exploitation? *Biodiversity Conservation* 2:556–566.
- Brown, J.R. and D. Warncke. 1988. Recommended cation tests and measures of cation exchange capacity, p. 15–16. In: W.C. Dahnke (ed.). *Recommended chemical soil test procedures for the north central region*. North Dakota Agr. Expt. Sta. Bul. 499.
- Buckland, P. 1993. Peatland archaeology: A conservation resource on the edge of extinction. *Biodiversity Conservation* 2:513–527.
- Bunt, A.C. 1988. Media and mixes for container-grown plants. Unwin Hyman, London.
- Byrne, P.J. and B. Carty. 1989. Developments in the measurement of air filled porosity of peat substrates. *Acta Hort.* 238:37–44.
- Fixen, P.E., R.H. Gelderman, and J.L. Denning. 1988. Chloride tests, p. 26–28. In: W.C. Dahnke (ed.). *Recommended chemical soil test procedures for the north central region*. North Dakota Agr. Expt. Sta. Bul. 499.
- Handrek, K.A. 1993. Properties of coir dust, and its use in the formulation of soilless potting media. *Commun. Soil. Sci. Plant Anal.* 23(3, 4):349–363.
- Jeganathan, M. 1992. Nut water analysis as a diagnostic tool in coconut nutrition studies. *Commun. Soil Sci. Plant Anal.* 23(17–20):2667–2686.
- Jones, J.B., Jr. 1977. Elemental analysis of soil extracts and plant tissue ash by plasma emission spectroscopy. *Commun. Soil Sci. Plant Anal.* 8:345–365.
- Keeney, D.R. and D.W. Nelson. 1982. Nitrogen—Inorganic forms, p. 643–698. In: A.L. Page (ed.). *Methods of soil analysis*, Part 2, 2nd ed. Amer. Soc. Agron., Madison, Wis.
- Menon, K.P.V. and K.M. Pandalai. 1958. The coconut palm—A monograph. Indian Central Coconut Comm. Ernakulam, S. India.
- Munter, R.C. and R.A. Grande. 1981. Plant tissue and soil extract analysis by ICP-atomic emission spectrometry, p. 653–672. In: R.M. Barnes (ed.). *Developments in atomic plasma spectrochemical analysis*. Heyden and Sons, London.
- Nelson, P.V. 1991. Greenhouse operation and management. 4th ed. Prentice-Hall, Englewood Cliffs, N.J.
- Peterson, J.C., L.L. Kramer, and J. O'Bryan. 1989. Just what is in my soil, anyway. *Interior Landscape Industry* 6(8):48–50.
- Puustjarvi, V. and R.A. Robertson. 1975. Physical and chemical properties, p. 23–38. In: D.W. Robinson and J.G.D. Lamb (eds.). *Peat in horticulture*. Academic, New York.
- Remison, S.U., G.O. Iremiren, and G.O. Thomas. 1988. Effect of salinity on nutrient content of the leaves of coconut seedlings. *Plant & Soil* 109:135–138.
- Robertson, R.A. 1993. Peat, horticulture and environment. *Biodiversity Conservation* 2:541–547.
- Tilt, K.M., T.E. Bilderback, and W.C. Fonteno. 1987. Particle size and container size effects growth of three ornamental species. *J. Amer. Soc. Hort. Sci.* 112:981–984.
- Wall, L.L., C.W. Gehrke, T.E. Neuner, R.D. Cathey, and P.R. Rexroad. 1975. Total protein nitrogen: Evaluation and comparison of four different methods. *J. Assn. Official Anal. Chem.* 58:811–817.
- Warncke, D. 1988. Recommended test procedure for greenhouse growth media, p. 34–37. In: W.C. Dahnke (ed.). *Recommended chemical soil test procedures for the north central region*. North Dakota Agr. Expt. Sta. Bul. 499.