Magnesium Desorption in Ultisols Soils Treated by *Rhodopseudomonas palustris* Bacterium

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Abstract**—** Fertilizer supplies nutrients into soils by adsorption process. The nutrients then desorbed from the soils for plants nutrients uptake activities. The higher the time for the nutrients to desorbed from soils, the more advantageous for the plants. However, in Ultisols soils type, the nutrient desorption can be too high and easily loss from soils due to high acidity of soils nature and heavy rain weather condition. To overcome this scenario, a versatile phototropic bacterium called *Rhodopseudomonas palustris* was used as an agent to increase the soil electrical conductivity (EC), which can reduced the nutrients desorption from the soil. Mg^{2+} ion was used in this study to monitor the isotherm and mechanism of nutrient desorption from the soils that influenced by *R. palustris*. From the results, *R. palustris* bacterium potentially play a role in nutrient desorption from the soils.

Keywords**—**Desorption, Ultisols, *R. palustris*, *Bungor*, Malaysia.

I. INTRODUCTION

TAGNESIUM (Mg) is an essential plant nutrient too frequently overlooked. Either primary or secondary minerals may provide adequate Mg in some soils; there are some soils that benefit from Mg additions. There are various soluble and slowly soluble Mg sources available to meet crop demands. Magnesium is present in the divalent Mg^{2+} form in nature. Magnesium is important for plant nutrition especially in unfertilized soil [1].

Magnesium is located both in clay minerals and associated with cation exchange sites on clay surfaces. Clays such as chlorite, vermiculite, and montmorillonite have undergone intermediate weathering and still contain some Mg as part of their internal crystal structure. The Mg release rate from these clays is generally slow. Illite clays may also contain Mg, but their release rate is even slower [2].

Several factors involved for magnesium losses from soil such as crop removal, leaching process, erosional process and ion interaction in the soils. However, in Malaysia with the high rainfall season for the whole year, runoff water leaving the farm or plantation area will carry with it large amount of magnesium [3].

The focus of this study is to delay the magnesium desorption in Ultisols by addition of phototropic bacteria to increase the soil electrical conductivity (EC). *R. palustris* bacteria is known as one of the most high electrochemically bacteria which can transfer the high amount of electron. With this ability, the soils EC can be increased to reduce the magnesium deficiencies during the water runoff [4].

To clarify the magnesium desorption mechanism of soils, a trace analysis has been done. The concentration profile of magnesium breakthrough curve soils bed was investigated. This desorption phenomenon was compared to a Thomas Model, the most convenient and widely used model for soils. The Thomas Model is a derivation from the assumption Langmuir kinetics of adsorption-desorption and no axial dispersion. The expression for the Thomas Model for adsorption soils bed is given as Equation 1 [5, 6].

$$\frac{C_t}{C_0} = \frac{1}{1+exp\left[\left(\frac{K_{Th} q_e x}{Q}\right) - k_{Th} C_0 t\right]} \qquad (1)$$

Where $C_{t,}$,C_0 are concentration of effluent and initial solution (mg/l), K_{Th} is Thomas model constant (ml/min.mg), q_e is predicted adsorption capacity (mg/g), x *is* mass of adsorbent (g), Q *is* influent flow rate (ml/min) and t *is* time (day).

The linear form of Thomas model, which derived from (1) can be written as,

$$ln\left(\frac{C_t}{C_0} - 1\right) = \left(\frac{K_{Th} q_e x}{Q}\right) - k_{Th} C_0 t \qquad (2)$$

II. MATERIALS AND METHODS

A. Dynamic Mg^{2+} Sorption

The experiment was carried out by flowing in 5.0 ml/min of 0.1N magnesium sulphate ($MgSO_4$) solution by a peristaltic pump into a stainless steel column (L = 100 cm, OD = 10 cm) compacted with soils sample. The effluent from the column was then collected at approximately 50 ml/day for a trace

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analysis. All column experiments were conducted at room temperature. The $MgSO_4$ concentrations were determined spectrophotometrically at 210 nm [7].

