UNIVERSITI PUTRA MALAYSIA

DETECTION OF TUNGRO DISEASE IN RICE LEAF IN RELATION TO NITROGEN LEVEL USING LASER LIGHT BACKSCATTERING IMAGING

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By

NUR AZIZAH BINTI BACHIK

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

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Abstract of the 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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June 2017

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Rice tungro disease (RTD) is one of the dangerous rice diseases that occurred due to two viruses i.e. rice tungro disease spherical virus (RTSV) and rice tungro disease baciliform virus (RTBV) which is transmitted by green leafhoppers (GLH). Hence, fast detection of this disease is required in order to prevent higher yield loss. The current conventional techniques i.e. serological and nucleic acid techniques are skill dependent and time consuming. Therefore, this study is proposed to investigate the capability of laser light backscattering imaging (LLBI) for detecting RTD in rice leaf. MR-219 rice cultivar was planted in a randomized complete block design (RCDB) with two factorial treatments i.e. inoculation (INO) and nitrogen (N) treatments with three replications. INO treatments including healthy (H), inoculation 1 (INO 1) (3 GLH/seedling) and inoculation 2 (INO 2)(5 GLH/seedling) while N treatments including N1 (0kg/ha), N2 (85 kg/ha), N3 (170 kg/ha) and N4 (250 kg/ha). The seedlings were inoculated with infected GLH during 20 days after planting (DAP). The data collection were carried out on youngest fully expanded leaf at where the readings were taken at three different location i.e. leaf tip, middle leaf and leaf base (4 cm interval).

The images then were analyse using image processing toolbox, MatlabR2013a (The Mathworks, Inc. Nattrick, MA, 2013a) to extract LLBI parameters from the images. The polymerase chain reaction (PCR) then was done as a confirmation of the RTD establishment. Results showed that the growth performance i.e. rice plant height and tiller number per hill were influenced by INO treatments but was not influenced by N treatments. Results also indicated significant difference between chlorophyll content and colour parameters i.e. lightness (L*) and chroma (C*) for INO treatments while

only colour parameters i.e. red/green (a*) and hue (h^o) were significantly influenced by N treatments. The PCR result showed that the expected deoxyribonucleic acid (DNA) size (500 base pairs (bp)) of RTBV was amplified for inoculated rice plants. The LLBI parameters showed that all parameters except maximum intensity, minimum intensity and ratio were influenced by INO treatments while only minimum intensity was influenced by N treatments. There were significant difference between reading points on rice leaf for soil plant analysis development (SPAD) reading, colorimeter parameters and LLBI parameters for INO treatments but no significant for N treatments. The principal component analysis (PCA) and linear discriminant analysis (LDA) showed that LLBI is more appropriate for accessing RTD infection and sensitive in differentiate between reading points location on rice leaf. LDA classification rates for H, INO 1 and INO 2 of LLBI were 83.82%, 75.85% and 78.81%, the colorimeter were 85.60%, 74.46%, and 69.90% while SPAD were 80.95%, 51.19%, and 42.86% respectively.

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

PENGESANAN PENYAKIT PMV PADA DAUN PADI MENGIKUT ARAS NITROGEN MENGGUNAKAN PENGIMEJAN PEMBALIKAN CAHAYA LASER

Oleh

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Penyakit merah virus (PMV) adalah salah satu penyakit padi merbahaya yang terjadi disebabkan oleh dua virus iaitu virus sfera PMV (RTSV) dan virus baciliform PMV (RTBV) yang dijangkitkan oleh bena hijau (GLH). Oleh itu, pengesanan yang cepat untuk penyakit ini diperlukan untuk mengelakkan kehilangan hasil yang lebih tinggi. Teknik-teknik konvensional semasa yang digunakan untuk mengesan PMV iaitu teknik serologi dan asid nukleik bergantung kepada kemahiran dan memakan masa. Oleh itu, kajian ini dicadangkan untuk menyiasat keupayaan pengimejan pembalikan cahaya laser (LLBI) untuk mengesan PMV pada daun padi. Kultivar padi MR-219 ditanam dalam blok yang direka bentuk secara rawak dan lengkap (RCDB) dengan dua rawatan faktorial iaitu rawatan inokulasi (INO) dan nitrogen (N) dengan tiga replikasi. Rawatan INO termasuk sihat (H), inokulasi 1 (INO 1) (3 GLH / anak benih) dan inokulasi 2 (INO 2) (5 GLH/ anak benih) sementara rawatan N termasuk N1 (0kg / ha), N2 (85 kg / ha), N3 (170 kg / ha) dan N4 (250 kg / ha). Anak benih diinokulasi dengan bena hijau yang telah dijangkiti PMV semasa 20 hari selepas menanam (DAP). Pengumpulan data telah dijalankan pada daun yang paling muda berkembang di mana bacaan telah diambil di tiga lokasi yang berbeza iaitu hujung daun, daun tengah dan pangkal daun (4 cm selang).

Imej-imej yang telah diambil dianalisis menggunakan toolbox pemprosesan imej, MatlabR2013a (Mathworks, Inc. Nattrick, MA, 2013a) untuk mengekstrak parameter LLBI dari imej. Tindak balas rantaian polimerase (PCR) kemudian dilakukan sebagai pengesahan jangkitan PMV pada daun padi. Hasil kajian menunjukkan bahawa prestasi pertumbuhan iaitu ketinggian tanaman padi dan bilangan anak padi setiap bukit dipengaruhi oleh rawatan INO tetapi tidak dipengaruhi oleh rawatan N. Keputusan juga menunjukkan perbezaan yang signifikan antara kandungan klorofil dan parameter warna iaitu keterangan cahaya (L*) dan kroma (C*) untuk rawatan inokulasi manakala hanya parameter warna iaitu merah/hijau (a *) dan hue (h^o) dipengaruhi dengan ketara oleh rawatan N. Hasil PCR menunjukkan bahawa saiz asid deoksiribonukleik (DNA) (500 pasangan asas (bp)) daripada RTBV seperti yang dijangka telah digandakan bagi pokok padi yang diinokulasi. Parameter LLBI menunjukkan bahawa semua parameter kecuali intensiti maksimum, intensiti minimum dan nisbah dipengaruhi oleh rawatan inokulasi manakala hanya intensiti minimum dipengaruhi oleh rawatan N. Terdapat perbezaan yang signifikan antara lokasi titik bacaan pada daun padi bagi bacaan pembangunan analisis tanah tumbuhan (SPAD), parameter kolorimeter dan parameter LLBI untuk rawatan inokulasi tetapi tidak signifikan untuk rawatan N. Analisis komponen utama (PCA) dan analisis diskriminan linear (LDA) menunjukkan bahawa LLBI adalah lebih sesuai untuk mengakses jangkitan PMV dan sensitif dalam membezakan antara lokasi titik bacaan pada daun padi. Kadar klasifikasi LDA untuk H, INO 1 dan INO 2 LLBI masing-masing adalah 83.82%, 75.85% dan 78.81%, colorimeter adalah 85.60%, 74.46% dan 69.90% manakala SPAD adalah 80.95%, 51.19% dan 42.86%.

