UNIVERSITI PUTRA MALAYSIA

EFFECTS OF TEMPERATURE AND RELATIVE HUMIDITY ON GROWTH OF GREEN LEAFHOPPER (Nephotettix virescens DISTANT)

TUAN NORIZAN BINTI TUAN YUSOF

EFFECTS OF TEMPERATURE AND RELATIVE HUMIDITY ON GROWTH OF GREEN LEAFHOPPER *(Nephotettix virescens* DISTANT*)*

By

TUAN NORIZAN BINTI TUAN YUSOF

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

June 2018

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

EFFECTS OF TEMPERATURE AND RELATIVE HUMIDITY ON GROWTH OF GREEN LEAFHOPPER *(Nephotettix virescens* DISTANT*)*

By

TUAN NORIZAN BINTI TUAN YUSOF

June 2018

Chairman : Aimrun Wayayok, PhD
Faculty : Engineering

Green leafhopper (GLH), *nephotettix virescens* is one of the insects that attacks paddy plants in Malaysia. This species carries tungro virus that could damage the paddy plant. Early detection is important in order to manage and control the spreads of this virus. This study was conducted in order to find out the effect of weather parameters such as temperature and relative humidity (RH) to the population growth of green leafhoppers. A total of 27 samples of paddy plants at the age of 30 Days After Planting (DAP) were investigated. An instrument that consists of an embedded system was used to control temperature and RH. Fans and humidifiers were also installed to the embedded system to detect and control the level of temperatures and RH. Population number of GLH were counted and recorded on daily basis from nymph until adult stages. The sizes of GLH were also taken by using a digital camera (resolution of 750 pixels by 1334 pixels). The data was analyzed in MATLAB, whereas the sizes of GLH were monitored and discriminated based on controlled temperature and RH. The number of paddy leaves were also recorded to find out the relationship between the number of paddy leaves hosted by GLH with the temperature and RH. Statistical analysis was then performed to find out the significance differences between the treatments. Results indicated that there were differences between the treatments but not on the number of paddy leaves. Temperature and RH obtained from the instrumentation system indicated that higher GLH populations were found when the temperature was 30°C and RH was 80%. However, there were no relationship between the number of leaves attached by GLH with the weather parameters, and this indicated that at any values of temperatures and RH, GLH might be anywhere on the leaves. Based on the number of death of GLH, the mortality rate was counted. The survivability of GLH reduced when the temperature goes higher. There were higher mortality between day 19 to day 21 especially for the interactions of INT7 (temperature 40°C, RH 70%), INT8 (temperature 40°C, RH 80%), and INT9 (temperature 40°C, RH 90%). This study concluded that by knowing the

meteorological data of temperature and RH, the GLH pest population can be forecasted in advance as an early warning mechanism to allow farmers to manage this pest in their farms. This preventive method of pest management can minimize the loss of yield in rice production due to pest and disease attack.

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

KESAN SUHU DAN KELEMBAPAN TERHADAP POPULASI BENA HIJAU (*Nephotettix virescens* DISTANT)

