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PHYSIOLOGY OF Erwinia mallotivora- INFECTED PAPAYA SEEDLINGS (Carica papaya L.) TREATED WITH SILICON

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By

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

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Papaya dieback disease caused by *Erwinia mallotivora* has been a threat to the Malaysia's papaya industry destroying more than one million plants and chemical control of the disease is almost impossible. Based on the available information on the possible beneficial effects of silicon (Si) in increasing crop resistant to bacterial diseases in plants, this study was designed. This study was conducted with the intention to characterize the development of dieback disease on papaya seedlings, to investigate the effects of varying concentrations of Si on dieback disease development, physiological and biochemical aspects of *E. mallotivora* infected papaya seedlings as well as to elucidate the possible mechanisms of Si in mediating the beneficial effects in reducing the occurrence of dieback disease in papaya seedlings. Two cultivars of papaya were used in the first and second experiments which were papaya cultivar Eksotika and papaya cultivar Eksotika II. Only papaya cultivar Eksotika II was used in the third experiment. In the first experiment, eight week old plants inoculated with *E. mallotivora* suspension (1 x 10^8 CFU/ml) showed a dieback disease symptoms started from day 3 after inoculation (DAI) with small water soaked lesion at point of inoculation (3 cm in length) and the size of lesion has increased with time. Dieback of shoot occurred at 9 DAI and the plant was fully wilted and dead at 11 DAI.

Besides visual symptoms appearance of dieback disease, infection with bacteria *E. mallotivora* had also caused biochemical changes in papaya Eksotika and Eksotika II in the second experiment. Leaf of Eksotika II had higher content of total sugar, total protein, peroxidase activity and polyphenol oxidase activity compared to papaya Eksotika. In stem, papaya Eksotika II had higher total phenol and total protein compared to papaya Eksotika. Higher total protein, peroxidase activity and polyphenol oxidase activity were found in roots of papaya Eksotika II compared to papaya Eksotika. Papaya Eksotika II had higher photosynthetic rate compared to papaya Eksotika. However, stomata conductance was found higher in papaya Eksotika compared to papaya Eksotika II. There was no significant different in transpiration rate for both papaya cultivars. Studies on photosynthetic activity of both papaya cultivars

showed that non-infected plant had higher photosynthetic rate, stomatal conductance and transpiration rate compared to inoculated plant.

To elucidate the effects of Si in regulating dieback disease in the third experiment, two-week old papaya seedlings were sprayed with 50 ml of sodium silicate (28.5 % SiO_2, 8.5% Na_2O) at four level of SiO_2 (0, 50, 100, 150 mg/L), at a weekly interval for 8 weeks. Results showed lesion length and disease symptom were reduced when treated with Si. At 100 mg/L Si level, highest content of total sugar, total phenol, total protein, peroxidase activity, polyphenol oxidase activity, photosynthesis, transpiration rate and stomatal conductance were recorded. Si content in plant tissues increased markedly with increasing Si level in the applied solution of 0 mg/L (control), 50 mg/L, 100 mg/L and 150 mg/L, with their respective concentrations (0.120 mg/g DW, 0.164 mg/g DW, 0.246 mg/g DW and 0.218 mg/g DW).

In conclusion, papaya dieback disease symptoms for papaya cultivar Eksotika and Eksotika II occurred as early as day 3 after inoculation with bacteria *E. mallotivora*. Infection with *E. mallotivora* caused certain biochemical and physiological changes in papaya plants. Si applied as sodium silicate had shown positive effects on papaya plant infected with dieback disease caused by bacteria *E. mallotivora*. Si at 100 mg/L showed positive effects in reducing dieback disease caused by the bacteria *E. mallotivora*. However, treatment with sodium silicate did not prevent plants from dying. Papaya seedlings were dead at 18 days after inoculation with bacteria *E. mallotivora*. Results showed that sodium silicate at concentration of 100 mg/L and 150 mg/L SiO_2 were able to slow down the outbreak of dieback disease development but failed to stop dieback disease development and results in death of papaya plants.

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

FISIOLOGI ANAKBENIH BETIK (*Carica papaya* L.) YANG DIJANGKITI *Erwinia mallotivora* DIRAWAT DENGAN SILIKON

Oleh

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April 2015

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Penyakit mati rosot betik yang disebabkan oleh *Erwinia mallotivora* telah menjadi ancaman kepada industri betik Malaysia dengan memusnahkan lebih daripada satu juta pokok dan kawalan kimia penyakit ini adalah hampir mustahil. Berdasarkan maklumat sedia ada berkenaan kemungkinan kesan baik silikon (Si) dalam meningkatkan daya tahan tanaman kepada bakteria di dalam tumbuhan, maka kajian ini dijalankan. Kajian ini dijalankan dengan tujuan untuk mencirikan perkembangan penyakit mati rosot pada anak benih betik, dan juga menyiasat kesan perbezaan kepekatan Si kepada anak benih betik dari segi aspek perkembangan penyakit mati rosot, fisiologi dan biokimia apabila dijangkiti oleh *E. mallotivora* dan untuk menjelaskan mekanisma Si yang berkemungkinan memberi kesan yang baik dalam mengurangkan kejadian penyakit mati rosot bagi anak benih betik. Dua kultivar betik telah digunakan dalam eksperimen pertama dan eksperimen kedua iaitu kultivar betik Eksotika dan betik Eksotika II. Hanya kultivar betik Eksotika II telah digunakan dalam eksperimen ketiga. Dalam eksperimen pertama, pokok berusia lapan minggu yang diinokulasi dengan bakteria *E. mallotivora* ($1x10^8$ CFU/ml) menunjukkan gejala penyakit mati rosot bermula dari hari ke-3 selepas inokulasi (DAI) dengan lecuh basah yang kecil pada bahagian inokulasi (3 cm panjang) dan saiz lecuh meningkat dengan peningkatan masa. Lecuh basah pada bahagian pucuk berlaku pada 9 DAI dan tumbuhan layu sepenuhnya dan mati pada 11 DAI.

