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VALIDATION OF GENE AND QUANTITATIVE TRAIT LOCI ASSOCIATED WITH Nilaparvata lugens Stål RESISTANCE IN Oryza sativa L. CULTIVAR RATHU HEENATI

RUZIAH BINTI MD YUSOFF

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By

RUZIAH BINTI MD YUSOFF

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

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Chair : Noor Azmi Bin Shaharuddin, PhD
Faculty : Biotechnolgy and Biomolecular Sciences

The use of resistant varieties has been recognized as more economical and environmental friendly approach to manage brown planthopper *Nilaparvata lugens* Stål (BPH) populations in the rice fields. Rathu Heenati has a broad spectrum resistance against BPH. At least, four genes and QTLs were reported in Rathu Heenati, namely *Bph3* located on chromosome 6, *Qbph3* (Chr 3), *Qbph4* (Chr 4), and *Qbph10* (Chr 10). Microsatellite markers, flanking these gene/QTLs has been identified and made available in the literatures. This study was aimed to validate the presence of those gene/QTLs in Rathu Heenati by using the F_2 population of a cross between Rathu Heenati/MR219 with the final aim to introgress them into MR219 through marker-assisted selection (MAS). Resistance assessment were based on plant damage score (a measure of tolerance) and amount of honeydew excretion (a measure of antibiosis) while the presence of the gene/QTLs in the individual F_2 plants was based on the polymorphism of their respective markers on F_2 plants, *Qbph3* (RM7 and RM1256), *Qbph4* (RM8213 and RM5473), *Bph3* (RM8072 and RM588) and *Qbph10* (RM5352, RM228 and RM5471). Levels of resistance of individual plants were estimated. Cluster analysis manages to divide the plants into four clusters at 0.06 semi partial R-square value. These clusters represent groups of resistant plants (IV), moderately resistant (III), moderately susceptible (II), and susceptible (I). Correlation analysis showed significant correlation between *Bph3* presence and the amount of honeydew excretion (r = -0.200*), while *Qbph10* presence is correlated with the plant damage score (r = -0.196*). There was no correlation observed between *Qbph3* or *Qbph4* presence to any of the two phenotypic parameters measured. This study indicated that the presence of *Bph3* and *Qbph4* from Rathu Heenati contributed to the BPH resistance among the progenies of Rathu Heenati/MR219 cross. Their flanking markers were successfully utilised in the marker-assisted selection to monitor the gene introgression among the progenies of the cross. There were 59 F_2 plants in the group IV which are resistant to BPH which could be promoted for further evaluation at the F_3 generation.

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

VALIDASI KE ATAS GEN DAN LOKUS TRAIT KUANTITATIF YANG BERSANGKUTAN DENGAN KERINTANGAN TERHADAP *Nilaparvata lugens* Stål DI DALAM KULTIVAR PADI *Oryza sativa* L. RATHU HEENATI

Oleh

RUZIAH BINTI MD YUSOFF

Februari 2018

Pengerusi : Noor Azmi Bin Shaharuddin, PhD
Fakulti : Bioteknologi dan Sains Biomolekul

Penggunaan varieti padi rintang telah dikenalpasti sebagai satu kaedah pengawalan populasi serangga bena perang (BPH), *Nilaparvata lugens* Stål yang berkesan, murah lagi mesra alam di sawah-sawah padi. Varieti padi Rathu Heenati mempunyai spektrum kerintangan yang tinggi dan meluas terhadap serangga ini. Sekurang-kurangnya empat gen telah dilaporkan wujud dan berperanan mengatur kerintangan Rathu Heenati terhadap bena perang iaitu *Bph3* yang dilaporkan terletak pada kromosom 6, manakala lokus-lokus trait kuantitatif *Qbph3,Qbph4,* dan *Qbph10* pula adalah terletak pada kromosom-kromosom 3, 4 dan 10 setiap satunya. Penanda-penanda mikrosatelit yang mengapit setiap gen atau QTL ini telah pun dikenalpasti dan dilaporkan di dalam pelbagai literatur sebelum ini. Kajian yang dijalankan ini pula adalah bertujuan untuk mengesahkan kehadiran gen atau QTL ini di dalam varieti padi Rathu Heenati. Kajian dijalankan dengan menggunakan populasi F_2 hasil dari kacukan Rathu Heenati dengan MR219. Matlamat akhir kajian ini adalah bagi membolehkan pengintrograsian gen/QTL ini ke dalam varieti padi MR219 dengan menggunakan kaedah pemilihan berbantukan penanda molekul (MAS). Tahap kerintangan pokok adalah berdasarkan kepada tahap skoran kerosakan pokok (i.e. suatu bentuk pengukuran tahap toleransi) dan jumlah rembesan serangga (satu bentuk pengukuran tahap antibiosis). Kehadiran gen/QTL dalam setiap pokok F_2 pula adalah berasaskan kepada bentuk polimorfisma penanda-penanda molekul berkenaan, di mana *Qbph3* adalah berdasarkan polimorfisma penanda molekul RM7 serta RM1256, *Qbph4* (RM8213 serta RM5473), *Bph3* (RM8072 serta RM588) dan *Qbph10* (RM5352, RM228 serta RM5471). Tahap kerintangan yang ditonjolkan oleh setiap gen secara sendirian atau kombinasi sesama gen juga telah dianggarkan. Analisa kluster telah membahagikan pokok-pokok F_2 ke dalam empat kluster pada tahap 0.06 bagi nilai semi partial R-square. Kluster ini mewakili pokok-pokok F_2 dari kumpulan rintang (IV), sederhana rintang (III), sederhana rentan (II) dan kumpulan rentan (I). Analisa menunjukkan kehadiran korelasi yang bermakna antara kehadiran gen *Bph3* dengan jumlah rembesan serangga (r = -0.200*), sementara kehadiran *Qbph10* pula berkorelasi dengan skoran kerosakan pokok (r = -0.196*). Tidak wujud korelasi yang

bermakna di antara kehadiran *Qbph3* atau *Qbph4* dengan kedua-dua parameter fenotip yang diukur. Kajian ini telah menunjukkan bahawa kehadiran *Bph3* dan *Qbph10* dari Rathu Heenati telah menyumbang kepada kerintangan terhadap BPH dalam kalangan progeni-progeni kacukan Rathu Heenati/MR219. Penanda-penanda molekul yang mengapit kedua-dua gen/QTL ini telah berjaya digunakan dalam pemilihan berbantukan penanda molekul (MAS) bagi mengesan kewujudan intrograsi gen berkenaan dalam kalangan progeni kacukan. Sejumlah 59 pokok F_2 dari kluster IV telah menunjukkan tahap kerintangan tinggi terhadap BPH, yang boleh dimajukan ke generasi F_3 bagi penilaian selanjutnya.

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I certify that a Thesis Examination Committee has met on 15 February 2018 to conduct the final examination of Ruziah binti Md Yusoff on her thesis entitled "Validation of Gene and Quantitative Trait Loci Associated with *Nilaparvata lugens* Stål Resistance in *Oryza sativa* L. Cultivar Rathu Heenati" 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.

Members of the Thesis Examination Committee were as follows:

Mohd Termizi bin Yusof, PhD
Senior Lecturer
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Chairman)

Mohd Rafii bin Yusop, PhD
Professor
Institute of Tropical Agriculture and Food Security
Universiti Putra Malaysia
(Internal Examiner)

Sreeramanan Subramaniam, PhD
Associate Professor
Universiti Sains Malaysia
Malaysia
(External Examiner)

RUSLI HAJI ABDULLAH, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 September 2018

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:

Noor Azmi Bin Shaharuddin, PhD
Senior Lecturer
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Chairman)

Mohamad Bahagia Bin Ab Ghaffar, PhD
Senior Research Officer
Rice and Industrial Crop Research Centre
Malaysian Agricultural Research and Development Institute (MARDI)
(Member)

____
ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: ______________________
Name of Chairman of Supervisory Committee: Noor Azmi Bin Shaharuddin

Signature: ______________________
Name of Member of Supervisory Committee: Mohamad Bahagia Bin Ab Ghaffar

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LIST OF ABBREVIATIONS

AFLP	Ampilified Fragment Length Polymorphism
ANOVA	Analysis of Variance
BLB	Bacterial Leaf Blight Disease
bp	Base Pair
BPH	Brown Planthopper
Chr	Chromosom
CV	Coefficients of Variation
ddh^2O	Deionized Water
D	Dark
DNA	Deoxyribonucleic Acid
FPLI	Funtional Plant Loss Index
GS	Honeydew excretion
H	Height
Hb	Heritability
hr	Hour
ICIIM	Inclusive Composite Internal
IRMI	International Rice Microsatellite Initiative
IRRI	International Rice Research Institute
K	Potassium
Kg	Kilogram
L	Light
MAB	Marker-Assisted Backcrossing
MARDI	Malaysian Agricultural Research and Development
MAS	Marker-Assisted Selection
mg	Milligram
ml	Millilitre
mm	Millimetre
N	Nitrogen
nm	Nanometre
O_2	Oxygen
P	Phosphorus
PCR	Polymerase Chain Reaction
PS	Plant damage Score
QTL	Quantitative Trait Loci
R	Radius
RAPD	Random Amplified Polymorphic DNA
RFLP	Restriction Fragment Length Polymorphism
RH	Rathu Heenati
rpm	Revolutions per minute
SAS	Statistical Analysis System
SE	Standard Error
SNP	Single Nucleotide Polymorphism
SSL	Self-sufficiency
SSR	Simple Sequence Repeat
SSST	Standard Seedbox Screening Test
TN1	Taichung Native 1
%	Percentage
°C	Degree Celsius

μg	Microgram
μl	Microliter
μm	Micrometer

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important crops in the world. It is the staple food for more than 3 billion people in Asia and several other countries. A further increment of more than 60% is needed to fulfill the demand of the growing world population by 2025 (Norimah *et al*., 2008; Ghaffar, 2012; Mamaduo *et al*., 2015). However, biotic and abiotic factors numerously impact rice productivity in many tropical regions that may affect the expected production increment. Amongst major biotic agents which may cause significant yield reduction or losses are diseases and insect pests. Globally, 52% of rice production is lost annually due damages caused by biotic factors, of which 21% is attributed to the infestation by various species of insect pests (Yarasi *et al*., 2008).

