



**UNIVERSITI PUTRA MALAYSIA**

**ASSESSMENT OF AGRONOMIC EFFECTIVENESS OF PHOSPHATE  
ROCKS APPLIED TO AN ULTISOL**

**ZULKIFLI HASHIM**

**FP 1996 5**

**ASSESSMENT OF AGRONOMIC EFFECTIVENESS OF PHOSPHATE ROCKS  
APPLIED TO AN ULTISOL**

By

**ZULKIFLI HASHIM**

Thesis Submitted in Fulfilment of the Requirements for  
the Degree of Master of Science in the Faculty of  
Agriculture, Universiti Pertanian Malaysia

May 1996



**Dedicated to everyone in the family**



## ACKNOWLEDGEMENTS

I would like to express my sincere thanks and appreciation to Assoc. Prof. Dr. Zaharah A.Rahman, chairman of the supervisory committee for her advice, guidance and encouragement throughout the course of this study. I would like also to extend my great appreciation for helpful and constructive suggestions made by members of the supervisory committee, Prof. Sharifuddin Hj. Abd. Hamid and Dr. Rosenani Abu Bakar.

Sincere appreciation and gratitude are also extended to PORIM and JPA for giving me the chance of self-improvement in the field of my specialization by providing financial support and granting me study leave.

To fellow graduate students, thank you for the friendship during the course of my research. I take pleasure to warmly acknowledge the cooperation and motivation from colleagues and staff at Agronomy section and laboratory in PORIM and Radiochemistry laboratory in Jabatan Sains Tanah, UPM... thank you for the support.

I thank my mother for showering me with endless love and constant encouragement all these years and a few special people that always stand by me either in good or bad times.

I would also like to manifest my gratitude to Almighty God, for the many blessings, keeping me strong and healthy, providing me the opportunity to pursue this degree, and meeting such wonderful people during the time I spent throughout the course.



## TABLE OF CONTENTS

	Page
<b>ACKNOWLEDGEMENTS</b> .....	iii
<b>LIST OF TABLES</b> .....	viii
<b>LIST OF FIGURES</b> .....	x
<b>LIST OF ABBREVIATIONS</b> .....	xi
<b>ABSTRACT</b> .....	xiii
<b>ABSTRAK</b> .....	xvii
<b>CHAPTER</b>	
<b>I INTRODUCTION</b> .....	1
<b>II LITERATURE REVIEW</b> .....	6
Phosphate Rocks .....	7
Chemical and Mineralogical Properties of Phosphate Rocks .....	9
Reactivity and Solubility of Phosphate Rocks .....	11
Response of Oil Palm to Phosphate Rocks .....	16
Phosphorus Status in Soil .....	17
Residual Phosphorus .....	20
Behaviour of Applied Phosphate Rocks in Soil .....	23
Phosphate Availability to Plant .....	27
Available Soil Phosphorus Analysed by Extractant Method .....	27
Available Soil Phosphorus Analysed by <sup>32</sup> P Isotopic Approach .....	28



	Page
Principle of $^{32}\text{P}$ Isotopic Method to Determine the Phosphorus in Soil as a Single Pool Size .....	29
Principle of $^{32}\text{P}$ Isotopic Method to Determine Many Pools of Phosphorus in Soil .....	30
Relative Agronomic Effectiveness (RAE) of Phosphate Rocks .....	31
<b>III GENERAL METHODOLOGY .....</b>	<b>34</b>
Glasshouse Experiment: Isotopic Dilution Approach .....	34
Management of the Experiment .....	35
Soil Characterization .....	37
Characterization of Phosphate Rocks .....	40
Solubility Test of Phosphate Rocks .....	40
Dissolution of PR with Time in Soil Taken from Glasshouse Experiment .....	41
Dissolution of PR by Chemical Extraction Method.....	41
Dissolution of PR by Isotopic Dilution Technique .....	43
Statistical Analysis .....	43
Characterization of Immediate and Residual Availability of P using Isotopic Exchange Kinetic Laboratory Experiment (E Value) .....	44
Determination of Isotopically Exchangeable Phosphorus (E Value) .....	44
Determination of Phosphorus in the Soil Solution (Cp) ..	45
Determination of P Status and P Kinetics Parameters .....	45
Calculation of P Derived from Fertilizer (% Pdf) in Soil Solution .....	49