Selain simptom kemunculan penyakit mati rosot, jangkitan bakteria *E. mallotivora* juga telah menyebabkan perubahan biokimia dalam pokok betik Eksotika dan Eksotika II di dalam eksperimen kedua. Betik kultivar Eksotika II mempunyai kandungan jumlah gula, jumlah protein, aktiviti peroksidase (PO) dan aktiviti polifenol oksidase (PPO) yang lebih tinggi berbanding betik Eksotika di dalam daun. Dalam batang, betik Eksotika II mempunyai jumlah fenol dan jumlah protein yang lebih tinggi berbanding betik Eksotika. Jumlah protein, aktiviti peroksidase dan aktiviti polifenol oksidase yang lebih tinggi juga ditemui di dalam akar betik Eksotika II berbanding betik Eksotika. Betik Eksotika II mempunyai kadar fotosintesis yang lebih tinggi berbanding dengan betik Eksotika. Walau bagaimanapun, kealiran stomata didapati lebih tinggi di dalam

betik Eksotika berbanding betik Eksotika II. Tiada hasil yang ketara dalam kadar transpirasi untuk kedua-dua kultivar betik. Kajian ke atas aktiviti fotosintesis bagi kedua-dua kultivar betik menunjukkan tumbuhan yang tidak dijangkiti mempunyai kadar fotosintesis, kealiran stomata dan kadar transpirasi yang lebih tinggi berbanding tumbuhan yang telah disuntik dengan *E. mallotivora*.

Untuk menjelaskan kesan Si dalam mengawal penyakit mati rosot di dalam eksperimen ketiga, anak benih betik berusia dua minggu telah disembur dengan 50 ml natrium silikat (28.5 % SiO_2, 8.5 % Na_2O) pada empat tahap SiO_2 (0, 50, 100, 150 mg/L), setiap minggu selama 8 minggu. Keputusan menunjukkan bahawa panjang lecuh dan gejala penyakit berkurangan apabila dirawat dengan Si. Pada tahap Si 100 mg/L, kandungan tertinggi bagi jumlah gula, jumlah fenol, jumlah protein, aktiviti peroksidase, aktiviti polifenol oksidase, fotosintesis, kadar transpirasi dan kealiran stomata telah direkodkan. Kandungan silikon dalam tisu tumbuhan meningkat dengan ketara selari dengan peningkatan tahap Si yang digunakan iaitu 0 mg/L (kawalan), 50 mg/L, 100 mg/L dan 150 mg/L, dengan kepekatan masing-masing 0.120 mg/g berat kering, 0.164 mg/g berat kering, 0.246 mg/g berat kering dan 0.218 mg/g berat kering.

Kesimpulannya, simptom penyakit mati rosot betik bagi betik Eksotika dan Eksotika II berlaku seawal 3 hari selepas inokulasi dengan bakteria *E. mallotivora*. Jangkitan *E. mallotivora* menyebabkan perubahan biokimia dan fisiologi tertentu dalam tanaman betik. Si yang digunakan iaitu natrium silikat telah menunjukkan kesan positif ke atas pokok betik yang dijangkiti penyakit mati rosot yang disebabkan oleh bakteria *E. mallotivora*. Si pada tahap 100 mg/L menunjukkan kesan positif dalam mengurangkan penyakit mati rosot pokok betik yang disebabkan oleh bakteria *E. mallotivora*. Walau bagaimanapun, rawatan dengan natrium silikat tidak menghalang tumbuhan daripada mati. Anak pokok betik mati pada 18 hari selepas inokulasi dengan bakteria *E. mallotivora*. Hasil kajian menunjukkan bahawa natrium silikat pada kepekatan 100 mg/L dan 150 mg/L SiO_2 dapat melambatkan simptom penyakit lecuh basah tetapi gagal untuk menghentikan perkembangan penyakit mati rosot dan menyebabkan kematian pokok betik.

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I certify that a Thesis Examination Committee has met on 28 April 2015 to conduct the final examination of Noor Shahida Binti Yamanludin on her thesis entitled Physiology of *Erwinia Mallotivora*- Infected Papaya Seedlings (*Carica Papaya L.*) Treated with Silicon 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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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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µmol	micromole
CFU	colony forming unit
DAI	days after inoculation
DW	dry weight
FW	fresh weight
h	hour
M	molar
min	minute
mM	milimolar
mmol	mili-mole
N	normality
OD	optical density
ppm	parts per million
YBGA	Yeast Bactopeptone Glucose Agar

CHAPTER 1

INTRODUCTION

1.1 Background Information

Papaya (*Carica papaya)*, is a well-known commercial fruit consumed in most part of the world. Papaya plant is native to northern Mexico and Central America and it is widely grown in the subtropical and tropical regions including Malaysia. In Malaysia, papaya is mostly grown in state of Perak, Sarawak and Johor. The plant is a short-lived and fast-growing plant (Papaya Fruit Facts, 2011). According to Department of Agriculture Malaysia, papaya production in Malaysia had increased from 1993 to 2001 by an average rate of 5.21 % per annum. The market demand for papaya fruits was huge. Global papaya production in 2010 was estimated at 11.22 metric tonnes, growing at an annual rate of 4.35 % between 2002 and 2010. Global papaya production in 2010 was 7.26 % higher than 2009, and 34.8 2% higher than 2002 (FAOSTAT, 2012). Papaya fruit is important in Malaysian economy due to an export value of around RM100 – 120 million per year (Rabu and Mat Lin, 2005).

Papaya is sold in the market throughout the year in Malaysia. Papaya produced in Malaysia is exported to Singapore, Hong Kong, Middle East and Europe as well as for local consumption. The export market is expected to be extended to China, USA, Japan, Australia, New Zealand and Russia, when the government increase the activity promotion in the future (MOA, 2012). In year 2011, Malaysian Department of Agriculture reported that papaya planting area was 2,462 hectares (Ha) with a yield of 43,364 metric tonnes (t). These values increase from year 2011 to year 2013. In 2013, papaya planting areas were 2,869 hectares (Ha) with yield of 48,078 metric tonnes (t) (Figure 1.1 and Figure 1.2).

