The Initial and Residual Value of Phosphorus from Apatite Rock Phosphates and Superphosphates as Measured by ^{32}P Dilution Technique

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ABSTRAK

Satu kajian nilai agronomi sembilan jenis baja batuan fosfat apatit dan superfosfat tigaan ke atas pokok jagung (Zea mays, L.) yang ditanam di atas satu tanah Ultisol di dalam pasu yang dilabel dengan isotop ^{32}P telah dilakukan. Keputusan telah menunjukkan keberkesanan baja fosfat batuan amat berbeza sekali dibandingkan dengan superfosfat tigaan setelah diukur pada tahap 30 hari selepas benih jagung ditanam. Akan tetapi, keberkesanan baja-baja fosfat batuan ini didapati meningkat tiga hingga lima kali ganda dibandingkan dengan keberkesanan baja superfosfat tripel dalam tanaman kali kedua.

ABSTRACT

A pot trial using maize (Zea mays, L.) grown on an Ultisol labelled with ^{32}P was carried out to evaluate the agronomic value of nine types of apatite rock phosphates and triple superphosphate. Results show that the effectiveness of tested rock phosphates is variable as compared to superphosphate, when measured at 30 days after planting. However, these rock phosphates were three to five times more effective than triple superphosphate in the second cropping.

INTRODUCTION

Phosphorus is known to be one of the most limiting nutrients in Malaysian soils for crop production. Thus for annual crop production, phosphorus is supplied in the form of chemical fertilisers such as superphosphates and mono- and di-ammonium phosphates. Since these fertilisers are often expensive, direct use of apatite rock phosphates, which are often cheaper, have been suggested (Juo and Kang 1978; Cabala-Roland and Wild 1982; Chien 1982). This paper investigates the effectiveness of nine types of rock phosphate fertilisers against triple superphosphate to two crops of corn, grown consecutively on an Ultisol. ^{32}P was used to label the soil-P fraction in order to quantify the P derived from fertilisers used. The use of this tracer technique has been shown to provide more reliable indexes of P availability than the non tracer method (Kucey and Bole 1984).

MATERIALS AND METHODS

Nine sources of rock phosphate (RP) fertilisers were tested against triple superphosphate (TSP). The rock phosphate fertilisers used were commercial grade Christmas Island Rock Phosphate (CIRP), CIRP-A dust, CIRP-B dust, CIRP-C dust, CIRP-A/L dust, Red Mud C grade, Barandite, Citraphose, and Moroccon Rock Phosphate (MRP). Each of the rock phosphate fertilisers tested were ground and seived to pass through a 0.125 mm sieve and analysed for water soluble P, citrate soluble P and total P content using the method proposed by AOAC (1975) as shown in Table 1. The soil used for the study is a Typic Paleudult (Bungor series soil) which was taken from the top 15 cm, air-dried, ground and sieved to pass a 2 mm size sieve. The soil has a pH of 4.57, nitrogen content of 0.18% and Bray and Kurtz extractable P of 5.35 ug/g soil.

Five mg P in the form of KH_2PO_4 was dissolved in 400 ml distilled water and a ^{32}P carrier free solution of 3.7 x 10^6 Bq (100 uCi) activity was added to this solution and applied to the 2 kg soil placed in plastic bags. The soil was thoroughly mixed by shaking and allowed to equilibrate for one week. The phosphate fertilisers were then added to each soil bag at 133.33 mg P/2 kg soil. Nitrogen as urea at 174 mg N/2 kg soil and potassium as Muriate of Potash at 133 mg K/ 2 kg soil were also added to this soil and thoroughly mixed. These soils were then placed in plastic pots. Four replicates of each treatment, including a TSP treatment, a labelled control (no fertilizer P added) and a non radioactive control (for background counts of ^{32}P in plant sample) were prepared, giving a total of 12 treatments with 48 pots laid out in a completely randomised design.

