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ENHANCEMENT OF GROWTH, YIELD AND LODGING RESISTANCE OF RICE VARIETY MR219 THROUGH SILICON AND PACLOBUTRAZOL APPLICATION

DEIVASEENO A/P DORAIRAJ

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By

DEIVASEENO A/P DORAIRAJ

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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Chairman: Assoc. Prof. Uma Rani Sinniah, PhD
Faculty: Agriculture

Lodging which is the displacement of plant from its vertical position is a factor affecting rice yield. It could be minimized by increasing the strength of the culm. Silicon (Si) is associated with sturdiness and rigidity whereas paclobutrazol (PBZ) inhibits gibberellin synthesis thus halting internode elongation. To date, no comprehensive research has been carried out in Malaysia particularly on the role of Si in rice. Thus, Si and PBZ were utilized to reveal its effect on agronomic traits and lodging resistance in MR219. Silicon was applied at 0, 2, 4 and 6 g per pot at 56 DAS as topdressing on soil surface in the first screenhouse experiment. Number of tillers, spikelets per panicle, percentages of filled spikelets and effective tillers, weight per panicle, hardness, flag leaf area, chlorophyll content, Si and lignin content increased as the rate of Si increased. Silicon application of 4 g/pot increased and improved yield performance and lodging resistance. The next experiment resolved the best method and stage of Si application whereby plants treated with 4 g/pot of Si as topdressing on soil surface at reproductive stage improved yield and fiber contents. Number of tillers per pot, spikelets per panicle, percentage of filled spikelets, weight per panicle and Si content were highest in application at reproductive stage as topdressing followed by soil incorporation. Meanwhile, chlorophyll *a* content of topdressed and soil incorporated and flag leaf area of plants treated at reproductive stage as topdressing was the highest. Fiber contents of plants treated at reproductive and maturity stages as topdressing and soil incorporation were significantly higher. The third experiment combined Si with PBZ and tested six treatments: untreated, Si applied at 4 g and 6 g, PBZ applied at 400 mg/l, Si applied at 4 g and 6 g with PBZ 400mg/l. Silicon was applied as topdressing whereas PBZ as foliar at 57 DAS. Application of PBZ reduced plant height, culm length and flag leaf area but increased chlorophyll content. Percentage of filled spikeletes and weight per panicle of plants treated with Si or PBZ were significantly higher as compared to plants treated with combination of two factors. Silicon treated plants had significantly higher lignin and Si content. Cinnamyl alcohol dehydrogenase was up-regulated 3.4 fold in Si treated plants compared to others. Acidified phloroglucinol staining of leaf sample proved the presence of lignin with varying intensity. Hardness and brittleness was highest in plants treated with Si or PBZ. Scanning electron micrographs showed prominent deposition of trichomes, silica bodies, dumb-belled shaped or ladder like structures whereas X-ray spectra of leaf surface attest silicification of silica cells was more intensive in Si treated plants. In conclusion, Si enhanced yield components, reinforced cell structure and improved overall growth of rice plant. Farmers could use crop residues, such as rice husk ash, straw or rice hull as a cheaper alternative of Si source at the start of reproductive stage to maximize output. Amino acids such as glutamine and histidine, and Si solubilizers could be incorporated to increase Si uptake in rice plant.

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

PENAMBAHBAIKAN PERTUMBUHAN, HASIL DAN KETAHANAN REBAH PADI MR219 MELALUI PENGAPLIKASIAN SILIKON DAN PAKLOBUTRAZOL

Oleh

DEIVASEENO A/P DORAIRAJ

April 2017

Pengerusi: Prof. Madya Uma Rani Sinniah, PhD
Fakulti: Pertanian

Rebah yang merupakan anjakan pokok daripada kedudukan menegak ialah satu faktor yang mengehadkan hasil padi. Ini dapat dikurangkan dengan meningkatkan ketahanan batang padi. Silikon (Si) dikaitkan dengan kekukuhan dan ketegaran manakala paklobutrazol (PBZ) menghalang sintesis giberelin lalu menganggu pemanjangan ruas. Sehingga ke hari ini, tidak ada sebarang penyelidikan komprehensif yang dijalankan di Malaysia terutamanya peranan Si dalam padi. Maka, Si dan PBZ digunakan untuk mendedahkan kesannya terhadap ciri-ciri agronomik dan ketahanan rebah MR 219. Aplikasi Si dilakukan secara taburan pada permukaan dengan kadar 0, 2, 4 dan 6 g setiap bekas pada 56 HLT dalam eksperimen pertama. Bilangan anak pokok, spikelet setiap tangkai, peratus spikelet berisi dan anak tangkai efektif, berat setangkai, kekerasan batang, luas daun pengasuh, kandungan klorofil, si dan lignin meningkat seiring dengan kadar Si. Aplikasi Si pada kadar 4 g/bekas meningkatkan prestasi hasil dan ketahanan rebah. Eksperimen seterusnya menentukan kaedah dan peringkat terbaik bagi aplikasi Si di mana hasil aplikasi Si pada kadar 4 g di peringkat reproduktif secara penaburan atas tanah meningkatkan hasil dan kandungan serat. Bilangan anak pokok setiap bekas, spikelet setiap tangkai, peratus spikelet berisi, berat tangkai dan kandungan Si adalah paling tinggi dalam aplikasi pada peringkat reproduktif secara tabur atas tanah diikuti dengan campuran tanah. Sementara itu, kandungan klorofil *a* dalam pokok yang ditabur Si atas tanah dan dicampur dalam tanah serta luas daun pengasuh adalah tertinggi pada pokok yang diaplikasikan dengan Si pada peringkat reproduktif secara tabur atas tanah. Kandungan serat dalam pokok yang diaplikasikan Si pada peringkat reproduktif dan matang secara kaedah tabur atas tanah dan campur dalam tanah adalah lebih tinggi. Eksperimen ketiga mengabungkan Si dengan PBZdan menguji enam rawatan: tiada rawatan, aplikasi Si kadar 4 g dan 6 g, PBZ 400 mg/l, aplikasi Si kadar 4 g dan 6 g dengan PBZ 400mg/l. Si diaplikasi secara tabur atas tanah manakala PBZ secara semburan pada 57 HLT. Aplikasi PBZ mengurangkan tinggi pokok, panjang batang padi dan luas daun pengasuh tetapi meningkatkan kandungan

klorofil. Peratus spikelet berisi dan berat setiap tangkai didapati lebih tinggi dan signifikan pada pokok yang diaplikasikan Si atau PBZ berbanding dengan pokok yang diberikan kombinasi kedua-dua rawatan. Pokok-pokok yang diaplikasikan dengan Si mempunyai kandungan lignin dan Si yang lebih tinggi. Sinamyl-alkohol dehidrogenase, mengalami peningkatan sebanyak 3.4 kali pada pokok yang diaplikasi Si berbanding yang lain. Pewarnaan floroglusinol berasid pada sampel daun menunjukkan kehadiran lignin dengan keamatan yang berbeza. Kekerasan dan kerapuhan batang adalah lebih tinggi dalam pokok yang dirawat dengan Si atau PBZ. Mikrograf imbasan elektron menunjukkan kehadiran trikom,“silika bodies”,“dumb-belled shaped” atau struktur-struktur seperti tetingkat yang jelas manakala analisis spektra sinar-X pada permukaan daun menampakkan silifikasi sel-sel silika yang lebih tinggi dalam pokok yang diaplikasi Si. Kesimpulannya, Si menambahbaik komponen hasil, menguatkan struktur sel dan meningkatkan penumbesaran pokok padi secara keseluruhannya. Para petani boleh menggunakan hampas tanaman seperti abu sekam padi, jerami atau sekam sebagai sumber alternatif Si yang lebih murah pada awal peringkat reproduktif untuk memaksimumkan hasil. Amino asid seperti glutamin dan histidin, serta pelarut Si boleh digunakan untuk meningkatkan pengangkutan Si dalam pokok padi.

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I certify that a Thesis Examination Committee has met on 19 April 2017 to conduct the final examination of Deivaseeno a/p Dorairaj on her thesis entitled "Enhancement of Growth, Yield and Lodging Resistance of Rice Variety MR219 through Silicon and Paclobutrazol Application" 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 Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Mahmud bin Tengku Muda Mohamed, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Siti Aishah binti Hassan, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Mohamed Hanafi bin Musa, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Jeremy A. Roberts, PhD
Professor
University of Nottingham
United Kingdom
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 8 August 2017

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

Uma Rani Sinniah, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Mohd Razi Bin Ismail, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Tan Kar Ban, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

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ROBIAH BINTI YUNUS, PhD
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School of Graduate Studies
Universiti Putra Malaysia

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This is to confirm that:

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Signature: ______________________________
Name of Chairman of Supervisory Committee: Uma Rani Sinniah

Signature: ______________________________
Name of Member of Supervisory Committee: Mohd Razi Bin Ismail

Signature: ______________________________
Name of Member of Supervisory Committee: Tan Kar Ban

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LIST OF ABBREVIATIONS

ADF	Acid detergent fiber
ADL	Acid detergent lignin
Al	Aluminium
AID	autoclaved induced digestion
bp	Base pair
C	Control
CAD	cinnamyl alcohol dehydrogenase
cDNA	Complementary Deoxyribonucleic acid
cm	Centimeter
°	Degree
°C	Degree Celcius
DNA	Deoxyribonucleic acid
EDX	Energy dispersive X-ray
GA	Gibberellin
g	Gram
g/l	Gram/litre
G	Guaiacyl
GC	Guanine - cytosine content
H	p-hydroxyphenyl
hr	Hours
ICP	Inductively Coupled Plasma
IRRI	International Rice Research Institute
KADA	Kemubu Agricultural Development Authority
KETARA	Northern Integrated Agricultural Development Area
kg	Kilogram
kg ha-1	Kilogram per hectare
kPa	Kilo Pascal
Mn	Manganese
mRNA	Messenger Ribonucleic Acid
µl	Microlitre
mg	Miligram
ml	Millilitre
mm	Millimetre
mM	Milimolar
min	Minutes
MADA	Muda Agricultural Development Authority

nm	Nanometer
NDF	Neutral detergent fiber
NPK	Nitrogen, phosphorus and potassium
N	Normality
OD	Optical density
PBZ	Paclobutrazol
PBLS	Barat Laut Selangor Integrated Agricultural Development Area
%	Percentage
P	Phosphorus
PCR	Polymerase Chain Reaction
qPCR	Quantitative polymerase Chain Reaction
SEM	Scanning electron Microscopy
Si	Silicon
S	syringyl
TGA	Thioglycolic acid lignin
ton/ha	Tonnes per hectare
w/w	Weight/weight
XRF	X-Ray Fluorescence
Zn	Zinc

CHAPTER I

INTRODUCTION

Oryza sativa, rice is a tropical grain that serves as the most important staple food for a large part of the human population especially Asians. This major food crop is relatively cheap as compared to other crops, nutritious and fulfils one's calorie intake. According to IRRI (1995), more than a billion people depend on rice cultivation for livelihoods. In most of the developing countries such as Malaysia and Thailand, rice which is heavily regulated and subsidized is equated to food security and political stability.

