WASHED RICE WATER AS A POTENTIAL LIQUID FERTILIZER AND SOIL AMENDMENT FOR CROP PRODUCTIVITY

By

NABAYI ABBA

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

February 2023

FP 2023 5

DEDICATION

TO MY BELOVED PARENTS, FRIENDS, AND FAMILY FOR THEIR PRAYERS AND MORAL ENCOURAGEMENT THROUGHOUT MY LIFE

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

WASHED RICE WATER AS A POTENTIAL LIQUID FERTILIZER AND SOIL AMENDMENT FOR CROP PRODUCTIVITY

By

NABAYI ABBA

February 2023

Chairman: Assoc. Prof. Christopher Teh Boon Sung, PhD
Faculty : Agriculture

Wastewater from washed rice water (WRW) is often recommended as liquid fertilizer in most Asian countries. However, WRW studies are very scarce and they lack scientific rigor, particularly on how the rice washing intensity, volumetric water-to-rice ratio (W:R), the kind and type of bacteria in the WRW after fermentation, and condition of the WRW before use could influence both the WRW nutrients and its effect on plant growth. Therefore, a series of experiments were carried out with the following objectives: 1) to determine the nutrient contents of WRW forms (fermented and unfermented) as affected by different washing intensities, rice to water ratio and fermentation periods, 2) to isolate, characterize, and identify the bacteria in WRW at different fermentation periods; 3) to evaluate the effect of continuous WRW application on the nutrient leaching losses and retention of three different soil textures and; 4) to evaluate the effects of the continuous use of fresh and fermented WRW under glasshouse conditions by examining their effects on the growth and yield of choy sum (*Brassica chinensis* var. parachinensis) and the soil chemical properties and microbial population of three contrasting soil textures over three planting cycles and, 5) to evaluate the best WRW (based on the glasshouse study) as a nutrient source and soil amendment on the growth and yield of choy sum in the field. The results showed that all nutritional elements of WRW increased (except P, Mg, and Zn) with longer fermentation and with higher W:R. Beneficial microbes were isolated from the WRW at different fermentation periods and identified using gene sequencing as *Bacillus velezensis*, *Enterobacter spp*., *Pantoea agglomerans*, *Klebsiella pneumoniae* and *Stenotrophomonas maltophilia.* The identified isolates were positive to atmospheric nitrogen fixation, P- and K- solubilization, catalase enzyme and phytohormone production. 3-day fermented WRW had the significantly higher bacterial population (2.12×10^8 CFU mL^{-1}), N fixation, P and K solubilizations, and phytohormone production, which all decreased with longer fermentation periods. Because WRW contains nutrients, a leaching study carried out indicated that the sandy clay loam soil had the higher cumulative leaching of K, P, Mg, Ca, NH_4^+-N, and NO_3^-—N of 666, 378, 140, 51, 45, and 27 mg L^{-1}, respectively, while the clay and silt loam mostly

had a comparably lower nutrients leaching. The WRW was further evaluated in glasshouse with treatments as follows: 3-day fermented WRW (F3), 450 kg ha^{-1} of NPK 15: 15: 15 (NPK), fresh WRW (F0), and tap water as control (CON), and three soil types: sandy clay loam, clay, and silt loam soils were arranged factorially in a randomized completely block design. Choy sum used as the test crop was grown in the same soils receiving similar treatments consecutively for three planting cycles. The results showed that NPK and F3 had the significantly higher plant height, number of leaves, leaf fresh and dry weight, and total leaf area by 5-61% as compared with the other treatments in all the planting cycles. Comparable plant growth and yield in F3 with NPK could be attributed to the beneficial bacteria in the WRW in addition to the nutrients present. The soil bacterial population increased with the continuous planting cycle for all treatments. The F3 had 73 % increase in soil bacterial population while the NPK had 25 % increase relative to their previous planting cycles. Based on the higher performance of the F3, it was selected for field evaluation. The field experiment had four treatments: 3-day fermented WRW (RW3), 450 kg ha^{-1} of NPK 15: 15: 15 (NPK), 50 % NPK with RW3 (NPK+RW3), and tap water (CON), which were replicated thrice, and the experiment was conducted for three consecutive planting cycles on the same soil and choy sum was used as the test crop. The results showed that the NPK+RW3 had the significantly higher crop yield, nutrient contents, and nutrients uptake by 4-53 %, 9-25 %, and 36-71 %, respectively. The soil and plant nutrient contents and uptake were significantly positively correlated with one another. The presence of nutrient and beneficial microbes in the fermented WRW gave rise to the higher choy sum's growth. The continuous increase in the plant growth with successive planting cycles indicated the carryover effects of both theiiutriaents and beneficial bacteria applied into the soil through the fermented WRW application. Overall, combining the 50 % NPK recommended rate with RW3 gave a better growth and yield in the field, while the use of either NPK or fermented WRW alone had a comparable plant yield in both the glasshouse and the field. Therefore, addition of organic amendments to improve the water and nutrient retention of the soil for agricultural practices is encouraged; thereby, minimizing the nutrient leaching losses of the soils. This research suggests the use of 3-day fermented WRW to derive the microbial benefits contained in the WRW, and better WRW performance is obtained when combined with NPK fertilizer.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

AIR BERAS YANG DIBASUH SEBAGAI POTENSI BAJA CECAIR DAN PINDAAN TANAH UNTUK PRODUKTIVITI TANAMAN

Oleh

NABAYI ABBA

Februari 2023

Pengerusi: Prof. Madya Christopher Teh Boon Sung, PhD
Fakulti : Pertanian

Air sisa dari air beras yang dibasuh (WRW) sering disyorkan sebagai baja cecair di kebanyakan negara Asia. Walau bagaimanapun, kajian WRW sangat terhad dan mereka tidak mempunyai ketelitian saintifik, terutamanya mengenai bagaimana intensiti mencuci beras, nisbah volumetrik air-ke-beras (W:R), kategori dan jenis bakteria di WRW setelah penapaian, dan keadaan WRW sebelum digunakan dapat mempengaruhi nutrien WRW dan kesannya terhadap pertumbuhan tanaman. Oleh itu, satu siri eksperimen telah dijalankan dengan objektif berikut: 1) untuk menentukan kandungan nutrien bentuk WRW (ditapai dan tidak ditapai) seperti yang terjejas oleh intensiti pencucian yang berbeza, nisbah beras kepada air dan tempoh penapaian, 2) untuk mengasingkan, mencirikan, dan mengenal pasti bakteria dalam WRW pada tempoh penapaian yang berbeza; 3) untuk menilai kesan aplikasi WRW berterusan terhadap kehilangan larut lesap nutrien dan pengekalan tiga tekstur tanah yang berbeza dan; 4) untuk menilai kesan penggunaan berterusan WRW segar dan choy sum (*Brassica chinensis* var. parachinensis) dan sifat kimia tanah dan populasi mikroba dengan tiga tekstur tanah yang berbeza selama tiga kitaran penanaman dan, 5) untuk menilai WRW terbaik (berdasarkan kajian glasshouse) sebagai sumber nutrien dan pindaan tanah terhadap pertumbuhan dan hasil choy sum di ladang. Hasil kajian menunjukkan bahawa semua unsur pemakanan WRW meningkat (kecuali P, Mg, dan Zn) dengan penapaian yang lebih lama dan dengan W:R. Mikroba bermanfaat diasingkan dari WRW pada tempoh penapaian yang berbeza dan dikenal pasti menggunakan penjujukan gen sebagai *Bacillus velezensis*, *Enterobacter* spp., *Pantoea agglomerans*, *Klebsiella pneumoniae* dan *Stenotrophomonas maltophilia*. Isolat yang dikenal pasti positif terhadap penetapan nitrogen atmosfera, P - dan K - solubilisasi, enzim katalase dan pengeluaran fitohormon. Air beras yang dibasuh yang ditapai selama 3 hari mempunyai populasi bakteria yang jauh lebih tinggi (2.12×10^8 CFU mL^{-1}), fiksasi N, larutan P dan K, dan pengeluaran fitohormon, yang semuanya menurun dengan tempoh penapaian yang lebih lama. Oleh kerana WRW mengandungi nutrien, kajian larut lesap yang dijalankan menunjukkan bahawa tanah liat tanah liat berpasir mempunyai larut lesap kumulatif yang lebih tinggi iaitu K, P, Mg, Ca, NH_4^+-N, and NO_3^--N daripada 666, 378, 140, 51, 45, dan 27 mg L^{-1}, masing-masing, manakala loam tanah liat dan kelodak kebanyakannya mempunyai larut lesap nutrien yang lebih rendah. Lanjutan itu, WRW kemudian dinilai di rumah kaca dengan rawatan seperti berikut: WRW fermentasi 3 hari (F3), 450 kg ha^{-1} NPK 15: 15: 15 (NPK), WRW segar (F0), dan air paip sebagai kawalan (CON), dan tiga jenis tanah: tanah liat berpasir, tanah liat, dan tanah liat lumpur disusun secara faktorial dalam reka bentuk blok sepenuhnya secara rawak. Choy sum yang digunakan sebagai tanaman ujian ditanam di tanah yang sama menerima rawatan serupa berturut-turut selama tiga kitaran penanaman. Hasil kajian menunjukkan bahawa NPK dan F3 mempunyai ketinggian tanaman yang jauh lebih tinggi, jumlah daun, berat daun segar dan kering, dan jumlah luas daun sebanyak 5-61% dibandingkan dengan rawatan lain dalam semua kitaran penanaman. Pertumbuhan dan hasil tanaman yang setanding dalam F3 dengan NPK dapat dikaitkan dengan bakteria bermanfaat di WRW selain nutrien yang ada. Populasi bakteria tanah meningkat dengan kitaran penanaman berterusan untuk semua rawatan. F3 mengalami peningkatan 73% populasi bakteria tanah sementara NPK mengalami peningkatan 25% berbanding dengan kitaran penanaman sebelumnya. Berdasarkan prestasi F3 yang lebih tinggi, ia dipilih untuk penilaian lapangan. Eksperimen lapangan mempunyai empat rawatan: WRW fermentasi 3 hari (RW3), 450 kg ha^{-1} NPK 15: 15: 15 (NPK), 50% NPK dengan RW3 (NPK+RW3), dan air paip (CON), yang direplikasi tiga kali, dan eksperimen dilakukan selama tiga kitaran penanaman berturut-turut di tanah yang sama dan choy sum digunakan sebagai tanaman ujian. Hasil kajian menunjukkan bahawa NPK + RW3 mempunyai hasil tanaman, kandungan nutrien, dan pengambilan nutrien yang jauh lebih tinggi masing-masing sebanyak 4-53 %, 9-25 %, dan 36-71%. Kandungan dan pengambilan nutrien tanah dan tumbuhan berkorelasi positif antara satu sama lain. Kehadiran mikrob nutrien dan berfaedah dalam WRW yang ditapai menimbulkan pertumbuhan choy sum yang lebih tinggi. Peningkatan berterusan dalam pertumbuhan tumbuhan dengan kitaran penanaman berturut-turut menunjukkan kesan pengalihan kedua-dua nutrien dan bakteria berfaedah yang digunakan ke dalam tanah melalui aplikasi WRW yang ditapai. Secara keseluruhan, menggabungkan kadar yang disyorkan NPK 50% dengan RW3 memberikan pertumbuhan dan hasil yang lebih baik di lapangan, sementara penggunaan NPK atau WRW fermentasi saja memiliki hasil tanaman yang setanding di rumah kaca dan di ladang. Oleh itu, penambahan pindaan organik untuk meningkatkan pengekalan air dan nutrien tanah untuk amalan pertanian digalakkan; dengan itu, meminimumkan kehilangan pencucian nutrien tanah. Penyelidikan ini mencadangkan penggunaan WRW yang ditapai selama 3 hari untuk mendapatkan faedah mikrob yang terkandung dalam WRW, dan prestasi WRW yang lebih baik diperoleh apabila digabungkan dengan baja NPK.

ACKNOWLEDGEMENTS

All praises are for Allah, the most gracious, the most merciful who taught human with means of pen how to write and taught man which he knew not.

I would like to express my heartfelt appreciation to Assoc. Prof. Dr Christopher Teh Boon Sung, the chairman of my supervisory committee for his advice and guidance, tolerance and encouragement, fruitful criticism, close supervision, and patience in reading this dissertation and my manuscripts thoroughly in short time. He offered me an opportunity for the improvement of my scientific knowledge and research work. Moreover, all the research materials were made available in time by the chairman of my supervisory committee to enable me to complete the research work smoothly and on time, so I cannot thank him enough for his contribution to my understanding of research. I would like to gratefully acknowledge the effort of Dr Ali Tan Kee Zuan, a member of my supervisory committee for his valuable advice, guidance, and scholarly criticism throughout my study time. I thank him for the role he played towards the successful completion of my research. I am also thankful to Dr Tan Ngai Paing, a member of my supervisory committee for sparing his precious time whenever I needed. My appreciation and thanks are extended to the tertiary education trust fund (TETFund) through my Institution (Federal University Dutse) in Nigeria for giving me the scholarship opportunity to further my study in UPM, for without their help, cooperation, and financial support, it would not have been possible for me to successfully complete my study. I acknowledged Universiti Putra Malaysia Research Management Center (UPM RMC) for providing me the research grant (Uni. Putra Malaysia Grant 2022, Geran Inisiatif Putra Siswazah (GP IPS) (No. GP IPS/2022/9709600)) to conduct this research. I am also thankful to all those who directly and indirectly assisted me.

My heartfelt and special acknowledgment goes to Baba Aziz Abdullah for his untiring, kind, and fatherly intervention in making sure this research is actualized. Without Baba Aziz, I cannot imagine the duration this work would take. So, I cannot thank him enough for his help. May Almighty rewards him with Jannatul Firdaus. I would like to extend my especial thanks to my Malaysian families; Nur Izzati- the one and only best friend I have, Hameed Al-Arefee, Alhassan Abare, Amaily Akter, Mr Annur, Akma, Mr Mat, Miss Bell, Puan Syaza, Puan Nazira, Puan Shikin, Ellya, Puan Suanita, and all the staff in the Department of Land Management for their kindness and moral support during my study. The constant prayer and support of my family and friends plays a pivotal role in this difficult journey which is now transformed to a joyous one. Habu Sani, Sabo Sani, Sani Isah, Isyaka Umar, Aminu Ibrahim, Hassan, Dady, Sulaiman, Hassan Santuraki, Abubakar Halilu Girei, Habu Musa, Baby, Sadiya, Hussaina, Hajiya Ummi, Fatin bayi, Fatima Sale Tiri, Dr Mohammed Ibrahim Mohammed, Barde just to mention few. I would like to express my heartfelt thanks to my beloved parents and brothers and sisters who in one way or the other made my dreams to achieve this degree, and their constant prayers and encouragements to accomplish my goals. May Allah continue to reward you abundantly.

