GROWTH, YIELD AND ISOTOPE COMPOSITION OF CARBON AND NITROGEN IN RICE AS INFLUENCED BY DIFFERENT POTASSIUM FERTILIZER SOURCES IN SELECTED GRANARY AREAS

By

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Thesis Submitted to the School of Graduate Studies University 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 fulfillment of the requirement for the Degree of Master of Science

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Rice (*Oryza sativa L.*) plays a vital role in ensuring food security in Malaysia, particularly in the granary areas such as MADA and KADA. These regions serve as significant rice-producing areas, contributing substantially to the nation's rice production. The key role of potassium (K) fertilization is crucial in rice cultivation, impacting various physiological processes and contributing significantly to the quality and yield of rice crops in granary areas. Exploring alternative potassium sources, such as polyhalite, holds potential for improving Malaysian agriculture.

The examination of $\delta^{13}C$ and $\delta^{15}N$ provides significant insights into the acquisition of resources and interactions among plants. This is because the natural abundance of carbon-13 and nitrogen-15 in plants reflects the isotopic composition of their carbon and nitrogen sources and plays a crucial role in advancing our understanding of various ecological and biological processes. However, the extent to which the intake of K affects the isotopic variance in rice has not been well studied.

Therefore, this study aims to comprehensively investigate the effects of potassium (K) fertilizers on rice plant physiological parameters and yield performance. The primary objectives include assessing the impact of K fertilizer sources on stable carbon and nitrogen isotope values (specifically $\delta^{13}C$ and $\delta^{15}N$) in rice tissues, examining the influence of K fertilizers on rice photosynthesis, and investigating the effects of K fertilizers on rice yield. Field tests in KADA and MADA regions and a rain shelter experiment were conducted to achieve these goals, providing valuable insights into agriculture and crop management.

Rice plants were cultivated in the field and under a rain shelter with five treatments, which are T1 (no-K), T2 (Muriate of Potash), T3 (Sulphate of Potash), T4 (Polyhalite),

and T5 (conventional fertilizer). The fertilizers were applied 3, 15, 55, and 75 days after planting (DAP). Leaf photosynthesis and stomata conductance measurements were taken at 85 DAP and dried and reserved for carbon and nitrogen isotope analyses. Meanwhile, the rice yield was determined at 110 DAP during harvest.

In this study, the rain shelter trials highlighted the positive influence of K fertilizers on rice yield, with Polyhalite consistently providing the highest yields under controlled conditions with 490.4 g/pot for KADA and 489.60 g/pot for MADA soils compared to other treatments. Overall, adding K fertilizer proved beneficial for rice plant health, tiller productivity, and grain yield, emphasizing the importance of potassium fertilization in enhancing overall rice productivity. While soil type does not significantly impact rice yield, MADA soil demonstrates a more conducive environment for photosynthesis and improved efficiency in water and nutrient absorption with a mean of 52.77 µmol CO_2 m^{-2} s^{-1} for rate of photosynthesis and 1.88 mmol m^{-2} s^{-1} for stomata conductance. Polyhalite, a potassium source, significantly boosted photosynthetic rates and stomata conductance. The findings also indicated that K fertilizer application could influence $\delta^{15}N$ in plants, with variations observed in different treatments and environmental conditions. The comprehensive analysis of correlation coefficients highlighted complex interactions between rice yield, rate of photosynthesis, stomata conductance, and isotopic values, providing valuable insights for crop management and sustainable agricultural practices. In conclusion, the study emphasized the importance of K in enhancing rice productivity, influencing plant physiology, and contributing to the intricate dynamics of carbon and nitrogen isotopic signatures in plants.

