EFFECT OF PLANT PROBIOTIC ON GROWTH AND YIELD OF PADDY (*Oryza sativa*)

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

CROP PRODUCTION PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH
2017

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: EFFECT OF PLANT PROBIOTIC ON GROWTH AND YIELD OF PADDY (oryza sativa)

IJAZAH: BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

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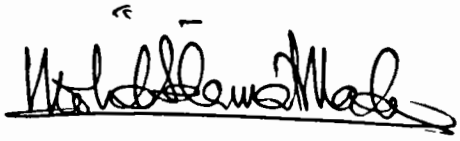

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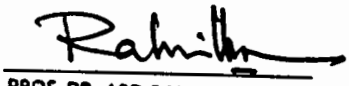

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ACKNOWLEDGMENTS

Firstly, I would like to express my deepest gratitude to my supervisor, Dr. Mohammed Selamat Madom, for his excellent guidance, advice, care and patience throughout the research. I would also like to thank him for providing me with an excellent atmosphere for doing research. Special thanks go to my co-supervisor, Prof. Dr. Abd. Rahman Milan, who helped me in statistical analysis and experimental design. I would also like to thank him for giving an advice and suggestion on the research. This thesis would not be the same as presented here without their guidance and support. I, therefore, appreciate their consultation very much.

In my daily work, I have been blessed with a friendly and cheerful group of fellow friends. I would like to express my gratitude to them for their help, moral support and friendly advice for the research. Besides, I would like to thank my seniors, who were always willing to help and give their best suggestions to me. Without them, I would not be able to finish my thesis.

Last but not least, I would like to express my sincere appreciation to my beloved family members who were always giving spiritual support and unfailing love to me. In addition, I would like to express deepest gratitude to my beloved parents, Abdulah Bin Kodin and Nora'ziah Binti Mat Rani, who always be there for me to count on when times are rough and never gives up on me.

ABSTRACT

Plant probiotic soil amendment is claimed significantly improved nutrient absorption due to more developed plant roots. This study was carried out at the Faculty of Sustainable Agriculture, Universiti Malaysia Sabah from June 2016 until November 2016 to investigate the effect of plant probiotic (0.0, 3.0, 5.0, and 7.0 g/25L water) on growth and yield of rice variety TR-8 and MRIA-1 for wetland rice and aerobic rice, respectively. Treatment were arranged using Complete Randomized Design (CRD) with four replications. Data collected were analysed using two-way ANOVA at 5% significance level and mean was separated by Duncan's Multiple Range Test (DMRT). The results showed that vegetative growth of rice plants, treatment P3 produced the highest mean plant height among all the treatments (105.3cm) for MRIA-1 and treatment P4 for TR-8 which was 86.37cm. Treatment P3 had the highest number of tillers (23) while treatment P4 had the highest percentage of productive tillers (85.94%) for MRIA-1, while for TR-8, treatment P4 had the highest number of tillers (44) while treatment P2 had the highest percentage of productive tillers (60.08%). In terms of moisture content, treatment P3 and P4 showed the higher moisture content of rice MRIA-1 (55.06%) and TR-8 (32.82%) compared to other treatments. For shoot:root ratio, treatment P1 showed the highest ratio for both treatments that revealed the roots obtained more nutrients and well developed than shoot. For yield component of rice plant, treatment P3 produced the highest number of spikelets per panicle (214) for MRIA-1 rice variety and treatment P2 (320) for TR-8 rice variety. For analysis for pH value of soil, treatment P3 had the highest pH value for both rice variety. Best performance was obtained as follows: aerobic rice, MRIA-1, with treatment P3 (5g/25L water) increase 122% in panicle number compared to other treatments while 92% increase in panicle number for TR-8 with treatment P2 (3g/25L water). Thus, it can be recommended that the treatment P3 and P2 is the best rate to be recommended to farmers for MRIA-1 and TR-8, respectively, because they produce the highest yield components.