B. Soils Properties

In this work, *Bungor* soils series was used. The soil characteristics as indicated in Table 1.

TABLE 1
CHARACTERISTICS OF SOIL SERIES

Parameters	Amount
pH	4.10
C/N ratio	9.42
Cation exchange capacity (C.E.C), m_{eq}/100g	10.10
Electrical conductivity (EC), µS	69.20
Clay, %	47.00
Silt, %	9.00
Coarse sand, %	6.00
Fine sand, %	38.00

Dried pineapple leaf (DPL) was used in this experiment to immobilize the *R. palustris* colony. Three different soil samples were prepared, which are i) *Bungor* soils, ii) *Bungor* soils with DPL and iii) *Bungor* soils with *R. palustris* bacterium adhered on DPL. All soils sample were from *Bungor* series purchased from FELDA Sdn. Bhd. soil laboratory. The soil was compacted in the column fixed to 1.0 kN/m^2 by the standard Proctor compaction test, ASTM.D.698(1933) [8]. The average moisture contents for all soil samples are 12.0% dry basis. The adhesion of bacteria onto DPL was done by soaking the leaves (70µm) with *R. palustris* in sterilized deionised water and further natural drying for 1 to 2 days in desiccator [9].

To confirm the attachment of *R. palustris* bacteria on the DPL, the leaves were analyzed by field emission scanning electron microscopy (FESEM) imaging technique. Fig. 1 and Fig. 2 show the image of DPL before and after the adhesion with *R. palustris* bacterium [10]. The soils electrical conductivity (EC) for soils added with DPL and *R. palustris* bacterium adhered on DPL were then measured by Camlab CW6220 portable conductivity meter.

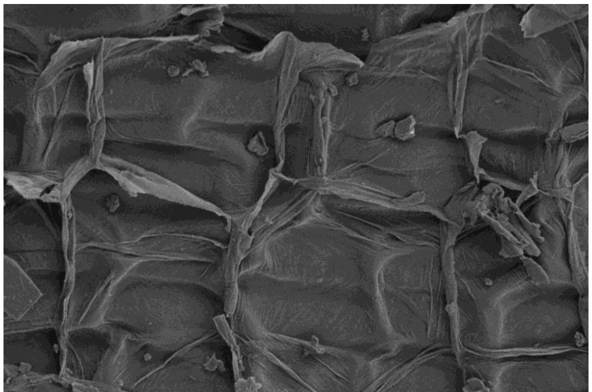


Fig. 1 FESEM image of Dried Pineapple Leaf (DPL)

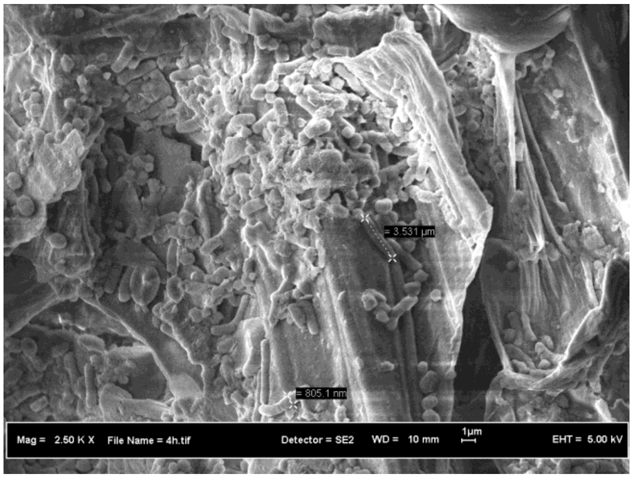
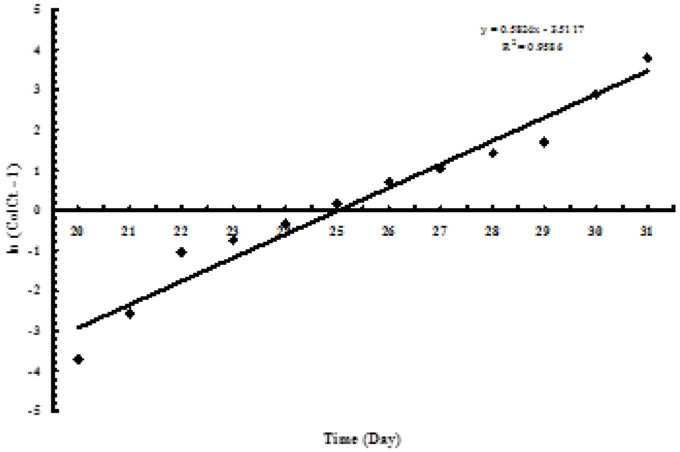