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

PERTUMBUHAN, HASIL, DAN KOMPOSISI ISOTOP KARBON DAN NITROGEN DALAM PADI YANG DIPENGARUHI OLEH SUMBER BAJA KALIUM YANG BERBEZA DI KAWASAN JELAPANG PADI YANG TERPILIH

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Padi (*Oryza sativa L.*) memainkan peranan penting dalam memastikan jaminan makanan di Malaysia, terutamanya di kawasan-kawasan bendang seperti MADA dan KADA. Kawasan-kawasan ini berperanan besar dalam pengeluaran padi negara. Peranan utama baja kalium (K) adalah penting dalam penanaman padi, ia mempengaruhi pelbagai proses fisiologi dan memberi sumbangan yang signifikan kepada kualiti dan hasil tanaman padi di kawasan-kawasan bendang. Penerokaan sumber kalium alternatif, seperti polihalit, memiliki potensi untuk meningkatkan pertanian Malaysia.

Nisbah metabolit Karbon (C) kepada metabolit Nitrogen (N) dalam sel, yang dirujuk sebagai keseimbangan C/N, juga penting untuk pengawalan pertumbuhan dan perkembangan tumbuhan. Oleh itu, pengukuran isotop yang dikaitkan dengan sumber tumbuhan kritikal, seperti karbon dan nitrogen, telah membantu memperdalam pemahaman ekologi tentang pemerolehan sumber tumbuhan dan interaksi tumbuhan. Ini kerana kelimpahan semula jadi karbon-13 dan nitrogen-15 dalam tumbuhan mencerminkan komposisi isotop sumber karbon dan nitrogen serta memainkan peranan penting dalam meningkatkan pemahaman tentang pelbagai proses ekologi dan biologi tumbuhan. Namun, sejauh mana pengambilan kalium (K) mempengaruhi variasi isotop dalam padi masih belum dikaji dengan baik.

Oleh itu, kajian ini bertujuan untuk menyelidik secara komprehensif kesan baja kalium (K) ke atas parameter fisiologi tanaman padi dan prestasi hasil padi. Objektif utama termasuk menilai impak sumber baja K ke atas nilai isotop karbon dan nitrogen yang stabil (khususnya $\delta^{13}C$ dan $\delta^{15}N$) dalam tisu padi, mengkaji pengaruh baja K terhadap fotosintesis padi, dan menyiasat kesan baja K terhadap hasil padi. Ujian lapangan di kawasan KADA dan MADA, berserta eksperimen di dalam rumah lindungan hujan,

telah dijalankan untuk mencapai objektif ini untuk memberikan pandangan berharga dalam bidang pertanian dan pengurusan tanaman.

Padi ditanam di lapangan dan di dalam rumah lindungan hujan dengan lima rawatan, iaitu T1 (tanpa K), T2 (Muriate of Potash), T3 (Sulphate of Potash), T4 (Polyhalite), dan T5 (baja konvensional). Baja telah diberikan kepada tanaman pada 3, 15, 55, dan 75 hari selepas tanam (HST). Ukuran fotosintesis daun dan pengukuran konduktiviti stomatal diambil pada 85 (HST) dan kemudiannya dikeringkan serta dikhaskan untuk analisis isotop karbon dan nitrogen. Sementara itu, hasil padi ditentukan pada 110 (HST) semasa menuai.