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

Christopher Teh Boon Sung, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Ali Tan Kee Zuan, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Tan Ngai Paing, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

____
ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 13 April 2023

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

AA	Auto analyzer
AAS	Atomic absorption spectrophotometer
ANOVA	Analysis of variance
CEC	Cation exchange capacity
CON	Control
EC	Electrical conductivity
ET	Evapotranspiration
FC	Field capacity
GMC	Gravimetric moisture content
PWP	Permanent wilting point
RCBD	Randomize completely block design
SE	Standard error
HSD	Honest significant difference
ICP-OES	Inductive couple plasma-optical emission spectroscopy
USDA	United state department of agriculture
VMC	Volumetric moisture content
W:R	Water-to-rice volumetric ratio
WRW	Washed rice water

CHAPTER 1

INTRODUCTION

1.1 Background

The world produced 502 million metric tonnes of rice in 2016 and used 498 million metric tonnes. Ninety percent (90%) of the world's rice was produced in Asia, where 87% of the world's rice was consumed (Omar et al., 2009). The paddy and rice industries in Malaysia frequently receive significant attention and emphasis from the government, due to its strategic importance as the nation's main food source (Fahmi et al., 2013). There were roughly 300,000 rice farmers in 2009 who rely on rice farming as their main source of income (Norsida & Sami, 2009). The most common staple food in the world is rice (Maclean et al., 2002). Rice is a staple food for about 50% of the world's population and serves as the food intake of 60% of Southeast Asian people (Anjum et al., 2007). In Malaysia, analyses of their food consumption patterns of the adult nutrition survey revealed that cooked rice was consumed by 97% of the population twice daily (Norimah et al., 2008). The classification of rice is based on the degree of milling it is being subjected to. They are being classified as brown rice, white rice, Arborio, Basmati, Sweet rice; Jasmine, Bhutanese red rice, and Forbidden rice (Abbas et al., 2011).

Washed rice water (WRW) is the water obtained after rice grain is pre-cooked or washed before cooking. Washed rice water contains water-soluble nutrients (Juliano, 1993). Researchers such as Malakar and Banerjee (1959) and Juliano (1985) reported that washed rice water contains many nutrient contents. Juliano (1985) reported that washing rice prior to cooking result in nutrient loses up to 7% protein, 65% crude fat, 30% crude fiber, 59% thiamine, 26% riboflavin, 60% niacin, 26% Ca, 47% P, 47% Fe, 11% Zn, 70% Mg, and 41% K washed from the rice, which means that these nutrients would end up being in the WRW. Washed rice water also tends to ferment with time, which suggests its nutrient contents could be further enriched, irrespective of its rice types.

Water demand is projected to increase yearly by 55% by 2050, with up to 80% of available surface and groundwater being used (OECD, 2012b). The need for food to feed the ever-increasing population will increase by 70% by 2035. The AQUASTAT database of the Food and Agriculture Organization of the United Nations (FAO) stated that more than 50% of the global freshwater withdrawals are being thrown into environment as wastewater (WWAP, 2017). Wastewater reuse is a necessary practice to overcome water scarcity (Amoro et al., 2019). Increasing water scarcity has led to greater interest in non-potable water reuse elsewhere. The use of urban wastewater for agriculture can also be considered as a strategy to reduce water and nutrients demand for irrigation and fertilization which is a common practice in many countries (Amoro et al., 2019).

Jakarta Post (2017) reported the use of a centralized water collection system in a village in Central Bogor, Indonesia, where the town citizens collected washed rice water. The collected WRW was used to irrigate and fertilized their crops and vegetables. The report concludes that WRW can be used as a fertilizer; when WRW is used for irrigation, there is no need to fertilize the soil. To substantiate the scientifically unproven claims, research were conducted (Bahar, 2016; Istiqomah, 2012; Wardiah & Hafnati, 2014) on the use of WRW as fertilizer in Indonesia. The results indicated that the WRW increased the growth of their test crops significantly such as: tomato (Ariwibowo, 2012; Hariyadi, 2020; Istiqomah, 2012; Leandro, 2009), water spinach (Bahar, 2016; Karlina et al., 2013; Syuhaibah, 2017), eggplant (Bukhari, 2013; Yulianingsih, 2017), and pak choy (Wardiah & Hafnati, 2014). However, Wulandari et al. (2012) reported no significant influence of either white or brown rice water in the growth of lettuce (*Lactuca sativa* L.), with a significant increase in only the root weight. Similarly, a research was also carried out in Malaysia by Syuhaibah (2017) and found a significant effect of the WRW on water spinach growth. In addition, an experiment by Norimah et al. (2008) and Siti Narasimha et al. (2012) also indicated that the use of WRW as a good soil amendment that better promotes the growth of a plant growth-promoting rhizobacteria (PGPR) *Pseudomonas fluorescens,* which increases soil fertility. Washed rice water has also been studied for its potential use as a growth media for the bacteria *Bacillus thuringiensis* (Blondine & Yuniarti, 2008) and an alternative media carrier for *Pseudomonas fluorescence.* These bacteria help to control rust disease and to stimulate the growth of plants (Nurhasanah et al., 2010). Washed rice water can support the growth of useful microorganisms (bacteria) such *as Rhizobium, Azospirillum, Azotobacter, Pseudomonas, Bacillus* for plant growth, and soil fertility increased (Akib et al., 2015).

Choy sum (*Brassica chinensis* var. parachinensis) was used as the test crop in this study because it is a popular vegetable worldwide (Austin, 2007; Wiersema & León, 2016). It is also fast growing, easy to maintain, and has a short life cycle (Khairun et al., 2016). This crop has a short life cycle and may be harvested in a month. It is also high in vitamins and fibre (Chin, 1999). The optimal growing conditions for this crop are those with enough moisture (10 to 12 mm of water per day), 68 kg of nitrogen per hectare, and air temperatures between 23 and 35 °C (Vimala & Chan, 1999). Choy sum is nutritious and is especially rich in folate (Vitamin B9) and carotenoid (Houlihan et al., 2011; Wills et al., 1984). Like other vegetables of Brassicaceae (Cruciferae), choy sum also contains high levels of sulfur compounds that can reduce the risk of cardiovascular diseases and some cancers (Lin & Harnly, 2010). Antioxidants were almost triple in steamed choy sum compared with raw (Wachtel-Galor et al., 2008).

1.2 Problem Statement and Justification

Water and nutrients are expensive and there is possibility of a potential loss of valuable resources for not reusing WRW as plant's nutrient source. Rice is a staple food for Malaysians, and it is estimated that Malaysians consume nearly 3 million tons of rice per year (Bee, 2019). As a conservative estimate, this would work out to at least 3 billion L of WRW produced per year by Malaysians, and this amount is unused and simply discarded. The reuse of WRW as a beneficial liquid plant fertilizer and soil amendment have been advocated because WRW contains nutrients that would have been leached from rice during the grain wash (Bahar, 2016; Supraptiningsih & Nuriyanti, 2019; The

Jakarta Post, 2017). However, currently, there are no scientifically rigorous studies that have clearly demonstrated the beneficial properties of WRW for agriculture use. Instead, most studies of WRW have been on reusing WRW as animal and human health supplements or for cosmetics (Kesare et al., 2021). Many write on the benefits of using WRW for hair growth, face cleansing and skin beauty (Cynthia, 2019; Reema, 2020)

Our in-depth review of literature on WRW reuse for agriculture found a total of only 41 papers, of which 90% of them are either unpublished research reports or published in non-peer review journals (Nabayi et al., 2021a). These studies also often do not report essential details on their research methodology. They also neglect carrying out crucial additional experiments or observations that would have helped explain their research findings or show that their findings are conclusive. In short, the reuse of WRW for agriculture is very rare, and even if advocated, the purported benefits are very often presented as anecdotal. To clearly demonstrate the benefits of WRW for agriculture, several persisting unknowns about WRW must be answered. This includes, the plant-available N and micronutrient contents in WRW; how would washing rice with different volumes of water and washing aggression affect the nutrient content in WRW; how would fermentation of WRW affect its nutrient contents, and more importantly, would its fermentation lead to higher presence of beneficial bacteria, particularly the N-fixing and P- and K-solubilizing bacteria, which in the long run, could promote beneficial soil bacteria, and increase WRW's worth as a natural fertilizer and soil amendment.

Our research findings will provide useful empirical data that could lead to a national or regional science-based policy or initiative to collect and reuse WRW as part of community or social programs. Reusing WRW would increase water use efficiency by reducing water wastages and lead to lower dependency on synthetic or mineral fertilizers, and ultimately, lower use of energy because, for instance, less fertilizers would need to be produced and less wastewater needs to be treated. Greater resource use efficiency and lower energy use are two key strategies in mitigating climate change and environmental damage.

1.3 Aims and Hypotheses of the Study

This research aims to evaluate the use of WRW as a liquid plant fertilizer and as soil amendment. The main objectives were as follows:

1. To determine the nutrient contents of WRW as affected by different washing intensities (50, 80, 100 rpm), fermentation periods (0, 3, 6, and 9 days) and rice to water (W:R) ratios (1:1, 3:1, and 6:1)
2. To isolate, characterize, and identify the bacteria in WRW at different fermentation periods.
3. To determine the effect of continuous WRW application on nutrient leaching losses and retention of three different soil texture.
4. To evaluate the effects of the continuous use of fresh and fermented WRW under glasshouse conditions by examining their effects on the growth and yield of choy sum (*Brassica chinensis* var. parachinensis) and the soil chemical properties and microbial population of three contrasting soil textures.

5. To evaluate the best WRW (based on the glasshouse study) as a nutrient source and soil amendment on the growth of choy sum in the field.

The hypotheses of this study were:

1. Fermented washed rice water would have more plant-available nutrients and, hence, would influence the plant growth more than fresh washed rice water;
2. Fermented washed rice water would have higher bacterial population and diversity and hence, is expected to have higher beneficial microbes;
3. Sandy soil would have higher leachate of nutrients, while the clay soil would have the least;
4. Lower leachate nutrient content (particularly NPK) would be observed in irrigating the plants with WRW than NPK treatment, and CON would have the lowest of all; The use of WRW is expected to have minimal effect on the plant growth in the first growing cycle; from the second onwards, a more significant influence would be observed; The use of WRW will have higher or similar effect on plant growth and yield with NPK in the long run.
5. The use of either NPK fertilizer or fermented WRW are expected to have a similar effect on plant growth and yield in the field because of they share a similar nutrients loss mechanism-leaching.

1.4 Thesis Structure

The thesis is organized in the alternative form of Universiti Putra Malaysia's alternative thesis format, which is based on publication format.

Chapter 1: Background of the study, problem statement and specific objective of the study presented in this chapter.

Chapter 2: This chapter provides a detailed assessment of the literature review on the subject matter of this study. Furthermore, the research gaps identified throughout the review were emphasized inside the chapter. A published review paper on WRW has been presented in this chapter titled "**Wastewater from Washed Rice Water as Plant Nutrient Source: Current Understanding and Knowledge Gaps**"

Chapter 3: This chapter describes the methods applied in this research for material preparation, experimental procedures, and data collection.

Chapter 4: The first research article is presented in this chapter "**Chemical and Microbial Characterization of Washed Rice Water Waste to Assess Its Potential as Plant Fertilizer and for Increasing Soil Health**". This chapter measured both the macro- and micronutrients in WRW, as well as the plant-available N forms of NH_4^+-N and NO_3^--N (typically, only the macronutrients are analyzed by other studies). Second, this chapter determined how washing rice with several different volumes of water and washing intensities affect the chemical properties and nutrient content in WRW. Third, WRW will ferment over time, so this study additionally determined how fermentation led to higher nutrient content and higher microbial count in WRW.

Chapter 5: This chapter presents the second paper "**Fermentation of Washed Rice Water Increases Beneficial Plant Bacterial Population and Nutrient Concentrations**". The chapter identified the bacteria from the WRW using gene sequencing. In addition, the study further explained how the fermentation of WRW promotes the growth of beneficial soil bacteria, particularly the N-fixing and P- and K-solubilizing bacteria, as well as the catalase- and indole acetic acid-producing bacteria.

Chapter 6: This chapter presents the third research paper titled "**Nutrient leaching losses from continuous application of washed rice water on three contrasting soil textures**". Based on chapter 4, and 5, WRW was found to contain nutrients at different rate and proportions. Therefore, this chapter explained on a short-term basis, the nutrients leaching behavior of different soil texture when subjected to a continuous WRW application.

Chapter 7: Based on the higher nutrients and beneficial microbial content of the 3-day fermented WRW (Chapter 4 and 5), 0-day unfermented WRW and 3-day fermented WRW were selected to be evaluated, alongside the effects of applying conventional NPK fertilizer and control (only tap water). This chapter answers how strong would be the consecutive application effects (i.e., carryover effects) of WRW, where the continuous application of WRW over three consecutive planting cycles on the same soil could affect crop growth, soil chemical, and soil microbial counts. The results are presented in the fourth research paper "**Consecutive application effects of washed rice water on plant growth, soil chemical properties, nutrient leaching, and soil bacterial population on three different soil textures over three planting cycles**"

Chapter 8: This chapter answers objective 5: to evaluate the best WRW (based on the glasshouse study) as a nutrient source and soil amendment on the growth of choy sum in the field. Based on the previous chapter (Chapter 7), the 3-day fermented WRW was generally on a par with the use of mineral fertilizer in most plant and soil's measured parameters, and as such it was selected for further evaluation in the field. In addition, a new treatment was introduced by combining the 3-day fermented WRW (RW3) with 50% NPK mineral fertilizer recommended rate to see how the use of the two would complement each other. In addition, the NPK+RW3 was chosen to determine whether the addition of NPK to WRW could further boost yields and improve soil health, so that their combined effects are higher than RW3 and NPK acting alone.

Chapter 9: In this chapter, a summary, and links between the published articles was given, followed by the contributions of the findings as well as the conclusions and recommendations for future research.

REFERENCES

Abbas, A., Murtaza, S., Aslam, F., Khawar, A., Rafique, S., & Naheed, S. (2011). Effect of processing on nutritional value of rice (*Oryza sativa*). *World Journal of Medical Sciences*, *6*(2), 68–73.

Adesemoye, A., & Kloepper, J. (2009). Plant–microbes interactions in enhanced fertilizer-use efficiency. *Applied Microbiology and Biotechnology*, *85*, 1–12.

Adrover, M., Farrús, E., Moyà, G., & Vadell, J. (2012). Chemical properties and biological activity in soils of Mallorca following twenty years of treated wastewater irrigation. *Journal of Environmental Management*, *95*(SUPPL.), S188–S192. https://doi.org/10.1016/j.jenvman.2010.08.017

Adugna, G. (2016). A review on impact of compost on soil properties, water use and crop productivity. *Agricultural Science Research Journal*, *4*(3), 93–104. https://doi.org/10.14662/ARJASR2016.010

Aeron, A., Kumar, D., Gurukula, M., Vishwavidyalaya, K., Pgpr, Z. S., View, I., & Jha, C. K. (2011). Enterobacter : Role in plant growth promotion. In *: Bacteria in agrobiology : Plant growth responses*. pp.159-182.

Aghtape, A. A., Ghanbari, A., Sirousmehr, A., Siahsar, B., Asgharipour, M., & Tavssoli, A. (2011). Effect of irrigation with wastewater and foliar fertilizer application on some forage characteristics of foxtail millet (*Setaria italica*). *International Journal of Plant Physiology and Biochemistry*, *3*(3), 34–42.

Ahemad, M., & Kibret, M. (2014). Mechanisms and applications of plant growth promoting rhizobacteria: Current perspective. *Journal of King Saud University-Science*, *26*(1), 1–20.