	Page
Determination of Relative Agronomic Effectiveness .....	50
Statistical Analysis .....	50
Efficiency of Phosphate Rocks with Time by Oil Palm Seedlings	50
Plant Tissue Analysis .....	51
Determination of Labile P (L Value) .....	52
P Uptake by Plant from Soil and Fertilizers .....	52
Determination of Relative Agronomic Effectiveness .....	53
Statistical Analysis .....	54
<b>IV     ASSESSMENT OF METHODS FOR EXAMINING THE CHARACTERICS AND DISSOLUTION OF PHOSPHATE ROCKS IN SOIL.</b>	
Introduction .....	55
Materials and Methods .....	58
Results and Discussion .....	59
Chemical and Mineralogical Characteristics of Phosphate Rocks .....	61
Solubility Characteristics of Phosphate Rocks.....	67
Dissolution of Phosphate Rocks in Soil .....	70
Conclusions .....	75
<b>V     EVALUATION OF BIOAVAILABILITY OF PHOSPHATE ROCK FERTILIZER: A PREDICTIVE LABORATORY ISOTOPIC TECHNIQUE</b>	
Introduction .....	77
Materials and Methods .....	80



	Page
Results and Discussion .....	81
Soil P Status Parameters .....	81
Soil P Kinetics Parameters .....	87
Relationships between the Isotopically Exchangeable P and P Uptake by Oil Palm Seedlings after One Year of PR Application .....	97
Conclusions .....	101
 <b>VI AN ISOTOPIC APPROACH IN EVALUATING P FERTILIZER EFFICIENCY IN SOIL-PLANT ECOSYSTEM: GREENHOUSE EXPERIMENT</b>	
Introduction .....	103
Materials and Methods .....	105
Results and Discussion .....	106
Dry Matter Yields .....	106
P Uptake by the Plant from Soil and Fertilizer .....	106
Comparison between L and E Value .....	112
Conclusions .....	117
 <b>VII SUMMARY AND CONCLUSIONS</b> .....	119
<b>BIBLIOGRAPHY</b> .....	125
<b>APPENDICES</b>	
A Additional Figures .....	134
B Isotopic Dilution Technique .....	142
<b>VITAE</b> .....	145





## LIST OF TABLES

Table		Page
1	Rates of Basal Fertilizer of N, K and Mg .....	36
2	Chemical Characteristics of the Rengam Series Soil before starting the Experiment .. .....	60
3	Some Chemical Compositions of the Phosphate Rocks Studied .....	62
4	Solubility Properties of Phosphate Rocks Studied .....	68
5	The Ranking of Phosphate Rocks Studied according to Solubility Tests .....	69
6	Correlation Coefficient of Solubility Tests with P Uptake by Oil Palm Seedlings after One Year of PR Application.....	69
7	Dissolved P and Ca with Time in the Soil Planted with Oil Palm Seedlings .....	71
8	Percentage Dissolution of Phosphate Rocks with Time in the Soil Planted with Oil Palm Seedlings.....	72
9	Correlation Coefficient among Methods of Determining Dissolution of PR with Time in the Soil Planted with Oil Palm Seedlings .....	74
10	The Ranking of Phosphate Rocks according to Dissolution Methods .....	75
11	Soil Phosphorus Status Parameters .....	82
12	Experimental Parameters of Isotopically Exchangeable P at One Minute ( $E_1$ ) .....	84
13	Size of the P Pools and P Kinetic Parameters in the Soil ...	90
14	Expected P Derived from Fertilizer (% Pdf $\bar{f}$ ) in the Soil Solution .....	91
15	Experimental Parameters of Isotopically Exchangeable P at 3 Months of Growing Period of Oil Palm Seedlings after PR Application .....	92



