Chemical Methodologies

Journal homepage: http://chemmethod.com

Original Research article

A Study on Cation Exchange Capacity of Sieved Coir Pith

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ARTICLE INFORMATION

Received: 26 June 2018
Received in revised: 28 August 2018
Accepted: 13 September 2018
Available online: 13 September 2018

DOI:
10.22034/chemm.2018.137306.1065

KEYWORDS

Coir pith
Lignocelluloses
Cations
Calcium and magnesium

ABSTRACT

Coirpith which can be regarded as the short fibers and dusts is a lignocellulosic biomass and a recalcitrant one under ordinary conditions. It has the innate character of exchanging ions from the inner matrix which consists of minute pores. In the present study, the ion exchange capacity of coir pith was carried out and was subjected particle size. The results showed that the calcium nitrate and calcium phosphate impregnated coir pith illustrating a gradual increase in the level of calcium in all the concentrations of calcium compound impregnation. Other cations such as potassium and sodium were decreased in linear and parallel pattern during the above impregnation. Calcium got exchanged for sodium and potassium ions. The magnesium nitrate and magnesium phosphate which impregnated coir pith showed a gradual increase at the level of the cation, magnesium in all concentrations of magnesium compound impregnation. Other cations such as potassium and sodium were knocked out from the inner matrix of coir pith. The expulsion of potassium was comparatively higher than that of sodium in all grades of coir pith and in all concentrations of magnesium nitrate impregnation. The study proved that waste emitted from coir fibre production could be used after ionic impregnation.

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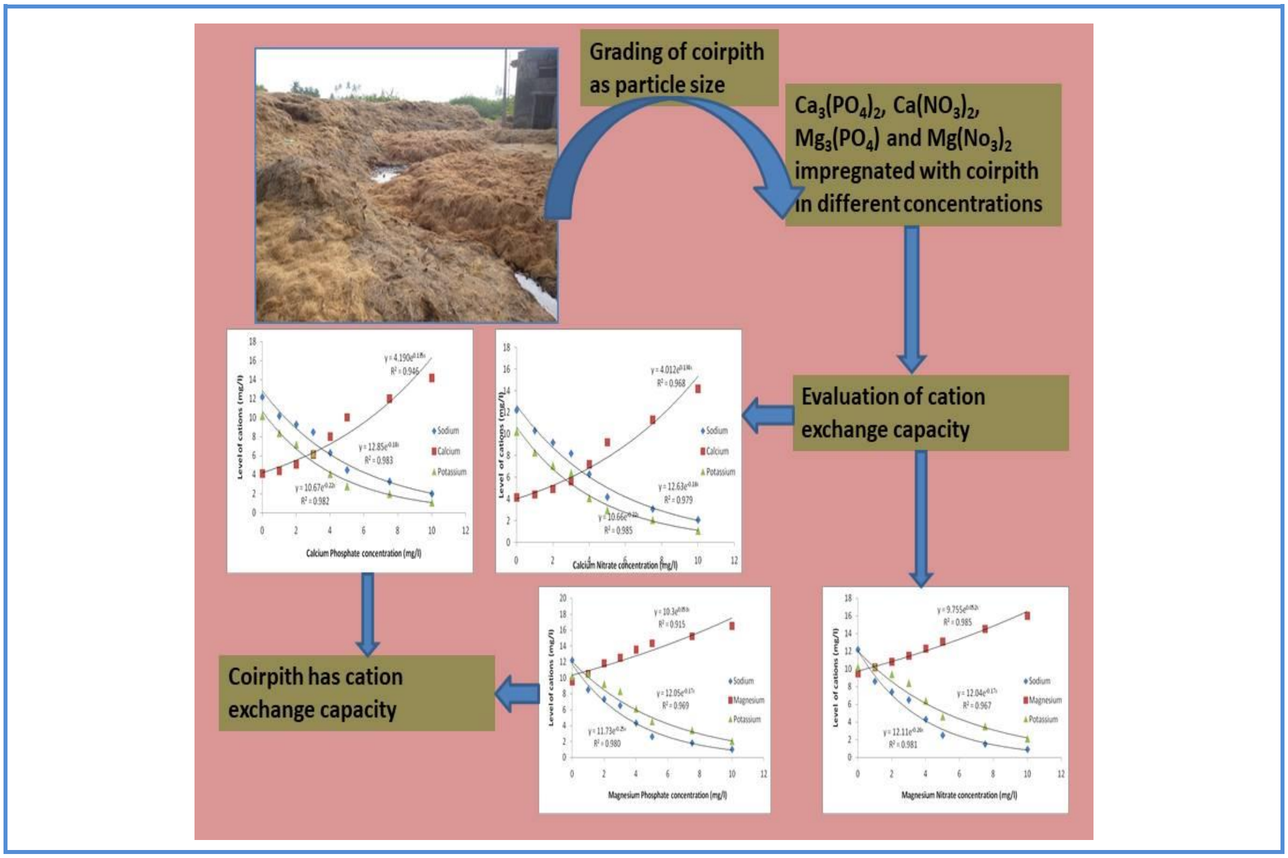
Graphical Abstract