There are more than 100 species of insects are found in the rice crop. About 20 species were identified as insect pests that have potential to cause significant damage affecting productivity of the crop. These included many species of stem borers, leafhoppers and planthoppers (Pathak and Khan, 1994). Rice brown planthopper (BPH) *Nilaparvata lugens* (Stål) is identified as one of the important insect pests in the world. This insect caused significant yield reduction to rice crops in many countries (Huang *et al*., 1997; Sogawa *et al*., 2003; Sun *et al*., 2005; Shabanimofrad *et al*., 2017). Invading BPH population congregates at the base of paddy plants and sucks the sap from the stem and leaf through phloem ingestion. Excessive feeding caused plant dehydration and loss of nutrition. The symptoms of damage can be identified by the leaves turn yellowing initially, followed by complete wilting and drying of rice plants. Under severe cases, paddy field looks a 'burnt-like' appearance in circles known as "hopperburn". The insect is also capable of transmitting two viral diseases, the ragged stunt virus and grassy stunt virus (Bhogadhi *et al*., 2015).

The rice crops in several South and South East Asian countries have been damaged by BPH in a large scale since 1970s (Dyck and Thomas, 1979; Latif, 2000). Annually, about 1 million tons of rice losses have been recorded in China due to brown planthopper infestation. A loss of about 2.7 million tons was recorded in year 2005 and 2008 (Brar *et al*., 2009; Hu *et al*., 2016), while in 2006 and 2007, a bigger damage was observed resulting with 9.4 million and 8.7 million ton loss (Catindig *et al*., 2009). Japan and Korea also affected by the numerous BPH outbreaks in 2005 (Otuka, 2013). In 2007, due to the high losses in rice production by BPH in Vietnam, rice exportation has been suspended by several producing countries (IRRI, 2011). Over tens of thousands hectares of rice fields were also reportedly affected in Indonesia since 2008. BPH infestations and its associated virus diseases (ragged and grassy stunt diseases) were also reported in 2009 in Central Thailand, southern provinces of China, northern Vietnam, and Indonesia. The BPH infestation in Thailand affected more than 3 million hectares of rice growing areas, causing losses in excess of 1.1 million tons, with an export potential of US$275 million (IRRI, 2014). In 1967, a brown planthopper outbreak was occurred in Terengganu affecting more than 6, 000 ha of rice. Another outbreak was also reported in Tanjong Karang in 1977 affecting a large area of rice fields (Lim and Heong, 1977). Several other outbreaks were also reported in the subsequent years (Habibuddin, 2012) and thus BPH was identified as one of the important insect pests in Malaysia.

Traditionally, BPH population in Malaysia is controlled by using insecticides. However, application of insecticides increases the cost of rice production. An indiscriminate use of them may also affecting environment and the health of farmers. As such, utilization of resistant varieties to lower the potential loss and preventing BPH outbreaks was later adopted and promoted (Habibuddin, 2012). Many resistant genes to BPH were identified and utilized in the breeding program in Malaysia to develop BPH resistant varieties. Among them are *Bph1* from the donor variety Mudgo, *bph2* gene from ASD7, *Bph3* gene from Rathu Heenati and *bph4* gene from rice variety Babawee. So far, the *indica* rice cultivar Rathu Heenati was found to show high resistance and found to be resistant to all the four BPH biotypes, biotype 1, biotype 2, biotype 3 and biotype 4 worldwide (Li *et al*., 2017; Jairin *et al*., 2007a), including to BPH populations in Malaysia (Ito *et al*., 1994).

Conventional BPH resistant rice breeding protocol based on symptoms or phenotypic characterization was useful but it had certain limitations. Among the limitation of conventional resistant breeding program is the long duration period taken in the breeding processes to identify resistant breeding lines. It also has difficulty in identifying resistant genes playing their roles in those resistant lines, especially when the breeding processes were involving multiple crosses involving multiple donor parents. However, these limitations might be overcome by utilizing molecular DNA markers in the marker-assisted selection (MAS) breeding program. The presence of the desired targeted genes, of which in this case the BPH resistant gene(s), will be confirmed through the identification of their close-linked flanking DNA markers.

The *Bph3* gene in Rathu Heenati was mapped on the short arm of chromosome 6, flanking by the linked markers RM589 and RM588 (Jairin *et al*., 2007a). There were also reported findings that resistance of Rathu Heenati to BPH is also contributed by other quantitative trait loci (QTLs), reportedly located on different chromosomes (Sun *et al*., 2005; Jairin *et al*., 2007a; Kumari *et al*., 2010; Hu *et al*., 2016). Three QTLs were assigned to chromosome 3, 4, and 10, respectively (Sun *et al*., 2005). The loci in chromosome 3 which was designated as *Qbph3*, was found located between markers RM313 and RM7. The second QTL, *Qbph4*, was found located between markers RM8213 and RM5953 on the short arm of chromosome 4, with a map distance of 3.6 cM and 3.2 cM, respectively. On the other hand, the *Qbph10* on the chromosome 10 was flanked between markers RM484 and RM496 (Sun *et al*., 2005). The other major BPH resistance gene in Rathu Heenati was designated as *Bph17,* which was mapped between markers RM8213 and RM5953 on the chromosome 4 (Sun *et al*., 2005). However, there were also reports of contradictory findings on the identification and loocations of these genes in the variety.

In Malaysia, MR219 has been grown as a popular variety for more than 10 years, covering more than 90% of the planted area. The variety which is carrying *Bph1* gene was resistant to BPH when released, but was succumbed to BPH infestation in recent years. There is a need to incorporate other resistant genes from Rathu Heenati into

MR219 so that improved MR219 varieties with higher resistance levels to local BPH population could be introduced, and durabilities of these varieties could be prolonged in the fields. Hence, the present studies were conducted with the following objectives;

1.1. To validate several resistance genes and quantitative trait loci (QTLs) reportedly controlling BPH resistance in Rathu Heenati.
1.2. To assess and validate the flanking markers of the identified gene and QTLs for their possible application in a marker assisted selection program.

REFERENCES

Abdullah, S.N.A., Hakeem, K.R., and Akhtar, M.S. (2016). Plant, Soil and Microbes *Implications in Crop Science,* 366.

Acquaah, G. (2015). Conventional Plant Breeding Principles and Techniques. In *Advances in Plant Breeding Strategies: Breeding, Biotechnology and Molecular Tools* (pp. 115-158). Springer International Publishing.

Acquaah, G. (2012). Polyploidy in plant breeding. *Principles of Plant Genetics and Breeding, Second Edition*, 452-469.

Ahmed, A.M., Muhamad, R., Omar, D., Grozescu, I.V., Majid, D.L. and Manjeri, G. (2016). Mating Behaviour of Brown Planthopper *Nilaparvata lugens* Stàl (Homoptera: Delphacidea) Under Certain Biological and Environmental Factors. *Pakistan Journal of Zoology*, 48(1): 11-23.

Akagi, H., Yokozeki, Y., Inagaki, A., and Fujimura, T. (1996). Microsatellite DNA markers for rice chromosomes. *Theoretical and Applied Genetics*, 93: 1071-1077.

Alam, S.N., and Cohen, M.B. (1998). Detection and analysis of QTLs for resistance to the brown planthopper *Nilaparvata lugens* in a doubled haploid rice population. *Theoretical and Applied Genetics*, 97:1370–9.

Ali, M.P., Huang, D., Nachman, G., Ahmed, N., Begum, M.A., and Rabbi, M.F. (2014). Will climate change affect outbreak patterns of planthoppers in Bangladesh. *PLoS One*, *9*(3), e91678.

Ali, M., Alghamdi, S., Begum, M., Anwar Uddin, A., Alam, M., and Huang, D. (2012). Screening of rice genotypes for resistance to the brown planthopper,*Nilaparvata lugens* Stål, *Cereal Research Communications*, 40(4), 502-508.

Alias, I., Mohammad, H., Othman, O., Saad, A., Habibuddin, H., Aszlan, S., Lim, K.H., and Guok, H. P. (2001). Pembentukan dan prestasi variety padi baru MR219. *MARDI Report.* 196. 8p.

