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Potassium Uptake Kinetics by Oil Palm Root via Radiotracer Techniques

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ABSTRACT

Rubidium is widely used as a tracer for potassium in many physiological studies because its physicochemical properties are similar to potassium. The usage of rubidium as tracer are often used with caution as several plant species were able to selectively acquire potassium over rubidium. However, its usage depends on the non-selective absorption of potassium and rubidium by the plant. Therefore a study to determine the absorption of potassium and rubidium by oil palm and measure the potassium uptake rate was conducted. Results showed that the uptake of potassium and rubidium was similar making rubidium a suitable tracer for potassium in oil palm. Prior to reaching potassium saturation in the root, the non-lignified "white" root tip segment were actively absorbing ^{86}Rb at a rate of 194.9 cpm/g/h. The rate of ^{86}Rb uptake would then correlate to rate of uptake at approximately 16 pM of potassium per gram per hour. As excised root tip were use, the root almost reaches it saturation phase after 8 h of uptake. The maximum activity of ^{86}Rb absorbed by the excised root plateaued at 586 cpm g^{-1}.

Key words: *Elaeis guineensis* (Jaq), oil palm root, K uptake rate, radiotracer

INTRODUCTION

Radiotracer technique is a non-destructive method used widely for studying absorption of radiolabelled ions by plants and their transport and redistribution in the plant tissues. Such technique is ideal for non-destructive quantification study of ion transport and redistribution as well as differential quantification of nutrients absorbed from fertilizer source or inherent soil nutrients.

Rubidium has been used to substitute potassium as a tracer to study plant uptake of K because in general plant cells have little discrimination between them and can be scarcely distinguished by cell's uptake mechanisms (Lauchli and Epstein, 1970). Moreover the longer half-life of ^{86}Rb (18.6 days) compared with ^{42}K (12 h) increases its application in studying nutrient uptake kinetics. This is particularly useful for oil palm which has relatively slow growth rate in the first 12 months from sowing.

Despite its common use, several published studies reported rubidium might be considered an inappropriate analogue for certain situation as some potassium transporters and channels are strongly selective for potassium over rubidium (Cuin *et al*., 2008; Kronzucker *et al*., 2003; Bange, 1979; Memon *et al*., 1985). Radioassay by means of ^{86}Rb labelling overestimated the absorption of K by 20% in corn roots (Lauchli and Epstein, 1970). Accurate estimation of K+ influx kinetics in oil palm roots using ^{86}Rb tracer technique could yield gross estimation error if its potassium transporters and channels were selective for potassium over rubidium. Applicability of rubidium as tracer for potassium hence cannot be universally accepted for all plant species as differential uptake was many times reported.

Zaharah *et al.* (1991) first reported the successful use of ^{86}Rb to quantify potassium uptake by oil palm from different sources of potassium fertilizers. They demonstrated that the oil palm was able to absorb ^{86}Rb as K analogue, hence opening the opportunity for more detailed physiological study in oil palm nutrition. It is in the interest of this present study to use ^{86}Rb in quantifying K+ influxes rate in excised oil palm root as well as to attest the ability of oil palm roots to differentiate between potassium and its analogue, rubidium.

MATERIALS AND METHODS

Growth of seedlings: Four months old oil palm seedlings were individually planted in 10 kg plastic container containing acid washed sand mixed with 500 mL of hydrated hydro-gel (to reduce watering frequency after the application of ^{86}Rb).

Seedlings were allowed to grow for 1 month, before the application of ^{86}Rb to allow the palms to recover from transplanting shock. Seedlings was watered twice a day during the recovery period and reduced to once a day after application of ^{86}Rb. Seedlings was watered ½ strength modified Hoagland solution (Table 1). Oil palm progenies of selected origins used were supplied by Applied Agricultural Resources Sendirian Berhad and FELDA Agricultural Services Sendirian Berhad.