KESAN PROBIOTIK TUMBUHAN TERHADAP PERTUMBUHAN DAN HASIL PADI (Oryza sativa)

ABSTRAK

Pindaan tanah, probiotik tumbuhan didakwa dapat meningkatkan penyerapan nutrisi disebabkan oleh pertumbuhan akar yang lebih banyak dengan ketara. Kajian ini dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah dari Jun 2016 sehingga November 2016 untuk mengkaji kesan probiotik tumbuhan (0.0, 3.0, 5.0, 7.0 g/25L air) ke atas pertumbuhan dan hasil padi TR-8 dan MRIA-1 untuk jenis padi tanah rendah dan padi aerobic, masing-masing. Rawatan-rawatan tersebut diatur sebagai Reka Bentuk Rawak Lengkap (CRD) dengan empat replikasi. Data yang diperoleh telah dianalisis dengan menggunakan ANOVA dua-hala pada keertian 5% dan min dipisahkan oleh Ujian Julat Pelbagai Duncan (DMRT). Hasil kajian bagi pertumbuhan pokok padi menunjukkan rawatan P3 menghasilkan bacaan tertinggi bagi ketinggian pokok berbanding rawatan lain (105.3sm) untuk MRIA-1 dan rawatan P4 untuk TR-8 iaitu 86.37sm. Rawatan P3 menunjukkan bilangan anakan padi yang tertinggi berbanding rawatan lain (23) manakala rawatan P4 mempunyai peratusan anakan padi produktif (85.94%) untuk MRIA-1, manakala untuk TR-8, rawatan P4 mempunyai bilangan anakan padi tertinggi (44) dan rawatan P2 mempunyai peratusan anakan padi produktif (60.08%). Dari segi kandungan kelembapan, rawatan P3 dan P4 menunjukkan kandungan kelembapan yang lebih tinggi bagi padi MRIA-1 (55.06%) dan TR-8 (32.82%) berbanding rawatan lain. Bagi nisbah pucuk:akar, rawatan P1 menunjukkan nisbah tertinggi bagi kedua-dua rawatan yang menunjukkan bahawa akar mendapat lebih banyak nutrisi dan pertubuhan yang lebih baik daripada pucuk. Untuk komponen hasil tanaman padi, rawatan P3 menghasilkan jumlah tertinggi butir padi per bunga (214 butir) untuk MRIA-1 dan rawatan P2 menghasilkan jumlah tertinggi butir padi per bunga (320 butir) untuk TR-8. Untuk analisis nilai pH bagi tanah, rawatan P3 mempunyai nilai tertinggi untuk kedua-dua jenis padi. Hasil terbaik telah diperoleh seperti berikut: padi aerobic, MRIA-1, dengan rawatan P3 (5g/25L air) meningkat 122% bagi bilangan bunga berbanding rawatan lain manakala 92% peningkatan bagi bilangan bunga untuk TR-8 dengan rawatan P2 (3g/25L air). Oleh itu, rawatan P3 dan P2 adalah kadar terbaik untuk dicadangkan kepada petani bagi MRIA-1 dan TR-8, masing-masing, kerana boleh menghasilkan komponen hasil tertinggi.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	Percentage
ANOVA	Analysis of Variance
cm	Centimeters
CRD	Completely Randomized Design
DMRT	Duncan's Multiple Range Test
DOA	Department of Agriculture
g	Gram
H_a	Alternative hypothesis
ha	Hectare
H_o	Null hypothesis
IRRI	International Rice Research Institute
K_2O	Potassium Oxide
kg	Kilogram
MARDI	Malaysia Agriculture Reasearch and Development Institute
MOP	Muriate of Potash
N	Nitrogen
P	Probiotic rate
P_2O_5	Phosphorus Pentoxide
SAS	Statistical Analysis Software
t	Tonne
TR-8	Tuaran Rice 8
TSP	Triple Super Phosphate
V	Variety

CHAPTER 1

INTRODUCTION

1.1 Introduction

Rice is an important commodity in Malaysia since it is the staple for the growing population. For instance, in1974, Thailand decided not to sell rice to Malaysia due to high demand and it was a bitter experience for Malaysia rice board. In Malaysia, rice is the third most planted crop after oil palm and rubber plantation. Department of Agriculture in Peninsular Malaysia (2014) reported that in 2012, Malaysia had successfully produced 2,750,404 metric tonnes of rice, but in 2013, Malaysia rice production had decreased to 2,626,881 metric tonnes. This amount of rice is not sufficient to meet the domestic demand. The irrigation and other facilities for rice production is not enough, so that the number of crops establish will depend on the speed of field operation such as land preparation, crop establishment, and harvesting.

