UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF PRESCRIPTION-BASED LIQUID FERTILIZER APPLICATION IN THE SYSTEM OF RICE INTENSIFICATION

MUHAMMAD NURFAIZ BIN ABD KHARIM

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By

MUHAMMAD NURFAIZ BIN ABD KHARIM

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

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DEDICATION

This Thesis Is Dedicated to

Those Who Are Ready to Change Themselves and Prevail to Change the World.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF PRESCRIPTION-BASED LIQUID FERTILIZER APPLICATION IN THE SYSTEM OF RICE INTENSIFICATION

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July 2020

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Uniform-based fertilizer application is still being normally used in nutrient management of System of Rice Intensification (SRI) with very less consideration of Precision Farming (PF). The overall study was to develop a precise prescription-based liquid fertilizer formulation for the SRI field by using Unmanned Aerial Vehicle (UAV). The aerial images of the SRI field were captured using a digital camera mounted on a UAV flying at low altitude (< 50 m). The precise amount of nitrogen (N) was then determined by using vegetation indices of I_{PCA}-RGB model and prescribed according to the actual requirement of the rice plant. A laboratory-scale experiment in the greenhouse was performed to establish fertilizer formulation and found that an additional foliar fertilization needs to be conducted during the grain formation stage. A study on the performance of the UAV flying parameters and spraying requirements was performed to establish the operating procedure of aerial fertilizer spraying. Results showed that the droplet pattern and droplet deposition density (59.08 L/min) was higher with a lower coefficient of variations (CV) of droplet uniformity (3.59%) when the UAV flying speed was maintained at 2 m/s and spraying rate of 3.00 L/min at a constant height of 2 m above the rice canopy compared to the higher-flying speeds (4 & 6 m/s) and lower spraying rates (0.75, 1.5, & 2.25 L/min). Twenty plots were set up according to 2 types of liquid fertilizer (organic and inorganic) and 2 methods fertilizer based-rate (uniform and prescription) with 5 replications for each of the treatments. Fertilizer spraying was 5 times during 15 Days After Transplanting (DAT), 35 DAT, 55 DAT, 65 DAT, 75 DAT and harvested at 110 DAT. Aerial image acquisition of the SRI field with the I_{PCA}-RGB model showed a positive result in determining N content for precise fertilizer application. The I_{PCA}-RGB model had a close relationship with SPAD chlorophyll meter in the assessment of chlorophyll content at the rice leaf canopy scale during all the five times fertilization periods. In terms of crop growth and yield performances, results showed that treatment uniform-based rate with inorganic fertilizer had higher plant heights (107.43cm) compared to other treatments. However, the treatment of prescription-based with organic fertilizer showed higher performances for the number of tillers (34a), the number of panicles (19a), and spikelet per hill (46a) compared to

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other treatments at p = 0.05. Moreover, prescription-based with organic fertilizer treatment showed higher values for yield performances compared to other treatments namely; grain yield (g) (771.35a), net grain yield (g) in 1m2 Crop Cutting Test (CCT) (614.13a), and effective tillers in 1m2 CCT (309a) at p = 0.05. Thus, prescription-based treatment with organic fertilizer shows the lowest moisture content (18.67%) compared to other treatments for the grain moisture comparison. While, for the UAV performance of aerial spraying, treatments that spray prescribed liquid fertilizer had a faster time to complete the spraying cycle and refilling process compared to treatments of uniform-based rate. In terms of cost analysis, prescription-based treatment with organic fertilizer had higher in total revenue (RM 9,405), net profit (RM 3,707.16), and return of investment (ROI) (65.06%) compared to other treatments. However, organic-based treatment either for uniform (RM 5,714.38) or prescription-based (RM 5,697.84) showed a higher amount of production cost compared to inorganic-based treatment either for uniform (RM 5,669.54) or prescription-based (RM 5,589.04). Overall, a prescription-based fertilizer application was feasible to be applied to the rice plant with better yield performances and saving in fertilizer amounts compared to uniform-based rate treatment. Thus, results from this study can provide technical procedure, and theoretical basis for the application of precise liquid fertilizer through the prescription-based method and usage of UAV for liquid fertilizer spraying within the SRI farming.

