UNIVERSITI PUTRA MALAYSIA

SILICON UPTAKE BY SELECTED PLANT SPECIES, AND ITS ROLE IN GROWTH PROMOTION AND BASAL STEM ROT RESISTANCE IN PALMS

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By

NURUL MAYZAITUL AZWA JAMALUDIN

Thesis Submitted to the School of Graduates Studies, Universiti PutraMalaysia, in Fulfillment of the Requirements for the Degree of Master of Science

April 2015

DEDICATION

THIS THESIS IS DEDICATED

TO

MY PARENTS, BELOVED FAMILY AND DEAREST FRIENDS

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

SILICON UPTAKE BY SELECTED PLANT SPECIES, AND ITS ROLE IN GROWTH PROMOTION AND BASAL STEM ROT RESISTANCE IN PALMS

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April 2015

Chairman : Professor Mohamed Hanafi Musa, PhD
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Silicon (Si) is the second most abundant and beneficial element for plant growth in higher plants. The differences in Si accumulation have been attributed to the Si absorbing ability of the roots. The most important aspect in this research is to make full use of the role of Si in conferring tolerance in plants against stresses. Thus, the goals of this research were: (i) to investigate the role of individual root and root system in Si uptake by selected plant species, and (ii) to assess the effects of GanoCare™ NRICH OCSpecial 1 (OCS 1) on vegetative growth and reducing the risk of *Ganoderma* disease in palms seedlings. To reveal the ability of root to take up Si, the study was conducted using the hydroponic culture system with modified Hoagland's nutrient solution containing different amount of Si. The results showed that the Si uptake was higher in the root- than shoot-part of mangroves and oil palm under study with the values of 51.8% and 38.2%, respectively. In contrast, betel nut palms uptake 32.4% more Si in the shoot-than root-parts. The Si uptake per root dry matter and Si uptake per 4 cm of root was higher in mangroves than in oil palms and followed by betel nut palms. Based on the ability to take up Si, the different oil palm progenies and clones in the study were clustered using Jaccard Similarity Coefficient into 5 groups. The vegetative growth and selected physiological parameters of oil palm and betel nut palm seedlings and the effectiveness of OCS 1 (6: 6: 8: 2 + GanoCare™) against basal stem rot (BSR) disease caused by *Ganoderma boninense* was performed under nursery condition. Results showed that the T2-seedlings of oil palm increased the total number of fronds (11.8%), seedlings height (15.4%), rachis length (9.3%), girth size (24.4%), chlorophyll content (10.2%), photosynthesis rate (21.0%), leaf area index (27.3%) and total biomass (18.3%) compared to control. Application of OCS 1 to betel nut palm seedlings increased the total number of fronds, seedlings height, rachis length, girth size, chlorophyll content and total biomass to more than 16.7, 12.3, 13.4, 31.3, 14.8 and 30.2%, respectively. The DI of oil palm (50.0%) and betel nut palm (44.4%) for T3-seedlings were significantly different ($p \leq 0.05$) compared to T2-seedlings with both values of 94.4%. The BSR disease incidence in oil palm and betel nut palm of T3-seedlings were reduced 52.6% and 67.4%, respectively. This supports the contention that the beneficial element in GanoCare™ may provide protection against *Ganoderma*

infection in both palms. The results confirmed that an individual root and root system in selected plants' play an important role in response to Si uptake ability. The higher uptake of Si in root-parts may provide good indicator for the plant to be resistant against root-infecting organisms. Hence, the addition of OCS 1 had successfully enhanced the growth and reduced the BSR disease in palm seedlings.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENGAMBILAN SILICON DARIPADA SPESIS TUMBUHAN TERPILIH, DAN PERANANNYA DALAM MENGGALAKKAN PERTUMBUHAN DAN KETAHANAN TERHADAP REPUT PANGKAL BATANG PADA PALMA