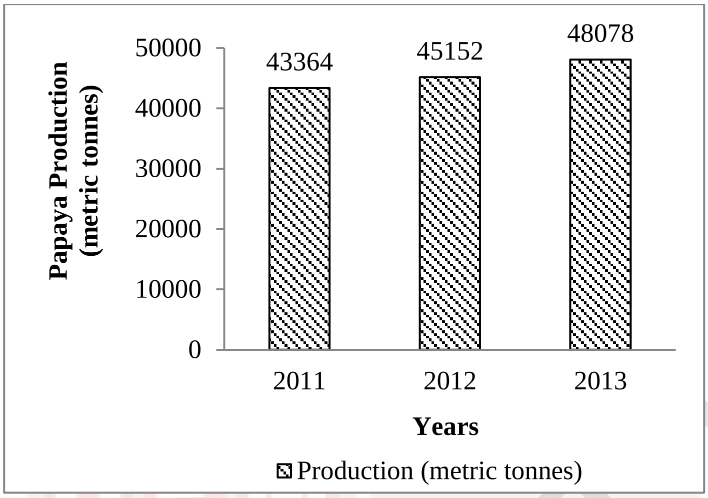

Figure 1.1. Papaya Production in Malaysia from Year 2011 to 2013.

(DOA, 2013)

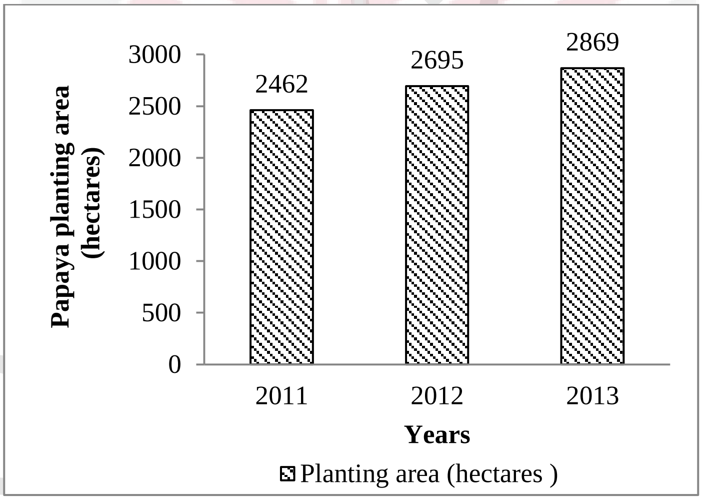

Figure 1.2. Papaya Planting Area in Malaysia from Year 2011 to 2013.

(DOA, 2013)

In expanding it cultivation in Malaysia, papaya has faced many problems. One of them is dieback disease. Papaya dieback disease caused by *Erwinia mallotivora* is a threat to papaya industry in Malaysia and around the world (Noriha *et al*., 2011). There is no solution to counteract the disease once the plant has been infected with *E. mallotivora*. Infected papaya plant must be destroyed in order to prevent the spread and this has caused lots of losses to the papaya industry. Papaya cultivars infected by papaya dieback disease were Eksotika, Sekaki, Solo and Hong Kong. Infected areas was 806 hectares and estimated losses was RM30 millions (DOA, 2012).

One way to reduce the incidence and the spread of the bacteria dieback disease is by increasing its resistance. Among the technique is by increasing the content of silicon (Si) in plant tissues. The beneficial effect of silicon in increasing the crop resistance has been reported for both fungal and bacterial diseases in both Si-accumulators plant and Si non-accumulators plant (Wydra *et al*., 2005). Apart from increasing disease resistance, Si have been reported to play a role in increasing photosynthetic activity, increase insect resistance, reduced mineral toxicity, improvement of nutrient imbalance, and enhanced drought and frost tolerance (Ma, 2004). Increasing level of Si in culture solution lead to increase in Si content of the leaves and thus, reduced disease incidence (Kanto, 2002). Menzies *et al*. (1991) found that infection efficiency, colony size, and germination of conidia were reduced when cucumbers were grown in nutrient solutions with high concentration of Si.

In the view of the effect of Si on disease resistance and the successful Si application in reducing disease incidence and severity and also enhanced host defence mechanisms, it is suggested that application of Si might help in inducing papaya defence against dieback disease caused by *E. mallotivora*. This would then help to reduce the overall occurrence and destruction of this disease on papaya. There were no investigation on Si application in papaya plant recorded and the possibility of using Si in reducing dieback diseases caused by *E. mallotivora* is unknown.

1.2 Objectives of the Study

The objectives of this study were:

i. to characterise the development of dieback disease on papaya seedlings;

ii. to investigate the effects of varying concentrations of silicon on dieback disease development, physiological and biochemical aspects of *E. mallotivora* infected papaya seedlings; and

iii. to elucidate the possible mechanisms of silicon in mediating the beneficial effects in reducing the occurrence of dieback disease in papaya seedlings.

REFERENCES

Adatia, M. H., and Besford, R. T. (1986). The effect of silicon on cucumber plants grown in recirculating nutrient solution. *Annual Botany*, 58, 343-351.

Agrios, G. N. (1997). *Plant Pathology*, Academic Press, New York, 635 pp.

Agrios, G. N. (2005). *Plant Pathology*, 5th Ed. Elsevier Academis Press, Amsterdam.

Aguirreolea, J., Irigoyen, J., Sanchez-Diaz, M., and Salaverri, J. (1995). Physiological alterations in pepper during wilt induced by *Phytophthora capsici* and soil water deficit. *Plant Pathology,* 154, 587–596.

Aleemullah, M., and Walsh, K. B. (1996). Australian papaya dieback: evidence against the calcium deficiency hypothesis and observations on the significance of laticifer auto-fluorescence. *Australian Journal of Agricultural Research*, 47, 371–385.

Ashtiani, A. F., Kadir, J. B., Selamat, A. B., Hanif, A. H. B. M., and Nasehi, A. (2012). Effect of foliar and root application of silicon against rice blast fungus in MR219 rice variety. *Plant Pathology*, 28, 164-171.