Introduction

Coir pith or coir dust is a major waste product of coir fiber extracting industries [1, 2]. The estimated annual production of coir pith in coir industries of India is about 7.5 million tons [3, 4]. The elastic cellular cork like pithy material forming the non-fibrous tissue of the husk is generally referred to as the coir pith, which accounts for 50-60% of the total weight of the husk [5]. The extraction of one kilogram of coir fiber generates two kilograms of coir pith [6]. Coir pith holds a unique property of retaining cations and anions in its inner matrix. These native ions prevalent in coir pith are mostly non-essential or toxic to the plants if grown on coir pith at large. Hence, keeping in view of the ion exchange capacity in coir pith, efforts were formulated to retain the essential ions in the inner core of the coir pith and to knock out the non-essential or toxic ions from coir pith. In addition, the eliminated non-essential ions may exchange the coir pith with essential ions from the treated chemical. This will ultimately enrich the coir pith with an abundance of anions and cations very much required for the plants grown over it. These exchanged ions, in turn, will slowly get released from the matrix of coir pith when required by the cultured plants. The present investigation is a novel work because the cation exchange capacity of sieved coir pith was illustrated by using different concentrations of calcium phosphate, calcium nitrate, magnesium phosphate and magnesium nitrate. The similar kind of work has not been reported by any researcher from any institute.

Meerow [7] proved that coir pith has high cation exchange capacity. Organic manures help in increasing the adsorptive power of soil with reference to both cations and anions particularly phosphorus, nitrate, calcium and magnesium. These absorbed nutrient ions are released slowly for the benefit of the crop during the entire growth period. It also helps to improve physical and chemical properties of the soil [8]. Exchangeable calcium was determined by leaching the substrate material with two successive equal volumes of normal sodium chloride solution. In the present investigation to be study the cation exchange statuses in sieved coir pith.

Experimental

Material and methods

Dried coir pith was well mixed and passed through 250 micron sieve. The coir pith mass, retained below the sieve, was separated, packed and labeled as 0 to 250 micron particles. The left over coir pith mass was, then, passed through 500 micron sieve. The retained mass below the sieve was separated and labeled as 251 to 500 micron particles. The left over coir pith was again passed through 850 micron sieve. The retained mass below the sieve was labeled as 501 to 850 microns and the mass retained above the sieve was labeled as >850 micron particles.