Oleh

TUAN NORIZAN BINTI TUAN YUSOF

Jun 2018

Pengerusi : Aimrun Wayayok, PhD
Fakulti : Kejuruteraan

Serangga Bena Hijau (GLH) adalah salah satu serangga yang menyerang tanaman padi di Malaysia. Spesies ini membawa virus tungro yang boleh merosakkan tanaman padi. Pengesanan awal adalah penting untuk mengurus dan mengawal penyebaran virus ini. Kajian ini dijalankan untuk mengetahui kesan parameter cuaca seperti suhu dan kelembapan relatif (RH) kepada pertumbuhan populasi bena hijau. Sebanyak 27 sampel tanaman padi pada usia 30 Hari Selepas Penanaman (DAP) telah disiasat. Peralatan yang terdiri daripada sistem terpendam digunakan untuk mengawal suhu dan RH. Kipas dan pelembap juga dipasang pada sistem ini untuk mengesan dan mengawal tahap suhu dan RH. Bilangan populasi GLH dikira dan direkodkan setiap hari dari nymph hingga tahap dewasa. Saiz GLH juga diambil dengan menggunakan kamera digital (resolusi 750 piksel dengan 1334 piksel). Data dianalisis dengan menggunakan MATLAB, yang mana saiz GLH dipantau dan diskriminasi berdasarkan pada suhu dan RH yang dikawal. Bilangan daun padi juga direkodkan untuk mengetahui hubungan antara jumlah daun padi yang dihinggap oleh GLH dengan suhu dan RH. Analisis statistik kemudiannya dilakukan untuk mengetahui perbezaan penting antara suhu dan RH. Keputusan menunjukkan bahawa terdapat perbezaan di antara suhu dan RH kecuali jumlah daun padi yang dihinggap oleh GLH. Suhu dan RH yang diperoleh dari sistem instrumentasi yang dibangunkan menunjukkan bahawa GLH dikesan apabila suhu 30°C dan RH 80% adalah populasi GLH yang lebih tinggi. Walau bagaimanapun, tidak terdapat hubungan antara bilangan daun yang dilampirkan oleh GLH dengan parameter cuaca dan ini menunjukkan bahawa pada mana-mana nilai suhu dan RH, GLH mungkin berada di mana sahaja di daun. Berdasarkan bilangan kematian GLH, kadar kematian dikira. Kehidupan GLH berkurang apabila suhu semakin tinggi. Terdapat kematian yang lebih tinggi antara hari ke-19 hingga hari ke-21 terutamanya untuk interaksi INT7 (suhu 40°C, RH 70%), INT8 (suhu 40°C, RH 80%), dan INT9 (suhu 40°C, RH 90%). Kajian ini merumuskan bahawa dengan pengetahuan data meteorologi tentang suhu

dan RH, populasi serangga GLH dapat diramalkan terlebih dahulu sebagai mekanisma ramalan awal untuk membolehkan petani mengurus serangga padi ini dalam sawah mereka. Kaedah pencegahan bagi pengurusan serangga ini dapat mengurangkan kerugian hasil pengeluaran beras yang disebabkan oleh serangan serangga dan penyakit.

ACKNOWLEDGEMENTS

First and foremost, I would like to express profound gratitude to my supervisor Dr. Aimrun Wayayok for giving me the opportunity to be a part of this project and providing me the necessary guidance and support along the way. I greatly appreciate the way he encouraged me to delve into complex issues and patiently allowed me to work and learn at my own pace. I am inspired by his attention to detail and his intense commitment to work. I have thoroughly enjoyed working with him.

I am deeply indebted to my parents who motivated me to pursue graduate study in UPM. I also want to thank to my friends and my husband Nik Mohd Hisyam for his best efforts to support me in entire of my Master study. I am grateful to Dr Mohd Saufi bin Mohd Kassim my committee member who helped me in my working time.

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

Aimrun Wayayok, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Muhamad Saufi Mohd Kassim, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

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

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: _____ Date: _____

Name and Matric No: Tuan Norizan Binti Tuan Yusof, GS43726

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: Dr. Aimrun Wayayok

Signature: _____
Name of Member of Supervisory Committee: Dr. Muhamad Saufi Mohd Kassim

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 General Overview

Paddy is an important crop in Malaysia and it is essential for national food security. Apart from this, the statistic has also proven that paddy industry in Malaysia has generated stable income for the country (Zaim et al., 2013). Subsequently, it reflected the accomplishment of this industry. Malaysian paddy and rice industry regularly get consideration and truly emphasized by the government because of its vital significance as the primary staple food. Moreover, rice has supported a greater number of people for a longer period of time than any other crop since it was domesticated between 8,000 to 10,000 years ago (Greenland, 1997). At present, rice is the staple food for more people than wheat, and 90 percent of total rice production is grown and consumed in Asia (Evans, 1998). Paddy is cultivated in at least 114 countries, mostly for developing countries and is the main source of wages and employment for more than 100 million households in Africa and Asia (FAO, 2014). There are many parameters that can influence the economics of rice cultivation, and the appropriate control of pest for maintaining the crop is one of them.

Green leafhoppers (*Nephotettix virescens)* are the most common leafhoppers in rice fields and are primarily harmful because these insect spread the viral disease tungro (Takahashi et al., 1993). Both nymphs and adults fed by extracting the plant sap with their needle-formed mouthparts. Green leafhoppers are common in rained and irrigated wetland environments but not predominant in upland rice. Both the nymphs and adults eat the dorsal surface of the leaf blades instead of the ventral surface. GLH like to feed upon the lateral leaves as opposed to the leaf sheaths and the middle leaves. In addition, these pests prefer toward rice plants that have been treated with large amount of nitrogen. It was reported that the nitrogen content in rice plant is one of the main causes that attract pests to host under the canopy (Lu et al., 2005).