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

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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) are adhered to.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

a*	red/green coordinate
A_I	Illuminated area
$A_{260/280}$	Ratio of absorbance at 260 nm and 280 nm
ANOVA	Analysis of variance
b*	yellow/blue coordinate
bp	Base pair
BIS	Backscattering Imaging System
CV	Computer vision
CCD	Charged-couple device
C*	Chroma
D	Diameter
DNA	Deoxyribonucleic acid
DAP	Days after planting
EDTA	Ethylenediaminetetraacetic acid
ELISA	Enzyme-linked immunosorbent assay
GLH	Green leafhopper
H	Healthy
h^o	Hue
HIS	Hyperspectral imaging
HBI	Hyperspectral backscattering imaging
HSD	Tukey's honest significant difference
I_C	Reflectance intensity captured by CCD camera
I_L	Light intensity
INO 1	Inoculation 1
INO 2	Inoculation 2
IR	Infrared
I_R	Apparent, corrected light intensity on the fruit surface
K	Potassium
Kb	Kilobase
kg/ha	Kilogram per hectare
L*	Lightness
LCC	Leaf colour chart
LCD	Liquid crystal display
LDA	Linear discriminant analysis
LEDs	Light emitting diodes
LLBI	Laser light backscattering imaging
MARDI	Malaysian Agricultural Research and Development Institute
MBI	Multispectral backscattering imaging
MR219	Malaysian indica rice 219
N	Nitrogen
nm	Nanometer
NIR	Near infrared range
NIRS	Near infrared spectroscopy
P	Phosphorus

PCA	Principal component analysis
PCR	Polymerase Chain Reaction
PMV	Penyakit merah virus
r	Correlation coefficient
R^2	R-squared
RCBD	Randomized complete block design
RNA	Ribonucleic acid
RMSE	Root-mean-square error
ROI	Region of interest
RTBV	Rice tungro bacilliform virus
RTSV	Rice tungro spherical virus
RTD	Rice tungro disease
RS	Remote sensing
SPAD	Soil plant analysis development
TBE	Tris/Borate/EDTA
TIF	Tagged Image Format
TN1	Taichung native 1
UV	Ultraviolet
VA	Visual assessment
VIS	Visible
W	Week
WPI	Week post-inoculation

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Rice (*Oryza sativa*) is a cereal grain that is widely consumed as staple food. It is a predominant food for Asian countries as it is consumed by 2.9 billion people (Bunawan, Dusik, Bunawan, & Amin, 2014). Asia produces about 90% and above of the world rice production. The largest rice producer is China which followed by India, Indonesia, Bangladesh and Vietnam (Bunawan et al.,2014). In Malaysia, the rice production is around 2.5 million metric tonnes annually involving 300,000 farmers that cultivated on 674,928 ha land area (Rabu & Mohd Shah, 2013).

However, in major rice-growing countries, rice diseases remain a major threat to sustainable rice production. One of the serious diseases that widely spread in South and South-east Asian countries is rice tungro disease (RTD). Rice tungro disease (RTD) was found to be associated with two distinct viruses i.e. rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV) (Bunawan et al., 2014). This disease is transmitted via leafhopper as a vector (Mohd Daud, Jozani, & Arab, 2013).

The typical symptoms of the infected rice plant with RTD are stunting, yellow to orange leaves discolouration, reduced in number of tillers, panicles sterility, and the appearance of irregular-shaped dark brown specks on the leaves (Bunawan et al., 2014). A conventional method for RTD detection in the field is visual observation. However, the disease is difficult to identify as the symptoms are not similar from one infected varieties to another. It is also sometimes being misdiagnosed as a non-pathogenic disorder as the appeared symptoms are similar to the symptoms that are exhibited due to overwatering, nutritional deficiencies, or insect damage (Azzam, 2002 ; Bunawan et al., 2014).

It was reported that leaf colour can be used to indicate the plant nutrient and health status and the changes of the colour is closely related to the amount and proportion of nitrogen (N) content (Senoaji & Praptana, 2013). Furthermore, N content has been identified as one of the main causes that attract pest to host under a canopy (Lu et al., 2005). N is one of the vital minerals for growth of plant that is extremely important for encouraging root development, flowering and ripening. Deficiency of N results in stunted and slow growth, and chlorosis with small unit leaf area (Lu et al., 2005). As N is mobile, the older leaves exhibit chlorosis and necrosis with the appearance of light green to yellow discoloration symptoms earlier than the younger leaves.

There are several laboratory methods that being used to detect the RTD in rice plants i.e. serological method, nucleic acid technique and electron microscopy (Nath et al,

2000 ; Takahashi et al., 1993; Hibino, Roechan, & Sudarisman, 1978). All of these methods are destructive, time consumed in which it needs one to two days period to get the result and requires high cost and skills as well as very sensitive to contamination. As colour is one of the symptoms for the detection of N content as well as RTD, the presence of N in paddy leaf and RTD infection probably can be detected rapidly, accurately and non-destructively using optical imaging method.

Laser light backscattering imaging (LLBI) system is an advancement of computer vision technology which uses laser light at different wavelength to detect physic-chemical properties in tissues. This technology combines vision system and spectral readings using laser diode light source which emits photons in the visible to near infrared range that produce backscattering images (Hashim et al., 2013). This technique has been proven for the detection of internal and external quality of fruit such as apples (Lu, 2004; Qing, Ji, & Zude, 2007; Qin & Lu, 2008) peach, pear, plums, tomatoes, zucchini, cucumber (Qin & Lu, 2008), citrus (Lorente, Zude, et al., 2013), kiwifruit (Baranyai & Zude, 2009), papaya (Udomkun et al., 2014) and banana (Hashim et al., 2013). As the changes of backscattering parameters could be used to detect the changes in pigment and fruit tissues that are related to quality, hence the potential of the system could be explored on its feasibility in the detection of crop diseases.

