UNIVERSITI PUTRA MALAYSIA

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

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**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

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Dedicated to everyone in the family

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| | | |
|---|---|---|
| C | - | Capacity Factor |
| CIPR | - | Christmas Island Phosphate Rocks |
| Cp | - | Water Soluble P |
| CPR | - | China Phosphate Rocks |
| DMRT | - | Duncan's Multiple Range Test |
| E (t) | - | Isotopically Exchangeable Phosphorus at time t |
| $E_1$ | - | Isotopically Exchangeable Phosphorus at 1 minute |
| FFB | - | Fresh Fruit Bunch |
| Fm | - | Mean flux of phosphate ion from solid phase to soil solution |
| GPR | - | Gafsa Phosphate Rocks from Tunisia |
| JPR | - | Jordanian Phosphate Rocks |
| Km | - | The mean exchange rate of phosphate ion |
| L Value | - | Labile Phosphorus |
| LSC | - | Liquid Scintillation Counter |
| MPR | - | Morrocan Phosphate Rocks |
| n | - | Power function describing E(t) |
| NCPR | - | North Carolina Phosphate Rocks |
| Pdff | - | Phosphorus derived from fertilizer |
| P*i* | - | 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

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BY

**ZULKIFLI HASHIM**

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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 solubity 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 glasshpouse.

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 $^{32}P$ isotopic exchange kinetics showed that TSP was always superior in rating the P fertilizers in terms of Cp, ratio of remaining $^{32}P$ 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.

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

OLEH

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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 terhad, 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 menilaikan kelarutan dan penguraian dalam masa setahun di atas tanah siri Rengam yang ditanam 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 nutral (ASN) memberikan korelasi positif dengan pengambilan P oleh anak benih sawit ditanam selama 12 bulan di dalam eksperimen rumah kaca. Amoniam sitrat nutral (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 Pi 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 Kp, nisbah kadar aktiviti $^{32}P$ yang tinggal di dalam tanah (r/R), penukaran P dalam masa satu minit ($P_1$), peratusan P dari BF (Pdbf) 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 sperti berikut: BFNC > BFG > BFJ > BFM > BFC > 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 effeciency (RAE) values has been reported for pot and field experiment by direct application of PR (Stephen & Condron, 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 effeciency 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.