Belanger, R. R., Bowen, P. A., Ehret, D. L., and Menzies, J. G. (1995). Soluble silicon: its role in crop and disease management of greenhouse crops. *Plant Disease*, 79, 329–36.

Belanger, R. R., Benhamou, N. and Menzies, J. G. (2003). Cytological evidence of an active role of silicon in wheat resistance to powdery mildew (*Blumeria graminis f.sp. tritici*). *Phytopathology*, 93, 402-412.

Benhamou, N., Gagne, S., Quere, D. L., and Dehbi, L. (2000). Bacterial mediated induced resistance in cucumber beneficial effect of the endophytic bacterium *Serratia plymuthica* on the protection against infection by *Pythium ultimum*. *Phytopathology*, 90, 45-56.

Berger, S., Benediktyova, Z., Matous, K., Bonfig, K. B., Mueller, M. J., Nedbal, L., and Roitsch, T. (2007). Visualization of dynamics of plant–pathogen interaction by novel combination of chlorophyll fluorescence imaging and statistical analysis: differential effects of virulent and avirulent strains of *Pseudomonas syringae* and of oxylipins on *Arabidopsis thaliana*. *Journal of Experimental Botany,* 58, 797-806.

Bi, Y., and Zhang, W. Y. (1993). The research on the respiratory rate, ethylene evolution and peroxidase activity of the infected melon. *Acta Phytopathologica Sinica*, 23, 69-73.

Bowen, P., Menzies, J., Ehret, D., Samuels, L., and Glass, A. D. M. (1992). Soluble silicon sprays inhibit powdery mildew development on grape leaves. *Journal of the American Society for Horticultural Science*, 117, 906-912.

Bradford, M. M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry,* 72, 248–54.

Brisson, L. F., Tenhaken, R., and Lamb, C. J, (1994). Function of oxidative cross-linking of cell wall structural proteins in plant disease resistance. *Plant Cell*, 6, 1703–1712.

Brunings, A. M., Datnoff, L. E., and Ma J. F. (2009). Differential gene expression of rice in response to silicon and rice blast fungus *Magnaporthe oryzae*. *Annals of Applied Biology,* 155, 161–70.

Chan, Y. K. (2004). The Eksotika papaya: Malaysia's flagship variety for export. Abstract W09, p. 40, 3rd International Symposium on Tropical and Subtropical Fruits. 12-17 September 2004, Fortaleza, Brazil. ISHS.

Cheng, G. W., and Crisosto, C. H. (1995). Browning potential, phenolic composition, and polyphenol oxidase activity of buffer extracts of peach and nectarine skin tissue. *Journal of the American Society for Horticultural Science* 120(5), 835-838.

Cherif, M. and Belanger, R.R. (1992). Use of potassium silicate amendments in recirculating nutrient solutions to suppress *Pythium ultimum* on long English cucumber. *Plant Disease*, 76, 1008-1011.

Cherif, M., Benhamou, N., and Belanger, R. R. (1992). Ultrastructural and cytochemical studies of fungal development and host relations in cucumber plants infected by *Pythium ultimum*. *Physiological and Molecular Plant Pathology*, 39, 353–75.

Cherif, M., Benhamou, N., Menzies, J. G., and Bélanger, R. R. (1992a). Silicon-induced resistance in cucumber plants against *Pythium ultimum*. *Physiological and Molecular Plant Pathology*, 41, 411–25.

Cherif, M., Menzies, J. G., Benhamou, N., Bélanger, R. R. (1992b). Studies of silicon distribution in wounded and *Pythium ultimum* infected cucumber plants. *Physiological and Molecular Plant Pathology*, 41, 371–85.

Chérif. M., Asselin, A., Bélanger, R. R. (1994). Defense responses induced by soluble silicon in cucumber roots infected by *Pythium spp*. *Phytopathology,* 84, 236–242.

Cherif, M., Menzies, J. G., Ehret, D. L., Bogdanoff, C., and Belanger, R. R. (1994a). Yield of cucumber infected with *Pythium aphanidermatum* when grown with soluble silicon. *HortScience*. 29(8), 896-897.

Cocker, K. M., Evans, D. E., and Hodson, M. J. (1998). The amelioration of aluminium toxicity by silicon in wheat (*Triticum aestivum L.*): malate exudation as evidence for an in plant mechanism. *Planta,* 204, 318-323.

Conrath, U., Pieterse, C. M., Mauch-Mani, B. (2002). Priming in plant–pathogen interactions. *Trends in Plant Science*, 7, 210–216.

Constabel, C. P., and Ryan, C. A. (1998). A survey of wound- and methyl jasmonate-induced leaf polyphenol oxidase in crop plants. *Phytochemistry*, 47, 507–511.

Correa, R. S. B., Moraes, J. C., Auad, A. M., and Carvalho, G. A. (2005). Silicon and acibenzolar-s-methyl as resistance inducers in cucumber, against the whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) Biotype B. Neotrop. *Entomology*, 34, 429-433.

Dallagnol, L. J., Rodrigues, F. A., DaMatta, F. M., Mielli, M. V. B., and Pereira, S. C. (2011). Deficiency in silicon uptake affects cytological, physiological, and biochemical events in the rice–*Bipolaris oryzae* interaction. *Phytopathology*, 101, 92–104.

Dann, E. K., and Muir, S. (2002). Peas grown in media with elevated plant-available silicon levels have higher activities of chitinase and beta-1,3-glucanase, are less susceptible to a fungal leaf spot pathogen and accumulate more foliar silicon. *Australasian Plant Pathology*, 31, 9–13.

Datnoff, L. E., Snyder, G. H., Raid, R. N., and Jones, D. B. (1991). Effect of calcium silicate on blast and brown spot intensities and yields of rice. *Plant Disease*. 75, 729-732.

Datnoff, L. E., and Snyder, G. H. (2001). Silicon in Agriculture. Elsevier Publisher, London.

Datnoff, L. E., Seebold, K. W. and Correa-V, F. J. (2001). The use of silicon for integrated disease management: reducing fungicide applications and enhancing host plant resistance. In: Datnoff, L. E., Snyder, G. H. and Korndorfer, G. H. Silicon in Agriculture. *Elsevier Science*, The Netherlands, 171-180.