Amonsilpa, S., and Jackson, B.R. (1980). Performance of a male-sterile IR36/KN361 population in Thailand. *International Rice Research Newsletter*.

Alves, A.A., Rosado, C.C.G., Faria, D.A., da Silva Guimaraes, L.M., Lau, D., Brommonschenkel, S. H., and Alfenas, A.C. (2012). Genetic mapping provides evidence for the role of additive and non-additive QTLs in the response of inter-specific hybrids of Eucalyptus to *Puccinia psidii* rust infection. *Euphytica*, *183*(1), 27-38.

Arif, I.A., Bakir, M.A., Khan, H.A., Al Farhan, A.H., Al Homaidan, A.A., Bahkali, A.H., and Shobrak, M. (2010). A brief review of molecular techniques to assess plant diversity. *International journal of molecular sciences*, *11*(5), 2079-2096.

Arunachalam, V. (2001). Quantitative genetics from the perspective of Mendelian and molecular breeding. *Crop Improvement India.* 28(2): 129-156.

Asfaliza, R. (2017). Rice varietal development in MARDI for food sovereignty. Retrieved from https://blogmardi.wordpress.com.

Ashkani, S., Rafii, M.Y., Shabanimofrad, M., Miah, G., Sahebi, M., Azizi, P., and Nasehi, A. (2015). Molecular breeding strategy and challenges towards improvement of blast disease resistance in rice crop. *Frontiers in Plant Science*, *6*.

Auclair, J.L. (1958). Honeydew excretion in the pea aphid, Acyrthosiphon pisum (Harr.)(Homoptera: Aphididae). *Journal of Insect Physiology*, *2*(4), 330IN19333-332337.

Baehaki, S.E and Iswanto, E.H. (2017). The filtering of rice resistance and population buildup to determine antibiosis and tolerance as characteristics of rice resistance to brown planthopper Biotype 3. *American Journal of Engineering Research*, 6 (3): 188-196.

Bae, S.H., and Pathak, M.D. (1970). Life history of *Nilaparvata lugens* (Homoptera:Delphacidae) and susceptibility of rice varieties to its attack *Annals of the Entomological Society of America*, 63:149-53.

Baker, P.S., Cooter, R.J., Chang, P.M., and Hashim, H.B. (1980). The flight capabilities of laboratory and tropical field populations of the brown planthopper*Nilaparvata lugens*(Stål)(Hemiptera: Delphacidae). *Bulletin of Entomological Research*, *70*(4), 589-600.

Bale, J.S., Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K., and Good, J.E. (2002). Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biology*, *8*(1): 1-16.

Bashar, Z.U., Wayayok, A., and Mohd, A.M.S. (2014). Determination of some physical properties of common Malaysian rice MR219 seeds. 2014. *Australian Journal of Crop Science*, *8*(3): 332-337.

Bhanu, K.V., Lakshmi, V.J., Katti, G., and Reddy, A.V. (2014). Antibiosis and tolerance mechanisms of resistance in rice varieties carrying brown planthopper resistance genes. *Asian Journal of Biological and Life Sciences*, *3*(10): 108-113.

Bhogadhi, S.C., Bentur, J.S., Rani, C.V.D., Thappeta, G., Yamini, K.N., Kumar, N.A.P., and Satynarayana, P.V. (2015). Screening of rice genotypes for resistance to brown planthopper Biotype 4 and detection of BPH resistance genes. *International Journal of Life Sciences Biotechnology and Pharma Research*, *4*(2), 90.

Boopathi, N.M. (2013). Marker-assisted selection. In *Genetic Mapping and Marker-assisted Selection* (pp. 173-186). Springer India.

Botstein, D., White, R.L., Skolnick, M., and Davis, R.W. (1980). Construction of a genetic linkage map in man using restriction fragment length polymorphisms. *The American Journal of Human Genetics*, *32*: 314-331.

Brar, D.S., Virk, P.S., Jena, K.K., and Khush, G.S. (2009). Breeding for resistance to planthoppers in rice. *Planthoppers: new threats to the sustainability of intensive rice production systems in Asia*, 401-409.

Catindig, J.L.A., Arida, G.S., Baehaki, S.E., Bentur, J.S., Cuong, L.Q., Norowi, M., and Heong, K.L. (2009). Situation of planthoppers in Asia. *Planthoppers: new threats to the sustainability of intensive rice production systems in Asia*, 191-220.

Cha, Y.S., Ji, H., Yun, D.W., Ahn, B.O., Lee, M.C., Suh, S.C., and Sohn, J.K. (2008). Fine mapping of the rice *Bph1* gene, which confers resistance to the brown planthopper (*Nilaparvata lugens* Stal), and development of STS markers for marker-assisted selection. *Molecules and Cells (Springer Science and Business Media BV)*, *26*(2): 146-151.

Chakravarthi, B.K., and Naravaneni, R. (2006). SSR marker based DNA fingerprinting and diversity study in rice (*Oryza sativa* L). *African Journal of Biotechnology*, *5*(9): 684-688.

Chen, X., Temnykh, S., Xu, Y., Cho, Y.G., and McCouch, S.R. (1997). Developmentof a microsatellite framework map providing genome wide coverage in rice (*Oryza sativa* L.). *Theoretical and Appllied Genetics*, *95*: 553-567.

Chen, J., Wang W., Pang, X.F. and Pan, Q.H. (2006). Genetic analysis and fine mapping of a rice brown planthopper *Nilaparvata lugens* Stal resistance gene *bph19(t). Molecular Genetics andGenomics*, *275*: 321–329

Chen, Y.H. (2009). Variation in planthopper-rice interactions: possible interactions among three species. *Planthoppers: new threats to the sustainability of intensive rice production systems in Asia, Heong KL and Hardy B (eds). Los Baños (Philippines)*, 315-326.

Cheng, X., Zhu, L., and He, G. (2013). Towards understanding of molecular interactions between rice and the brown planthopper. *Molecular Plant, 6*: 621–634.

Chopra, R.K., and Sinha, S.K. (1998). Prospects of success of biotechnological approaches for improving tolerance to drought stress in crop plants. *Current Science*, 74: 25-34.

Choudhury, B., Khan, M.L., and Dayanandan, S. (2013). Genetic structure and diversity of indigenous rice (*Oryza sativa*) varieties in the Eastern Himalayan region of Northeast India. *Springer Plus*, *2*(1): 228.

Coburn, J., Temnykh, S., Paul, E., and McCouch, S.R. (2002). Design and application of microsatellite marker panels for semi- automated genotyping of rice (*Oryza sativa* L.). *Crop Science*, *42*: 2092-2099.

Coffman, W.R. and Herrera, R.M. (1980). Rice. In: *Hybridization of Crop Plants* (Fehr, W.R. and Hardley, H.H., eds). American Society of Agronomy, Madison, pp. 511-522.

Collard, B.C., and Mackill, D.J. (2008). Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *363*(1491): 557-572.

Cohen, M. B., Alam, S. N., Medina, E. B., and Bernal, C. C. (1997). Brown planthopper, *Nilaparvata lugens*, resistance in rice cultivar IR64: mechanism and role in successful *Nilaparvata lugens* management in Central Luzon, Philippines. *Entomologia Experimentalis et Applicata*, *85*(3): 221-229.

Cook, A. G., Woodhead, S., Magalit, V. F., and Heinrichs, E. A. (1987). Variation in feeding behaviour of Nilaparvata lugens on resistant and susceptible rice varieties. *Entomologia Experimentalis et Applicata*, *43*(3), 227-235.

Cooke, R. J. (1995). Variety identification of crop plants. In: New Diagnostics in Crop Science. eds. Skerrit, J. H. and R. Appels, Biotechnology in Agriculture No. 13. CAB International,Wallingford, UK, p.33-63.

Costa, R., Pereira, G., Garrido, I., Tavares-de-Sousa, M. M., and Espinosa, F. (2016). Comparison of RAPD, ISSR, and AFLP molecular markers to reveal and classify orchardgrass (*Dactylis glomerata* L.) germplasm variations. *PLoS One*, *11*(4): e0152972.

Cruz, P.A., Arida, A., Heong, K.L., Horgan, F.G. (2011). Aspects of brown planthopper adaptation to resistant rice varieties with the *Bph3* gene. *Entomologia Experimentalis et Applicata*, 141:245–257.

Cruz, A. P. (2010). Brown planthopper (*Nilaparvata lugens* Stal.) (Delphaciedae: family) adaptation to rice resistance genes. (Doctoral dissertation). Public University of Navarre (UPNA), Spain.

Das, B., Sengupta, S., Parida, S.K., Roy, B., Ghosh, M., Prasad, M., and Ghose, T.K. (2013). Genetic diversity and population structure of rice landraces from Eastern and North Eastern States of India. *BMC genetics*, *14*(1), 71.

DOA (2015). Perangkaan Padi 2014. Jabatan Pertanian Malaysia.

Du, B., Zhang, W., Liu, B., Hu, J., Wei, Z., Shi, Z., and He, G. (2009). Identification and characterization of Bph14, a gene conferring resistance to brown planthopper in rice. *Proceedings of the National Academy of Sciences*, *106*(52), 22163-22168.