Dalam kajian ini, eksperimen di dalam rumah lindungan hujan menonjolkan pengaruh positif baja K ke atas hasil padi, dengan Polyhalite secara konsisten memberikan hasil tertinggi di bawah keadaan terkawal dengan 490.4 g/pot untuk tanah KADA dan 489.60 g/pot untuk tanah MADA berbanding rawatan lain. Secara keseluruhan, penambahan baja K terbukti bermanfaat bagi kesihatan tanaman padi, produktiviti anakan padi, dan hasil bijirin, menekankan kepentingan penanaman kalium dalam meningkatkan produktiviti padi secara keseluruhan. Walaupun jenis tanah tidak memberi kesan yang signifikan kepada hasil padi, tanah MADA menunjukkan persekitaran yang lebih kondusif untuk fotosintesis dan penyerapan air serta nutrien yang lebih baik dengan purata 52.77 µmol CO_2 m^2 s^{-1} untuk kadar fotosintesis dan 1.88 mmol m^2 s^{-1} untuk konduktan stomata. Polyhalite, sebagai sumber kalium, secara signifikan meningkatkan kadar fotosintesis dan konduktan stomata. Penemuan juga menunjukkan bahawa penggunaan baja K boleh mempengaruhi $\delta^{15}N$ dalam tumbuhan, dengan variasi yang diperhatikan dalam rawatan dan keadaan alam sekitar yang berbeza. Analisis menyeluruh bagi pekali korelasi menonjolkan interaksi yang kompleks antara hasil padi, kadar fotosintesis, konduktan stomata, dan nilai isotopik, memberikan pemahaman berharga untuk pengurusan tanaman dan amalan pertanian lestari. Kesimpulannya, kajian ini menekankan kepentingan K dalam meningkatkan produktiviti padi, mempengaruhi fisiologi tanaman, dan menyumbang kepada dinamika rumit nisbah isotopik karbon dan nitrogen dalam tumbuhan.

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I am grateful to God Almighty for His protection, guidance, wisdom, and strength throughout my studies. He has brought me to a successful end, just as he promised. Therefore, all praise and thanks are due to Allah.

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I thank Dr. Zulkarami Berahim, a teacher at the Institute of Tropical Agriculture and Food Security (ITAFoS), for assisting me with my project on leaf physiology. He has given me valuable advice and input. In particular, his direction in operating the open-top portable photosynthesis system (Li-6400XT, LI-COR, Lincoln, Nebraska, USA) has been indispensable to the research.

Words cannot express my sincere appreciation to the research assistants who played a significant role in this project's success. Their unwavering guidance, contributions, and expertise, particularly in statistical analysis and lab experiment management, have been invaluable. I would also like to acknowledge their constant support, motivation, and encouragement during my low points, which gave me the strength to persevere. I am equally grateful to my classmates and friends whose constructive recommendations and comments have significantly enhanced the quality of my thesis. I am confident that this project's outcome will be of immense value, and I pray that God blesses everyone who played a part in its success.

I want to take a moment to express my sincere gratitude to my family for their incredible patience, sacrifice, support, and encouragement during my research. I am so lucky to have such kind and gentle parents who have always been there for me, believing in me and supporting me no matter what. Finally, to all those who have provided me with their encouragement and support throughout my studies, I want to say a heartfelt thank you. Your kindness and generosity have meant more to me than words can express.

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

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LIST OF ABBREVIATIONS

UPM	Universiti Putra Malaysia
KRI	Khazanah Research Institute
DOA	Department of Agriculture
KADA	Kemubu Agricultural Development Authority
MADA	Muda Agricultural Development Authority
IADA	Integrated Agricultural Development Area
BLS	Barat Laut Selangor
K	Potassium
C	Carbon
N	Nitrogen
P	Phosphorus
Mg	Magnesium
Ca	Calcium
Al	Aluminium
Fe	Iron
CO_2	Carbon Dioxide
O_2	Oxygen
H^+	Hydrogen
NH^{4+}	Ammonium
NO^{3-}	Nitrate
K_2O	Potassium Oxide
K_2SO_4	Potassium Sulphate
KCl	Potassium Chloride

MgO	Magnesium Oxide
CaO	Calcium Oxide
SOP	Sulphate of Potash
MOP	Muriate of Potash
ROS	Reactive Oxygen Species
NADPH	Nicotinamide Adenine Dinucleotide Phosphate
WUE	Water Use Efficiency
DAP	Days After Planting
HST	Hari Selepas Tanam
Δ13C	Carbon 13 Discrimination
Δ15N	Nitrogen 15 Discrimination
g_s	Stomata Conductance
T1	Treatment 1
T2	Treatment 2
T3	Treatment 3
T4	Treatment 4
T5	Treatment 5
AAS	Atomic Absorption Spectrometry
AES	Atomic Emission Spectrometry
ICP	Inductively Coupled Plasma
LI-COR	Portable Photosynthesis System
IRMS	Isotope Ratio Mass Spectrometry
SAS	Statistical Analysis Software

