

**WEED ECOLOGY OF BALIK PULAU RICE
ECOSYSTEM**

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WEED ECOLOGY OF BALIK PULAU RICE ECOSYSTEM

by

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LIST OF SYMBOLS AND ABBREVIATIONS

cm	centimetres
°C	degree celcius
DAS	Days After Sowing
DOA	Department of Agriculture
g	gram
ha	hectare
kg	kilogram
km	kilometres
km ²	kilometres square
m	metres
mm	millimetres
%	Percentage
PPK	Pertubuhan Peladang Kawasan
USM	Universiti Sains Malaysia

EKOLOGI RUMPAI BAGI EKOSISTEM PADI DI BALIK PULAU

ABSTRAK

Eksperimen bank benih rumputai telah dijalankan di rumah tumbuhan di Pusat Pengajian Sains Kajiayatan, Universiti Sains Malaysia (USM) selama 6 bulan bermula pada 20 Disember 2013 sehingga 20 Mei 2014. Eksperimen dimulakan dengan persampelan tanah di empat plot sawah padi yang berbeza (Pokok Kenanga, PPK Fasa 3, PPK Fasa 1, dan Sungai Burung Darat) di ekosistem sawah padi di Balik Pulau. Sampel tanah kemudiannya telah dibawa pulang ke USM untuk kajian lanjut. Tiga keadaan aras air [cetek (3 cm), separa penuh (5 cm), dan penuh (10 cm)] serta satu perlakuan kawalan keadaan aras air (0 cm) telah diaplikasikan di dalam eksperimen. Terdapat 12 spesis rumputai yang wujud di dalam eksperimen iaitu *Echinochloa crus-galli* (L.) Beauv, *Echinochloa colona* (L.) Link, *Ischaemum rugosum* Salibs., *Leptochloa chinensis* (L.) Nees., *Oryza sativa complex* (L.), *Cyperus difformis* (L.), *Cyperus iria* (L.), *Fimbristylis milliacea* (L.) Vahl, *Lemna minor* L., *Ludwigia hyssopifolia* (G.Don) Exell, *Monochoria vaginalis* (Burm.f) Presl, dan *Sphenoclea zeylanica* Gaertn.. Bagi kaedah bank benih, kemunculan spesis rumputai yang tertinggi di plot Pokok Kenanga, PPK Fasa 3, PPK Fasa 1, dan Sungai Burung Darat masing-masing adalah *M. vaginalis*, *L. chinensis*, *E. crus-galli*, dan *S. zeylanica* mengikut turutan. Jumlah anak benih rumputai yang hadir mengikut turutan menurun adalah sebanyak 86 anak benih bagi (plot Pokok Kenanga) > diikuti oleh 69 anak benih bagi (plot Sungai Burung Darat) > 44 anak benih bagi plot (PPK Fasa 3) > dan 26 anak benih bagi plot (PPK Fasa 1). Bagi kaedah tabur terus, kemunculan spesis rumputai yang tertinggi di plot Pokok Kenanga, PPK Fasa 3, PPK Fasa 1, dan Sungai Burung Darat adalah *L. chinensis*. Jumlah anak benih rumputai yang hadir mengikut turutan menurun adalah sebanyak 82 anak benih (plot Sungai Burung Darat) > diikuti oleh 74 anak

benih (plot PPK Fasa 1) > 42 anak benih (plot PPK Fasa 3) > 12 anak benih (plot Pokok Kenanga). Bagi kaedah mencedung, kemunculan spesis rumput yang tertinggi adalah *M. vaginalis* di (plot Pokok Kenanga dan PPK Fasa 1) manakala kemunculan *L. chinensis* adalah tertinggi di (plot PPK Fasa 3 dan Sungai Burung Darat). Jumlah anak benih rumput yang hadir mengikut turutan menurun adalah sebanyak 47 anak benih (plot PPK Fasa 1) > diikuti oleh 20 anak benih (plot Pokok Kenanga) > 13 anak benih (plot PPK Fasa 3) > 6 anak benih (plot Sungai Burung Darat). Kemunculan *M. vaginalis* dan *S. zeylanica* merupakan rumput daun lebar yang tertinggi di dalam setiap eksperimen, manakala *L. chinensis* merupakan rumput lalang yang dominan di dalam kajian. Kedalaman air tinggi (10 cm) memberikan tekanan kepada benih di dalam bank benih menyebabkan hanya sedikit bilangan rumput yang tumbuh. Kesimpulannya, rumput lalang dan rusiga adalah lebih tinggi di dalam keadaan aras air yang cetek dan separa penuh manakala rumput daun lebar ditemui di dalam keadaan aras air penuh.