Ahmad, F., Ahmad, I., & Khan, M. S. (2008). Screening of free-living rhizospheric bacteria for their multiple plant growth promoting activities. *Microbiological Research*, *163*(2), 173–181. https://doi.org/10.1016/j.micres.2006.04.001

Ahmadi, S. H., Andersen, M. N., Plauborg, F., Poulsen, R. T., Jensen, C. R., Sepaskhah, A. R., & Hansen, S. (2010). Effects of irrigation strategies and soils on field grown potatoes: Yield and water productivity. *Agricultural Water Management*, *97*(11), 1923–1930. https://doi.org/10.1016/j.agwat.2010.07.007

Akib, M. A., Setiawaty, H., Haniarti, H., & Sulfiah, S. (2015). Improving the quality of "Leri" rice washing waste by different period of fermentation and yeast concentration as an alternative liquid organic fertilizer. *International Journal of Agriculture System*, *2*(2), 153–162. http://pasca.unhas.ac.id/ijas/pdf/6) IJAS Vol. 2 Issue 2 December 2014.pdf

Alfaro, M. A., Alfaro, M. A., Jarvis, S. C., & Gregory, P. J. (2004). Factors affecting potassium leaching in different soils. *Soil Use and Management*, *20*(2), 182–189. https://doi.org/10.1079/sum2004249

Amalia, N., & Chitra, A. S. (2018). The effect of application of rice dishwater and manure as organic fertilizer to the growth of mustard (*Brassica Juncea* L.). *Agricultural Science Journal.*, *5*(2), 74–82.

Amoro, I., Laura, M., Yolanda, M., & Jose, L. A. (2019). Wastewater and leafy greens. *Encyclopaedia for Food Security and Sustainability*, *3*, 385–389. https://doi.org/10.1016/B978-0-08-100596-5.22431-1.

Andrade, M., Marcet, P., Reyzábal, M., & Montero, M. (2000). Contenido, evolución de nutrientes y productividad en un suelo tratado con lodos residuales urbanos. *Edafología*, *7*, 21–23. http://edafologia.ugr.es/revista/tomo7tr/a21v7tt.htm

Andrianto, H. (2007). *Effect of rice washing water on Adenium plant growth*. Unpublished Udergraduate Thesis. Universitas Muhamadiyah Surakarta. Surakarta, Indonesia. http://etd.eprints.ums.ac.id/2132/1/A420032058.pdf

Anjana, S. U., & Iqbal, M. (2007). Nitrate accumulation in plants, factors affecting the process, and human health implications. A review. *Agronomy for Sustainable Development*, *27*(1), 45–57.

Anjum, F. M., Pasha, I., Bugti, M. A., & Butt, M. S. (2007). Mineral composition of different rice varieties and their milling fractions. *Pak. J. Agri. Sci*, *44*(2), 332–336.

Ariwibowo, F. (2012). *Utilization of chicken eggshells and rice washed water on the growth of tomato plants (Solonum Lycopercium L.) with hydroponic growing media.* Unpublished Undergraduate Thesis. Universitas Muhammadiah Surakarta. Surakarta, Indonesia.

Arkhipova, T. N., Veselov, S. U., Melentiev, A. I., Martynenko, E. V., & Kudoyarova, G. R. (2005). Ability of bacterium *Bacillus subtilis* to produce cytokinins and to influence the growth and endogenous hormone content of lettuce plants. *Plant and Soil*, *272*(1–2), 201–209. https://doi.org/10.1007/s11104-004-5047-x

Ashraf, M., Hasnain, S., Berge, O., & Mahmood, T. (2004). Inoculating wheat seedlings with exopolysaccharide-producing bacteria restricts sodium uptake and stimulates plant growth under salt stress. *Biology and Fertility of Soils*, *40*(3), 157–162. https://doi.org/10.1007/s00374-004-0766-y

Atique-ur-Rehman, Farooq, M., Rashid, A., Nadeem, F., Stuerz, S., Asch, F., Bell, R. W., & Siddique, K. H. M. (2018). Boron nutrition of rice in different production systems. A review. *Agronomy for Sustainable Development*, *38*(3), 1–25. https://doi.org/10.1007/s13593-018-0504-8

Austin, D. F. (2007). Water Spinach (*Ipomoea aquatica*, Convolvulaceae): A food gone wild. *Ethnobotany Research and Applications*, *5*, 123–146.

Babu, P. D., Subhasree, R. S., Bhakyaraj, R., & Vidhyalakshmi, R. (2009). Brown rice-beyond the color reviving a lost health food – a review. *American-Eurasian Journal of Agronomy*, *2*(2), 67–72.

Bahar, A. (2016). Pengaruh pemberian limbah air cucian beras terhadap pertumbuhan tanaman kangkung darat (*Ipomoea reptans* Poir). *Jurnal Ilmiah Mahasiswa Fakultas Pertanian*, *3*(2), 1–9.

Baldock, J., & Nelson, P. (2010). Soil organic matter. In *Handbook of Soil Sciences* (pp. 25–84). CRC Press: Boca Raton.

Balkhair, K. S., El-Nakhlawi, F. S., Ismail, S. M., & Al-Solimani, S. G. (2013). Treated wastewater use and its effect on water conservation, vegetative yeild, yield components and water use efficiency of some vegetable crops grown under two different irrigation systems in western region, Saudi Arabia. *European Scientific Journal*, *9*(21), 395-402. https://doi.org/10.19044/esj.2013.v9n21p%p.

Baning, C., & R. Hafnati. (2016). Effect of red rice washed water application on vegetative growth of pepper plants (*Piper nigrum* L.). J Ilmiah Mahasiswa Pendidikan Biology. *Jurnal Ilmiah Mahasiswa Pendidikan Biology.*, *1*(1), 1–9.

Barnawal, D., Maji, D., Bharti, N., Chanotiya, C. S., & Kalra, A. (2013). ACC deaminase-containing *Bacillus subtilis* reduces stress ethylene-induced damage and improves mycorrhizal colonization and rhizobial nodulation in trigonella foenum-graecum under drought stress. *Journal of Plant Growth Regulation*, *32*(4), 809–822. https://doi.org/10.1007/s00344-013-9347-3

Baron, C. (2023). *Global demand for agricultural fertilizer by nutrient from 2011/2012 to 2021/2022*. STATISTA. https://www.statista.com/statistics/438930/fertilizer-demand-globally-by-nutrient/#:~:text=In 2021%2F2021%2C the total,especially noted in recent years. Accessed on 6/2/2023.

Barton, C. J. (1948). Photometric analysis of phosphate rock. *Analytical Chemistry*, *20*(11), 1068–1073.

Basso, A. S., Miguez, F. E., Laird, D. A., Horton, R., & Westgate, M. (2013). Assessing potential of biochar for increasing water-holding capacity of sandy soils. *Gcb Bioenergy*, *5*(2), 132–143.

Becerra, C., Cristina, L., Vaz-Moreira, A. R., Ivone, S., Elisabete, F. N., Célia, M. N., & Olga, C. (2015). Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health. *Environment International*, *75*, 117–135. https://doi.org/10.1016/j.envint.2014.11.001

Bee, Y. G. (2019). *Food supply chain in Malaysia: Review of agricultural policies, public institutional setup and food regulations. Kuala Lumpur: Khazanah Research Institute*. pp 1-27.

Beneduzi, A., Ambrosini, A., & Passaglia, L. M. P. (2012). Plant growth-promoting rhizobacteria (PGPR): Their potential as antagonists and biocontrol agents. *4*, 1044–1051. http://www.scielo.br/pdf/gmb/v35n4s1/20.pdf

Bhattacharyya, P. N., & Jha, D. K. (2012). Plant growth-promoting rhizobacteria (PGPR): Emergence in agriculture. *World Journal of Microbiology and Biotechnology*, *28*(4), 1327–1350. https://doi.org/10.1007/s11274-011-0979-9

Bizari, D. R., & Cardoso, J. C. (2016). Reuse water and urban horticulture: Alliance towards more sustainable cities. *Horticultura Brasileira*, *34*(3), 311–317. https://doi.org/10.1590/s0102-05362016003002

Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D., & Webb, C. (2003). Cereal-based fermented foods and beverages. *Food Research International*, *36*(6), 527–543. https://doi.org/10.1016/S0963-9969(03)00009-7

Blondine, C. P., & Yuniarti, R. A. (2008). Peran serta masyarakat secara mandiri dalam melestarikan *Bacillus thuringiensis* H-14 galur lokal dalam buah kelapa untuk mengendalikan jentik anopheles sp di kampung laut kabupaten cilacap. *YARSI Medical Journal*, *16*(1), 33–38.

Boddey, R. M., De Moraes Sá, J. C., Alves, B. J. R., & Urquiaga, S. (1997). The contribution of biological nitrogen fixation for sustainable agricultural systems in the tropics. *Soil Biology and Biochemistry*, *29*(5–6), 787–799. https://doi.org/10.1016/S0038-0717(96)00221-0

Bohn, L., Meyer, A. S., & Rasmussen, S. K. (2008). Phytate: Impact on environment and human nutrition. A challenge for molecular breeding. *Journal of Zhejiang University: Science B*, *9*(3), 165–191. https://doi.org/10.1631/jzus.B0710640

Bollyn, J., Faes, J., Fritzsche, A., & Smolders, E. (2017). Colloidal-bound polyphosphates and organic phosphates are bioavailable: A nutrient solution study. *Journal of Agricultural and Food Chemistry*, *65*(32), 6762–6770. https://doi.org/https://pubs.acs.org/doi/abs/10.1021/acs.jafc.7b01483

Boubekri, K., Soumare, A., Mardad, I., Lyamlouli, K., Hafidi, M., Ouhdouch, Y., & Kouisni, L. (2021). The screening of potassium-and phosphate-solubilizing actinobacteria and the assessment of their ability to promote wheat growth parameters. *Microorganisms*, *9*(3), 470.

Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Science*, *59*(1), 39–46.

Brega-Filho, D., & Mancuso, P. C. (2003). *Reúso de Água; Universidade de São Paulo-*

Facultade de Saúde Pública [Reuse of water; University of São Paulo-public health faculty]. São Paulo, Brasil.

Brown, S., Kurtz, K., Bary, A., & Cogger, C. (2011). Quantifying benefits associated with land application of organic residuals in Washington State. *Environmental Science & Technology*, *45*(17), 7451–7458.

Bukhari, C. (2013). The effect of organic fertilizer and rice washing water on growth and yield of eggplant (*Solanum melongenal* L). *Jurnal Sains Riset*, *3*(1), 1–8.

Cainglet, A., Tesfamariam, A., & Heiderscheidt, E. (2020). Organic polyelectrolytes as the sole precipitation agent in municipal wastewater treatment. *Journal of Environmental Management*, *271*, 111002. https://doi.org/https://doi.org/10.1016/j.jenvman.2020.111002

Campbell, C. R., & Plank, C. O. (1998). Preparation of plant tissue for laboratory analysis. *Methods for Plant Analysis*, *37*, 37–49.

Candela, L., Fabregat, S., Josa, A., Suriol, J., Vigués, N., & Mas, J. (2007). Assessment of soil and groundwater impacts by treated urban wastewater reuse. A case study: Application in a golf course (Girona, Spain). *Science of the Total Environment*, *374*(1), 26–35. https://doi.org/10.1016/j.scitotenv.2006.12.028

Carstens, J. F., Bachmann, J., & Neuweiler, I. (2018). Effects of organic matter coatings on the mobility of goethite colloids in model sand and undisturbed soil. *European Journal of Soil Science*, *69*(2), 360–369. https://doi.org/https://doi.org/10.1111/ejss.12510

Cavagnaro, T. R., Bender, S. F., Asghari, H. R., & van der Heijden, M. G. A. (2015). The role of arbuscular mycorrhizas in reducing soil nutrient loss. *Trends in Plant Science*, *20*(5), 283–290. https://doi.org/10.1016/j.tplants.2015.03.004

Cerovic, Z. G., Masdoumier, G., Ghozlen, N. Ben, & Latouche, G. (2012). A new optical leaf-clip meter for simultaneous non-destructive assessment of leaf chlorophyll and epidermal flavonoids. *Physiologia Plantarum*, *146*(3), 251–260. https://doi.org/10.1111/j.1399-3054.2012.01639.x

Chandini, K. R., Kumar, R., & Prakash, O. (2019). The impact of chemical fertilizers on our environment and ecosystem. *Research Trends in Environmental Sciences*, 69–86.

Chandra, S., Medha, I., & Bhattacharya, J. (2020). Potassium-iron rice straw biochar composite for sorption of nitrate, phosphate, and ammonium ions in soil for timely and controlled release. *Science of the Total Environment*, *712*, 136337. https://doi.org/10.1016/j.scitotenv.2019.136337

Chen, X. H., Koumoutsi, A., Scholz, R., Eisenreich, A., Schneider, K., Heinemeyer, I., Morgenstern, B., Voss, B., Hess, W. R., Reva, O., Junge, H., Voigt, B., Jungblut, P. R., Vater, J., Süssmuth, R., Liesegang, H., Strittmatter, A., Gottschalk, G., & Borriss, R. (2007). Comparative analysis of the complete genome sequence of the plant growth-promoting bacterium *Bacillus amyloliquefaciens* FZB42. *Nature Biotechnology*, *25*(9), 1007–1014. https://doi.org/10.1038/nbt1325

Chen, Y. S., Yanagida, F., & Shinohara, I. (2005). Isolation and identification of lactic acid bacteria from soil using an enrichment procedure. *Letters in Applied Microbiology*, *40*(3), 195–200. https://doi.org/10.1111/j.1472-765X.2005.01653.x

Chi, Q., Tang, W., Liu, L., Meng, J., Dong, X., Chen, W., & Li, X. (2018). Isolation and properties of *Enterobacter* sp. LX3 capable of producing indoleacetic acid. *Applied Sciences (Switzerland)*, *8*(11), 2108. https://doi.org/10.3390/app8112108

Chin, H. F. (1999). Malaysian vegetables in colour: A complete guide. In *Tropical Press Sdn Bhd.* Tropical Press Sdn Bhd.

Cirelli, G. L., Consoli, S., Licciardello, F., Aiello, R., Giuffrida, F., & Leonardi, C. (2012). Treated municipal wastewater reuse in vegetable production. *Agricultural Water Management*, *104*, 163–170.

Cogger, C. G. (2005). Potential compost benefits for restoration of soils disturbed by urban development. *Compost Science & Utilization*, *13*(4), 243–251.

Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D., & Savelli, H. (2010). *Sick water? The central role of wastewater management in sustainable development: A rapid response assessment*. Earthprint Arendal, Norway.

Covarrubias, S. A., de-Bashan, L. E., Moreno, M., & Bashan, Y. (2012). Alginate beads provide a beneficial physical barrier against native microorganisms in wastewater treated with immobilized bacteria and microalgae. *Applied Microbiology and Biotechnology*, *93*(6), 2669–2680. https://link.springer.com/article/10.1007/s00253-011-3585-8

Cresswell, N., & Wellington, E. M. H. (1992). Detection of genetic exchange in the terrestrial environment. In J. D. Wellington, E.M.H. & van Elsas (Ed.), *Genetic Interactions Among Microorganisms in the Natural Environment* (pp. 59–82). Pergamon Press.

Cui, S., Kong, F., Li, Y., Jiang, Z., & Xi, M. (2021). Effect of mineral loaded biochar on the leaching performances of nitrate and phosphate in two contrasting soils from the coastal estuary area. *Science of the Total Environment*, *779*, 146346. https://doi.org/10.1016/j.scitotenv.2021.146346

Cynthia, C. (2019). *Does washing your face with rice water help your skin?* https://www.healthline.com/health/rice-water-for-skin#benefits. Accessed on 6/2/2023.