Pregerminated maize seeds (*Zea mays* L) were planted in each pot at 4 seeds/pot. These pots were watered regularly with distilled water. The plants were harvested at 30 days old at the soil surface. Each sample was then cut into small pieces, dried in a forced air oven at 65 °C until a constant weight was achieved. Two grams of the dried tissue were then ashed in the furnace at 550 °C and dissolved in 20 ml 2 M HCl and filtered. Fifteen ml of the filtrate was pipetted into plastic scintillation vials

and ^{32}P activity in the samples counted using a Liquid Scintillation counter. The P content of these solutions was determined using the method of Scheel (1936)

Six months later, these soils were again thoroughly mixed with 5 mg P as KH_2PO_4 dissolved in 400 ml distilled water and a ^{32}P activity of 3.7 x 10^6 Bq (100 uCi). This was again allowed to equilibrate for one week before four pregerminated maize seeds were planted. The same amount of N and K fertilisers were applied to the second crop, which was allowed to grow for one month. The plants were harvested, processed and analysed in the same manner as the first crop.

RESULTS AND DISCUSSION

Phosphate Fertiliser Source
Table 1 gives the total, water soluble and citrate soluble P content of each of the fertilisers used. It can be seen that Triple superphosphate has the highest P content and the highest percentage of water soluble P with about 98% of its total P content being in the available form. All the other phosphate sources, derived from rock phosphates, had only between 47-58% of the total P content in the available form with the water soluble P fraction ranging from 0.02% to 0.19% of the total P content.

TABLE 1
P contents of fertilisers used

Fertilisers	Total P (%)	H_2O sol.	Citrate sol. % of total P	Available P
CIRP	15.00	0.186	58.70	58.886
CIRP Dust A	14.82	0.177	56.90	57.077
CIRP Dust B	14.49	0.160	56.30	56.460
Red Mud Grade C	14.23	0.022	47.00	47.022
CIRP Dust C	14.00	0.163	54.60	54.763
CIRP A/L Dust	13.56	0.148	51.20	51.348
Barandite	13.08	0.123	51.00	51.123
Citraphos	13.91	0.154	52.10	52.254
Moroccon Rock Phosphate	13.30	0.133	60.20	60.333
Triple Super- phosphate	18.43	46.52	52.00	98.52

TABLE 2

Dry matter yield of corn as affected by different
P fertilizer treatments

Treatments	Dry Matter Yield			Total P Taken Up		
	Crop 1	Crop 2 (g/pot)	Total	Crop 1	Crop 2 (mg/pot)	Total
TSP	11.89 a	2.53 c	14.42	9.42 a	3.06 c	12.48
Red Mud C	5.39 b	4.38 a	9.77	2.67 c	14.03 a	16.70
MRP	5.13 b	4.40 a	9.53	4.84 bc	14.51 a	19.35
CIRP A/L Dust	4.13 bc	3.91 ab	8.04	4.86 bc	13.06 a	17.92
CIRP	3.96 bc	3.16 abc	7.12	4.99 bc	9.93 b	14.92
CIRP Dust A	3.76 bc	3.24 abc	7.00	5.33 bc	10.97 b	16.30
Citraphos	3.38 cd	3.18 abc	6.56	3.43 bc	8.71 b	12.14
CIRP Dust C	3.13 d	3.24 abc	6.37	6.03 b	7.83 b	13.86
CIRP Dust B	3.04 d	4.22 a	7.26	3.86 bc	15.59 a	19.45
Barandite	2.12 e	2.83 bc	4.95	1.50 c	8.43 b	9.93

Values in a column followed by the same alphabet are not significant at P = 0.05

Dry Matter Yield

In the first crop, triple superphosphate treated plants gave the highest dry matter yield while rock phosphate treated plants gave significantly lower yields (Table 2). This is due to the triple super-phosphate having the highest percentage of water soluble phosphate as compared to the rock phosphates. Short term fast growing crops grown in pots, where the root system is restricted have been known to require P fertilisers with high water soluble P fraction for maximum yield (De Geus 1973).

