

CHEMICAL CHARACTERISTICS OF COIR PITH AS A FUNCTION OF ITS PARTICLE SIZE TO BE USED AS SOILLESS MEDIUM

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INTRODUCTION

Coconut palm (*Cocos nucifera* L.) is being largely cultivated in Philippines, Indonesia, India and Sri Lanka. Among the major coconut producing countries, India has emerged as a premier coconut producer in the world and its annual production is about 12 billion nuts from an area of 1.9 million ha. More than 90 percent of the coconut is grown in the southern states namely Kerala, Karnataka, Tamil Nadu and Andhra Pradesh (Mathew, 2004).

The nut of this palm has a spongy mesocarp called husk. After the removal of the kernel from the nut, the husk is used as a raw material in coir fibre industries. The industries in turn leave elastic, cellular and cork like spongy non-fibrous tissue which is generally referred to as coir pith or coco-peat (Bhowmic and Debnath, 1985). In each nut around 14-17g of coir pith is available (Kamaraj, 1994 and Reddy, 1996).

Total generation of coir pith in India is estimated to be around 0.5 million tonnes per year while the world production is around 3.6 million tonnes (Pillai *et al.*, 1981). Therefore coir industries are facing great difficulties in the disposal of coir pith (Dan, 1993). Very often coir pith is heaped as mounds on way side. Large quantities of coir pith thus stored causes contamination of ground water due to the percolation of leachates containing residual phenol from these dumps (Gopal and Gupta, 2001) especially during rainy season. It also offers an ideal breeding base for rodents and insect pests (Grimwood, 1975). Coir pith is easily blown by wind due to its light weight thereby creating air pollution. In comparison to saw dust, rice husk and groundnut shell, coir pith is found to have a higher heat value (3975 kcal/kg) which is close to that of coal (Krishnan, 1990; Sudhira and Jacob, 2000). Unfortunately, high levels of carbon dioxide and smoke are released from coir pith due to its poor combustion properties while burning.

In certain parts of India, coir pith finds its application in making bricks (Dan, 1993) and particle-boards (Viswanathan, 1998). A combination of cow dung and coir pith at 4:1 ratio increases the biogas production (Mathew *et al.*, 2000). Coir pith forms a good bedding material in poultry shed (Maheswarappa *et al.*, 2000). The coir pith bed enriched with poultry litter is directly used as manure for crops such as sorghum, groundnut and sunflower (Savithri *et al.*, 1991). Removal of fluoride from drinking water is also effected by the application of activated carbon prepared by carbonisation of coir pith (Dahiya and Kaur, 1999). Charcoal made from coir pith is also employed in selected industries to absorb toxic metals (cadmium, arsenic, nickel, copper and lead), harmful dyes (rhodamine B, acid violet and cargo red) and chosen pesticides (paraquet) (Anonymous, 1999).

Vermicomposting process of coir pith employing earthworms increases the major and minor nutrients in available forms, enzymes, vitamins and plant growth hormones (Prabhu *et al.*, 1998). Field trial made by Edsor (2005) indicated that *Abelmoschus esculentus* grown on coir pith based compost gave high biomass

ABSTRACT

Coir pith is a byproduct of coir industry. The chemical characteristics of the coconut waste-coir pith were investigated according to the particle size for use as a soilless medium. pH of coir pith was found to be acidic in nature. The electrical conductivity of different particle sizes of coir pith was observed to be high in lower grades of coir pith (6.2 mS / cm) which gradually decreased as the size of the coir pith particle increased (5.3 mS / cm). The individual ion analysis made on coir pith did not show any significant change according to particle size. But potassium, sodium and chloride ions are found to be higher in amount than phosphorous, iron and calcium. High cation exchange capacity of 168 m.eq / 100g was recorded in 925 μ m particles. Ash content is a measure of mineral element which shows a negative trend with the particle size of coir pith. Approximately, three fold changes were observed in ash content when the particle size changed to ten fold. Phenol concentration is very low in lower and higher grade particles and it is high in 925 μ m (2.42 mg/L) and 1100 μ m (2.1mg/L) particles.