Dastager, S. G., Deepa, C. K., Puneet, S. C., Nautiyal, C. S., & Pandey, A. (2009). Isolation and characterization of plant growth-promoting strain *Pantoea* NII-186. from Western Ghat forest soil, India. *Letters in Applied Microbiology*, *49*(1), 20–25. https://doi.org/10.1111/j.1472-765X.2009.02616.x

Davidson, E. A. (2009). The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860. *Nature Geoscience*, *2*(9), 659–662. https://doi.org/10.1038/ngeo608

Davis, K. E. R., Joseph, S. J., & Janssen, P. H. (2005). Effects of growth medium, inoculum size, and incubation time on culturability and isolation of soil bacteria. *Applied and Environmental Microbiology*, *71*(2), 826–834. https://doi.org/10.1128/AEM.71.2.826-834.2005

Deepa, C. K., Dastager, S. G., & Pandey, A. (2010). Isolation and characterization of plant growth promoting bacteria from non-rhizospheric soil and their effect on cowpea (*Vigna unguiculata* L. Walp.) seedling growth. *World Journal of Microbiology and Biotechnology*, *26*(7), 1233–1240. https://doi.org/10.1007/s11274-009-0293-y

Deepa, G., Singh, V., & Naidu, K. A. (2008). Nutrient composition and physicochemical properties of Indian medicinal rice - Njavara. *Food Chemistry*, *106*(1), 165–171. https://doi.org/10.1016/j.foodchem.2007.05.062

del Mar Alguacil, M., Torrecillas, E., Torres, P., García-Orenes, F., & Roldán, A. (2012). Long-term effects of irrigation with waste water on soil AM fungi diversity and microbial activities: The implications for agro-ecosystem resilience. *PLoS ONE*, *7*(10), 1–7. https://doi.org/10.1371/journal.pone.0047680

Diana, R. Y. (2016). *Gardening Tips: Benefits of Rice Washing Water for Fertilizing Plants*. https://mitalom.com/manfaat-air-cucian-beras-untuk-menyuburkan-tanaman/. Accessed on 6/4/2021

Diaz, O. A., Reddy, K. R., & Moore, P. A. (1994). Solubility of inorganic phosphorus in stream water as influenced by pH and calcium concentration. *Water Research*, *28*(8), 1755–1763. https://doi.org/10.1016/0043-1354(94)90248-8

Ding, X., Jiang, Y., Zhao, H., Guo, D., He, L., Liu, F., Zhou, Q., Nandwani, D., Hui, D., & Yu, J. (2018). Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (*Brassica campestris* L. ssp. Chinensis) in a hydroponic system. *PLoS ONE*, *13*(8), 1–15. https://doi.org/10.1371/journal.pone.0202090

Ding, Y., Wang, J., Liu, Y., & Chen, S. (2005). Isolation and identification of nitrogen-fixing bacilli from plant rhizospheres in Beijing region. *Journal of Applied Microbiology*, *99*(5), 1271–1281. https://doi.org/10.1111/j.1365-2672.2005.02738.x

Dini, I. R., & Salbiah, D. (2019). Growth and pepper yields (*Capsicum annuum* L.) by giving a formulation of biological fertilizer of cellulolytic bacteria based on organic liquid waste. *Journal of Physics: Conference Series*, *1351*(1), 12097.

DOA. (1998). *Package of technology for sawi.* Department of Agriculture. Malaysia.

Döbereiner, J., & Day, J. M. (1976). Associative symbioses in tropical grasses: Characterization of microorganisms and dinitrogen-fixing sites. *Proceedings of the 1st International Symposium on Nitrogen Fixation*, *2*, 518–538.

DOE. (2017). *National Water Quality Standards for Malaysia*. https://www.doe.gov.my/portalv1/wp-content/uploads/2019/05/Standard-Kualiti-Air-Kebangsaan.pdf

Drechsel, P., Scott, A., Sally, R., Redwood, M., & Bachir, A. (2010). *Wastewater irrigation and health: Assessing and mitigating risk in low-income countries* (Earthscan (ed.)). International Water Management Institute.

Drinkwater, L. E., Schipanski, M., Snapp, S., & Jackson, L. E. (2017). Ecologically based nutrient management. In S. Snapp & B. Pound (Eds.), *Agroecology and Rural Innovation for Development Agricultural Systems* (Second Edi, pp. 203–257). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-802070-8.00007-4

Duaja, M. D., Arzita, & Redo, Y. (2012). Growth analysis of lettuce (*Lactuca sativa* L.) at different type of liquid organic fertilizer. *Jurnal Program Studi Agroekoteknologi. Fakulti Pertanian Univ Jambi*, *1*(1), 33–41.

Duncomb, D. R., Larson, W. E., Clapp, C. E., Dowdy, R. H., Linden, D. R., & Johnson, W. K. (1982). Effect of liquid wastewater sludge application on crop yield and water quality. *Journal* (*Water Pollution Control Federation*), *54*(8), 1185–1193.

Dunlap, C. A., Kim, S. J., Kwon, S. W., & Rooney, A. P. (2016). Bacillus velezensis is not a later heterotypic synonym of *Bacillus amyloliquefaciens*; *Bacillus methylotrophicus, Bacillus amyloliquefaciens* subsp. Plantarum and 'Bacillus oryzicola' are later heterotypic synonyms of *Bacillus velezensis* based on phylogenom. *International Journal of Systematic and Evolutionary Microbiology*, *66*(3), 1212–1217. https://doi.org/10.1099/ijsem.0.000858

Edokpayi, J. N., Odiyo, J. O., & Durowoju, O. S. (2017). Impact of wastewater on surface water quality in developing countries: A case study of South Africa. *Water Quality*. 10, 6651. https://doi.org/10.5772/66561

Ehmann, A. (1977). The van URK-Salkowski reagent - a sensitive and specific chromogenic reagent for silica gel thin-layer chromatographic detection and identification of indole derivatives. *Journal of Chromatography A*, *132*(2), 267–276. https://doi.org/10.1016/S0021-9673(00)89300-0

Enders, A., & Lehmann, J. (2012). Comparison of wet-digestion and dry-ashing methods for total elemental analysis of biochar. *Communications in Soil Science and Plant Analysis*, *43*(7), 1042–1052.

Exhibition, T. (2023). *Choy sum*. https://www.tridge.com/intelligences/choy-sum/MY Accessed on 6/2/2023.

Fahmi, Z., Abu Samah, B., & Abdullah, H. (2013). Paddy industry and paddy farmers well-being: A success recipe for agriculture industry in Malaysia. *Asian Social Science*, *9*(3), 177–181. https://doi.org/10.5539/ass.v9n3p177

Fan, B., Blom, J., Klenk, H. P., & Borriss, R. (2017). *Bacillus amyloliquefaciens*, *Bacillus velezensis,* and *Bacillus siamensis* Form an "Operational Group B. *amyloliquefaciens*" within the B. *subtilis* species complex. *Frontiers in Microbiology*, *8*, 22. https://doi.org/10.3389/fmicb.2017.00022

Fang, L., Li, J. shan, Donatello, S., Cheeseman, C. R., Poon, C. S., & Tsang, D. C. W. (2020). Use of Mg/Ca modified biochars to take up phosphorus from acid-extract of incinerated sewage sludge ash (ISSA) for fertilizer application. *Journal of Cleaner Production*, *244*, 118853. https://doi.org/10.1016/j.jclepro.2019.118853

FAO. (2015). World fertilizer trends and outlook to 2018. *Food and Agriculture organization of the united nations report*. FAO.

Fatta-Kassinos, D., Kalavrouziotis, I. K., Koukoulakis, P. H., & Vasquez, M. I. (2011). The risks associated with wastewater reuse and xenobiotics in the agroecological environment. *Science of the Total Environment*, *409*(19), 3555–3563. https://doi.org/10.1016/j.scitotenv.2010.03.036

Feng, G., Zhang, Y., Chen, Y., Li, Q., Chen, F., Gao, Q., & Mi, G. (2016). Effects of nitrogen application on root length and grain yield of rain-fed maize under different soil types. *Agronomy Journal*, *108*(4), 1656–1665. https://doi.org/10.2134/agronj2015.0367

Fitriani, C. L. (2019). *Effect of spraying concentration of washed water of various types of rice on plant growth and yield of pak coy (Brassica rapa L.)*. Unpublished Diploma Thesis. Universitas Andalas Padang. Padang, Indonesia. http://scholar.unand.ac.id/id/eprint/52640 (accessed on 3/5/2020).

Fitzpatrick, T. B., & Chapman, L. M. (2020). The importance of thiamine (vitamin B1) in plant health: From crop yield to biofortification. *Journal of Biological Chemistry*, *295*(34), 12002–12013. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7443482/pdf/zbc12002.pdf

Gao, M., Li, B., Yu, A., Liang, F., Yang, L., & Sun, Y. (2010). The effect of aeration rate on forced-aeration composting of chicken manureand sawdust. *Bioresource Technology*, *101*(6), 1899–1903.

Gardner, W. H. (1986). Water content. In: Klute, A., (ed.). *Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods*. American Society of Agronomy-Soil Science Society of America, 5, (pp. 493–544).

Gatta, G., Libutti, A., Gagliardi, A., Beneduce, L., Brusetti, L., Borruso, L., Disciglio, G., & Tarantino, E. (2015). Treated agro-industrial wastewater irrigation of tomato crop: Effects on qualitative/quantitative characteristics of production and microbiological properties of the soil. *Agricultural Water Management*, *149*, 33–43.

Gatta, G., Libutti, A., Zagliardi, A., Disciglio, G., Beneduce, L., D'Antuono, M., Rendina, M., & Tarantino, E. (2015). Effects of treated agro-industrial wastewater irrigation on tomato processing quality. *Italian Journal of Agronomy*, *10*(632), 97–100. https://doi.org/10.4081/ija.2015.632

Gee, G. W., & Bauder, J. W. (1986). Particle size analysis. In: Klute, A. (ed.) Methods of soil analysis. Part 1. Physical and mineralogical methods. ASA and SSSA, Madison, WI. USA, 9, (pp. 383–411).

Gemma, C., Nortcli, S., & Potter, R. (2008). Urban wastewater reuse for irrigated agriculture in Jordan: Soil sustainability, perceptions and management. In D. Thevenot (Ed.), *Urban waters: resource or risks?* WWW-YES. No. 15

Ghafari, S., Hasan, M., & Aroua, M. K. (2008). Bio-electrochemical removal of nitrate from water and wastewater—a review. *Bioresource Technology*, *99*(10), 3965-3974. https://www.sciencedirect.com/science/article/abs/pii/S0960852407004476?via%3Dihub

Ginting, K. A., & R. Dianita. (2017). *The effect of nitrogen and phosphorous on the growth of Calopogonium mucunoides, Centrosema pubescens and Arachis pintoi.* Fakultas Peternakan Universitas Jambi. https://repository.unja.ac.id/id/eprint/849 (accessed on 28/4/2020).

Glick, B.R. (1995). The enhancement of plant growth by free-living bacteria. *Canadian Journal of Microbiology*, *41*(2), 109–117.

Glick, Bernard R. (2014). Bacteria with ACC deaminase can promote plant growth and help to feed the world. *Microbiological Research*, *169*(1), 30–39. https://doi.org/10.1016/j.micres.2013.09.009

Gómez-Brandón, M., Lazcano, C., & Domínguez, J. (2008). The evaluation of stability and maturity during the composting of cattle manure. *Chemosphere*, *70*(3), 436–444.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Gonçalves, R. F., Assis, T. I., Maciel, G. B., Borges, R. M., & Cassini, S. T. A. (2020). Co-digestion ofmunicipal wastewater and microalgae biomass in an upflow anaerobic sludge blanket reactor. *Algal Resource*, *52*, 102117. https://doi.org/https://doi.org/10.1016/j.algal.2020.102117

Gordon, S. A., & Weber, R. P. (1951). Colorimetric estimation of indole-3-acetic acid. *Plant Physiology*, *26*, 192–195. https://doi.org/10.1016/0003-2697(76)90514-5

GRiSP. (2013). *Global rice science partnership rice almanac.* (4th ed.). International Rice Research Institute, Los Baños.

Guerreiro, R. C. S., Jerónimo, E., Luz, S., Pinheiro, H. M., & Prazeres, A. R. (2020). Cheese manufacturing wastewater treatment by combined physicochemical processes forreuse and fertilizer production. *Journal of Environmental Management*, *264*, 110470. https://doi.org/10.1016/j.jenvman.2020.110470

Hairudin, R. (2015). Effectiveness of organic fertilizer rice washing water on the growth of mustard plants (*Brassica juncea* L.). *Journal Perbal*, *3*(3), 79–84.

Handiyanto, S., Hastuti, U. S., & Prabaningtyas, S. (2013). The effect of rice water washing medium on the speed of mycelium growth of white oyster mushrooms (*Pleurotusostreatus* var. Florida). *Seminar Nasional X Pendidikan Biologi FKIP UN.*, 1–6.

Hardy, R. W. F., Holsten, R. D., Jackson, E. K., & Burns, R. C. (1968). The acetylene-ethylene assay for N_2 fixation: laboratory and field evaluation. *Plant Physiology*, *43*(8), 1185–1207.

Hariyadi, S. P. (2020). The Effect of watering on rice washing water, MSG water, and AC (Air Conditioner) wastewater on yields components and tomato yields (*Lycopersicon esculentum* L.) in the deep peatland. *Universal Journal*, *7*, 1–12.

Harrison, R. B. (2008). Composting and formation of humic substances. *Encyclopedia of Ecology,* 713–719.

Hasegawa, M., Kishino, H., & Yano, T. aki. (1985). Dating of the human-ape splitting by a molecular clock of mitochondrial DNA. *Journal of Molecular Evolution*, *22*(2), 160–174. https://doi.org/10.1007/BF02101694

Hashem, A., Tabassum, B., & Fathi Abd_Allah, E. (2019). Bacillus subtilis: A plant-growth promoting rhizobacterium that also impacts biotic stress. *Saudi Journal of Biological Sciences*, *26*(6), 1291–1297. https://doi.org/10.1016/j.sjbs.2019.05.004

He, Q., Feng, C., Chen, N., Zhang, D., Hou, T., Dai, J., Hao, C., & Mao, B. (2019). Characterizations of dissolved organic matter and bacterial community structures in rice washing drainage (RWD)-based synthetic groundwater denitrification. *Chemosphere*, *215*, 142–152. https://doi.org/10.1016/j.chemosphere.2018.10.026

He, Q., Feng, C., Hu, Q., Li, R., & Chen, N. (2016a). Biological denitrification using rice washing drainage (RWD) as carbon source for removing nitrate from groundwater. *Desalination and Water Treatment*, *57*(46), 21990–21999. https://doi.org/10.1080/19443994.2015.1127780

He, Q., Feng, C., Peng, T., Chen, N., Hu, Q., & Hao, C. (2016b). Denitrification of synthetic nitrate-contaminated groundwater combined with rice washing drainage treatment. *Ecological Engineering*, *95*, 152–159.

Helmyati, S., Kiasaty, S., Amalia, A. W., Sholihah, H., Kurnia, M., Wigati, M., Rohana, A. J., Ishak, W. R. W., Hamid, N. A., Malik, V., & Hu, F. (2020). Substituting white rice with brown and black rice as an alternative to prevent diabetes mellitus type 2: A case-study among young adults in Yogyakarta, Indonesia. *Journal of Diabetes and Metabolic Disorders*, *19*(2), 749–757. https://doi.org/10.1007/s40200-020-00555-8

Henze, M., & Comeau, Y. (2008). Wastewater characterization. In *Biological Wastewater Treatment: Principles, Modelling and Design* (pp. 33–52). IWA Publishing.

Hernawan, E., & Meylani, V. (2016). Physicochemical characteristics analysis of white rice, brown rice, and black rice (*Oryza sativa* L., *Oryza nivara* and *Oryza sativa* L. indica). *Journal Kesehat Bakti Tunas Husada*, *15*(1), 79–91.

Heydari, N. (2014). Water productivity in agriculture: Challenges in concepts, terms and values. *Irrigation and Drainage*, *63*(1), 22–28.