Datnoff, L. E., and Rodrigues, F. A. (2005). The role of silicon in suppressing rice diseases. Online. February APSnet Feature. *American Phytopathological Society*, St. Paul, MN.

Datnoff, L. E., Brecht, M. O., Stiles, C. M., and Rutherford B. A. (2005). The role of silicon in suppressing foliar diseases in warm season turf. *International Turfgrass Society Research* J. Vol. 10, 175-179.

Datnoff, L. E., Rodrigues, F. A., and Seebold, K. W. (2007). Silicon and plant disease. In: Datnoff LE, Elmer WH, Huber DM, eds. *Mineral Nutrition and Plant Disease*. St. Paul, MN, USA, APS Press, 233–46.

Diogo, R. V. C., and Wydra. (2007). Silicon-induced basal resistance in tomato against *Ralstonia solanacearum* is related to modification of pectic cell wall polysaccharide structure. *Physiological and Molecular Plant Pathology*, 70, 120-129.

DOA. (2012). Panduan menanam betik (*Carica papaya*). http://pertanianperak.gov.my/jpp/index.php/joomla/tanaman/buah-buahan sayursayuran/303-maklumat/tanaman/buah-buahan-sayur-sayuran/1059-panduan-menanam-betik-carica-papaya. [14 January 2013].

Dutta, S., and Chatterjee, N. C. (2000). Peroxidase activity vis-à-vis resistance to Rhizopus rot of jackfruit. *Indian Biologist*. 32(2), 61-63.

Edreva, A. (1989). Stress and pathogenesis in plants involvement of the peroxidase system and of endogenous elicitors. *Genetika I Selektsiya*. 22(4), 354-364.

Epstein, E. (1994). The Anomaly of Silicon in Plant Biology. *Proceedings of the National Academy of Sciences,* USA. 91, 11-17.

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

Fauteux, F., Remus-Borel, W., Menzies, J. G., Bélanger, R. R. (2005). Silicon and plant disease resistance against pathogenic fungi. *FEMS Microbiol Lett*, 249, 1–6.

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

Fawe, A., Menzies, J. G., Cherif, M., and Belanger, R. R. (2001). Silicon and disease resistance in dicotyledons. In: Datnoff, L. E, Snyder, G. H, Korndorfer, G. H, editors. *Silicon in agriculture*. The Netherlands: Elsevier Science, p. 159–69.

FAOSTAT. (2012). Crop Production. http://faostat.fao.org/site/567/default.aspx# ancor. [11 April 2014].

Gascho, G. J. (2001), "Silicon sources for Agriculture" In "Silicon in Agriculture" (Eds Datnoff, L. E., Snyder, G. H. and Korndorfer, G. H.), Elsevier Science, Amsterdam, The Netherlands.

Ghareeb, H., Bozso, Z., Ott, P. G., Repenning, C., Stahl, F., and Wydra, K. (2011). Transcriptome of silicon-induced resistance against *Ralstonia solanacearum* in the silicon non-accumulator tomato implicates priming effect. *Physiological and Molecular Plant Pathology*, 75, 83–89.

Glennie J. D., and Chapman, K. R. (1976). A review of dieback- a disorder of the papaw (*Carica papaya* L.) in Queensland. *Queensland Journal of Agricultural and Animal Sciences*, 33, 177-188.

Guthrie, J. N., Walsh, K. B., Scott, P. T. and Rasmussen, T. S. (2001). The phytopathology of Australian papaya dieback: a proposed role for the phytoplasma. *Physiological and Molecular Plant Pathology*, 58, 23-30.

Gwynne, D. C. (1984). Fire blight in perry pears and cider apples in the South West of England. *Acta Horticulturae*, 151, 41-47.

Habermann, G., Machado, E. C., Rodrigues, J. D., and Medina, C. L. (2003). CO_2 assimilation, photosynthetic light response curves, and water relations of 'Pêra' sweet orange plants infected with *Xylella fastidiosa*. *Brazilian Journal of Plant Physiology*, 15, 79–87.

Havlickova, H., Cvikrova, M., Eder, J., and Hrubcova, M. (1998). Alterations in the levels of phenolics and peroxidase activities induced by *Rhopalosiphum padi (L)* in two winter wheat cultivars. *Z Pflanzenk Pflanzen,* 105, 140-148.

Hedge, J. E., and Hofreiter, B. T. (1962). In: Carbohydrate Chemistry, 17, Academic Press, New York.

Hirage, S., Sasaki, K., Ito, H., Ohashi, Y., and Matsui, H. (2001). A large family of class III plant peroxidases. *Plant Cell Physiology*, 42, 462-468.

Horiguchi, T., and Morita, S. (1987). Mechanism of manganese toxicity and tolerance of plants. VI. Effect of silicon on alleviation of manganese toxicity of barley. *Journal Plant Nutrition,* 10, 2299 – 2310.

Horst, W. J., and Marschner, H. (1978). The effect of silicon on manganese tolerance of bean plants (*Phaseolus vulgaris L*.). *Plant Soil*, 50, 287–303.

Inbar, M., Doostdar, H., Gerling, D., Mayer, R. T. (2001). Induction of systemic acquired resistance in cotton by BTH has a negligible effect on phytophagous insects. *Experimental and Applied Entomology,* 99, 65-70.

Iwasaki, K., and Matsumura, A. (1999). Effect of silicon on alleviation of manganese toxicity in pumpkin (*Cucurbita moschata Duch* cv. Shintosa). *Soil Science. Plant Nutrition*, 45, 909 – 920.

Jose, A., Del Rio., Gonzalez, A., Fuster, M. D., Botia, J. M., Gomez, P., Frias, V., and Ortuno, A. (2001). Tylose formation and changes in phenolic compounds of grape roots infected with *Phaeomoniella chlamydospora* and *Phaeoacremonium* species. *Phytopathology Mediterranean*, 40, Supplement, S394-S399.