1.2 Problem Statement

RTD disease is a serious setback in the production of rice in Asia. This disease is transmitted by leafhopper that attack seriously on the N-enriched rice plants (Lu & Heong, 2009; Chau et al., 2003). It was reported that every fold increase in N application may increase plant hopper densities by 40-fold (Lu & Heong, 2009). Since RTD could causes severe damage such as “degenerated growth” and total loss of grain yields besides difficult to control, henceforth appropriate method for the detection and RTD management is required.

The current practice of detecting the diseases i.e. serological assay and nucleic acid are laborious, skill dependent, time consuming and costly. On the other hand, the current practices to control RTD which are by using insecticides and conventional resistance breeding offers inefficient solution. Application of heavy insecticide may result in not only masking the effects of natural biological control but also stimulating the development of insecticide resistance. Application of resistance breeding was not sustainable due to high disease pressure. Very often varieties with vector resistance were defeated by RTD as the vector population become adapted after their release (Bunawan et al., 2014). Thus, an approach of using LLBI for detection of RTD as well as N is proposed as a new monitoring device for fast and effective diagnostic technique.

1.3 Objective

The objective of this study is to detect rice tungro disease (RTD) infection in rice leaf as relation to nitrogen (N) treatments by using laser light backscattering imaging system (LLBI). The specific objectives of this study are stated as follows:

1. To determine RTD infection in rice leaf using reference methods i.e. SPAD chlorophyll meter and colorimeter
2. To determine RTD infection in rice leaf using LLBI
3. To investigate RTD infection as relation to N treatments
4. To compare the efficiency of RTD detection between SPAD chlorophyll meter, colorimeter and LLBI

1.4 Scope and Limitation of Study

This study is focused on the detection of RTD infection and influences of N treatments on RTD infection in rice leaf by using LLBI. The data collection is conducted about seven weeks starting from week 2 to week 9 of post-inoculation (WPI) i.e.36 until 78 days after planting (DAP). The sample used in this study is limited to Malaysian indica rice (MR219) variety.

1.5 Significance of the study

As the most devastating viral disease of rice in South and Southeast Asia, RTD become one of the significant fears to sustainable annual rice production in the world. Due to the increasing world population and subsequent increase in demand for food, identifying the causal agents, symptoms of disease and method of disease management of monitoring are important keys to understand how to reduce the economic damage caused by rice pathogens.

Since one of the symptoms of this disease is the changes of rice leaf colour which could be related to the N level of the paddy plant, application of LLBI for detection of the symptom is expected to be able to provide alternative solution. Hence, the application of LLBI is proposed in this study. The findings of this study could promote to the development of rapid and non-destructive tool, also a fundamental study for the detection of other similar diseases in agricultural produce and crops.

1.6 Thesis Layout

There are five chapters reported in this thesis. Chapter one highlights the background of food security and RTD in Asian countries and Malaysia, problem statements, scope of the study, the objectives of the study, hypothesis, and study interests. Chapter two follows by outlining the literature review of the techniques used for detection and

monitoring RTD and N content. Chapter three explains the methodology of this study which includes planting rice plant, rearing of green leafhopper, and method of data collection. In the chapter four, the results obtained from the study 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

Abo, M. E., & Fadhila, H. A. (2000). Epidemiology and management of rice viruses and virus diseases. *Plant Virology*, *11*, 113–134.

Abu-khalaf, N. (2015). Sensing tomato ' s pathogen using Visible / Near infrared (VIS / NIR) spectroscopy and multivariate data analysis (MVDA). *Palestine Technical University Research Journal*, *3*(1), 12–22.

Adebayo, E. S., Hashim, N., Abdan, K., & Hanafi, M. (2016). Application and potential of backscattering imaging techniques in agricultural and food processing- A review. *Journal of Food Engineering*, *169*, 155–164.

Altschul, S. F., Gish, W., Miller, W., Myers, E. W., & Lipman, D. J. (1990). Basic local alignment search tool. *Journal of Molecular Biology*, *215*(3), 403–10.

Anthonys, G., & Wickramarachchf, N. (2009). An Image Recognition System for Crop Disease Identification of Paddy fields in Sri Lanka. In *Fourth International Conference on Industrial and Information Systems, ICIIS* (pp. 403–407). Sri Lanka.

Arivazhagan, S., Shebiah, R. N., Ananthi, S., & Varthini, S. V. (2013). Detection of unhealthy region of plant leaves and classification of plant leaf diseases using texture features. *International Agricultural Engineering Journal*, *15*(1), 211–217.

Asfarian, A., Herdiyeni, Y., Rauf, A., & Mutaqin, K. H. (2013). Paddy diseases identification with texture analysis using fractal descriptors based on fourier spectrum. In *International Conference on Computer, Control, Informatics and Its Applications* (pp. 77–81).

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

Bachik, N.A., Hashim, N., Wayayok, A., Che Man, H. and Saipin, S. 2017. The determination of nitrogen value at various reading points on rice leaf using RGB imaging. Acta Hort. (ISHS) 1152:381-386.

Bajet, N. B., Aguiero, V. M., Daquioag, R. D., Jonson, G. B., Cabunagan, R. C., & Mesina, E. M. (1986). Occurrence and Spread of Rice Tungro Spherical Virus in the Philippines. *Plant Disease*, *70*(10), 971–973.

Baranoski, G. V. G., & Rokne, J. G. (2001). Efficiently simulating scattering of light by leaves. *The Visual Computer*, *17*, 491–505.

Baranowski, P., Mazurek, W., Wozniak, J., & Majewska, U. (2012). Detection of early bruises in apples using hyperspectral data and thermal imaging. *Journal of Food Engineering*, *110*(3), 345–355.

Baranyai, L., & Zude, M. (2009). Analysis of laser light propagation in kiwifruit using backscattering imaging and Monte Carlo simulation. *Computers and Electronics in Agriculture*, *69*(1), 33–39.

Bauriegel, E., & Herppich, W. B. (2014). Hyperspectral and Chlorophyll Fluorescence Imaging for Early Detection of Plant Diseases, with Special Reference to Fusarium spec. Infections on Wheat. *Agricultural*, *4*, 32–57.

Bintory, M. A., Seetharamu, G., Munikrishnappa, P., Ramegowda, G., & Basavaraj, G. (2015). Evaluation of the Colour of Dried Dutch Rose Flowers Using a Colorimeter. *Journal of Horticulture*, *2*(4), 2–4.

Boehm, C. D. (1989). Use of Polymerase Chain Reaction for Diagnostics of Inherited Disorders. *Clinical Chemistry*, *35*(9), 1843–1848.

Brosnan, T., & Sun, D. (2004). Improving quality inspection of food products by computer vision — a review. *Journal of Food Engineering*, *61*, 3–16.