KEY WORDS

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Cation exchange capacity
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production. The earthworms produce enzymes which destroy the complex bio-molecules in the coir pith converting them into simpler compounds. These simpler compounds are then utilised by the micro-organisms present in the gut of the worms to produce useful compounds such as antibiotics, vitamins and plant growth hormones.

Application of coir pith in soil helps in improving the structure and other physical and chemical properties of the soil (Bopaiah, 1991). Coir pith improves the physical properties such as bulk density, pore space, infiltration rate and hydraulic conductivity of even the heaviest clay soils and allows free drainage when coir pith is incorporated as an ameliorant. Because of its sponge like structure coir pith helps to retain water and improve aeration in root zone (Savithri and Khan, 1994).

Seven different media were tested by Suharban *et al.*, (2004) for the cultivation of anthurium (*Anthurium andreaeanum* L.) and observed that the combination of coarse sand, coconut husk and coir pith in the ratio of 1:1:1 or coarse sand, coconut husk, dry cow dung and coir pith in the ratio of 1:1:1:1 is the best medium for the *anthurium* cultivation. The increase in flower yield was due to the increased bulk density, particle density, maximum water holding capacity and volume expansion of the medium (Savithri and Khan, 1994). Coir pith was also known to increase the oxygen supply to the rooting medium (Nagarajan *et al.*, 1985).

Successful greenhouse and nursery production of container-grown plants are largely dependent on the chemical and physical properties of the growing media. Growers normally like to have heavy weight medium in containers especially in outdoor nursery to minimize blow-over. However when container plants are to be transported, light weight medium is preferred. Electrical conductivity (EC) is an index of the presence of total soluble salts in a medium. High EC causes poor shoot and root growth. The level of soluble salts that may be tolerated is highly crop specific. It is important to identify the components of the salt present in coir pith for developing suitable fertility programmes and to get away from certain nutrient disorders.

Substrates that replace soil in agriculture must have certain physical, chemical and biological properties to allow optimal plant growth (Handreck, 1993 and Heiskanen, 1995). Thus present investigation deals in characterizing its chemical nature to enhance it to be a better soilless medium.

MATERIALS AND METHODS

Coir pith required for the present study was collected from the coir mounds near the coir industry at Solavanthan, Madurai where coir processing is being carried out commercially. Samplings (50kg) were made on fresh mounds and were then transported to the laboratory. They were sun dried for 3-5 days. Subsequently long fibres were removed by hand sorting. The assorted particles of varied size of coir pith were sorted out into twelve different grades (150, 250, 350, 450, 550, 725, 925, 1100, 1300, 1550, 1850 and 2000 μm) based on the particle size.

Aqueous extract of raw coir pith was prepared as per the procedure followed by Ross (2002) and Edsor (2005) which is a modified procedure of Landis *et al.*, (1989) and Lang

(1996). The sieved pith was taken in a glass tray. It was wetted by spraying distilled water till one or two drops came out on squeezing it with hand. In a measuring cylinder distilled water was taken up to 333 mL mark. Then the wetted pith was introduced into the same cylinder till the total level reached 500 mL mark. The contents were continuously stirred with a rod for 20 minutes. The mixture was then transferred to a glass tray and was hand squeezed. The resultant extract was collected and filtered through a *Whatman* No. 1 filter paper. The filtered extract was used for the analysis of pH, EC, sodium, potassium, calcium, chloride, phosphorus, iron, and phenol.

pH and conductivity measurements were made on the aqueous extract of raw coir pith using a pH meter (Elico India 101 E) and conductivity meter (Elico India CM 180) respectively.

Sodium, potassium and calcium were analysed on the aqueous extract of raw coir pith using a flame photometer (Elico India, CL 22 D).