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PEMBANGUNAN APLIKASI BAJA CECAIR BERASASKAN PRESKRIPSI DALAM SISTEM INTENSIFIKASI PADI

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Pembajaan secara seragam masih diamalkan dalam pengurusan pembajaan penanaman Sistem Intensifikasi Padi (SIP) dan kurang menitikberatkan prinsip pertanian persis. Secara keseluruhannya, kajian ini bertujuan merencana satu formula pengiraan baja secara persis dan menggunakan "Unmanned Aerial Vehicle (UAV)" untuk menyembur baja cecair di seluruh petak sawah SIP. Baja cecair ditentukan berdasarkan keperluan semasa pokok padi melalui pengambilan gambar petak sawah secara udara dengan menggunakan kamera digital yang dipasang pada UAV dan diterbangkan pada ketinggian rendah (< 50 m) untuk tujuan pemetaan. Pengiraan jumlah baja nitrogen (N) ditentukan melalui penggunaan model pemantulan spektrum daun iaitu model I_{PCA}-RGB. Kajian didalam rumah hijau dijalankan untuk menetapkan formula pengiraan baja dan menemukan bahawa satu tambahan pembajaan cecair perlu dilakukan pada tempoh pembentukan beras padi. Satu kajian mengenai prestasi penerbangan dan kadar semburan secara UAV dilaksanakan untuk menilai parameter yang optimal untuk penetapan prosedur pembajaan cecair secara semburan udara. Keputusan ujikaji menunjukkan corak titisan semburan dan jumlah pemendapan titisan semburan (59.08 L/min) adalah lebih tinggi berserta "coefficient of variations (CV)" keserataan titisan semburan (3.59%) yang rendah, apabila UAV diterbangkan pada kelajuan 2 m/s dan disembur pada kadar 3.00 L/min pada ketinggian malar 2 m dari kanopi pokok padi berbanding keputusan yang terhasil apabila diterbangkan pada kelajuan yang lebih tinggi (4 & 6 m/s) dan disembur pada kadar semburan yang lain (0.75, 1.5, & 2.25 L/min). Dua puluh plot rawatan disediakan berdasarkan 2 jenis baja cecair (organik dan inorganik) dan 2 jenis cara bekalan nutrien (seragam dan preskripsi) yang dimana setiap rawatan mempunyai 5 replikasi untuk eksperimen di sawah. Pembajaan dilakukan pada 5 peringkat umur pokok padi iaitu semasa hari ke-15**,** hari ke-35, hari ke-55, hari ke-65, hari ke-75 dan dituai pada hari ke-110 penanaman. Pengambilan gambar sawah secara udara bersama model I_{PCA}-RGB menunjukkan keputusan yang positif dalam menentukan jumlah N untuk aplikasi pembajaan dengan persis. Model I_{PCA}-RGB mempunyai hubungan yang rapat dengan SPAD klorofil meter dalam penilaian jumlah klorofil di kanopi daun padi semasa tempoh lima kali pembajaan. Keputusan