Calcium nitrate, calcium phosphate, magnesium nitrate and magnesium phosphate were taken in different concentrations (1, 2, 3, 4, 5, 7.5, 10 gm/ liter of coir pith), mixed thoroughly with different grades of washed coir pith for about 10 minutes in each chemical. Then, it was washed in distilled water and squeezed out. The above washing process was repeated four times. After the exchange process, the quantum of exchanged ions was analyzed from the extracts of exchanged ion and washed coir pith as per standard protocol using Digital Flame Photometer (Model-381). The magnesium content was estimated by EDTA titration method described in APHA [9] for the seven sequentially washed coir pith extracts.

Result and Discussion

Coir pith has the innate character of exchanging ions from the inner matrix which consists of minute pores. As native raw coir pith holds abundance of toxic and non-essential cations and anions, this exchange study was formulated with an objective of enriching the pith material with essential ions which may be significantly required for its further utility. Various salts were tried and evaluated for this particular study.

The calcium nitrate impregnated coir pith showed a gradual increase in the level of calcium in all the concentrations of calcium nitrate impregnation. The R^2 value is fit for 250 (0.968) (Figure 1A) and 500 (0.966) (Figure 1B) micron sized particles and R^2 value is unfit for 850 (0.845) (Figure 1C) and >850 (0.817) (Figure 1D) micron sized particles. Other cations such as potassium and sodium decreased in linear and parallel pattern during the above impregnation. Calcium got exchanged for sodium and potassium ions. But, sodium showed little stiffness during exchange process as it was less exchanged when compared to that of potassium. At initial concentrations of calcium nitrate impregnation, there was a steep decline in the knocking out of sodium and potassium from the inner matrix of coir pith, whereas it reached a steady state level between 8-10 mg/L concentration of calcium nitrate impregnation.

