Sains Malaysiana 46(6)(2017): 975–980
http://dx.doi.org/10.17576/jsm-2017-4606-17

A Study on the Physical and Hydraulic Characteristics of Cocopeat Perlite Mixture as a Growing Media in Containerized Plant Production

(Kajian terhadap Sifat Fizikal dan Hidraulik Campuran *Cocopeat Perlite* sebagai Media Pertumbuhan dalam Pengeluran Tanaman dalam Bekas)

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ABSTRACT

A well-known planting medium in soilless culture is a coconut based material famously known in Malaysia as cocopeat. It is a viable ecologically friendly peat soil substitute for containerized crop production. The multipurpose growing media had received much interest particularly in commercial applications. This study focused on the physical and hydraulic characteristics of cocopeat perlite mixture as a growing media in containerized plant production. Perlite was added to cocopeat at a ratio of 3 cocopeat: 1 perlite. Bulk density, particle density, porosity, particle size distribution, water holding capacity, wettability and hydraulic conductivity of the media were evaluated. About 82.93% of the total particles were in the range between 0.425 and 4 mm in diameter at a bulk density of 0.09 g/cm^3*. Total porosity (79%) and wettability improved with the incorporation of perlite to cocopeat. This study showed that water holding capacity was very high at 912.54% whereas the saturated hydraulic conductivity was low at 0.1 cm/s. The results showed that adding perlite to cocopeat had improved the physical and hydraulic characteristics of the media.*

Keywords: Bulk density; cocopeat; hydraulic conductivity; perlite; water holding capacity

ABSTRAK

Media tanaman yang diketahui baik dalam budaya tanaman tanpa tanah ialah bahan berasaskan kelapa dikenali sebagai cocopeat *di Malaysia. Ia mesra hijau dan mampu menggantikan gambut untuk pengeluaan tanaman di dalam bekas. Bahan tanaman serbaguna ini telah menarik minat pelbagai pihak terutamanya dalam aplikasi komersial. Kajian ini memfokuskan kepada sifat fizikal dan hidraulik campuran* perlite *dan* cocopeat *sebagai media tanaman di dalam pengeluaran tanaman dalam bekas.* Perlite *telah ditambah kepada* cocopeat *pada nisbah 3* cocopeat*: 1* perlite*. Ketumpatan pukal, ketumpatan zarah, kadar keliangan, pengasingan saiz zarah, daya pegangan air, kebolehbasahan dan kekonduksian hidraulik telah dikaji. Purata 83% daripada jumlah zarah berada dalam julat lingkungan antara 0.425 dan 4 mm diameter untuk ketumpatan pukat 0.09 g/cm*^{3}*. Jumlah kadar keliangan (79%) dan kebolehbasahan telah meningkat dengan penambahan* perlite *kepada* cocopeat*. Kajian ini telah menunjukkan daya pegangan air adalah sangat tinggi iaitu 912.54% sementara kadar kekonduksian hidraulik adalah rendah 0.1 cm/s. Keputusan kajian telah menunjukkan penambahan* perlite *kepada* cocopeat *meningkatkan ciri fizikal dan hidraulik media.*

Kata kunci: Cocopeat*; daya pegangan air; kekonduksian hidraulik; ketumpatan pukal;* perlite

INTRODUCTION

Substrates or growing media is defined as solid materials other than soil, which can be in the form of mixtures or alone. These media should guarantee better rooting conditions and provide anchorage for the root system, supply water and nutrients to plants and suitable aeration environment to roots (Gruda et al. 2013, 2006) . A wide selection of growing media is available and the choice depends on grower's financial and technical implications (Gruda et al. 2013). However, most growers use substrates that are locally available as it is cheap and reliable. In tropical and subtropical area, coir which is a natural fiber material extracted from coconut husk are most popular. This coconut husk contains fibrous material known as coir that contains thick mesocarp of the coconut fruit (Meerow 1997). From the coconut husk, long fibers of coir are extracted and used for manufacturing products like brushes, mattress stuffing and seats. The process of extracting long coir fiber will leave behind waste product namely short coir fiber and dust. Hume (1949) in his paper mentioned that this short coir fiber is a mass of tiny, brown and irregular shape bits known as coir dust. Later he suggested that coir dust was renamed to cocopeat as this material has many characteristic of horticultural peat. This coconut coir dust or cocopeat is widely used for containerized growing medium for the production of ornamental potter plants (Bagci et al. 2011; Scagel 2003; Tariq et al. 2012) and other horticultural species (Ayesha et al. 2011; Erwan et al. 2013; Rubio et al. 2011; Tehranifar et al. 2007).

