ESTIMATION OF MICROCLIMATE PARAMETERS ON INFESTATION RATE OF YELLOW STEM BORER (*Scirpophaga incertulas*) ON MR297 RICE VARIETY

By

DAUDA IDRIS

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

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

ESTIMATION OF MICROCLIMATE PARAMETERS ON INFESTATION RATE OF YELLOW STEM BORER (*Scirpophaga incertulas*) ON MR297 RICE VARIETY

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August 2023

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Scirpophaga incertulas is a predominant insect pest in rice cultivation that causes significant yield losses and is responsible for severe infestation exhibiting dead heart and white ear symptoms at vegetative and reproductive stages. Rice is the second highest-yielding grain and a staple diet in most countries. In Malaysia, rice is a vital plant, with an average daily consumption of 2.5 plates per head, and about 10% to 33% of the yield losses in the granary area of Malaysia during rice production are due to *S. incertulas*. However, information on the estimation of microclimate parameters in Malaysia on the infestation rate of yellow stem borer on MR297 rice variety is still not studied. The use of Artificial Neuron Network (ANN) and Multi-Linear Regression (MLR) in forecasting pest infestation and development has been used. However, this was not the case for yellow stem borer. Therefore, a series of experiments were conducted to obtain a study on the yellow stem borer. Adult yellow stem borers were collected using a Malaise trap from the Integrated Agricultural Development Area (IADA) Laut Barat Selangor. They released into a cage with 21-day-old paddy to allow them to copulate to achieve the following specific objective of the study.

The first study objective was to investigate the in-vitro culture and developmental changes of *S. incertulas* under different microclimate conditions in the Laboratory (27.26ºC $\pm$ 0.92 and RH of 67.43% $\pm$ 1.3) and shade house (33.16ºC $\pm$ 0.87 and RH 84.30% $\pm$ 1.43). Based on the findings, culturing of *S. incertulas* under laboratory and shade house conditions assumes significance in addressing the developmental growth of *S. incertulas* via identifying the lengths and widths as essential parameters for appropriate identification of the larval and pupal stages. The development time taken by the *S. incertulas* increases as insects develop faster, leading to early population growth. The correlation analysis of the data showed a significant relationship between the length and width of the fourth and fifth instar development in the Laboratory correlated to the minimum and maximum relative humidity. In contrast, pupae length and width in the

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field were significantly related to the minimum relative humidity and maximum temperature.

For the second aimed to determine the infestation and damage of *S. incertulas* on rice under different microclimatic conditions in Shade House (33.16ºC ± 0.87 and RH of 84.30% ± 1.43) and glass house (25.20ºC ± 0.29 and RH of 74.50% ± 2.12). The dead hearts at the vegetative phase revealed a significant mean percentage of infestation rate at 10 Days after treatments (DATS) to 40DATS ranging from 10.00% to 71.25% in the glass house, slightly higher than in the shade house 6.25% to 70.63%. Also, at the reproductive stage, the glass house had the highest infestation rate of white ears, which varied from 5.00% to 58.75%, in contrast to the shade house, which had a mean percentage of 5.00% to 31.88% during the 40DATS to 70DATS under different microclimate conditions. Therefore, microclimates like temperature and relative humidity significantly affect the infestation rate of the *S. incertulas* on rice.

The final study aimed to estimate the yellow stem borer infestation rate with abiotic factor using an artificial neuron network (ANN) and Multi-linear regression model, which effectively estimate the best model and their comparison on performance. The Lavenberg-Marquardt algorithm was used to train the input and target. The slightly large dispensary between ANN's training, validation, and testing performance over MLR suggests that ANN revealed significant positive coefficients of determination between the microclimate and infestation rate of *S. incertulas*. The results showed a strong coefficient of determination between the *S. incertulas* infestation rate with the morning minimum and maximum temperature in a shade house compared to the glass house, where the infestation rate of *S. incertulas* was positively correlated to the afternoon minimum and maximum relative humidity.

In conclusion, the estimation of microclimate parameters on the infestation rate of yellow stem borer on MR297 rice variety in Malaysia to estimate the infestation rate with abiotic factors was the first of its kind for modeling and forecasting the infestation rate of *S. incertulas*. The present study's finding recommends that rice farmers and entomologists develop a pest management program for yellow stem borer and stimulate research workers for sustainable bio-resource management. Further studies are required for proof of concept in the field experiment to ascertain the infestation rate of *S. incertulas* using forecasting of imaging processing and prediction with abiotic factors.