Hikmah, N. (2015). *Utilization of cassava peels extract and water washing rice on the growth of the plant soursop (Annona muricata L.)*. Program studi pendidikan biologi, Fakultas keguruan dan ilmu pendidikan. Unpublished Diploma Dissertation. Universitas Muhammadiyah Surakarta. Surakarta, Indonesia. Retrieved on August 7, 2020, from Naskah Publikasi.pdf (ums.ac.id)

Hill, G. T., Mitkowski, N. A., Aldrich-Wolfe, L., Emele, L. R., Jurkonie, D. D., Ficke, A., Maldonado-Ramirez, S., Lynch, S. T., & Nelson, E. B. (2000). Methods for assessing the composition and diversity of soil microbial communities. *Applied Soil Ecology*, *15*(1), 25–36. https://doi.org/10.1016/S0929-1393(00)00069-X

Hirel, B., Te´tu, T., Lea, P., & Dubois, F. (2011). Improving nitrogen use efficiency in crops for sustainable agriculture. *Sustainability (Switzerland)*, *3*, 1452–1485.

Hobbie, J. E., & Fletcher, M. M. (1988). The aquatic environment. In J. E. . Lynch, J.M., Hobbie (Ed.), *Micro-organisms in action: concepts and applications in microbial ecology* (pp. 132–262). Blackwell Scientific Publications.

Hoffland, E., Hakulinen, J., & Van Pelt, J. A. (1996). Comparison of systemic resistance induced by avirulent and nonpathogenic *Pseudomonas* species. *Phytopathology*, *86*(7), 757–762.

Houlihan, A., M., Pyke, P., Scheelings, G., Graham, G., Eagle-sham, T., O'Hare, L., Wong, P., Puwastien, & Jongjitsin, W. (2011). *Folate content of Asian vegetables. Project report. Rural Industries Research and Development Corporation (RIRDC). RIRDC Publication No. 10/167, Project No. PRJ-000044*.

Hu, X., Chen, J., & Guo, J. (2006). Two phosphate-and potassium-solubilizing bacteria isolated from Tianmu Mountain, Zhejiang, China. *World Journal of Microbiology and Biotechnology*, *22*(9), 983–990.

Ibekwe, A. M., Gonzalez-Rubio, A., & Suarez, D. L. (2018). Impact of treated wastewater for irrigation on soil microbial communities. *Science of the Total Environment*, *622*, 1603–1610. https://doi.org/10.1016/j.scitotenv.2017.10.039

Iniguez, A. L., Dong, Y., & Triplett, E. W. (2004). Nitrogen fixation in wheat provided by *Klebsiella pneumoniae* 342. *Molecular Plant-Microbe Interactions*, *17*(10), 1078–1085. https://doi.org/10.1094/MPMI.2004.17.10.1078

Iskarlia, G. R. (2017). The growth of hydroponic mustard plant (*Brassica rapa* L.) using the nutrition of washed rice water and chicken egg shells. *Agric Sains Journal of Budidaya Tanaman Perkebunan Politeknik Hasnur.*, *3*(2), 42–51.

Islam, M. M., Karim, A. J., Jahiruddin, M., Majid, N. M., Miah, M. G., Ahmed, M. M., & Hakim, M. A. (2011). Effects of organic manure and chemical fertilizers on crops in the radish-stem amaranth-Indian spinach cropping pattern in homestead area. *Australian Journal of Crop Science*, *5*(11), 1370-1378.

Istiqomah, N. (2010). Influence of brown rice washing water application on growth and yield of celery (*Apium graveolens* L.) on Lebak's mashland. *Agroscientiae*, *3*(17), 152–155.

Istiqomah, N. (2012). Efektivitas pemberian air cucian beras coklat terhadap produktivitas tanaman kacang hijau (*Phaseolus radiatus* L.) pada lahan rawa lebak. *Ziraa'ah*, *33*(1), 99–108.

Itani, T., & Ogawa, M. (2004). History and recent trends of red rice in Japan. *Japan Journal of Crop Science*, *73*, 137–147.

Jaramillo, M. F. (2014). *Potential for Reuse of Domestic Wastewater as a Pollution Prevention and Control Strategy in the Geographic Valley of the Cauca River*. Universidad del Valle, Cali, Colombia.

Jaramillo, M. F., & Restrepo, I. (2017). Wastewater reuse in agriculture: A review about its limitations and benefits. *Sustainability*, *9*(10), 1734.

Jiménez-Cisneros, B. (1995). Wastewater reuse to increase soil productivity. *Water Science and Technology*, *32*(12), 173–180. https://doi.org/10.1016/0273-1223(96)00152-7

Jones, D. L., & Kielland, K. (2012). Amino acid, peptide and protein mineralization dynamics in a taiga forest soil. *Soil Biology and Biochemistry*, *55*, 60–69.

Jones, K. M., Kobayashi, H., Davies, B. W., Taga, M. E., & Walker, G. C. (2007). How rhizobial symbionts invade plants: The Sinorhizobium-Medicago model. *Nature Reviews Microbiology*, *5*(8), 619–633.

Julca-Otiniano, A., Meneses-Florián, L., Blas-Sevillano, R., & Bello-Amez, S. (2006). La materia orgánica, importancia Y experiencia de su uso en la agricultura. *Idesia (Arica)*, *24*(1), 49–61. https://doi.org/10.4067/s0718-34292006000100009

Juliano, B. O. (1985). *Rice: Chemistry and technology*. (2nd Edn.). American Association of Cereal Chemists, Eagan, MN.

Juliano, B. O. (1993). *Rice in human nutrition*. In FAO Food and Nutrition Series (No. 26).

Juwarkar, A., Dutta, S. A., & Pandey, R. A. (1988). Impact of domestic wastewaters on soil microbial populations. *Water, Air, and Soil Pollution*, *39*(1–2), 169–177.

Kalavrouziotis, I. K. (2015). The reuse of municipal wastewater in soils. *Global Nest Journal*, *17*(3), 474–486.

Kalsum, U. S., Fatimah, & Wasonowati, C. (2011). Effectiveness of washed rice water provision on growth and yield of white oyster mushroom (*Pleurotus ostreatus*). *Journal of Agrovigor*, *4*(2), 86–92.

Kanchanawongkul, V. (2004). Performance comparison on materials surface of paddies hulling for rice-hulling machine. *Engineering for Increasing Productivity*, *13*, 3–15.

Kang, S. M., Radhakrishnan, R., Lee, K. E., You, Y. H., Ko, J. H., Kim, J. H., & Lee, I. J. (2015). Mechanism of plant growth promotion elicited by *Bacillus* sp. LKE15 in oriental melon. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, *65*(7), 637–647.

Kang, S. M., Radhakrishnan, R., You, Y. H., Joo, G. J., Lee, I. J., Lee, K. E., & Kim, J. H. (2014). Phosphate solubilizing *Bacillus megaterium* mj1212 regulates endogenous plant carbohydrates and amino acids contents to promote mustard plant growth. *Indian Journal of Microbiology*, *54*(4), 427–433. https://doi.org/10.1007/s12088-014-0476-6

Karakas, I., Sam, S. B., Cetin, E., Dulekgurgen, E., & Yilmaz, G. (2020). Resource recovery froman aerobic granular sludge process treating domestic wastewater. *Journal of Water Process Engineering*, *34*, 101148. https://doi.org/https://doi.org/10.1016/j.jwpe.2020.101148.

Karlina, A., Yursida, & Ruli, J. P. (2013). Growth response of water spinach (*Ipomea reptans*) to the application of liquid organic fertilizer from cow urine and organic fertilizer in tidal land overflow type C. *Journal of Ilmiah Agriculture*, *1*, 1–16.

Katupitiya, S., Millet, J., Vesk, M., Viccars, L., Zeman, A., Lidong, Z., Elmerich, C., & Kennedy, I. R. (1995). A mutant of *Azospirillum brasilense* Sp7 impaired in flocculation with a modified colonization pattern and superior nitrogen fixation in association with wheat. *Applied and Environmental Microbiology*, *61*(5), 1987–1995. https://doi.org/10.1128/aem.61.5.1987-1995.1995

Kesare, K., Tawri, U., Barai, M., Parmal, G., & Joshi, K. (2021). *Use of rice water (oryza sativa) & hibiscus (hibiscus rosa-sinensis) for hair*. *8*(6), 181–194.

Khairun, N. K., Teh, C. B. S., & Hawa, Z. E. J. (2016). Simultaneous effects of water and nitrogen stress on the vegetative and yield parameters of choy sum (*Brassica chinensis* var. parachinensis). *Pertanika Journal of Tropical Agricultural Science*, *39*(1), 101–116.

Khalid, S., Shahid, M., Bibi, I., Sarwar, T., Shah, A. H., & Niazi, N. K. (2018). A review of environmental contamination and health risk assessment of wastewater use for crop irrigation with a focus on low and high-income countries. *International Journal of Environmental Research and Public Health*, *15*(5), 895.

Khalid, S., Shahid, M., Dumat, C., Niazi, N. K., Bibi, I., Gul Bakhat, H. F. S., Abbas, G., Murtaza, B., & Javeed, H. M. R. (2017). Influence of groundwater and wastewater irrigation on lead accumulation in soil and vegetables: Implications for health risk assessment and phytoremediation. *International Journal of Phytoremediation*, *19*(11), 1037–1046. https://www.tandfonline.com/doi/full/10.1080/15226514.2017.1319330

Khalifa, A. Y. Z., Alsyeeh, A. M., Almalki, M. A., & Saleh, F. A. (2016). Characterization of the plant growth promoting bacterium, *Enterobacter cloacae* MSR1, isolated from roots of non-nodulating *Medicago sativa*. *Saudi Journal of Biological Sciences*, *23*(1), 79–86. https://doi.org/10.1016/j.sjbs.2015.06.008

Kleinman, P. J. A., Sharpley, A. N., Wolf, A. M., Beegle, D. B., & Moore, P. A. (2002). Measuring water-extractable phosphorus in manure as an indicator of phosphorus in runoff. *Soil Science Society of America Journal*, *66*(6), 2009–2015. https://doi.org/10.2136/sssaj2002.2009

Kleinman, P. J. A., Wolf, A. M., Sharpley, A. N., Beegle, D. B., & Saporito, L. S. (2005). Survey of water-extractable phosphorus in livestock manures. *Soil Science Society of America Journal*, *69*(3), 701–708. https://doi.org/10.2136/sssaj2004.0099

Kloepper, J. W., Ryu, C. M., & Zhang, S. (2004). Induced systemic resistance and promotion of plant growth by *Bacillus* spp. *Phytopathology*, *94*(11), 1259–1266. https://doi.org/10.1094/PHYTO.2004.94.11.1259

Kretschmer, N., Ribbe, L., & Hartmut, G. (2002). Wastewater reuse for agriculture. *Technology Resource Management & Development-Scientific Contributions for Sustainable Development*, *2*, 37–64.

Kuan, K. B., Othman, R., Rahim, K. A., & Shamsuddin, Z. H. (2016). Plant growth-promoting rhizobacteria inoculation to enhance vegetative growth, nitrogen fixation and nitrogen remobilisation of maize under greenhouse conditions. *PLoS ONE*, *11*(3), 1–19. https://doi.org/10.1371/journal.pone.0152478

Kumar, S., Stecher, G., & Tamura, K. (2016). MEGA7: Molecular evolutionary genetics analysis version 7.0 for bigger datasets. *Molecular Biology and Evolution*, *33*(7), 1870–1874. https://doi.org/10.1093/molbev/msw054

Kumar, K. V, Srivastava, S., Singh, N., & Behl, H. M. (2009). Role of metal resistant plant growth promoting bacteria in ameliorating fly ash to the growth of *Brassica juncea*. *Journal of Hazardous Materials*, *170*(1), 51–57.

Lahav, O., Telzhensky, M., Zewuhn, A., Gendel, Y., Gerth, J., Calmano, W., & Birnhack, L. (2013). Struvite recovery from municipal-wastewater sludge centrifuge supernatant using seawater NF concentrate as a cheap Mg(II) source. *Separation and Purification Technology*, *108*, 103–110. https://doi.org/https://doi.org/10.1016/j.seppur.2013.02.002

Laird, D., Fleming, P., Wang, B., Horton, R., & Karlen, D. (2010). Biochar impact on nutrient leaching from a Midwestern agricultural soil. *Geoderma*, *158*(3–4), 436–442. https://doi.org/10.1016/j.geoderma.2010.05.012

Lal, K., Yadav, R. K., Kaur, R., Bundela, D. S., Khan, M. I., Chaudhary, M., Meena, R. L., Dar, S. R., & Singh, G. (2013). Productivity, essential oil yield, and heavy metal accumulation in lemon grass (*Cymbopogon flexuosus*) under varied wastewater-groundwater irrigation regimes. *Industrial Crops and Products*, *45*, 270–278. https://doi.org/10.1016/j.indcrop.2013.01.004

Laurie, R. N., Du Plooy, C. P., & Laurie, S. M. (2009). Effect of moisture stress on growth and performance of orange fleshed sweet potato varieties. *African Crop Science Conference Proceedings*, *9*, 235–239.

Leandro, M. (2009). *Effect of rice wash water concentration on growth of tomato and eggplant plants*. Retrieved on 21 August 2020, from http://cikaciko.blogspot.com/2009/01/PengaruhKonsentrasiAirCucianBerasterhadapPertumbuhanTanamanTomatdanTerong.html

Lee, W., An, S., & Choi, Y. (2021). Ammonia harvesting via membrane gas extraction at mod-erately alkaline pH: a step toward net-profitable nitrogen recovery from domestic wastewater. *Chemical Engineering Journal*, *405*, 126662. https://doi.org/https://doi.org/10.1016/j.cej.2020.126662

Lehmann, S. (2011). Resource recovery and materials flow in the city: zero waste and sustainable consumption as paradigm in urban development. *Journal of Green Building. 6*, 88–105.

Lestari, B. K. (2010). *Effectiveness of watering washed rice water and soybean extract on the growth of hybrid chili plants (Capsicum annum L)*. Unpublished Diploma Thesis. Universitas Muhammadiyah Surakarta, Surakarta, Indonesia. Retrieved on September 11, 2020, from http://eprints.ums.ac.id/id/eprint/9784.

Li, W., & Li, Z. (2009). In situ nutrient removal from aquaculture wastewater by aquatic vegetable Ipomoea aquatica on floating beds. *Water Science and Technology*, *59*(10), 1937–1943. https://iwaponline.com/wst/article-abstract/59/10/1937/31455/In-situ-nutrient-removal-from-aquaculture?redirectedFrom=fulltext

Lin, L. Z., & Harnly, J. M. (2010). Phenolic component profiles of mustard greens, yu choy, and 15 other *Brassica* vegetables. *Journal of Agricultural and Food Chemistry*, *58*(11), 6850–6857.

Liu, G., Simonne, E. H., Morgan, K. T., Hochmuth, G. J., Agehara, S., & Mylavarapu., R. (2019). Fertilizer management for vegetable production in Florida. In *University of Florida Institute of Food and Agricultural Sciences*.

Liu, S., Kong, F., Li, Y., Jiang, Z., Xi, M., & Wu, J. (2020). Mineral-ions modified biochars enhance the stability of soil aggregate and soil carbon sequestration in a coastal wetland soil. *Catena*, *193*(2020), 104618. https://doi.org/10.1016/j.catena.2020.104618

Liu, Y.-J., Tong, Y.-P., Zhu, Y.-G., Ding, H., & Smith, F. A. (2006). Leaf chlorophyll readings as an indicator for spinach yield and nutritional quality with different nitrogen fertilizer applications. *Journal of Plant Nutrition*, *29*(7), 1207–1217.