Cocopeat is a suitable growing media with acceptable physical and chemical attributes such as pH, electrical conductivity, bulk density and others (Abad et al. 2002).

However cocopeat has a very high water holding capacity which causes poor aeration in the root zone. This will later affect the oxygen diffusion to the roots. Depending on the handling and processing technique, the physical properties of cocopeat can easily affect the air capacity and water retention (Abad et al. 2002). Incorporation of coarser material into cocopeat media will solve this problem and improve aeration (Yahya et al. 2009). Perlite is recognized as media additive to increase aeration and draining of a media. It has large particles and low water holding capacity hence is most suitable for mixing with cocopeat. The physical shape of perlite will create passage forms which consequently balance the moisture retention and aeration in the root zone. In order to obtain the optimum growing media condition, incorporation of 1 part of perlite to 3 parts of cocopeat was most recommended (Cho et al. 2006; Mobini et al. 2009). Addition of 25% perlite into cocopeat has improved aeration level in the media and significantly increased the growth and yield of potato (*Solanum tuberosum* L.) (Mobini et al. 2009).

The possibility of combining cocopeat and perlite mixture in a ratio of 3:1 to be used as growing media was examined in this study. Physical properties of this mixture including its bulk density, particle density, porosity, particle size distribution, water holding capacity, wettability and hydraulic conductivity was investigated. Thus, the objectives of this study was to establish and categorized the physical properties of cocopeat perlite mixture (3 cocopeat: 1 perlite) and its applicability as a growing media in containerized crop production.

Materials and Methods

MEDIA PREPARATION

The study on physical characteristics was carried out at the Soil and Water Engineering Laboratory, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia. The media chosen was a ratio of 3 cocopeat: 1 perlite (by volume). Mixture was prepared in a large tank and mixed proportionally. A growing container 2 m long, 0.2 m high and 0.3 m wide was placed on a raised bench. The mixture was then placed into the growing container and compacted lightly by hand. As much as five samples of the media were collected for the bulk density, particle density and porosity analyses, while three samples were collected for the particle size distribution, water holding capacity, wettability and hydraulic conductivity analyses. The results for each characterization were obtained from the mean procedure of samples used.

Characterization

BULK DENSITY

Evaluation of bulk density was done by adapting the method by De Boodt et al. (1973) and Yahya et al. (2009) using core rings. Core rings were pushed into the media until it fully penetrated and excess media at the top and bottom of the ring was cut. After recording their weights, core rings together with media were oven dried at 105°C for 24 h. The internal dimension of the core ring was measured to determine bulk density using the following formula,

$$\rho_b = W_b - W_r / (\pi h\, d^2/4),$$

where ρ_b is the bulk density; W_b is the weight of media and core ring after oven dried (g); W_r is the weight of the core ring (g); h is the height of the core (cm); and d is the core diameter (cm).

PARTICLE DENSITY

The particle density was determined using the pycnometer method. Five to ten grams of oven dried media was inserted into a dry and weighed S.G. bottle and weighted again. Deaired distilled water was added into the bottle until sample was covered. The bottle was placed inside a desicator and vacuumed until 'boiling' stops and refilled with deaired distilled water. In order to obtain mass of bottle with oven dried sample and water, the bottle stopper was first fitted and outside bottle was dried. The weight of bottle and water was also measured by weighing the bottle filled with deaired distilled water. Particle density can be calculated using the following formula,

$$\rho_s = \rho_w M_s / M_{dw},$$

where ρ_s is the particle density; ρ_w is the density of water (g/cm^3); M_s is the mass of oven dried media (g); and M_{dw} the mass of water displaced by media (g).

