Fertilizer nutrient mobility in peat and uptake by sago palm

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Introduction

Sago palms (*Metroxylon sp.*) are wetland plants which are found growing on shallow peat lands in Malaysia. These peat areas are characteristically acidic and the water table is at or nearer the soil surface throughout the year. They are reported to be poor in fertility status, but despite this, sago palms are reportedly growing well on them with minimum maintenance and without using fertilizers and lime (Tie et al., 1991; Lim et al., 1991). Presently, no successful fertilizer trials have been reported for sago palms on both organic and mineral soils. Therefore there is no fertilizer recommendations for its production (Kueh et al., 1991). Flach and Schuiling (1991) reported that fertilizer trials conducted on water saturated peat land could not lead to any significant yield response. Similarly, Lim et al. (1991) reported little or no response to fertilizer treatments on natural peat. They also found that sago palms have extremely slow growth rate on drained peat .The aim of this study is to evaluate the effect of the nutrient adsorptive ability of peat on the mobility of fertilizer nutrients and the uptake of ammonium, phosphate and potassium ions by sago palms. We hypothesized that the interaction of peat soil with the applied fertilizer nutrients will influence the mobility of ammonium, potassium and phosphate ions in the peat soil system

Materials and Methods

Peat soil collected from Banting, Selangor was air-dried and sieved while still wet through a 1.2 cm x 2.4 cm mesh sieve. The soil was bagged wet in 37 L polybags amounting to 6.1 kg on oven-dried basis. The air-dried soil was sieved through 2 mm sieve. Nutrient sorption isotherm data were obtained for NH_4^+, PO_4^{3-} and K^+ ions as described by Fox and Kamprath (1970) for phosphate sorption isotherms. Each treatment was done in triplicates and two drops of toluene were added into each cup to inhibit microbial activity. Equilibration for NH_4^+ sorption was done for 1 day and those for PO_4^{3-} and K^+ was done for 8 days. Equilibrated solution concentrations of the nutrients were determined in the filtered samples with respect to the treatments. Solution concentration of NH_4^+ ion was determined by steam distilling 10 mL of each filtrate with magnesium oxide and titration with 0.002 M HCl solution; PO_4^{3-} concentration was determined with 3 mL of each filtrate by Murphy-Riley method and colour absorbance was measured at 882 nm wavelength on a Spectrophotometer; and K^+ concentration was measured on Atomic Absorption Spectrophotometer. For each case, the amount of nutrient adsorbed by peat was estimated by subtracting the amount of the nutrient concerned in the equilibrated solution from the amount added in equilibrating solution. Effects of soil nutrient adsorption ability and aeration status on fertilizer nutrient transport in peat soil was studied where three similar experiments were conducted with the peat soil (with growing young sago palms) where the mobility of NH_4^+, PO_4^{3-} and K^+ ions released from the applied fertilizers. Two depths of water table (10 and 40 cm) were simulated to mimic poorly drained peat (10 cm) and drained peat (40 cm). The experiments were of three-factor type in which the depth of water table is the main factor, the rate of fertilizer nutrient is the sub factor and the time of water sampling is the third factor. Three rates of N (2.15, 3.22 and 7.53 g N bag^{-1} soil) as urea, three rates of P (0.34, 0.68 and 1.02 g P bag^{-1} soil) as Triple Super Phosphate (TSP) and three rates of K (0, 1.34 and 3.47 g K bag^{-1} soil) as Muriate of Potash (MOP) were applied. Soil solutions sampled prior to and 5, 10 and 40 days for N, 15 and 30 days for P and 30 and 60 days for K and these nutrient concentrations in the filtered solutions were measured as above.

Results and Discussion

The graphs of equilibrium concentrations of ammonium (Ne), phosphate (Pe) or potassium (Ke) against the respective initial concentrations (No, Po or Ko) of the equilibrating solution were linear within the concentration range considered for each nutrient. The respective regression equations for NH_4^+, PO_4^{3-} and K^+ ions are $Ne= 4.16+ 0.91No$, $R^2 = 0.999$, $Pe = 0.89 + 1.11Po$. $R^2 = 0.998$ and $Ke = 8.81 + 0.54Ko$, $R^2 = 0.996$. Also, the amounts of nutrient sorbed per unit kilogram soil (Ns, Ps or Ks) against the respective nutrient equilibrium concentrations (Ne, Pe and Ke) showed negative adsorption of NH_4^+ and K^+ ions and no sorption of PO_4^{3-} ion. Two distinct time-dependent phases did occur after the application of N, P and K fertilizers: (a) the concentration buildup phase described by Eqs 1 and 2 and (b) the concentration depletion phase described by Eqs 3 and 4. This is due to the concurrent processes taking place in the soil system: (i) nutrients release from the applied fertilizers, (ii) nutrients adsorption processes by the peat soil, (iii) nutrient movement from the point of fertilizer application towards plant roots and through the soil column by diffusion and mass flow mechanisms, (iv) nutrient uptake by the growing sago palms, and (v) in the case of nitrogen, nitrification process taking place. Contributions from the peat decomposition are ignored because of the high C:N ratio.