Rice production systems are distinctive as they are grown in a wide range of ecological and climatic conditions, such as rainfed lowlands, uplands, mangroves and deepwater areas. The lowland rice agriculture is now responsible for 86% of the total world rice crop and the yields are typically in the range of 2.0 – 3.5 ton/ha (Ladha et al., 1997). In Malaysia, rice is the third most important crop, after rubber and oil palm. Rice is mainly grown in the eight granaries in Peninsular Malaysia namely, MADA, KADA, KETARA, PBLS, Krian, Seberang Perak, Seberang Perai and Kemasin. The total area dedicated to rice planting in Malaysia is 674 928 ha of which two third is in Peninsular Malaysia whereas one third of the area is in Sabah and Sarawak (Ramli et al., 2012). For a population of 30 million, rice production is only 70% sufficient and the demand will continue to increase as the population increases. It is suffice to state that in Malaysia, rice production is not parallel to population increment.

Reliance on neighbouring countries such as Thailand and Vietnam for 30% of rice importation is not a wise solution. What would befall this nation if major rice exporters refuse to sell this prized grain due to shortage, economical or political grounds? To address the crisis, Malaysia needs to produce at least 2.5 million metric tonnes of paddy annually or increase the yield to 10 ton/ha from the current average of 4.5 ton/ha to meet the demand. The National Food Security Policy aims to increase its domestic production to at least 85% by 2015 which will then reduce importation of rice by 15% (Mohd Rashid and Mohd Dainuri, 2013). This remains a distant vision as of 2016, since our production is yet to even hit 75%. Lack of arable land, improper nutrient management practices, unchanged agronomic practices, failure of farmers to adopt and adapt to new technological inputs, biotic and abiotic stresses had collectively led to the failure to reach potential rice yield.

Lodging, a yield limiting factor that is caused by both biotic and abiotic factors, is defined as the displacement of the stem from its upright position (Fageria et al., 2006). Lodging can be bending of the stem, breaking of the stem and also the inability of the root structure to support the plant. Lodging is a complex phenomenon that interferes with water and nutrient uptake, reduces light interception, provides favourable environment for leaf disease, increases harvesting cost and losses and decreases grain yield (Kono, 1995; Tripathi et al., 2003). IRRI (1995) has reported a yield loss of 1 ton/ha which accounts for 20% of the total rice production whereas in Southern India there was a loss of 26 kg/ha due to lodging (Duwaryi et al., 2000). MADA granary which covers an area of 98 860 ha is the largest granary in Malaysia producing 25% of the total national rice production (MOA, 2008). A loss of 41% of yield due to lodging has been reported in this granary. As direct seeding is the main mode of rice establishment in Malaysia, the occurrence of lodging is more pronounced due to weed infestation, weaker and shallow root system.

Several studies had shown that silicon (Si), a beneficial element, can prevent lodging, increase photosynthesis, decrease susceptibility to disease and insect damage, prevent lodging, and alleviate water and various mineral stresses (Korndorfer and Lepsch, 2001; Epstein, 1999; Ma, 2004; Wu et al., 2006). Silicon could increase thickness of culm wall and increase size vascular bundles (Shimoyama, 1958; Wu et al., 2006). Highly abundant it may be but Si rarely exists in pure form. It is usually found in various forms of silicon dioxide (silica) or silicates. For instance, it exists as alumina silicate in clay soils where rice is grown. This element is widely used in the field of plant pathology as an alleviator of biotic stresses. Silicon applied as silicon dioxide, SiO_2 in fields are absorbed and appears to accumulate in leaves and promote mechanical strengthening. As rice is a Si accumulator, it is vastly utilized in China and Japan to increase productivity. Despite its significance, there is a glaring void and lack of researches on the effect of Si in growth, yield and lodging resistance in Malaysia specifically.

Malaysia which has a hot and humid climate is predominantly covered by tropical soils that undergo chemical weathering and leaching. As rice is grown continuously without the need for rotation with at least two harvests a year on the same plot of land, depletion of available silicon is very much higher due to the process of desilicification. In a study carried out by Japanese researchers on paddy soils in tropical Asia, the available silicon dioxide in Malaysian soil is 10.4 mg/100 g dry soil which according to criterion adopted in Japan for silica fertilization is low (Kawaguchi and Kyuma, 1974). Based on that standard, values less than 10.5 mg/100 g dry soil are considered low whereas values in the region of 13 mg is considered positive. This remains the only research which gave an indication of Si status in Malaysian soil. Though it has been about four decades since then, to date no studies has been undertaken to reveal the potential benefits in terms of agronomic traits and lodging resistance with the application of Si.

Besides fertilizers, growth regulators are known to control many processes within plants. There are various reports on the effect of exogenously applied plant growth regulators on plant growth and development (Bevilaqua et al., 1993,1995; Pan and Zhao, 1994; Asborno et al., 1999). Paclobutrazol (PBZ) is a triazole fungicide that is often termed as a plant growth retardant as it is a known opponent of the plant hormone gibberellin. It acts by inhibiting gibberellin biosynthesis, reducing internodial growth to give stouter stems, increasing root growth, causing early fruitset and increasing seed set. Paclobutrazol is used to reduce shoot growth too and has been utilized in rice by Bambang (2012) who found that an application of 400 mg/l was optimum in reducing plant height and culm height, increased bending resistance and yield.

Lodging could be reduced by lowering the centre of gravity that is to reduce the plant height. Increasing the mechanical or physical strength of the rice culm is also another mean of addressing lodging. Cell wall which is a highly complex structure and primarily made up of cellulose, also contains hemicelluloses, lignin, polysaccharides and protein. The structural carbohydrates such as lignin, cellulose and hemicelluloses can be termed as the backbone for plants and play a more dominant role as it provides mechanical support hence an increase in these contents would further improve culm strength. In addition, the thickness of cell walls in the sclerenchyma and the number of vascular bundles are important factors that affect the stem mechanical strength of rice (Li et al., 2009).

Silicon, a non-essential nutrient as many biologists believe, is often excluded in nutrient solution and fertilization as it is often thought that the soil itself can sustain its supply. Unfortunately their conviction is wrong since the silica that occurs in soil is in an unavailable polymerized form and for its absorption by plants it has to be depolymerized and rendered soluble by means of biological or chemical reactions in soil. Plants absorb Si exclusively as monosilicic acid, also called orthosilicic acid, by diffusion and also by the influence of transpiration-induced root absorption known as mass flow (Elawad and Green, 1979).

It is believed that lodging can be reduced by optimum use of nitrogen, right amount of water, reducing the plant height, strengthening the culm and incorporation of plant growth regulators. Breeding is by far the most effective method to combat lodging but it takes about 12 to 15 years to develop a new variety. As such, farmers lose opportunities to grow better varieties earlier. Thus, the best method to overcome the problem is to manipulate physiological activities of plants by use of chemical for convenience, in this case it would be a plant nutrient, Si and plant growth retardant, PBZ.

Therefore, the overall strategy will be to incorporate Si which can enhance the mechanical strength of the rice culm with PBZ which has proven to decrease the length of internodes. The hypothesis is that a short plant with an increase in rigidity will help our cause in overcoming the problem of lodging. However, Si will remain the main focus of this study as its combination with PBZ is yet to be tested.

1.2 Objectives

The primary objective of this research is to look into the possible use of Si in increasing yield and lodging resistance.

The specific objectives of this research were:
1. To determine the best rate of Si application on yield, growth and lodging resistance of MR219.
2. To resolve the best method of Si application on yield, growth and lodging resistance of MR219.

3. To study effect of timing of Si application on yield, growth and lodging resistance of MR219.
4. To study the combined effect of Si and PBZ on yield, growth and lodging resistance of MR219.

REFERENCES

Acreche, M.M. and Slafer, G.A. 2011. Lodging yield penalties as affected by breeding in Mediterranean wheats. *Field Crops Research* 122 (1): 40-48.

Adatia, M.H. and Besford, R.T. 1986. The effects of silicon on cucumber plants grown in recirculating nutrient solution. *Annals of Botany* 58:343–351.

Adler, A. 1977. Lignin chemistry—past, present and future. *Wood Science and Technology* 11:169–218.

Al-aghabary, K., Zhu, Z. and Shi Q. 2004. Influence of silicon supply on chlorophyll content, chlorophyll fluorescence, and antioxidant enzyme activities in tomato plants under salt stress. *Journal of Plant Nutrition* 27: 2101–2115.

