



**UNIVERSITI PUTRA MALAYSIA**

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

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**DOCTOR OF PHILOSOPHY  
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**By**

**YUSDAR HILMAN**

**Thesis Submitted to School of Graduate Studies,  
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**April 2003**



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

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**April 2003**

**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 ( $\Delta P_s$ ) 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 ( $\Delta P_s$ ) and P dissolution ( $\Delta P$ ) as well as P uptake ( $\Delta P_s$ ), and P availability ( $\Delta P_b$ ). 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<sup>-1</sup> for Ultisols, 15 mg P ha<sup>-1</sup> for Oxisols and 16 mg P ha<sup>-1</sup> for Inceptisols. Plant growth increased with increase in the level of soluble P fertilizer (TSP) application, reaching a maximum of 172 kg P ha<sup>-1</sup> for

Lebak Ultisols and Bogor Inceptisols, and 215 kg P ha<sup>-1</sup> for Bogor Oxisols. The results also suggested that the acid soils have the ability to release P over period of 42 days. The P<sub>ox</sub> 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<sup>-1</sup> 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

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**April 2003**

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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 ( $\Delta P_s$ ) 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 ( $\Delta P_s$ ) dengan disolusi P ( $\Delta P$ ) dan serapan fosforus dengan ketersediaan P tanah ( $\Delta P_b$ ). 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<sup>-1</sup> untuk Ultisols, 15 mg P kg<sup>-1</sup> untuk Oxisols dan 16 mg P kg<sup>-1</sup> untuk Inceptisols. Tumbesaran tanaman dalam ketiga-tiga tanah meningkat dengan meningkatnya paras pemberian baja TSP



dengan mencapai paras optima  $172 \text{ kg P ha}^{-1}$  untuk Lebak Ultisols dan Bogor Inceptisols dan  $215 \text{ kg P ha}^{-1}$  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  $55.94 \text{ kg P ha}^{-1}$  menghasilkan buah tertinggi ( $10208.67 \text{ g per petak}$ ). 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 3<sup>rd</sup> 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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**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.



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**YUSDAR HILMAN**

Date: 28/04/2003

## TABLE OF CONTENTS

		<b>Pages</b>
<b>ABSTRACT</b>		ii
<b>ABSTRAK</b>		v
<b>ACKNOWLEDGEMENTS</b>		viii
<b>APPROVAL SHEETS</b>		x
<b>DECLARATION</b>		xii
<b>TABLE OF CONTENT</b>		xiii
<b>LIST OF TABLES</b>		xvii
<b>LIST OF FIGURES</b>		xix
<b>LIST OF PLATES</b>		xxii
<b>LIST OF ABBREVIATION</b>		xxiii
 <b>CHAPTER</b>		
<b>ONE</b>	<b>INTRODUCTION</b>	1
<b>TWO</b>	<b>LITERATURE REVIEW</b>	7
	2.1 Present Status of Cucumber Production	7
	2.2 Cultural Practice Requirements	8
	2.3 The Role of Phosphorus in Increasing Cucumber Yield	10
	2.4 Soils of Indonesia and Constraints to Increased Phosphate Fertilizer Efficiency	12
	2.5 Factors Affecting Phosphorus Solubility	16
	2.5.1 Soil texture	16
	2.5.2 Type of Phosphate Sources	18
	2.5.2.1 Water Soluble Phosphate Fertilizers	18
	2.5.2.2 Phosphate Rocks	18
	2.5.2.2.1 Fertilizer Factor	19
	2.5.2.2.2 Soil and Environmental Factors	20
	2.5.2.2.3 Plant (Root) Factor	23
	2.5.3 pH	24
	2.5.4 Organic Matter Content	26
	2.5.5 Vesicular Arbuscular Mycorrhiza Fungus (VAMF)	29
	2.6 Summary	38
<b>THREE</b>	<b>DISSOLUTION OF THREE PHOSPHATE ROCKS IN ACID SOILS</b>	
	3.1 Introduction	41
	3.2 Materials and Methods	43
	3.2.1. Phosphate Sources	43
	3.2.1.1 Source of Phosphate Rocks	43
	3.2.1.2 Chemical Characteristics	44