Junqueira, A., Bedendo, I., and Pascholati, S. (2004). Biochemical changes in corn plants infected by the maize bushy stunt phytoplasma. *Physiological and Molecular Plant Pathology,* 65, 181–185.

Kamenidou, S., Cavins, T. J. and Marek, S. (2009). Evaluation of silicon as a nutritional supplement for greenhouse zinnia production. *Scientia Horticulturae*, 119(3), 297-301.

Kanto, T. (2002). Research of silicate of improvement of plant defense against pathogens in Japan. *Abstract of Second Silicon in Agriculture Conference*, 22-26.

Keck, M., Richter, S., Suarez, B., Kopper, E., and Jungwirth. (2002). Activity of peroxidases in plant material infected with *Erwinia aymlovora*. *Acta Horticulturae* 590, 343-350.

Kerr, A. and Gibb, K. S. (1997). Bacterial and phytoplasma diseases and their control. *Plant Pathogens and Plant Diseases*. Rockvale Publishers. Armidale. 29, 468-487.

Khatun, S, Bandyopadhyay, P. K., and Chatterjee, N. C. (2009). Phenols with their oxidizing enzymes in defense against black spot of rose (*Rosa centifolia*). *Asian Journal Experimental Science*, 23, 249-252.

Khatun, S., Cakilcioglu, U., Chakrabarti, M., Ojha, S., and Chatterjee, N.C. (2011). Biochemical defense against die-back disease of a traditional medicinal plant *Mimusops elengi L*. *Europian Journal of Medicinal Plants*, 1, 40-49.

Kim, S. G., Kim, K. W., 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. *Phytopathology*, 92 (10), 1095-103.

Kokkinakis, D. M., and Brooks, J. L. (1979). Tomato peroxidase: purification, characterization and catalytic properties. *Plant Physiology*, 63(2), 93-99.

Kombrink, E., and Somssich, I. E. (1995). Defense responses of plants to pathogens. In: Callow JA, ed. *Advances in Botanical Research*, Vol. 21. London, UK: Academic Press, 1–34.

Lattanzio, V., Lattanzio, V. M. T., and Cardinali, A. (2006). Role of phenolics in the resistance mechanisms of plants against fungal pathogens and insects. *Phytochemistry*: Advances in Research, 23-67.

Lepka, P., Stitt, M., Moll, E., and Seemüller, E. (1999). Effect of phytoplasmal infection on concentration and translocation of carbohydrates and amino acids in periwinkle and tobacco. *Physiology and Molecular Plant Pathology*, 55, 59–68.

Li, L., and Steffens, J. C. (2002). Overexpression of polyphenol oxidase in transgenic tomato plants results in enhanced bacterial disease resistance. *Planta*, 215, 239–247.

Li, Q. F, Ma, C. C., and Shang, Q. L. (2007). Effects of silicon on photosynthesis and anti-oxidative enzymes of maize under drought stress. *Chinese Journal of Applied Ecology*, 18, 531-536.

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.

Liang, Y. C., Sun, W. C., Zhu, Y. G., and Christie, P. (2007). Mechanisms of silicon mediated alleviation of abiotic stresses in higher plants: A review. *Environmental Pollution*, 147, 422-428.

Lawlor, D. W. (2001). Photosynthesis: Molecular, Physiological and Environmental Processes. Bios Scientific Publishers. Oxford, UK.

Ma, J. F., Miyake, Y., and Takahashi, E. (2001a). Silicon as a beneficial element for crop plants. *Silicon in Agriculture*. Edited by Datonoff L, Korndorfer G, Synder G. New York: Elsevier Science, 17-39.

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

Ma, J. F., and Takahashi, E. (2002). Soil, fertilizer, and plant silicon research in Japan. Elsevier Science: Amsterdam.

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, J. F., and Yamaji, N. (2006). Silicon uptake and accumulation in higher plants. *Trends Plant Science*, 11392–11397.

Mahmud, T. M. M., Eryani-Raqeeb, A. A., Syed Omar, S. R., Mohamed Zaki, A. R., and Abdul Rahman, A. E. (2008). Effects of different concentrations and applications of calcium on storage life and physicochemical characteristic of papaya (*Carica papaya L.*). *American Journal Agricultural and Biological Science*., 3, 526-533.

Maktar, N. H., Kamis, S., Mohd Yusof, F. Z., and Hussain, N. H. (2008). *Erwinia papayae* causing papaya dieback in Malaysia. *New Disease Reports*, 57, 774.

Marschner, H. (1995). Mineral Nutrition of Higher Plants. Academic Press, London.

Matoh, T., Kairusmee, P., and Takahashi, E., (1986). Salt-induced damage to rice plants and alleviation effect of silicate. *Soil Science and Plant Nutrition*, 32, 295-304.

Matoh, T., Murata, S., and Takahashi, E. (1991). Effect of silicate application on photosynthesis of rice (*Oryza sativa*) plants. *Japanese Journal of Soil Science and Plant Nutrition*, 62(3), 248-251.

Maust, B. E., Espadas, F., Talavera, C., Aguilar, M., Santamaría, J. M., and Oropeza, C. (2003). Changes in carbohydrate metabolism in coconut palms infected with the lethal yellowing phytoplasma. *Phytopathology*, 93, 976–981.

Meena, R. K., Patni, V., and Arora, D. K. (2008). Study on phenolics and their oxidative enzyme in *Capsicum annuum L.* infected with geminivirus. *Asian Journal of Experimental Science*, 22, 307-310.

Mehrotra, R. S., and Aggarwal, R. S. (2003). Plant Pathology. Tata Mc-Graw Hill Publishing Company Limited, New Delhi, 846.

Menzies, J. G., Ehret, D. L., Glass, A. D. M., and Samuels, A. L. (1991). The influence of silicon on cytological interactions between *Spaerotheca fuliginea* and *Cucumis sativus*. *Physiology and Molecular of Plant Pathology*, 39, 403-414.

Menzies, J. G., Ehret, D. L., Glass, A. D. M., Helmer, T., Koch, C., and Seyward, F. (1991a). The effects of soluble silicon on the parasitic fitness of *Sphaerotheca fuliginea* (Schlecht: Fr.) Poll. on *Cucumis sativus L*. *Phytopathology*, 81, 84-88.