Basic climate parameters, such as temperature and humidity influence insects both directly and indirectly (Tomasv, 2013). Insects are cold blooded organisms and hence the temperature of their bodies is approximately the same as that of the environment. Therefore, temperature is probably the single most important environmental factor influencing insect behavior, distribution, development, survival, and reproduction (Ramya et al., 2012). However, Relative Humidity (RH) is also important to plant growth. It affects size and thickness of leaves, stems and fruits. Abiotic factors like temperature and relative humidity play a vital role in the development of insect pests infection fluctuation.

1.2 Problem Statements

Based on previous researches, tungro virus disease is one of the main diseases in rice farming and it is carried by Green leafhopper (Yoshito, 1992). Both nymphs and adults feed by extracting plant sap with their needle-shaped mouthparts. Tungro viruses give symptoms such as stunting and yellow or orange yellow discoloration of the leaves, plant stunting and reduced in yield (Azzam and Chancellor, 2002). More than that, pest population in paddy field is specified to be related with synoptic weather conditions. Unselective use of fertilizers and pesticides and double cropping, extensive rice cultivation can lead to the existence of pests. Besides, GLH can exist for about 25-28 days in temperature of 25-30^{o}C and it consists of three growth stages; egg, nymph and adult.

Disease detection during the early stage of infection is important for preventing the reduction of yield in crop production and offering better solution to the farmers. Rice has been the staple food for humans in many countries. Over half of the humans depend on rice as an energy source for daily lives (Bhullar and Gruissem, 2013). A number of factors have been suggested as being related to the risk of tungro problems (Thresh and Chancellor, 1996). Rice cultivars infected with tungro diseases show typical symptoms such as severe arrested growth, yellowing of the leaves and reduced tillering (Jefferson and Chancellor, 2002). Nowadays, the farmers apply the pesticide or insecticide for the pests in their farms based on farming schedule such as age of the rice, without having the information about the insects in paddy field and the factors leading the GLH insects to the paddy field. Pest prevention method is a costly act and on the other hand, using inappropriate content of pesticide has many harmful consequences on paddy, particularly, when it uses in inappropriate time (Faranak et al., 2014). Early detection on the factors that affect the growth of GLH in paddy plant and the understanding of the factors surrounding such as temperature and RH could be a potential solution to overcome the attacks of the GLH in paddy plant. At the same time, it could overcome the problem in tungro virus bring out by GLH. Study on the population build-up of paddy pests and their relationship with weather parameters is an important component of pest managements since it gives information that can be utilized to improve cultural, mechanical, and chemical and behaviors method of insect control. With the knowledge in understanding the relation between the growth behaviors of GLH and some weather parameters, tungro virus bring out by GLH could be early predicted to prevent a severe loss in rice production.

1.3 Objectives of Study

The main objective of this research is to study the effect of environmental temperature and RH on the growth of green leafhopper *(nephotettix virescens)* on paddy leaves

This study embarks on the following specific objectives:

i. To develop an instrumentation system to study the effect of temperature and RH on growth of GLH.
ii. To determine the effect of temperature and relative humidity on the growth, size of GLH and number of paddy leaves attacked by GLH.
iii. To study on the mortality rate of the GLH.

1.4 Scope and Limitations of the Study

The study is focused on the developing of the instrumentation to control the weather parameters such as temperature and relative humidity (RH). Then, focused on the populations of the GLH and related with the weather parameters designated. The temperature and RH were categorized into three levels: For temperature, (T1; 30^{o}C, T2; 35^{o}C, T3; 40^{o}C). For relative humidity, three levels were assigned (RH1; 70%, RH2; 80%, RH3; 90%). The data collection was conducted about 4 weeks at 30 days after planting (DAP) until 60 DAP. The sample used in this study is limited to *Malaysian indica rice* (MR219) variety.