Fig. 2 FESEM image of DPL adhered with *R. palustris* bacterium (rod-shaped structures). The number of colony forming unit (CFU) of *R. palustris* used in this experiment was 10^7 which was freshly prepared

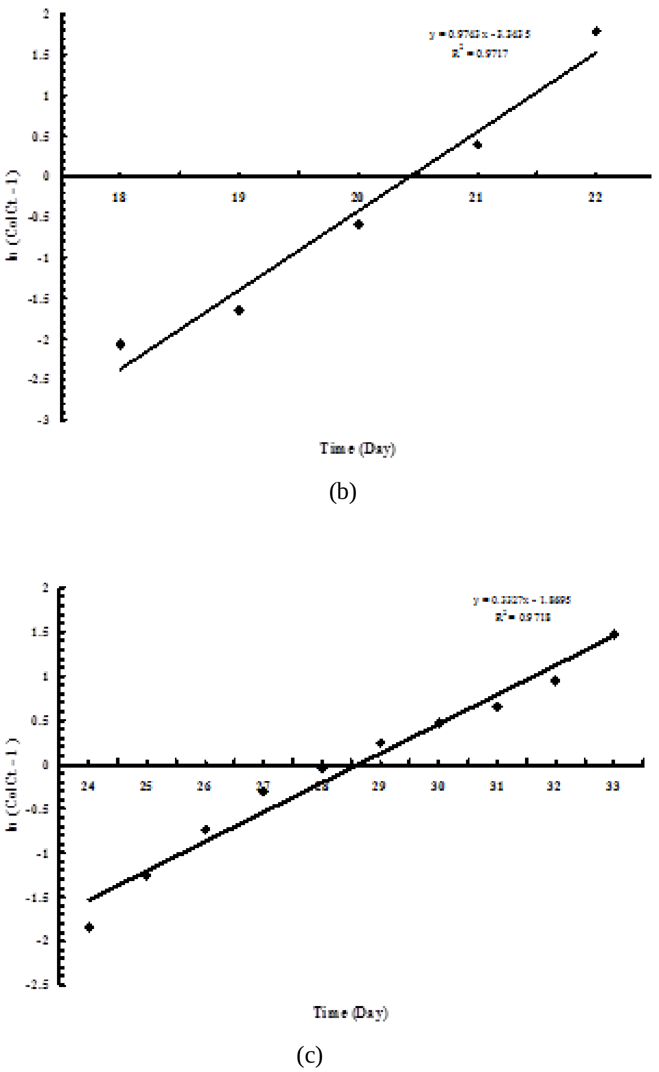
III. RESULT AND DISCUSSION

0.1N magnesium sulphate ($MgSO_4$) was filled in the column compacted with *Bungor* soils until similar concentration of C_t,C_0 was achieved. Then the deionized water (DI) will replace the 0.1N $MgSO_4$ to monitor desorption of Mg^{2+} from soil through the effluent collected.

All three sets of experimental data for (a) *Bungor* soils (b) *Bungor* soils with DPL and (c) *Bungor* soil with *R. palustris* adhered on DPL were fitted into (2) and results obtained are as shown in Fig. 3 (a), (b) and (c). All data showed good correlation with R^2 values of 0.9586, 0.9717 and 0.9718 respectively. The calculated values of the kinetic coefficient, K_{th} and adsorption capacity of the soils, q_e , (listed in Table III) from the linear plot, were fitted into (1) to generate a model curve for a breakthrough profile for each sets of experimental data. The breakthrough profiles are presented in Figure 4 (a), (b) and (c).