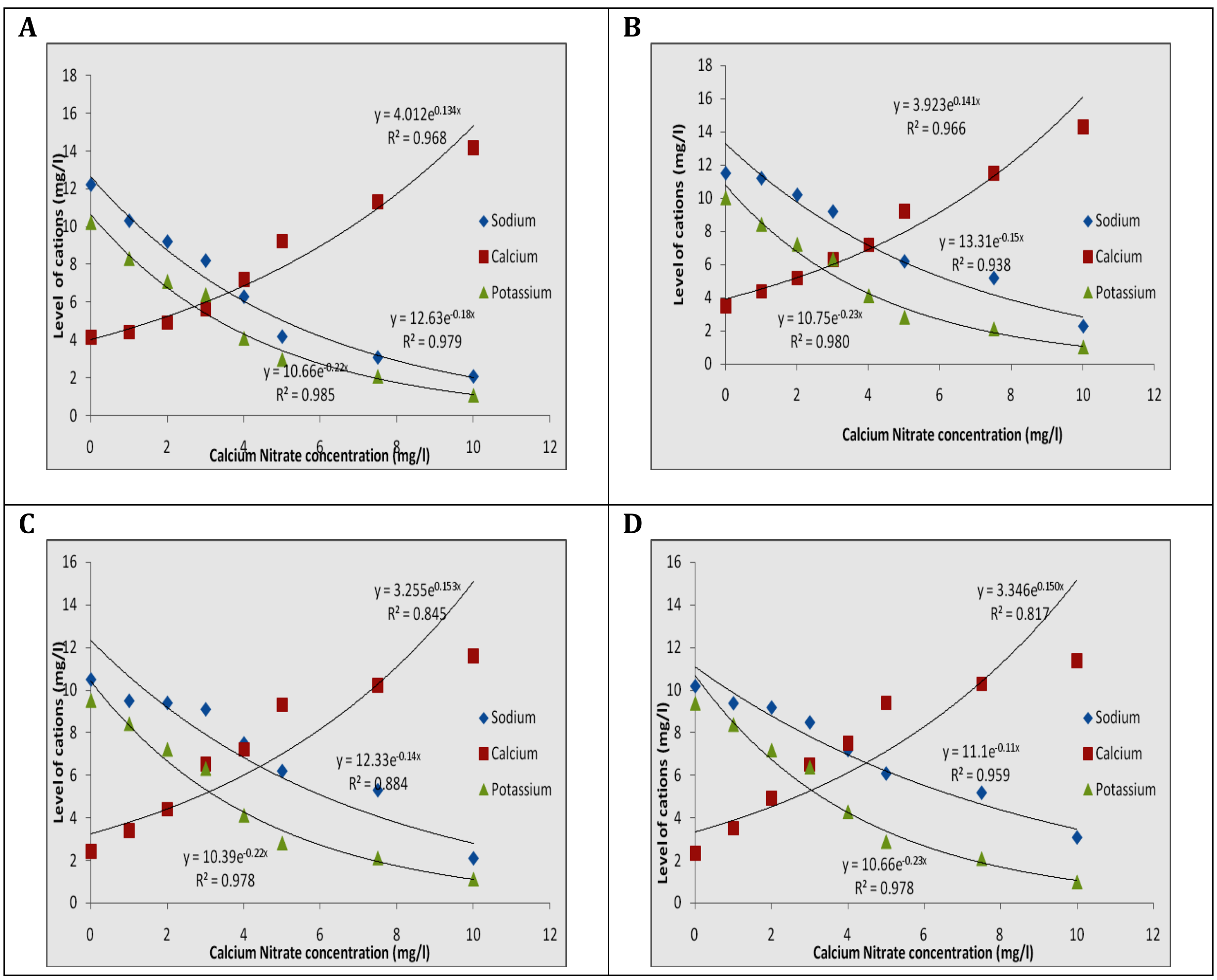


Figure 1. Calcium nitrate impregnated coir pith

The calcium phosphate impregnated coir pith showed a gradual increase in the level of calcium in all the concentrations of calcium phosphate impregnation. The R^2 value is fit for 250 (0.946) (Figure 2A) and 500 (0.932) (Figure 2B) micron sized particles and R^2 value is unfit for 850 (0.854) (Figure 2C) and >850 (0.861) (Figure 2D) micron sized particles. Other cations such as potassium and sodium decreased in linear and parallel pattern. The trend in exchange process was almost similar to that of calcium nitrate impregnation.