Some specific limitations are:

1. This study did not cover on the aspect of other effect such as nitrogen levels
2. The study was at an experimental plot only and was not tested at the actual field because, it needs to be controlled.
3. The observation on the growth of GLH was only at one cycle

1.5 Thesis Layout

There are five chapters reported in this thesis. Chapter one highlights the background of the paddy plants and populations of GLH in paddy plants, problem statements, scope of the study, and the objectives of the study. Then, chapter two followed by outlining the literature review about the damage of paddy plants and related with the populations of the GLH. More than that, in this chapter discussion on the control of the GLH in paddy plants was reviewed. In addition, chapter three explains the methodology used in this project. The methodology includes developing control system, planting rice plant, rearing of the GLH, and the method of data collections. In chapter four, the results that are obtained are presented and discussed thoroughly. Lastly, summary and conclusions from this study as well as recommendations for further studies are derived in chapter five.

REFERENCES

Amna, M. H., Abolmanty, S.M., Hassanein, M. K., Abdel, N. Y. (2012). Impact of type of greenhouse cover sheets on certain major cucumber pests under protected cultivation. *New York Science Journal*.

Arief, H.S. (2014). Perbandingan akurasi pengukuran suhu dan kelembapan antaraSensor DHT11 dan DHT22. *Jurnal Infotel 6*, 2.

Astuti, L.P., Mudijono, G., Rasmimah, S., Rahardjo, B. T. (2013). Influence of temperature and humidity on the population growth of rhyzopertha dominica (coleoptera: bostrichidae) on milled rice. *Dept. Plant Protection agri. Fac.UnivBrawijayaMalang, Indonesia*.

Ausilio, D. (2012). Arduino: low-cost multipurpose lab equipment. *Behav. Res. Methods 44*, 305.

Azzam, O. (2002). The biology, epidemiology, and management of rice tungro disease in Asia. *Plant Disease 86*(2), 88–100.

Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezeme, R. T. M., Brown, V. K., Watt, J. (2002). Herbivory in global climate change research:direct effects of rising temperaure on insect herbivores, *Global Change Biology* 8:1.

Bhullar, N.K. and Gruissem, W. (2013). Nutritional enhancement of rice for humanhealth: the contribution of biotechnology. *Biotechnology Advance* 31: 50-57.

Brian, E., Robert, A. (2004). Managing the greenhouse environment to control plant diseases. *University of Kentucky College of Agriculture, Plant Pathology* Fact Sheet PPFSGH-01.

Brian, G., Nile, K, Kent, K. (2015). Preliminary design of a low-cost greenhouse with open source control system. *Hum Tech* 2015, 470-479.

Bunawan, H., Lukas, D., Siti, N.B., Noriha, M.A. (2014). Rice tungro disease: from identification to disease control. *World applied science journal* 1221-1226.

Cheng, C.H., Pathak, M.D. (1970). Resistance to *nephotettix virescens* in rice varieties. *Journal Econ. Entomol* 65:1148-1153.

Der, T. B., Ali, M., Huseyin, H. (2014). Performance analysis of a greenhouse fan-pad cooling system: gradients of horizontal temperature and relative humidity. *Journal Agricultural Science* 132-143.

Eileen, F. W. (2009). Evaluating greenhouse ventilation fan capacity. *Agricultural and Biological Engineering* 1-43.

Evans, L.T. (1998). Feeding the ten billion:plants and population growth. *Cambridge University Press, Cambridge, UK* 247.

Faranak,G. 2015. *Pest attack determination in paddy areas using multispectral remote sensing images*, PhD thesis, Universiti Putra Malaysia.

Gene, A.G. (2003). Evaporative cooling system:mist and fog. *Agriculture and Biosystem Engineering, University of Arizon*.

Gene, A. G. (2003). Control environment system. *Agriculture and Biosystem Eng, Univ. Of Arizon.*

Gholizadeh, A., Amin, M.S.M., Anuar, A. R., & Aimrun, W. (2009). Evaluation of 153 leaf total nitrogen content for nitrogen management in a malaysian paddy field by using soil plant analysis development chlorophyll meter. *American Journal of Agricultural and Biological Sciences 4*(4), 278–282.

Greenland, D.J. (1997). The sustainability of rice farming. *CAB International, Wallingford, UK* 273.