Chloride content present in the aqueous extract of raw coir pith was estimated by Argentometric method (Section 4500-Cl - B of Standard methods for the Examination of Water and Waste Water) (APHA / AWWA / WEF, 1998) and the values were expressed in mg Cl / L.

Phosphorus content of the aqueous extract of raw coir pith was determined by Stannous chloride method as described in Section 4500- PD of Standard Methods for the Examination of Water and Waste Water (APHA / AWWA / WEF, 1998). The values were reported as phosphate phosphorus.

Iron content of the aqueous extract of raw coir pith was determined by Phenanthroline method as described in Section 3500 - Fe B of Standard methods for the Examination of Water and Waste Water (APHA / AWWA / WEF, 1998). The values were reported in mg Fe / L.

Cation exchange capacity (CEC) of the coir pith refers to the measure of negative sites present in the coir pith particles which can retain positively charged ions (cations) through electrostatic forces. It was analysed as per the method of Jackson (1967) and as followed by Gandhi, 2005.

Ash content of coir pith was determined by taking a known quantity of the original sample (a) in a crucible and was placed in a furnace (maintained at 750°C) for 2h. It was removed from the furnace and cooled in a desiccator and weighed (b). The ash content was calculated using the formula (Campbell, 1951).

$$\text{Ash (\%)} = \frac{b-i}{a} \times 100$$

b = weight of the ash along with crucible (g)

i = weight of the crucible (g)

a = weight of the original sample (g)

Phenol content in the aqueous extract of coir pith was estimated by colorimetric method described in Section 5530-D of Standard Methods for the Examination of Water and Waste Water (APHA / AWWA / WEF, 1998). The values were reported in mg / L.

RESULTS

pH of the extract of the raw coir pith ranges from 6.43 to 6.77 and is depicted in Fig. 1. It slowly increases from 6.43 (150

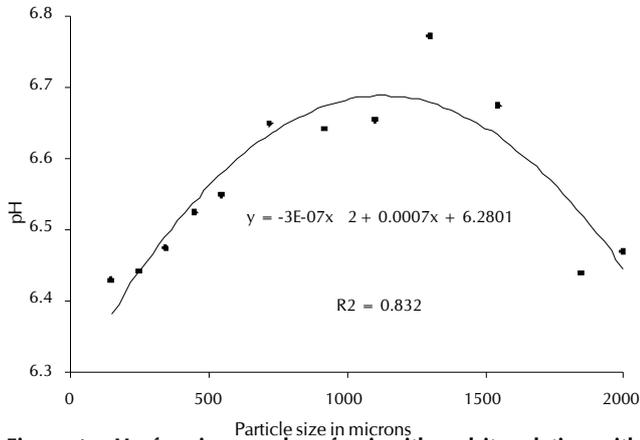


Figure 1: pH of various grades of coir pith and its relation with particle size (n = 12)

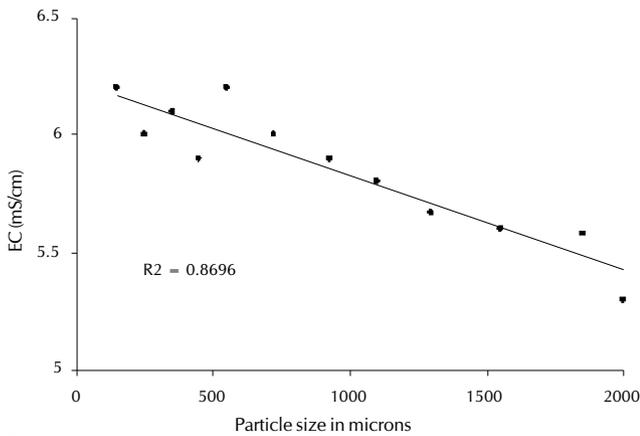


Figure 2: Electrical conductivity of various grades of coir pith and its relationship with particle size (n = 12)