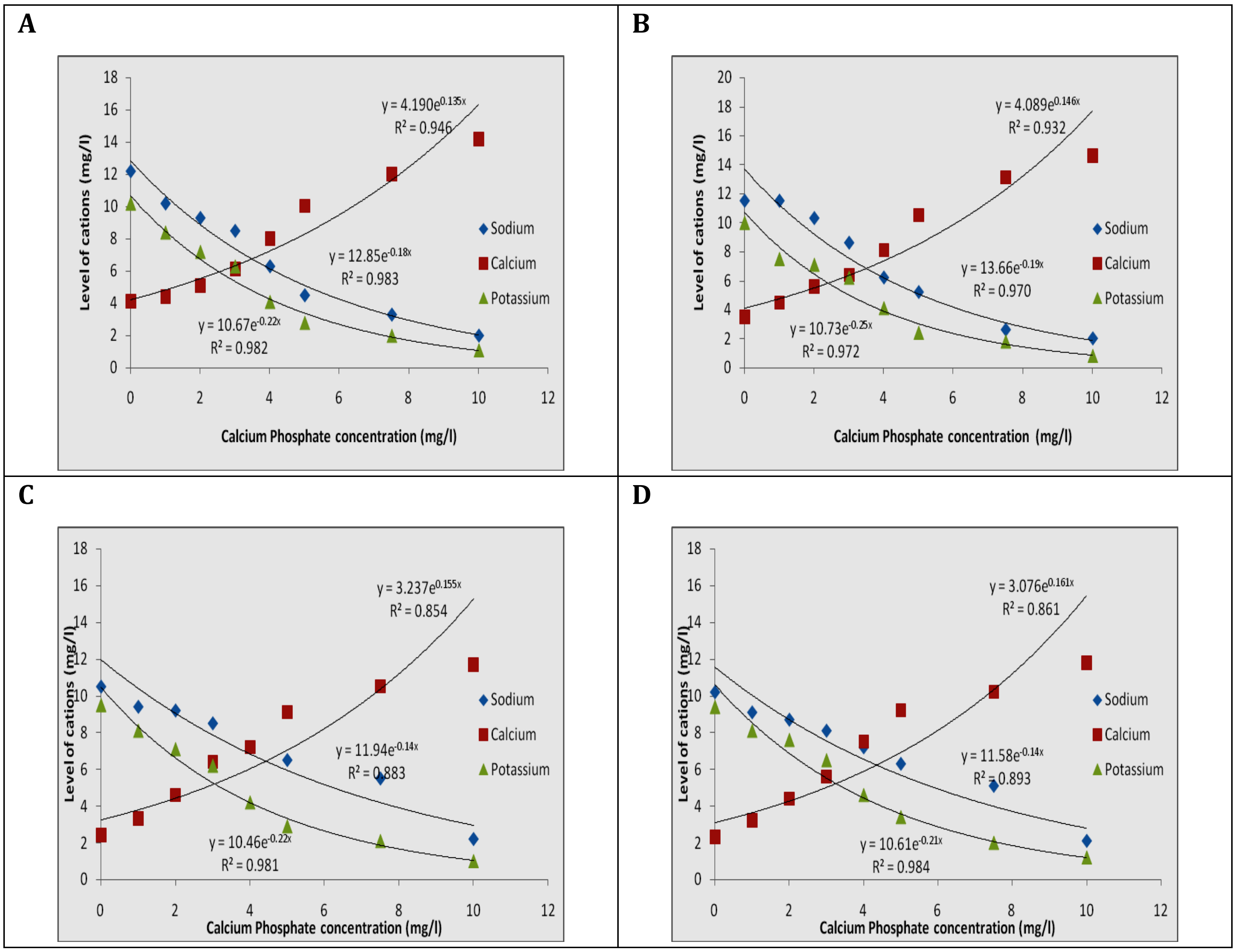


Figure 2. Calcium phosphate impregnated coir pith

The magnesium nitrate impregnated coir pith showed a gradual increase in the level of the cation, magnesium in all concentrations of magnesium nitrate impregnation. The R^2 value is fit for all the grades of coir pith viz. 250 (0.985) (Figure 3A), 500 (0.909) (Figure 3B), 850 (0.936) (Figure 3C) and >850 (0.961) (Figure 3D) micron sized particles. Other cations such as potassium and sodium were knocked out from the inner matrix of coir pith. The expulsion of potassium was comparatively higher than that of sodium in all grades of coir pith and in all concentrations of magnesium nitrate impregnation.