Alvarez, R.F., Crusciol, C.A.C., Nascente, A.S., Rodrigues, J.D. and Habermann, G. 2012. Gas exchange rates, plant height, yield components, and productivity of upland rice as affected by plant regulators. *Pesquisa Agropecuária Brasileira* 47(10): 1455-1461.

Arnon D. I. and Stout, P. R. 1939. The essentiality of certain elements in minute quantity for plants with special reference to copper. *Plant Physiology* 14: 371–375.

Asborno, M.D., Vidal., A.A., Bezus, R. and Beltrano, J. 1999. Rice: temperature and gibberelic acid effect on initial growth stages. *Agro Ciencia* 15(1): 47-53.

Avila, F.W., Baliza, D.P., Faquin, V., Araujo, J. and Ramos, S.J. 2010. Silicon-nitrogen interaction in rice cultivated under nutrient solution. *Revista Ciencia Agronomica* 41: 184–190.

Bambang, S.A.S. 2012. Effect of paclobutrazol on lodging resistance, growth and yield of direct seeded rice. PhD Thesis, Universiti Putra Malaysia.

Bandara, P.M.S. and Tanino, K.K. 1995. Paclobutrazol enhances mini tuber production in Norland potatoes. *Journal of Plant Growth Regulator* 14: 151–155.

Barker, A.V. and Pilbeam, D.J. 1992. Physiological role of silicon in photosynthetic Handbook of Plant Nutrition. CRC Press, pp: 551-568.

Barker, A.V. and Pilbeam, D.J. 2006. Handbook of plant nutrition. Taylor and Francis, London.

Baucher, M., Monties, B., Van Montagu, M. and Boerjan, W. 1998. Biosynthesis and genetic engineering of lignin. *Critical Reviews in Plant Science* 17: 125–197.

Bernards, M.A. and Lewis, N.G. 1998. The macromolecular aromatic domain in suberized tissue: a changing paradigm. *Phytochemistry* 47: 915-933.

Berova, M. and Slate, Z. 2000. Physiological response and yield of paclobutrazol treated tomato plants (*Lycopersicon esculentum* Mill.). *Plant Growth Regulation* 30:117-123.

Bevilaqua, G.A.P., Cappelaro,C. and Peske, S.T. 1995. Benefits of treating seeds of irrigated rice with gibberelic acid. *Lavoura Arrozeira* 48(4): 9-12.

Bevilaqua, G.A.P., Peske, S.T., Santos-Filho, B.G. and Baudet, L.M.L. 1993. Performance of irrigated rice seed treated with growth regulator. I. Effect on emergence in the field. *Revista Brasileira de Sementes* 15(1): 67-74.

Blaikie, S.J., Kulkarni, V.J. and Muller, W.J. 2004. Effects of morphactin and paclobutrazol floweringtreatments on shoot and root phenology in mango cv. Kensington Pride. *Scientia Horticulturae* 101: 51–68.

Boerjan, W., Ralph, J. and Baucher, M. 2003. Lignin biosynthesis. *Annual Review of Plant Biology* 54: 519–546.

Bonawitz, N.D. and Chapple, C. 2010. The genetics of lignin biosynthesis: connecting genotype to phenotype. In *Annual Review of Genetics*, ed. Campbell, A., Lichten, M. and Schupbach, G., vol. 44, pp. 337–363. USA: Annual Reviews Inc.

Boudet, A. M. 2000. Lignins and lignification: Selected issues. *Plant Physiology and Biochemistry* 38: 81–96.

Boudet, A.M., Hawkins, S.W., Cabane, M., Ernst, D., Galliano, H., Heller, W., Lange, M., Sanderman, H. and Lapierre, C. 1995. Developmental and stress lignification. In *Eurosilva: Contribution to Forest Tree Physiology*, ed. Sandermann, H. Jr and BonnetMassimbert, M., pp.13-14. Paris: INRA Editions.

Bowen, P., Menzies, J. and Ehret, D. 1992. Soluble silicon sprays inhibit powdery mildew development on grape leaves. *Journal of the American Society for Horticultural Science* 117: 906–12.

Brar, J.S., Dhaliwal, H.S. and Bal, J.S. 2011. Influence of 'Cultar' on fruiting behaviour of 'L-49' guava (*Psidium guajava* L.) plants under different spacing. *Agricultural Journal of Research* 48 (3): 153-156.

Brill, E.M., Abrahams, S., Hayes, C.M., Jenkins, C.L. and Watson, J.M .1999. Molecular characterisation and expression of a wound-inducible cDNA encoding a novel cinnamyl-alcohol dehydrogenase enzyme in lucerne (*Medicago sativa* L.). *Plant Molecular Biology* 41: 279–291.

Brinkmann, K., Blaschke, L. and Polle, A. 2002. Comparison of different methods for lignin determination as a basis for calibration of near-infrared reflectance spectroscopy and implications of lignoproteins. *Journal of Chemical Ecology* 28: 2483-2501.

Brunings, A.M., Datnoff, L.E., Ma, J.F., Mitani, N., Nagamura, Y., Rathinosabapathi, B. and Kirst, M. 2009. Differential gene expression of rice in response to silicon and rice blast fungus *Magnaporthe oryzae*. *Annals of Applied Biology* 155:161-170.

Burrows, L.L., Boag, T.S. and Stewart, W.P. 1992. Changes in leaf, stem, and root anatomy of chrysanthemum cv. Lillian Hoek following paclobutrazol application. *Journal of Plant Growth Regulation* 11: 189–194.

Catling, D. 1992. Rice in Deep Water. MacMillan Press, London.

Chabannes, M., Ruel, K., Yoshinaga, A., Chabbert, B., Jauneau, A., Joseleau, J.P. and Boudet, A.M. 2001. In situ analysis of lignins in transgenic tobacco reveals a differential impact of individual transformations on the spatial patterns of lignin deposition at the cellular and subcellular levels. *The Plant Journal* 28: 271–282.

Chang, T.T. 1964. Varietal differences in lodging resistance. *International Rice Communication Newsletter* 13(4):1-11.

Chang, S. J., Tzeng, D. D. S. and Li, C. C. 2002. Effect of silicon nutrient on bacterial blight resistance of rice (*Oryza sativa* L.). In *Second Silicon in Agriculture Conference*, ed. T. Matoh, pp 31-33. Press-Net, Kyoto, Japan.

Chaoming, Z., Jianfei, L. and Liping, C. 1999. Yield effects on the application of silicon fertilizer early hybrid rice. *Zhejiang Nongye Kexue* 2: 79-80.

Chaturvedi, G.S., Misra, C.H., Singh, C.N., Pandey, C.B., Yadav, V.P., Singh, A.K., Divivedi, J.L., Singh, B.B. and Singh, R.K. 1995. Physiological flash flooding. In: *Rainfed Rice* pp 79–96. Los Banos: International Rice Research Institute.

Chen, W., X. Yao, K. Cai and J. Chen. 2011. Silicon alleviates drought stress of rice plants by improving plant water status, photosynthesis and mineral nutrient absorption. *Biological Trace Element Research* 142: 67-76.

Chutichudet, B., Chutichudet, P., Boontiang, K. and Chanaboon, T. 2006. Effect of chemical paclobutrazol on fruit development, quality and fruit yield of Kaew mango (*Mangifera indica* L.) in Northeast Thailand. *Pakistan Journal of Biological Sciences* 9: 717-722.

Coombs, J., Hall, O.O., Long, S.P. and Scurlock, J.M.O. 1985. Techniques in bioproductivity and photosynthesis, pp.57. Pergamon Press, Oxford.

Currie, H.A. and Perry, C.C. 2007. Silica in plants: Biological, biochemical and chemical studies. *Annals of Botany* 100: 1383-1389.

Datnoff, L.E. and Rodrigues, F.A. 2005. The role of silicon in suppressing rice diseases. APS*net* Features. doi 10.1094/APSnetFeature-2005-0205.

Datnoff, L.E., Snyder, G.H. and Korndorfer, G.H. 2001. Silicon in Agriculture. Amsterdam: Elsevier Science.

Davis, T.D. and Curry, E.A. 1991. Chemical regulation of vegetative growth. *Critical Reviews in Plant Sciences* 10:151–188.

De Datta, S.K. 1986. Technology development and the spread of direct-seeded rice in Southeast Asia. *Australian Journal of Experimental Agriculture* 22:417-426.

Delden, S.H.V., Vos, J., Ennos, A.R. and Stomph, T.J. 2010. Analysing lodging of the panicle bearing cereal teff (*Eragrotis tef*). *New Phytologist* 186: 696-707.

Deren, C.W., Datnoff, L.E., Snyder, G.H. and Martin, F.G. 1994. Silicon concentration, disease response, and yield components of rice genotypes grown on flooded organic histosols. *Crop Science* 34: 733-737.

Dofing, S.M. and Karlsson, M.G. 1993. Growth and development of uniculm and conventional-tillering barley lines. *Agronomy Journal* 85: 58-61.

Duke, J.A. 1983. Handbook of Energy Crops. https://www.hort.purdue.edu/newcrop/duke_energy/Oryza_sativa.html. Accessed 01 May 2016.

Duwayri, M., Tran, D.V. and Nguyen, V. N. 2000. Reflections on yield gaps in rice production: how to narrow the gaps. Binding the Rice Yield Gap in the Asia-Pacific Region.

Elawad, S.H. and Green, V.E. 1979. Silicon and the rice plant environment: A review of recent research. *Riso* 28:235-253.

El Debaby, A.E., Ibrahim, K.E., Saad, A.M.M. and El Salhy, T.S. 1994. Wheat lodging and growth characters as affected by some agricultural practices. *Annals of Agricultural Sciences* 32: 1325–1337.