CHAPTER 1

INTRODUCTION

1.1 Research Background

Rice (Oryza sativa L.), a staple crop globally, is crucial for food security and agricultural sustainability. Malaysia, a leading global importer of rice, faces the challenge of meeting the yearly domestic rice demand exceeding 1000 metric tonnes. Potassium (K) is an essential macronutrient that influences plant well-being, strength, and ability to withstand biological and environmental challenges. It plays a significant role in controlling stomatal conductance, increasing photosynthesis, osmotic adjustment, enzymatic processes, protein synthesis, and preserving ionic balance in plant cells.

Stable isotope analysis, specifically targeting $\delta^{13}C$ (carbon isotopes) and $\delta^{15}N$ (nitrogen isotopes), has become an effective methodology for understanding plant resource acquisition and interactions. This study aims to fill a gap in current knowledge by examining the impact of various potassium fertilizer sources on rice growth, yield, and isotopic ratio. The experimental design involves rice plants treated with five different treatments, including T1 (absence of K), T2 (Muriate of Potash), T3 (Sulphate of Potash), T4 (Polyhalite), and T5 (conventional fertilizer).

The experiments were conducted in the field and under a rain shelter. The MR219 were planted in Malaysia's two largest granary areas (KADA and MADA). These areas are significant in the rice industry and contribute to the country's overall production. This study also explains the selection of these regions for the field trial sites due to their strategic importance in agricultural research and their valuable insights into optimizing rice production and nutrient management practices. Additionally, including a rain shelter experiment addresses the challenges of conducting field trials and creates a controlled environment for studying the effects of potassium fertilizers on rice growth. The rain shelter provided a consistent and controlled space where important environmental factors could be managed, leading to more accurate and reliable data collection.

1.1.1 The World Rice Situation

In 2017, the United Nations estimated the worldwide population to be 7.5 billion, with Asia contributing the largest share; regionally, Asia has the world's greatest population (Figure 1.1). While rice is a staple in the majority of Asian nations, the region uses more than 80% of the global supply. It is anticipated that rice demand will increase in the future. Rice consumption is already high, and this tendency is anticipated to continue as the population increases. Most of the world's rice production and consumption is concerted in Asia.

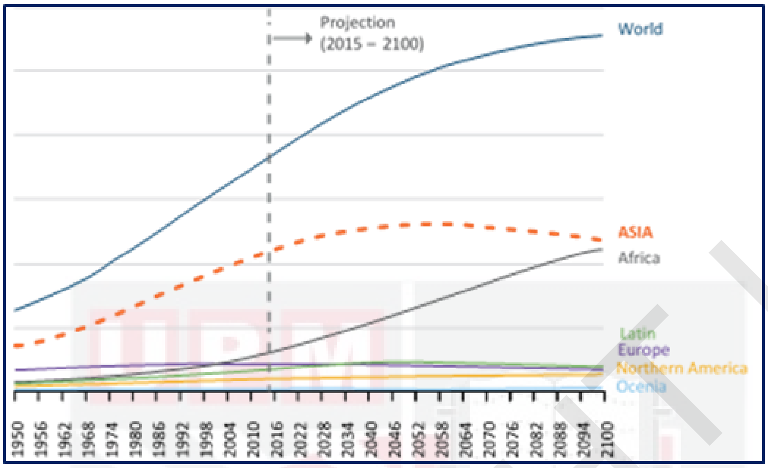

Figure 1.1: Total Population estimates by Region, the Year 1950 – 2100 (Billion)
(Source: Khazanah Research Institute, 2019)

1.1.2 Malaysia Rice Production

Located in Southeast Asia, Malaysia encounters an equatorial environment distinguished by elevated temperatures (averaging from 21 to 32 °C) and humidity (with an annual precipitation of approximately 2500 mm) during the entirety of the year (Tan et al., 2020; Suhaila et al., 2012). In the significant granary areas, rice farmers typically engage in two planting cycles annually: the off-season cycle, which spans from March to July, and the main season cycle, which occurs from August to February. The primary season aligns with the northeast monsoon, leading to substantial precipitation and elevated atmospheric moisture levels. On the other hand, it has been observed that during the off-season, there is a decrease in air humidity and a reduction in rainfall (Firdaus et al., 2014).