WEED ECOLOGY OF BALIK PULAU RICE ECOSYSTEM

ABSTRACT

Weed seedbank experiment was conducted in plant house of School of Biological Sciences Universiti Sains Malaysia (USM) for about 6 months from 20th of December 2013 until 20th of May 2014. The experiment started by soil sampling at four different rice field plots (Pokok Kenanga, PPK Fasa 3, PPK Fasa 1, and Sungai Burung Darat) in Balik Pulau rice field ecosystem. The soil samples were then brought back to USM for further experiments. Three water level conditions [saturated (3 cm), partial (5 cm), and flooded (10 cm)] and one control treatment (0 cm) were applied in this experiment. There were 12 weeds species that emerged in this experiment namely *Echinochloa crus-galli* (L.) Beauv, *Echinochloa colona* (L.) Link, *Ischaemum rugosum* Salibs., *Leptochloa chinensis* (L.) Nees., *Oryza sativa* complex (L.), *Cyperus difformis* (L.), *Cyperus iria* (L.), *Fimbristylis milliacea* (L.) Vahl, *Lemna minor* L., *Ludwigia hyssopifolia* (G.Don) Exell, *Monochoria vaginalis* (Burm.F) Presl, and *Sphenoclea zeylanica* Gaertn.. For weed seedbank method, the highest emergence of weed species in Pokok Kenanga, PPK Fasa 3, PPK Fasa 1, and Sungai Burung Darat plots were *M. vaginalis*, *L. chinensis*, *E. crus-galli* and *S. zeylanica* respectively. The total number of weed seedlings present in descending order were 86 seedlings for (Pokok Kenanga plot) > followed by 69 seedlings (Sungai Burung Darat plot) > 44 seedlings for (PPK Fasa 3 plot) > and 26 seedlings for (PPK Fasa 1 plot). For direct seeding method, the highest emergence of weed species in Pokok Kenanga, PPK Fasa 3, PPK Fasa 1, and Sungai Burung Darat plots were *L. chinensis*. In descending order, the total number of weed seedlings that present were 82 seedlings (Sungai Burung Darat plot) > followed by 74 seedlings (PPK Fasa 1 plot) > 42 seedlings (PPK Fasa 3 plot) > and 12 seedlings

(Pokok Kenanga plot). For transplanting method, the highest emergence of weeds species were *M. vaginalis* for (Pokok Kenanga and PPK Fasa 1 plots) meanwhile *L. chinensis* was highest in (PPK Fasa 3 and Sungai Burung Darat plots). In descending order, the total number of weeds seedlings emerged were 47 seedlings (PPK Fasa 1 plot) > followed by 20 seedlings (Pokok Kenanga plot) > 13 seedlings (PPK Fasa 3 plot) > 6 seedlings for (Sungai Burung Darat plot). The emergence of *M. vaginalis* and *S. zeylanica* were broadleaved weeds which are dominant in each experiment meanwhile *L. chinensis* was a dominant grassy weed in this study. High water level (10 cm) suppressed the seeds in soil seed bank and causes only a few number of weeds germinated. As a conclusion, the grassy and sedges weeds were higher in saturated and partial water level conditions while broadleaved weeds mostly in flooded water level condition.

CHAPTER 1

INTRODUCTION

1.1 Background

Weed infestation is one of the most troublesome incident that occur in rice cultivation field. Cultivation practices, land preparation, soil moisture content, and management strategies are the factors that influence the emergence and abundance of weeds in rice ecosystem (Ismail and Phaik-Hong 2004). Earlier researches have proved that weeds that are emerged in direct seeded rice ecosystem were more complex as compared to transplanted rice ecosystem. Water management and soil preparation are the factors that influence weed dominance and composition. In the early period of land preparation with better tillage when the rice field soil is sink, it could decrease weed growth. Juraimi et al., (2013) mentioned that weeds in transplanted and direct seeded rice ecosystem induce rice yield losses of 16 % and 62 % respectively.

Weed problems started with weed seed in the soil and they caused troubles, even trials to avoid them from entering the soil to seed in the rice ecosystem are made. Hence, knowledge about the total number and type of buried seeds is very crucial in assuming which weed species are obviously to grow in any rice field. The importance of seed banks in cultivated soils in connection to weed management has been well known in previous study (Mahfuza et al., 2011).

Nowadays, about 75 % of direct seeding rice cultivation culture become the main practice in Malaysia rice granary agro-ecosystem (Weerakoon et al., 2011).

1.2 Importance of the Study

There are a little number of researches who have had studied previously on weeds in Balik Pulau rice ecosystem especially in weed composition and population from seedbank. The purpose of this study was to observe weed population and composition from weed seedbank in four different rice plots from Balik Pulau rice ecosystem. In this study, four different water level conditions including control water treatment will be applied to each soil from four different rice plots and the weed composition, distribution, and population will be determined. The effect of rice cultivation and the methods of rice cultivation which were direct seeding and transplanting rice cultivation on weed population and composition also have been studied. Limited study has been done on comparative weeds composition and population from seedbank in direct seeded and transplanted rice cultivation cultures. Therefore, this study has been done to fulfill that purposes.