In order to fulfil the demand for the growing population, Malaysia has to sustain and increase the productivity of rice. The total physical lowland rice area in Malaysia is 385,683 ha and the total planted area of 688,207 ha involves approximately 159,000 farm families. In 2013, the county's rice population amounted to 2,626,881 tonnes of rice (approximately 1,692,852 tonnes of white rice) and achieved 72.5% self-sufficiency level (SSL) in rice (MARDI, 2013).

In Malaysia, there are three different types of ecosystems for the rice production that are wetland rice, upland rice, and aerobic rice. Each type of rice demand a special environmental condition in order to enhance its productivity level. Difference water depth

are required for different types of rice. Wetland rice needs a lot more water than aerobic rice.

However, with the current situation of world weather, the source of water is becoming a scarce resource especially for agriculture industry. Irrigated agriculture uses 90% of total diverted fresh water and more than half of that is used for rice production (Bouman *et al.*, 2002). The total water withdrawal for irrigation in the agriculture sector in Malaysia is 76% and is mainly used for irrigated rice production. A study conducted in 2010 found that, as a result of rising temperature and decreasing solar radiation during the later years of 20th century, the wetland rice yield and growth rate has decreased to 10 – 20% in many parts in Asia (Sariam, 2014).

1.2 Justification

This study investigated the effect of plant probiotic in order to improve the productivity of different varieties of rice in its recommended environment. For wetland rice, TR-8 rice variety was selected in this study since it is the common type of rice planted in Sabah. It is also been called "Sri Aman" which is resistant to the red disease attributed to the *rice tungro bacilliform virus* (RTBV) and can produce five to seven tonnes of rice per hectare (Bernama, 2009).

Recently, Malaysia Agriculture Research and Development Institute (MARDI) has developed a new type of rice which can be grown aerobically with supplemental irrigation. The new type of rice that is called as aerobic rice, MRIA-1, is the new concept in water saving technology. The aimed of aerobic technique is to maximize the crop productivity by growing rice without flooding or puddling and targeted at areas with greater water scarcity. In irrigated rice production system where water is either physically or economically scarce, aerobic rice could be a profitable alternative to wetland rice (Sariam, 2014).

'Plant Probiotic Tumbuhan' is used as the soil amendment to see the effect towards each varieties of rice production. This substance helps to promote plant growth and development and also improve soil condition. It also provide significant improvement of nutrient absorption and developed better plant root. This plant probiotic contain various types of microorganism such as nitrogen fixing bacteria, phosphorus and potassium solubilizing bacteria. As reported in Nanyang Siang Pau (2014), 'Plant Probiotic Tumbuhan' is used in *Pertubuhan Peladang Kawasan* (PPK) Kg Pelet in order to improve rice land conditions, resulting in year where rice harvest increased to an average of more than five tonnes per hectare. For two years from 2012, they have increased the rice harvest from an average of 3.8 tonnes per hectare to more than 5 tonnes. However, research still needs to be carried out to see if the plant probiotic can produce the higher yield of wetland rice and aerobic rice or not because of the different environment and planting practices of both rice varieties.

1.3 Significance of the Study

This study is significant because it could enhance the development of Malaysian agriculture, especially plant probiotic as a new type of soil amendment to farmers and agriculturist. It can help to enhance plant growth and development by improve the soil condition and nutrient absorption. With these positive response, cultivation of rice can be increased in order to achieve food security by measuring the productivity of each rice variety.

1.4 Objectives

The objectives of this study are:

i. To compare the effect of different rates of plant probiotic concentration on growth development of each rice variety, MRIA-1 and TR-8.

ii. To determine the optimum rates of plant probiotic application for maximum potential yield of each variety, MRIA-1 and TR-8.

1.5 Hypothesis

H_o: There is no significant difference in the effect of plant probiotic application on growth and potential yield of rice.

H_a: There is significant difference in the effect of plant probiotic application on growth and potential yield of rice.