Rice is Malaysia's third most widely planted crop, after oil palm and rubber. In 2020, 644,859 ha of its land was planted with rice. In 2021, the area was 647,859 ha, of which 525.984 ha were in Peninsular Malaysia, with the remaining in Sabah and Sarawak (Khazanah Research Institute, 2019).

Most of the irrigated rice areas in Peninsular Malaysia are in the ten designated granary areas (Figure 1.2), totaling approximately 416,415 ha. Granary areas refer to major irrigation schemes (areas greater than 4,000 ha) and are recognized by the government in the National Agricultural Policy as the main rice-producing areas. There are rice planting area of 10 granary areas in Peninsular Malaysia, namely MADA, KADA, IADA

KERIAN, IADA BLS, IADA Pulau Pinang, IADA Seberang Perak, IADA KETARA and IADA Kemasin-Semerak, IADA Pekan, and IADA Rompin since 2017 until 2021 is shown in Table 1.1.

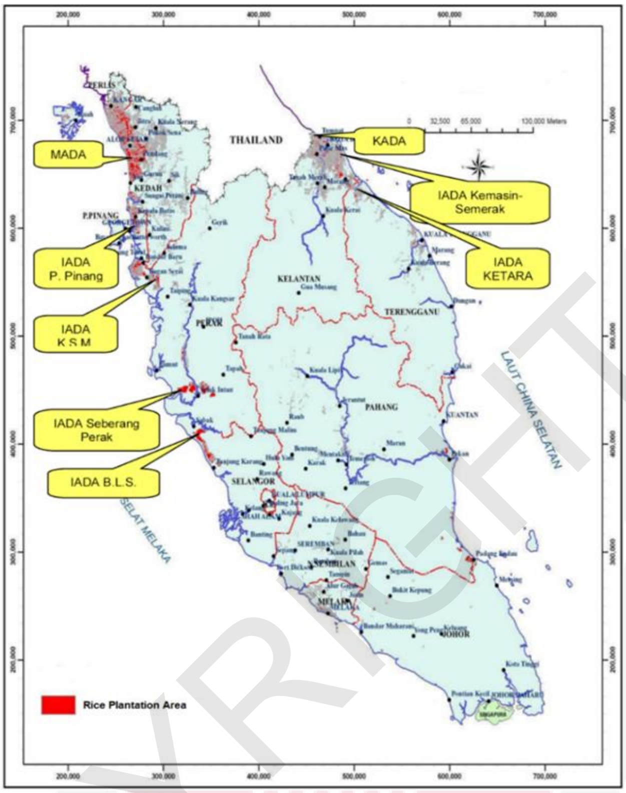

Figure 1.2: Distribution Map of Rice Production Areas in Peninsular Malaysia
(Source: Khazanah Research Institute, 2019)

Domestic rice production in Malaysia relies heavily on ten important granary locations. The country produced 2.7 million metric tonnes of rice in 2017, where granary lands produced a total of 2.0 million MT or 74.1% of the total paddy yield for that year. Muda Agricultural Development Authority (MADA) in Malaysia's Northern Peninsular produced approximately 38.8% of the country's total paddy production and is known as the "Rice Bowl," followed by Kemubu Agricultural Development Authority (KADA) at 9.1% and Integrated Agricultural Development Area (IADA) Barat Laut Selangor (BLS) at 8.1% (DOA, 2022). These granary regions have varied levels of agricultural output due to differences in their locations (various environmental conditions) and soil management.