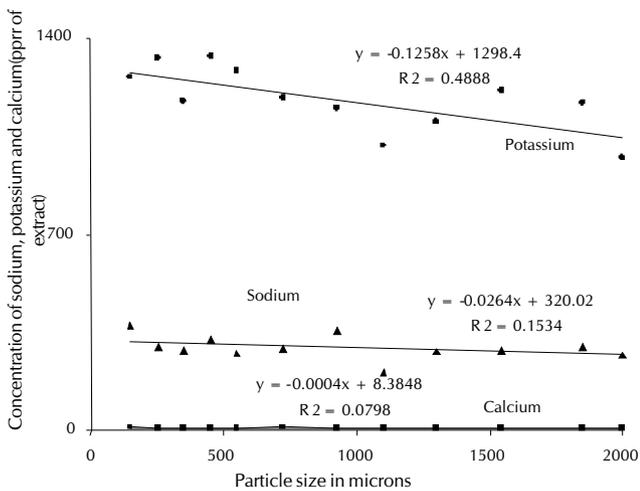


Figure 3: Levels of sodium, potassium and calcium present in the extracts of various grades of coir pith (n = 12)

μm) and reaches maximum in 1300 μm particles (6.77) and further steadily decreases to 6.47 (2000 μm).

The electrical conductivity of the coir pith extract is shown in Fig. 2 which decreases linearly with a correlation value of 0.8696 and the regression equation of $y = -0.0004x + 6.2337$ where y indicates electrical conductivity and x

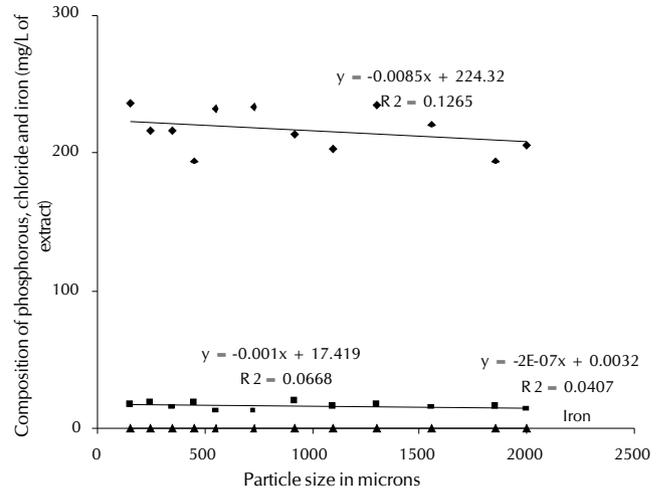


Figure 4: Levels of phosphorous, chloride and iron present in the extracts of coir pith according to particle size (n = 12)

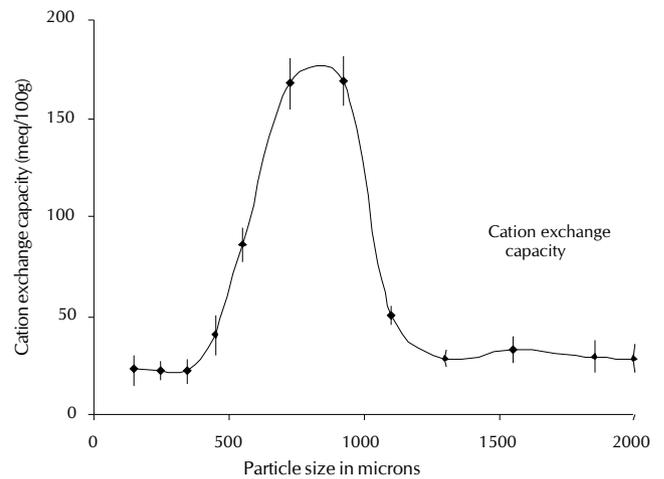


Figure 5: Relationship between cation exchange capacity of various grades of coir pith and the corresponding particle size