	Page
16	Experimental Parameters of Isotopically Exchangeable P at 6 Months of Growing Period of Oil Palm Seedlings after PR Application ..... 93
17	Experimental Parameters of Isotopically Exchangeable P at 9 Months of Growing Period of Oil Palm Seedlings after PR Application ..... 94
18	Experimental Parameters of Isotopically Exchangeable P at 12 Months of Growing Period of Oil Palm Seedlings after PR Application ..... 95
19	Comparison of Experimental Parameters of Isotopically Exchangeable P in the Laboratory Experiment and the Glasshouse Experiment under 12 Months Growing Period of Oil Palm Seedlings ..... 96
20	The Content of Dissolved Ca and pH Values in the Soil Planted with Old Oil Palm Seedlings during One Year of PR Application ..... 98
21	Correlation Coefficient among Status and Kinetic Parameters of Isotopically Exchangeable P ..... 99
22	Correlation Coefficient between Isotopically Exchangeable P Values and P Uptake by Oil Palm Seedlings after One Year of PR Application ..... 100
23	Dry Matter Production of Oil Palm Seedlings at Various Ages ..... 107
24	Percentage Uptake and Utilization of P by Oil Palm Seedlings at Various Ages ..... 109
25	Plant P Uptake in Oil Palm Seedlings in the Four Periods (0-3 Month, 3-6 Month, 6-9 Month, 9-12 Month) after PR Application ..... 111
26	The Ranking of Phosphate Rocks according to P Utilization ..... 114
27	Comparison of E Value (Laboratory Experiment) and L Value (Glasshouse) ..... 115



## LIST OF FIGURES

Figure		Page
1	Available Soil P as a System with Multi Compartments .....	29
2	Modelling of Isotopic Dilution Method .....	30
3	Modelling of Isotopic Dilution Method with Two Pools .....	31
4	Arrangement of Treatments in the Completely Randomized Design .....	35
5	X-Ray Diffraction Patterns of PR Studied .....	65
6	The Relationships between NAC Solubility of PR with Ca:P Mole Ratio expressed as % Rock and % P <sub>2</sub> O <sub>5</sub> .....	66
7	The Relationships between Plant P Uptake and E Value .....	86
8	Available Soil P as a Multi-Compartmental System in the Soil treated with Phosphate Rocks .....	88
9	The Relationships between Plant P Uptake and L Value .....	113
10	The Relationships between E Value and L Value .....	116



## LIST OF ABBREVIATIONS

C	-	Capacity Factor
CIPR	-	Christmas Island Phosphate Rocks
C <sub>p</sub>	-	Water Soluble P
CPR	-	China Phosphate Rocks
DMRT-		Duncan's Multiple Range Test
E (t)	-	Isotopically Exchangeable Phosphorus at time t
E <sub>1</sub>	-	Isotopically Exchangeable Phosphorus at 1 minute
FFB	-	Fresh Fruit Bunch
F <sub>m</sub>	-	Mean flux of phosphate ion from solid phase to soil solution
GPR	-	Gafsa Phosphate Rocks from Tunisia
JPR	-	Jordanian Phosphate Rocks
K <sub>m</sub>	-	The mean exchange rate of phosphate ion
L Value	-	Labile Phosphorus
LSC	-	Liquid Scintillation Counter
MPR	-	Moroccan Phosphate Rocks
n	-	Power function describing E(t)
NCPR	-	North Carolina Phosphate Rocks
P <sub>dff</sub>	-	Phosphorus derived from fertilizer
P <sub>i</sub>	-	Inorganic P
PORIM	-	Palm Oil Research Institute of Malaysia
PR	-	Phosphate Rocks
r/R	-	Radioactivity that remains in the solution after specific time