Table 1.1: The Rice Planting Area for Granary Areas in Malaysia

No	Year	2017	2018	2019	2020	2021[e]
	Locations	Planted Area (ha)				
1	**MADA**	201,259	210,324	201,338	201,306	210,347
2	**KADA**	54,067	53,710	50.348	52,164	52,589
3	**IADA,** Kerian	41.898	41,898	41,898	38,578	36,994
4	**IADA Barat,** LautSelangor	36,708	36,868	36,602	36,004	35,885
5	**IADA** P.Pinang	25,564	25,564	25.564	24,210	24,210
6	**IADA** SeberangPerak	27,735	27,735	27,334	26,296	26,296
7	**IADA KETARA**	9,752	9.752	9,752	9,752	9,752
8	**IADA** Kemasin, Semerak	7,129	6.902	7,564	8,129	8,401
9	**IADA** Pekan	6,832	6,429	6,634	4,764	7,446
10	**IADA** Rompin	5,101	5,071	5,108	5,158	5,272

(Source: DOA, 2022)

Table 1.2 shows that the national average yield is approximately 4000 kg/ha, with yields surpassing 5000 kg/ha in regions such as IADA Pulau Pinang, IADA Ketara, and MADA. Conversely, granaries such as IADA Pekan and Batang Lupar are low-yield producers, with yields of less than 3000 kg/ha (DOA, 2022).

Table 1.2: The Average Yield of Rice for Granary Areas in Malaysia

No	Year	2017	2018	2019	2020	2021[e]
	Locations	**Average Yield (kg/ha)**				
1	**MADA**	4,841	5,111	4,933	4,833	4,192
2	**KADA**	4,448	4,695	4,032	4,621	4,874
3	**IADA,** Kerian	4,087	3,957	3,584	3,223	3,830
4	**IADA Barat,** Laut Selangor	4,510	4,731	4,756	4,431	4,337
5	**IADA** P.Pinang	5,737	5,228	5,012	5,022	5,655
6	**IADA** Seberang Perak	3,180	3,417	2,923	2,774	2,613
7	**IADA KETARA**	5,172	5,349	5,162	5,407	5,218
8	**IADA** Kemasin, Semerak	3,779	4,079	3,733	3,666	3,656
9	**IADA** Pekan	1,506	2,673	2,637	2,707	1,860
10	**IADA** Rompin	3,338	2,910	2,373	4,156	4,610
11	**IADA** Kota Belud	2,511	3,112	2,908	2,914	3,540
12	**IADA** Batang Lupar	2,009	2,492	2,754	2,599	2,847

(Source: DOA, 2022)

1.1.3 Potassium (K) Fertilizer

Potassium (K) is an essential nutrient for plants. Plants absorb K+, which is found in soils and fertilizers like potassium chloride (KCl), potassium nitrate (KNO_3), potassium sulfate (K_2SO_4), and potassium carbonate (K_2CO_3). With a few exceptions, KCl, or muriate of potash, is the most affordable and widely utilized form for agronomic crops (Kafkafi et al., 2001). Although more expensive, other forms, such as K_2SO_4 and KNO_3, are utilized for some crops sensitive to chloride (Cl).

In addition, Jin et al. (2011) found that plants absorb more K than any other mineral element (except for nitrogen), and K is the nutrient that most frequently inhibits plant growth and crop yields. Additionally, increased K application has been demonstrated to increase photosynthetic rate, plant development, yield, and drought resistance in diverse crops (Egilla et al., 2005; Pervez et al., 2001).

Potassium (K) is the most numerous inorganic cation essential for plant growth (White and Karley, 2010). It is vital for expanding yield and improving quality (Oosterhuis et al., 2014). Potassium activates enzymes involved in, amongst other processes, protein synthesis, sugar transport, N and C metabolism, and photosynthesis. Potassium is also required for cell division, an essential aspect of plant development and function (Hepler et al., 2001).