Elliott, C. L. and Snyder, G.H. 1991. Autoclave-induced digestion for the colorimetric determination of silicon in rice straw. *Journal of Agricultural and Food Chemistry* 39:1118-1119.

Entz, P. 2012. Lodging in rice. *Proceedings of Manitoba Agronomists Conference* 1: 127-128.

Epstein, E. 1991. The anamoly of silicon in plant biology. *Proceedings of the National Academy of Science USA* 91(1): 11-17.

Epstein, E. 1999. Silicon. *Annual Review of Plant Physiology and Plant Molecular Biology* 50: 641–664.

Epstein, E. and Bloom, A. J. 2003. Mineral Nutrition of Plants: Principles and Perspectives, 2nd edn, John Wiley and Sons, New York.

Fageria, N.K., Santos, A.B. and Baligar, V.C. 1997. Phosphorus soil test calibration for lowland rice on an Inceptisol. *Agronomy Journal* 89: 737-742.

Fageria, N.K., Baligar, V.C. and Ralph, B. Clark. 2006. Physiology of crop production.

Fageria, N.K., Barbosa, F.M.P., Moreira, A. and Guimaraes, C.M. 2009. Foliar fertilization of crop plants. *Journal of Plant Nutrition* 32(6): 1044-1064.

Fallah, A. 2008. Study of the effect of silicon on lodging parameters in rice plants under hydroponics culture in greenhouse experiment. Silicon in Agriculture Conference, South Africa, 2008.

Fallah, A. 2012. Silicon effect on lodging parameters of rice plants under hydroponic culture. *International Journal of AgriScience* 2(7): 630-634.

Fan, L., Shi, W.J., Hu, W.R., Hao, X.Y., Wang, D.M., Yuan, H. and Yan, H.Y. 2009. Molecular and biochemical evidence for phenylpropanoid synthesis and presence of wall-linked phenolics in cotton fibers. *Journal of Integrative Plant Biology* 51(7):626–637.

Farnaz, A.A, Jugah, K., Ahmad, S., Ahmad Husni, M.H. and Abbas N. 2012. Effect of foliar and root application of silicon against rice blast fungus in MR219 rice variety. *The Plant Pathology Journal* 28(2): 164-171.

Farooq, M., Siddique, K.H.M., Rehman, H., Aziz, T., Dong-Jin, Lee. and Wahid, A. 2011. Rice direct seeding: Experiences, challenges and opportunities. *Soil Tillage Research* 111: 87–98.

Fawe, A., Abou-Zaid, M., Menzies, J.G. and Belanger, R.R. 1998. Silicon-mediated accumulation of flavonoid phytoalexins in cucumber. *Phytopathology* 88: 396–401.

Fornasieri Filho, D. and Fornasieri, J.L. 1993. Manual of Rice. FUNEP, Jaboticabal, SP, Brazil.

Foy, C.D. 1992. Soil chemical factors limiting plant root growth. *Advances in Soil Science* 19:97–149.

Francescangeli, N., Marinangeli, P. and Curvetto, N. 2007. Paclobutrazol for height control of two *Lilium* L.A. hybrids grown in pots. *Spanish Journal of Agricultural Research* 5: 425-430.

Froggatt, P.J., Thomas, W.D. and Batch, J.J. 1982. Opportunities for manipulation of cereal productivity, Monograph 7 p 71-87. *British Plant Growth Regulator Group*

Fujisaka, S., Guino, R.A, Lubigan, R.T. and Moody. K. 1993. Farmers' rice seed management practices and resulting weed seed contamination in the philippines. *Seed Science and Technology* 21: 149-157.

Gao, J., Hofstra, G. and Fletcher, R.A. 1987. Anatomical changes induced by triazole in wheat seedling. *Canadian Journal of Botany* 66: 1178–1185.

Gartner, S., Charlot, C.and Paris-Pireyre, N. 1984. Microanalyse de la silice et résistance à la verse mécanique du blé tender. Physiol Vég 22: 811-820.

Gent, M.P.N 1995. Canopy light interception, gas exchange, and biomass in reduced height isolines of winter wheat. *Crop Science* 35: 1636-1642.

Gerami, M., Fallah, A. and Mohammad, R.K.M. 2012. Study of potassium and sodium silicate on the morphological and chlorophyll content on the rice plant in pot experiment (*Oryza sativa* L.). *International Journal of Agriculture and Crop Sciences* 4 (10): 658-661.

Gholami, Y. and Falah, A. 2013. Effects of two different sources of silicon on dry matter production, yield and yield components of rice, Tarom Hashemi variety and 843 Lines. *International Journal of Agriculture and Crop Science* 5: 227-231.

Girma, K., Martin, K. L., Freeman, K. W. , Mosali, J., Teal, R. K., Raun, W. R., Moges, S. M. and Arnall, D.B. 2007. Determination of optimum rate and growth for foliar applied phosphorus in corn. *Communications in Soil Science and Plant Analysis* 38: 1137–1154.

Gong, H. J., Zhu, X. Y., Chen, K. M., Wang, S. M. and Zhang, C. L. 2005. Silicon alleviates oxidative damage of wheat plants in pots under drought. *Plant Science* 169: 313–321.

Goto, M, Ehara, H., Karita, S., Takabe, K., Ogawa, N., Yamada, Y., Ogawa, S., Yahaya, M.S. and Morita, O. 2003. Protective effect of silicon on phenolic biosynthesis and ultraviolet spectral stress in rice crop. *Plant Science* 164: 349-356.

Gowariker, V., Krishnamurthy, V.N., Gowariker, S., Dhanokar, M. and Paranjape, K. 2009. The Fertilizer Encyclopaedia. John Wiley, New York.

Graebe, J.E. 1987. Gibberellin biosynthesis and control. *Annual Review of Plant Physiology* 38:419–465.

Grist, D.H. 1986. Rice (6th edition). Singapore, Longman Singapore Publishers.

Grossman, K. 1992. Plant growth retardants: Their mode of action and benefit for physiological research. In *Progress in plant growth regulation*, ed. Karssen, C.M., Van Loon, L.C., Vreugdenhil, D., pp 788–797. Dordrecht, The Netherlands: Kluwer Academic Publishers,

Hach, C.C., Brayton, S.V. and Kopelove, A.B. 1985. A powerful nitrogen method using peroxymonosulfuric acid. *Journal of Agriculture and Food Chemistry* 33:1117-1123.

Hafeez, R., Asif, K.M. and Khalid, M.K. 1989. Effect of paclobutrazol on growth and yield of tomato. *Pakistan Journal of Agricultural Research*. 10(1): 49-52.

Hai, L., Guo, H.J., Xiao, S.H., Jiang, G.L., Zhang, X.Y., Yan, C.S., Xin, Z.Y. and Jia, J.Z. 2005. Quantitative trait loci (QTL) of stem strength and related traits in a doubled-haploid population of wheat (*Triticum aestivum* L.). *Euphytica* 141: 1–9.

Hammond, K.E., Evans, D.E. and Hodson, M.J. 1995. Aluminium/silicon interactions in barley (*Hordeum vulgare* L.) seedlings. *Plant Soil* 173: 89–95.

Hasan, S., Shimojo, M. and Goto, I. 1993. Chemical components influencing lodging resistance of rice plant and its straw digestibility *in vitro*. *Asian-Australasian Journal of Animal Sciences* 6(1): 41-44.

Haughan, P.A., Burden, R.S., Lenton, J.R. and Goad, L.J., 1989. Inhibition of celery cell growth and sterol biosynthesis by the enantiomers of paclobutrazol. *Phytochemistry* 28(3): 781-787.

Haynes, R.J. 2014. A contemporary overview of silicon availability in agricultural soils. *Journal of Plant Nutrition and Soil Science* 177:831–844.

Haynes, R.J., Belyaeva, O.N. and Kingston, G. 2013. Evaluation of industrial wastes as sources of fertilizer silicon using chemical extractions and plant uptake. *Journal of Plant Nutrition and Soil Science* 176:238–248.

Haysom, M.B. and Ostatek-Boczynski, Z.A. 2006. Rapid, wet oxidation procedure for the estimation of silicon in plant tissue. *Communications in Soil Science and Plant Analysis* 37: 2299–2306.

He, W.M. and Zhang, X.S. 2003. Responses of an evergreen shrub Sabina vulgaris to soil water and nutrient shortages in the semi-arid Mu Us Sandland in China. *Journal of Arid Environments* 53: 307–316.

Hirst, K.K. 2012. History of rice, part one. The origins of rice domestication in China. http://archaeology.about.com/od/domestications/a/rice.htm. Accesed on 12 March 2012.

Hitaka, H.1969. Studies on the lodging of rice plants. *Japan Agricultural Research Quarterly* 4(3): 1-6**.**

Ho, N.K. 1994. Management innovation and technical transfer in wet-seeded rice: a case study of the Muda Irrigation Scheme, Malaysia. In: International Workshop on Constraints, Opportunities and Innovation for Wet-Seeded Rice, Bangkok, Thailand.

Hodson, M.J. and Evans, D.E. 1995. Aluminium/silicon interactions in higher plants. *Journal of Experimental Botany* 46**:** 161–171.

Hogendorp, B.K. 2008. Effects of silicon-based fertilizer applications on the development and reproduction of insect pests associated with greenhouse-grown crops. PhD Dissertation University of Illinois, Urbana–Champaign, IL.

Huang, Y.L. 1988. Morphological factors and control techniques of lodging in wheat. *Jiangsu Agricultural Science* 10: 5-8.

Inanaga, S., Okasaka, A. and Tanaka, S. 1995. Does silicon exist in association with organic compounds in rice plant? *Japanese Journal of Soil Science and Plant Nutrition* 11: 111–117.