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perbandingan untuk prestasi pertumbuhan dan pengeluaran hasil menunjukkan bahawa rawatan yang menggunakan baja cecair inorganik pada kadar yang seragam mempunyai keputusan yang tinggi dari segi ketinggian tumbuhan (107.43cm) berbanding rawatan yang lain. Walau bagaimanapun, rawatan secara preskripsi dengan menggunakan baja organik menunjukkan prestasi yang lebih baik berbanding rawatan yang lain untuk ciri-ciri seperti; bilangan tiller (34a), bilangan panikel (19a) dan spikelet (46a) berbanding rawatan yang lain pada p = 0.05. Selain itu, rawatan yang menggunakan baja cecair organik pada kadar yang preskripsi menunjukkan nilai yang lebih tinggi berbanding rawatan secara kadar seragam untuk ciri-ciri pengeluaran seperti; hasil beras (g) (771.35a) , hasil beras bersih (g) dalam Crop Cutting Test (CCT) $1m^2$ (614.13a), dan billangan efektif tiller dalam CCT $1m^2$ (309a) pada p = 0.05. Perbandingan kadar kelembapan bijian beras mendapati rawatan secara preskripsi bersama baja organik mempunyai nilai yang rendah (18.67%) berbanding rawatan yang lain. Manakala untuk penilaian prestasi semburan baja cecair melalui UAV, rawatan secara preskripsi mempunyai masa yang lebih pantas untuk operasi dilapangan berbanding rawatan secara seragam. Selain itu, perbandingan kos analisis menunjukkan rawatan secara preskripsi dengan menggunakan baja organik menunjukkan nilai yang tinggi untuk jumlah hasil (RM 9,405), keuntungan bersih (RM 3,707.16) dan pulangan pelaburan (ROI) (65.06%) berbanding rawatan yang lain. Namun, rawatan yang menggunakan baja organik samada secara seragam (RM 5,714.38) ataupun secara preskripsi (RM 5,697.84) menunjukkan jumlah yang tinggi untuk kos pengeluaran berbanding rawatan yang menggunakan baja inorganik samada secara seragam (RM 5,669.54) ataupun secara preskripsi (RM 5,589.04). Secara keseluruhannya, rawatan secara preskripsi untuk aplikasi pembajaan cecair boleh dilaksanakan kepada pokok padi kerana menunjukkan prestasi hasil yang lebih baik dan menjimatkan penggunaan baja berbanding rawatan secara seragam. Justeru itu, hasil dapatan kajian ini boleh menyediakan teknikal prosedur dan teori asas untuk aplikasi baja cecair secara persis melalui kaedah preskripsi dan penggunaan UAV untuk semburan baja cecair dalam penanaman SIP.

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Faiz Kharim

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LIST OF ABBREVIATTIONS

ANNOVA	Analysis of Variances
ASEAN	Association of Southeast Asian Nations
CBD	Complete Block Design
CEC	Cation Exchange Capacity
CCD	Charged-Coupled Device
CCT	Crop Cutting Test
CV	Coefficient variation
DAT	Days After Transplanting
DCA	Department of Civil Aviation
DOA	Department of Agriculture
EFC	Effective Field Capacity
EVI	Enhanced Vegetation Index
FAO	Food and Agricultural Organization
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FE	Field Efficiency
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HSD	Tukey's honest significant difference
IOT	Internet of Thing
I_{PCA}	Principal Components Analysis Index
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
IKAW	Kawashima index
LAI	Leaf Area Index

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LARS	Low Altitude Remote Sensing
LCC	Leaf Colour Chart
MARDI	Malaysian Agricultural Research and Development Institute
MBI	Menteri Besar Incorporated
MOA	Ministry of Agriculture and Agro-based Industry
MOU	Memorandum of Understanding
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental Organization
NGRDI	Normalized Green Red Difference Index
NIR	Near infrared
NOSC	Indonesian NGO Nusantara Organic SRI Center
PF	Precision Farming
PPE	Personal Protective Equipment
PWM	Pulse Width Modulation
RGB	Red, Green, Blue
RCBD	Randomized Complete Block Design
RTK	Real Time Kinematic
SAVI	Soil Adjusted Vegetation Index
SAS	Statistical Analysis System Software
SCI	System of Crop Intensification
SPAD	Soil Plant Analysis Development
SRI	System of Rice Intensification
SSL	Self-Sufficiency Level
TFC	Theoretical Field Capacity
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle

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VI	Vegetation Indices
VRA	Variable rate application
VRT	Variable rate technology
VRS	Virtual Reference Station

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Rice is a staple food for many countries, especially in the Asia continent. In Malaysia, the consumption rate is about 80kg/person in a year however the production is lesser than the required amount (Khazanah Research Institute, 2019). The production rate to support the nation's need is the so-called self-sufficiency level (SSL) and SSL for Malaysia was reported only 67 % at the moment (Khazanah Research Institute, 2019). This means the rest is imported about 33% primarily from Thailand, Vietnam, and Pakistan (Khazanah Research Institute, 2019). Therefore, the government has to emphasize local production to reduce the import rate and for national food security.