Liu, Y. Y., & Haynes, R. J. (2011). Origin, nature, and treatment of effluents from dairy and meat processing factories and the effects of their irrigation on the quality of agricultural soils. In *Critical Reviews in Environmental Science and Technology, 41*(17), 1531-1599. https://doi.org/10.1080/10643381003608359

Lucy, M., Reed, E., & Glick, B. R. (2004). Applications of free living plant growth-promoting rhizobacteria. *Antonie van Leeuwenhoek, International Journal of General and Molecular Microbiology*, *86*(1), 1–25. https://doi.org/10.1023/B:ANTO.0000024903.10757.6e

Lugtenberg, B., & Kamilova, F. (2009). Plant-growth-promoting rhizobacteria. *Annual Review of Microbiology*, *63*, 541–556. https://doi.org/10.1146/annurev.micro.62.081307.162918

Macias, F. (2004). Recovery of degraded soils, reuse of waste and carbon sequestration. A comprehensive alternative to improve environmental quality. *Resources Rurais*, *1*, 49–56.

Maclean, J. L., Dawe, D. C., Hardy, B., & Hettel, G. P. (2002). *Rice almanac: Source book for the most important economic activity on earth*. International Rice Research Institute.

Macolino, S., & Zanin, G. (2014). Effectiveness of a zeolite-based fertilizer in reducing nutrient leaching in a recently sodded turfgrass. *XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014)*, 73–82.

Madaki, Y. S., & Seng, L. (2013). Palm oil mill effluent (POME) from Malaysia palm oil mills: waste or resource. *International Journal of Science, Environment and Technology*, *2*(6), 1138–1155.

Malakar, M. C., & Banerjee, S. N. (1959). Effect of cooking rice with different volumes of water on the loss of nutrients and on digestibility of rice in vitro. *Food Research*, *24*, 751–756.

Manevski, K., Børgesen, C. D., Andersen, M. N., & Kristensen, I. S. (2015). Reduced nitrogen leaching by intercropping maize with red fescue on sandy soils in North Europe: A combined field and modeling study. *Plant and Soil*, *388*(1–2), 67–85. https://doi.org/10.1007/s11104-014-2311-6

Manga, J., Logreira, N., & Serralt, J. (2001). Reuso de aguas residuales: Un recurso hídrico disponible [Wastewater Reuse: An Available Water Resource]. *Ingeniería y Desarrollo*, *9*, 12–21.

Matheyarasu, R., Bolan, N. S., & Naidu, R. (2016). Abattoir wastewater irrigation increases the availability of nutrients and influences on plant growth and development. *Water, Air, and Soil Pollution*, *227*(8). https://doi.org/10.1007/s11270-016-2947-3

Matichenkov, V., Bocharnikova, E., & Campbell, J. (2020). Reduction in nutrient leaching from sandy soils by Si-rich materials: Laboratory, greenhouse and filed studies. *Soil and Tillage Research*, *196*, 104450. https://doi.org/https://doi.org/10.1016/j.still.2019.104450

McGuire, S. (2015). *FAO, IFAD, and WFP. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: Taking stock of uneven progress. Rome: FAO, 2015*. Oxford University Press.

McInnes, L., Healy, J., Saul, N., & Großberger, L. (2018). UMAP: uniform manifold approximation and projection. *Journal of Open Source Software*, *3*(29), 861.

McLean, E. O. (1983). Soil pH and lime requirement. In: A. L. Page, R.H. Miller, & D. R. Keeney (Eds). *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties*, *9*, 199–224. Agronomy Monographs. https://doi.org/10.2134/agronmonogr9.2.2ed.c12

MDA. (2011). Ringkasan Maklumat Perangkaan Agromakanan. *Malaysia Department of Agriculture*. Retrieved from: http://www.moa.gov.my (accessed on 3/5/2022)

Mechri, B., Chehab, H., Attia, F., Mariem, F. B., Braham, M., & Hammami, M. (2010). Olive mill wastewater effects on the microbial communities as studied in the field of olive trees by analysis of fatty acid signatures. *European Journal of Soil Biology*, *46*(5), 312–318. https://doi.org/10.1016/j.ejsobi.2010.06.001

Mechri, B., Mariem, F. B., Baham, M., Elhadj, S. B., & Hammami, M. (2008). Change in soil properties and the soil microbial community following land spreading of olive mill wastewater affects olive trees key physiological parameters and the abundance of arbuscular mycorrhizal fungi. *Soil Biology and Biochemistry*, *40*(1), 152–161.

Messiha, N. A. S., van Diepeningen, A. D., Farag, N. S., Abdallah, S. A., Janse, J. D., & van Bruggen, A. H. C. (2007). *Stenotrophomonas maltophilia*: A new potential biocontrol agent of *Ralstonia solanacearum*, causal agent of potato brown rot. *European Journal of Plant Pathology*, *118*(3), 211–225. https://doi.org/10.1007/s10658-007-9136-6

Miransari, M. (2011). Interactions between arbuscular mycorrhizal fungi and soil bacteria. *Applied Microbiology and Biotechnology*, *89*, 917–930.

Miransari, M. (2013). Soil microbes and the availability of soil nutrients. *Acta Physiologiae Plantarum*, *35*(11), 3075–3084. https://doi.org/10.1007/s11738-013-1338-2

Miransari, M., & Smith, D. (2008). Using signal molecule genistein to alleviate the stress of suboptimal root zone temperature on soybean-Bradyrhizobium symbiosis under different soil textures. *Journal of Plant Interaction*, *3*, 287–295.

Mitrogiannis, D., Psychoyou, M., Baziotis, I., Inglezakis, V. J., Koukouzas, N., Tsoukalas, N., Palles, D., Kamitsos, E., Oikonomou, G., & Markou, G. (2017). Removal of phosphate from aqueous solutions by adsorption onto $Ca(OH)_2$ treated natural clinoptilolite. *Chemical Engineering Journal*, *320*, 510–522. https://doi.org/10.1016/j.cej.2017.03.063

Moore, S., & Morgan, W. (1998). Chinese Flowering Cabbage. In K. W. Hyde (Ed.), *The New Rural Industries* (pp. 178–181). Rural Industries Research and Devel_opment Corporation.

Moradi, A., Teh, C. B. S., Goh, K. J., Husni, M. H. A., & Ishak, C. F. (2014). Decomposition and nutrient release temporal pattern of oil palm residues. *Annals of Applied Biology*, *164*(2), 208–219.

Moscoso, J., Egocheaga, L., Ugaz, R., & Trellez, E. (2002). Integrated wastewater treatment and use systems in Latin America: Reality and potential. *In Congreso Iberoamericano de Ingeniería Sanitaria y Ambiental*.

Mosharrof, M., Uddin, M. K., Sulaiman, M. F., Mia, S., Shamsuzzaman, S. M., & Haque, A. N. A. (2021). Combined application of rice husk biochar and lime increases phosphorus availability and maize yield in an acidic soil. *Agriculture*, *11*(8), 793. https://doi.org/10.3390/agriculture11080793

Murtaza, G., Ghafoor, A., Qadir, M., Owens, G., Aziz, M. A., Zia, M. H., & Saifullah. (2010). Disposal and use of sewage on agricultural lands in Pakistan: A review. *Pedosphere*, *20*(1), 23–34. https://doi.org/10.1016/S1002-0160(09)60279-4

Musa, A. M., Ishak, C. F., Karam, D. S., & Jaafar, N. M. (2020). Effects of fruit and vegetable wastes and biodegradable municipalwastes co-mixed composts on nitrogen dynamics in an oxisol. In *Agronomy,* 10, 1609. https://doi.org/10.3390/agronomy10101609

Muyang, K. S. T., Ahmed, O. H., Khew, C. Y., Zehnder, J. A. M., Jalloh, M. B., Musah, A. A., & Abdu, A. (2021). Chemical and biological characteristics of organic amendments produced from selected agro-wastes with potential for sustaining soil health: A laboratory assessment. *Sustainability (Switzerland)*, *13*(9), 1–15. https://doi.org/10.3390/su13094919

Nabayi, A., Teh, C. B. S., Husni, M. H. A., Jaafar, A. H., & Isnar, M. S. (2016). Comparison of three irrigation systems for the BX-1 system for nursery seedlings. *Malaysian Journal of Soil Science*, *20,* 19-36.

Nabayi, A., Teh, C. B. S., Husni, M. H. A., & Sulaiman, Z. (2018). Plant growth, nutrient content and water use of rubber (Hevea brasiliensis) seedlings grown using root trainers and different irrigation systems. *Pertanika Journal of Tropical Agricultural Science*, *41*(1), 251-270.

Nabayi, Abba, Sung, C. T. B., Tan, A. K. Z., & Tan, N. P. (2021c). Fermentation of washed rice water increases beneficial plant bacterial population and nutrient concentrations. *Sustainability*, *13*(23), 1–19. https://doi.org/10.3390/su132313437

Nabayi, Abba, Teh, C. B. S., Ngai, T. P., & Tan, A. K. Z. (2021a). Wastewater from washed rice water as plant nutrient source: Current understanding and knowledge gaps. *Pertanika Journal of Science and Technology*, *29*(3), 1347–1369. https://doi.org/10.47836/pjst.29.3.11

Nabayi, Abba, Teh, C. S. B., Zuan, A. T. K., Paing, T. N., & Akhir, N. I. M. (2021b). Chemical and microbial characterization of washed rice water waste to assess its potential as plant fertilizer and for increasing soil health. *Agronomy*, *11*(12), 2391. https://doi.org/10.3390/agronomy11122391

Naher, U. A., Radziah, O., Shamsuddin, Z. H., Halimi, M. S., & Mohd Razi, I. (2009). Isolation of diazotrophs from different soils of Tanjong Karang rice growing area in Malaysia. *International Journal of Agriculture and Biology*, *11*(5), 547–552.

Naidu, R., Megharaj, M., & Owens, G. (2004). Recyclable urban and industrial waste-benefits and problems in agricultural use. In *Managing soil quality: Challenges in modern agriculture* (pp. 219–237). CAB International Oxfordshire.

Nautiyal, C. S. (1999). An efficient microbiological growth medium for screening phosphate solubilizing microorganisms. *FEMS Microbiology Letters*, *170*(1), 265–270.

Nelson, D. W., & Sommers, L. (1983). Total carbon, organic carbon, and organic matter. In A. L. Page, R.H. Miller, & D. R. Keeney (Eds), *Methods of soil analysis* (pp. 539–579). Agronomy Monographs. https://doi.org/10.2134/agronmonogr9.2.2ed.c29

Nemali, K. S., & Van Iersel, M. W. (2004). Light intensity and fertilizer concentration: I. Estimating optimal fertilizer concentrations from water-use efficiency of wax begonia. *HortScience*, *39*(6), 1287–1292. https://doi.org/10.21273/hortsci.39.6.1287

Ng, L. C., Sariah, M., Sariam, O., Radziah, O., & and Abidin, M. A. Z. (2012). Rice seed bacterization for promoting germination and seedling growth under aerobic cultivation system. *Australian Journal of Crop Science*, *6*, 170–175.

Nguyen, V. Q. (1992). Growing Asian Vegetables. *Agfact*. Report number H8.1.37

Nkhata, S. G., Ayua, E., Kamau, E. H., & Shingiro, J. B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food Science and Nutrition*, *6*(8), 2446–2458. https://doi.org/10.1002/fsn3.846

Nobel, P. S. (2009). *Physicochemical and Environmental Plant Physiology* (4th ed.). Elsevier Academic Press.

Nooten, T. Van, Diels, L., & Bastiaens, L. (2008). Design of a multifunctional permeable reactive barrier for the treatment of landfill leachate contamination: laboratory column evaluation. *Environmental Science & Technology*, *42*(23), 8890–8895.

Norimah, A. K., Safiah, M., Jamal, K., Siti, H., Zuhaida, H., Rohida, S., Fatimah, S., Siti, N., Poh, B. K., Kandiah, M., Zalilah, M. S., Wan Manan, W. M., Fatimah, S., Azmi, M. Y., Norimah, J. A. K., Safiah, M., Jamal, K., Haslinda, S., Zuhaida, H., … Kandiah, M. (2008). Food consumption patterns: Findings from the Malaysian Adult Nutrition Survey (MANS). *Malaysian Journal of Nutrition*, *14*(1), 25–39.

Norsida, M., & Sami, I. S. (2009). Off-farm employment participation among paddy farmers in the Muda Agricultural Development Authority and Kemasin Semerak granary areas of Malaysia. *Asia-Pacific Development Journal*, *16*(2), 141–153.

Nurhasanah. (2011). *Rice washing water nutrient content*. Yogyakarta: Pustaka Belaja.

Nurhasanah, Y. S., N. Nelly, P. Reka, Anik, N., & Muhammad, L. F. (2010). *Potential Waste Water Washing Rice as a Propagation Media for Plant Probiotic Bacteria.* Institute Pertanian Bogor.

OECD. (2012a). *OECD Environmental Outlook to 2050: The Consequences of Inaction* (O. Publishing (ed.)).

OECD. (2012b). *Water Quality and Agriculture: Meeting the Policy Challenge* (O. Publishing (ed.)).

Oliveira, A., & Pampulha, M. E. (2006). Effects of long-term heavy metal contamination on soil microbial characteristics. *Journal of Bioscience and Bioengineering*, *102*(3), 157–161. https://www.sciencedirect.com/science/article/abs/pii/S1389172306706454?via%3Dihub

Oliveira, S. C., & Von Sperling, M. (2008). Reliability analysis of wastewater treatment plants. *Water Research*, *42*(4–5), 1182–1194. https://doi.org/10.1016/j.watres.2007.09.001

Omar, S. C., Shaharudin, A., & Tumi, S. A. (2009). *The Status of the Paddy and Rice Industry in Malaysia*. Retrieved from: http://www.krinstitute.org/. Accessed on 6/2/2023

Osman, M. A. (2011). Effect of traditional fermentation process on the nutrient and antinutrient contents of pearl millet during preparation of Lohoh. *Journal of the Saudi Society of Agricultural Sciences*, *10*(1), 1–6. https://doi.org/10.1016/j.jssas.2010.06.001

Park, H., & DuPonte, M. W. (2008). How to cultivate indigenous microorganisms. *Tropical Agriculture, University of Hawaii*, *9*, 1–7. http://scholarspace.manoa.hawaii.edu/handle/10125/12174

Park, J. (2013). Environment and health: An overview of current trends at WHO and OECD. *Journal of Environmental Health Sciences*, *39*(4), 299–311.

Pascual, C. de S. C. I., Massaretto, I. L., Kawassaki, F., Barros, R. M. C., Noldin, J. A., & Marquez, U. M. L. (2013). Effects of parboiling, storage and cooking on the levels of tocopherols, tocotrienols and γ-oryzanol in brown rice (*Oryza sativa* L.). *Food Research International*, *50*(2), 676–681. https://doi.org/10.1016/j.foodres.2011.07.013

Patindol, J., Flowers, A., Kuo, M. I., Wang, Y. J., & Gealy, D. (2006). Comparison of physicochemical properties and starch structure of red rice and cultivated rice. *Journal of Agricultural and Food Chemistry*, *54*(7), 2712–2718. https://doi.org/10.1021/jf0523418

Pérez, E., Sulbarán, M., Ball, M. M., & Yarzábal, L. A. (2007). Isolation and characterization of mineral phosphate-solubilizing bacteria naturally colonizing a limonitic crust in the south-eastern Venezuelan region. *Soil Biology and Biochemistry*, *39*(11), 2905–2914. https://doi.org/10.1016/j.soilbio.2007.06.017

Pescod, M. B. (1992). *Wastewater treatment and use in agriculture-FAO irrigation and drainage paper 47*.