TOTAL POROSITY

Porosity was determined using the following formula,

$$\phi = 1 - (\rho_b/\rho_s),$$

where ϕ is the porosity; ρ_b is the bulk density; and ρ_s (g/cm^3) is the particle density. Bulk and particle densities were determined earlier thus porosity can be determined.

PARTICLE SIZE DISTRIBUTION

Particle size analysis was determined using different sieve sizes and an electromagnetic vibratory shaker (Unit Test Scientific (UTS) Malaysia). It was used to separate the different particle size fractions of the media. The sieves size were 9.5, 6.3, 5.6, 4, 2, 1.4, 0.6, 0.425, 0.3, 0.25 and 0.125 mm. The media was shacked for 10 min and media left in each sieve was calculated using the formula, percent passing = Percent arriving - percent retained.

WATER HOLDING CAPACITY

The water holding capacity is defined as the total amount of water a media can hold. Determination of water holding capacity was done by adapting the method used by Shinohara et al. (1999) and followed by Harding and Ross (1964). By using filtered funnel with the lower part plugged with stopper, media samples were saturated in water at a ratio of 1 media: 2 water and left overnight. After water was left to drain for 3 h, the remaining media was oven-dried for 24 h at 105°C. Water holding capacity can be calculated using the following formula,

$$\text{WHC} = (M_w/M_s) \times 100,$$

where WHC is the water holding capacity; M_w is the mass of water retained in the sample (g); and M_s is the mass of oven dried sample (g).

WETTABILITY

Evaluation of wettability was done following the method described by Yahya et al. (2009). Measurements were taken by soaking the pots filled with 1 L media sample in standing water of 2 cm deep in plastic trays. Water was added to the tray whenever the 2 cm water level decreased. Wettability of the media was monitored every hour for the duration of 6 h using an electronic balance. Moisture content absorbed by the media was determined by subtracting the wet weight of the media with the dry weight and graph of moisture content against time can be plotted.

HYDRAULIC CONDUCTIVITY

Hydraulic conductivity (k) is the measurement of how ease water can flow through pore spaces in a media while saturated hydraulic conductivity (ks) describes the movement of water through saturated media. Higher values of k refer to permeable material that allows water to flow easily while lower values means less permeable material and restrict water flow. Hydraulic conductivity at saturation was determined by using the constant head method as described by Klute and Dirksen (1986) using the permeameter device. This method allows water to flow through a column of cylindrical media sample under constant head condition. At the same time, discharge was monitored through the media over a period of time. With the known discharge, time and measured length and cross sectional area of the sample, hydraulic conductivity can be calculated using the following formula,

$$k = Q/(I\ A\ t),$$

where Q is the amount of water (cm^3) measured in the graduate cylinder according to time t (s); I is the hydraulic gradient; and A is the sample cross section area (cm^2).

RESULTS AND DISCUSSION

PARTICLE SIZE DISTRIBUTION

Cocopeat perlite mixture were sieved to separate their particles at twelve fractions (<0.125, 0.125 - 0.25, 0.25 - 0.3, 0.3 - 0.425, 0.425 - 0.6, 0.6 - 1.4, 1.4 -2, 2.0 - 4.0, 4.0 - 5.6, 5.6 - 6.3, 6.3 - 9.5 and >9.5 mm) as shown in Figure 1. Most of the mixture particles were in the range between 0.425 and 4 mm in diameter (82.93%). Among these particles, perlite was only found in sieves size 1.4, 2 and 4 mm. More than 90% of the cocopeat particles were from pith tissues which were less than 8 mm (Evans et al. 1996; Fornes et al. 2003). A similar result was obtained by Noguera et al. (2003) with 90% of coconut coir dust particles were less than 8 mm. Furthermore, long and short fibers were found in sieves size 9.5, 2, 1.4 and 0.6 mm. Long and short fibers were not found in sieves less than 0.6 mm. The length of the fibers varied in each sieve according to the sieve diameter. Sieve size 9.5 mm collected the longest fiber of 100 to 110 mm length while in sieve 0.6 mm collected the shortest fiber from 10 to 20 mm.