3.2.1.3	Mineralogy of Phosphate Rock	46
3.2.1.4	Morphology of Phosphate Rock	47
3.2.2.	Soils	48
3.2.2.1	Description	48
3.2.2.2	Location	48
3.2.2.3	Classification	49
3.2.3	Incubation System	50
3.2.4	Statistical Analysis	51
3.3.	Results and Discussion	52
3.3.1	Phosphate Source	52
3.3.1.1	Chemical Characteristics of Phosphate Rocks	52
3.3.1.2	Mineralogy of Phosphate Rock	53
3.3.1.3	Morphology of Indonesian Phosphate Rocks	54
3.3.2	Soils	55
3.3.2.1	Description	55
3.3.2.2	Classification	55
3.3.2.3	Chemical Characteristics of Eight Selected Soils	56
3.3.3	Relationship Between Soil Characteristics and Phosphorus Dissolution	59
3.3.4	Changes in Phosphorus and Calcium in a Closed Incubation System	64
3.4	Conclusions	71

<b>FOUR</b>	<b>PLANT AVAILABILITY OF PHOSPHORUS, AGRONOMIC AND ECONOMIC EFFECTIVENESS OF SELECTED PHOSPHATE ROCK MATERIALS IN THREE ACID SOILS</b>	73
4.1.	Introduction	73
4.2.	Materials and Methods	76
4.2.1	Phosphate Sources and Soils	76
4.2.2	Glasshouse Experiment	76
4.2.3	Assessment of Plant Available Phosphorus	77
4.2.4	Soil and Plant Analysis	78
4.2.5	Statistical Analyses	79
4.3.	Results and Discussion	80
4.3.1	Growth Response of Cucumber , Relative Agronomic Effectiveness, and Relative Economic Effectiveness	80
4.3.1.1	Dry matter Yield and Leaf area	80
4.3.1.2	Relative Agronomic and Effectiveness of Phosphate Rock Materials	85
4.3.1.3	Economic Analysis of The Phosphate Source	86
4.3.2	Plant Availability of Dissolved Phosphorus	88



	4.3.3	Correlation Coefficient of Changes in Phosphorus Concentration and Availability to Phosphorus Uptake	91
	4.3.4	Residual Effectiveness of Phosphorus Using Olsen Extractable Phosphorus	92
	4.3.5	Critical Level of $P_b$ in the Soil	94
	4.3.6	Residue and Uptake of Calcium, Nitrogen and Potassium	97
	4.3.6.1	Calcium	97
	4.3.6.2	Nitrogen and Potassium	99
	4.4.	Conclusions	102
<b>FIVE</b>		<b>EFFECT OF WATER SOLUBLE PHOSPHATE ADDITION ON GROWTH PERFORMANCE OF CUCUMBER AND DEGREE OF PHOSPHORUS SATURATION OF HIGH PHOSPHATE RETENTION SOILS</b>	<b>104</b>
	5.1.	Introduction	104
	5.2.	Materials and methods	106
	5.2.1	Phosphate Source and Soils	106
	5.2.2	Glasshouse Experiment	107
	5.2.3	Statistical Analysis	108
	5.3.	Results and Discussions	108
	5.3.1	Phosphorus Rates and Growth of Cucumber	108
	5.3.2	Oxalate-extractable Al, Fe, and P, Phosphorus Sorption Capacity and Degree of Phosphorus Saturation After Harvest	113
	5.4.	Conclusions	117
<b>SIX</b>		<b>INFLUENCE OF VAM, ORGANIC MATTER AND RATES OF PR ADDITION ON ITS PLANT AVAILABILITY AND GROWTH OF CUCUMBER ON AN ULTISOL</b>	<b>118</b>
	6.1.	Introduction	118
	6.2.	Materials and Methods	121
	6.2.1	Incubation Systems	121
	6.2.2	Field Experiment	122
	6.2.3	Statistical Analyses	123
	6.3.	Results and Discussion	124
	6.3.1	Incubation Study	125
	6.3.1.1	Dissolution of IPR	125
	6.3.1.2	Availability of Phosphorus	126
	6.3.2.	Field experiment	128
	6.3.2.1	Multivariate Statistical Analysis of Yield-Determining Factors	128
	6.3.2.2	Plant Growth Factor	137
	6.3.2.2.1	Effect of Mycorrhiza, Organic Matter Amendment and IPR Rate	