$$\Delta C_{X,T2-T1} = (Q_X \text{ released} - Q_X \text{ uptake} - \Delta Q_X \text{ sorbed} - Q_X \text{ loss})/V \quad (\text{for } PO_4^{3-} \text{ and } K^+) \quad 1$$

$$\Delta C_{NH4,T2-T1} = (Q_{NH4} \text{ released} - Q_{NH4} \text{ uptake} - \Delta Q_{NH4} \text{ sorbed} - \Delta Q_{NH4} \text{ nitrified} - Q_{NH4} \text{ loss})/V \quad 2$$

$$\Delta C_{X,T3-T2} = -(Q_X \text{ uptake} + \Delta Q_X \text{ sorbed} + Q_X \text{ loss})/V \quad (\text{for } PO_4^{3-} \text{ and } K^+) \quad 3$$

$$\Delta C_{NH4,T3-T2} = -(Q_{NH4} \text{ uptake} + \Delta Q_{NH4} \text{ sorbed} + Q_{NH4} \text{ nitrified} + Q_{NH4} \text{ loss})/V \quad 4$$

The mass or leaching flow equation (Eq. 5) shows that the mass flow of nutrient ions in the soil system is influenced by the rate of water flow (n_l) and the solution concentration of the nutrient (C). The rate of nutrient flow (n_s) and the rate of water flow (n_l) and the soil nutrient b-value are related by Eq. 6. Thus, in the case of nutrient movement to plant roots for absorption, mass flow of NH_4^+, PO_4^{3-} and K^+ ions will be enhanced in an un-drained peat soil because of the high volumetric moisture content (q), sago palm high water demand that govern water flow rate (n_l), and the low soil b-values of the nutrients.

$$J_S = v_l C \quad 5$$

$$v_S = \frac{v_l}{1 + (b\rho/\theta)} \quad 6$$

On the other hand, in the case of a drained peat, the equations also imply low soil volumetric water content (q) of the drained portion, the high flow rate of percolating rain water (n_l) through peat soil, and the low soil b-values of the nutrients will enhance their leaching losses. It is evident from the that days after the applications of N, P and K fertilizers, the solution concentrations of NH_4^+, PO_4^{3-} and K^+ ions at depth 40 cm have increased with respect to the rates of individual fertilizer applied and despite the concurrent uptake of the nutrients by the growing sago palms. This implies that the rates of nutrient release from the applied fertilizers are greater than the rates of uptake by the palms such that there was net concentration buildup that was dependent on the rate of fertilizer applied. Since the 40 cm water depth simulated a drained peat, the buildup could have been possible because of the leaching flow of the nutrients by percolating rain or irrigated water from the point of fertilizer application through the soil column and then into the saturated portion.

The diffusion equation for a one-dimensional case Eq. 7 shows that the propensity of diffusive losses of the nutrients in an un-drained peat would be great because of the soil's high volumetric moisture content (q), which increases the tortuosity factor (f_l) and their low b-values that significantly influence the concentration gradient ($\partial C_l/\partial x$).

$$J_S = -\frac{D_l f_l \theta_l}{b} \cdot \frac{\partial C_l}{\partial x} \quad 7$$

The results obtained from the systems with water depth at 10 cm (simulating and un-drained peat) show that concentration buildup observed after the N, P and K applications were brought about by diffusive flow of the nutrients from the point of application through the soil column despite the concurrent uptake by the growing palms. Uptake of N, P and K by sago palms increased with increasing rates of the nutrients applied.

Conclusions

The concentration buildup observed for NH_4^+, PO_4^{3-} and K^+ ions days after the application of Urea, TSP and MOP fertilizers is an indication of nutrient movement from the point of application at the soil surface and through the soil column either by mass flow (leaching) in the case of drained peat (water table at 40 cm depth) or diffusion in the case of un-drained peat (water table at 10 cm depth). This buildup, that is dependent on the rate of each fertilizer applied, occurs despite the concurrent uptakes by the growing sago palms. The evidence from the nutrient sorption study shows that there is no positive adsorption of the nutrients by peat soil within the concentration range considered for each nutrient. Thus, the interactions between the peat and the nutrient ions released from the applied fertilizers are very weak such that the nutrients are susceptible to diffusion or leaching losses.

Benefits from the study

The study showed that: (1) peat is a poor medium in regulating the concentration of the nutrients in soil solution such that high concentration of the nutrients will be maintained in soil solution at a time, (2) it will be poor in holding the nutrient ions added as fertilizers against leaching and diffusion losses, and (3) low rate of N, P and K fertilizers could be used at a time for crop production on peat soil.

Patent(s), if applicable:

Nil

Stage of Commercialization, if applicable :

Nil

Project Publications in Refereed Journals:

Nil

Project Publications in Conference Proceedings:
Nil

Graduate Research

Name of Graduate	Research Topic	Field of Expertise	Degree Awarded	Graduation Year
Vincent Adebiyi	Fertilizer management and nutrient use by Sago palm on peat and mineral soils	Soil Chemistry	PhD	2003

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