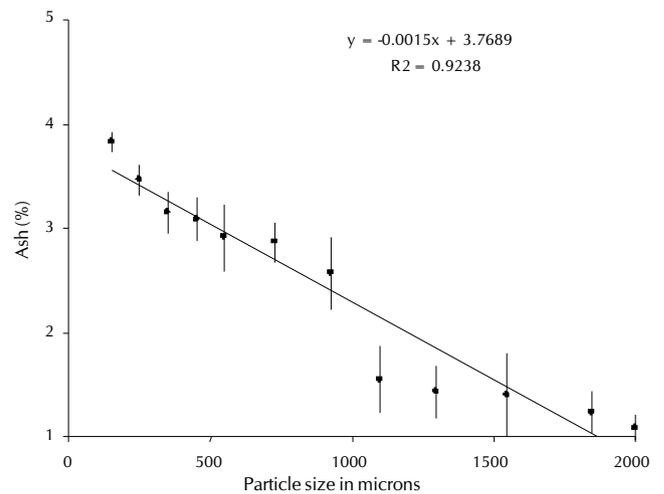


Figure 6: Relationship between ash content of various grades of coir pith and the particle size of coir pith

indicates particle size of raw coir pith. Thus it is known that small particles contain more salt.

The levels of sodium and calcium present in the extract of

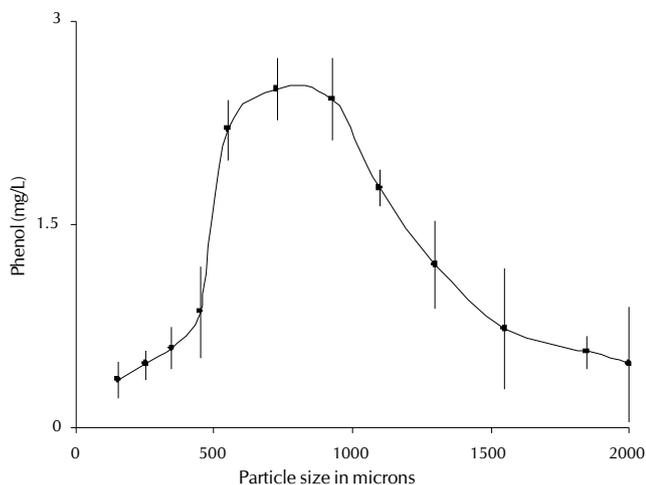


Figure 7: Relationship between phenol concentration of various grades of raw coir pith and the respective particle size

various grades of coir pith (Fig. 3) do not show any drastic change according to particle sizes of coir pith. The levels of potassium decreases when particle size increases. The calcium content was awfully poor in the extract.

The relation between calcium and particle size, sodium and particle size and potassium and particle size are $y = -0.0004x + 8.3848$, $y = -0.0264x + 320.02$ and $y = -0.1258x + 1298.4$ respectively where y refers to the concentration of calcium, sodium and potassium and x refers to the particle size. The concentration of iron is in the order of $K > Na > Ca$. Potassium was found to be in higher concentration (975 to 1333.33 mg/L) when compared to the other two. Sodium concentration was in the range of 200-380 mg/L. Calcium was found in a meagre quantity (< 10 mg/L) in all the particle sizes of raw coir pith.

Concentration of phosphorus, chloride and iron present in the extracts of coir pith particles are shown in Fig. 4. Chloride content was found to be higher in all the extracts (194.05 to 235.67 mg/L) compared to phosphorus (< 29 mg/L). Thus chloride content was 14 times higher than phosphorus and 72,000 times higher than iron. Iron is present in meagre amount (0.001 to 0.003 mg/L).

Cation exchange capacity (CEC) of various grades of coir pith is given in Fig. 5. It was found to be low (< 30 meq / 100g) in smaller particles as well as in bigger particles (150, 250, 350 and > 1550 μm). High CEC of 168.8 meq / 100g was recorded in 925 μm particles. The optimum CEC needed for agriculture is 140 meq / 100g. It is observed that the particle size ranging from 800 to 1112.5 μm exhibits CEC above 140 meq / 100g. Similar negative trend was also observed between the ash content and the particle size (Fig. 6). Approximately three fold changes were observed in ash content when the particle size changed to ten fold. Ash content was very high when the particle size was small. Such small particles have high salt content (EC) in the extract (Fig. 2). Thus ash content and salt levels (EC) in the extract have very positive relation.