Bunawan, H., Dusik, L., Bunawan, S. N., & Amin, N. M. (2014). Rice Tungro Disease: From Identification to Disease Control. *World Applied Sciences Journal*, *31*(6), 1221–1226.

Cabauatan, P. Q., Cabunagan, R. C., & Koganezawa, H. (1995). Biological Variants of Rice Tungro Viruses in the Philippines. *Phytopathology*, *85*(1), 77–81.

Cabauatan, P. Q., & Hibino, H. (1987). Isolation,Purification and Serology of Rice Tungro Bacilliform and Rice Tungro Spherical Viruses. *Plant Disease*, *72*(6), 526–528.

Capobiango, J. D., Monica, T. C., Ferreira, F. P., Mitsuka-Breganó, R., Navarro, I. T., Garcia, J. L., & Reiche, E. M. V. (2016). Evaluation of the western blotting method for the diagnosis of congenital toxoplasmosis. *Journal of Pediatrics*, *92*(6), 616–623.

Carter, G. a, & Knapp, a K. (2001). Leaf optical properties in higher plants: linking spectral characteristics to stress and chlorophyll concentration. *American Journal of Botany*, *88*(4), 677–684.

Casanova, J., O'Shaughnessy, S., Evett, S., & Rush, C. (2014). Development of a Wireless Computer Vision Instrument to Detect Biotic Stress in Wheat. *Sensors*, *14*, 17753–17769.

Chau, L. M., Cat, H. D., Ben, P. T., Phuong, L. T., Cheng, J., & Heong, K. L. (2003). Impacts of Nutrition Management on Insect Pests and Diseases of Rice. *OmonRice*, *11*, 93–102.

Chen, X., Ke, S., Wang, L., Xu, H., & Chen, W. (2012). Classification of Rice Appearance Quality Based on LS-SVM Using Machine Vision. *International Conference on Information Computing and Applications*, *307*, 104–109.

Chowdhury, A. K., Hibino, H., & Teng, P. S. (1994). Dispersal of Rice Tungro Associated Viruses by Leafhoppers in the Presence of Singly or Jointly Infected Source Plants under Caged Conditions. In *National Academy of Sciences India* (Vol. 3, pp. 281–286).

Curran, P. J. (1985). Aerial photography for the assessment of crop condition: a review. *Applied Geography*, *5*(4), 347–360.

Dasgupta, I., Das, B. K., Nath, P. S., Mukhopadhyay, S., Niazi, F. R., & Varma, A. (1996). Detection of rice tungro bacilliform virus in field and glasshouse samples from India using the polymerase chain reaction. *Journal of Virological Methods*, *58*(1–2), 53–8.

Dasgupta, I., Hull, R., Eastop, S., Poggi-Pollini, C., Glakebrough, M., Boulton, M. I., & Davies, J. W. (1991). Rice tungro bacillliform virus DNA independently infects rica after Agrobacterium-mediated transfer. *Journal of General Virology*, *72*(1991), 1215–1221.

Dénes, D. L., Parrag, V., Felföldi, J., & Baranyai, L. (2013). Influence of parameters of drying on laser induced diffuse reflectance of banana discs. *Journal of Food Physics*, *26*, 11–16.

Druka, A., Burns, T., Zhang, S., & Hull, R. (1996). Immunological characterization of rice tungro spherical virus coat proteins and differentiation of isolates from the Philippines and India. *Journal of General Virology*, *77*(8), 1975–1983.

Elmasry, G., Sun, D., & Allen, P. (2011). Non-destructive determination of water-holding capacity in fresh beef by using NIR hyperspectral imaging. *Food Research International*, *44*(9), 2624–2633.

Elmasry, G., Wang, N., Elsayed, A., & Ngadi, M. (2007). Hyperspectral imaging for nondestructive determination of some quality attributes for strawberry. *Journal of Food Engineering*, *81*, 98–107.

Fan, Z., Dahal, G., Dasgupta, I., Hay, J., & Hull, R. (1996). Variation in the genome of rice tungro bacilliform virus: Molecular characterization of six isolates. *Journal of General Virology*, *77*(5), 847–854.

Fang, Y., & Ramasamy, R. P. (2015). Current and prospective methods for plant disease detection. *Biosensors*, *5*(3), 537–561.

Fernández-San José, C., Moraga-Llop, F. A., Codina, G., Soler-Palacín, P., Espiau, M., & Figueras, C. (2015). The use of polymerase chain reaction in the diagnosis of invasive meningococcal disease. *Anales de Pediatría (English Edition)*, *82*(3), 139–143.

Finzi, A., Oberti, R., Negri, A. S., Perazzolo, F., Cocolo, G., Tambone, F., & Provolo, G. (2015). Effects of measurement technique and sample preparation on NIR spectroscopy analysis of livestock slurry and digestates. *Biosystems Engineering*, *134*, 42–54.

Fung, Y. S., Huey, C. C., Sia, M., & Sum, H. (2014). Over expression of Recombinant CP3 Protein of Rice Tungro Spherical Virus in Prokaryotic Expression System. *Bioremediation Science & Technology Research*, *2*(2), 38–42.

Garrido-novell, C., Pérez-marin, D., Amigo, J. M., Fernández-novales, J., Guerrero, J. E., & Garrido-varo, A. (2012). Grading and color evolution of apples using RGB and hyperspectral imaging vision cameras. *Journal of Food Engineering*, *113*, 281–288.

Gholizadeh, A., Amin, M. S. M., Anuar, A. R., & Aimrun, W. (2009). Evaluation of 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.

Govaerts, Y. M., Jacquemoud, S., Verstraete, M. M., & Ustin, S. L. (1996). Three-dimensional radiation transfer modeling in a dicotyledon leaf. *Applied Optics*, *35*(33), 6585–6598.

Griffin, J. F. T., Spittle, E., Rodgers, C. R., Liggett, S., Cooper, M., Bakker, D.,& Bannantine, J. P. (2005). Immunosorbent Assay for Diagnosis of Johne â€™ s Disease in Red Deer (Cervus elaphus) Immunoglobulin G1 Enzyme-Linked Immunosorbent Assay for Diagnosis of Johne ' s Disease in Red Deer (Cervus elaphus). *Clinical and Vaccine Immunology*, *12*(12), 1401–1409.

Habibuddin, H., Ahmad, I. B., Mahir, a M., Jalani, S., & Omura, T. (1995). Resistance in rice to multiplication of the two tungro viruses +, *23*(1), 27–36.

Habibuddin, H., Hadzim, K., Othman, O., & Azlan, S. (2000). Y 1286 is a Balimau Putih-derived rice line resistant to rice tungro bacilliform and spherical viruses. *Journal of Agricultural and Food Science*, *28*(9344), 13–22.