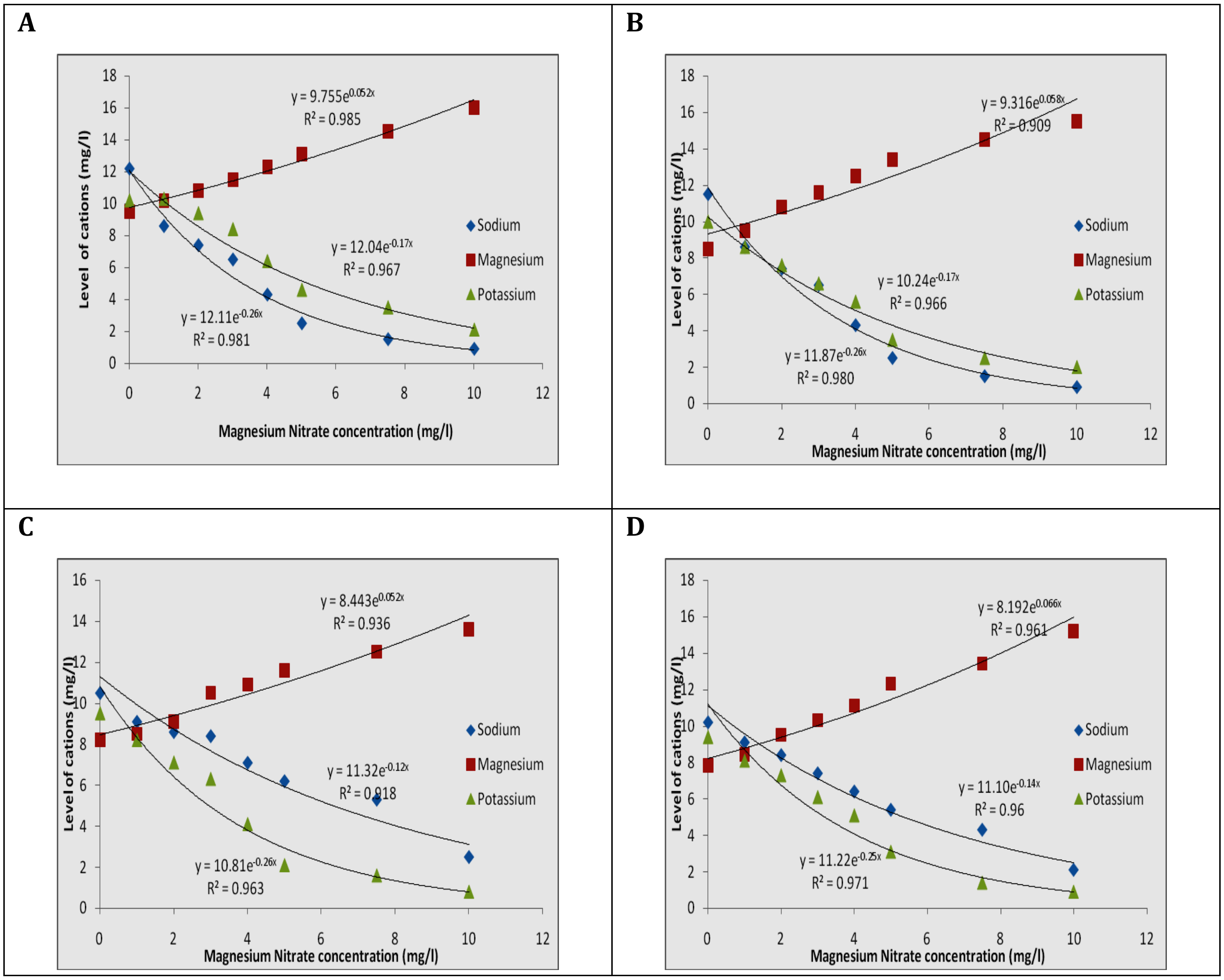


Figure 3. Magnesium nitrate impregnated coir pith

The magnesium phosphate impregnated coir pith exhibited a gradual increase in the level of the cation, magnesium in all concentrations of magnesium phosphate impregnation and in all grades of coir pith. The R^2 value is fit for all the grades of coir pith except 500 micron sized particles i.e. 250 (0.915) (Figure 4A), 500 (0.870) (Figure 4B), 850 (0.937) (Figure 4C) and >850 (0.903) (Figure 4D) micron sized particles. Other cations such as potassium and sodium decreased in linear and parallel pattern. Comparatively, potassium expulsion was higher in all grades of coir pith and all concentrations of magnesium phosphate impregnation.