Dixit, S. (2014). *Fine mapping of QTLs for grain yield and yield related traits under water stress condition in rice (Oryza sativa* L.*)* (Doctoral dissertation) Indira Gandhi Krishi Vishwavidyalaya, Raipur.

Dyck, V.A. and Thomas, B. (1979). The brown planthopper problem: Threat to Rice Production in Asia. International Rice Research Institute, Los Banos, pp. 3-17.

Fernando, H, Senadhera, D., Elikawela, Y., Alwis, H.M.D and Kudagamage, C. (1979*)*. Varietal resistance to the brown planthopper in Sri Lanka. In : Kalode M B and Khrishna T S (ed) *Brown Planthopper: Threat to Rice Production in Asia.* Pp 241-49. International Rice Research Institute, Los Banos, Philippines.

Fischer, K., and Fiedler, K. (2000). Response of the copper butterfly *Lycaena tityrus* to increased leaf nitrogen in natural food plants: evidence against the nitrogen limitation hypothesis. *Oecologia*, *124*(2), 235-241.

Fisk J. 1980. Effects of hydrogen. Entomologia Experimentalis et Applicata. 27:211-222.

Fujita, D., Kohli A. and Horgan F.G. (2013). Rice Resistance to Planthoppers and Leafhoppers. *Critical Reviews in Plant Sciences*, *32*:3, 162-191.

Fukuda, K. (1934). Investigation on the brown planthopper. *Bulletin Agricultural Division Central Research Institute (Government of Formosa),* 99: 1-19.

Garris, J., Thomas, H. T., Coburn, J., Kresovich, S., and McCouch, S. (2005). Genetic Structure and Diversity in *Oryza sativa* L. Genetics Society of America *169* (3):1631-1638.

Ghaffar, M.B.A., Bakar, N.T.A., Pritchard, J., and Lloyd, B.F. (2016). Identification of candidate genes involved in brown planthopper resistance in rice using microarray analysis. *Journal of Tropical Agriculture and Food Science*, *44*(1), 49-62.

Ghaffar, M.B.A. (2012). *Transcripttomics Analysis of Phloem-feeding insect resistance in rice germplasm* (Doctoral dissertation). University of Birmingham, United Kingdom.

Ghaffar, M.B.A., Pritchard, J., and Ford-Lloyd, B. (2011). Brown planthopper (*N. lugens* Stal) feeding behaviour on rice germplasm as an indicator of resistance. *PLoS One*, *6*(7), e22137.

Gianessi, L. (2013). Insecticides are key for managing brown planthoppers in Japanese Rice Fields. *International Pesticide Benefits*, Case study no 82, Washington, DC, August, 2013.

Ghosh, A., Samanta, A., and Chatterjee, M.L. (2014). Dinotefuran: A third generation neonicotinoid insecticide for management of rice brown planthopper. *African Journal of Agricultural Research*, 9(8): 750-754.

Habibuddin, H. (1989). Variation of brown planthopper population from major rice regions of Peninsular Malaysia. *MARDI Research Journal, 17(2): 218-224*.

Habibuddin, H. (2012). Managing pests and diseases of rice using resistant varieties. *Research Inaugural Lecture*, MARDI, Serdang, Selangor, March 15, 2012. 41p

Habibuddin, H., Ahmad, I.B., Mahir, A.M., Jalani, S., Imbe, T., and Omura, T. (1994). Differentiation of vector and virus resistance in several rice varieties to tungro disease. *MARDI Research Journal, 22 (1)*, 157-67.

Harini, A.S., Kumar, S.S., Balaravi, P., Sharma, R., Dass, M.A., and Shenoy, V. (2013). Evaluation of rice genotypes for brown planthopper (BPH) resistance using molecular markers and phenotypic methods. *African Journal of Biotechnology*, *12*(19): 2515-2525.

Hattori, M. and Sogawa, K. (2002). Oviposition behavior of the rice brown planthopper, *Nilaparvata lugens* (Stål), and its electronic monitoring. *Journal Insect Behavior*, 15: 283-293.

Hattori, M. and Sogawa, K. (2002). Oviposition behavior of the rice brown planthopper, *Nilaparvata lugens* (Stål), and its electronic monitoring. *Journal Insect Behavior*, 15: 283-293.

Hearne, C.M., Ghosh, S. and Todd, J.A. (1992). Microsatellite for linkage analysis of genetic traits.*Trends in Genetics*, 8: 288-294.

Heinrichs, E. A. (1979). Control of leafhopper and planthopper vectors of rice viruses in leafhopper vectors and planthopper disease agents (eds. K. Moramorosch and K.F. Arris), *Academic Press, New York*. pp. 529-558.

Heinrichs, E.A. (1985). *Genetic evaluation for insect resistance in rice*. International Rice Research Institute.

Heong, K.L., and Hardy, B. (Eds.). (2009). *Planthoppers: new threats to the sustainability of intensive rice production systems in Asia*. International Rice Research Institute.

Heong, K.L., Manza, A., Catindig, J., Villareal, S., and Jacobsen, T. (2007). Changes in pesticide use and arthropod biodiversity in the IRRI research farm. *Outlooks on Pest Management*, *18*(5): 229.

Heong, K.L., Cheng, J., and Escalada, M.M. (2016). *Rice Planthoppers*. Springer.

Hirabayashi, H., and Ogawa, T. (1995). RFLP mapping of *Bph-1* (brown planthopper resistance gene) in rice. *Japanese Journal of Breeding*, *45*(3): 369-371.

Horber, E. (1972). Plant resistance to insects. *Agricultural Science Review*, *10*(2), 1.

Horgan, F.G., Srinivasan, T.S., Naik, B.S., Ramal, A.F., Bernal, C.C., and Almazan, M.L.P. (2016). Effects of nitrogen on egg-laying inhibition and ovicidal response in planthopper-resistant rice varieties. *Crop Protection*, *89*: 223-230.

Huang, N., Parco, A., Mew, T., Magpantay, G., McCouch, S., Guiderdoni, E., and Khush, G.S. (1997). RFLP mapping of isozymes, RAPD and QTLs for grain shape, brown planthopper resistance in a doubled haploid rice population. *Molecular Breeding*, *3*(2): 105-113.

Hu, G., Lu, F., Zhai, B.P., Lu, M.H., and Liu, W.C. (2014). Outbreaks of the Brown Planthopper. *Nilaparvata lugens* (Sta°l) in the Yangtze River Delta: Immigrationor Local Reproduction. *PLoS One*, 9(2): e88973.

Hu, J., Xiao, C., Cheng, M., Gao, G., Zhang, Q., and He, Y. (2015). Fine mapping and pyramiding of brown planthopper resistance genes *QBph3* and *QBph4* in an introgression line from wild rice O. officinalis. *Molecular Breeding*, *35*(1): 3.

Hu, J., Xiao, C., and He, Y. (2016). Recent progress on the genetics and molecular breeding of brown planthopper resistance in rice. *Rice*, *9*(1): 1-12.

Huang, J., Qiao, F., Zhang, L., and Rozelle, S. (2001). Farm pesticides, rice production, and human health in China. Research Report, No. 2001-RR3, Economy and Environment Program for Southeast Asia, Singapore.

Huang, Z., He, G., Shu, L., Li, X., and Zhang, Q. (2001). Identification and mapping of two brown planthopper resistance genes in rice. *TAG Theoretical and Applied Genetics*, *102*(6): 929-934.

IRRI, (2016). IR8, world's first high-yielding rice, turns 50. International Rice Research Institute. Retrieved from http://irri.org.
IRRI, (2014) *World Rice Statistics*. International Rice Research Institute, Manila, Los Banos, Philippine.
IRRI, (2011). Media releases supports stop insecticide use in the rice. International Rice Research Institute. Retrieved from http://irri.org.
IRRI, (2012). Preventing planthopper outbreaks in rice. International Rice Research Institute, Los Banos, Philippines. Retrieved from http://www.irri.org.
IRRI (1998). Standard Evaluation System for Rice (SES). Los Baños, Philippines: International Rice Research Institute.
IRRI, (1986). Rice Genetics: Proceedings of the International Rice Genetics Symposium, 27–31 May 1985. International Rice Research Institute, P.O. Box 933, Manila, Philippines. 932 pp. Retrieved from http://books.irri.org.
IRRI. (1970). The International Rice Research Institute annual report for 1969. Manila: Philippines.
Ishii, T., Brar, D.S., Multani, D.S., and Khush, G.H. (1994). Molecular tagging of genes for brown planthopper resistance and earliness introgressed from *Oryza autraliensis* into cultivated rice *Oryza sativa*. *Genome* 37: 217-221.
Ito, K., Wada, T., Takahashi, A., Noor, N.S., and Habibuddin, H. (1994). Brown planthopper *Nilaparvata lugens* Stål (Homoptera: Delphacidae) biotypes capable of attacking resistant rice varieties in Malaysia. *Applied Entomology and Zoology*, *29*(4): 523-532.
Jairin, J. (2008). High-resolution mapping of a brown planthopper (BPH) resistance gene, *Bph3*, and marker-assisted selection for BPH resistance in rice (Doctoral dissertation). Kasetsart University, Bangkok, Thailand.
Jairin, J., Phengrat, K., Teangdeerith, S., Vanavichit, A., and Toojinda, T. (2007a). Mapping of a broad-spectrum brown planthopper resistance gene, *Bph3*, on rice chromosome 6. *Molecular Breeding*, 19: 35–44.
Jairin, J., Teangdeerith, S., Leelagud, P., Phengrat, K., Vanavichit, A., and Toojinda, T. (2007b). Detection of brown planthopper resistance genes from different rice mapping populations in the same genomic location. *Science Asia*, *33*: 347-352.
Jakowitsch, J., Mette, M. F., van Der Winden, J., Matzke, M.A., and Matzke, A.J.M. (1999). Integrated pararetroviral sequences define a unique class of dispersed repetitive DNA in plants. *Proceedings of the National Academy of Sciences*, *96*(23): 13241-13246.
Jena, K.K. (2010). The species of the genus Oryza and transfer of useful genes from wildspecies into cultivated rice, *Oryza sativa. Breeding Science* 60: 518-523.
Jena, K.K., and Kim, S.M. (2010). Current Status of Brown Planthopper (BPH) Resistance. *Genetics.Rice*, 3:161–171.
Jena, K.K., Jeung, J.U., Lee, J.H., Choi, H.C., and Brar, D.S. (2006). High-resolution mapping of a new brown planthopper (BPH) resistance gene, *Bph 18(t)*, and marker-assisted selection for BPH resistance in rice (*Oryza sativa* L.). *Theoretical Applied Genetics*, 112: 288-297.
Jeon, Y.H., Ahn, S.N., Choi, H.C., Hahn, T.R., and Moon, H.P. (1999). Identification of a RAPD marker linked to a brown planthopper resistance gene in rice. *Euphytica*, *107*(1): 23-28.
Jiang, G.L. (2013). Plant marker-assisted breeding and conventional breeding: challenges and perspectives. *Advance in Crop Science and Technology*, *1*, e106.