Habibuddin, H., Mahir, A. M., Ahmad, I. B., Jalani, B. S., & Imbe, T. (1997). Genetic analysis of resistance to rice tungro spherical virus in several rice varieties. *Journal of Tropical Agricultural and Food Science*, *25*(1), 1–7.

Hashim, N., Pflanz, M., Regen, C., Janius, R. B., Abdul Rahman, R., Osman, A., & Zude, M. (2013). An approach for monitoring the chilling injury appearance in bananas by means of backscattering imaging. *Journal of Food Engineering*, *116*(1), 28–36.

Hay, J. M., Jones, M. C., Blakebrough, M. L., Dasgupta, I., Davies, J. W., Hull, R., & Nr, N. (1991). An analysis of the sequence of an infectious clone of rice tungro bacilliform virus , a plant pararetrovirus. *Nucleic Acids Research*, *19*(10), 2615–2621.

He, Q., Chong, K. H., Chng, H. H., Leung, B., Ling, A. E., Wei, T.,& Kwang, J. (2004). Development of a Western blot assay for detection of antibodies against

coronavirus causing severe acute respiratory syndrome. *Clinical and Diagnostic Laboratory Immunology*, *11*(2), 417–22.

Henriques, A. M., Fagulha, T., Barros, S. C., Ramos, F., Duarte, M., Luís, T., & Fevereiro, M. (2016). Development and validation of a blocking ELISA test for the detection of avian influenza antibodies in poultry species. *Journal of Virological Methods*, *236*, 47–53.

Hibino, H., Roechan, M., & Sudarisman, S. (1978). Association of Two Types of Virus Particles with Penyakit Habang (Tungro Disease) of Rice in Indonesia. *Phtopathology*, *68*, 1412–1416.

Huang, J., Sun, J., Liao, H., & Liu, X. (2015). Detection of brown planthopper infestation based on SPAD and spectral data from rice under different rates of nitrogen fertilizer. *Precision Agricultural*, *16*, 148–163.

Huang, S., Qi, L., Ma, X., Xue, K., Wang, W., & Zhu, X. (2015). Hyperspectral image analysis based on BoSW model for rice panicle blast grading. *Computers and Electronics in Agriculture*, *118*, 167–178.

Islam, M. S., Bhuiya, M. S. U., Rahman, S., & Hussain, M. M. (2009). Evaluation of SPAD and LCC based nitrogen management in rice (Oryza sativa L.). *Bangladesh Journal of Agricultural Research*, *34*(4), 661–672.

Jacquemoud, S., & Baret, F. (1990). PROSPECT : A Model of Leaf Optical Properties Spectra. *Remote Sensing of Environment*, *34*, 75–91.

Jacquemoud, S., & Ustin, S. L. (2001). Leaf optical properties: A state of the art. In *International Symposium Physical Measurements & Signatures in Remote Sensing* (pp. 223–232). Aussois, France.

Joshi, M., & Deshpande, J. D. (2010). Polymerase Chain Reaction : Methods , Pr. *International Journal of Biomedical Research*, *1*(5), 81–97.

Kajale, R. R. (2015). Detection & recognition of plant leaf diseases using image processing and android O . S . *International Journal of Engineering Research and General Science*, *3*(2).

Katsantonis, D., Koutroubas, S. D., Ntanos, D. A., & Lupotto, E. (2009). Effect of blast disease on nitrogen accumulation and remobilization to rice grain. *Journal of Plant Pathology*, *90*(2), 263–272.

Kezhu, T., Yuhua, C., Weixian, S., & Xiaoda, C. (2014). Identification of diseases for soybean seeds by computer vision applying BP neural network. *International Journal of Agricultural and Biological Engineering*, *7*(3), 43–50.

Khan, M. A., Hibino, H., Aguiero, V. M., & Daquioag, R. D. (1991). Rice and Weed Hosts of Rice Tungro Associated Viruses and Leafhopper Vectors. *Plant Disease*, *75*(9), 926–930.

Knipling, E. B. (1970). Physical and Physiological Basis for the Reflectance of Visible and Near-Infrared Radiation from Vegetation. *Remote Sensing of Environment*, *1*(3), 155–159.

Kobayashi, T., Kanda, E., Kitada, K., Ishiguro, K., & Torigoe, Y. (2000). Detection of Rice Panicle Blast with Multispectral Radiometer and the Potential of Using Airborne Multispectral Scanners. *Phytopatology*, *91*(28), 316–323.

Kono, M., Yamamoto, K., Nagamatsu, M., & Kutsuna, S. (2015). Use of polymerase chain reaction in the diagnosis of Whipple's disease. *Journal of Infection and Chemotherapy*, *21*(12), 885–888.

Kortum, G. (1969). *Reflectance Spectroscopy : Principles, Methods, Applications*. Tubingen, Wihelmstrabe: Springer-Verlag New York Inc. 1969.

Kumar, M. A., Barathidasan, R., Palanivelu, M., Singh, S. D., Wani, M. Y., Malik, Y. S., & Dhama, K. (2016). A novel recombinant Meq protein based dot-ELISA for

rapid and confirmatory diagnosis of Marek's disease induced lymphoma in poultry. *Journal of Virological Methods*, *236*, 271–280.

Kurenda, A., Zdunek, A., Schlüter, O., & Herppich, W. B. (2014). VIS/NIR spectroscopy, chlorophyll fluorescence, biospeckle and backscattering to evaluate changes in apples subjected to hydrostatic pressures. *Postharvest Biology and Technology*, *96*, 88–98.

Kurien, B. T., & Scofield, R. H. (2006). Western blotting. *Methods*, *38*(4), 283–293. https://doi.org/10.1016/j.ymeth.2005.11.007

Kurniawati, N. N., Abdullah, S. N. H. S., Abdullah, S., & Abdullah, S. (2009a). Investigation on Image Processing Techniques for Diagnosing Paddy Diseases. *International Conference of Soft Computing and Pattern Recognition*, 272–277.

Kurniawati, N. N., Abdullah, S. N. H. S., Abdullah, S., & Abdullah, S. (2009b). Texture analysis for diagnosing paddy disease. In *International Conference on Electrical Engineering and Informatics* (pp. 23–27). Bangi, Selangor.

Lan, Y., Huang, Y., Martin, D. E., & Hoffmann, W. C. (2009). Development of an Airborne Remote Sensing System for Crop Pest Management: System Integration and Verification. *Applied Engineering in Agriculture*, *25*(4), 607–616.