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

ANGGARAN PARAMETER IKLIM MIKRO TERHADAP KADAR SERANGAN PENGOREK BATANG KUNING (*Scirpophaga incertulas*) PADA PADI VARIETI MR297

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Scirpophaga incertulas adalah perosak serangga yang dominan dalam penanaman padi yang menyebabkan kerugian hasil yang ketara dan bertanggungjawab atas serangan teruk yang menunjukkan gejala mati anak dan bulu ayam pada peringkat vegetatif dan pembiakan. Padi adalah bijirin yang kedua tinggi penghasilannya dan makanan utama di kebanyakan tempat di dunia. Di Malaysia, padi adalah tanaman penting, dengan purata penggunaan harian 2.5 pinggan seorang, dan kira-kira 10% hingga 33% kehilangan hasil di kawasan jelapang padi di Malaysia semasa pengeluaran padi disebabkan oleh *S. incertulas*. Walau bagaimanapun, maklumat mengenai penentuan faktor abiotik pada kadar serangan menggunakan Rangkaian Neural Buatan (ANN) dan model regresi berbilang linear (Multi-linear) di Malaysia masih lagi perlu dikaji. Oleh itu, kajian dijalankan untuk mendapatkan kajian fiskal pada pengorek batang kuning. Serangga pengorek batang kuning dewasa ditangkapkan menggunakan perangkap Malaise dari Kawasan Pembangunan Pertanian Bersepadu (IADA) Laut Barat Selangor dan dilepaskan ke dalam sangkar yang mengandungi pokok padi berusia 21 hari untuk membolehkan mereka membiak.

Objektif kajian pertama adalah untuk mengkaji biologi dan pertumbuhan pengorek batang kuning di bawah iklim mikro di dalam makmal (27.26ºC ± 0.92 dan kelembapan relatif 67.43% ± 1.3) dan rumah teduhan (33.16ºC ± 0.87 dan kelembapan relatif 84.30% ± 1.43). Berdasarkan penemuan ini, pengkulturan *S. incertulas* di dalam makmal dan rumah teduh menunjukkan iklim mikro mempengaruhi kelebaran dan panjang di peringkat larva dan pupa pengorek batang kuning Masa untuk pengembengan *S. incertulas* meningkat dengan tumbesaran serangga, seterusnya menyebabkan pertumbuhan awal populasi. Data analisis korelasi menunjukkan hubungan yang signifikan antara panjang dan lebar larva pada tahap perkembangan instar keempat dan kelima di dalam makmal yang berkait rapat dengan kelembapan relatif minimum dan maksimum. Sebaliknya, panjang dan lebar pupa di lapangan berkait rapat dengan kelembapan relatif minimum dan suhu maksimum.

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Untuk kajian kedua, penentuan kadar serangan pengorek batang kuning pada padi MR297 di bawah iklim mikro di rumah teduh (suhu 33.16ºC ± 0.87 dan kelembapan relatif 84.30% ± 1.43) dan rumah kaca (suhu 25.20ºC ± 0.29 dan kelembapan relatif 74.50% ± 2.12). mati anak pada fasa vegetatif menunjukkan purata peratusan jangkitan yang signifikan pada 10 hari selepas serangan (DATS) hingga 40DATS mempunyai julat 10.00% hingga 71.25% di rumah kaca, iaitu sedikit tinggi daripada di rumah teduhan 6.25% hingga 70.63%. Pada peringkat reproduksi, rumah kaca mempunyai kadar jangkitan bulu ayam tertinggi, yang berbeza dari 5.00% hingga 58.75%, berbeza dengan rumah teduhan, yang mempunyai peratusan purata 5.00% hingga 31.88% selama 40DATS hingga 70DATS di bawah keadaan iklim mikro yang berbeza. Oleh itu, iklim mikro seperti suhu dan kelembapan relatif memberi kesan yang ketara kepada kadar serangan *S. incertulas* pada pokok padi.