CHAPTER 2

LITERATURE REVIEW

2.1 Rice Cultivation

Rice is from the Poaceae family and the genus is *Oryza*. It contains 25 recognized species but only two are cultivated which are *Oryza sativa* and *Oryza glaberrima*. The other 23 species are wild species (Morishima, 1984; Brar and Khush, 2003). There are three types of rice varieties in *O. sativa* which are indica rice, japonica rice and javanica rice (Table 2.1).

Table 2.1 Characteristics of *Oryza sativa* varietal groups

Characteristics	Subspecies		
	Indica	Japonica	Javanica
Tillering	High	Low	Low
Height	Tall	Medium	Tall
Lodging	Easily	Not easily	Not easily
Photoperiod	Sensitive	Non-sensitive	Non-sensitive
Cool temperature	Sensitive	Tolerant	Tolerant
Grain shattering	Easily	Not easily	Not easily
Grain type	Long to medium	Short and round	Large and bold
Grain texture	Non-sticky	Sticky	Intermediate

Source: Ministry of Science and Technology Government of India (2009)

Rice crop can be grown in different ecosystems and under different climate and soil moisture conditions. The soil moisture can influence the physiological and

biochemical change in various plant parts to sense soil water status. It also can give an effect of rice yield by directly affecting the physiological process involved in vegetative growth and rice production. Intermittent flooding and drying of the soils depresses availability of several nutrients for rice uptake and low nutrient supply will limit the yield potential (Bell *et. al.,* 2001).

In Malaysia, the traditional cultivation of rice is performed by the planting of rice crops on small hills as the land suitable for growing wetland rice is often scarce. Rice in Malaysia is often grown in rice fields to prevent the growth and spread of weeds. However, land resources in Malaysia have become scarce and are limited for rice cultivation. Consequently, this problem leads to insufficient rice production. Since rice is a strategic crop in Malaysia, it is essential to maintain a domestic production level for food security reason and the targeted self-sufficiency must be in tandem with the growing population.

2.2 Morphology of Rice

Morphological characteristics of rice are used to monitor plant development and done by visual identification of critical growth stage such as emergence, tillering, panicle formation, booting, heading and maturation (Moldenhauer *et al.,* 1993). Rice is an annual plant consists of round, hollow, jointed culms as well as flat leaves and terminal panicle. The culm is made up of a series of nodes and internodes that are alternative orders. The leaves are attached to the node and panicles are a group of spikelet borne on the uppermost node of the culm. The uppermost leaf below the panicle is flag leaf and leaves number on the culm keep reducing from main culm to tertiary tillers. Tillers are side shoots produced from the basal node on the main culm known as primary tillers, which give rise to secondary tillers and secondary tillers turn branch into tertiary tillers. Rice plant also consists of fibrous roots which made up of rootlets and root hairs. During germination, the seedlings will produce embryonic roots which live only for a short period after germination. Then the temporary roots are replaced by the secondary adventitious roots which are produced from the underground nodes of the young culms (Wayne and Robert, 2003).

2.3 Growth and Development Phase in Rice

There is three-phase of rice growth which is the vegetative, reproductive and ripening phase. The stages of development in each phase are further divided according to numerical scales (from 0 to 9) to identify the growth stage of a rice plant. Specific growth stage corresponds to each number on the scale Table 2.2.

Table 2.2 The development stages of rice plant according to 0-9 numerical scale

Growth phase		Stage
I.	Vegetative phase (germination to panicle initiation)	0 – From germination to emergence
		1 – Seedling
		2 – Tillering
		3 – Stem elongation
II.	Reproductive phase (panicle initiation to flowering)	4 – Panicle initiation to booting
		5 – Heading or panicle exsertion
		6 – Flowering
III.	Ripening phase (flowering to mature grain)	7 – Milk grain stage
		8 – Dough grain stage
		9 – Mature grain stage

Source: Ministry of Science and Technology Government of India (2009)

During the growth process, rice completes two distinct growth phases: vegetative and reproductive. The vegetative phase is subdivided into germination, early seedling growth and tillering. The reproductive phase is characterized by culm elongation, a decline in tiller number, and the emergence of the flag leaf, booting, heading, and flowering of the spikelets. Panicle initiation is the stage about 25 days before heading when the panicle has grown to about 1 mm long. Spikelet anthesis begins with panicle exertion, or on the following day. It takes 10 to 14 days for a rice plant to complete heading. Within the same panicle, it takes seven to ten days for all the spikelets to complete anthesis. Ripening phase is subdivided into milky dough, yellow-ripe and maturity stages according to the texture and colour of the growing grains. The length of ripening varies among varieties from about 15 to 40 days.