Menzies, J. G., Ehret D. L., Glass A. D. M., and Samuels A. L. (1991b). The influence of silicon on the cytological interactions between *Sphaerotheca fuliginea* and *Cucumis sativus*. *Physiology and Molecular of Plant Pathology*, 39, 403-414.

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, 902–112905.

Miyake, Y., and Takahashi, E. (1982). Effect of silicon on the resistant of cucumber plant to the microbial disease. Comparative studies on silica nutrition in plants (part 18). *Japanese Journal of Soil Science and Plant Nutrition*, 53, 106-110.

Miyake, Y., and Takahashi, E. (1983). Effect of silicon on solution cultured cucumber plant. *Soil Science and Plant Nutrition*. Tokyo, 29, 71-83.

MOA. (2009). Profil betik. http://www.moa.gov.my/documents. [5 December 2012].

MOA. (2012). Potensi Industri Betik. http://www.moa.gov.my/c/document_library. [24 January 2013].

Mozzetti, C., Farraris, I., Tamietti, G., and Matta, A. (1995). Variations in enzyme activities in leave and cell suspension as markers of incompatibility in different Phytophthora-pepper interactions. *Physiological and Molecular Plant Pathology*, 46, 91-107.

Musseti, R., Favali, M. A., and Pressaco, L., (2000). Histopathology and polyphenol content in plants infected by phytoplasmas. *Cytobios*, 102, 133-147.

Musetti, R. (2010). Biochemical changes in plants infected by phytoplasmas. In: *Phytoplasmas genomes, plant hosts and vectors* (Eds P.G. Weintraub & P. Jones), CABI, 132-146.

Nakamura, Y., Watanabe, S., Miyake, N., Kohno, H., and Osawa, T. (2003). Dihydrochalcones: Evaluation as Novel Radical Scavenging Antioxidants. *Journal of Agricultural and Food Chemistry*, 51, 3309-3312.

Nicholson, R. L., and Hammerschmidt, R. (1992). Phenolic compounds and their role in disease resistance. *Annual Review of Phytopathology*, 30, 369–389.

Nogues, S., Cotxarrera, L., Alegre, L., and Trillas, M. I. (2002). Limitations to photosynthesis in tomato leaves induced by *Fusarium wilt*. *New Phytology*, 154, 461–70.

Noriha, M. A., Hamidun, B., Rohaiza, A. R and Indu, B. S. J. (2011). E*rwinia mallotivora sp.*, a new pathogen of papaya (*Carica papaya*) in Peninsular Malaysia. *International Journal of Molecular Sciences*, 12, 39-45.

Ohyama, N. (1985). Effect of improvement in fertilization on the alleviation of cool-summer damage to rice. *Agriculture and Horticulture*, 11, 1385-1389.

Okuda, A., and Takahashi, E. (1962). Studies on the physiological role of silicon in crop plant. Part 9. Effect of various metabolic inhibitors on the silicon uptake by rice plant. *Journal of Science and Soil Manure* (Japan), 33, 453–455.

Olabiyi, A. M. (2010). First Report of *Erwinia* Stem Canker of Papaya (*Carica papaya L.*) in Nigeria. *European Journal of Scientific Research*, Vol. 46 Issue 3, 422.

Papaya Fruit Facts. http://www.crfg.org/pubs/ff/papaya.html. [26 June 2012].

Paranidharan, V., Palaniswami, A., Vidhyasekaran, P., and Velazhahan, R. (2009). Induction of enzymatic scavengers of active oxygen species in rice in response to infection by *Rhizoctonia solani*. *Acta Physiologiae Plantarum*, 25, 91-96.

Pascholati, S. F., Deising, H., Leite, B., Anderson, D., and Nicholson, R. L. (1993). Cutinase and nonspecific esterase activities in the conidial mucilage of *Colletotrichum graminicola*. *Physiological and Molecular Plant Pathology*, 42, 37–51.

Petit, A. N., Boulay, M., Clément, C., Fontaine, F., Vaillant, N. (2006). Alteration of photosynthesis in grapevines affected by esca. *Phytopathology*, 96, 1060–1066.

Poiatti, V. A. D, Dalmas, F. R., and Astarita, L. V. (2009). Defense mechanisms of *Solanum tuberosum L*. in response to attack by plant-pathogenic bacteria, *Biological Research*, 42, 205–215.

Pradeep, T., and Jambhale, N. D. (2002). Relationship between phenolics, polyphenol oxidase and peroxidase, and resistance to powdery mildew in Zizyphus. *Indian Phytopathology*, 55, 195–196.

Rabu, M. R., and Mat Lin, R. (2005). Prospect of papaya in the world market: Malaysia perspective. In Proceeding of First International Symposium on Papaya, Genting Higlands, Malaysia, 22–24.

Reifschneider, F. J. B., and Lopes, C. A. (1982). Bacterial top and stalk rot of maize in Brazil. *Plant Disease*. 66, 519–520.

Remus-Borel, W., Menzies, J. G., and Bélanger, R. R. (2005). Silicon induces antifungal compounds in powdery mildew-infected wheat. *Physiological and Molecular Plant Pathology*, 66, 108–15.

Reuveni, R., Shimoni, M., Karchi, Z., and Kuc, J. (1992). Peroxidase activity as a biochemical marker for resistance of muskmelon (*Cucumis melo*) to *Pseudoperonospora cubensis*. *Phytopathology*, 82, 749-753.

Rodrigues, F. A., Datnoff, L. E., Korndorfer, G. H., Rush, M. E., Seebold, K. W., and Linscombe, S. (1998). Effects of calcium silicate and resistance on the development of sheath blight in Rice I. 24th Rice Tech. Working .Meeting, Reno, Nevada.

Rodrigues, F. A., McNally, D. J., Datnoff, L. E., Jones, J. B., Labbé, C., Benhamou, N., Menzies, J. G., and Bélanger, R. R. (2004). Silicon enhances the accumulation of diterpenoid phytoalexins in rice: a potential mechanism for blast resistance. *Phytopathology*, 94, 177-183.