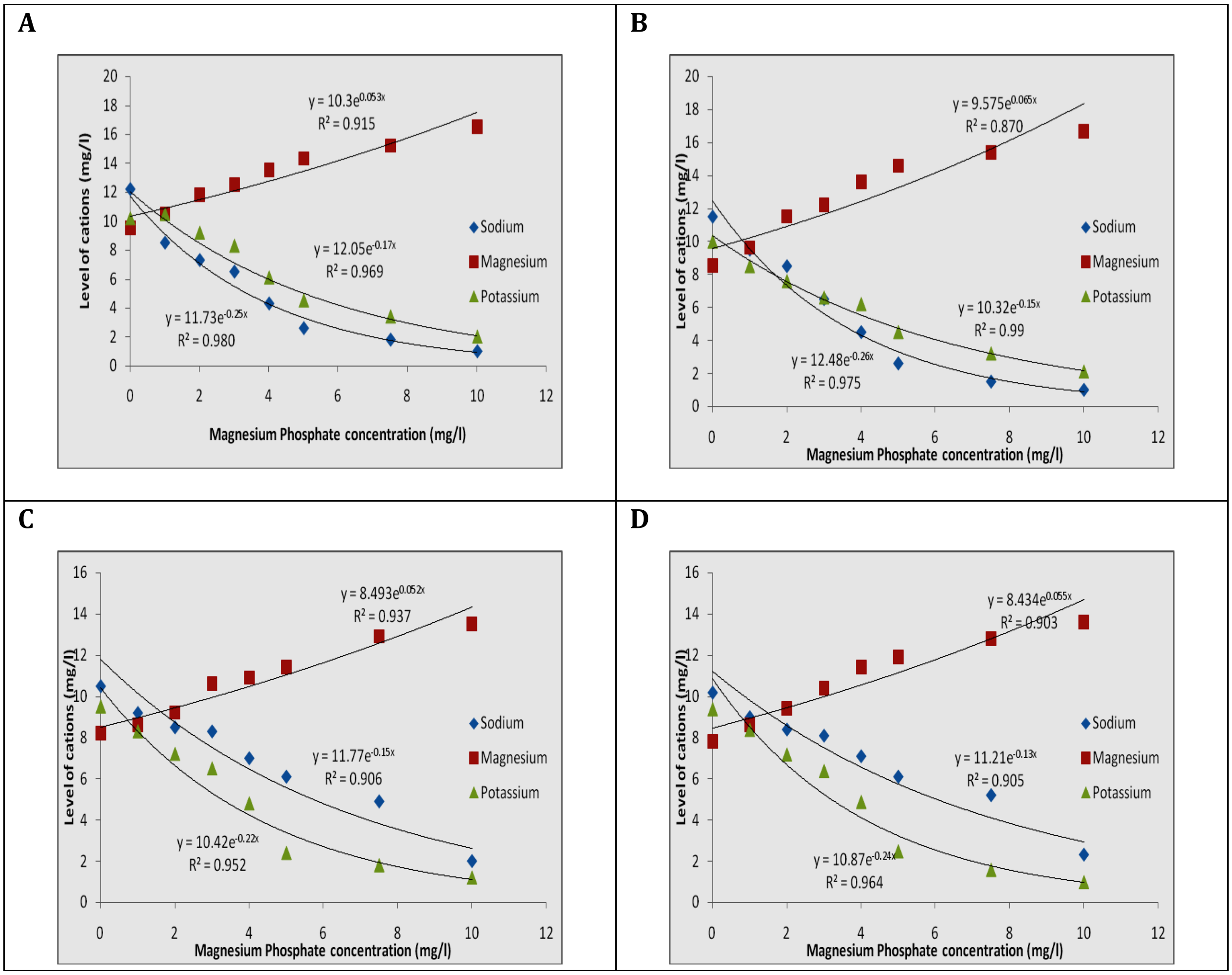


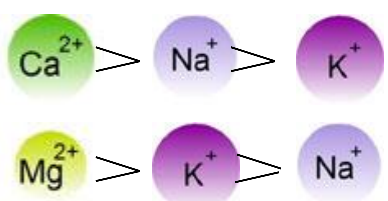
Figure 4. Magnesium phosphate impregnated coir pith

Cation exchange capacity of coir pith was high when compared to composts of other wastes reported elsewhere [10]. It was due to high lignin content in coir pith that is rich in functional groups. The cation exchange capacity (CEC) of coir pith is a measure of the quantity of negative sites on its surface which can positively retain charged ions (cations) such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}) and ammonium (NH^{4+}), zinc (Zn^{+}), manganese (Mn^{++}), iron (Fe^{2+}), copper (Cu^{+}) and hydrogen (H^{+}). 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 particles having more surface area attracted more ions [11].