2.4 *Rice Ecosystem in Malaysia*

Rice is one of the crop that can adapt to a wide range of water conditions which can be grown in soil with moisture condition that ranges from submerged wetlands to water deficient upland conditions. In Malaysia, the cultivation of rice is divided into three types based on their ecosystem which are irrigated lowland, rainfed lowland, and upland or dryland rice. Each type of rice demands a special environment condition in order to enhance its productivity level. Different water depth is required for different varieties of rice. Wetland rice needs a lot amount of water than while aerobic rice required less water than wetland rice. Table 2.3 is the productivity of rice based on production system in the different ecosystem.

Table 2.3 Comparison of the productivity of two different rice production systems

System	Yield (t/ha)	Crop/year	Fallow period (year)	Productivity (t/ha/year)
Irrigated wetland rice	4.0	2.0	0	8.0
Rainfed wetland rice	2.5	1.0	0.5	2.5

Source: Sariam (2014)

2.4.1 Irrigated Wetland Rice Ecosystem

Wetland rice cultivation in Malaysia constitutes to 87% which mainly concentrated in eight granary areas and many mini granary areas. The contribution of 66% of the total rice production is from eight granary areas with a total parcel area of 200,552 ha. Wetland producing two rice crops per year on submerged soils are highly sustainable, as indicated by sustained nutrient supply capacity, sustained soil carbon levels, and sustained trends in rice yields (Buresh *et al.,* 2001). Irrigated wetland rice usually has standing water for most of the growing season and the availability of irrigation assures that ponded water is maintained for at least 80% of the crop growth duration. In irrigated

wetlands, a huge amount of water is lost through seepage, percolation and evaporation when the soil is submerged (Bouman and Tuong, 2001).

2.4.2 Rainfed Wetland Rice Ecosystem

In this systems, there is no proper irrigation and drainage system and water supply depends solely on rainfall. Rainfall is the only source of water to the field and no certain duration of ponded water can be assured (Sariam, 2014). Rice varieties planted in wetland areas are normally the similar high yielding varieties grown under irrigated wetland. The example of rice variety that suitable to grow in this type of ecosystem is aerobic rice.

2.5 Rice Variety

Oryza sativa is the most common rice cultivar in Malaysia and acts as important food crop among Asian people. In *Oryza sativa*, there is a various variety that been establish in this following years.

2.5.1 TR-8 Rice Variety

The TR-8 rice variety is also known as rice 'Seri Aman' as its commercial name. It has been produced at International Rice Research Institute (IRRI), Filipina. TR-8 (IR 51675-62-2-1-1-3) rice variety is produce after the crossing of IR 24594-204-1-3-2-6-2 and IR 28222-9-2-2-2-2. In 1995, the seed of TR-8 rice was brought to Rice Unit of Agriculture Research Centre Tuaran (Department of Agriculture, 2009). TR-8 rice variety has a high resistance to diseases of rice such as red disease attributed to the *rice tungro bacilliform virus* (RTBV) and can give a high yield of between 5-7 tonnes ha^{-1} (BERNAMA, 2009). It also helps to maintain and increase the rice productivity level, increase the agronomic characteristics and eating quality level.

Each rice varieties have their own specialize characteristics that make them been chosen in this study. Table 2.4 below show the characteristics of TR-8 rice variety according to Department of Agriculture Sabah (2009).