Phenol concentration of various grades of coir pith is shown in Fig. 7. It is very low in lower and higher grade particles (150, 250, 350, 450, 550, 725, 1300, 1550, 1850 and 2000 μm) and it is high in 925 (2.42 mg/L) and 1100 μm particles (2.1 mg/L).

Phenol concentration of various grades of coir pith is shown in Fig. 7. It is very low in lower and higher grade particles (150, 250, 350, 450, 550, 725, 1300, 1550, 1850 and 2000 μm) and it is high in 925 (2.42 mg/L) and 1100 μm particles (2.1 mg/L).

DISCUSSION

Coir pith samples collected from Solavanthan were subjected to particle size distribution studies by sifting the coir pith mass sequentially with twelve different sieves as particle size is generally determined by sieve fractionation (Agnew and Leonard, 2003). The main purpose of studying the particle size distribution is to know the particle-wise chemical characteristics.

The pH of the graded coir pith was acidic in nature (Landis, 1990; Cresswell, 1992; Boceta, 1997; Baskar and Saravanan, 1997; Mak and Yeh, 2001; Rao *et al.*, 2001; Abad *et al.*, 2002; Arenas *et al.*, 2002; Krishnasamy *et al.*, 2002 and Pardo *et al.*, 2003). pH plays a significant role in the availability of nutrients especially micronutrients (Landis, 1990) and consequently it reveals upon plant growth and yields (Rippy *et al.*, 2004). The optimum pH range for growing media for greenhouse crops is 5.5 to 6.5 (Poole *et al.*, 1981; Warncke and Krauskopf, 1983 and Landis, 1990).

If pH is too low (< 4), micronutrients become more mobile and are absorbed in excess by the plant, resulting in a state of potential toxicity. If it is too high (> 9), micronutrients are less mobile and the plant cannot absorb enough which result in deficiencies (Pennisi and Thomas, 2005).

Electrical conductivity of various grades of coir pith was observed to be high in lower grades of coir pith (6.2 mS / cm) which gradually decreased as the size of coir pith particle increased (5.3 mS / cm). The electrical conductivity was significantly higher in smaller sized coir pith (Noguera *et al.*, 2003). The highest value was obtained in the finest particle size fraction. The electrical conductivity of 0.2 to 0.5 mS / cm for coir pith was reported to be ideal.

The salt level of coir pith samples from Mexico and Thailand was high which adversely affected the growth of certain salt-sensitive plants (Bunt, 1988) and it reduced the nutrient availability (Cox and Smith, 1997). High salinity (> 3.5 dS/m) had adverse effects on the rate of seed germination and on the growth and development of seedlings (Bernstein, 1975). Higher EC of a coir pith based medium caused high physiological stress to *Spathiphyllum* when grown under sub-irrigation conditions (Mak and Yeh, 2001). Too low an EC (0.24 and 0.29 mS/cm) may lead to nutrient deficiency in plants (Ngamau, 2004).

The excess soluble salts could be easily and effectively leached out from the medium under normal irrigation regimes (Noguera *et al.*, 1997; Noguera *et al.*, 2000a and Noguera *et al.*, 2000b). The soluble salts from containerized compost media can be rapidly leached out within days after planting, thereby minimizing any adverse effects on container grown woody plants (Raymond *et al.*, 1998). If the salinity is higher than desirable (> 1 dS/m) the unwanted salt can be easily removed with a heavy irrigation (Cresswell, 1992).