In the second cropping, Moroccon Rock Phosphate, Red Mud C and CIRP dust B gave the highest dry matter. TSP treated pots gave a drastic reduction in yield, while the yields obtained from the RP sources remained the same as in the first crop. A similar observation was made by Bolland *et al.* (1984), and Bolland and Bowden (1984), where they concluded that the effectiveness of the RP remained constant with time, and the effectiveness of superphosphate is reduced.

Summation of the dry matter yields obtained from the two crops grown still show that TSP produced the highest yield, due to the high yield obtained in the first crop. Total P taken up by the plants is seen to be almost equal from triple super-phosphate as well as rock phosphates treated plants. Barandite treated plants took up to the least

amount of P eventhough its available P content was 51% (Table 2). Both MRP and CIRP did not show significant difference in their yield and total P taken up by the plants. This is also observed in the analysis of the available P content in the initial fertilisers used.

P Derived from Fertilisers

The percent P derived from the fertilisers (% Pdff) tested was calculated using the equation

$$\%Pdff = 1 - \frac{\text{specific activity (treated plants)}}{\text{specific activity (control plants)}} \times 100$$

This fraction when multiplied with the total P taken up by the plants will give the proportion of P that came from the fertilisers added (Pdff). This assumes that the plant will absorb P in relation to its availability and that the ratio of availability of soil P and labelled carrier P (KH_2PO_4) is not affected by the addition of RP or TSP. The more available the P source added, the more it will dilute the ^{32}P activitiy of the P in plant tissue.

Table 3 shows the percent P derived from fertilisers, the amount of P taken up from the fertilisers added and the percent P fertilisers utilis-

TABLE 3

P derived from fertilizers added and percent P
fertilizers utilized by the crop

Treatments	%Pdff		P derived from Fertilizers (mg/pot)		P Fertilizer Utilized (%)	
	Crop I	Crop II	Crop I	Crop II	Crop I	Crop II
TSP	85.3 a	85.2 ab	8.16 a	2.59 e	6.12 a	1.94 e
CIRP Dust C	80.67 a	87.73 ab	4.88 b	6.92 e	3.66 b	5.20 d
CIRP Dust A	82.46 a	70.23 b	4.43 bc	10.19 bcd	3.33 bc	7.97 bcd
CIRP	82.57 a	90.85 ab	4.13 bc	9.02 bcd	3.10 bc	6.77 bcd
CIRP A/L Dust	79.45 ab	93.18 a	3.96 bc	12.15 abc	2.97 bc	9.12 abc
MRP	75.81 b	93.50 a	3.67 bc	13.41 ab	2.76 bc	10.06 ab
CIRP Dust B	82.84 a	95.00 a	3.26 bc	14.80 a	2.44 bc	11.10 a
Citraphos	79.47 ab	91.30 ab	2.75 bc	7.97 cd	2.07 bc	5.98 cd
Red Mud C	52.50 c	92.20 ab	1.37 c	12.94 ab	1.03 c	9.71 ab
Barandite	73.77 b	89.90 ab	1.10 c	7.59 d	0.83 c	5.69 d

Values in a column followed by the same alphabet are not significant at P = 0.05

ed by the crop. For the superphosphate treated plants, 85.3% of the P taken up by the plants was derived from the fertiliser added. This corresponds to 8.16 mg P/pot, or 6.124% of P fertiliser being utilised by the crop. The same percentage of efficiency was observed in an isotope aided field study of efficiency of superphosphates by corn plants (Zaharah et al. 1989). The lowest amount of fertiliser P utilised was from Barandite (0.83%). All the other rock phosphates were utilised up to about 3% of the total amount of fertiliser P added to the crop. This value is slightly higher than those obtained under field conditions (Zaharah, et al. 1989) and may be due to these rock phosphates being homogenously mixed with the soil as compared to the field condition, where the rock phosphates were applied in bands.

In the second cropping, the amount of P derived from fertilisers was highest in the CIRP dust B treated plants, with 11.1% of the P added being utilised. All the RP sources showed an increase of between 2 to 3 fold in P utilised by the crop. TSP treated plants gave only 1.94% of the added P being utilised. This is also in accordance with the results obtained by Bolland and Bowden (1984) and Palmer and Gilkes (1983).