Oleh

NURUL MAYZAITUL AZWA JAMALUDIIN

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Silikon (Si) adalah elemen yang kedua paling banyak dan bermanfaat untuk pertumbuhan tanaman dalam tumbuh-tumbuhan yang lebih tinggi. Perbezaan dalam pengumpulan Si telah dikaitkan dengan keupayaan menyerap Si dari akar. Aspek yang paling penting dalam kajian ini adalah untuk menggunakan sepenuhnya peranan Si dalam memberikan toleransi dalam tumbuh-tumbuhan terhadap tekanan. Aspek yang paling penting dalam kajian ini adalah untuk menggunakan sepenuhnya peranan Si dalam memberi toleransi kepada tanaman terhadap tekanan. Oleh itu, tujuan kajian ini adalah: (i) untuk menyiasat peranan akar individu dan sistem akar untuk mengambil Si oleh sepsis tumbuh-tumbuhan yang terpilih, dan (ii) untuk menilai kesan GanoCare^{TM} NRICH OCSpecial 1 (OCS1) terhadap pertumbuhan vegetatif dan mengurangkan risiko penyakit *Ganoderma* pada anak pokok kelapa sawit dan pinang. Untuk mendedahkan kemampuan akar untuk mengambil Si, kajian dilakukan dengan menggunakan sistem kultur hidroponik yang mengandungi larutan nutrisi Hoagland yang telah diubahsuai dengan jumlah Si yang berbeza. Hasil kajian menunjukkan bahawa pengambilan Si adalah lebih tinggi di bahagian akar berbanding pucuk pada anak pokok bakau dan kelapa sawit dengan nilai 51.8% dan 38.2%. Sebaliknya, pinang mengambil Si 32.4% lebih di bahagian pucuk daripada akar. Pengambilan Si setiap akar bahan kering dan pengambilan Si per 4 cm akar adalah lebih tinggi pada anak pokok bakau daripada kelapa sawit dan diikuti oleh pinang. Berdasarkan keupayaan untuk mengambil Si, progeni kelapa sawit yang berbeza dan klon dalam kajian dapat dikelompokkan menggunakan "Jaccard Similarity Coefficient" kepada 5 kumpulan. Pertumbuhan vegetatif dan parameter fisiologi yang terpilih pada anak pokok kelapa sawit dan pinang untuk melihat keberkesanan baja OCS 1 (6: 6: 8: 2 + GanoCare^{TM}) terhadap penyakit reput pangkal batang (RPB) yang disebabkan oleh *Ganoderma boninense* telah dilakukan di bawah keadaan nurseri. Hasil kajian menunjukkan bahawa anak pokok kelapa sawit-T2 meningkat pada jumlah pelepah (11.8%), ketinggian anak pokok (15.4%), panjang lidi (9.3%), saiz ukur lilit (24.4%), kandungan klorofil (10.2%), kadar fotosintesis (21.0%), indeks luas kawasan daun (27.3%) dan jumlah biojisim (18.3%) berbanding dengan kawalan. Penggunaan OCS 1 pada pinang meningkatkan jumlah pelepah, ketinggian anak pokok, panjang lidi, saiz ukur lilit, kandungan klorofil dan jumlah biomass dengan nilai 16.7, 12.3, 13.4, 31.3,

14.8 dan 30.1%. Peratus kejadian penyakit pada anak pokok kelapa sawit (50.0%) dan pinang (44.4%) untuk T3 berbeza secara ketara ($p \leq 0.05$) berbanding T2 dengan kedua-duanya bernilai 94.4%. Kejadian penyakit RPB pada anak pokok kelapa sawit dan pinang untuk T3 telah berkurang dengan nilai 52.6% dan 67.4%. Ini menyokong pendapat bahawa unsur bermanfaat dalam GanoCare™ mungkin memberikan perlindungan dari jangkitan *Ganoderma* pada kedua-dua anak benih. Keputusan mengesahkan bahawa sistem untuk kesuluruhan akar dan akar individu dalam tumbuhan yang terpilih memainkan peranan penting dalam tindak balas terhadap keupayaan mengambilan Si. Pengambilan Si yang lebih tinggi di bahagian akar memberi petunjuk yang baik bahawa tanaman akan lebih tahan terhadap organism yang menyerang akar. Oleh itu, penambahan OCS 1 telah berjaya meningkat pertumbuhan dan mengurangkan penyakit RPB dalam anak pokok kelapa sawit dan pinang.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank to Allah S.W.T for all His blessings that enabled me to complete this thesis successfully. I would like to first express my heartiest appreciation and sincere gratitude to my supervisor, Prof. Dr. Mohamed Hanafi Musa who has guided, supervised and supported my research work and thesis preparation.

I would like to take this opportunity to thank my supervisory committee members, Prof. Dr. Datin Siti Nor Akmar Abdullah, Prof. Dr. Mohd. Rafii Yusop and Dr. Idris Abu Seman for their valuable advice and guidance. I wish to thank UPM and MPOB for funding this research project through research grant. This study would not have been concluded according to the time frame without the assistance of all the staffs of Land Management Department, Institute of Tropical Agriculture, UPM and MPOB. "Thank you very much".