Bernstein (1975) and Ross (2002) washed the coir pith with plenty of water to remove excess salts present in coir pith. The influence of the density of coir pith medium on the EC was high in high density particles (small size) since the surface area (area of particles in unit volume) of high density particles is high (high surface area is offered by smaller particles). In the present case, the electrical conductivity was reduced (between 0.45 and 0.55 mS / cm) by sequential washing of various grades of coir pith with dis. water.

Moreover, the individual ion analysis made on coir pith did not show any significant change according to particle size. But potassium, sodium and chloride ions are found to be higher in amount than phosphorus, iron and calcium. Potassium, sodium and chloride levels of coir pith from various countries such as Costa Rica, Ivory Coast, India, Mexico, Sri Lanka and Thailand were found higher when compared to that of peat (Abad *et al.*, 2002).

As the phenomenon of adsorption of ions is confined to the surface of the coir pith, larger surface area caused greater adsorption of water and ions. Smaller particle having more surface area attracted more ions. Rich availability of potassium was known to inhibit the uptake of nitrogen, calcium and magnesium in plants (Nelson, 1985). Since smaller particles have high level of potassium, smaller particles are unable to promote the growth actively. It is well known that the coir pith medium has rich quantities of potassium, sodium and chloride but has low levels of phosphorus, calcium and nitrate (Handreck, 1993 and Evans *et al.*, 1996). High concentration of sodium and chloride in the pore space may result in poor calcium absorption in plant as well (Bennett and Adams, 1970 and Shear, 1975). The available calcium is usually bound with the pith, making it unavailable to plants. Consequently, repeated accumulation of sodium and chloride in pore space would lead to a build up of the above ions leading to specific ion toxicity.

As already indicated unfavourable characteristics of the coir pith is due to high level of K, Cl and Na (Handreck, 1993 and Konduru *et al.*, 1999) and low level of Ca (Rose and Haase, 2000). Savithri and Khan (1994) and Abad (2002) observed an increase of potassium in the soil due to the application of coir pith which has high content of potassium. Phosphorus content of unamended coir pith with peat and most other organic media is too low to contribute greatly to plant nutrient needs (Boceta, 1997).

The cation exchange capacity (CEC) of coir pith is a measure of the quantity of negative sites on its surface which can retain positively charged ions (cations) calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and ammonium (NH_4^+), zinc (Zn^{2+}), manganese (Mn^{2+}), iron (Fe^{2+}), copper (Cu^+) and hydrogen (H^+). While hydrogen is not a nutrient, it affects the degree of acidity (pH). CEC is expressed in milliequivalents per 100 g of coir pith. The micronutrients such as iron, manganese, zinc and copper are stored in the coir pith media particles until they are taken up by the root system. The amounts of nutrients stored by a growing medium are directly related to the cation exchange capacity and in turn, the fertility of the growing medium (Craul, 1982). High CEC of the growing media which is a desirable property selectively adsorb the cations from the growing medium solution and release back slowly. It also aids

in nutrient retention against leaching during irrigation and increases the buffering action in the root system of the seedling against sudden changes in pH or salinity (Whitcomb, 1988). The disadvantages of a low CEC obviously include the limited availability of mineral nutrients to the plant and the medium's inefficiency to hold the applied nutrients.

In the present study, coir pith particle of the size range 800 to 1112.5 μm (average 956.25 approx. 1000 μm) exhibited CEC above 140 m.eq / 100 g which were considered to be adequate (Miller and Jones, 1995). The amount of CEC measured varied considerably according to the nature of the cation used, concentration of salt applied and the equilibrium pH (Sumner and Davidtz, 1965 and Arnold, 1977).

Ash content which is a measure of mineral element Meyer *et al.*, (1960) is present in higher amount in small sized coir pith particles. Presence of high ash content represents the presence of substantial quantity of salt (Burger, 1999).

The phenol content was observed to be relatively high in the coir pith particles of the size 925 to 1100 μm . Lokeshia *et al.*, (1988) indicated that the slow release of phenolic compounds from coir pith promoted growth in *Bougainvillea* sp (Offord *et al.*, 1998).

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