Rubidium-86 as potassium tracer: The oil palm seedlings were treated with either rubidium chloride ($RbCl_2$) as a substitute for potassium in the Hoagland solution to determine potassium uptake. Four palms of each progeny were randomly selected and applied with K^+ Hoagland solution whilst another four with Rb^+ Hoagland solution. Each seedlings was applied with 400 mL of treatment solutions (K^+ or Rb^+) containing 20 µCi of ^{86}Rubidium (as $^{86}RbCl_2$). Watering with Hoagland solution frequency was reduced to every alternate day after the application of ^{86}Rb. In the experiment involving root uptake, excised root tip were used. Two centimeter of actively absorbing white root (Liew, 2008) were dipped into 2% phytagel prepared with "Rb^+ " solution laced with 2 µCi of ^{86}Rb. Roots were then incubated in the dark at room temperature. Decay activity of ^{86}Rb was measured using Packard Tri-carb Liquid Scintillation Counter.

Table 1: Nutrient composition of ½ strength modified Hoagland solution No. 2[a] (Hoagland and Arnon, 1950) as carrier solution used in this experiment

Salts	Final concentration mM	mg L^{-1}
$Ca(NO_3)_2.4H_2O$	2.00	
$MgSO_4.7H_2O$	1.00	
NH_4NO_3	1.00	
$(NH_4)H_2PO_4$	0.50	
H_3BO_3		1.43
$MnCl_2.4H_2O$		0.91
$ZnSO_4.7H_2O$		0.11
$CuSO_4.5H_2O$		0.03
$(NH_4)_6Mo_7O_{24}.4H_2O$		0.06
5 g L^{-1} FeEDTA-1 mL/L twice weekly		5.00
$RbCl_2$ in "Rb^+ " solution	3.00	
KCl in "K^+ " solution	3.00	

pH adjusted to 5.5 with HCl 0.1 M

Experimental design and data analysis: The experiment was conducted in an experimental glasshouse for 90 days (October 2012 to December 2012) at the Experimental Farm No. 2, Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia. Treatments were arranged in a Completely Randomized Design (CRD) with 4 replications. Analysis of Variance (ANOVA) and Fisher's L.S.D. (Gomez and Gomez, 1984) at $p<0.05$, were used to analyze the data with Genstat V12.1.

RESULTS AND DISCUSSION

Differential uptake of rubidium versus potassium: The activity of ^{86}Rb detected in seedlings after two months of application via nutrient solution was shown in Table 2. The ^{86}Rb activity in whole plant with different carrier solutions were found to be statistically insignificant at $p_{0.05}$. The ^{86}Rb activity was highly significant between the progenies and there was no interaction effect. This indicated that the oil palm roots could not distinguish rubidium from potassium in absorbing these elements. In corn roots the absorption of K was overestimated by 16-20% when ^{86}Rb was used as tracer (Lauchli and Epstein, 1970). Epstein *et al.* (1963) studied the absorption of ^{86}Rb by barley roots and found only slight differences in the rates of absorption. Hence it was concluded that K and Rb were absorbed with similar affinities through common ion transporter mechanisms. This conclusion appears to be valid for oil palm roots, also.

Rate of potassium uptake by oil palm root: The uptake rate of ^{86}Rb declined (Fig. 1) as its concentration in excised root approached the saturation point which begins after 100 min. The uptake rate of Rb-86 prior to saturation phase follows a linear function, of which would be the uptake rate demonstrated by intact roots (Fig. 2) which would not be saturated. Absorption of ^{86}Rb by corn roots was linear with time up to at least 90 min (Lauchli and Epstein, 1970). The non-lignified "white" root tip segment could actively absorb ^{86}Rb at a rate of 194.9 cpm/g/h which is equavalent to approximately 16 pM of potassium per gram per hour.