Lima, J. A. A., Nascimento, A. K. Q., Radaelli, P., & Purcifull, D. E. (2009). Serology Applied to Plant Virology. In *Serological Diagnosis of Certain Human, Animal and Plant Diseases* (pp. 72–94).

Lin, F. F., Qiu, L. F., Deng, J. S., Shi, Y. Y., Chen, L. S., & Wang, K. (2010). Investigation of SPAD meter-based indices for estimating rice nitrogen status. *Computers and Electronics in Agriculture*, *71*, S60–S65.https://doi.org/10.1016/j.compag.2009.09.006

Liu, H., Song, X., Ni, Y., Lu, L., Zhou, X., & Wu, J. (2014). Highly Sensitive and Specific Monoclonal Antibody-Based Serological Methods for Rice Ragged Stunt Virus Detection in Rice Plants and Rice Brown Planthopper Vectors. *Journal of Integrative Agriculture*, *13*(9), 1943–1951.

Liu, L., & Zhou, G. (2009). Extraction of the Rice Leaf Disease Image Based on BP Neural Network. In *International Conference on Computational Intelligence and Software Engineering* (pp. 9–11).

Liu, Z.-Y., Shi, J., Zhang, L., & Huang, J. (2010). Discrimination of rice panicles by hyperspectral reflectance data based on principal component analysis and support vector classification. *Journal of Zhejiang University-SCIENCE B*, *11*(1), 71–78.

Liu, Z.-Y., Wu, H.-F., & Huang, J.-F. (2010). Application of neural networks to discriminate fungal infection levels in rice panicles using hyperspectral reflectance and principal components analysis. *Computers and Electronics in Agriculture*, *72*(2), 99–106.

Liu, Z., Cheng, J., Huang, W., Li, C., Xu, X., Ding, X., … Zhou, B. (2012). Hyperspectral Discrimination and Response Characteristics of Stressed Rice Leaves Caused by Rice Leaf Folder. *International Federation for Information Processing*, *369*, 528–537.

Long, D. H., Lee, F. N., & TeBeest, D. O. (2000). Effect of Nitrogen Fertilization on Disease Progress of Rice Blast on Susceptible and Resistant Cultivars. *Plant Disease*, *84*(4), 403–409.

Lorente, D., Blasco, J., Serrano, A. J., Soria-Olivas, E., Aleixos, N., & Gomez-Sanchis, J. (2013). Comparison of ROC Feature Selection Method for the Detection of Decay in Citrus Fruit Using Hyperspectral Images. *Food Bioprocess Technology*, *6*, 3613–3619.

Lorente, D., Escandell-montero, P., Cubero, S., Gómez-sanchis, J., & Blasco, J. (2015). Visible – NIR reflectance spectroscopy and manifold learning methods applied to the detection of fungal infections on citrus fruit. *Journal of Food Engineering*, *163*, 17–24.

Lorente, D., Zude, M., Regen, C., Palou, L., Gómez-Sanchis, J., & Blasco, J. (2013). Early decay detection in citrus fruit using laser-light backscattering imaging. *Postharvest Biology and Technology*, *86*, 424–430.

Lu, R. (2004). Multispectral imaging for predicting firmness and soluble solids content of apple fruit. *Postharvest Biology and Technology*, *31*(2), 147–157.

Lu, R., & Peng, Y. (2006). Hyperspectral scattering for assessing peach fruit firmness. *Biosystems Engineering*, *93*(2), 161–171.

Lu, Z., & Heong, K. L. (2009). Effects of nitrogen-enriched rice plants on ecological fitness of planthoppers. In *Planthoppers: new threats to the sustainability of intensive rice production systems in Asia.* (pp. 247–256). Los Banos, Philippines.

Mahesh, S., Jayas, D. S., Paliwal, J., & White, N. D. G. (2015). Hyperspectral imaging to classify and monitor quality of agricultural materials. *Journal of Stored Products Research*, *61*, 17–26.

Maheshwari, C. V. (2013). Machine Vision Technology for Oryza Sativa L .(Rice). *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, *2*(7), 2893–2900.

Mahlein, A., Steiner, U., Hillnhütter, C., Dehne, H., & Oerke, E. (2012). Hyperspectral imaging for small-scale analysis of symptoms caused by different sugar beet diseases. *Plant Methods*, *8*, 1–13.

Mcintosh, D., & Austin, B. (1996). The validity of Western blotting for the diagnosis of bacterial kidney disease based on the detection of the p57 antigen of Renibacterium salmoninarum. *Journal of Microbiological Methods*, *25*, 329–335.

Mirik, M., Jones, D. C., Price, J. A., Workneh, F., Ansley, R. J., & Rush, C. M. (2011). Satellite Remote Sensing of Wheat Infected by Wheat streak mosaic virus. *Plant Disease*, *95*(1), 4–12.

Mohd Daud, S., Jozani, H. J., & Arab, F. (2013). A Review on Predicting Outbreak of Tungro Disease in Rice Fields Based on Epidemiological and Biophysical Factors. *International Journal of Innovation, Management and Technology*, *4*(4), 447–450.

Mollazade, K., Omid, M., Akhlaghian Tab, F., Kalaj, Y. R., Mohtasebi, S. S., & Zude, M. (2013). Analysis of texture-based features for predicting mechanical properties of horticultural products by laser light backscattering imaging. *Computers and Electronics in Agriculture*, *98*, 34–45.

Mollazade, K., Omid, M., Tab, F. A., & Mohtasebi, S. S. (2012). Principles and Applications of Light Backscattering Imaging in Quality Evaluation of Agro-food Products: A Review. *Food and Bioprocess Technology*, *5*(5), 1465–1485.

Moscetti, R., Haff, R. P., Stella, E., Contini, M., Monarca, D., Cecchini, M., & Massantini, R. (2015). Feasibility of NIR spectroscopy to detect olive fruit infested by Bactrocera oleae. *Postharvest Biology and Technology*, *99*, 58–62.

Myers, J. S., & Miller, R. L. (2005). Optical Airborne Remote Sensing. In *Remote Sensing of Coastal Aquatic Environments* (pp. 51–67). Netherlands: Springer.

Nath, P. D., Kenyon, L., Bartolome, V. I., McLaren, G., & Azzam, O. (2000). Simple Serological Assays for Detecting Rice Tungro Viruses. *Food and Agricultural Immunology*, *12*(2), 139–151.

Norliza, A. B., Lau, H. Y., Habibuddin, H., & Tan, C. S. (2014). Cloning , expression

and purification of recombinant RTSV and RTBV coat proteins for polyclonal antibody production. *Journal of Tropical Agricultural and Food Science*, *42*(1), 93–103.