	on Plant Dry Matter Yield and Leaf Area of Cucumber	137
6.3.2.2.2	Effect of Mycorrhizal Inoculation, Organic Matter Amendment, and IPR Rate On Plant Phosphorus and Calcium Uptake	142
6.3.2.3	Plant Chemical Nutrient and Soil Microbial Population Factor	146
6.3.2.3.1	Effect of Mycorrhiza, Organic Matter Amendment and IPR Rate on Plant Chemical Nutrient	146
6.3.2.3.2	Effect of Mycorrhizal Inoculation, Organic Matter Amendment And Phosphorus Rate on Population of Soil Beneficial Microorganisms	149
6.3.2.4	Soil Fertility Factor	150
6.3.2.5	Mycorrhizal Infection Factor to Cucumber Root System	153
6.3.2.6	Effect of Mycorrhiza, Organic Matter Amendment, and Phosphorus Level on the Yield of Cucumber	156
6.3.2.7	Fractional Contribution of Each Treatment To Yield	158
6.4.	Conclusions	159
<b>SEVEN</b>	<b>GENERAL DISCUSSION AND CONCLUSIONS</b>	<b>162</b>
7.1.	General Discussion	162
7.2.	General Conclusions	163
	<b>BIBLIOGRAPHY</b>	<b>166</b>
	<b>APPENDICES</b>	<b>186</b>
	<b>VITA</b>	<b>195</b>

## LIST OF TABLES

<b>Table</b>		<b>Page</b>
2.1	Area and distribution of soil in Indonesia	14
2.2	Some chemical characteristics of acid Indonesian soils	15
3.1	Selected characteristics of phosphate rock materials used	52
3.2	Selected chemical properties of the soils	56
3.3	Range, mean and standard deviation of the acid soil characteristics	60
3.4	The mean value of $\Delta P$ and PR dissolution of eight acid Indonesian soils as affected by the addition of 500 mg P kg <sup>-1</sup> soil PR materials at d 90 in a closed incubation system	69
3.5	Amount of protons consumed and Ca exchange sites occupied by Ca at the maximum of IPR dissolution in a closed incubation systems	70
4.1	The RAE of two PR materials calculated from total DM of cucumber on three Indonesian acid soils at d 28	85
4.2	Cost of the three P sources and cost ratio of TSP to PR materials per kg P in Indonesia	87
4.3	The REE of GPR and IPR for three acid Indonesian soils	87
4.4	Changes in $\Delta P$ , $\Delta P_b$ , and PDP in a closed incubation system, and P uptake by cucumber in a glasshouse experiment with incubation time in three soils following the addition of GPR, IPR and TSP at 43 and 86 kg P ha <sup>-1</sup>	90
4.5	Correlation between the amounts of P taken up by cucumber and $\Delta P$ , $\Delta P_b$ and PDP	91
4.6	Amount of $P_b$ in soil and $P_s$ with cucumber from three acid Indonesian soils at d 28 after the addition of TSP, GPR and IPR	93

4.7	Regression equation and correlation coefficients between extractable P ( $P_b$ ) and P uptake ( $P_u$ ) at d 28 (a) and d 42 (b) after planting of cucumber in soils amended with GPR, IPR and TSP	94
4.8	Effect of soils, P source and P rate on residual concentration and uptake of N by cucumber plants	99
4.9	Effect of soils, P source and P rate on residual concentration and uptake of K by cucumber plants	100
6.1	Chemical characteristics of OM (sheep manure)	125
6.2	Range , mean, and standard deviation of the variables	130
6.3	Factor pattern for the first five principal components	131
6.4	Factor scores computed for experimental plot	135
6.5	Multivariate model of yield determining factor	136
6.6	Phosphate fraction in Ultisols grown with cucumber at d 14	153
6.7	Fractional contribution of each treatment to cucumber yield	158

## LIST OF FIGURES

Figure		Page
3.1	Location of IPR mining at Ciamis county, West Java, Indonesia	45
3.2	Location of the Study Area (Soil Sampling) in West Java (a, b, and c), Banten (d), and Lampung (e) Provinces	49
3.3	The X-ray Diffractogram of a) CPR, and b) IPR [d Spacing in Å]	53
3.4	Eigenvalue for PC plotted against the Component Number	61
3.5	Plot of Loading of Variables on the First Three Principal Component After Varimax Rotation	61
3.6	Changes in P ( $\Delta P$ ) in Soils Incubated with a) CPR, b) IPR and GPR at 500 mg kg <sup>-1</sup> in a Closed Incubation System	65
3.7	Changes in Ca ( $\Delta Ca$ ) in Soils Incubated with a) CPR, b) IPR and c) GPR at 500 mg kg <sup>-1</sup> in a Closed Incubation System	66
3.8	Relationship between $\Delta P$ and P Retention Capacity for Dissolution Of CPR, IPR and GPR in a Closed Incubation System	67
3.9	Relationship between Dissolution estimated by $\Delta P$ and $\Delta Ca$ for CPR, IPR and GPR in a Closed Incubation System	68
4.1	Effect of Soils and Phosphorus Rate on Leaf Area and Plant Dry Matter Yield of Cucumber	81
4.2	Effect of Phosphate Source and Phosphorus Rate on Leaf Area and Plant Dry Matter Yield of Cucumber	83
4.3	Scatter Diagram of Percentage Yield of Cucumber ( <i>Cucumis sativus</i> ) Grown on (a) Lebak Ultisols, (b) Bogor Oxisols and (c) Bogor Inceptisols versus Soil Test P ( $P_b$ )	96
4.4	Effect of Soils, Phosphate Sources and Phosphate Rate on Residual Calcium Concentration in Soils and Calcium Uptake by Cucumber	98