Hafizal, M.M., Idris, A.B. (2014). Temporal population abundance of leafhopper and planthopper affected by temperature, humidity, and rice growth stage. *Academic Journal of Entomology.*

Hatfield, J.L., Boote, K.J., Fay, P., Hahn, L., Izaurralde, R.C., Kimball, B.A., Wolfe, D. (2008). Agriculture in the effect of climate change on agriculture, land resources, water resources,and biodiversity in the United States. *U.S Department of Agriculture, Washington, DC, USA,* 362 pp

Hatfield,J.L., Boote, K.J.,Kimball,B.A.,Ziska,L.H.,Izaurralde,R.C.,Ort, D.,Thomson, A.M., Wolfe, D. W. (2011). Climate impacts on agriculture:implications for crop production. *Agronomy Journal 103*, 351–370.

Hkalita, R.K., Avasthe, K., Ramesh. (2015). Effect of weather parameters on population buildup of different insect pests of rice and their natural enemies. *ICAR Research Complex for NEH Region, Sikkim Centre 28*(1), 69-72.

Holt, J. and Chancellor, T.C.B. (1996). Simulation modelling of the spread of rice tungro virus disease: The potential for management by roguing. *Journal Applied Ecology* 33:927-936.

Hibino, H. and Cabunagan, R.C. (1986). Rice tungro-associated viruses and their relations to host plants and vector leafhopper. *Tropical Agricultural Resources* 19, 173-182.

Heong, K. L. and Hardy, B. (2009). Planthoppers: new threats to the sustainability of intensive rice production systems in asia. *International Rice Research Institute (IRRI)* 978-971.

Ishii-Eiteman, M.J. and Power, A.G. (1997). Response of green rice leafhoppers to rice planting practices in northern Thailand. *Ecological Applications* 7:194-208.

Jefferson, O.A. and Chancellor, T. (2002). The biology, epidemiology and management of rice tungro disease in Asia. *Journal of Applied Plant Pathology* 86: 88-100.

Johnson, C., Siew, F. Y. and Lily, E. (2015). Rice tungro disease in Sarawak: past and present status. *Pakistan Journal of Biological Sciences* 18: 285-289.

Jonathan, A.E. (2014). An automated greenhouse control system using arduino prototyping platform. *Australian Journal Eng. Research.*

Jero, M., Dela, O.A.G., Ferrer. (2015). Open source hardware to monitor environment parameters in precision agriculture. *Journal of Biosystems Engineering 7,* 73-83.

Kittas, C., Bartzanas, T., Jaffarin, A. (2001). Greenhouse evaporative cooling: measurement and data analysis. *Transactions of the ASAE 44(*3): 683–689.

Koganezawa, H. (1998). Present status of controlling rice tungro virus in plant virus disease control. *American Phytopathological Society* 459-469.

Kuang, Y. L., Sung, J. H., Wen, T. S. (2013). Intelligent multi-sensor control system based on innovative technology integration via ZigBee and Wi-Fi networks. *Journal of Network and Computer Applications.*

Lady, A. (2017). DHT11, DHT22, and AM302 sensors. *Adafruit Learning System.*

Ling, K. C. (1992). Rice Virus Diseases. *The International Rice Research Institute.*

Litsinger, J.A. (2009). When is a rice insect a pest yield loss and the green revolution. *Integrated pest management: innovation-development process*.

Lukas, B., Ondrej, K. (2015). Design and realization of low cost control for greenhouse environment with remote control. *International Federations of Accountants* 368-373.

Manwan, I., Sama, S. and Rizvi, S. A. (1987). Management strategy to control rice tungro in Indonesia. *Ministry of Agriculture, Maros, South Sulawesi, Indonesia* 91-97, 24-27.

Michael, J. B., George, F. G. (2004). Controlling the environment in greenhouse used for tomato production. *Agricultural Extension Service* 1-10.

Muhammad, S. (2002). Biology of rice green leafhopper under laboratory condition. *Pakistan Journal of Agrio Vol 17*.

Nyoman, W., Yoshita, S., Hiroichi, S., Fusao, N. (1990). Population dynamic of the green leafhopper *nephotettix virescens* Distant (Hemiptera:Cicadellidae) in synchronized and staggered transplanting areas of paddy fields in Indonesia. *Society of Population Ecology 32*,319-328.