IRRI (International Rice Research Institute). 1986. Program report for 1985. Los Baños,Philippines. p 168-169.

IRRI, 1995. World Rice Statistics, 1993-94.

Islam, M.S., Peng, S.,Visperas, R.M., Ereful, N., Bhuiya, M.S.U. and JulWquar, A.W. 2007. Lodging related morphological traits of hybrid rice in a tropical irrigated ecosystem. *Field Crops Research* 101: 240-248.

Iwasaki, K., Maier, P., Fecht, M. and Horst, W.J. 2002. Effects of silicon supply on apoplastic manganese concentrations in leaves and their relation to manganese tolerance in cowpea (*Vigna unguiculata* (L.) Walp.). *Plant Soil* 238: 281–288.

Jaleel, C.A., Manivannan, P., Kishorekumar, A., Sankar, B., Gopi, R., Somasundaram, R. and Panneerselvam, R. 2007. Alterations in osmoregulation, antioxidant enzymes and indole alkaloid levels in *Catharanthus* roseus exposed to water deficit. *Colloids and Surfaces B: Biointerfaces* 59: 150–157.

Jones, L., Ennos, A.R. and Turner, S.R. 2001. Cloning and characterization of irregular xylem4 (irx4): a severely lignin-deficient mutant of Arabidopsis. *The Plant Journal* 26: 205–216.

Jones, L.H.P. and Handreck, K.A. 1967. Silica in soils, plants, and animals. *Advances in Agronomy* 19:107–49

Kaack, K. and Schwarz, K. U. 2001. Morphological and mechanical properties of Miscanthus in relation to harvesting, lodging, and growth conditions. *Industrial Crops and Products* 14: 145-154.

Kakimoto, T. 2003. Perception and signal transduction of cytokinins. *Annual Review of Plant Biology* 54: 605–627.

Kang, Y. S., Lee, J. H., Kim, J. I. and Lee. J. S. 1997. Influence of silicate application oil rice grain quality. *Korean Journal of Crop Science* 42(6):800-804.

Karathanasis, A.D. 2002. Mineral equilibria in environmental soil systems. In *Soil mineralogy with environmental applications*, ed. Dixon, J.B. and Weed, S.B., pp 109–151. USA: Soil Science Society of America, Madison.

Karathanasis, A. D. 2006. Clay minerals: weathering and alteration. In *Encyclopedia of Soil Science*, ed. Lal, R., vol.2 pp 281–286. Boca Raton: CRC Press.

Kashiwagi, T. 2008. Improvement of lodging resistance with QTLs for stem diameter in rice (*Oryza sativa* L.). *Theoretical and Applied Genetics*. 117(5): 749-757.

Kashiwagi, T. and Ishimaru, K. 2004. Identification and functional analysis of a locus for improvement of lodging resistance in rice. *Plant Physiol*ogy 134: 676-683.

Kashiwagi, T., Madoka, Y., Hirotsu, N. and Ishimaru, K. 2006. Locus *prl5* improves lodging resistance of rice by delaying senescence and increasing carbohydrate reaccumulation. *Plant Physiology and Biochem*istry 44: 152-157.

Kashiwagi, T., Sasaki, H. and Ishimaru, K. 2005. Factors responsible for decreasing sturdiness of the lower part in lodging of rice (*Oryza sativa* L.). *Plant Production Science* 2: 166-172.

Katz, E., Ziv, O., Venkatachalam,E, Shlomo, A.H., Halvy, A.H. and Weiss, D. 2003. Promotion of *Globularia sarcophylla* flowering by Uniconazol, an inhibitor of gibberelin biosynthesis. *Scientia Horticulturae* 98: 423-431.

Kawaguchi, K. and Kyuma, K. 1974. Paddy soils in tropical Asia. Part 1: Description of fertility characteristics. *Southeast Asian Studies* 12(1): 1-24.

Khalil, I.A. and Rahman, H.V. 1995. Effect of paclobutrazol on growth, chloroplast pigments and sterol biosynthesis of maize (*Zea mays* L.). *Plant Science* 105:15-21.

Kheiralla, K.A., Mehdi, E.E. and Dawood, R.A. 1993. Evaluation of some wheat cultivars for traits related to lodging resistance under different levels of nitrogen. *Assiut Journal of Agricultural Sciences* 24: 257–271.

Keller, C., Guntzer, F., Barboni, D., Labreuche, J. and Meunier, J.D. 2012. Impact of agriculture on the silicon biogeochemical cycle: input from phytolity studies. *Comptes Rendus Geoscience* 344: 739-746.

Kidd, P.S., Llugany, M., Poschenrieder, C., Gunsé, B. and Barceló, J. 2001.The role of root exudates in aluminum resistance and silicon-induced amelioration of aluminum toxicity in three varieties of maize (*Zea mays* L.). *Journal of Experimental Botany* 52**:** 1339–1352.

Kim, S.G., Kim, W.K., Park, E.W. and Choi, D. 2002. Silicon-induced cell wall fortification of rice leaves: A possible cellular mechanism of enhanced host resistance to blast. *The American Phytopathological Society* 92 (10): 1095-1103.

Kono, M. 1995. Physiological aspects of lodging. In *Science of The Rice Physiology* ed. Matsuo, T., Kumazawa, K., Ishii, R., Ishihara, K. and Hirata, H., vol. II. pp. 971-982. Tokyo, Japan: Food and Agricultural Policy Research Center,.

Kono, M. and Takahashi, J. 1961. Studies on the relationships between breaking strength and chemical components of paddy stem. *Journal of the Science of Soil and Manure Japan* 32:149-152.

Korndorfer, G.H. and Lepsch, I. 2001. Effect of silicon on plant growth and crop yield. In *Silicon in Agriculture* ed. Datonoff, L.E., Korndorfer, G.H. and Synder, G.H., pp. 133–147. New York: Elsevier Science.

Kraska, J.E. 2009. Assessing the silicon status of rice (*Oryza sativa*). Thesis Master of Science. Louisiana State University and Agricultural and Mechanical College.

Krug, B.A. 2004. The chemical growth regulation of bulb crops using flurprimidol as foliar sprays, substrate drenches, and pre-plant bulb soaks. Thesis of Master of Sciences. North Carolina State University, Raleigh, North Carolina, USA.

Kumleh, S. A. and Kavossi, M. 2003. Evaluation of interaction of silica and phosphorous on the growth and grain yield of rice (*Oryza sativa* L.). *Iranian Journal of Agricultural Science* 35(3): 581-586.

Ladha, J.K., De Brujin, F.J. and Malik, K.A.1997. Assessing opportunities for nitrogen fixation in rice: a frontier project. *Plant Soil* 194: 1-10.

Lau, E., Goldoftas, M., Baldwin, V.D., Dayanandan, P., Srinivasan, J. and Kaufman, P.B. 1978. Structure and localization of silica in the leaf and internodal epidermal system of the marsh grass, *Phragmites australis. Canadian Journal of Botany* 56:1096-1107.

Li, Y H. 1979. Morphology and anatomy of cereal. Shanghai: Shanghai Science Press: 143–148.

Li, Y., Qian, Q., Zhou, Y.,Yan, M.,Sun, L., Zhang, M., Fu, Z., Wang, Y., Han, B., Pang, X., Chen, M. and Li, J. 2003. *Brittle Culm1,* which encodes a cobra-like protein,affects the mechanical properties of rice plants. *The Plant Cell* 15: 2020-2031.

Li, X., Yang, Y., Yao, J., Chen, G., Li, X., Zhang, Q. and Wu, C. 2009. *Flexible Culm 1* encoding a cinnamyl-alcohol dehydrogenase controls culm mechanical strength in rice. *Plant Molecular Biology* 69: 685–697.

Li, Q.Q. 1998. Creation, evaluation and utilization of winter wheat germplasm. pp. 203-219. Shandong Science and Technology Press.

Liang, Y.C., Sun, W.C., Si, J and Römheld, V. 2005. Effects of foliar- and root applied silicon on the enhancement of induced resistance to powdery mildew in *Cucumis sativus. Plant Pathology* 54: 678–685.

Ma, Q.H. 2010. Functional analysis of cinnamyl alcohol dehydrogenase involved in lignin biosynthesis in wheat. *Journal of Experimental Botany* 61(10): 2735-2744.

Ma, J.F. 1990. Studies on beneficial effects of silicon on rice plants. PhD Thesis. Kyoto University, Japan.

Ma, J.F. 2003. Function of silicon in higher plants. In *Silicon Biomineralization*, ed. Muller, W.E.G., pp. 127–147. Berlin: Springer.

Ma, J.F. 2004. Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. *Soil Science and Plant Nutrition* 50: 11–18.

Ma, Q.H. 2009. The expression of caffeic acid 3- O-methyltransferase in two wheat genotypes differing in lodging resistance. *Journal of Experimental Botany* 60: 2763–2771.

Ma, J.F., Goto, S., Tamai, K. and Ichii, M. 2001. Role of root hairs and lateral roots in silicon uptake by rice. *Plant Physiology* 127: 1773–1780.

Ma, J., Nishimura, K. and Takahashi, E. 1989. Effect of silicon on the growth of rice plant at different growth stages. *Soil Science and Plant Nutrition* 35: 347-356.

Ma, J.F., Sasaki, M. and Matsumoto, H. 1997. Al-induced inhibition of root elongation in corn, *Zea mays*L. is overcome by Si addition. *Plant Soil* 188**:** 171–176.

Ma, B.L., and Smith, D.L. 1992. Growth regulator effects on above ground dry matter partitioning during grain fill of spring barley. *Crop Science* 32: 741-746.

Ma, J.F. and Takashashi, E. 2002. Soil, fertilizer, and plant silicon research in Japan. Amsterdam: Elsevier science.