Petrucci, Ralph, H., Geoffrey, H. F., Jeffrey, D. M., & Bissonnette, C. (2011). *General chemistry: Principles and modern applications.* (10th (ed.)). Upper Saddle River, New Jersey: Pearson Education.

Pikovskaya, R. I. (1948). Mobilization of phosphorus in soil in connection with vital activity of some microbial species. *Mikrobiologiya*, *17*, 362–370.

Pimentel, D., & Pimentel, M. H. (2007). *Food, energy, and society*. CRC press.

Pourbabaee, A. A., Bahmani, E., Alikhani, H. A., & Emami, S. (2016). Promotion of wheat growth under salt stress by halotolerant bacteria containing ACC deaminase. *Journal of Agricultural Science and Technology*, *18*(3), 855–864.

Powlson, D., Smith, P., & Smith, J. U. (2013). Evaluation of soil organic matter models: Using existing long-term datasets. In *Evaluation of soil organic matter models*. Springer Science & Business Media. https://doi.org/10.1007/978-3-642-61094-3

Pranoto, Y., Anggrahini, S., & Efendi, Z. (2013). Effect of natural and *Lactobacillus plantarum* fermentation on in-vitro protein and starch digestibilities of sorghum flour. *Food Bioscience*, *2*, 46–52. https://doi.org/10.1016/j.fbio.2013.04.001

Pratiwi, E. P. A., Hillary, A. K., Fukuda, T., & Shinogi, Y. (2016). The effects of rice husk char on ammonium, nitrate and phosphate retention and leaching in loamy soil. *Geoderma*, *277*, 61–68. https://doi.org/10.1016/j.geoderma.2016.05.006

Purba, M. A., Fauzi, F., & Sari, K. (2015). Pengaruh pemberian fosfat alam dan bahan organik pada tanah sulfat masam potensial terhadap p-tersedia tanah dan produksi padi (*Oryza sativa* L.). *Jurnal Agroekoteknologi Universitas Sumatera Utara*, *3*(3), 938–948.

Purnami, W. G., & N.H. Yuswanti. (2014). Effect of type and frequency of washed rice water on growth of orchid seeds (Phalaenopsis sp) after acclimatization. . *Jurnal of Agroekoteknologi Tropica*, *3*(1), 22–31.

Qurban Ali Panhwar. (2012). Isolation and characterization of phosphate-solubilizing bacteria from aerobic rice. *African Journal of Biotechnology*, *11*(11), 2711–2719. https://doi.org/10.5897/ajb10.2218

Rabbee, M. F., Sarafat Ali, M., Choi, J., Hwang, B. S., Jeong, S. C., & Baek, K. hyun. (2019). *Bacillus velezensis*: A valuable member of bioactive molecules within plant microbiomes. *Molecules*, *24*(6), 1–13. https://doi.org/10.3390/molecules24061046

Radhakrishnan, R., Kang, S. M., Baek, I. Y., & Lee, I. J. (2014). Characterization of plant growth-promoting traits of *Penicillium* species against the effects of high soil salinity and root disease. *Journal of Plant Interaction*, *9*, 754–762.

Radhakrishnan, R., & Lee, I. J. (2016). Gibberellins producing *Bacillus methylotrophicus* KE2 supports plant growth and enhances nutritional metabolites and food values of lettuce. *Plant Physiology and Biochemistry*, *109*, 181–189. https://doi.org/10.1016/j.plaphy.2016.09.018

Radhakrishnan, Ramalingam, Hashem, A., & Abd Allah, E. F. (2017). *Bacillus*: A biological tool for crop improvement through bio-molecular changes in adverse environments. *Frontiers in Physiology*, *8*, 667. https://doi.org/10.3389/fphys.2017.00667

Ranjard, L., & Richaume, A. (2001). Quantitative and qualitative microscale distribution of bacteria in soil. *Research in Microbiology*, *152*(8), 707–716. https://www.sciencedirect.com/science/article/pii/S0923250801012517?via%3Dihub

Ratnadi, N. W. Y., N.I. Sumardika, & Setiawan., N. A. G. (2014). Effect of watering rice washing water and urea fertilizer with different concentrations on the growth of henna plants (*Impatiens balsamina* L.). *Journal of Science Biological Education*, *1*(1), 1–9.

Razali, W. A. W., Baharuddin, A. S., Talib, A. T., Sulaiman, A., Naim, M. N., Hassan, M. A., & Shirai, Y. (2012). Degradation of oil palm empty fruit bunches (OPEFB) fibre during composting process using in-vessel composter. *BioResources*, *7*(4), 4786–4805.

Reema, P. (2020). *Benefits of rice water for the skin*. Retrieved from: https://www.medicalnewstoday.com/articles/rice-water-for-the-skin. Accessed on 6/2/2023

Renato, I., & Giraldi, D. (2011). Sources and composition of sewage effluent: treatment systems and methods. In B.-T. Levy, G. J., Pinchas, F., Asher (Ed.), *Treated Wastewater in Agriculture: Use and Impacts on the Soil Environment and Crops* (pp. 3–48). Blackwell Publishing Ltd.

Ribeiro, C. M., & Cardoso, E. J. B. N. (2012). Isolation, selection and characterization of root-associated growth promoting bacteria in Brazil Pine (*Araucaria angustifolia*). *Microbiological Research*, *167*(2), 69–78.

Richards, L. A. (1947). Pressure-membrane apparatus, construction and use. *Agricultural Engineering*, *28*(10), 451–454.

Richardson, A., Barea, J. M., McNeill, A., & Prigent-Combaret, C. (2009). Acquisition of phosphorus and nitrogen in the rhizosphere and plant growth promotion by microorganisms. *Plant and Soil*, *321*, 305–339.

Riddle, M., Cederlund, H., Schmieder, F., & Bergström, L. (2018). Magnetite-coated biochar as a soil phosphate filter: From laboratory to field lysimeter. *Geoderma*, *327*, 45–54. https://doi.org/10.1016/j.geoderma.2018.04.025

Rodríguez, H., & Fraga, R. (1999). Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnology Advances*, *17*(4–5), 319–339. https://doi.org/10.1016/S0734-9750(99)00014-2

Rousk, J., Brookes, P. C., & Bååth, E. (2009). Contrasting soil pH effects on fungal and bacterial growth suggest functional redundancy in carbon mineralization. *Applied and Environmental Microbiology*, *75*(6), 1589–1596. https://doi.org/10.1128/AEM.02775-08

Roy, P., Orikasa, T., Okadome, H., Nakamura, N., & Shiina, T. (2011). Processing conditions, rice properties, health and environment. *International Journal of Environmental Research and Public Health*, *8*(6), 1957–1976. https://res.mdpi.com/d_attachment/ijerph/ijerph-08-01957/article_deploy/ijerph-08-01957-v3.pdf

Rstudio, T. (2021). *RStudio Team RStudio: Integrated Development Environment for R 2021* (1.4.1717). https://www.rstudio.com/products/team/

Sadaf, J., Shah, G. A., Shahzad, K., Ali, N., Shahid, M., Ali, S., Hussain, R. A., Ahmed, Z. I., Traore, B., Ismail, I. M. I. I., & Rashid, M. I. (2017). Improvements in wheat productivity and soil quality can accomplish by co-application of biochars and chemical fertilizers. *Science of the Total Environment*, *607*, 715–724. https://doi.org/10.1016/j.scitotenv.2017.06.178

Sagasta, J. M., Medlicott, K., Qadir, M., Raschid-Sally, L., Drechsel, P., & Liebe, J. (2013). The safe use of wastewater in agriculture project. In R. Liebe, J., Ardakanian (Ed.), *Proceeding of the UN -WATER project on the Safe Use of Wastewater in Agriculture* (pp. 9–38). UNW-DPC.

Sahu, O., Rao, D. G., Gopal, R., Tiwari, A., & Pal, D. (2017). Treatment of wastewater from sug-arcane process industry by electrochemical and chemical process: Aluminum (metaland salt). *Journal of Water Process Engineering*, *17*, 50–62. https://doi.org/https://doi.org/10.1016/j.jwpe.2017.03.005

Sairi, F., Ismail, N., & Ibrahim, N. (2018). The effect of FRAW towards the growth of chilli seedlings and its associated microorganisms. *Malaysian Journal of Microbiology*, *14*(6), 606–610.

Sakiah, & Wahyuni, M. (2018). Analysis of C-organic, nitrogen, phosphorus and potassium in application areas and without application of palm oil mill effluent. . *Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, *11*(4), 23–27.

Sancho, I., Licon, E., Valderrama, C., de Arespacochaga, N., López-Palau, S., & Cortina, J. L. (2017). Recovery of ammonia from domestic wastewater effluents as liquid fertilizersby integration of natural zeolites and hollowfibre membrane contactors. *Science of the Total Environment*, *584–585*, 244–251. https://doi.org/https://doi.org/10.1016/j.scitotenv.2017.01.123

Santos, C., Fonseca, J., Aires, A., Coutinho, J., & Trindade, H. (2017). Effect of different rates of spent coffee grounds (SCG) on composting process, gaseous emissions and quality of end-product. *Waste Management*, *59*, 37–47. https://www.sciencedirect.com/science/article/abs/pii/S0956053X16305918?via%3Dihub

Schulz, R., & Römheld, V. (1997). Recycling of municipal and industrial organic wastes in agriculture: Benefits, limitations, and means of improvement. In *Plant Nutrition for Sustainable Food Production and Environment* (Vol. 43, pp. 581–586). Springer. https://doi.org/10.1080/00380768.1997.11863716

Scott, C. A., Drechsel, P., Raschid-Sally, L., Bahri, A., Mara, D., Redwood, M., & Jiménez, B. (2010). Challenges and outlook for mitigating risks in low-income countries. In *Wastewater irrigation and health* (pp. 381–394). Earthscan.

Shahbandeh, M. (2021). *Total global rice consumption 2008-2021*. Retrieved on 12 August 2021, from: https://www.statista.com/statistics/255977/total-global-rice-consumption/

Shahbandeh, M. (2022). *Total global rice consumption 2008-2022*. Retrieved on 21 September 2022, from: https://www.statista.com/statistics/255977/total-global-rice-consumption/

Shamshuddin, J. (1989). Lime requirements of highly weathered Malaysian soils. Communication 4. *Pertanika*, *12*(1), 107-112.

Shamshuddin, J., & Fauziah, C. I. (2010). *Weathered tropical soils: The Ultisols and Oxisols*. Universiti Putra Malaysia, Press.

Shariati, V. J., Malboobi, M. A., Tabrizi, Z., Tavakol, E., Owilia, P., & Safari, M. (2017). Comprehensive genomic analysis of a plant growth-promoting rhizobacterium *Pantoea agglomerans* strain P5 /631/208/212/748 /631/208/464 /38/43 /45 article. *Scientific Reports*, *7*(1), 1–12. https://doi.org/10.1038/s41598-017-15820-9

Shaviv, A. (2001). Advances in controlled-release fertilizers. *Advances in Agronomy*, *71*, 1–49.

Shuler, K. D. (1995). Guidelines for chinese leafy and root crop vegetable production in South Florida. In G. J. Hochmuth & D. N. Maynard (Eds.), *FACTS 1995 Vegetable Crop Proc.* (pp. 53–57).

Siagian, A. S. (2018). *Response of organic fertilizer to liquid water wash on growth and production of lettuce (Lactuca sativa L)*. University of Medan Area Faculty of Agricultural Studies Program of Agrotechnology. Retrieved on May 26, 2021, from http://repository.uma.ac.id/handle/123456789/10578

Sianipar, O. P. (2004). *Effect of frequency of vitamin B1 and KNO_3 fertilizer concentration on vegetative growth of dendrobium orchid seeds (Dendrobium)*. (Unpublished Diploma thesis). Fakultas Pertanian Universitas Udayana Indonesia. Retrieved on September 15, 2020, from digilib.unimed.ac.id

Sitepu, I. R., Hashidoko, Y., Santoso, E., & Tahara, S. (2007). Potent phosphate-solubilizing bacteria isolated from dipterocarps grown in peat swamp forest in Central Kalimantan and their possible utilization for biorehabilitation of degraded peatland. *Proceedings of the International Symposium and Workshop on Tropical Peatland, Yogyakarta*, 27–29.

Skjemstad, J. O., & Baldock, J. A. (2007). Total and organic carbon. In: M.R. Carter, E.G. Gregorich (Eds.), Soil sampling and method of analysis, Canadian Society of Soil Science, Taylor and Francis Group, USA, pp. 225-237.

Somasegaran, P., & Hoben, H. J. (1985). *Methods in Legume-Bradyrhizobium japonicum Technology. Hawaii: University of Hawaii. Hawaii Institute of Tropical Agriculture and Hunan Resources College of Tropical Agriculture and Human Resource*. Retrieved from : https://www.ctahr.hawaii.edu/bnf/Downloads/Training/Rhizobium technology/Title Page.PDF

Sommers, L. E. (1977). Chemical composition of sewage sludges and analysis of their potential use as fertilizers. *Journal of Environmental Quality*, *6*(2), 225–232.

Sousa, J. T. de, Ceballos, B. S. O. de, Henrique, I. N., Dantas, J. P., & Lima, S. M. S. (2006). Reúso de água residuária na produção de pimentão (*Capsicum annuum* L.). *Revista Brasileira de Engenharia Agrícola e Ambiental*, *10*(1), 89–96. https://doi.org/10.1590/s1415-43662006000100014

Sreenivasan, J., Govindan, M., Chinnasami, M., & Kadiresu, I. (2012). Solid waste management in Malaysia–A move towards sustainability. *Waste Management an Integrated Visions*, *2005*, 55–70. http://dx.doi.org/10.5775/50870

Sripriya, G., Antony, U., & Chandra, T. S. (1997). Changes in carbohydrate, free amino acids, organic acids, phytate and HCl extractability of minerals during germination and fermentation of finger millet (*Eleusine coracana*). *Food Chemistry*, *58*(4), 345–350. https://doi.org/10.1016/S0308-8146(96)00206-3

Stevenson, F. J. (1996). Nitrogen-organic forms. In D. L. Sparks, A. L. Page, P. A. Helmke, R. H. Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnston, & M. E. Sumner (Eds.), *Methods of Soil Analysis, Part 3 Chemical Methods.* (pp. 1185–1200). Soil Science Society of America. https://doi.org/https://doi.org/10.2136/sssabookser5.3.c39

Sugumaran, P., & Janarthanum, B. (2007). Solubilization of potassium containing minerals by bacteria and their effect of plant growth. *World Journal of Agriculture Science*, *3*(3), 350–355.

Suhaimee, S., Ibrahim, I. Z., & Abdul Wahab, M. A. M. (2016). *Organic Agriculture in Malaysia*. FFTC agricultural policy articles production policy: Taipei, Taiwan. https://ap.fftc.org.tw/article/1010

Sullivan, D. M., Bary, A. I., Miller, R. O., & Brewer, L. J. (2018). Interpreting compost analyses. In *OSU Extension Catalog* (Issue October). Oregon State University Extension Service. https://doi.org/EM9217

Sun, P. F., Fang, W. T., Shin, L. Y., Wei, J. Y., Fu, S. F., & Chou, J. Y. (2014). Indole-3-acetic acid-producing yeasts in the phyllosphere of the carnivorous plant *Drosera indica* L. *PLoS ONE*, *9*(12), 1–22. https://doi.org/10.1371/journal.pone.0114196

Supraptiningsih, L. K., & Nuriyanti, R. (2019). Processing household waste (washed rice water) into liquid organic fertilizer in probolinggo regency empowering. *Journal Pengabdian Masyarakat Fakulti Psikologi*, *3*, 12–20.