BULK DENSITY, PARTICLE DENSITY AND TOTAL POROSITY

The bulk density of the mixture was 0.09 g/cm^3 (Table 1) which is less than 1 g/cm^3 thus can be categorized as light media. This value was also obtained by Evans and Stamps (1996) for cocopeat perlite mixture at 60:40 and 80:20.

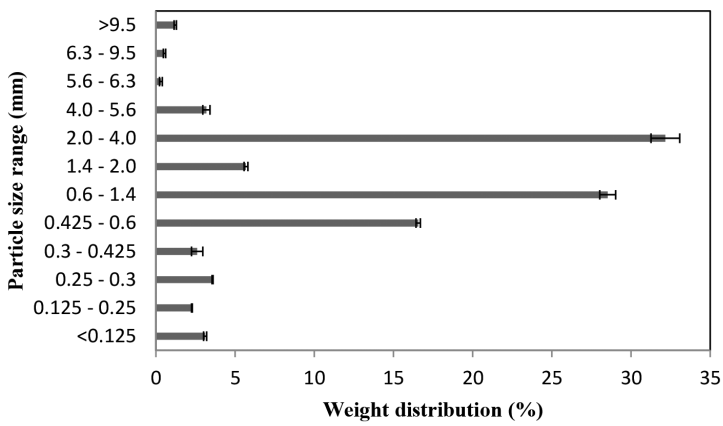

FIGURE 1. Particle size distribution and standard deviation (SD) of cocopeat perlite mixture (3:1). Data are mean ± SD (n=3 samples)

However, lower bulk density (0.05 g/cm^3) was found by Yahya et al. (2009) and higher bulk density (0.2 g/cm^3) from Cho et al. (2006) for the cocopeat perlite mixture (3:1). The difference of bulk density values were due to the variation of particle size distribution in the mixtures (Yahya et al. 2009). In this study, particle size from 2 to 4 mm had the highest weight distribution of 32.17% which leads to a higher bulk density compared to other studies. Using light materials in the mixture also resulted in a low particle density of 0.42 g/cm^3 (Table 1). According to Sudhagar & Sekar (2009) particle density is lower when higher amount of cocopeat is available in the mixture. This might be due to the lighter weight of cocopeat. Adding 1 part of perlite to 3 parts of cocopeat in the mixture resulted to an acceptable porosity level of 79% (Table 1) which is adequate for the root gas exchanges between the root zone and the environment (Cho et al. 2006; Khalaj et al. 2011; Mobini et al. 2009).

WATER HOLDING CAPACITY

In this study, the water holding capacity was 912.54% of dry weight (Table 1) comparable from studies of Evans and Stamps (1996) but lower than Mobini et al. (2009) and higher than Cho et al. (2006) for the cocopeat perlite ratio at 3:1. Cocopeat is known for its high water holding capacity and can be comparable to sphagnum peat which normally holds 400% to 800% of its weight in water (Abad et al. 2005; Evans et al. 1996). Evans et al. (1996) obtained water holding capacities of coir dust samples ranged from 750% to 1100% of dry weight while Evans and Stamps (1996) obtained 977% for 60:40 coir and perlite mixture. Higher water holding capacity had resulted to a greater root fresh weight, heights and shoot fresh weights of geranium, petunia and marigold plant (Evans & Stamps 1996). For a growing media mixture, increase in cocopeat will increase the water holding capacity.

HYDRAULIC CONDUCTIVITY

In this study, k_s was 0.1 cm/s (Table 1). This value is between the values obtained in other studies from 0.046 to 0.19 cm/s (Quintero et al. 2008, 2006; Raviv et al. 2001) for cocopeat alone. Londra (2010) obtained a value of 0.185 cm/s for k_s in 50% coir and 50% perlite. Comparing the results obtain in this study and previous studies; it can be said that the k_s at 0.1 cm/s is acceptable and in the range obtained by the previous studies. The hydraulic properties and conductivity of a media is influenced by the particle size distribution. Clearly the media used in this study has low k_s which indicate water can retain much longer in the particles.