Jordan, S.A. and Humpheries, P. (1994). Single nucleotide polymorphism in exon 2 of the BCP gene on 7q31 - q35. *Human Molecular Genetics*, 3: 1915-1917.

Kabir, M.A., Khush, G.S. (1988) Genetic analysis of resistance to brown planthopper in rice (*O. sativa* L). *Plant Breeding*, 100: 54–58.

Kalode, M.B. (1976). Brown planthopper in rice and its control. *Indian farming*, *27*(5): 3-5.

Kaneda, C. (1982). Breeding approaches for resistance to BPH in Japan. In *International Rice Research Conference*.

Karuppaiah, V., and Sujayanad, G.K. (2012). Impact of Climate Change on Population Dynamics of Insects Pests. *World Journal of Agricultural Sciences* 8(3): 240-246.

Kaur, G. (2011). Biology of Brown planthopper, *Nilaparvata lugens* (Stal) on rice (Doctoral dissertation, Punjab Agricultural University Ludhiana).

Kawaguchi, M., Murata, K., Ishii, T., Takumi, S., Mori, N., and Nakamura, C. (2001). Assigment of a brown planthopper (*Nilaparvata lugens* Stål) resistance gene *bph4* to the rice chromosome 6. *Breeding Science,* 51: 13-8.

Kelly, J.D., and Miklas, P.N. (1998). The role of RAPD markers in breeding for disease resistance in common bean. *Molecular Breeding*, *4*(1): 1-11.

Kenmore, P.E., Perez, C.A., Dyck, V.A., and Gutierrez, A.P. (1984). Population regulation of the rice brown planthopper (*Nilaparvata lugens* Stål) within rice fields in the Philippines. *Journal of plant protection in the Tropics*, *1*(1): 19-37.

Khush, G.S. (1984). Breeding rice for resistance to insects. *Protection Ecology*, *7*(2-3): 147-165.

Khush, G.S. (1979). Genetics of and breeding for resistance to the brown planthopper. *Brown planthopper: Threat to rice production in Asia*, 321-332.

Kim, S.M., and Sohn, J.K. (2005). Identification of a rice gene (*Bph 1*) conferring resistance to brown planthopper (Nilaparvata lugens Stal) using STS markers. *Molecules and Cells (Springer Science and Business Media BV)*, *20*(1): 30-34.

Kobayashi, T., Yamamoto, K., Suetsugu, Y., Kuwazaki, S., Hattori, M., Jairin, J., Sanada-Morimura, S., Matsumura, M. (2014). Proceedings from The Royal Society of London '14: *Genetic mapping of the rice resistance breaking gene of the brown planthopperNilaparvata lugens*, United Kingdom.

Kochert, G. (1994). RFLP technology. In: DNA-Based Markers in Plants. (Eds.) Philips, R.L. and I.K. Vasil (pp. 8-38). Dordrecht: Kluwer Academic Publishers.

Kogan, M., and Ortman, E.F. (1978). Antixenosis–a new term proposed to define Painter's “non preference” modality of resistance. *Bulletin of the ESA*, *24*(2): 175-176.

Krishnaiah, N.V. (2014). A Global Perspective of Rice Brown Planthopper Management I Crop-Climatic Requirement, *International Journal of Molecular Zoology*, 4(2): 9-18.

Krishnaiah, N.V. (2016). Varietal resistance breaking ability and insecticide resistance developing ability of BPH-Is there any relation between the two?. *Molecular Entomology*, *7*(1): 1-9.

Kumari, S., Sheba, J.M., Marappan, M., Ponnuswamy, S., Seetharaman, S., Pothi, N., and Natesan, S. (2010). Screening of IR50× Rathu Heenati F7 RILs and Identification of SSR Markers Linked to Brown Planthopper (*Nilaparvata lugens Stål*) Resistance in Rice (*Oryza sativa* L.). *Molecular Biotechnology*, *46*(1): 63-71.

Lagercrantz, U., Ellegren, H., and Andersson, L. (1993). The abundance of various polymorphic microsatellite motifs differs between plants and vertebrates. *Nucleic Acids Research*, *21*(5): 1111-1115.

Latif, M.A. (2000). *Morphological, Molecular Genetic and Host Plant Relationship Studies of Rice and Weed Infesting Populations of Brown Planthopper, Nilaparvata lugens (Stål) (Homoptera: Delphacidae)* (Doctoral dissertation). Universiti Putra Malaysia.

Lakshminarayana, A., and Khush, G.S. (1977). New genes for resistance to the brown planthopper in rice. *Crop Science*. 17: 96-100.

Li, C., Luo, C., Zhou, Z., Wang, R., Ling, F., Xiao, L., Lin, Y., and Chen, H. (2017). Gene expression and plant hormone levels in two contrasting rice genotypes responding to brown planthopper infestation. *BMC Plant Biology*. Doi: 10.1186/s12870-017-1005-7.

Li, H., Ye, G., and Wang, J. (2006). A modified algorithm for the improvement of composite interval mapping. *Genetics*, 175: 361-374.

Li, M.Y., Lin, H.F, Li, S.G., Xu, A.M and Feng, M.F. (2012). Efficiency of entomopathogenic fungi in the control of eggs of the brown planthopper *Nilaparvata lugens* Stål (Homopera: Delphacidae). *African Journal of Microbiology Research*, 6(44): 7162-7167.

Li, S., Wang, J., and Zhang, L. (2015). Inclusive composite interval mapping of QTL by environment interactions in biparental populations. *PLoS one*, *10*(7), e0132414.

Lim, G.S., and Heong, K.S. (1977). Recent brown planthopper incidence and its implications in Malaysia. *International Rice Research Newsletter,* 2(6): 14-15.

Lim, G.S., Ooi, P.A.C., and Koh, A.K. (1980). Brown planthopper outbreaks and associated yield losses in Malaysia. *International Rice Research Newsletter*, *5*(1): 15-16.

Lin, K.S. (1958). Control of rice hoppers based on their behaviour and population changes*. Plant Protection Bulletin,* 5: 17-18.

Liu G., Saxena R.C. and Wilkins R.M. (1994). Behavioral responses of the whitebacked planthopper, *Sogatella furcifera* (Homoptera: Delphacidae) on rice plants whose
odors have been masked. In: Journal of Insect Behaviour. 7: 343-353.

Liu, G., Yan, H., Fu, Q., Qian, Q., Zhang, Z., Zhai, W., and Zhu, L. (2001). Mapping of a new gene for brown planthopper resistance in cultivated rice introgressed fromOryza eichingeri. *Chinese Science Bulletin*, *46*(17): 1459-1462.

Liu, Y., Chen, L., Liu, Y., Dai, H., He, J., Kang, H., Pan, G., Huang, J., Qiu, Z., Wang Q., Hu, J., Liu, L., Chen, Y., Cheng, X., Jiang, L., and Wan, J. (2016). Marker-assisted pyramiding of two brown planthopper resistance genes, *Bph3* and *Bph27* (t), into elite rice Cultivars. *Rice Open Access pp 1-7*. Doi: 10.1186/s12284-016-0096-3.

Lv, W., Du, B., Shangguan, X., Zhao, Y., Pan, Y., Zhu, L., and He, G. (2014). BAC and RNA sequencing reveal the brown planthopper resistance gene BPH15 in a recombination cold spot that mediates a unique defense mechanism. *BMC genomics*, *15*(1), 674.