Recently, a new agroecology farming system known as System of Crop Intensification (SCI) has emerged around the globe and has been used to grow a wide range of crops. Rice was the beginning of the SCI system and known as SRI (System of Rice Intensification) (Abraham et al., 2014). SRI is recognized by some research universities like Cornell University from the United States of America, and important institutions such as the World Bank, IRRI, and FAO. The main reason why the agroecology farming system becomes a new wave of agriculture practices because of its concepts to produce more with fewer inputs that are fit to mitigate current issues of climate change, drought, insufficient water supply, and food scarcity. As noted, SRI is practiced by most poor rice farmers around the globe due to its many advantages such as less use of seeds and water, thus able to increase the rice production (Laulanié, 1993; Uphoff, 2003; Abraham et al., 2014).

However, SRI nutrients management still practiced a uniform-based rate of fertilization without taking considerations of the Precision Farming (PF) principle. SRI farmers generally applied sources of nutrients such as organic matter in the amount of 2 until 10 tons per hectare and spraying the organic liquid in high volume with improper rate measurement which might not meet the potential needs of the rice plant and soil requirement on the field (Styger & Jenkins, 2014). This practice can lead to problems of fertilizer insufficient, wastages due to fertilizer over usage, and potential of soil disturbances and environmental degradation. So, most likely the SRI farmer will suffer the losses due to overspending and less yield produces from the inefficient fertilizer application.

Parallel with the emergence of the SRI, PF is widely been used in managing the variability within crop farming. PF has been applied within the rice farming around the international rice bowl such as in Japan, the United States, Australia, Europe, and including countries in Southeast Asia. PF is a term used to describe the management of variability within field boundaries, i.e. applying agronomic inputs at the right place, at

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the right time with the right quantity to improve the economic efficiency and diminish the environmental impact of crop production (Bongiovanni & lowenberg-Deboer, 2004). Besides, it is a comprehensive system designed to optimize agriculture production by carefully tailoring soil and crop management to fit the different conditions found in each field while maintaining environmental quality (Blackmore, 2000). PF offers a chance to improve agriculture productivity, crop quality, reduces agro-chemical wastage through an efficient application, and minimize the pollution and conserve the energy used (Tey & Bridal, 2012).

Apart from that, the application of spraying liquid fertilizer on leaves of growing crops with estimated concentration is called a foliar application technique (Oosterhuis, 2009). Recently liquid fertilizer spraying has become an important practice in farm management while maintaining soil fertilizer application based (Alam et al., 2010). Liquid fertilizer spraying can help to reduce the fertilizer amount into the soil, fix the nutritional deficiency disorder, and fasten the uptake time by the plant through better nutrient absorption through the leaf cuticle and move into the cells compared through root adsorption from the soil-based fertilizer application (Fernandez and Eichert, 2009). Thus, the capability of liquid fertilizer to reduces the dependant on soil-based fertilizer can minimize the environmental degradation impact by reducing the amount of nutrients leaching, drainage, groundwater contamination, and nutrients runoff (Jamal et al., 2006).

During foliar application, leaves plant absorbed nutrients directly during the critical time and help to increase the photosynthesis rate and stimulate root function for better nutrients absorption (Fageria et al., 2009). Liquid fertilization might be able to help to reduce the excessive application of chemical fertilizer to the soil (Alam et al., 2015). Today liquid fertilizer was mainly used as a supplementary basis for micro-nutrient sources in rice farming to correct the nutritional deficiency of the rice plant however the rates and volume of the liquid fertilizer still in the uniform-based rates. Therefore, liquid fertilizer application with the prescribed rate and help of sensors such as Soil Plant Analysis Development (SPAD) chlorophyll meter, and Principal Components Analysis Index (I_{PCA})-RGB model that developed by Saberioon et al. (2014) able to assess nitrogen (N) content in the rice plant and predict accurately fertilizer amount that needed by the rice plant and soil requirements in the management zone.

Commonly, a conventional agricultural system was created and innovated with the advancement of sciences and technologies is to fulfill the increasing demand for foods from a vast growing worldwide population. Even though modern and intensive agricultural production system has multiplied the yielding, however, it produced adverse consequences to the environment. Luckily, a new farming system called PF and SRI able to intensifies rice production while protect and preserve the ecosystem for the better and sustainable agriculture industry.