Table 2.4 The characteristics of TR-8 rice variety

Origin	: IR 24594-204-1-3-2-6-2/ IR 28222-9-2-2-2-2 (IRRI)
Progeny code	: IR 51672-62-2-1-1-2-3
Matured age	: 130 – 135 days
Plant height	: 105 – 112cm
Leaf senescence	: Medium
Grain per panicle stalk	: ±132 grains
No. of stalk/ culms	: 14 – 16
Length of seed	: 10mm
Width of seed	: 3mm
Thousand weight grain	: ±23.5 g
Average yield	: 5.5 – 7.0 tonnes/ha
Resistance level	: Resistant to: - Red diseases (Tungro virus)
Fertilizers requirement	: Nitrogen (N) 170kg/ha Phosphorus (P_2O_5) 80kg/ha as basal Potassium (K_2O) 150kg/ha

Source: Department of Agriculture (2009)

2.5.2 MRIA-1 Rice Variety

MRIA-1 is a rice variety for aerobic rice that has been cultivated in Sabah. The rice seed is obtain from Malaysia Agricultural Research and Development Institute (MARDI), Kota Kinabalu, Sabah. It can be grown aerobically with supplemental irrigation and it is the new concept in water saving technology. The aimed for aerobic to establish is to maximize the crop productivity by growing rice without flooding or pudding and targeted at the situation with greater water scarcity (Bouman *et al.,* 2007). In irrigated rice

production system where water is either physically or economically scarce, aerobic rice could be a profitable alternative to lowland rice (Sariam, 2014). The time required for aerobic rice to complete their growth and produce their grain yield is around 3 to 4 month which is the same duration with lowland rice.

Aerobic rice can be considered as a mature technology in temperate countries in China and Brazil, where aerobic rice area are estimated at 350,000 ha and 250,000 ha, respectively. In China, aerobic rice yields is up to 5.7 t/ha was obtained, compared with 8.8 t/ha of flooded wetland rice using half of the water required for flooded rice (Sariam, 2014). In Malaysia, research on aerobic rice has been initiated by MARDI since 2004 and an aerobic rice variety has been developed and a manual on aerobic rice production is also available (Sariam *et al.,* 2013).

Breeding programme for aerobic rice in MARDI started in 2005 by using several rice lines from IRRI as breeding material. A potential aerobic rice lines, MRIA-1 (initially known as Aeron1) was developed through chemical mutation of IR 76569-259-1 with potential yield of about 5 t/ha and the others characteristics are shown in Table 2.5 below.

Table 2.5 The characteristics of aerobic rice lines

Maturation days	: 79 – 88 days
Culm height	: 92 – 99 cm
Panicle length	: 22 – 24 cm
Spikelets per panicles	: 106 – 129 cm
Grain length	: 9.9 – 10.9 cm
Grain width	: 1.99 – 2.18 cm
Thousand grain weight	: 27.2 ± 0.4 g
Pest and diseases resistance	: Leaf blast
	Panicle blast
Pest and diseases moderate resistance	: Bacterial leaf blight
	PMV
	Brown plant hopper
	Sheath blight
	Stem borer

Source: Zainudin *et al.* (2013)

The aerobic rice production system may reduce irrigation water consumption to less than half that is required for conventional flooded culture, but often causes a significant yield loss (Peng *et al.,* 2006). The chemistry of aerobic rice soils is different from flooded soil, which in turn influences nutrient availability for the rice crop (Sariam, 2014). Aerobic rice targeted more favourable where the land is flat, and soil can be frequently brought to water field capacity by rainfall or supplemental irrigation. Aerobic rice can be a replacement of wetland rice wherever the available water is insufficient for wetland rice but sufficient for aerobic rice. Aerobic is adapted to aerobic soil conditions but aerobic rice varieties are more input-responsive and higher yielding than traditional upland varieties.

2.6 Soil Properties

Soil properties play an important role in determining the soil behaviour and nutrient uptake. Soil properties have two major subdivision which is soil texture and soil structure. Basically, soil texture can be divided into the sand, silt, and clay. Sand particles have gritty feels; silt particles have smooth silky feel when both wet and dry but are onl very slightly plasticity, and clay particles are distinctly sticky and plasticity in wet but compact and hard in dry. According to Fitzpatrick in 1986, soil structure is the degree and type of aggregation and the nature and distribution of pores and pore space. By knowing the soil type, will ease the evaluation of the physical properties of soil including bulk density, water, and moisture holding capacity, soil pH, soil organic matter content, and nutrient available in the soil.