I wish to dedicate my thesis to my parents Jamaludin Bin Ahmad and Sahemah Binti Amir whom have always been proud of me and believed in me, I really appreciate their love, care, support and blessings that made their dream for me to come through. Last but not least, a special heartfelt appreciation to my beloved friends Akmal, Shuhada, Faiz, Siti, Hun and Aizul for their help, endless, understanding, motivation and continuous encouragement throughout the process of completing my research and thesis has made the journey a painless one.

I certify that a Thesis Examination Committee has met on 23 April 2015 to conduct the final examination of Nurul Mayzaitul Azwa binti Jamaludin on her thesis entitled "Silicon Uptake by Selected Plant Species, and its Role in Growth Promotion and Basal Stem Rot Resistance in Palms" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

%	Percentage118
µ	Micro
µg	Microgram
µm	Micrometer
µmol	Micromole
^{0}C	Degree celcius
AA	Auto analyzer
AAS	Atomic absorption spectroscopy
AID	Autoclave-induces digestion
AMF	Arbuscular mycorrhiza fungi
ANOVA	Analysis of variance
AUDPC	Area under the disease progressive curve
BSR	Basal stem rot
C	Carbon
Ca	Calcium
CEC	Cation exchangeable capacity
cm	Centimetre
CO_2	Carbon dioxide
CRD	Completely randomized design
DI	Disease incidence
DSBI	Disease severity bole index
DSFI	Disease severity foliar index
DSRI	Disease severity root index
EFB	Empty fruit bunch
FAS	FELDA agricultural Services
Fe	Iron
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
g	Gram
G. boninense.	*Ganoderma boninense*
GanoEF	*Ganoderma* endophytic fungi

GSM	*Ganoderma* selective medium
H_2O_2	hydrogen peroxide
H_2SO_4	sulphuric acids
ha	Hectare
HCl	Hydrochloric acid
Jacq.	Jacquelina
K	Potassium
K_2SiO_3	Potassium silicate
kg	Kilogram
kPa	Kilopascal
L	Litre
LAI	Leaf area index
LSD	Least significant difference
m	Metre
MEA	Malt extract agar
Mg	Magnesium
mg	Milligram
mL	Millilitre
mM	Millimolar
Mn	Manganese
Monit	Monomolecular model
MPOB	Malaysian Palm Oil Board
N	Nitrogen
Na_2SiO_3	Sodium metasilicate
NaOH	Sodium hydroxide
P	Phosphorus
PDA	Potato Dextose Agar
PEG	Polyethylene glycol
PER 71	*Ganoderma boninense*
ppm	Part per million
psi	Pressure/pounds per square inch
s	Second
SAS	Statistical analysis software

SB	Silica body
SEA	South East Asia
SEM	Scanning electron microscopy
Si	Silicon
$Si(OH)_4$	Silicic acid
SiO_2	Silicon dioxide
SiO_2-nH_2O	Amorphous silica
SL	Silica layer
spp	Species
TE	Trace element
TEM	Transmission electron microscopy
UPM	Universiti Putra Malaysia
UPMB3	*Pseudomonas aeruginosa*
UPMP3	*Burkholderia aeruginosa*
YLD	Yellow Leaf Disease

CHAPTER 1

INTRODUCTION

Silicon (Si) is the second most abundant element, both in terms of weight and number of atoms in the earth's crust. Silicon is a beneficial element for plant growth in higher plants (Ma *et al*., 2001). The beneficial effects of Si are characterized by helping plants to overcome various stresses including biotic and abiotic stresses (Epstein, 1999; Richmond and Sussman, 2003; Ma, 2004, Ma and Yamaji, 2006). For example, Si increases the resistance of plants to fungi, pests, lodging and drought stresses. Silicon also alleviates mineral stresses, such as manganese toxicity, aluminium toxicity and phosphorus deficiency (Ma and Takashi, 1990; Ma *et al*, 1997; Iwasaki *et al*., 2002). However, the beneficial effects of Si are characteristically differing with the plant species. Usually the effects are more obvious in a plant that accumulates Si in the shoots. The more Si accumulates in shoots, the larger is the effect that is gained. This is because most effects of Si are expressed through the formation of silica gel, which is deposited on the surface of leaves, stems and other organs of plants (Ma *et al*., 2001). Therefore, the Si effect is characterized by larger effect associated with a greater Si accumulation in the shoots (Mitani and Ma, 2005). The beneficial effects of Si are also characteristically varying with the growth conditions. The effects are usually expressed more clearly when plants were under various abiotic and biotic stresses (Epstein, 1999; Ma *et al*., 2001). In addition, Si is the only element that does not damage plants when accumulated in excess due to its properties of un-dissociation at physiological pH and polymerization.