Mamadou, G., Chengye, Y., Omboki, R.B., Xiaojian, W., Guo, X., Xin, M.C.H., Mou, T. (2015). Developing rice restorer lines resistant to bacterial blight, blast and brown planthopper by molecular pyramiding. *International Journal of Agronomy and Agricultural Research* (IJAAR). 7(4): 155-165.

Manikandan, N., Kennedy, J. S., Geethalakshmi, V. (2015). Effect of temperature on life history parameters of brown planthopper (*Nilaparvata lugens* Stal). *African Journal of Agricultural Research*, 10(38): 3678-3685.

MARDI. 2006. MR219 – Varieti padi tinggi sesuai untuk tabur terus. Retrieved from http://www.mardi.my.

Matsubayashi, M., R. Ito., T. Nomoto., T, Takase., and N., Yamada. (eds.). (1965). Theory and practice of growing rice. Fuji Publishing Co., Tokyo.

McCouch, S.R., Teytelman, Y., Xu, K., Lobos, B., Clare, K., Walton, M., Fu, B., Maghirang, R., Li, Z., Xing, Y., Zhang, Q., Kono, I., Yano, M., Jellstrom, R.F, De Clerck, G., Schneider, D., Cartinhour, S., Ware, D., and Stein, L. (2002). Development and mapping of 2240 new SSR markers for rice (*Oryza sativa* L.). *DNA Research*, 9: 199-207.

McCouch, S.R., Temnykh, S., Lukashova, A., Coburn, J., Declerck, G., Cartinhour, S. (2001). Microsatellite markers in rice: Abundance, diversity and applications. In: Rice genetics IV (pp. 117-135). IRRI, Manila, Philippines.

McCouch, S.R., Chen, X., Panaud, O., Temnykh, S., Xu, Y., Cho, Y.G., Huang, N., Ishii, T., and Blair, M. (1997). Microsatellite marker development, mapping and applications in rice genetics and breeding. *Plant Molecular Biology*, 35: 89-99.

McCouch, S.R., Chen, X., Panaud, O., Temnykh, S., Xu, Y., Cho, Y.G., and Blair, M. (1997). Microsatellite marker development, mapping and applications in rice genetics and breeding. In *Oryza: From Molecule to Plant* (pp. 89-99). Springer Netherlands.

Mekonnen, T., Haileselassie, T., and Tesfaye, K. (2017). Identification, mapping and pyramiding of genes/quantitative trait loci (QTLs) for durable resistance of crops to biotic stress. *Journal of Plant Pathology and Microbiology*, 8: 6. Doi: 10.4172/2157-7471.1000412.

Merrill, R.M., Gutiérrez, D., Lewis, O.T., Gutiérrez, J., Díez, S.B., and Wilson, R.J. (2008). Combined effects of climate and biotic interactions on the elevational range of a phytophagous insect. *Journal of Animal Ecology*, *77*(1): 145-155.

Miah, G., Rafii, M.Y., Ismail, M.R., Puteh, A.B., Rahim, H.A., Asfaliza, R., and Latif, M.A. (2013). Blast resistance in rice: a review of conventional breeding to molecular approaches. *Molecular Biology Reports*, *40*(3): 2369-2388.

Moose, S.P. and Mumm, R.H. (2008). Molecular Plant Breeding as the Foundation for 21stCentury Crop Improvement. *Plant Physiology*, 147: 969-977.

Mui, P.T., and Bong, B. (1999). Evaluation of rice varieties for resistance to brown planthopper in the Mekong Delta. *Omonrice*, *7*(1): e7.

Muir, F., and Giffard, W.M. (1924). Studies in North American Delphacidae (Homoptera). *Bulletin of the Hawaiian Sugar Planter's Association (Entomological Series)*, *15*: 1-53.

Murata, K., Fujiwara, M., Murai, H., Takumi, S., Mori, N., and Nakamura, C. (2001). Mapping of a brown planthopper (*Nilaparvata lugens* Stål) resistance gene *Bph9* on the long arm of rice chromosome 12. *Cereal Research Communications*, 245-250.

Mustapha, N.H. (1996). Sustainable development of Malaysian rice industry in the context of Asian countries: an assessment. *Jurnal Ekonomi Malaysia*, *30*: 67-86.

Myint, K,K.M., Fujita, D., Sonoda, T., Yoshimura, A., Yasui, H., Matsumura, M. (2012). Mapping and pyramiding of two major genes for resistance to the brown planthopper *Nilaparvata lugens* Stal in the rice cultivar ADR52. *Theoretical and Applied Genetics*, 124:495–504.

Nanthakumar, M., Lakshmi, V.J., Shashi Bhushan, V., Balachandran, S.M., Mohan, M. (2012). Decrease of rice plant resistance and induction of hormesis and carboxylesterase titre in brown planthopper, *Nilaparvata lugens* (Stål) by xenobiotics. *Pesticide Biochemistry and Physiology*, 102: 146–152.

Nasu, S. (1967). Rice leafhoppers : The major insect pests of the rice plant. Pp 493-523. Johns Hopkins University Press, Baltimore, Md. (USA).

Nazuri, N.S., and Man, N. (2016). Acceptance and Practices on New Paddy Seed Variety Among Farmers in MADA Granary Area. *Academic Journal of Interdisciplinary Studies*, *5*(2): 105.

Norimah, J.A., Safiah, M., Jamal, K., Haslinda, S., Zuhaida, H., Rohida, S., and Zalilah, M.S. (2008). Food Consumption Patterns: Findings from the Malaysian Adult Nutrition Survey (MANS). *Malaysian Journal of Nutrition*, *14*(1): 25-39.

Odeomenem, I.U. and Inakwu, J.A. (2011). Economic analysis of rice production in Cross River State, Nigeria. Journal *of Development and Agricultural Economics*, 3(9): 469-474.

Oladosu, Y., Rafii, M.Y., Abdullah, N., Abdul Malek, M., Rahim, H.A., Hussin, G., and Kareem, I. (2014). Genetic Variability and Selection Criteria in Rice Mutant Lines as Revealed by Quantitative Traits. *The Scientific World Journal*, *2014*, 190531. http://doi.org/10.1155/2014/190531

Ortiz-Lopez, A., Chang, H.C., and Bush, D.R. (2000). Amino acid transporters in plants. *Biochimica et Biophysica Acta (BBA)-Biomembranes*, *1465*(1): 275-280.

Otuka, A. (2013). Migration of rice planthoppers and their vectored re-emerging and novel rice viruses in East Asia. *Frontiers in Microbiology*, *4*.

Pacific, P.A. (2010). Rice Plant Hopper Outbreaks: A Man-Made Plague Rice Sheets.Retrieved from http://www.panap.net.

Paguia, P., Pathak, M.D., and Heinrichs, E.A. (1980). Honeydew excretion measurement techniques for determining differential feeding activity of biotypes of *Nilaparvata lugens* on rice varieties. *Journal of Economic Entomology*, *73*(1): 35-40.

Painter, R.H. (1951). *Insect Resistance in Crop Plants*. The Macmillan Company New York.

Panaud, O., Chen, X., and McCouch, S.R. (1996). Development of microsatellite markers and characterization of simple sequence length polymorphism (SSLP) in rice (*Oryza sativa* L.). *Molecular and General Genetics*, 252: 597-607.

Panaud, O., Chen, X., McCouch, S.R. (1995). Frequency of microsatellite sequences in rice (*Oryza sativa* L.). *Genome*, 38: 1170-1176.

Panda, N. and Khush, G.S. (1995). *Host plant resistance to insects*. Wallingford, UK: CABInternational.

Panda, N., and Heinrichs, E.A. (1983). Levels of tolerance and antibiosis in rice varieties having moderate resistance to the brown planthopper, *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae). *Environmental Entomology*, *12*(4): 1204-1214.

Panse, V.G., and Sukhatme, P.V. (2000). Statistical Methods for Agricultural Workers. *Indian Council for Agricultural Research*, pp. 68-87.

Pathak, M.D., and Khan, Z.R. (1994). *Insect pests of rice*. International Rice Research Institute.

Pathak, P.K., and Heinrichs, E.A. (1982). Bromocresol green indicator for measuring feeding activity of *Nilaparvata lugens* on rice varieties. *Philippines Entomologist*, *5*(195): e198.

Pathak, P.K., Saxena, R.C., and Heinrichs, E.A. (1982). Parafilm sachet for measuring honeydew excretion by *Nilaparvata lugens* on rice. *Journal of Economic Entomology*, *75*(2): 194-195.

Pathak, P.K. and Heinrichs, E.A. (1980). A rapid technique for estimation brown planthopper feeding activity. International Rice Research Newsletter. 5: 18-19.

Pathak, M.D., Cheng, C.H., and Fortuno, M.E. (1969). Resistance to *Nephotettix impicticeps* and *Nilaparvata lugens* in varieties of rice. *Nature*, *223*(5205): 502-504.

Paul, B. (2015). *Food security in Malaysia: Challenges and opportunities for Malaysia of present and in 2050 for maintaining foods security*. University of Alberta.

Piyaphongkul, J., Pritchard, J., and Bale, J. (2012). Can tropical insects stand the heat? A case study with the brown planthopper *Nilaparvata lugens* (Stål). *PLoS One*, *7*(1), e29409.

