UNIVERSITI PUTRA MALAYSIA

PHOSPHORUS USE EFFICIENCY FOR CUCUMBER (CUCUMIS SATNUS L) GROWN ON ACID SOILS

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By

YUSDAR HILMAN

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

PHOSPHORUS USE EFFICIENCY FOR CUCUMBER (*CUCUMIS SATIVUS L.*) GROWN ON ACID SOILS

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YUSDAR HILMAN

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Chairman : Associate Prof. Dr. Anuar Abdul Rahim

Faculty : Agriculture

Phosphorus (P) use efficiency for cucumber grown on acid soils was studied. The objectives of this experiment were: (i) to screen the solubility of three phosphate rocks in acid soils with the aim of selecting one phosphate rock (PR) with the best P and calcium (Ca) solubility in acid soils – a laboratory study, (ii) to determine the most economical P source, critical P level, and the relationship between P uptake (ΔP_s) and phosphorus dissolution from PR (PDP) or $\Delta P_b/\Delta P$ – green house study, and (iii) to improve upon P availability in an acid soil cultivated with cucumber influenced by mycorrhiza (VAM) inoculation, organic matter (OM) amendment and P rate – field study. Results of the experiment indicated that in a closed incubation system, dissolution of

Indonesian phosphate rock (IPR) (30.20 to 100.00%) was the highest followed by Gafsa phosphate rock (GPR) (17.00 to 68.80%) and then China phosphate rock (CPR) (19.80 to 53.80%). Three major factors which may affect the PR dissolution were identified: (i) soil texture (STF), (ii) soil acidity (SAF) and (iii) fertilizer (FF). Soil texture (clay, silt and sand contents) and P retention capacity showed the highest magnitude (54%) of the factor effect on P dissolution. In a green house, there was significant difference between soils and P levels with regards to total plant dry matter yield (DMY), leaf area, soil N, K and Ca nutrients, and N, K and Ca uptake by cucumber at three harvests extending from 14 to 42 days. The IPR (RAE = 177.10%) and GPR (RAE = 145.50%) were superior to triple superphosphate (TSP). On the soils with high P retention capacity (> 50%), the supply of P from both IPR and GPR on cucumber were much cost effective than TSP, with relative economic effectiveness (REE) values of 495.50% and 318.60% for IPR and GPR, respectively. For GPR, there was a positive correlation between P uptake (ΔP_s) and P dissolution (ΔP) as well as P uptake (ΔP_s), and P availability (ΔP_b). Similar observation was made for IPR and not TSP. There was a close relationship between residual P determined by P_b method and P uptake (P_s) by cucumber at 28 and 42 days with correlation coefficients varying from 0.76 to 0.97 for GPR, IPR and TSP in the three acid soils. The critical P_b values were determined by Cate and Nelson's method were 13 mg P ha^{-1} for Ultisols, 15 mg P ha^{-1} for Oxisols and 16 mg P ha^{-1} for Inceptisols. Plant growth increased with increase in the level of soluble P fertilizer (TSP) application, reaching a maximum of 172 kg P ha^{-1} for

Lebak Ultisols and Bogor Inceptisols, and 215 kg P ha^{-1} for Bogor Oxisols. The results also suggested that the acid soils have the ability to release P over period of 42 days. The P_{ox} and plant DMY have been successful in predicting the degree of phosphorus saturation (DPS) over a 42 day reaction period. In a field study on Ultisols, cucumber plants fertilized with IPR produced higher plant dry matter yield, leaf area, soil P and Ca content, P and Ca uptake at all growth stages with greater fruit yield (fruit fresh weight). Addition of P in combination with mycorrhiza inoculation and OM amendment improved soil P, plant growth, nutrient uptake and cucumber yield. Inoculation with mycorrhiza gave the beneficial effect when the soil was supplied with sufficient OM. Under mycorrhizal inoculation and OM, P fertilizer at a rate of 55.94 kg P ha^{-1} produced the highest fruit weight (10208.67 g per plot). Principal component analysis (PCA) indicated that the plant growth factors showed the highest contribution as the yield-determining factors and explained as much as 97% of the variance on cucumber yield. The contribution of the variables on cucumber yield followed the order: plant growth > soil fertility > plant chemical/nutrient content and soil microbial activity > mycorrhizal infection > soil acidity. Although this research focused on acid soils, the method developed from PCA would be useful for predicting the yield potential of cucumber under the different environments/ conditions.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

KECEKAPAN PENGGUNAAN FOSFAT OLEH TIMUN (*CUCUMIS SATIVUS L.*) PADA TANAH BERASID

Oleh

YUSDAR HILMAN

April 2003

Penyelia : Prof. Madya Dr. Anuar Abdul Rahim

Fakulti : Pertanian

Kecekapan penggunaan fosfat oleh timun pada tanah berasid telah dikaji. Tujuan penyelidikan ini adalah untuk: (i) menilai kelarutan tiga jenis batuan fosfat di tanah asid untuk memperolehi batuan fosfat yang memberikan kelarutan P dan Ca yang terbaik pada tanah asid tertentu – kajian di makmal, (ii) menentukan sumber P yang paling ekonomik, paras genting P dan perkaitan antara serapan P (ΔPs) dengan disolusi fosforus daripada batuan fosfat (PDP atau $\Delta P_b/\Delta P$) – kajian di rumah hijau, (iii) meningkatkan ketersediaan P dalam tanah berasid yang ditanam dengan timun serta ditambah dengan suntikan mikoriza arbuskul, baja organik dan batuan fosfat