Rodrigues, F. A., Jurick, W. M., Datnoff, L. E., Jones, J. B., and Rollins, J. A. (2005). Silicon influences cytological and molecular events in compatible rice-*Magnaporthe grisea* interactions. *Physiological and Molecular Plant Pathology*, 66, 144–59.

Roemmelt, S., Treutter, D., Speakman, J.B., and Rademacher, W. (1999). Effects of prohexadione-Ca on the flavonoid metabolism of apple with respect to plant resistance against fire blight. *Acta Horticulturae*, 489, 359-363.

Roitsch, T., Balibrea, M. E., Hofmann, M., Proels, R., and Sinha, A. K. (2003). Extracellular invertase: key metabolic enzyme and PR protein. *Journal of Experimental Botany*, 54, 513-524.

Saharan, G. S., Joshi, U. N., and Saharan, M. S. (2000). Phenolic compounds and oxidative enzymes in healthy and *Altermaria* blight infected leaves of clusterbean. *Acta Phytopathologica et Entomologica Hungarica*, 34, 299-306.

Sahoo, M. R., Kole, P. H., Dasgupta, M., Mukherjee, A. (2009). Changes in phenolics, polyphenol oxidase and its isoenzyme pattern in relation to resistance in taro against *Phytophthora colocasiae*. *Journal of Phytopathology*, 157, 145-153.

Samuels, A.L., A.D.M. Glass, D.L. Ehret, and J.G. Menzies. (1991). Mobility and deposition of silicon in cucumber plants. *Plant Cell & Environment*, 14, 485-492.

Schaad, N. W. (1988). *Laboratory Guide for Identification of Plant Pathogenic Bacteria*, 2nd Edition. Aps Press: St. Paul, Minnesota, USA. Illus. Paper. Ix+164p.

Schneider, H. (1977). Indicator hosts for pear decline: symptomatology, histopathology, and distribution of mycoplasma-like organisms in leaf veins. *Phytopathology*, 67, 592-601.

Scholes, J. D. (1992). Photosynthesis: cellular and tissue aspects in diseased leaves. In: Ayres PG, ed. Pests and Pathogens: Plant Responses to Foliar Attack. Oxford, UK: BIOS Scientific Publishers, 85–106.

Seebold, K., Kucharek, T., Datnoff, L., Correa-Victoria, F., and Marchetti, M. (2001). The influence of silicon on components of resistance to blast in susceptible, partially resistant, and resistant cultivars of rice. *Phytopathology*, 91, 63-69.

Sondeep, S., Bavita, A., Navtej, S. B., and Satwinder, K. M. (2009). Induction of Carbohydrate Metabolism in Relation to Leaf Blight in Barley (*Hordeum vulgare*). *Advances in Biological Research*, 3, 61- 66.

Stewart, R. J., Sawyer, B. J. B., Bucheli, C. S., and Robinson, S. P. (2001). Polyphenol oxidase is induced by chilling and wounding in pineapple. *Australian Journal of Plant Physiology*, 28, 181-191.

Stintzi, A., Heitz, T., Prasad, V., Wiedemann-Merdinoglu, S., Kauff- mann, S., Geoffroy, P., Legrand, M., and Fritig, B. (1993). Plant 'pathogenesis-related' proteins and their role in defense against pathogens. *Biochimie*, 75, 687-706.

Stout, M. J., Fidantsef, A. L., Duffey, S. S., and Bostock, R. M. (1999). Signal interactions in pathogen and insect attack: systemic plant-mediated interactions between pathogens and herbivores of the tomato, *Lycopersicon esculentum*. *Physiological and Molecular of Plant Pathology*, 54, 115–130.

Teixeira da Silva, J. A., Rasyid, Z., Nhut, D. T., Sivakumar, D., Souza Jr, M. T., and Tenant, P. F. (2007). Papaya (*Carica papaya L.*) biology and biotechnology. *Tree and Forestry Science and Biotechnology,* 1, 47-73.

Thipyapong, P., Hunt, M. D., and Steffens, J. C. (1995). Systemic wound induction of potato (*Solanum tuberosum*) polyphenol oxidase. *Phytochemistry*, 40, 673–676.

Thipyapong, P., and Steffens, J. C. (1997). Tomato polyphenol oxidase – Differential response of the polyphenol oxidase F promoter to injuries and wound signals. *Plant Physiology*, 115, 409–418.

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, 487- 490.

Vermerris, W., and Nicholson, R. (2006). Phenolic Compound Biochemistry. USA: Springer. New York, EEUU. 3-16, 151-153.

Volk, R. J., Kahn, R. P., and Weintraub, R. L. (1958). Silicon content of the rice plant as a factor in influencing its resistance to infection by the rice blast fungus *Piricularia oryzae*. *Phytopathology*, 48, 121-178.

War, A. R., Paulraj, M. G., War, M. Y., and Ignacimuthu, S. (2011). Role of salicylic acid in induction of plant defense system in chickpea (*Cicer arietinum L.*). *Plant Signal Behaviour*, 6, 1787–1792.

Winstead, N., and Kelman, A. (1952). Inoculation techniques for evaluating resistance to *Pseudomonas solanacearum*. *Phytopathology*, 42, 628–634

Wydra, K., Diogo, R., Dannon, E., and Semrau, J. (2005). Soil amendment with silicon and bacterial antagonists induces resistance against bacterial wilt caused by *Ralstonia solanacearum* in tomato. Conference on International Agricultural Research for Development. Stuttgart-Hohenheim, 11-13.

Yedidia, I., Benhamou, N., and Chet, I. (1999). Induction of defense responses in cucumber plants (*Cucumis sativus L.*) by the biocontrol agent *Trichoderma harzianum*. *Applied Environtmental Microbiology*, 65, 1061-70.

Yoshida, S., Ohnishi, Y., and Kitagishi, K. (1962). Chemical forms, mobility, and deposition of silicon in the rice plant. *Japanese Journal of Soil Science and Plant Nutrition*, 8, 107-111.