5.1	Effect of Soils and P Rate on Plant Height, Leaf Number, Leaf Area And Plant Dry Matter Yield of Cucumber	109
5.2	Effect of Soils and P Rate on Root Volume, Root Fresh Weight and Root Dry Weight of Cucumber	111
5.3	Effect of Phosphorus Rate on $Fe_{ox}$ , $Al_{ox}$ , $P_{ox}$ , PSC and DPS of Three Acid Soils	113
5.4	Relationship between PSC or DPS and Oxalate Extractable Iron, Aluminum and Phosphorus	115
5.5	Relationship between Degree of Phosphorus Saturation and Plant Dry Matter Yield of Cucumber	116
6.1	Changes in P ( $\Delta P$ ) in Soils Incubated with (a) Indonesian Phosphate Rock (IPR) and IPR + OM in a Closed Incubation System	126
6.2	Phosphorus Availability as Affected by Organic Matter Amendment and Phosphorus Rate at d 14, 28 and 42	127
6.3	Eigenvalue versus the Component Number	129
6.4	Contribution of Factor Components to Cucumber Yield	137
6.5	Plant Dry Matter and Leaf Area Response of Non-mycorrhizal, Mycorrhizal Inoculation, Non-organic Matter Amendment to P Rate	138
6.6	Effect of VAM Inoculation, OM Amendment and P Rate on Plant P And Ca Uptake	142
6.7	Effect of VAM, OM Amendment and P Rate on P and Ca in Fruits	144
6.8	Effect of Mycorrhizal Inoculation, Organic Matter Amendment and Phosphorus Rate on Concentration of Phosphorus and Calcium In (a) Shoot and (b) Fruit	147
6.9	Effect of VAM Inoculation, OM Amendment and P Rate on Population of Beneficial Microorganisms	150
6.10	Effect of Mycorrhizal Inoculation, Organic Matter Amendment and Phosphate Rate on P Availability at Days 14 and 28 After Planting	151
6.11	Effect of VAM Inoculation, OM Amendment, and P Rate on AM Infection in Cucumber Root System	155

6.12	<b>Effect of VAM Inoculation, OM Amendment and P Rate on Fruit Fresh Weight of Cucumber</b>	156
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**LIST OF PLATE**

<b>Plate</b>		<b>Page</b>
3.1	The Dahllite and Collophane Minerals in the Micrograph of IPR [Lable on the Plate]	54
4.1	Response of Cucumber to P Sources at Different P Rates on Oxisols	85
6.1	Performance of Cucumber Crops which are treated by (a) VAM Inoculation, OM Amendment and Without P and (b) Without AM Inoculation, Without OM Amendment and High P Rate (86 kg P ha <sup>-1</sup> )	141
6.2	The Performance of (a) Non-mycorrhizal and (b) Mycorrhizal Infection of Cucumber Roots	154



## LIST OF ABBREVIATION

Al	aluminum
Al <sub>ox</sub>	oxalate extractable Aluminum
ANOVA	analysis of variance
BaCl <sub>2</sub>	barium chloride
Ca	calcium
CaCl <sub>2</sub>	calcium chloride
CaCO <sub>3</sub>	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 <sub>2</sub>	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 <sub>ox</sub>	oxalate extractable iron
FF	fertilizer factor
g	gram
GPR	Gafsa (Tunisian) phosphate rock
H <sup>+</sup>	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 <sub>3</sub>	potassium nitrate
L	litre
M	molar = mole L <sup>-1</sup>
mm	millimeter
mg	milligram