Qiu, Y., Guo, J., Jing, S., Zhu, L., and He, G. (2012). Development and characterization of japonica rice lines carrying the brown planthopper-resistance gene *Bph12* and *Bph6*. *Theoretical and Applied Genetics*, 124: 485–494.

Qiu, Y., Guo, J., Jing, S., Zhu, L., and He, G. (2010). High-resolution mapping of the brown planthopper resistance gene *Bph6* in rice and characterizing its resistance in the 9311 and Nipponbare near isogenic backgrounds. *Theoretical and applied genetics*, *121*(8): 1601-1611.

Rahman, M.L., Jiang, W., Chu, S.H., Qiao, Y., Ham, T.H., Woo, M.O., and Brar, D.S. (2009). High-resolution mapping of two rice brown planthopper resistance genes, *Bph20* (t) and *Bph21* (t), originating from *Oryza minuta*. *Theoretical and Applied Genetics*, *119*(7): 1237-1246.

Raja, S., and Marappan, M. (2013). Irradiating seeds of Rathu Heenati and PTB33 with γ-rays at various doses and developing mutant populations (M1 generation) and evaluation. *International Journal of Plant Sciences*, 8(2): 365-370.

Rashid, M.M., Jahan, M., and Islam, K.S. (2016). Impact of Nitrogen, Phosphorus and Potassium on Brown Planthopper and Tolerance of Its Host Rice Plants. *Rice Science*, *23*(3): 119−131.

Rathnathunga, E.U.U., Senanayake, G., Dissanayake, N., Seneweera, S., and Geekiyanage, S. (2016). Development of a mini core collection from Sri Lankan traditional rice for flowering time variation. *Australian Journal of Crop Science*, *10*(9): 1357-1367.

Reddy, B.N., Lakshmi, V.J., Maheswari, T.U., Ramulamma, A., and Katti, G.R. (2016). Non preference/Antixenosis mechanism to brown plant hopper (*Nilaparvata lugens* Stal) in selected rice entries. *Journal of Research PJTSAU*, *44*(1/2): 1-10.

Renganayaki, K., Fritz, A.K., Sadasivam, S., Pammi, S., Harrington, S.E., McCouch, S.R., and Reddy, A.S. (2002). Mapping and progress toward map-based cloning of brown planthopper biotype-4 resistance gene introgressed from into cultivated rice. *Crop science*, *42*(6): 2112-2117.

Ribaut, J.M., and J, Betran. (1999). Single large-scale marker-assisted selection (SLS-MAS). *Molecular Breeding*, 5: 531-541.

Ripper, W.E. (1956). Effect of pesticides on balance of arthropod populations. *Annual Review of Entomology.* 1: 403–438.

Sable, M.G., and Rana, D. K. (2016). Impact of global warming on insect behavior-A review. *Agricultural Reviews*, *37*(1): 81-84.

Salgotra, R.K., Gupta, B.B., Bhat, J.A., and Sharma, S. (2015). Genetic diversity and population structure of Basmati rice (*Oryza sativa* L.) germplasm collected from North Western Himalayas using trait linked SSR markers. *PloS one*, *10*(7), e0131858.

Sandhu, C. (2014). Effect of temperature on developmental and reproductive physiology of Sogatella furcifera (Horvath) on rice(Doctoral dissertation, Punjab Agricultural University, Ludhiana).

Sangha, J.S., Chen, Y.H, Kaur, J., Khan, W., Abduljaleel, Z., Alanazi, M.S., Mills, A., Adalla, C.B., Bennett, J., Prithiviraj, B., Jahn, G.C., and Leung, H. (2013). Proteome Analysis of Rice (*Oryza sativa* L.) Mutants Reveals Differentially Induced Proteins during Brown Planthopper(*Nilaparvata lugens*) Infestation. *International Journal of Molecular Sciences,* 14: 3921-3945.

Sarao, P.S., Sahi, G.K., Neelam, K., Mangat, G.S., Patra, B.C., Singh, K. (2016). Donors for Resistance to Brown Planthopper *Nilaparvata lugens* (Stål) from Wild Rice Species. *Rice Science*, 23(4): 219-224.

Saxena, R.C., and Pathak, M.D. (1977). Factor affecting resistant of rice varieties to the brown planthopper, *Nilaparvata lugens*. In *Proceedings of 8th Annual Conference of Pest Control Council of the Phillipines, Bacolod City* (pp. 18-20).

Saxena, R.C. (1986). Biochemical bases of insect resistance in rice varieties, pp. 142–149,*in* M.B. Green and P. Hedin (eds.). Natural Resistance of Plants to Pests: Roles of Allelochemicals. American Chemical Society, Washinton, D.C.

Saxena, R.C. (1989). Durable resistance to insect pests of irrigated rice. *Progress in Irrigated Rice Research*, 111-32.

Schuelke, M. (2000). An economic method for the fluorescent labeling of PCR fragments. *Nature Biotechnology*, 18(2): 233-234.

Sehgal, D., Singh, R., and Rajpal, V.R. (2016). Quantitative trait loci mapping in plants: Concepts and approaches. *Molecular Breeding for Sustainable Crop Improvement*. Springer International Publishing. (pp. 31-59).

Shabanimofrad, M., Rafii, M.Y., Ashkani, S., Hanafi, M.M., Adam, N.A., Harun, A.R., Latif, M.A., Miah, G., Sahebi, M., and Azizi, P. (2017). Mapping of QTLs conferring resistance in rice to brown planthopper, *Nilaparvata lugens*. *Entomologia Experimentalis et Applicata*, *162*(1): 60-68.

Sharma, P.N., Torii, A., Takumi, S., Mori, N., and Nakamura, C. (2004). Marker-assisted pyramiding of brown planthopper (*Nilaparvata lugens* Stal.) resistance genes *Bph1* and *Bph2* on rice chromosome 12. *Hereditas*, 140 (1): 61-69.

Sidhu, G.S., and Khush, G.S. (1978). Genetic analysis of brown planthopper resistance in twenty varieties of rice, *Oryza sativa* L. *TAG Theoretical and Applied Genetics*, *53*(5): 199-203.

Singh, N., Choudhury, D.R., Tiwari, G., Singh, A.K., Kumar, S., Srinivasan, K., and Singh, R. (2016). Genetic diversity trend in Indian rice varieties: an analysis using SSR markers. *BMC genetics*, *17*(1): 127.

Smith, C.M., Khan, Z.R., and Pathak, M.D. (1993). *Techniques for evaluating insect resistance in crop plants*. CRC press.

Sogawa, K., and Pathak, M.D. (1970). Mechanisms of brown planthopper resistance in Mudgo variety of rice (Hemiptera: Delphacidae). *Applied Entomology and Zoology*, *5*(3): 145-158.

Sogawa, K., Liu, G.J., and Shen, J.H. (2003). A review on the hyper-susceptibility of Chinese hybrid rice to insect pests. *Chinese Journal of Rice Science*, 17: 23–30.

Sogawa, K. (2015). Planthopper outbreaks in different paddy ecosystems in Asia: man-made hopper plagues that threatened the green revolution in rice. In *Rice Planthoppers* (pp. 33-63). Springer Netherlands.

Soundararajan, R.P., Gunathilagaraj, K., Chitra, N., Maheswaran, M., and Kadirvel, P. (2005). Mechanisms and genetics of resistance to brown planthopper, *Nilaparvata lugens* (Stal) in rice, *Orvza sativa* L.–A review. *Agricultural reviews*, *26*(2): 79-91.

Srivastava, P.N., and Auclair, J.L. (1975). Role of single amino acids in phagostimulation, growth, and survival of Acyrthosiphon pisum. *Journal of Insect Physiology*, *21*(11): 1865-1871.

Su, C.C., Wan, J., Zhai, H.Q., Wang, C.M., Sun, L.H., Yasui, H., and Yoshimura, A. (2005). A new locus for resistance to brown planthopper identified in the indica rice variety DV85. *Plant breeding*, *124*(1): 93-95.

Subudhi, P.K., and Huang, N. (1999). RAPD mapping in a doubled haploid population of rice (*Oryza sativa* L.). *Hereditas*, 130: 41 -49.

Suh, J.P., Yang, S.J., Jeung, J.U., Pamplona, A., Kim, J.J., Lee, J.H., Hong, H.C., Yang, C.I., Kim, Y.G., Jena, K.K. (2011). Development of elite breeding lines conferring *Bph18* gene-derived resistance to brown planthopper (BPH) by marker-assistedselection and genome-wide background analysis in japonica rice (*Oryza sativa* L.). *Field Crops Research*, 120: 215–222.

Sun, L.H, Su, C., Wang, C., Zai, H., and Wan, J. (2005). Mapping of a major resistance gene to brown planthopper in the rice cultivar Rathu Heenati. *Breeding Science*, 55: 391–6.

Sun, L.H., Wang, C.M., Su, C.C., Liu, Y.Q., Zhai, H.Q., and Wan, J.M. (2006). Mapping and marker-assisted selection of a brown planthopper resistance gene *bph2* in rice (*Oryza sativa* L.). *Acta Genetica Sinica*, *33*(8): 717-723.

Tahsin, S. (2012). *Molecular approaches to understand plant-insect interaction to enhance pest control* (Thesis dissertation). Newcastle University, Newcastle, United Kingdom.