Ogawa, Y. (2008). *Quality Evaluation of Rice*. *Computer Vision Technology for Food Quality Evaluation*. Elsevier Inc.

Padhye, P., Rajani, K., Shikalgar, S., & Khot, S. T. (2014). Machine Vision Guided System for Classification and Detection of Plant Diseases using Support Vector Machine. *International Journal of Electronics Communication and Computer Engineering*, *5*(4), 249–254.

Peng, Y., & Lu, R. (2005). Modeling multispectral scattering profiles for prediction of apple fruit firmness. *Transactions of the ASAE*, *48*(1), 235.

Pereira, S. R., Travassos, C. E., Huguenim, A., Guimarães, a C., Silva, a G., & Guimarães, M. a. (1998). Western blot detection of infectious bursal disease virus infection. *Brazilian Journal of Medical and Biological Research*, *31*(5), 671–674.

Periasamy, M., Niazi, F. R., & Malathi, V. G. (2006). Multiplex RT-PCR , a novel technique for the simultaneous detection of the DNA and RNA viruses causing rice tungro disease. *Journal of Virological Methods*, *134*, 230–236.

Phadikar, S., & Sil, J. (2008). Rice disease identification using pattern recognition techniques. In *International Conference on Computer and Information Technology* (pp. 420–423). Kjulna, Bangladesh.

Phadikar, S., Sil, J., & Das, A. K. (2012). Classification of Rice Leaf Diseases Based on Morphological Changes. *International Journal of Information and Electronics Engineering*, *2*(3), 460–463.

Phadikar, S., Sil, J., & Das, A. K. (2013). Rice diseases classification using feature selection and rule generation techniques. *Computers and Electronics in Agriculture*, *90*, 76–85.

Pixia, D., & Xiangdong, W. (2013). Recognition of Greenhouse Cucumber Disease Based on Image Processing Technology. *Journal of Applied Sciences*, *3*, 27–31.

Prasannakumar, N. R., Chander, S., & Sahoo, R. N. (2014). Characterization of brown planthopper damage on rice crops through hyperspectral remote sensing under field conditions. *Phytoparasitica*, *42*, 387–395.

Praud, A., Durán-Ferrer, M., Fretin, D., Jaÿ, M., O'Connor, M., Stournara, A., & Garin-Bastuji, B. (2016). Evaluation of three competitive ELISAs and a fluorescence polarisation assay for the diagnosis of bovine brucellosis. *The Veterinary Journal*, *216*(June), 38–44.

Qin, J., Burks, T. F., Ritenour, M. A., & Bonn, W. G. (2009). Detection of citrus canker using hyperspectral reflectance imaging with spectral information divergence. *Journal of Food Engineering*, *93*(2), 183–191.

Qin, J., & Lu, R. (2008). Measurement of the optical properties of fruits and vegetables using spatially resolved hyperspectral diffuse reflectance imaging technique. *Postharvest Biology and Technology*, *49*(3), 355–365.

Qin, Z., & Zhang, M. (2005). Detection of rice sheath blight for in-season disease management using multispectral remote sensing. *International Journal of Applied Earth Observation and Geoinformation*, *7*, 115–128.

Qing, Z., Ji, B., & Zude, M. (2007). Predicting soluble solid content and firmness in apple fruit by means of laser light backscattering image analysis. *Journal of Food Engineering*, *82*(1), 58–67.

Rabu, M. R., & Mohd Shah, M. D. (2013). Food and livelihood security of the Malaysian paddy farmers. *Economic and Technology Management Review*, *8*,

59–69.
Rajkumar, P., Wang, N., EImasry, G., Raghavan, G. S. V, & Gariepy, Y. (2012). Studies on banana fruit quality and maturity stages using hyperspectral imaging. *Journal of Food Engineering*, *108*(1), 194–200.
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.
Renugambal, K., & Senthilraja, B. (2015). Application of Image Processing Techniques in Plant Disease Recognition. *International Journal of Engineering Research & Technology*, *4*(3), 919–923.
Roy, R. N., Finck, A., Blair, G. J., & Tandon, H. L. S. (1992). Nutrient management guidelines for some major field crops. In *Plant nutrition for food security* (pp. 235–248).
Saberioon, M. M., Amin, M. S. M., Gholizadeh, A., & Ezri, M. H. (2014). A Review of Optical Methods for Assessing Nitrogen Contents During Rice Growth. *Applied Engineering in Agriculture*, *30*(4), 657–669.
Saberioon, M. M., Mohd Amin, S. M., Wayayok, A., Gholizadeh, A., & Anuar, A. R. (2013). Assessment of colour indices derived from conventional digital camera for determining nitrogen status in rice plants. *Journal of Food, Agriculture & Environment*, *11*(2), 655–662.
Salim, M. (2002). Biology of rice green leafhopper, Nephitettix virecens (Distant) under laboratory condition. *Pakistan Journal Agricultural Research*.
Sanjana, Y., Ashwath Sivasamy, & Sri Jayanth. (2015). Plant Disease Detection Using Image Processing Techniques. *International Journal of Innovative Research in Science, Engineering and Technology*, *4*(6), 295–301.
Sankaran, S., Ehsani, R., A. Inch, S., & C. Ploetz, R. (2012). Evaluation of Visible-Near Infrared Reflectance Spectra of Avocado Leaves as a Non-destructive Sensing Tool for Detection of Laurel Wilt. *Plant Disease*, *96*, 1683–1689.
Sankaran, S., Mishra, A., Maja, J. M., & Ehsani, R. (2011). Visible-near infrared spectroscopy for detection of Huanglongbing in citrus orchards. *Computers and Electronics in Agriculture*, *77*(2), 127–134.
Sannakki, S. S., & Rajpurohit, V. S. (2015). Classification of Pomegranate Diseases Based on Back Propagation Neutral Network. *International Journal of Advance Foundation and Research in Computer (IJAFRC)*, *2*(Special Issues), 309–316.
Senoaji, W., & Praptana, R. H. (2013). Interaction between Nitrogen and Tungro Disease Incidence and Its Integrated Control in Rice. *Iptek Tanaman Pangan*, *8*(2), 80–89.
Shahjahant, M., Zaktrit, A. H., Imbet, T., Jalani, B. S., & Omuras, T. (1991). Efficient method of determining tungro virus resistance in rice (Oryza sativa L .)*. *Crop Protection*, *10*, 195–198.
Sharma, S., & Dasgupta, I. (2012). Development of SYBR Green I based real-time PCR assays for quantitative detection of Rice tungro bacilliform virus and Rice tungro spherical virus. *Journal of Virological Methods*, *181*(1), 86–92.
Silvain, J. F., & Vassal, J. M. (1991). Characterization of the Genome of Rice Tungro Bacilliform Virus: Comparison with Commelina Yellow Mottle Virus and Caulimoviruses. *Virology*, *185*, 354–364.
Singh, A. K., Ponnuswamy, R., Donempudi, K., & Mangrauthia, S. K. (2016). The Differential Reaction of Rice Hybrids to Tungro Virus by Phenotyping and PCR Analysis. *Journal of Phytopathology*, *164*, 177–184.
Singh, B., Singh, Y., Ladha, J. K., Bronson, K. F., Balasubramanian, V., Singh, J., &

Khind, C. S. (2002). Chlorophyll meter- and leaf color chart-based nitrogen management for rice and wheat in northwestern India. *Agronomy Journal*, *94*(4), 821–829.