Norberto, B., Luis, M. B., Velez, F. J., Fernando, M., Marcin, G., Joao, C. Wireless sensor networks for temperature and humidity monitoring within concrete structures. *Construction and Building Materials 40*, 1156-1166.

Prakash, K. K. (2014). Impact of climate change on rice production in Nepal.*South Asian Network for Development and Environmental Economics (SANDEE)* 85, 14.

Pathak, M. D. and Khan, Z. R. (1994). Insect Pests of Rice. *International Rice Research Institute.* (pp 19-27, pp 33-36) International centre of Insect Phsiology and Ecology.

Pathak, M.D. (1977). Defense of the rice crops against insects pest. *New York Acedamy of Science.*

Pearce, J. M. (2012). Building research equipment with free open-source hardware. *Materials Science and Engineering, Michigen Technology University USA* 337(6100), 1303-1304.

Porter, J. H., Parry, M. L., Carter, T. R. (1991). The potential effects of climate changes on agricultural insects pest. *Agricultural Forest Meteorology* 57: 221-240.

Rapusas, H. R. & Heinrichs, E. A. (1982). Plant age and levels of resistance to green leafhopper, Nephotettix virescens (Distant), and tungro virus in rice varieties. *Crop Protection 1*(1), 91–98.

Saxena, R. C., Khan, Z. R. (1999). Factor affecting resistance of rice varieties to planthopper and leafhopper pests. *Agricultural Zoology* 3:97-132.

Sama, S., Hassanudin, A., Manwan, I., Cabunagan,R.C., Hibino, H. (1991). Integrated rice disease management in South Sulawesi, Indonesia. *Crop Protection* 34- 40.

Shukla, V. D., Anjaneyulu, A. (1981). Plant spacing to reduce rice tungro incidence. *Plant Diseases* 65:584-586.

Tiongco, E. R., Flores, Z.M., Koganezawa, H., Teng, P. S. (1993). Inoculum sources of rice tungro viruses. *Philippine Phytopathology* 29:30-41.

Tomas, J., Jacek, H. (2013). The effect of temperature and humidity changes on insects development and their impact. *Forest research paper 74* (4): 345–355.

Uda, M. N. A., Hasfalina, C. M., Samsuzana, A. A., Faridah, S., Zamri, I., Noraini, B. S., & Hashim, U. (2014). Comparison Study of Two Different Isolation and Purification Method for Rice Tungro Bacilliform Virus (RTBV). In *Agriculture and Agricultural Science Procedia* (Vol. 2, pp. 107–112). Elsevier Srl.

Welch, J. R., Jeffrey, R., Vincent, Maximilian, A., Piedad, F. M., Achim, D. D. D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. *National Academy of Science of the United Stated of America.*

Warburton, H., Palis, F. L., Villareal, S. (1997). Farmers' perceptions of rice tungro disease in the Philippines in: pest management practices of rice farmers in asia. *International Rice Research Institute, Manila, Philippines* 129-141

Welch, J. R., Vincent, J. R., Auffhammer , M., Moya, P. F., Dobermann, A., Dawe, D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. *Proceedings of the National Academy of Sciences 107*, 14562–14567.

Xu, J., Li, Y., Wang, R. (2015). Experimental performance of evaporative cooling pad system in greenhouses in humid subtropical climates. *Applied Energy 3* 138-291.

VinhGia, N. N. (2006). On weather affecting to Brown Planthopper. *Master of Science Trinvasion using an Agentbased model* 151-152.

Yoshito, S., Astika, I. G. N., Widrawan, I. K. R. (1992). Rice tungro diseases transmitted by Green Leafhopper:Its epidemiology and forecasting technology. *Japan Agricultural Research Quarterly 26*, 98-104.

Zaim, F., Bahaman, A. S., Haslinda, A. (2013). Paddy industries and paddy farmers well being : A success recipe for agriculture industry in Malaysia. *Asian Social Science 9* 3.

Zoltan, N. D., Rossi, C. H., Silvia, D. I., Clayton, M., A.S. (2014). Balancing envelope and heating system parameters for zero emissions retrofit using building sensor data. *Applied Energy.*

Zulfiqar, M. A., Sabri, M., Raza, M. A., Hamza, A., Hayat, A., Khan, A. (2010). Effect of temperature and relative humidity on the population dynamic of some insects pests of maize. *Journal of Pakistan Lifesocial Science* 16-18.