Although all plants contain Si but its concentration vary greatly in plant aboveground parts among plant species, ranging from 0.1 to 10.0% Si in the dry weight (Ma and Takashi, 2002). Among higher plants, only Gramineae and Cyperacea showed a high Si accumulation. Cucurbitales, Urticales and Commelinaceae have an intermediate Si accumulation, whereas most other plant species have low Si accumulation. Based on the Si concentration in the shoot, plants are classified into Si accumulator, intermediate type and Si excluder species (Takashi *et al*., 1990). Species containing more than 1.0% Si are called Si accumulators, while those having less than 0.5% Si are called excluders. Plant species with Si content between 0.5 and 1.0% are called intermediate type. In higher plants, only a few crop species of Gramineae and Cyperacea are Si accumulators and rice (*Oryza sativa*) shows the highest Si accumulation in Gramineae (Ma and Takashi, 2002). The differences in Si accumulation have been attributed to the Si absorbing ability of the roots. However, Ma *et al*. (2001) believed that lateral root play an important role in Si uptake, while root hairs do not contribute to Si uptake. There is also genotypic variation in the Si concentration in the shoot within a species, although the variation is usually not as large as the one among species. In a survey of about 400 cultivars of barley, the Si concentration in barley grain showed a large variation, ranging from 1.24 to 3.80 mg g^{-1} in hulled barley cultivars (Ma *et al*., 2003). Besides, Dern (2001) reported that in sugarcane grown in the field, the Si concentration in the shoot varied with the species variety, ranging from 6.4 to 10.2 mg g^{-1}.

Despite its abundance and importance, Si has received far less study than N, P and K. One reason for the limited study of Si maybe that it is not considered being among the essential plant nutrients, traditionally the priority research focus in plant nutrition (Epstein, 1994). However, more extensive and intensive studies have been performed aiming at better understanding of the possible mechanisms for Si enhanced resistance and tolerance of higher plants to both abiotic and biotic stresses over last two decades (Eipstein, 1999; Liang *et al*., 2003). More recently, rapid progress has been made in Si uptake and transport in higher plant. The role of silicon in mangroves may involve many glycoproteins and polysaccharides enriched by many amino acids, including threonine, proline, serine, glycine, glutamic acid and aspartic acids (Mahbod *et al*., 2014). However, information on the link between mangrove and the Si status of the plants is still scant. Answers to these questions are urgently needed in light of the increasing demand for the future study. Therefore, the present investigation was designed as an attempt to determine in which part mangroves accumulate Si in their body and to compare the Si status of mangrove trees (*Rhizophora apiculata*) with both palm species, oil palm (*Elaeis guineensis* Jacq.) and betel nut palm (*Areca catechu*). The higher uptake of Si in root-part may provide good indicator for the plant to be resistant against root-infecting organisms.

This research is being focus on the comparison of individual root for Si uptake system in different type of plants, which are betel nut palm (*Areca catechu*), oil palm (*Elaeis guineensis* Jacq.) and 'Bakau Minyak' (*Rhizophora apiculata*). Since the roots are the uptake organ for Si, thus a systematic analysis of Si uptake directly from the roots is necessary. The most important aspect in this research is to make full use of the role Si in conferring tolerance in plants against stresses especially in biotic stresses, such a basal stem rot (BSR) disease which caused by fungus species of *Ganoderma*. The information from this research maybe use to develop and produce good quality and high yields, cost-effective and environmentally benign agriculture crops (Liang *et al.*, 2006).

Therefore, the objectives of this study were: (i) To investigate the role of individual root and root system in the Si uptake ability between selected plant species especially the oil palm (*Elaeis guineensis* Jacq.), betel nut palm (*Areca catechu*) and mangrove (*Rhizophora apiculata*), and (ii) To assess the effects of GanoCare™ NRICH OCSpecial 1 treatment on vegetative growth and suppress *Ganoderma* infection in two palms species, oil palm (*Elaeis guineensis* Jacq.) and betel nut palm (*Areca catechu*).

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