R	-	Initial Radioactivity
RAE	-	Relative Agronomic Effectiveness
SA	-	Specific Radioactivity
Tm	-	Mean sojourn time of phosphate ions in the soil solution
TSP	-	Triple Superphosphate
XRD	-	X-ray Diffraction
AAS	-	Atomic Absorption Spectrophotometer



Abstract of the Thesis Presented to the Senate of Universiti Pertanian Malaysia in  
Fulfillment of the Requirements for the Degree of Master of Science

**ASSESSMENT OF AGRONOMIC EFFECTIVENESS OF PHOSPHATE  
ROCKS APPLIED TO AN ULTISOL**

BY

**ZULKIFLI HASHIM**

May 1996

Chairman: Associate Prof. Dr. Zaharah Abd. Rahman

Faculty: Agriculture

Phosphate rocks (PR) available in Malaysia market are originated from North Carolina (NCPR), Gafsa, Tunisia (GPR), China (CPR), Jordan (JPR), Morocco (MPR) and Christmas Island (CIPR). Little information is available on their fate when applied to Malaysian soils in terms of their dissolution and agronomic effectiveness. Thus, a laboratory and glasshouse experiments to evaluate the extent of agronomic effectiveness during one year after PR application to a Rengam series soil were carried out. The objectives of the study were:

- (1) to characterize the chemical and some mineralogical properties of these PR and evaluating their solubility and dissolution with time.



- (2) to characterize the immediate and residual availability of P in the different fractions or compartments during one year after PR application using a laboratory exchange kinetic experiment (E Value).
- (3) to determine the plant P uptake and the relative agronomic effectiveness (RAE) of these PR using isotopic dilution techniques (L Value) on oil palm seedling grown for 12 months in the glasshouse.

The indirect solubility tests assessed by 2% formic acid (FA), 2% citric acid (CA) and neutral ammonium citrate (NAC) gave positive correlation with P uptake by oil palm seedling in the glasshouse. Neutral ammonium citrate (NAC) proved a better indicator of PR solubility and its correlation coefficient with P uptake improved by expressing citrate solubility as percent of rock rather than as percent of total  $P_2O_5$ .

The direct method to determine the PR dissolution in the soil planted with oil palm seedlings for one year after PR application in the glasshouse was assessed by determining the dissolved inorganic P ( $P_i$ ) by 0.5M NaOH, Pi strip and labile P (isotopic dilution technique) and dissolved Ca by 1M  $NH_4OAc$ . The results varied quite greatly among PR. The more reactive PR (more soluble as determined with FA, CA and NAC) such as North Carolina (NCPR) and Gafsa (GPR), dissolved more than those from Christmas Island (CIPR) and China (CPR). All the direct methods tested gave high correlation with plant P uptake throughout the one year growing period,

with 0.5M NaOH being the best direct method for determining PR dissolution in the soil planted with oil palm seedling.

A laboratory procedure using  $^{32}\text{P}$  isotopic exchange kinetics showed that TSP was always superior in rating the P fertilizers in terms of  $C_p$ , ratio of remaining  $^{32}\text{P}$  activity ( $r/R$ ), exchangeable P at one minute ( $E_1$ ), percentage of P derived from fertilizer ( $Pdff$ ) and capacity factor ( $C$ ) followed by NCPR, GPR, JPR, MPR, CIPR and CPR.

The plant P uptake determined in the glasshouse showed that only small amount of P, (less than 6%) was taken up by the oil palm seedling after one year of PR application. More than 94% of applied P were retained or fixed in the soil. TSP was the most superior in terms of plant P uptake, whilst NCPR and GPR were about 32% and 21 % as effective as TSP respectively while other sources were about 9% to 20% as effective as TSP during one year period. The relative agronomic effectiveness as measured by L value technique ranked the PR in the following order: NCPR > GPR > JPR > MPR > CPR > CIPR, where NCPR and GPR were 39% and 31% as effective as TSP, while JPR, MPR, CPR and CIPR were 21%, 19%, 16% and 13% as effective as TSP respectively.