Table 2: Rubidium-86 activity at harvest

Oil palm progeny	DPM/plant Carrier-K	Carrier-Rb	Mean	DPM/g Carrier-K	Carrier-Rb	Mean
Prog 1	466,696	533,383	500,039[a]	15,824	12,804	14,314[b]
Prog 2	698,802	753,332	726,067[bc]	24,734	19,305	22,020[c]
Prog 3	812,102	944,510	878,306[c]	28,979	22,043	25,510[c]
Prog 4	456,379	447,812	452,095[a]	8,891	7,167	8,029[a]
Prog 5	559,000	601,498	580,249[ab]	6,080	5,956	6,018[a]
K vs Rb	598,596	656,107	ns	16,902	13,455	ns
LSD 5%						
Progeny[**]	153,250			4,770		
Carrier[ns]	96,923			3,507		

DPM: Disintegration per minute, Prog 1: AVROS origin, Prog 2 and 3: Yangambi X AVROS, Prog 4 and 5: Nigerian

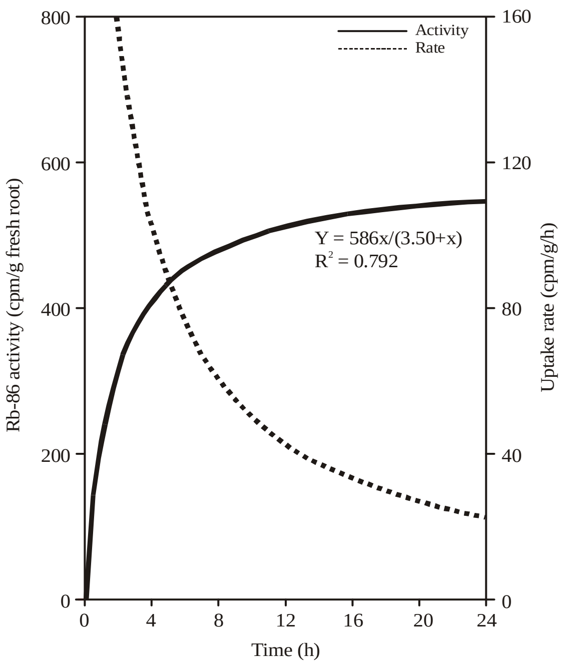

Fig. 1: Rubidium-86 uptake by excised root tip of oil palm during 24 h in $^{86}RbCl_2$ solution

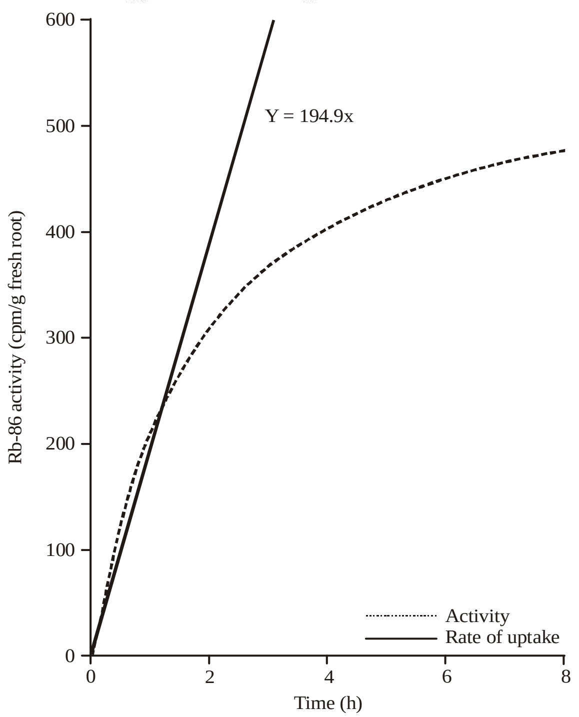

Fig. 2: Estimated rate of rubidium uptake at initial uptake prior to saturation phase

CONCLUSION

The oil palm (*Elaies guineensis* var. Jacq.) does not exhibits the ability of selectively acquire potassium over rubidium. Hence, rubidium could accurately use as potassium analogue in studying the potassium uptake mechanism of oil palm. Prior to saturation point, the non-lignified "white" root tip segment were actively absorbing ^{86}Rb at a rate of 194.9 cpm/g/h which equivalent to approximately 16 pM of potassium per gram per hour. As excised root tip were use, the root almost reaches its saturation phase after 8 h of uptake. The maximum activity of Rb-86 absorbed by the excised root plateaued at 586 cpm g^{-1}.

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