Tao, C.H. (1966) Studies on biology of brown planthopper, *Nilaparvata lugens* Stal and its chemical control measures. *Annual Report* for 1965. *Taiwan Agricultural Research Institute*.

Temnykh, S., Declerck, G., Lukashova, A., Lipovich, L., Cartinhour, S., and McCouch, S. (2001). Computational and experimental analysis of microsatellites in rice (*Oryza sativa* L.,) frequency, length variation ,transposon associations, and genetic marker potential. *Genome Research*, 11: 1441-1452.

Thomson, L.J., Macfadyen, S., and Hoffmann, A.A. (2010). Predicting the effects of climate change on natural enemies of agricultural pests. *Biological control*, *52*(3): 296-306.

Thomson, M.J., Septiningsih, E.M., Suwardjo, F., Santoso, T.J., Silitonga, T.S., and McCouch, S.R. (2007). Genetic diversity analysis of traditional and improved Indonesian rice (*Oryza sativa* L.) germplasm using microsatellite markers. *Theoretical and Applied Genetics*, *114*(3): 559-568.

Thorburn, C. (2015). The rise and demise of integrated pest management in rice in Indonesia. *Insects*, *6*(2): 381-408.

Tong, L. (2008). Studies on direct-seeding adaptability of Cambodian rice cultivars and development of cultivars with good eating quality. *Plant Production Science*, *10*(1): 129-135.

Van Mai, T., Fujita, D., Matsumura, M., Yoshimura, A., and Yasui, H. (2015). Genetic basis of multiple resistance to the brown planthopper (*Nilaparvata lugens* Stål) and the green rice leafhopper (*Nephotettix cincticeps* Uhler) in the rice cultivar 'ASD7'(*Oryza sativa* L. ssp. indica). *Breeding Science*, *65*(5): 420-429.

Vanitha, K., Suresh, S., and Gunathilagaraj, K. (2011). Influence of brown planthopper *Nilaparvata lugens* (Stal.) feeding on nutritional biochemistry of rice plant. *Indian Journals,* 48: 142–146.

Vaughan, D.A., and Morishima, H. (2003). Biosystematics of the genus of Oryza. Chapter 1.2. In C. W. Smith, RH Dilday, (Eds.), *Rice Origin, History, Technology, and Production*. (pp. 27-65) New Jersey: John Wiley and Sons Inc. Publishers.

Vengedasalam, D., Harris, M., and MacAulay, G. (2011). Malaysian rice trade and government interventions. In *Conference Paper. Contributed paper presented to the 55th Annual Conference of the Australian Agricultural and Resource Economics Society, Melbourne* (pp. 8-11).

Visanuvimol, L., and Bertram, S.M. (2011). How dietary phosphorus availability during development influences condition and lifehistory traits of the cricket, *Acheta domesticus. Journal of Insect Science*, 11:1–17.

Vos, P.R., Hogers, M., Bleeker, M., Reijans, T.M., Van de Lee, M., Hornes, M., Fritjers, A., Pot, J., Peleman, J., Kuiper, M., and Zabeau, M. (1995). AFLP: a new technique for DNA fingerprinting. *Nucleic Acids Research*, 23: 4407-4414.

Wahab, A.G. (2017). Malaysia Grain and Feed Annual. *Global Agricultural Information Network Report, MY7001.*

Wang, F., Dang, C., Chang, X., Tian, J., Lu, Z., Chen, Y., and Ye, G. (2017). Variation among conventional cultivars could be used as a criterion for environmental safety assessment of Bt rice on nontarget arthropods. *Scientific Reports*, *7*: 41918.

Wang, Y., Li, H., Si, Y., Zhang, H., Guo, H., and Miao, X. (2012). Microarray analysis of broad-spectrum resistance derived from an *indica* cultivar Rathu Heenati. *Planta*, *235*(4), 829-840.

Wang, H.Y., Yang, Y., Su, J.Y., Shen, J.L., Gao, C.F., and Zhu, Y.C. (2008). Assessment of the impact of insecticides on Anagrus nilaparvatae (Pang et Wang) (Hymenoptera: Mymanidae), an egg parasitoid of the rice planthopper, *Nilaparvata lugens* (Hemiptera: Delphacidae). *Crop Protection*, *27*(3): 514-522.

Wang, G.L., Mackill, D.J., Bonman, J.M., McCouch, S.R., Champoux, M.C., and Nelson, R.J. (1994). RFLP mapping of genes conferring complete and partial resistance to blast in a durably resistant rice cultivar. *Genetics*, *136*(4): 1421-1434.

Way, M.J., and Heong, K.L. (1994). The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice-a review. *Bulletin of Entomological Research,* 84: 567-87.

Williams, J.G.K., Kubelik, A.R., Livak, K.J., Rafalski, J.A., and Tingey, S.V. (1990). DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic AcidsResearch*, 18: 6531-6535.

Wilonita, W., Nurliyana, R., Asma, D.D., Noorazizah, M., and Hirzun, M.Y. (2013). Distribution of disease and pest resistance markers in Malaysian rice varieties. *ASM Science Journal*, 7(2): 105-112.

Woodhead, S., and Padgham, D. E. (1988). The effect of plant surface characteristics on resistance of rice to the brown planthopper, *Nilaparvata lugens*. *Entomologia experimentalis et applicata*, *47*(1): 15-22.

Wright, S. (1968). Evolution and Genetics of Populations. Volume 1. Genetic and Biometrical Foundations. University of Chicago Press, Chicago.

Xu, Y., Zhu, L., Xiao, J., Huang, N., and McCouch, S. R. (1997). Chromosomal regions associated with segregation distortion of molecular markers in F2, backcross. Double haploid and recombinant inbred populations in rice (*Oryza sativa* L.). *Theoretical and Applied Genetics*, 253: 535–545.

Xu, Y. (2010). Molecular plant breeding, *CAB International*, Wallingford, p: 734.

Yang, H., Ren, X., Weng, Q., Zhu, L., and He, G. (2002). Molecular mapping and genetic analysis of a rice brown planthopper (*Nilaparvata lugens* Stål) resistance gene. *Hereditas*, *136*(1): 39-43.

Yang, H., You, A., Yang, Z., Zhang, F., He, R., Zhu, L., and He, G. (2004). High-resolution genetic mapping at the *Bph15* locus for brown planthopper resistance in rice (*Oryza sativa* L.). *Theoretical and Applied Genetics*, *110*(1): 182-191.

Yarasi, B., Sadumpati, V., Immanni, C.P., Vudem, D.R., and Khareedu, V.R. (2008). Transgenic rice expressing *Allium sativum* leaf agglutinin (ASAL) exhibits high-level resistance against major sap-sucking pests. *BMC Plant Biology*, *8*(1): 102.

Ye, M., Song, Y., Long, J., Wang, R., Baerson, S.R., Pan, Z., Zhu-Salzmand, K., Xie, J., Cai, K., Luo, S., and Zeng, R. (2013). Priming of jasmonate-mediated antiherbivore defense responses in rice by silicon. PNAS Ecology E3631-E3639. Retrieved from http://www.pnas.org/cgi/

Yoshihara, T., Sogawa, K., Pathak, M.D., Juliano, B.O., and Sakamura, S. (1979). Soluble silicic acid as a sucking inhibitory substance in rice against the brown plant hopper (Delphacidae, Homoptera). *Entomologia Experimentalis et Applicata*, *26*(3): 314-322.

Yoshihara, T., Sogawa, K., Pathak, M.D., Juliano, B.O., and Sakamura, S. (1980). Oxalic acid as a sucking inhibitor of the brown planthopper in rice (Delphacidae, Homoptera). *Entomologia Experimentalis et Applicata*, *27*(2): 149-155.

Yu, S.B., Xu, W.J., Vijaykumar, C.H.M., Ali, J., Fu, B.Y., Xu, J.L. (2003). Molecular diversity and multilocus organization of the parental lines used in the International Rice Molecular Breeding program. *Theoretical and Applied Genetics*, 108:131-40

Yuste-Lisbona, F.J., Capel, C., Sarria, E., Torreblanca, R., Gómez-Guillamón, M.L., Capel, J., and López-Sesé, A.I. (2011). Genetic linkage map of melon (*Cucumis melo* L.) and localization of a major QTL for powdery mildew resistance. *Molecular Breeding*, *27*(2): 181-192.

Zhang, Q., Liu, K. D., Yang, G. P., Maroof, M. A. S., Xu, C. G., and Zhou, Z. Q. (1997). Molecular marker diversity and hybrid sterility in *indica-japonica* rice crosses. *Theoretical and Applied Genetics*, 95: 112-118.

Zhao, X., and Kochert, G. (1992). Characterization and genetic mapping of a short, highly repeated, interspersed DNA sequence from rice (*Oryza sativa* L.). *Molecular and General Genetics*, 231: 353-359.

Zheng, X.M., Tao, Y.L., Chi, H., Wan, F.H., and Chu, D. (2017). Adaptability of small brown planthopper to four rice cultivars using life table and population projection method. *Scientific Reports*, *7*, 42399.

Zhu, Z.R. (1999). Population ecology and management strategy of the white-backed planthopper, S. furcifera (Horvath) in subtropical rice. Ph.D. Thesis. Nanjing Agricultural University, China.