In general, all methods tested, whether indirect solubility test, direct dissolution test, laboratory isotopic exchange kinetic or isotopic dilution procedure carried out in glasshouse, PR were ranked in a similar manner, in favour of NCPR





followed by GPR, followed by JPR, MPR, CIPR and CPR. The results obtained in the laboratory were similar in terms of agronomic effectiveness to that evaluated in the glasshouse. Therefore, the method used in the laboratory especially isotopic dilution technique is a quick and easy alternative method in determining PR effectiveness rather than expensive glasshouse experiment.

Abstrak Tesis yang Dikemukakan Kepada Senat Universiti Pertanian Malaysia Sebagai Memenuhi Syarat Keperluan Untuk Ijazah Master Sains

**PENIALAIAN KECEKAPAN AGRONOMIK BATUAN FOSFAT KE ATAS  
TANAH ULTISOL**

OLEH

**ZULKIFLI HASHIM**

Mei 1996

Pengerusi : Prof. Madya Dr. Zaharah Abd. Rahman

Fakulti : Pertanian

Batuan fosfat (BF) yang digunakan di Malaysia seperti BF berasal dari North Carolina (BFNC), Gafsa, Tunisia (BFG), China (BFC), Jordan (BFJ), Morocco (BFM) dan Christmas Island (BFCI). Informasi terhadap keberkesanan BF adalah terhadap, terutamanya dari segi kecekapan agronomik dan penguraiannya di dalam tanah. Oleh itu, untuk menilai keberkesanan agronomik beberapa jenis BF ini, percubaan di dalam makmal dan rumah kaca telah dijalankan dengan tujuan:

- (1) untuk mencirikan sifat kimia dan beberapa sifat mineral BF dan menilai kelarutan dan penguraian dalam masa setahun di atas tanah siri Rengam yang dianam dengan anak kelapa sawit.



- (2) mencirikan kebolehdapatan segera dan sisa-baki P di dalam tanah selama setahun diaplikasi BF dengan melibatkan percubaan kinetik penukaran isotopik.
- (3) untuk menentukan pengambilan P dan keberkesanan agronomik secara relatif bagi BF dengan menggunakan kaedah pencairan isotopik yang dilakukan ke atas anak benih kelapa sawit selama 12 bulan di dalam percubaan di rumah kaca.

Ujian kelarutan tak langsung batuan fosfat dilakukan dengan 2% asid formik (AF), 2% asid sitrik (AS) dan amoniam sitrat neutral (ASN) memberikan korelasi positif dengan pengambilan P oleh anak benih sawit ditanam selama 12 bulan di dalam eksperimen rumah kaca. Amoniam sitrat neutral (ASN) merupakan pengekstrak yang terbaik dan korelasinya dengan pengambilan P oleh anak benih sawit bertambah baik jika dikira berdasarkan peratusan batuan daripada peratusan jumlah  $P_2O_5$ .

Penguraian batuan fosfat dengan kaedah langsung di dalam tanah yang telah dicampur dengan BF selama setahun juga dilakukan dengan kaedah penentuan P inorganik terlarut ( $P_i$ ) oleh 0.5 M NaOH, strip  $P_i$  dan teknik isotop serta kaedah penentuan Ca terlarut oleh 1M  $NH_4OAc$ . Hasil yang didapati adalah amat berbeza di antara satu jenis BF dengan yang lain dengan sumber BF yang reaktif ( lebih larut di dalam AF, AS dan ASN). Didapati BFNC dan BFG lebih melarut daripada BFCI dan BFC. Kesemua kaedah langsung yang ditentukan, memberi korelasi yang tinggi

dengan pengambilan P oleh anak benih sawit, di mana 0.5M NaOH merupakan kaedah langsung yang terbaik di dalam penentuan penguraian batuan fosfat di dalam tanah yang ditanam dengan anak benih kelapa sawit.