Ma, J.F. and Yamaji, N. 2006. Silicon uptake and accumulation in higher plants. *Trends Plant Science* 11: 392-397.

Marschner, H. 1995. Mineral nutrition of higher plants. London, UK: Academic Press.

Massey, F.P. and Hartley, S.E. 2006. Experimental demonstration of the antiherbivore effects of silica in grasses:impacts on foliage digestibility and vole growth rates. *Proceedings of the Royal Socity of Botany* 273: 2299-2304.

Massey F. P. Ennos A. R. and Hartley S. E. 2006. Silica in grasses as a defence against insect herbivores: contrasting effects on folivores and a phloem feeder. *Journal of Animal Ecology* 75 595–603

Matoh, T., Murata, S. and Takahashi, E. 1991. Effect of silicate application on photosynthesis of rice plants. *Japanese Journal of Soil Science and Plant Nutrition* 62: 248-251.

Matsue, Y.1991. Studies on palatability of rice grown in northern Kyushu. Nihon sakumotsu gakkai kiji. *Japanese Journal of Crop Sciences* 60: 490–496 (In Japanese with English summary).

Matsushima, S. 1970. Crop science in rice. Tokyo: Fuji Publication Corporation.

Meena, V.D., Dotaniya, M.L., Coumar, V.,Rajendiran, S., Kundu, S. and Rao, A.S. 2014. A case for silicon fertilization to improve crop yields in tropical soils. Proceedings of the National Academy of Sciences, India Section B:Biological Sciences 84 (3): 505-518.

Menzies, J., Bowen, P., Ehret, D. and Glass, A.D.M. 1992. Foliar applications of potassium silicate reduce severity of powdery mildew on cucumber, muskmelon, and zucchini squash. *Journal of the American Society for Horticultural Science* 112: 902– 5.

Mitani, N. and Ma, J.F. 2005. Uptake system of silicon in different plant species. *Journal of Experimental Botany* 56: 1255-1261.

MOA (Ministry of Agriculture and Agro-based Malaysia).2008. Seksyen Industri Padi dan Beras (IPB). *Projek Pembangunan Pertanian Bersepadu (IADP) Jelapang Padi. http://agrolink.moa.my/moa/index.php?option=com_content&task=view&id=276&Itemid=170.* Accessed on 29 April 2012.

Mobasser, H.R., Malidarh, G.A. and Sedghi, H. 2008. Effects of silicon application to nitrogen rate and splitting on agronomic characteristics of rice (*Oryza sativa*). Silicon in Agriculture: 4th International Conference 26-31 October, South Africa: 76.

Mohd Rashid Rabu and Mohd Dainuri, M.S. 2013. Food and livelihood security of the Malaysian paddy farmers. *Economic and Technology Management Review* 8: 59-69.

Moldenhauer, K. and Slaton, N. 2011. Rice growth and development. http://baegrisk.ddns.uark.edu/test/Books/PDF/chapter1sl3.pdf. Accessed on 23 November 2011.

Moody, K. 1982. Weed control in dry-seeded rice. In: Report on Workshop on Cropping Systems Research in Asia. Manila (Philippines): International Rice Research Institute.

Moussa, H.R. 2006. Influence of exogenous application of silicon on physiological response of salt stressed maize (*Zea mays* L.) *International Journal of Agriculture and Biology* 8:293–297.

Neumann, D. and zur Nieden, U. 2001. Silicon and heavy metal tolerance of higher plants. *Phytochemistry* 56:685–692.

Ning, D., Song, A., Fan, F., Li, Z. and Liang, Y. 2014. Effects of slag-based silicon fertilizer on rice growth and brown-spot resistance. *PloS ONE* 9 (7): 102681

Ogle, K. 2003. Implications of interveinal distance for quantum yield in C4 grasses: A modeling and meta-analysis. *Oecologia* 136: 532–542.

Okuda, A. and Takahashi, E. 1961. Studies on the physiological role of silicon in crop plants, II. Effect of the period of Si deficiency on the growth of rice plant and nutrients uptake. *Journal of Soil Science and Manure Japan* 32: 481-488.

Ookawa, T. and Ishihara, K. 1992. Varietal difference of physical characteristics of the culm related to lodging resistance in paddy rice. *Japanese Journal of Crop Sciences* 61**:** 419–425.

Ookawa, T., Tanaka, S., Kato, H. and Hirasawa, T. 2008. The effect of the decrease in the density of lignin on the lodging resistance of the lignin deficient mutant, *gh2*, in rice. *Japanese Journal of Crop Sciences* 77: 210–211.

Pan, S., Rasul, F., Li, W., Tian, H., Mo, Z., Duan, M. and Tang, X. 2013. Roles of plant growth regulators on yield, grain qualities and antioxidant enzyme activities in super hybrid rice (*Oryza sativa* L.) *Rice* 6(9): 34-40.

Pan, R. and Zhao, R.J. 1994. Synergic effect of plant growth retardant and IBA on the formation of adventitious roots in hypocotyls cuttings of mung bean. *Plant Growth Regulators* 14: 15-19.

Pandey, S., Mortimer, M., Wade, L., Thong, T.P., Lopez. K. and Hardy, H. 2002. Direct Seeding: Research Issues and Opportunities. In: Proceedings of the International Workshop on Direct Seeding in Asian Rice Systems: Strategic Research Issues and Opportunities. 25-28 Jan, 2000. Bangkok, Thailand. Los Banos (Philippines): Intl. Rice Res. Inst. p. 383.

Pandey, S. and Velasco, L.E. 1998. Economics of direct-seeded rice in Iloilo: lessons from nearly two decades of adoption. Social Sciences Division Discussion Paper. Manila (Philippines): International Rice Research Institute.

Pandey, S. and Velasco, L. 2005. Trends in crop establishment methods in Asia and research issues. In: Rice is Life: Scientific Perspectives for the 21st Century, Proceeding of the Word Rice Research Conference, 4-7 November 2004, Tsukuba, Japan, pp. 178-181.

Peng, Z.P., Huang, J.C., Yu, J.H., Yang, S.H. and Li, W.Y. 2011. Effects of PP333 and nutrient elements applied on yields and root growth of rice. *Chinese Agriculture Science Bulletin* 27 (05): 234–237.

Pinthus, M..J. 1973. Lodging in wheat, barley and oats: the phenomenon, its causes, and preventive measures. *Advances in Agron*omy 25: 209–263.

Piperno, D.R. and Pearsall, D.M. 1998. The silica bodies of tropical American grasses: Morphology, taxonomy, and implications for grass systematics and fossil phytolith identification. Smithsonian Contributions to Botany. Washington: Smithsonian Institution Press.

Rademacher, W. 1997. Bioregulation of crop plants with inhibitors of gibberellin biosynthesis. *Proceedings of Plant Growth Regulation Society of America* 24: 27-31.

Rademacher, W., Fritsch, H., Graebe, J.E., Sauter, A. and Jung, J. 1987. Tetcyclacis and triazole plant growth retardants: Their influence on the biosynthesis of gibberellins and other metabolic processes. *Journal of Pesticide Science* 21:241–252.

Ramaiah, K. and Mudaliar, S.D. 1934. Lodging of straw and its inheritance in rice (*Oryza sativa*). *Indian Journal of Agricultural Science* 4: 880–894.

Ramli, N.N., Shamsudin, M.N., Mohamed, Z. and Radam, A. 2012. The impact of fertilizer subsidy on Malaysia paddy/rice industry using a system dynamics approach. *International Journal of Social Science* 2 (3): 213-219.

Ranganathan, S., Suvarchala, V., Rajesh, Y.B.R.D., Srinivasa Prasad, M., Padmakumari, A.P. and Voleti, S.R. 2006. Effects of silicon sources on its deposition, chlorophyll content, and disease and pest resistance in rice. *Biologia Plantarum* 50(4): 713-716.

Raven, J.A. 1983. The transport and function of silicon in plants. *Biology Review* 58:179–207.

Richmond, K.E. and Sussman, M. 2003. Got silicon? The non-essential beneficial plant nutrient. *Current Opinion in Plant Biology* 6: 268-272.

Rodrigues, F.Á. and Datnoff, L.E. 2015. Silicon and plant diseases. First Edition. Springer.

Rodrigues, F.Á., Jurick, W.M., Datnoff, L.E., Jones, J.B. and Rollins, J.A. 2005. Silicon influences cytological and molecular events in compatible and incompatible rice-*Magnaporthe grisea* interactions. *Physiological and Molecular Plant Pathology* 66: 144–159.

Rogalla, H. and Römheld, V. 2002. Role of leaf apoplast in silicon mediated manganese tolerance of *Cucumis sativus* L. *Plant Cell Environment* 25:549–555.

Romero-Aranda M. R., Jurado O. and Cuartero J. 2006. Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. *Journal of Plant Physiology* 163: 847–855.

Rubin, E.M. 2008. Genomics of cellulosic biofuels. *Nature* 454:(7206): 841–845.

Saigusa, M., Yamamoto, A. and Shibuya, K. 2000. Agricultural use of porous hydrated calcium silicate: Effect of porous hydrated calcium silicate on resistance of rice plant (*Oryza sativa* L.) to rice blast (*Pyricularia olyzae*). *Plant Production Science* 3(1): 51-54.

Sankhla, D., Davis, T.D. and Sankhla, N. 1992. Effect of gibberellin biosynthesis inhibitors on shoot generation from hypocotyl explants of *Albizzia julibrissin. Plant Cell Reports* 13:115–118.

Sattler, S., Funnell-Harris, D. and Pedersen, J. 2010. Brown midrib mutations and their importance to the utilization of maize, sorghum, and pearl millet lignocellulosic tissues. *Plant Science* 178:229–238.