Objektif terakhir kajian bertujuan untuk menentukan korelasi antara kadar jangkitan pengorek batang kuning pada varieti padi MR297 dan faktor abiotik menggunakan rangkaian saraf buatan (ANN) dan model regresi multi-linear, berkesan dalam menentukan model terbaik dan perbandingan prestasi mereka. Algoritma 'Lavenberg-Marquardt' digunakan untuk melatih input dan sasaran. Perbezaan yang agak ketara antara latihan, pengesahan dan prestasi ujian ANN berbanding MLR menunjukkan bahawa ANN menunjukkan pekali korelasi positif yang signifikan antara iklim mikro dan kadar serangan *S. incertulas*. Hasil mendapati korelasi yang kuat antara kadar serangan *S. incertulas* dengan suhu minimum dan maksimum pagi di rumah teduh berbanding rumah kaca, di mana kadar serangan *S. incertulas* berkorelasi positif dengan kelembapan relatif minimum dan maksimum petang.

Kesimpulannya, penentuan kadar jangkitan pengorek batang kuning dengan faktor abiotik menggunakan rangkaian saraf buatan (ANN) dan regresi multi-linear (MLR) di Malaysia untuk mengaitkan kadar jangkitan dengan faktor abiotik adalah yang pertama seumpamanya untuk pemodelan dan ramalan kadar jangkitan *S. incertulas*. Penemuan kajian ini mengesyorkan kepada para pesawah dan ahli entomologi untuk membangunkan program yang sesuai dalam pengurusan perosak pengorek batang kuning dan merangsang para penyelidik untuk pengurusan bio-sumber yang mampan. Kajian lanjut diperlukan untuk mengukuhkan konsep dalam eksperimen lapangan untuk menentukan kadar serangan *S. incertulas* menggunakan ramalan pemprosesan pengimejan dan ramalan dengan faktor abiotik.

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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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LIST OF ABBREVIATIONS

%	Percentage
ANN	Artificial Neuron Network
ANOVA	Analysis of Variance
CRD	Complete Randomized Designs
DAT	Day After Treatment
DH	Dead Heart
DMRT	Duncan's Multiple Range Test
DOA	Department of Agriculture
IADA	Integrate Agriculture Development Authority
MAFI	Ministry of Agriculture and Food Industries
MARDI	Malaysian Agriculture Research and Development Institute
Max RH	Maximum Relative Humidity
Max T.	Maximum Temperature
Min RH	Minimum Relative Humidity
Min T.	Minimum Temperature
MLR	Multi-Linear Regression
MM	Millimetre
^{o}C	Degree Celsius
PC	Principal Compound
PCA	Principal Compound Analysis
R	Correlation Coefficient
R^2	Determination Coefficient
RCBD	Randomized Complete Block Design

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WE	White Ear
YSB	Yellow Stem Borer

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CHAPTER 1

INTRODUCTION

1.1 Background

Rice (*Oryza sativa* L.), a member of the Poaceae family, is the world's second most significant cereal crop, feeding approximately 50% of the world's population and accounting for 19% of worldwide calorie intake (Patel & Singh, 2017). According to Aslam et al., (2016), Food consumption is expected to grow in 2050, necessitating a 40% increase in cereal crop production in developing countries. Meanwhile, 300,000 farmers are projected to be in rice farming in Malaysia, with 150 million hectares set aside for rice cultivation (Hashim et al., 2017). Malaysia's Gross Domestic Product (GDP) was RM1,196.4 billion in 2016, with agriculture, forestry, and fisheries contributing only RM106.5 billion (8.9%). Within agriculture, palm oil accounted for the lion's share of RM41.9 billion (40.2%), while rice accounted for only RM2.4 billion (2.3%) (Sarena et al., 2019). Annual increases in rice production in Malaysia, on the other hand, are inconsistent with the declining production over the last few years, which was attributed to adverse weather conditions, insect and disease outbreaks (Rahmat et al., 2019)

The yellow stem borer is one of the most important rice pests, responsible for significant economic losses in all rice-growing regions of Asia (Manikandan et al., 2013). Larvae of *S. incertulas* feed on central shoots of rice tillers during the vegetative stage and cause 'dead heart' and 'white ear' results if feeding coincides with the panicle initiation stage (Vennila et al., 2019). The YSB damage causes significant yield loss of up to 30% per season by inducing a dead central shoot tiller and empty ear head symptoms (Murali-Baskaran et al., 2021). In another research conducted by Haider et al., (2021), yield losses in rice due to YSB were estimated to be between 20% - 70%. The selection of MR297 as a potential cultivar is based on the distinct traits that render it well-suited for cultivation, such as pest or disease resistance, adaptation to the region's specific climate and soil conditions, and the potential for high yield or quality attributes. The sampling of yellow stem borer aims to enhance rice production in the Tanjong Karang region by selecting suitable and efficient management of the prominent rice pests, promoting sustainable agriculture and improving food security. This information is essential for implementing effective pest management strategies, such as the timing of pesticide application or the development of resistant crop varieties.