In the beginning, SRI was created to improve the rice production of a local farmer in Sri Lanka that had a problem with water supply for irrigation purposes (Laulanié, 2011). Although the basic principles of SRI focused on transplanting of young seedling, wider spacing, schedule weeding, and less use of water supply, innovation to integrate with

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SRI for improvement is still in progress (Uphoff, 2008). This implies that practices of SRI can be improved with the innovation of technology to achieve high yielding of rice while improving agroecology.

The farmer still having difficulties in adoption to implement the SRI despite the benefits of SRI. It was argued that more innovation and technology are needed to be designed accordingly with the SRI farming practice to improve the adoption rate of SRI among the farmers and rice producers. So that SRI benefits can be enlightening and becoming the next choice of method to implement rice farming.

Indeed, Malaysia's rice farming needs a new way of farming methods to meet the recent national rice SSL to provide enough food to the people. This concern can be accomplished by integrating SRI with the PF method. Since both SRI and PF practices have shown promising results in producing high rice yield with quality and organic rice, lesser wastages, more efficient and saving the application of the input, and environmentally friendly (Durga & Kumar, 2013; Naresh et al., 2012). For these reasons, this study aims to implement the framework of PF within the SRI nutrients management to increase the national and farmer rice production that recently shows a slow increase in yield percentage.

1.2 Problem Statement

Currently, in SRI's nutrients management, farmers are applying the inputs without taking consideration of the PF application. Therefore, problems of fertilizer insufficient, and wastages due to fertilizer over usage that increased costing becoming a pertinent issue. Generally, SRI farmer applied source of nutrients such as fertilizer, organic matter, farmyard manure, and other organic waste or residue to the rice field in random amount, inaccurate measurement thus not meet the potential needs of the rice plant and soil condition in the field (Styger & Jenkins, 2014). Nutrients were broadcasted manually and randomly with human labour without the integration of any modern mechanization and/or any specific method of application.

In SRI planting, sources of nutrients were usually applied at a uniform rate without taking consideration of soil fertility, site-specific variability (nutrients availability), and actual rice leave requirement. So, the study was mainly to determine the precise amount, and the number of times for fertilization of liquid fertilizer through the application of a ground sensor (SPAD chlorophyll meter) and aerial sensor (RGB digital camera) with vegetation indices of IPCA-RGB model to assess the N content of the rice leaves canopy within the SRI field. Prescription-based fertilizer mapping was produced according to the aerial images of the rice field based on rice leaves colorization and the actual N requirement was determined based on fertilizer calculation that has been developed from the previous research. This was crucial for the precise fertilizer application that needed by the rice plant throughout its life stage from the early planting until harvesting stages. Hypothesis: Does prescription-based fertilizer application with using the I_{PCA}-RGB

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model could provide better growth and yield performances compared to uniform-based rates.

Since SRI farmers still practice the method of manual broadcasting for fertilizer application and less integrate modern mechanization and tools, several problems such as uneven plant growth in the field, low field capacity, and high labour for the operation were observed. Therefore, this study would like to introduce the application of liquid fertilizer especially organic fertilizer with the site-specific nutrient procedure and the usage of Unmanned Aerial Vehicle (UAV) for aerial spraying process. Thus, the study would like to evaluate and determine the best optimal parameter of the UAV flying procedure for the aerial spraying of organic liquid fertilizer within rice farming. Hypothesis: Could different UAV fly speeds and spraying rates affect the droplet deposition density and uniformity on the water sensitive paper while performing the UAV aerial spraying process?

Other consequences such as soft hardpan of soil structure, environmental degradation (soil erosion, run-off, toxicity, etc.), increase in cost management due to over usage, wastages of nutrients, and high labour due to manual fertilizer application arose from this traditional practice of SRI fertilizer management. So, most likely SRI farmer will suffer the losses and affect the actual potential of yield production since most of them come from the poor background and cost-sensitive (Laulanié, 1993; Uphoff, 2003; 2006a; Styger & Jenkins, 2014). Hypothesis: Does the prescription-based fertilizer application could provide better cost performances compared to uniform-based rates throughout the planting process.