2.6.1 Soil Type

A chosen soil type depends on the suitability of growing each rice variety. In order to achieve a good yield with the help of plant probiotic on their naturally growing area, clay loam, and sandy loan soil are chosen for wetland rice and aerobic rice respectively.

REFERENCES

Arcand, M.M. and Schneider, K.D. 2006. Plant and Microbial-based Mechanisms to Improve the Agronomic Effectiveness of Phosphate Rock: A Review (Abstract in English). *Anais da Academia Brasileira de Ciências.* **78**: 791 – 807.

Artisan. 2014. Plant Probiotic Tumbuhan. Artisan Group of Company.

Bagge, M. and Lubberstedt, T. 2008. Functional Marker in Wheat: Techinical and Economic Aspects. *Molecular Breeding* **22(3)**: 319 – 328.

Bell, R.W., Ros, C. and Seng, V. 2001. Improving the Efficiency and Sustainability of Fertiliser Use in Drought-and Submergence-prone Rainfed Lowlands in Southeast Asia. In: Fukai S. Basnayake J, (Eds.). *Proceedings of an International Workshop.* 30 October – 1 November 200. Vientiane, Laos, 155 – 269.

Benito, S.V. 1992. A Farrmer' Primer on Growing Rice. International Rice Research Institute. Manila, Philippines: 51.

Bernama. 2009. Sabah Farmers Can Produce 10 Tonnes or More of Paddy per Hectare Musa. 8 July, 9.

Bouman, B.A.M. and Tuong, T.P. 2001. Field Water Management to Save Water and Increase Its Productivity in Irrigated Rice. *Agriculture Water Management* **49(1)**: 11 - 30.

Bouman, B.A.M. 2001. Water Efficient Management Strategies in Rice Production. *International Rice Research Notes* **16(2)**: 17 – 22.

Bouman, B.A.M., Xiaoguang, Y., Huaqi, W., Zhiming, W., Junfang, Z., Changgui, W. and Bin, C. 2002. Aerobic rice (Han dao); A New Way of Growing Rice in Water-Short Areas. *Proceedings of the 12th International Soil Conservation Organization Conference.* 26 – 31 May 2002. Beijing, China.

Bouman, B.A.M., Humphreys, E., Tuong, T.P. and Barker, R. 2007. Rice and water. *International Rice Research Notes* **16(2)**: 17 – 22.

Brar, D.S. and Khush, G.S. 2003. Utilization of Wild Species of Genus Oryza in Rice Improvement. In: Nanda, J.S. and Sharma, S.D. (Eds.). *Monograph on Genus Oryza,* 283 – 309.

Buresh, R.J., Dawe, D., Tuong, T.P, Ladha, J.K., Bouman, B.A.M., Lantin, R., Peng, S., Mortimer, M., and Hill, J.E. 2001. Sustainable Soil and Water Management of Irrigated Rice Ecosystems. Paper presented at the *Integrated Management for Sustainable Agriculture, Forestry and Fishery Workshop.* 28 – 31 August 2001. Centro International de Agricultura Tropical. Calli, Columbia.

Chang, T., Bardenas, E.A. 1965. The Morphology and Varietal Characteristics of the Rice Plant. The International Rice Research Institute. Manila, Philippines.

Chandola, R.P. 2010. Dictionary of Soil Science. Daya Publishing House.

Davidson, E.A. and Swank, W.T. 1986. Environmental Parameters Regulating Gaseous Nitrogen Losses from Two Forested Ecosystem via Nitrification and Denitrification. *Applied and Environmental Microbiology* **52**: 1287 – 1292.

Department of Agriculture. 2009. "Varieti Padi Baru TR 8 (Seri Aman)". Unit Perkhidmatan Penerangan Pertanian, Jabatan Pertanian, Kementerian Pertanian dan Insdustri Makanan Sabah.

Department of Agriculture. 2012. Paddy Production Survey Report, Malaysia, Main season 2011/2012, Department of Agriculture, Peninsular Malaysia.