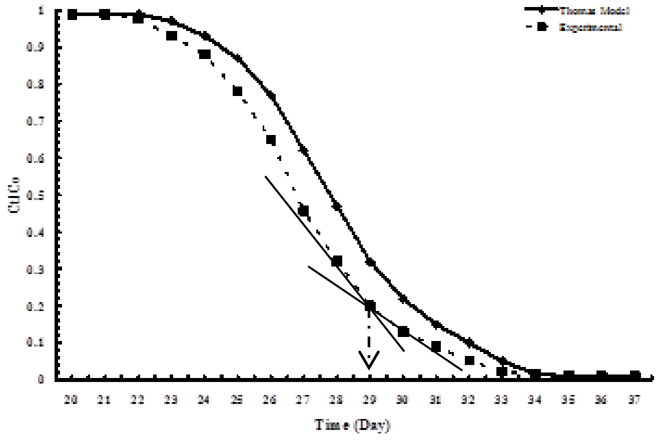
(a)



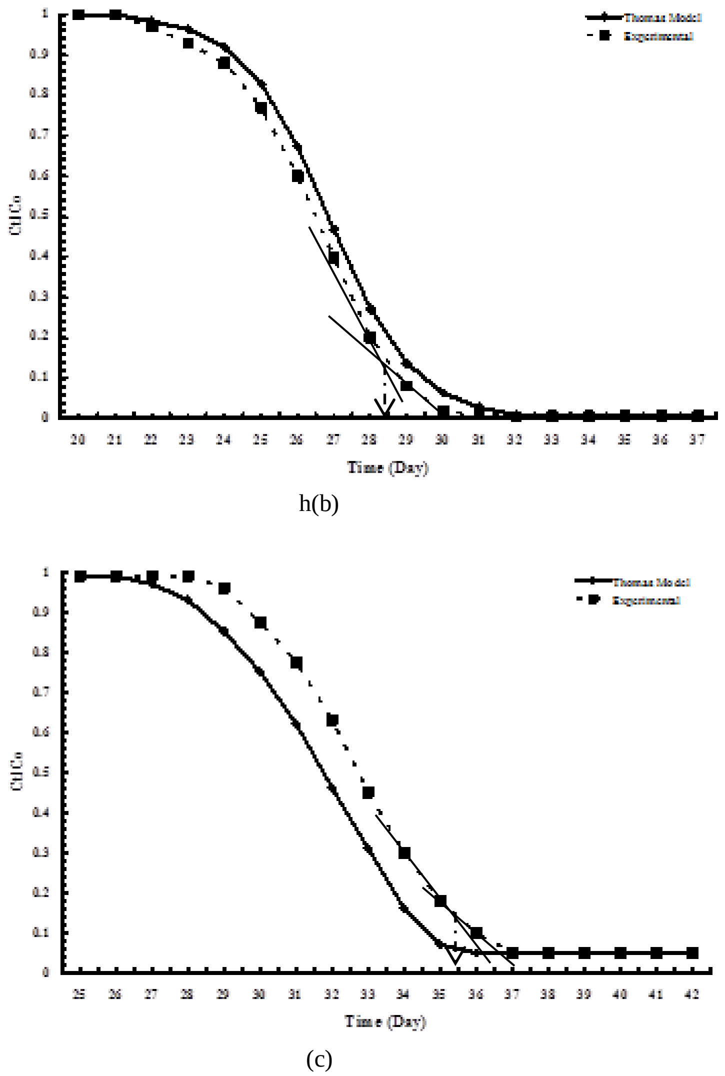
(b)

(c)

Fig. 3. Linear plot of Thomas model with experimental data. (a) *Bungor* soil (b) *Bungor* soil with DPL and (c) *Bungor* soil with *R. palustris* adhered on DPL



(a)



h(b)

(c)

Fig. 4. Curve Fitting of Thomas model with experimental data. (a) *Bungor* soil (b) *Bungor* soil with DPL and (c) *Bungor* soil with *R. palustris* adhered on DPL. (SD ± 0.05 for experimental data)