Relative availability of RP as compared to TSP has been calculated using the formula of Kucey and Bole (1984)

Relative Availability Isotope Dilution =

$$\frac{\text{P derived from RP}}{\text{P derived from TSP}} \times 100$$

It is seen that for crop 1, the relative availability of RP is only about 50% of TSP. The value obtained for Citraphos was found to be one-third of that obtained for triple superphosphate, which was also the value obtained by Palmer and Gilkes (1979). Red Mud Grade C and Barandite gave the lowest availability. In the second crop, RP availability increased tenfold, with the exception of Barandite, whose relative availability was still low (Table 4). Thus the release of P from RP increased with time, whereas TSP supplied P for immediate use by the plants. The low initial effectiveness of all the RP fertilisers tested in this experiment demonstrates that they cannot be regarded as an alternative phosphorus to superphosphate for the production of annual crops. However, their residual effectiveness is of significance for the use of RP in perennial crops.

TABLE 4
Relative availability of RP to TSP

Treatments	Relative Availability (%)	
	Crop I	Crop II
TSP	100	100
CIRP Dust C	60	267
CIRP Dust A	54	393
CIRP (Commercial grade)	50	348
CIRP A/L Dust	49	469
MRP	45	518
CIRP Dust B	40	571
Citraphos	34	308
Red Mud Grade C	17	500
Barandite	14	293

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REFERENCES

BOLLAND, M.D.A. and J.W. BOWDEN. 1984. The Initial and Residual Value for Subterranean Clover of Phosphorus from Crandellite Rock Phosphate, Apatite Rock Phosphates and Superphosphate. *Fertilizer Res.* **5**: 295-307.

BOLLAND, M.D.A., J.W. BOWDEN, M.F. D'ANTUONO and R.J. GILKES. 1984. The Current and Residual Value of Superphosphate, Christmas Island C-Grade Ore and Calciphos as Fertilizers for a Subterranean Clover Pasture. *Fertilizer Res.* **5**: 335-354.

CABALA-ROLAND, P. and A. WILD. 1982. Direct Use of Low Grade Phosphate Rock from Brazil as Fertilizers. I. Effect of Reaction Time in Soil. *Plant and Soil* **65**: 351-362.

CHIEN, S.H. 1981. Direct Application of Phosphate Rocks in Some Tropical Soils of South America: A Status Report. In *Proc. Int. Conf. Phos. Pot. in the Tropics.* ed. E. Pushparajah and H.A.H. Sharifuddin Hamid, p. 519-529. Malaysian Soc. Soil Sci. Kuala Lumpur, Malaysia.

DE GEUS, J. 1973. *Fertilizer Guide for the Tropics and Subtropics.* 2nd edn. Centre d'Etudede l'Azote. 774 p.

JUO, A.S.R. and B.T. KANG. 1978. Availability and Transformation of Rock Phosphates in Three Forest Soils from Southern Nigeria. *Commun. Soil Sci. Plant Anal.* **9**: 493-505.

KUCEY, R.M.N. and J.B. BOLE. 1984. Availability of Phosphorus from 17 Rock Phosphates in Moderately and Weakly Acidic Soils as Determined by ^{32}P Dilution, A Value and Total P Uptake Methods. *Soil Sci.* **138**: 180-188.

PALMER, B.B. and R.J. GILKES. 1979. A Re-evaluation of the Effectiveness of Calcined Christmas Island C-grade Rock Phosphate. *Aust. J. Exp. Agric. Anim. Husb.* **19**: 605-610.

PALMER, B.B. and R.J. GILKES, 1983. The Fertilizer Effectiveness of Calcined Christmas Island C-grade Aluminium-iron Phosphate Rock and Superphosphate during Early Stages of Plant Growth. *Fert. Res.* **4**: 31-43.

ZAHARAH. A.R. I. MOHD NASIR, and H.A.H. SHARIFUDDIN Uptake Efficiency by Corn from Three Phosphate Fertiliser Sources Using ^{32}P Isotope Dilution Technique. *Pertanika* **12(2)**: 153-158.

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