WETTABILITY

Wettability determines the aptitude of a material to reduce the surface tension of water in contact with the material so that it can wet and spread over the surface. In soilless culture, wettability has an important role to determine the initial uptake of water by media and its consequence water movement characteristic (Yahya et al. 2009). The capacity of cocopeat perlite mixture to absorb water is represented in Figure 2. For the first 2 h of soaking, the media absorb water drastically until it reached a peak at water content 119 mL. After 2 h of soaking, the water content still increase by time but at a slower rate. The same pattern was observed from the study of Yahya et al. (2009) with cocopeat as base media. Moreover, studies from Abad et al. (2005) and Mazuela et al. (2005) had shown that the wettability absorption was less than 7 min for coconut coir dust. This shows that cocopeat has a hydrophilic characteristic originally contain in the media that highly attract water (Cresswell 2002). Among the factors that may affect wettability over time in cocopeat are its particle size, pore spaces and amount of fiber contain in it. Wettability of cocopeat can be increased by manipulating the capillary pores in the media using wetting agents such as sand and perlite added into the media (Urrestarazu et al. 2008).

CONCLUSION

The increase interest in soilless media particularly cocopeat for containerized plant production had emphasized the importance of physical characteristics studies in order to improve the utilization of this media. Among the physical characteristics studied were bulk density, particle density, porosity, particle size distribution, water holding capacity, wettability and hydraulic conductivity. A percentage of 83.19% of the particles in the media were in the range between 0.425 and 4 mm in diameter. The bulk and particle densities of the media were 0.09 and 0.42 g/

TABLE 1. Physical characteristics of cocopeat perlite mixtures (3:1). For bulk density, particle density and porosity the means and standard deviation are from five different measurements (n=5) while those of water holding capacity and hydraulic conductivity are from three different readings (n=3)

Property	Value
Bulk density (g/cm^3)	0.09 ± 0.01
Particle density (g/cm^3)	0.42 ± 0.03
Total porosity (%)	79 ± 0.02
Water holding capacity (% wgt)	912.54 ± 24.4
Saturated hydraulic conductivity (cm/s)	0.1 ± 0.004

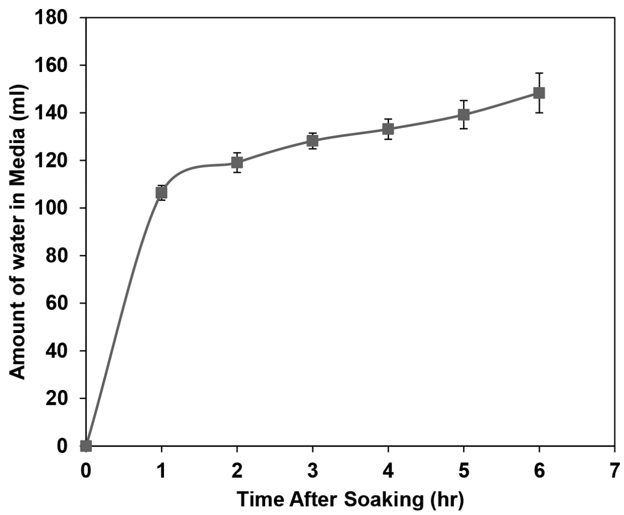

FIGURE 2. Wettability and standard deviation over time for cocopeat perlite mixture (3:1). Data are mean ± SD (n=3 samples)

cm^3, respectively, which represent light materials. The inclusion of perlite to cocopeat improved total porosity at an acceptable value of 79%. Moreover cocopeat has a very high water holding capacity of 912.54% which can be related to the low saturated hydraulic conductivity of 0.1 cm/s. The wettability of cocopeat perlite mixture was very high as the media continues to retain water over time. These findings provide useful information on the properties of the mixture for containerized plant production in soilless culture.

ACKNOWLEDGEMENTS

The authors wish to thank the Department of Biological and Agricultural, Faculty of Engineering, Universiti Putra Malaysia for funding this project. High appreciation to the staff and post graduate students from the Soil and Water Engineering Laboratory, Faculty of Engineering, Universiti Putra Malaysia for the assistance and technical lessons on the handling of laboratory equipment.

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Received: 20 October 2015
Accepted: 18 November 2016