Weather plays a vital role in determining the geographical distribution and periodic abundance of major insect pests of rice, including pest management adopted by farmers (Jasrotia et al., 2019; Vennila et al., 2019). Such factors as temperature, rainfall, and relative humidity greatly influence the outbreak of the insect population (Prasannakumar et al., 2015). Temperature, relative humidity, rain, and control techniques are all abiotic factors that influence insect abundance, dispersion, and population dynamics (Marina et al., 2021). Rainfall is crucial for the survival and dispersal of the insect population (Jasrotia et al., 2019). The study focused solely on temperature and humidity as these two microclimate parameters are known to have a significant and direct impact on the

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infestation rate of the Yellow Stem Borer (*Scirpophaga Incertulas*) on the MR297 rice variety is likely based on their known importance in pest ecology, ease of measurement, and the desire to obtain a focused and interpretable set of results. Various techniques have been developed to control rice pests, with chemical insecticide application serving as the primary control measure (Liu et al., 2016). However, the application of chemical insecticides has brought a series of problems, such as air, water, and soil pollution, food contamination, the resurgence of resistant herbivores, and outbreaks of minor pests, which have all resulted from the extensive cultivation of high-yielding varieties, intensified continuous rice cultivation, providing constant niches for pest multiplication and the reduction of populations of natural enemies of the crop pests. With these considerations in mind, the present research work was conducted to study and estimate the microclimate parameters on the infestation rate of yellow stem borer (*Scirpophaga incertulas*) on MR297 rice variety on population growth to establish their active times, which will improve forecasting and field management actions to safeguard the rice crop in Barat Laut, Selangor, Malaysia.

1.2 Problem Statement

Among all the insect pests of rice, *S. incertulas* is one of the significant essential pests chargeable for severe economic losses. In Malaysia, about 10% to 33% of the yield losses in the granary area of Malaysia during rice production are due to *S. incertulas* (Islam and Karim, 1997; Hamsein et al., 2020). Insects are poikilothermic and have no precise mechanism to regulate their body temperature. Temperature acts on insects in two ways: i. acts directly on survival and development and ii, indirectly through food, humidity, rainfall, wind, and atmospheric pressure (Gitz et al., 2016; Chen et al., 2019; Sandra et al., 2022).

In Justification, Climate change impacts insect growth and population, and meteorological conditions may influence pest population density over several weeks or months. As a result, it is worthwhile to investigate and examine the infestation rate of the yellow stem borer and its correlation with abiotic factors using an artificial neural network (ANN) and a multi-linear regression (MLR) model. There have been no attempts to identify the use of these models to discover the abiotic factors impacting yellow stem borer infestation rates under different microclimate conditions. Studies on YSB biology are needed to detect occurrences, identify the peak occurrence to determine the duration and level of infestation, and estimate the actual population density of the YSB under different microclimate conditions. Different models might have different accuracies in the correlation coefficient of insect growth. Still, there haven't been any attempts to compare artificial neural networks (ANN) and multi-linear regression (MLR) models to find the abiotic factors affecting yellow stem borer infestation rates under various microclimate conditions.

1.3 Objectives

To investigate the estimation of microclimate parameters on the infestation rate of yellow stem borer (*Scirpophaga incertulas*) on MR297 rice variety

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1.3.1 Specific Objective of the Study

The specific objectives of this study are:

1. To investigate the in-vitro culture and developmental changes of *S. incertulas* under different microclimate conditions.

2. To determine the infestation and damage of *S. incertulas* on rice under different microclimatic conditions.

3. To determine the estimation between *S. incertulas* infestation on rice with abiotic factors using artificial neural network (ANN) and multi-linear regression (MLR) models.

1.4 Scope of the Study

The scope of studying the estimation of microclimate parameters on the infestation rate of the yellow stem borer (*Scirpophaga incertulas*) on the MR297 rice variety involves a comprehensive investigation into the relationship between microclimate conditions and pest infestations in a specific rice variety. The present study can generate significant knowledge regarding the ecological dynamics of pest-rice interactions, facilitating the development of pest management strategies and promoting sustainable agricultural practices.

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