The coir pith as a lignocellulosic material adsorbs metal ions through several mechanisms such as adsorption, ion exchange, electrostatic attraction, complexation or chelation. The fact that coir pith exchangeable ions are relatively innocuous (sodium, calcium and potassium ions) makes it particularly suitable for removing undesirable heavy metal ions from industrial effluent and waste waters. Coir pith can therefore be a potential ion exchanger as a result of its constituents (lignin, cellulose, and extractives) bearing polyhydroxy groups which can exchange ions from surrounding solution [12, 13]. These cations (sodium, potassium or calcium) are exchangeable with certain cations in solution such as lead, copper, zinc and nickel [14, 15]. The effect of leaching is also evident by the decrease of electrical conductivity with aging which could be due to the removal of soluble salts.

From the data obtained from the ion exchange study, it was clear that most of the unipositive (K^+, Na^+) ions were leached out and inturn, dipositive (Ca^{2+}, Mg^{2+}) and higher negative ions were absorbed by the coir pith. This absorption of ions was largely governed by the type and nature of the ion. In the case of cations, higher the valance of the ion, stronger was the tendency of absorption. Though the exchange or replacement of such polyvalent ions would normally be difficult in other materials, the capacity of the coir pith to exchange such cations was an index of its cation exchange capability.

At low concentration and ordinary temperature, the extent of ion exchange increases with the valency. Among univalent ions, the extent of exchange increases with the decrease in the size and hydration of the ions. Therefore, the order of exchange in the present study during calcium combination impregnation, and magnesium combination impregnation showed the order of exchange as given below:



The exchange behaviour of Ca^{2+} and Mg^{2+} for K^+ and Na^+ in coir pith was found similar to that of cation exchange resin. Leaching out of more amount of K^+ compared to that of Na^+ however could be due to the open permeable molecular structure of the coir pith where in the ions and solvent molecules moved freely in and out making the ion exchange process to proceed sufficiently, rapidly and extensively. The particles of coir pith were sufficiently hydrophillic so as to permit the exchange of ions through its specialized structure at a finite and usable rate.

Hence the principal problem in using coir pith as a soilless medium was the accumulation of sodium, potassium and chloride in the root environment which on high concentration could readily affect the root function as viewed by Sonneveld and Van der burg [16]. As already indicated, the absorption of calcium will be adversely affected by high concentration of sodium and chloride [17, 18]. With increase in sodium concentration in the root environment, an increase in the calcium concentration may be necessary for the plant in order to maintain an adequate ion activity ratio.

Conclusion

Magnesium, although it is needed in smaller amounts than calcium, is no less indispensable for plants. Magnesium is involved in the synthesis of proteins and oils. Magnesium also activates more essential enzymes required for energy metabolism than does any other mineral nutrient. Most importantly, however, magnesium is the central core of the chlorophyll molecule in plant tissues and is, therefore, fundamentally involved in the process of plant photosynthesis. If magnesium is deficient, the shortage of chlorophyll manifests itself in poor and stunted plant growth.

Acknowledgements

The authors express their gratitude to the authorities of Annamalai University for extending permission to carry out the present work in the laboratory and thank the University Grants Commission for providing financial assistance to pursue the above work.

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How to cite this manuscript: J. Paramanandham*, P. Ronald Ross. A Study on Cation Exchange Capacity of Sieved Coir Pith. Chemical Methodologies 3(1), 2018, 94-103. DOI: 10.22034/chemm.2018.137306.1065.