yang berbeza – kajian di ladang. Hasil kajian memperlihatkan bahawa disolusi IPR (Indonesian phosphate rock) (30.20 hingga 100.00%) adalah tertinggi diikuti Gafsa phosphate rock (GPR) (17.00 hingga 68.80%), dan China phosphate rock (CPR) (19.80 hingga 53.80%). Tiga faktor utama yang boleh meningkatkan kesan disolusi PR (P) antara lain: (i) tekstur tanah, (ii) keasidan tanah, dan (iii) baja. Tekstur tanah (kandungan lempung, kelodak dan pasir) dan kapasiti pegangan P memberikan sumbangan tertinggi (54%) terhadap disolusi fosforus. Di rumah hijau, terdapat perbezaan bererti antara jenis tanah dan paras P terhadap berat kering, luas daun dan nutrien N, K dan Ca tanah serta serapan N, K dan Ca pada tiga tuaian (hari ke 14, 28 dan 42). Baja IPR (RAE = 177.10%) dan GPR (RAE = 145.50%) adalah lebih baik daripada TSP. Pada tanah berkapasiti pegangan P yang tinggi, bekalan P dari sumber PR (IPR and GPR) pada timun jauh lebih cekap daripada TSP dengan nilai REE 318.60% dan 495.50%, masing-masing untuk GPR dan IPR. Pada GPR, terdapat kaitan positif antara serapan fosforus (ΔP_s) dengan disolusi P (ΔP) dan serapan fosforus dengan ketersediaan P tanah (ΔP_b). Keputusan yang sama didapati untuk IPR dan tidak dengan TSP. Terdapat kaitan yang rapat antara kadar baki P tanah (P_b) pada hari ke 28 dan 42 dengan serapan P (P_s) dan koefisien korelasi (r) berjulat antara 0.76 hingga 0.97 untuk GPR, IPR dan TSP pada ketiga-tiga tanah berasid. Nilai kritikal P_b yang ditentukan dengan kaedah Cate dan Nelson adalah 13 mg P ha^{-1} untuk Ultisols, 15 mg P kg^{-1} untuk Oxisols dan 16 mg P kg^{-1} untuk Inceptisols. Tumbesaran tanaman dalam ketiga –tiga tanah meningkat dengan meningkatnya paras pemberian baja TSP dengan mencapai paras optima 172 kg P ha^{-1} untuk Lebak Ultisols dan Bogor Inceptisols dan 215 kg P ha^{-1} untuk Bogor Oxisols. Hasil kajian juga mendapati bahawa tanah-tanah berasid tersebut mempunyai kemampuan untuk melepas P dalam masa 42 hari. Nilai P_{ox} dan berat kering tanaman mampu untuk meramal darjah ketepuan fosforus (DPS) dalam jangka masa 42 hari. Pada kajian ladang di tanah Ultisols, pokok timun yang diberi baja IPR menghasilkan bahan kering lebih berat, saiz daun yang lebih luas, kandungan P dan Ca tanah serta serapan P dan Ca lebih tinggi disepanjang masa pertumbuhan, dengan hasil buah lebih banyak. Kombinasi Inokulasi kulat mikoriza, penambahan bahan organik dan aplikasi P memperbaiki P tanah, tumbesaran tanaman, serapan nutrien, dan hasil segar buah timun. Suntikan mikoriza memberi faedah bila tanah diberi bekalan baja organik yang mencukup. Pada tanaman bermikoriza dan bahan organik, pemberian 55.94 kg P ha^{-1} menghasil buah tertinggi (10208.67 g per petak). Analisis komponen utama (PCA) menunjukkan bahawa faktor tumbesaran tanaman timun memberikan sumbangan tertinggi sebagai faktor penentu hasil dan menerangkan sebanyak 97% variasi hasil timun (berat segar buah). Sumbangan pembolehubah terhadap hasil timun menurut darjah: tumbesaran tanaman > kesuburan tanah > kadar kimia/nutrien tanaman dan aktiviti mikrob > mikoriza > keasidan tanah. Walaupun penyelidikan ini hanya memfokus pada tanah berasid, kaedah yang dikembangkan daripada PCA sangat bermanfaat untuk meramal potensi hasil timun pada tanah-tanah lain.

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I certify that an Examination Committee met on 3rd April 2003 to conduct the final examination of Yusdar Hilman on his Doctor of Philosophy thesis entitled "Phosphorus Use Efficiency for Cucumber (*Cucumis sativus* L.) Grown on Acid Soils" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at UPM or other institutions.

YUSDAR HILMAN

Date: 28/04/2003

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATE

LIST OF ABBREVIATION

Al	aluminum
Al_{ox}	oxalate extractable Aluminum
ANOVA	analysis of variance
$BaCl_2$	barium chloride
Ca	calcium
$CaCl_2$	calcium chloride
$CaCO_3$	calcium carbonate
Ca-EC	calcium exchange capacity
ΔCa	difference in Ca concentration in soil amended with PR and control (without PR)
CA	citric acid
C/N	ratio between carbon and nitrogen
cm	centimeter
CMF	plant chemical/nutrient content and microbial activity factor
CL	critical level of phosphorus
CO_2	carbon dioxide
CPR	China phosphate rock
d	day
DMY	dry matter yield
DPS	degree of phosphorus saturation
Exch. Ca	exchangeable calcium
F	fluoride
FA	formic acid
FAO	Food Agriculture Organization
Fe	iron
Fe_{ox}	oxalate extractable iron
FF	fertilizer factor
g	gram
GPR	Gafsa (Tunisian) phosphate rock
H^+	proton
HSD	studentized range significant difference
ha	hectare
IFDC	International Fertilizer Development Center
JCPDS	Joint Committee on Powder Diffraction Standards
K	potassium
kg	kilo gram
KNO_3	potassium nitrate
L	litre
M	molar = mole L^{-1}
mm	millimeter
mg	milligram