TABLE II
THOMAS MODEL PARAMETERS USING LINEAR REGRESSION ANALYSIS FOR Mg^{2+} ADSORPTION UNDER DIFFERENT SOIL PREPARATION

	EC (µS)	$q_{e.max}$ (mg/g)	K_{th} (mL.min.mg)	$q_{e.max}$ (exp) (mg/g)	R^2
Soil	60.0	0.2765	0.0536	0.2700	0.9586
Soil + DPL	102.4	0.2604	0.0939	0.2336	0.9717
Soil + DPL + *R. palustris*	259.0	0.2259	0.1571	0.1649	0.9718

Fokus kepada unit untuk terangkan perbezaan desorption.

All profiles in the Figure 4 (a), (b) and (c) showed an S-shaped breakthrough profile with a good agreement between the experimental data with the Thomas Model desorption profile. To evaluate the overall performance, the column breakthrough time, t_b is determined at time when the fraction of Mg^{2+} concentration in the influent reached 95% (refer to the cross tangential x-axis). Whereas the exhaustion time, t_e is defined as the time which C/Co is equal to 5% of the effluent concentration. For the calculation for the total quantity of Mg^{2+} desorbed factor from the soils, q_e, the total area above the breakthrough curve was multiplied by the flow rate. The breakthrough time in *Bungor* soils is the highest with *R. palustris* adhered on DPL, which $t_b = 35.5$ days, followed by *Bungor* soil at day 29 and has the lowest in *Bungor* soil with DPL (day 28.5). This evidenced that with the attachment of bacteria to the soils, the breakthrough curve time for Mg^{2+} desorption could be prolonged. This could be related to the rise of soil electrical conductivity (EC) after applied the *R. palustris* in the soils (refer Table 2). The rise of EC in soils is related to the increase of contact period of the desorbed with the sorbent in the column [8]. Also, it is observed that the steepness (dc/dt) of breakthrough curve for Mg^{2+} desorption in soils is decreasing from plain soils (a) to the soils with attachment of DPL (b) and even lower with the soils attached with bacteria on DPL. As mentioned by [11], the steepness of curve is a direct indicator on the efficiency of column (soils compaction) to reach saturation; steeper curve would indicate a better performance [9].

Although the good agreement in breakthrough curve, the estimated equilibrium desorption, q_e, of Thomas model was one fold higher than experimental value *Bungor* soils with *R. palustris* adhered on DPL. The Thomas kinetic coefficient, K_{th} become lower with the increased of EC in soil. The value of q_e and K_{th} were obtained for the soils with *R. palustris* bacterium adhered on DPL (refer Table II). According to Table II, the experimental $q_{e,max}$ from Thomas model is lower than calculated $q_{e,max}$. It is also seen in Table II that as Co and desorbed weight decreased, the value of $q_{e,max}$ and K_{th} increased and decreased, respectively. This is because the driving force for desorption is the difference in concentration between the Mg^{2+} on the desorbed and in the solution. As the soil EC increased, the value of expermental qe,max decreased. This is because of unavailability of reaction sites, but the value of K_{th} increased.

IV. CONCLUSION

The Thomas model can be used to predict the breakthrough curves and determine the characteristics parameters of the magnesium desorption. By increasing the soil EC with *R. palustris* bacterium, the result shows decreasing of magnesium equilibrium factor, q_e. These suggest the role of this bacterium on delaying or reducing the magnesium loss from soil.

The same understanding of magnesium adsorption and desorption on soil particles as reported by [12] and the magnesium retention on the soil exchange complex controlling Mg isotope variations in soils, soil solutions and vegetation in volcanic soils also reported by [13].

ACKNOWLEDGEMENT

The authors acknowledge the support by Ministry of Higher Education of Malaysia (MOHE), Institute of Bioproduct Development, UTM and GUP UTM research grant (Q.J10030000.2525.00H98 and Q.J130000.2509.03H84) for funding of the research.

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