1.3 Objectives of the Study

The main objective of this research is to apply prescribe-based liquid fertilizer in the System of Rice Intensification (SRI) by using Unmanned Aerial Vehicle (UAV) as the main platform for aerial spraying across the SRI field. Thus, UAV is used to capture the image of the SRI field for fertilizer determination with help of the I_{PCA}-RGB vegetation index model. Below are the objectives that are designed to achieve the main objective of the research:

a) To investigate the use of the I_{PCA}-RGB model to calculate N requirement of rice crop
b) To determine UAV spraying requirements
c) To analyse crop and cost performance for prescription-based liquid fertilizers.

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1.4 Scope and Limitation

The scope of this study shall be to establish a formula for calculating the concentration rates of N liquid fertilizer and determine the number of spraying that is required for UAV aerial liquid spraying for both SRI and conventional rice farming. Then, this study shall calibrate and determine optimal UAV flying parameters and UAV spraying speed rates for the aerial liquid spraying process. Moreover, the procedure in acquiring the image of the rice field by using the UAV and method of post-processing for fertilizer calculation derived from the vegetation indices of the I_{PCA}-RGB model shall be established. Procedure for application of liquid spraying with UAV as part of mechanization for fertilizer management within the SRI farming shall be established within this study. Apart from that, cost analysis for the study including the comparison between treatments, SRI, and conventional rice farming was done on a one-hectare basis and limited to the rice field and farmer that involved the experimental areas of the study.

The prescription-based fertilizer application was limited to the capability of the sprayer nozzle and unable to spray the liquid fertilizer at the adjustable sprayer rates at the real-time mechanism while UAV flying in the air which requires further study in the future. The prescription-based fertilizer application was based on the N sensor only since the availability of in-situ technology for sensing plant nutrients only existed for N element. While the sensor for phosphorus (P) and potassium (K) element still required further study in the future. The intervention procedure to reduce spraying drift while performing UAV aerial liquid spraying was to monitor the wind speeds (below 2 m/s) and directions with an anemometer and flag windsock before flying the UAV for the aerial spraying process. Thus, UAV was flying below 5 m above the crop canopy with UAV flying speeds limited to 2 – 4 m/s only to avoid drift potential of liquid spraying. Meteorological information of the location, time, and day of the UAV aerial spraying process was monitored 24 hours earlier before the execution of the spraying procedure.

1.5 Significances of the Study

The application of PF principles and technologies within the SRI farming could improve the management of agricultural inputs, environmental impacts as well as less economic wastages, efficiency, and could increase profitability for the SRI farmers. It could be a significant contribution to developing better site-specific nutrient management decisions that enhance the application of UAV technologies and can lead to more sustainable sound practices. Since SPAD chlorophyll meter, UAV image acquisition, vegetative indices of I_{PCA}-RGB model, and UAV aerial spraying were used in the study, SRI farmers around the world can benefit from this proposed methodology. Such development could prove to be useful for long term planning and site-specific nutrient management activities within SRI farming. Hence, this study can provide a valuable contribution and technical support in the determination of precise N nutrient requirements based on the rice leaf chlorophyll content in the SRI field through UAV aerial imaging acquisition process and application of UAV aerial liquid spraying to fertilize the SRI field with the organic liquid fertilizer.

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Muhammad Nurfaiz Bin Abd Kharim was born on 19th December 1989 in Sungai Petani, Kedah. He is the third child of four of Abd Kharim bin Yahaya and Che Salma binti Shaari. He received his primary school education in Sekolah Kebangsaan Tunku Ismail and received his secondary school in Sekolah Menengah Kebangsaan Bakar Arang and Sekolah Menengah Sains Sultan Mohamad Jiwa, Sungai Petani, Kedah. Then he went for his matriculation study in Perak Matriculation College, Perak in 2007 until 2008. In July 2008, he continued his bachelor study in University Malaysia Kelantan and graduated with a Bachelor of Agro-Technology Entrepreneurship in the year 2012. After he graduated from his bachelor study, he had work experiences with the private institution in banking, strategic and marketing industry, plantation, and an educational institution such as UCAM. Whilst he was working, he further his master study in the year 2013 at Universiti Putra Malaysia and graduated in the year 2015 with a Master's degree in Plantation Management. Later he enrolled his Ph.D. in Geospatial Engineering in September 2016 under the supervision of Dr. Aimrun Wayayok in the Faculty of Engineering, UPM. The title of his research was 'Prescription-based Liquid Fertilizer Application in the System of Rice Intensification'.

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