Doran, J.W. and Smith, M.S. 1987. Organic Matter Management and Utilization of Soil and Fertilizer Nutrients. Chapter 4. In Follent, R.F., Stewart, J.W.B. and Cole, C.V (Eds.). *Soil Fertility and Organic Matter as Critical Components of Production Systems.* ASA, Madison.

Fitzpatrick, E.A. 1986. An Introduction to Soil Science (Second Eds.). Harlow: Longman.

Hanafi, M. M., Hartinie, A., Shukor, J. and Mahmud, T. M. M. 2009. Upland Rice Varieties in Malaysia: Agronomic and Soil Physico-Chemical *Characteristics Pertanika Journal of Tropical Agricultural Science.* **32(2)**: 225-245. UPM Malaysia

MARDI. 2013. Mutu dan Nilai Nutrisi Beras Aerob (Baka MRIA 1). *Poster Pelancaran Teknologi Pengeluaran Padi Aerob.* 22 August, 2013. MARDI Seberang Perai, Pulau Pinang.

Ministry of Science and Technology Government of India (2009). Biology of Rice. *Series of Crop Specific Biology Document.* Department of Biotechnology, Ministry of Science and Technology Government of India.

Moldenhauer, K. A. K., Wells, B. and R. Helms. 1994. Rice Growth Stages. *Rice Production Handbook.* 5-12

Morishima, H. 1984. Wild Plants and Domestication. In: Tsunoda, S. and Takahashi, N. (Eds.) *Biology of Rice,* 3 – 30.

Nanyang Siang Pau. 2014. PPK Kg. Pelet: Increase Rice Yield 5 mt. *Nanyang Siang Pau,* 23 August, 14.

Peng, S., Bouman, B.A.M., Viperas, R.M., Castaneda, A., Nie, L. and Park, H.K. 2006. Comparison between Aerobic and Flooded Rice in the Tropics: Agronomic Performance in an Eight-Season Experiment. *Field Crop Research* **52**: 249 – 260.

Raychaudhuri, S.P., Agarwal, R.R., Datta Biswas, N.R., Gupta, S.P. and Thomas P.K. 1963. Soils of India. In Goodin, J.R. and David, K.N. (Eds). *Plant Resources of Arid and Semi-arid Lands: A Global Perspective.* London: Academic Press Inc.

Sariam, O., Azmi, M., Chan, C.S., Badrulhadza, A., Mohd Khusairy, K., Mohd Fitri, M., Allicia, J., Rosnani, H., Shamsul Amri, S. 2015. "Manual Padi Aerob". Serdang: MARDI.

Sariam, O., Maisarah, M.S., Azmi, A.R., Zaki, M., Mohd Shahril Shah, M.G., Rosnani, H., Azmi, M. 2015. Manual Padi Bukit. Serdang: MARDI.

Sariam, O. 2014. Malaysian Rice Ecosystem. In: *More Rice with Less Water.* 5 – 8. Kuala Lumpur: Malaysian Agricultural Research and Development Institute (MARDI).

Sariam, O., Azmi, M., Chan, C.S., Zainudin, H., Azimah, A.K., Badrulhadza, A., Mohd Khusairy, K., Mohd Fitri, M., Allicia, J., Ismail, C.H., Shajarutlwardah, M.Y. and Rosnani, H. 2013. Manual teknologi penanaman padi aerob. Serdang: MARDI.

Song, B. and Ward, B.B. 2005. Genetic Diversity of benzoyl-CoA reductase genes and detected in denitrifying isolates and estuarine sediments. *Applied Environmental Microbiology* **72**: 2036 – 2045.

Stevenson, F.J. and Cole, M.A. 1999. Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients (2nd Eds.). New York: Wiley-Interscience.

Wayne, C. S. and Robert, H. D. 2003. Rice morphology and development. *Rice: Origin, History, Technology, and Production*. 104-124.

Zainudin, H., Sariam, O., Azmi, M., Norsuha, M., Badrulazha, A., Amirrudin, M., Chan, C.S., Khusairy, K., Rosniyana, A. and Marzukhi, H. 2013. MRIA 1 – Prioneer Aerobic Rice Variety. In: Brochure and poster, *The British Invention Show*. 23 26 October 2013. Barbicam Exhibition Centre, London.