Savant, N.K., Snyder, G.H. and Datnoff, L.E. 1997. Silicon management and sustainable rice production. *Advances in Agronomy* 58: 151–199.

Schmittgen, T.D. and Livak, K.J. 2008. Analyzing real-time PCR data by the comparative C_T method. *Nature Protocols* 3(6): 1101-1108.

Sebastian, B., Alberto, G., Emilio, A.C., Jose, A.F. and Juan A.F. 2002. Growth, development and color response of potted *Dianthus caryophyllus* cv. Mondriaan to paclobutrazol treatment. *Scientia Horticulturae* 1767: 1–7.

Setter, T.I., Laureles, E.V. and Mazaredo, A.M. 1997. Lodging reduces yield of rice by self shading and reduction of photosynthesis. *Field Crops Research* 49: 95-106.

Seyfferth, A.L., Kocar, B.D., Lee, J.A. and Fendorf, S. 2013. Seasonal dynamics of dissolved silicon in a California rice cropping system after straw incorporation. *Geochimica et Cosmochimica Acta*. 123:120 – 133.

Shamshuddin, J., Panhwar, Q.A., Shazana, M.A.R.S.,Elisa, A.A., Fauziah, C.I. and Naher, U.A. 2016. Improving the productivity of acid sulfate soils for rice cultivation using limestone, bsalt, organic fertilizer and or their combinations. *Sains Malaysiana* 45 (3): 383-392.

Shashidhar, H.E., Chandrashekhar, N., Narayanaswamy, C., Mehendra, A.C. and Prakash, N.B. 2008. Calcium silicate as silicon source and its interaction with nitrogen in aerobic rice. Silicon in Agriculture: 4th International Conference 26-31 October, South Africa: 93.

Shi, X.H., Zhang, C.C., Wang, H. and Zhang, F.S. 2005 Effect of Si on the distribution of Cd in rice seedlings. *Plant Soil* 272:53–60.

Shimoyama, S. 1958. Effect of calcium silicate application to rice plants on the alleviation of lodging and damage from strong gales: Studies in the improvement of ultimate yields of crops by the application of silicate materials. *Japanese Association for the Advancement of Science* 57–99.

Sibout, R., Eudes, A., Pollet, B., Goujon, T., Mila, I., Granier, F., Seguin, A., Lapierre, C. and Jouanin, L. 2003. Expression pattern of two paralogs encoding cinnamyl alcohol dehydrogenases in Arabidopsis: Isolation and characterization of the corresponding mutants. *Plant Physiology* 132: 848–860.

Singh, H. B., Hara, D.O., Herlth, D., Sachse, W., Blake, D.R., Bradshaw, J.D., Kanakidou, M. and Crutzen, P.J. 1994. Acetone in the atmosphere: Distribution, sources, and sinks. *Journal of Geophysical Research* 99: 1805 – 1819.

Silva,O.N., Lobato, A.K.S., Ávila, F.W., Costa, R.C.L., Oliveira Neto, C.F., Santos Filho, B.G., Martins Filho, A.P., Lemos, R.P., Pinho, J.M., Medeiros, M.B.C.L., Cardoso, M.S. and Andrade, I.P. 2012. Silicon-induced increase in chlorophyll is modulated by the leaf water potential in two water-deficient tomato cultivars. *Plant Soil Environment* 58 (11): 481-486.

Snyder, G.H., Jones, D.B. and Gascho, G.J. 1986. Silicon fertilization of rice on Everglades histosols. *Soil Science Society of America Journal* 50:1259–1263.

Sommer, M., Kaczorek, D., Kuzyakov, Y., and Breuer, J. 2006. Silicon pools and fluxes in soils and landscapes-a review. *Journal of Plant Nutrition and Soil Sciences* 169: 310–329.

Song, A.L., Li, P., Li, Z.J., Fan, F.L., Nikolic, M. and Liang, Y.C. 2011. The alleviation of zinc toxicity by silicon is related to zinc transport and antioxidative reactions in rice. *Plant Soil* 344(1): 319-333.

Sopher, C.R., Krol, M., Huner, N.P.A., Moore, A.E. and Fletcher, R.S. 1999. Chloroplastic changes associated with paclobutrazol- induced stress protection in maize seedling. *Canadian Journal of Botany* 77(2): 279–290.

Soratto, R.P., Crusciol, C.A.C., Castro, G.S.A., Costa, C.H.M. and Neto, J.F. 2012. Leaf application of silicic acid to white oat and wheat. *Brazillian Journal of Soil Science* 36: 1538-1544.

Still, J.R. and Pill, W.G. 2003. Germination, emergence and seedlings growth of tomato and impatients in response to seed treatment with paclobutrazol. *HortScience* 38: 1201 – 1204.

Sultana, N., Ikeda, T. and Kashem, M.A. 2001. Effect of foliar spray of nutrient solutions on photosynthesis, dry matter accumulation and yield in sea water-stressed rice. *Environmental and Experimental Botany* 46: 129-140.

Sun, T.P. 2004. Gibberellin signal transduction in stem elongation and leaf growth. In *Plant Hormones: Biosynthesis, Signal Transduction, Action*, ed. Davis, P.J., pp.304-320. Dordrecht: Kluwer Academic.

Sunitha, S., Perras, M.R., Falk, D.E., Zhang, R.R., Pharis, P. and Fletcher, R.A. 2004. Relationship between gibberellins, height and stress tolerance on barley seedlings. *Plant Growth Regulation* 42:125-35.

Swain, S.M. and Singh, D.P. 2005. Tall tales from sly dwarves: novel functions of gibberellins in plant development. *Trends in Plant Sciences* 10:123-129.

Syahputra, B.S.A., Sinniah, U.R., Rastan, S.O.S. and Ismail, M.R. 2013. Changes in gibberellic acid (GA_3) content in *Oryza sativa* due to paclobutrazol treatment. *Journal of Food and Pharmaceutical Sciences* 14-17.

Taber, H.G., Shogren, D. and Lu, G. 2002 Extraction of silicon from plant tissue with dilute HCl and HF and measurement by modified inductive coupled argon plasma procedures. *Communications in Soil Science and Plant Analysis* 33: 1661–1670.

Takahashi, E. 1995. Uptake mode and physiological functions of silica. In *Science of Rice Plant Physiology*, ed. Matusuo, T., Kumazawa, K., Ishii, R., Ishihara, K., Hirata, H., v.2, cap.5, p.420-433. Tokyo: Nobunkyo.

Takahashi, E., Aria, K. and Kasida, Y. 1966. Studies on the physiological role of silicon in crop plants. Effect of silicon on CO_2 assimilation and translocation of assimilate to panicle. *Journal of the Science of Soil and Manure Japan* 37: 594-598.

Takahashi, E., Ma, J.F. and Miyake, Y. 1990. The possibility of silicon as an essential element for higher plants. *Comments in Agriculture and Food Chemistry* 2: 99–122.

Takahashi, E. and Miyake, Y. 1977. Silicon and plant growth. Proceedings of the International Seminar on Soil Environment and Fertility Management in Intensive Agriculture.

Takatsuka, M. and Makihara, D. 2001. Plant water relation and silicon concentration in two rice varieties differing in salinity tolerance. *Japanese Journal of Tropical Agriculture* 45:259-265.

Tamai, K. and Ma, J.F. 2008. Reexamination of silicon effects on rice growth and production under field conditions using a low silicon mutant. *Plant and Soil* 307: 21-27.

Tanaka, K., Murata, K., Yamazaki, M., Onosato, K., Miyao, A. and Hirochika, H. 2003. Three distinct rice cellulose synthase catalytic subunit genes required for cellulose synthesis in the secondary wall. *Plant Physiology* 133: 73-83.

Taylor, N.G., Scheible, W.R., Cutler, S., Somerville, C.R. and Turner, S.R. 1999. The irregular xylem 3 locus of Arabidiopsis encodes a cellulose synthase required for secondary cell wall synthesis. *Plant Cell* 11: 769-779.

Tekalign, T. and Hammes, P.S. 2005. Growth and biomass production in potato grown in the hot tropics as influenced by paclobutrazol. *Plant Growth Regulation* 45: 37-46.

Teklu, Y. and Tefera, H. 2005. Genetic improvement in grain yield potential and associated agronomic traits of tef (*Eragrostis tef*). *Euphytica International Journal of Plant Breeding* 141: 247–254.

Terri, W.S. and Millie, S.W. 2000. Growth retardants affect growth and flowering of Scaevola. *HortScience* 3591: 36-38.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. 2002. Agricultural sustainability and intensive production practices. *Nature* 418 (6898): 671–677.

Trabucco, G.M., Matos, D.A., Lee, S.J., Saathoff, A.J., Priest, H.D., Mockler, T.C., Gautam, S. and Hazen, S.P. 2013. Functional characterization of cinnamyl alcohol dehydrogenase and caffeic acid O-methyltransferase in *Brachypodium distachyon*. *BMC Biotechnology* 13: 61.

Tripathi, S.C., Sayre, K.D., Kaul, J.N. and Narang, R.S. 2003. Growth and morphology of spring wheat (*Triticum aestivum* L.) culms and their association with lodging: Effects of genotypes, nitrogen levels and ethephon. *Field Crops Research* 84(3):271-290.

Tsunoda, S. 1964. A developmental analysis of yielding ability in varieties of field crops [in Japanese, English summary]. Nihon-Gakujitsu-Shinkokai, Maruzen Publ. CO., Tokyo.

Trenholm, L. E., Datnoff, L. E. and Nagata, R. T. 2004. Influence of silicon on drought and shade tolerance of St. Augustine grass. *Horticulture Technology* 14(4): 487-490.