Kaedah kinetik penukaran isotop yang dilakukan di dalam makmal mendapati bahawa TSP merupakan sumber P terbaik untuk nilai  $K_p$ , nisbah kadar aktiviti  $^{32}\text{P}$  yang tinggal di dalam tanah ( $r/R$ ), penukaran P dalam masa satu minit ( $P_1$ ), peratusan P dari BF ( $P_{dbf}$ ) dan faktor kapasiti ( $C$ ), diikuti oleh BFNC, BFG, BFJ, BFM, BFCI dan BFC.

Kadar pengambilan P oleh anak benih sawit yang ditanam di dalam rumah kaca adalah rendah iaitu kurang dari 6%, di mana yang selebihnya, iaitu 94% daripada PR yang dicampur ke dalam tanah selama satu tahun terikat di dalam tanah. TSP adalah sumber P terbaik, diikuti BFNC dan BFG yang masing-masing berkecekapan 32% dan 21% berbanding kecekapan TSP manakala sumber PR yang lain hanya berkecekapan 9% hingga 20% berbanding kecekapan TSP. Kecekapan agronomik secara relatif bagi tiap BF yang ditentukan dengan kaedah isotopic ( $L$  value) adalah seperti berikut:  $\text{BFNC} > \text{BFG} > \text{BFJ} > \text{BFM} > \text{BFC} > \text{BFCI}$ , di mana kecekapan BFNC dan BFG adalah 39% dan 31% berbanding kecekapan TSP, manakala BFJ, BFM, BFC dan BFCI adalah 21%, 19%, 16% dan 13% berbanding kecekapan TSP.

Secara am, kesemua kaedah yang digunakan memberikan aturan kecekapan batuan fosfat yang sama, di mana BFNC dan BFG adalah terbaik diikuti dengan BFJ,

BFM, BFCI dan BFC. Keputusan yang diperolehi di dalam makmal dan rumah kaca adalah seiring dengan hasil dari eksperimen di rumah kaca. Oleh itu, percubaan yang dilakukan di dalam makmal terutamanya kaedah isotop adalah lebih cepat dan agak mudah berbanding dengan kaedah yang dilakukan di dalam penentuan kecekapan agronomik di rumah kaca.

## CHAPTER I

### INTRODUCTION

Oil palm, *Elaeis guineensis* Jacq, is the most important agricultural crop in Malaysia, producing 7.82 million tonnes of crude palm oil (CPO) in 1995, which contributed 4.14 million tonnes to the world's oils and fats (PORLA, 1996). Despite rapid industrial development, agriculture remains an important contributor to Malaysian gross domestic product (GDP) and provides more than 250,000 jobs in the oil palm plantation. The fast expansion of oil palm planting, from 54,000 hectares in 1960 to 2.52 million hectares in 1995 (PORLA, 1996) leads to the increase in fertilizer demand and consumption.

Oil palm as a perennial and high yielder crop, produced 25 tonne/ha/yr FFB or about 5 tonne/ha/yr CPO (PORLA, 1996). In order to maintain good productivity it requires high nutrients especially major nutrients like nitrogen (N), phosphorus (P) and potassium (K). The import of nitrogenous, phosphatic and potassic fertilizers in 1993 was one million tonnes, 616,000 tonnes and 749,000 tonnes respectively, with the expenditure of RM658 million (Malaysian Agricultural Directory, 1995/96). Proper fertilizer management is therefore vital to attain efficient uptake, high yields and maximum benefits from the high expenditure which is about RM500/ha/yr spent on fertilizer (PORLA, 1996).