Suryana, H., M. Titiaryanti, & Yuniasih, B. (2017). Effect of types and doses of waste on the growth of oil palm seedlings (pre nursery). *Journal of Agromast*, *2*(1), 1–11.

Syuhaibah, S. A. (2017). *Use of washed rice water as a fertilizer*. Universiti Putra Malaysia, Serdang.

Tahir, S., & Marschner, P. (2017). Clay addition to sandy soil reduces nutrient leaching-effect of clay concentration and ped size. *Communications in Soil Science and Plant Analysis*, *48*(15), 1813–1821. https://doi.org/https://doi.org/10.1080/00103624.2017.1395454

Talaat, N. B., Ghoniem, A. E., Abdelhamid, M. T., & Shawky, B. T. (2015). Effective microorganisms improve growth performance, alter nutrients acquisition and induce compatible solutes accumulation in common bean (*Phaseolus vulgaris* L.) plants subjected to salinity stress. *Plant Growth Regulation*, *75*(1), 281–295. https://doi.org/10.1007/s10725-014-9952-6

Tan, K. Z., Radziah, O., Halimi, M. S., Khairuddin, A. R., Habib, S. H., & Shamsuddin, Z. H. (2014). Isolation and characterization of rhizobia and plant growth-promoting rhizobacteria and their effects on growth of rice seedlings. *American Journal of Agricultural and Biological Sciences*, *9*(3), 342–360. https://doi.org/10.3844/ajabssp.2014.342.360

Tan, S. L. (2021). *Utilization of graywater in formulating liquid organo mineral fertilizer and effects on growth and yield performance of chili (Capsicum Annuum L.)*. Unpublished Masters thesis; Universiti Putra Malaysia.

Tang, A., Haruna, A. O., Majid, N. M. A., & Jalloh, M. B. (2020a). Effects of selected functional bacteria on maize growth and nutrient use efficiency. *Microorganisms*, *8*(6), 1–25. https://doi.org/10.3390/microorganisms8060854

Tang, A., Haruna, A. O., Majid, N. M. A., & Jalloh, M. B. (2020b). Potential PGPR properties of cellulolytic, nitrogen-fixing, and phosphate-solubilizing bacteria of a rehabilitated tropical forest soil. *Microorganisms*, *8*(6), 1–22. https://doi.org/10.1101/351916

Taylor, J. R. N., Hugo, L. F., & Yetnerberk, S. (2005). Developments in sorghum bread making. In *using cereal science and technology for the benefit of consumers*. Woodhead Publishing Limited. https://doi.org/10.1533/9781845690632.3.51

Teh, C. B. S., Ishak, C. F., Rosazlin, A., Othman, R., Panhwar, Q. A., & Aziz, A. M. (2017). Soil Properties (Physical, Chemical, Biological, Mechanical). In M. A. Ashraf, M.A., R. Othman, & C. F. Ishak (Eds.), *Soils of Malaysia* (pp. 103–154). CRC Press, Taylor and Francis, LLC, Boca Raton, FL.

Teh, C. S. B. C. B. S. (2016). Availability, use, and removal of oil palm biomass in Indonesia. Report Prepared for the International Council on Clean Transportation. pp. 1–39. Retrieved on April 20, 2020, from Availability, use, and removal of oil palm biomass in Indonesia | International Council on Clean Transportation (theicct.org)

The Jakarta Post. (2017). Village in Bogor uses leftover rice water to grow plants. *Jakarta Post News Desk*. Accessed on May 26, 2021, from Village in Bogor uses leftover rice water to grow plants - City - The Jakarta Post

Thomas, G. W. (1982). Exchangeable cations. In: A.L. Page et al.(eds.), *Methods of soil analysis*. Part 2. Agron. Monogr. 9. ASA and SSSA, Madison, WI. p. 159–165.

Thomas, P., Sekhar, A. C., Upreti, R., Mujawar, M. M., & Pasha, S. S. (2015). Optimization of single plate-serial dilution spotting (SP-SDS) with sample anchoring as an assured method for bacterial and yeast cfu enumeration and single colony isolation from diverse samples. *Biotechnology Reports*, *8*, 45–55. https://doi.org/10.1016/j.btre.2015.08.003

Tin, K. P., Keng, H., & Avadhani, P. N. (2000). *A guide to common vegetables*. Science Centre.

Tonelli, M. L., Taurian, T., Ibáñez, F., Angelini, J., & Fabra, A. (2010). Selection and in vitro characterization of biocontrol agents with potential to protect peanut plants against fungal pathogens. *Journal of Plant Pathology*, 73–82.

Topić, M., Borišev, M., Orlović, S., Tomičić, M., Župunski, M., Nikolić, N., Pajević, S., Krstić, B., & Pilipović, A. (2013). Clonal differences of black poplar cuttings for morpho-physiological and biochemical responses to soil water deficits. *The Journal of Animal and Plant Sciences*, *23*(6), 1725–1732.

Toze, S. (2006). Reuse of effluent water - Benefits and risks. *Agricultural Water Management*, *80*(1-3 SPEC. ISS.), 147–159. https://doi.org/10.1016/j.agwat.2005.07.010

Tubiello, F. N., Salvatore, M., Rossi, S., Ferrara, A., Fitton, N., & Smith, P. (2013). The FAOSTAT database of greenhouse gas emissions from agriculture. *Environmental Research Letters*, *8*(1), 015009. https://doi.org/10.1088/1748-9326/8/1/015009

United Nations, G. A. (2016). United Nations World Water Assessment Programme (UNWWAP). *Paris, France: The united nations world water development report*, 1–148.

UNO. (2006). *5 de março World Urbanization Prospects: The 2005 Revision*.

Upadhyay, A., & Karn, S. K. (2018). Brown rice: Nutritional composition and health benefits. *Journal of Food Science and Technology Nepal*, *10*, 47–52.

USDA. (2022). *Global fertilizer challenge: Strengthening food security and reducing agriculture emissions by advancing fertilizer efficiency and alternatives*. White House Fact Sheet. Retrieved from: https://www.fas.usda.gov/newsroom/global-fertilizer-challenge. Accessed on 6/2/2023

Vergé, X. P. C., Dyer, J. A., Desjardins, R. L., & Worth, D. (2007). Greenhouse gas emissions from the Canadian dairy industry in 2001. *Agricultural Systems*, *94*(3), 683–693. https://doi.org/10.1016/j.agsy.2007.02.008

Vermaat, J. E., & Hanif, M. K. (1998). Performance of common duckweed species (*Lemnaceae*) and the waterfern Azolla filiculoides on different types of waste water. *Water Research*, *32*(9), 2569–2576.

Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil*, *255*(2), 571–586.

Villagra-Mendoza, K., & Horn, R. (2018). Effect of biochar addition on hydraulic functions of two textural soils. *Geoderma*, *326*, 88–95. https://doi.org/10.1016/j.geoderma.2018.03.021

Vimala, P., & Chan, S. K. (1999). Soil and fertilization. In *A guide of vegetables production*. Malaysian Research and Development Institute (MARDI).

Wachtel-Galor, S., Wong, K. W., & Benzie, I. F. (2008). The effect of cooking on *Brassica* vegetables. *Food Chemistry*, *110*(3), 706–710.

Wang, X., Pan, Q., Chen, F., Yan, X., & Liao, H. (2010). Effects of co_inoculation with arbuscular mycorrhizal fungi and rhizobia on soybean growth as related to root architecture and availability of N and P. *Mycorrhiza*, *21*, 173–181.

Wang, Y., & Liu, G. (2020). *Production Guide for Choy Sum—An Emerging Asian Vegetable in Florida*. Retrieved from: https://edis.ifas.ufl.edu/publication/HS1380. Accessed on 6/2/2023.

Wardiah, L., & Hafnati, L. R. (2014). Potensi limbah air cucian beras sebagai pupuk organik cair pada pertumbuhan pakchoy (*Brassica rapa* L.). *Jurnal Biologi Edukasi*, *6*(1), 34–38.

Watanabe, M., Ichinose, K., Sasano, K., Ozaki, Y., Tsuiki, T., Hidaka, H., & Kanemoto, S. (2011). Effect of enzymatic treatment on sedimentation and flocculation abilities of solid particles in rice washing drainage and its relationship with protein profiles. *Journal of Bioscience and Bioengineering*, *112*(1), 67–70. https://www.sciencedirect.com/science/article/abs/pii/S1389172311001095?via%3Dihub

Watanabe, M., Makino, M., Kaku, N., Koyama, M., Nakamura, K., & Sasano, K. (2013). Fermentative L-(+)-lactic acid production from non-sterilized rice washing drainage containing rice bran by a newly isolated lactic acid bacteria without any additions of nutrients. *Journal of Bioscience and Bioengineering*, *115*(4), 449–452. https://doi.org/10.1016/j.jbiosc.2012.11.001

Watanabe, M., Takahashi, M., Sasano, K., Kashiwamura, T., Ozaki, Y., Tsuiki, T., Hidaka, H., & Kanemoto, S. (2009). Bioethanol production from rice washing drainage and rice bran. *Journal of Bioscience and Bioengineering*, *108*(6), 524–526. https://www.sciencedirect.com/science/article/abs/pii/S1389172309002916?via%3Dihub

We, A. C. E., Aris, A., Zain, N. A. M., Muda, K., & Sulaiman, S. (2021). Influence of static mixer on the development of aerobic granules for the treatment of low-medium strength domestic wastewater. *Chemosphere*, *263*, 128209. https://doi.org/https://doi.org/10.1016/j.chemosphere.2020.128209

Wen Hua Ling, Qi Xuan Cheng, Ma, J., & Wang, T. (2001). Red and black rice decrease atherosclerotic plaque formation and increase antioxidant status in rabbits. *Journal of Nutrition*, *131*(5), 1421–1426. https://doi.org/10.1093/jn/131.5.1421

Wiersema, J. H., & León, B. (2016). *World economic plants: A standard reference*. CRC press.

Wijiyanti, P., Hastuti, E. D., & Haryanti, S. (2019). Effect of fertilizer fermentation period of rice wash water on green mustard plant growth (*Brassica juncea* L.). *Buletin Anatomi Dan Fisiologi*, *4*(1), 21–28.

Wills, R. B., Wong, A. W., Scriven, F. M., & Greenfield, H. (1984). Nutrient composition of chinese vegetables. *Journal of Agricultural and Food Chemistry*, *32*(2), 413–416.

Winance, G. M., Ernaningsih, D., & Eting, D. E. (2018). Effect of utilization of rice washing water and eggshells on the growth of tomato plants (*Lycopersium escuslentum* Mill). *BIOS Jurnal Pendidikan Biology dan Pengajaran*, *1*(1), 1–9.

Winpenny, J., Heinz, I., Koo-Oshima, S., Salgot, M., Collado, J., Hérnandez, F., & Torricelli, R. (2013). Reutilización del Agua en Agricultura:¿ Beneficios para Todos? *FAO: Rome, Italy*, *124*.

World Count. (2020). *Tons of waste from households*. Retrieved on 23 May 2020, from https://www.theworldcounts.com/challenges/planet-earth/waste/waste-from-households/story

Wu, L., Wei, C., Zhang, S., Wang, Y., Kuzyakov, Y., & Ding, X. (2019). MgO-modified biochar increases phosphate retention and rice yields in saline-alkaline soil. *Journal of Cleaner Production*, *235*, 901–909. https://doi.org/10.1016/j.jclepro.2019.07.043

Wulandari, C. G. M., Muhartini, S., & Trisnowati, S. (2012). Pengaruh air cucian beras merah dan beras putih terhadap pertumbuhan dan hasil selada (*Lactuca sativa* L.). *Vegetalika*, *1*(2), 24–35.

WWAP. (2017). The United Nations world water development report UNESCO. In *Wastewater: The untapped resource*.

Xie, K., Cakmak, I., Wang, S., Zhang, F., & Guo, S. (2021). Synergistic and antagonistic interactions between potassium and magnesium in higher plants. *Crop Journal*, *9*(2), 249–256. https://doi.org/10.1016/j.cj.2020.10.005

Xie, S. S., Wu, H. J., Zang, H. Y., Wu, L. M., Zhu, Q. Q., & Gao, X. W. (2014). Plant growth promotion by spermidine-producing *Bacillus subtilis* OKB105. *Molecular Plant-Microbe Interactions*, *27*(7), 655–663. https://doi.org/10.1094/MPMI-01-14-0010-R

Xu, M., Sheng, J., Chen, L., Men, Y., Gan, L., Guo, S., & Shen, L. (2014). Bacterial community compositions of tomato (*Lycopersicum esculentum* Mill.) seeds and plant growth promoting activity of ACC deaminase producing *Bacillus subtilis* (HYT-12-1) on tomato seedlings. *World Journal of Microbiology and Biotechnology*, *30*(3), 835–845. https://doi.org/10.1007/s11274-013-1486-y

Yadav, A. N., Kumar, R., Kumar, S., Kumar, V., Sugitha, T. C. K., Singh, B., Chauahan, V. S., Dhaliwal, H. S., & Saxena, A. K. (2017). Beneficial microbiomes: Biodiversity and potential biotechnological applications for sustainable agriculture and human health. *Journal of Applied Biology & Biotechnology*, *5*(6), 45–57. https://doi.org/10.7324/jabb.2017.50607

Yaghi, N., & Hartikainen, H. (2013). Enhancement of phosphorus sorption onto light expanded clay aggregates by means of aluminum and iron oxide coatings. *Chemosphere*, *93*(9), 1879–1886. https://doi.org/https://doi.org/10.1016/j.chemosphere.2013.06.059

Yin, S., Bai, J., Wang, X., Wang, X., Zhang, G., Jia, J., Li, X., & Liu, X. (2020). Hydrological connectivity and herbivores control the autochthonous producers of coastal salt marshes. *Marine Pollution Bulletin*, *160*(October 2019), 111638. https://doi.org/10.1016/j.marpolbul.2020.111638

Yulianingsih, R. (2017). Pengaruh air cucian beras terhadap pertumbuhan dan hasil terung ungu (*Solanum melongena* L.). *Publikasi Informasi Pertanian*, *13*(24), 61–68.

Zakry, F. A. A., Shamsuddin, Z. H., Khairuddin, A. R., Zin, Z. Z., & Anuar, A. R. (2012). Inoculation of *Bacillus sphaericus* UPMB-10 to young oil palm and measurement of its uptake of fixed nitrogen using the 15N isotope dilution technique. *Microbes and Environments*, *27*(3), 257–262. https://doi.org/10.1264/jsme2.ME11309

Zeng, Q., Qin, L., Bao, L., Li, Y., & Li, X. (2016). Critical nutrient thresholds needed to control eutrophication and synergistic interactions between phosphorus and different nitrogen sources. *Environmental Science and Pollution Research*, *23*(20), 21008–21019. https://doi.org/10.1007/s11356-016-7321-x

Zhang, Y., Xu, W., Duan, P., Cong, Y., An, T., Yu, N., Zou, H., Dang, X., An, J., Fan, Q., & Zhang, Y. (2017). Evaluation and simulation of nitrogen mineralization of paddy soils in Mollisols area of Northeast China under waterlogged incubation. *PLoS ONE*, *12*(2), 1–19. https://doi.org/10.1371/journal.pone.0171022

Zou, J., Guo, X., Han, Y., Liu, J., & Liang, H. (2012). Study of a novel vertical flow constructed wetland system with drop aeration for rural wastewater treatment. *Water, Air, & Soil Pollution*, *223*(2), 889–900.