Sōgawa, K. (1982). The Rice Brown Planthopper: Feeding Physiology and Host Plant Interactions. *Annual Review of Entomology*, *27*(1), 49–73.

Sta Cruz, F. C., Hull, R., & Azzam, O. (2003). Changes in level of virus accumulation and incidence of infection are critical in the characterization of Rice tungro bacilliform virus (RTBV) resistance in rice. *Archives of Virology*, *148*(8), 1465–1483.

Stroppiana, D., Boschetti, M., Brivio, P. A., & Bocchi, S. (2006). Remotely sensed estimation of rice nitrogen concentration for forcing crop growth models. *Italian Journal of Agrometeorology*, *57*(3), 50–57.

Stuart, B. (2004). *Infrared Spectoscopy : Fundamentals and Applications*. John Wiley & Sons, Ltf.

Suman, T., & Dhruvakumar, T. (2015). Classification of paddy leaf diseases using shape and color features. *International Journal of Electrical and Electronics Engineers*, *7*(1), 239–250.

Takahashi, Y., Tiongco, E. R., Cabauatan, P. Q., Koganezawa, H., Hibino, H., & Omura, T. (1993). Detection of Rice Tungro Bacilliform Virus by Polymerase Chain Reaction for Assessing Mild Infection of Plants and Viruliferous Vector Leadhoppers. *Phtopathology*, *83*(6), 655–659.

Tan, F., Ma, X., Wang, C., & Shang, T. (2012). Data Analysis of Cold Rice Blast Based on Near Infrared Spectroscopy. In *Computer and Computing Technologies in Agriculture* (Vol. 369, pp. 64–71).

Tuncay, Ö., Dursun, E., Ya, B., & Okur, B. (2011). Yield and quality of garden cress affected by different nitrogen sources and growing period, *6*(3), 608–617.

Uda, M. N. A., Hasfalina, C. M., Faridah, S., I., Z., B., S. N., Hashim, U.,& Adam, T. (2013). Comparative Study Between Elisa And Surface Plasmon Resonance (Spr) For Rice. *Journal of Applied Sciences Research*, *9*(11), 5568–5571.

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.

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 *2nd International Conference on Agricultural and Food Engineering* (Vol. 2, pp. 107–112). Elsevier Srl.

Udomkun, P., Nagle, M., Mahayothee, B., & Müller, J. (2014). Laser-based imaging system for non-invasive monitoring of quality changes of papaya during drying. *Food Control*, *42*, 225–233.

Uehara-ichiki, T., Shiba, T., Matsukura, K., Ueno, T., Hirae, M., & Sasaya, T. (2013). Detection and diagnosis of rice-infecting viruses. *Fontiers in Microbiology*, *4*, 1–7.

Vincelli, P., & Tisserat, N. (2008). Nucleic Acid – Based Pathogen Detection in Applied Plant Pathology. *Plant Disease*, *92*(5), 660–669.

Wallen, V. R., & Jackson, H. R. (1971). Aerial Photography as a Survey Technique for the Assessment of Bacterial Blight of Field Beans. *Canadian Plant Disease Survey*, *51*(4), 163–169.

Wang, Y., Wang, D., Shi, P., & Omasa, K. (2014). Estimating rice chlorophyll content

and leaf nitrogen concentration with a digital still color camera under natural light. *Plant Methods*, *10*(1), 36.

Wójtowicz, M., Wójtowicz, A., & Piekarczyk, J. (2016). Application of remote sensing methods in agriculture. *Communiications in Biometry and Crop Science*, *11*(1), 31–50.

Wolcott, M. J. (1992). Advances in nucleic acid-based detection methods. *Clinical Microbiology Reviews*, *5*(4), 370–386.

Yam, K. L., & Papadakis, S. E. (2004). A simple digital imaging method for measuring and analyzing color of food surfaces. *Journal of Food Engineering*, *61*(1), 137–142.

Yamamoto, Y. (2002). PCR in diagnosis of infection: detection of bacteria in cerebrospinal fluids. *Clinical and Diagnostic Laboratory Immunology*, *9*(3), 508–514.

Yang, C. (2010). Assessment of the severity of bacterial leaf blight in rice using canopy hyperspectral reflectance. *Precision Agricultural*, *11*, 61–81.

Yang, H., Yang, J., Yamin, L., & Junjun, H. (2014). SPAD Values and Nitrogen Nutrition Index for the Evaluation of Rice Nitrogen Status. *Plant Production Science*, *17*(1), 81–92.

Yang, Y., Chai, R., & He, Y. (2012). Early detection of rice blast (Pyricularia) at seedling stage in Nipponbare rice variety using near-infrared hyper-spectral image. *African Journal of Biotechnology*, *11*(26), 6809–6817.

Yao, Q., Guan, Z., Zhou, Y., Tang, J., Hu, Y., & Yang, B. (2009). Application of support vector machine for detecting rice diseases using shape and color texture features. *International Conference on Engineering Computation*, 79–83.

Zhao, J., Zhang, D., Luo, J., Dong, Y., Yang, H., & Huang, W. (2012). Characterization of the rice canopy infested with brown spot disease using field hyperspectral data. *Wuhan University Journal of Natural Sciences*, *17*(1), 86–92.

Zhong-xian, L., Xiao-ping, Y., Kong-luen, H., & Cui, H. (2005). Effects of nitrogen nutrient on the behavior of feeding and oviposition of the brown planthopper, Nilarpavata lugens on IR64. *Journal of Zhejiang University*, *31*(1), 62–70.

Zhou, Z., Zang, Y., Li, Y., Zhang, Y., Wang, P., & Luo, X. (2013). Rice plant-hopper infestation detection and classification algorithms based on fractal dimension values and fuzzy C-means. *Mathematical and Computer Modelling*, *58*(3–4), 701–709.