Some Malaysian soils especially Ultisols and Oxisols which constitute 72% of Malaysian soils have low phosphorus (P) status which arises because of very low concentration of orthophosphate in the soil solution, rather than from an inadequate total P content. Furthermore, these soils are low in pH, exchangeable calcium (Ca) and organic matter providing favourable condition for direct application of PR. Another factor closely related to soil Ca is the soil cation exchange capacity (CEC), which is also closely related to soil texture (Chien and Menon, 1995). Low CEC soils do not provide a sink for Ca ions released from PR; hence, the PR dissolution is slowed down, which may result in a reduction in agronomic effectiveness (Kanabo and Gilkes, 1988). The presence of oxides and hydroxides of iron (Fe) and aluminium (Al) will fix large amounts of applied P fertilizers, leading to low concentrations of plant available P in the soil solution (Owen, 1953; Pusparajah *et al.*, 1977; Kalpage and Wong, 1978; Zaharah, 1979). Due to strong sorption of phosphate, large amounts of phosphate fertilizers are needed to be applied to the crop to attain high yields.

The decision to use phosphate rocks (PR) for P fertilization in Malaysian plantation crops such as oil palm was based on research experiences and factors favouring these phosphate rocks over soluble P fertilizers. These factors include rapid P dissolution, high rainfall and temperature, residual effects and the fact that they are relatively cost effective. Phosphate rock is a popular P source for perennial crops because it is considerably cheaper than water-soluble P fertilizers. It can cost as little as one fifth the price of triple superphosphate (TSP), per unit of P. Although the

apparent initial efficiency and recovery of PR may be low but it has some residual values. Better description and prediction of the availability of residual P would enable the full agronomic and economic values of PR fertilizer to be assessed more correctly.

Upon P fertilization, phosphorus undergoes changes in forms and availability. In terms of biological availability, soil P can be classified into three categories; namely soluble P in soil solution, and labile and non-labile P in the solid phase. Labile P readily resupplies soil solution P, an important immediate nutrient source for plants. Upon depletion in the labile pool, nonlabile P become labile but very slowly. However, information is still lacking on the chemistry of P between solids and solution phase, P sorption as well as uptake by the plant of different types of PR.

Over the years, several studies have been carried out on the traditional source of PR such as PR from Christmas Island (CIPR) as the most common PR source, used for perennial crops like oil palm. However, with diminishing production and escalation in price of CIPR, growers are now trying to use other sources of phosphate rocks from various geographical locations such as phosphate rocks from Jordan, Morocco, North Carolina (USA), Tunisia and China. The potential of these phosphate rocks in terms of their agronomic effectiveness on crop performance especially oil palm need to be evaluated. Whether these PR will sufficiently be effective in overcoming the P deficiencies that limit the crop productivity is very much dependent upon the origin of the rock and its inherent ability to dissolve in the soil and become available to the



crop (Sale and Mokwunye, 1993). The reactivities of these PR and their effectiveness are expected to vary.

The usual method of investigating the relative agronomic efficiency of these various sources of PR involves field trials to evaluate biological responses (dry matter yield and/or P uptake) to an application of various forms of P fertilizers. For each P fertilizer, a large range in relative agronomic efficiency (RAE) values has been reported for pot and field experiment by direct application of PR (Stephen & Condon, 1986; Ghosh & Gilkes, 1987). But, this traditional procedure for evaluating fertilizers assumes that whatever the soil-fertilizer-plant system, increase in total plant uptake between no P treatment and fertilized treatment equals the plant P uptake from fertilizer. But by using isotopic labelling, accurate evaluation on agronomic efficiency is achieved as this method can distinguish plant P uptake from the fertilizer and from available soil phosphorus (Morel & Fardeau 1991). The isotopic exchange method also has an advantage over the chemical extractants because it does not disturb the soil components and there is an identity between the isotopically exchangeable P and the phosphate absorbed by plants (Fardeau, 1993). Thus, the objective of this work was to assess:

1. the degree of PR dissolution in Rengam series soil during one year after PR application, using indirect solubility test, direct chemical extractant and isotopic dilution approach.