Many researches on the impact of K on plant development have been undertaken. Through these mechanisms, potassium governs stomatal opening and shutting, cell elongation, and other vital physiological functions. Due to its high mobility, K is essential for controlling cell osmotic pressure and balancing cations and anions in the cytoplasm of plants (Hu et al., 2016). Insufficient potassium levels can impair photosynthetic CO_2 fixation and the transportation and utilization of assimilates (Hasanuzzaman et al., 2018).

Other than that, the availability of K+ from soil or fertilizers depends on soil texture, moisture, pH, and other factors (Hasanuzzaman et al., 2018). As a macronutrient, K is usually used as a soil base. In addition to the preceding considerations, plant species' K+ uptake regulates K release from soil minerals or fertilizers. Barley (*Hordeum vulgare L.*), rice (*Oryza sativa L.*), and capsicum (*Capsicum annuum L.*) contain low-affinity and high-affinity transporters identified using molecular methods (Nieves et al., 2014).

1.1.4 Natural Abundance of Isotopic Ratios

The term "natural abundance" relates to the relative ratios of various isotopes of an element that are present in the environment. The natural occurrence of isotopic abundance in plants is attributed to isotopic fractionation processes that occur during various biological and environmental interactions.

Carbon is an essential element found in plants, serving as the foundational component of organic compounds. Carbon is naturally present in two stable isotopes, namely carbon-12 (12C) and carbon-13 (13C). Plants actively uptake carbon dioxide (CO2) from the surrounding atmosphere during photosynthesis. Plants exhibit a preference for the lighter 12C isotope over the slightly heavier 13C isotope when engaging in the process of photosynthesis. The discrimination occurs due to the variances in kinetic reactions involving the two isotopes. Consequently, the carbon in plant tissues undergoes enrichment at 12C compared to atmospheric CO_2, resulting in a decreased $\delta^{13}C$ value in plant biomass.

Nitrogen is crucial for promoting optimal plant growth as it plays a fundamental role in forming proteins, nucleic acids, and other essential molecules. Nitrogen is present in two isotopic forms, namely nitrogen-14 (14N) and the comparatively heavier nitrogen-15 (15N) isotopes. Plants exhibit a preference for incorporating the lighter 14N isotope when they uptake nitrogen from different sources. The degree of this preference may vary depending on the source of nitrogen. For example, using organic fertilizers or leguminous plants, which can fix atmospheric nitrogen, typically leads to plant tissues exhibiting lower $\delta^{15}N$ values compared to those primarily reliant on inorganic nitrogen fertilizers.

In a nutshell, the natural occurrence of isotopic ratios in plants can be attributed to the processes of isotopic fractionation that take place during photosynthesis and nitrogen uptake. This phenomenon plays a critical role in comprehending plant physiology, nutrient sources, and ecological interactions. Through analyzing $\delta^{13}C$ and $\delta^{15}N$ values in plant tissues, researchers can obtain valuable information about nutrient cycling, environmental conditions, and agricultural practices.

1.2 Problem Statement

The research problem discussed in this thesis arises from the vital role that potassium (K) plays in the growth and productivity of rice, which is a crucial crop for ensuring food security worldwide. Previous research has shown that potassium significantly impacts photosynthetic rates, plant growth, and rice production. When plants do not have enough potassium, it causes them to experience physiological stress (Wang et al., 2013). This stress affects how their stomata open and close, impacting their exchange of gases and their metabolic processes. This situation highlights the importance of investigating rice's isotopic ratio of carbon and nitrogen. By doing so, we can gain insights into how the availability of potassium affects these essential physiological processes.