Tubana, B., Narayanaswamy, C. and Datnoff, L.E. 2012. Changes in pH and extractable nutrients of selected soils from the Midwest and South USA as influenced by different rates of iron calcium silicate slag. ASA-CSSA-SSSA International Annual Meetings, Cincinnati, 21–24 Oct.

Tulema, B., Zapata, F., Aune, J. and Sitaula, B. 2005. Nitrogen fertilisation, soil type and cultivars effects on nitrogen use efficiency in tef [*Eragrostis tef* (Zucc.) Trotter]. *Nutrient Cycling in Agroecosystems* 71: 203–211.

Upadhyaya, A., Davis, T.D., Walser, R.H. and Galbraith, A.B. 1989. Uniconazole-induced alleviation of low-temperature damage in relation to antioxidant activity. *HortScience* 24:955-957.

Van Bockhaven J., De Vleesschauwer D. and Höfte M. 2013. Towards establishing broad-spectrum disease resistance in plants: silicon leads the way. *Journal of Experimental Botany* 64: 1281–1293.

Van Soest, P. J., Robertson, J.B and Lewis, B. A. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583-3597.

Verma, V., Worland, A.J., Sayers, E.J., Fish, L., Caligari, P.D.S. and Snape, J.W. 2005. Identification and characterization of quantitative trait loci related to lodging resistance and associated traits in bread wheat. *Plant Breeding* 124: 234-241.

Wah, C. A. 1998. Direct seeded rice in Malaysia: A success story. Malaysia: APAARI Publication.

Walter, M.W., Grlma-Pettenati, J., Grand, C., Boudet, A.M. and Lamb, C. 1988. Cinnamyl-alcohol dehydrogenase, a molecular marker specific for lignin synthesis: cDNA cloning and mRNA induction by funga1 elicitor. *Proceedings of the National Academy of Science USA* 85: 5546-5550.

Wang, C.Y. 1985. Modification of chilling susceptibility in seedlings of cucumber and zucchini squash by the bioregulator paclobutrazol (PP333). *Scientia Horticulturae* 26:293–298.

Wang, S.Y. and Galletta, G.J. 1998. Foliar application and potassium silicate induces metabolic changes in strawberry plants. *Journal of Plant Nutrition* 21 (1): 157-167.

Wang, Y. and Li, C.H. 1996. Advances in the study of wheat lodging resistance. *Journal of Shangdong Agricultural University* 27 (4): 503 – 508.

Wang, L., Nie, Q., Li, M., Zhang, F., Zhuang, J. and Yang, W. 2005. Biosilicified structures for cooling plant leaves: a mechanism of highly efficient midinfrared thermal emission. *Applied Physics Letters* 87:194105.

Wang, C., Ruan, R., Yuan, X., Hu, D., Yang, H., Li, Y. and Yi, Z. 2014. Relationship between lignin metabolism and lodging resistance of culm in buckwheat. *Journal of Agricultural Science* 6(9): 29-36.

Wang, J., Zhu, J.M, Lin, Q.Q., Li, X.J., Teng, N.J., Li, Z.H.S.H., Li, B. and Zhang, A.M. 2006. The effect of the anatomical structure and chemical components of the culm on lodging resistance in wheat. *Science Bulletin* 51 (5): 1 – 7.

Wani, A.M. and Lone, I.A. 2007. Effects of plant growth, regulators on physical and chemical characteristics of apple cv. Red Delicious. *The Asian Journal of Agriculture* 2(1): 135-137.

Watanabe, T. 1997. Lodging resistance. Science of the rice plant. Vol.3, Par t II, Chap. 4. Food and Agriculture Policy Resource Center. Tokyo, 567−577.

Watanabe S., Fujiwara T., Yoneyama T. and Hayashi H. 2002. Effects of silicon nutrition on metabolism and translocation of nutrients in rice plants. *Developments in Plant and Soil Sciences* 92: 174–175.

Wedepohl, H. 1995. The composition of the continental crust. *Geochimica Cosmochimica Acta* 59: 1217–1239.

Weitz, E., Franck, H. and Schuchard, M. 1950. Silicic acid and silicates. *Chemistry Ztg* 74: 256-257.

Whetten, R. and Sederoff, R. 1995. Lignin biosynthesis. *Plant Cell* 7:1001-1013.

Whiley, A.W. 1993. Environmental effects on phenology and physiology of mango: A review. *Acta Horticulture* 341: 168-176.

White, A. F. 1995. Chemical weathering rates of silicate minerals in soils, in: Chemical weathering rates of silicate minerals. *Reviews in Mineralogy and Geochemistry* 31: 407–460.

Woperies, M.C.S., Defoer, T., Idinoba, P., Diack, S. and Dugué, M.J. 2009. PLAR–IRM Curriculum in Inland Valleys of Sub-Saharan Africa: Technical Manual.

Wu, L.L., Liu, Z.L., Wang, J.M., Zhou, C.Y. and Chen, K.M. 2011. Morphological, anatomical, and physiological characteristics involved in development of the large culm trait in rice. *Australian Journal of Crop Science*. 5(11): 1356-1363.

Wu, Q.S., Wan, X.Y., Su, N., Cheng, Z.J., Wang, J.K., Lei, C.L., Zhang, X., Jiang, L., Ma, J.F. and Wan, J.M. 2006. Genetic dissection of silicon uptake ability in rice (*Oryza sativa* L.). *Plant Science* 171: 441–448 .

Xie, X.J., Shen, S.H.H., Li, Y.X., Zhao, X.Y., Li, B.B. and Xu, D. F. 2011. Effect of photosynthetic characteristic and dry matter accumulation of rice under high temperature at heading stage. *African Journal of Agricultural Research* 6(7): 1931-1940.

Xu, Z.Y., Zhang, D.D., Hu, J., Zhou, X., Ye, X., Reichel, K.L., Stewart, N.R., Syrenne, R.D., Yang, X.H., Gao, P., Shi, W.B., Doeppke, C., Sykes, R.W., Burris, J.N., Bozell, J.J., Cheng, Z.M., Hayes, D.G., Labbe, N., Davis, M., Stewart, C.N. and Yuan, J.S. 2009. Comparative genome analysis of lignin biosynthesis gene families across the plant kingdom. *BMC Bioinformatics* 10:3

Yamanaka, S., Takeda, H., Komatsubara, S., Ito, F., Usami, H., Togawa, E. and Yoshino, K. 2009. Structures and physiological functions of silica bodies in the epidermis of rice plants. *Applied Physics Letters* 95:123−703.

Yang, X.D. 2010. Effect of nitrogen and silicon fertilizer on the growth and yield of Chinese cabbage. Masters Thesis, Shan Dong Agricultural University.

Yang, C. M., Yang, L. Z., Yan, T. M. and Ou, Y. Z. 2004. Effects of nutrient and water regimes on lodging resistance of rice. *Chinese Journal of Applied Ecology* 15(4): 646–650. (in Chinese with English abstract).

Yang, J., Zhang, J., Wang, Z. and Zhu, Q. 2001. Activited of starch hydrolytic enzymes and sucrose-phosphate synthase in the stems of rice subjected to water stress during grain filling. *Journal of Experimental Botany* 52: 2169-2179.

Yim, K.O., Kwon, Y.W. and Bayer, D.E. 1997. Growth responses and allocation of assimilates of rice seedlings by paclobutrazol and gibberellin treatment. *Journal of Plant Growth Regulation* 16: 35-41.

Yoshida, S. 1981. Physiological analysis of rice yield. In: Fundamentals of rice crop science. International Rice Research Institute, 231-251.

Yoshida, S., Naveser, S.A. and Ramirez, E.A. 1969. Effects of silica and nitrogen supply on some leaf characters of rice plant. *Plant and Soil* 31: 48-56.

Yoshida, S., Ohnishi, Y. and Kitagishi, K. 1962. Chemical forms, mobility and deposition of silicon in rice plant. *Soil Science and Plant Nutrition* 8(3): 15-21.

Yoshida, S. and Parao, F.T. 1976. Climatic influence on yield and yield components of lowland rice in the tropics. In *Climate and Rice*, pp. 471-494. Los Banos, Philippines: International Rice Research Institute.

You, T. T., Mao, J. Z., Yuan, T. Q.,Wen, J. L. and Xu, F. 2013. Structural elucidation of the lignins from stems and foliage of arundo donax Linn. *Journal of Agriculture and Food Chemistry* 61: 5361–5370.

Zeng, X.L., Liang, J.N. and Tan, Z.W. 2007. Effects of silicate on some photosynthetic characteristics of sugarcane leaves. *Journal of Huazhong Agricultural University* 26 (3): 330–334.

Zhang F.Z., Jin Z.X., Ma G.H., Shang W.N., Liu H.Y., Xu M.L. and Liu Y. 2010. Relationship between lodging resistance and chemical component contents in culm and sheaths of Japonica rice during grain filling. *Rice Science* 17(4): 311-318.

Zhang, Z.W., Wu, S.X. and Qiu, Y.P. 1987. Effects of PP 333 on controlling shoots of litchi. *Journal Guangdong Agricultural Sciences* 10: 10-13.

Zhu, Z., Wei, G., Li, J., Qian, Q. and Yu, J. 2004. Silcon alleviates salt stress and increases antioxidant enzymes activity in leaves of salt-stressed cucumber (*Cucumis sativus* L.) *Plant Science* 167:527–533.

Zhu, G.W., Zhou, T. and Yao, S. 2010. Advances in the use of exogenous plant growth regulators on litchi. *Agricultural Science and Technology*. 11 (6): 65-70.

Zuber, U., Winzeler, H., Messmer, M. M., Keller, M., Keller, B., Schmid, J.E. and Stamp, P. 1999. Morphological traits associated with lodging resistance of spring wheat (*Triticum aestivum* L.). *Journal of Agronomy and Crop Science* 182:17-24.