In addition, temperature and precipitation are essential factors that significantly influence the variation of plant carbon and nitrogen isotopes. In 2000, Robinson and colleagues suggested that by measuring the levels of carbon-13 (13C) and nitrogen-15 (15N) isotopes in plants, we can gain valuable information about how they react to environmental stressors such as nutrient deficiency. This insight applies to rice and other crops such as barley (Ellis et al., 2002) and quinoa (Hussain et al., 2018). Isotopic analysis has been used to study how these crops respond to stressful conditions (Trandel et al., 2018). It is interesting that much research has been conducted on the variability of isotope in plants. However, there is a significant gap in our knowledge regarding understanding how the availability of nutrients, specifically potassium, affects this variation in isotopes.

Furthermore, researchers in the past have conducted studies on carbon isotope discrimination in crops such as cotton, specifically concerning potassium deficiencies (Bednarz et al., 1998). These studies have emphasized the significance of potassium in the process of carbon metabolism. However, there is currently a lack of studies that quantitatively evaluate the degree of isotopic variation caused by potassium absorption in rice.

The main issue that this thesis aims to tackle is the necessity of studying how carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic responses, as well as the total carbon (C) and nitrogen (N) content, photosynthesis rates, stomatal conductance, and rice yield, are affected by various potassium fertilizer treatments. This research aims to bridge the existing knowledge gap by examining how varying potassium sources affect the isotopic composition of rice, providing insights into its physiological responses and ultimately contributing to the enhancement of rice production in granary areas.

1.3 Research Objectives

Generally, this study aimed to determine the effect of potassium fertilizer on stable carbon and nitrogen isotopic ratios in rice. The specific objectives of the study are as follows:

1. To determine the influences of different potassium fertilizer sources on the stable carbon and nitrogen isotope value in rice.
2. To investigate the effect of different types of potassium fertilizer on the rate of photosynthesis in rice.
3. To examine the effect of different types of potassium fertilizer on yield performance in rice.

1.4 Significance of the Study

First and foremost, it is important to acknowledge that rice is a crucial crop that serves as a staple food for over half of the world's population. This makes it essential to maintain food security. The study aims to understand how various K fertilizer sources affect the growth and yield of rice. This research is valuable in our efforts to improve rice production. This is especially important when the world population is growing and the need for rice is increasing.

In addition, this research holds the potential to improve the use of fertilizers, which is a crucial part of sustainable agriculture. Potassium is an essential nutrient that plants need for their growth. By studying how different sources of potassium fertilizer affect the growth of rice, we can find ways to use fertilizers more effectively and in a more targeted manner. This has the potential to increase crop yields and decrease the negative impact on the environment caused by excessive fertilizer use, all while benefiting the financial situation of farmers.

The study examines how different K fertilizer treatments affect the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic ratio in rice. This research could potentially lead to the development of rice varieties that are more resistant to environmental challenges such as nutrient deficiency. Ensuring that crops can thrive even in adverse conditions is crucial for maintaining agricultural sustainability.

Moreover, this study is important because it helps us understand how potassium uptake affects the variation in isotopes in rice. It contributes to our knowledge of plant physiology and how nutrients interact with each other. The knowledge acquired can be applied not only to rice but also to other types of crops and ecosystems, resulting in additional benefits.

The findings of this research are extremely valuable for farmers, agronomists, and policymakers. By analyzing the data, we can provide recommendations on which K fertilizer sources would be the best choice, ultimately resulting in better crop yields and improved food security.

1.5 Organization of the Thesis

This thesis is organized into five (5) chapters. The first (1) chapter begins with the introduction that includes the introduction of Malaysia's rice production, types of fertilizer, problem statement, objectives, and significance of the study. The second (2) chapter consists of the literature reviews of past studies and information relevant to the study. The third (3) chapter includes an explanation of the research methodology, including sampling techniques, data collection methods, study area descriptions, and statistical data analysis. The fourth (4) chapter provides results of the descriptive analysis, analysis of variance (oneway ANOVA) and in-depth discussion of the findings is also discussed in this chapter. The last chapter, chapter five (5), consists of a summary of the study, recommendations, study limitations, suggestions for further study, and the overall conclusion of the study.

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