1.3 Research Objectives

This study was conducted to meet the following objectives :

1. To identify weeds species that emerged from soil seedbank within four different rice plots in Balik Pulau rice ecosystem.
2. To count and record the emergence of weeds from different weed seedbank, direct seeding, and transplanting experiments.
3. To compare weeds species in direct seeded treatment and tranplanted treatment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Weed

Many problems are faced by the farmers in producing high yield of rice. One of the problem is weeds infestation. Weeds are plants growing where they are not wanted in certain areas. It is widely known that weeds have been efficiently established in a site because of its six ideal characteristics which are; ability to survive unfavourable growing condition, competitive ability, high reproductive capacity, rapid and spontaneous growth, appearing without being sown, and aggressiveness (Zainal Abidin, 2008). When a group of weeds has successfully established in the environment, the crop species together with other organisms including humans and animals will interact with each other to form an agro – ecosystem community. Hence, three characteristics associate with the weed ecology are; growth characteristics, adaptations and survival mechanisms of weeds that enable them to conquer environmental resources, and successfully colonize new habitats. Besides that, the occurrence of weeds vegetation of a certain area is determined by two factors like; biotic factor (microorganisms and plants) and abiotic factor (temperature, edaphic, and climatic conditions). Cultural practices like; irrigation, fertilizer, cultivar grown, tillage, herbicide applied, and crop rotation, are greatly affect weeds vegetation occurrence. The weeds vegetation is also greatly affected by edaphic factors such as; soil physical structure, pH, nutrient, and moisture status. Meanwhile, five factors that determined weeds spectrum and the degree of weeds infestation are ; types of rice

culture (irrigated, rainfed lowland, upland, deepwater, and tidal wetland), crop establishment method (transplanted or direct seeded), water regime (irrigated and rainfed), land preparation (lowland or upland), and cultural practices (flooding, fertilizer application, cultivar types). There are also major factors that influence weeds population in rice ecosystem for example ; control method applied, rice cultivar planted, and changes in soil and water management. Weeds are the most troublesome plants in rice cultivation areas worldwide. Weeds are particularly problematic in direct dry seeded rice, which is replacing transplanted rice in some Asian countries (Chauhan et al., 2010). Presence of weeds at cultivation site can lead to decrease on crop production as they can interrupt with crop growth and development through mechanisms of allelopathy and competition for space, light, nutrients, and water (Mesquita et al., 2013). Chauhan and Johnson (2009a) mentioned that in aerobic rice field, uncontrolled weed growth can result in decline of crop production by 96 %. The high yield of small seeds is one of the control strategy advanced by weeds to survive in rice ecosystem.

2.2 Weed Seedbank

Most agricultural soils contain a large resevoir of weed seeds which germinate over time. The number and type of seeds in the reservoir are determined by a field's cropping history, edaphic characteristics (moisture-holding capacity and pH), past weed control practices, tillage and land preparation practices, rate of germination and seedling growth of each species. Reservoir of weed seeds also known as the soil seedbank of plant community contributes significantly to the ability of that community to regenerate and to distribute the pattern of the vegetation, while the

seed production of the vegetation influenced the composition and abundance of the seedbank. The soil seedbank is a product of the past and represents the potential future of the above ground plant community. As a result, seedbanks are very crucial to the ecology of communities and to recruitment of species, particularly those that depend mainly on non-vegetative means reproduction. Besides that, the soil seedbanks are crucial components of vegetation dynamics affecting both ecosystem resistance and resilience caused of the viable seeds on the soil surface and in the soil for many years comprised an enormous reservoir of dormant and non-dormant seeds. The soil seedbank is divided into two components which are ; surface seedbank (active seedbank), and buried seedbank (dormant seedbank). Rao et.al, (2007) mentioned that seedbank composition which comprised many species can be divided into three groups, ; the first group includes a few dominant species accounting for 70 % to 90 % of total seedbank (these species represents most of the weed problems in a cropping system), the second group of species comprising 10 % to 20 % of the seedbank, generally includes those adapted to the geoghrapic area however not to current production practices, the third group accounts for a small percentage of the total seeds and includes recalcitrant seeds from previous seedbanks of the previous crop.

Weed seedbank characteristic influence weed populations that occur in the field and the success of the weed management. A lot of seeds produced by weeds. Most of the seeds entering the seedbank come from annual weeds (Rao and Ladha, 2011). New seeds may enter the seedbank through many sources, but the largest source is plants producing seed within the field. Management practices affect mostly on these processes. In fact, farming practices influence the quantities of seeds

returned to and removed from the soil. Hence, species composition and seed density are affected by cultural practices in agricultural fields. Furthermore, buried seed stays viable for several years and different types of tillage systems also may affect weed seed population depending on agronomic management practices used (tillage). The seedbank is a function of the longevity of seeds in the soil and determined by the inherent viability of seeds and dormancy mechanisms. According to the field survey, weed seeds at a density of 712,228 – 930,910 seeds/m² were recorded in the soil of direct seeded rice field in the Muda area. Considerable longevity of seeds is a widespread characteristic. Some seeds could be buried up to 10” (26 cm) deep and do not up to surface for years. Hence, seed longevity and seedling emergence are important biological characteristics for an eradication program because seed longevity determines the number of years required to repeat eradication treatments while seedling emergence determines when to apply eradication treatments. For example, weed seed population in ricefields were the highest (about 793,000/m²) even greater than in the other two plantation crops. These seeds had a high germination rate of about 80 %. Seed longevity in the soil is ecotype-dependent and is also affected by burial depth, soil type and moisture, and dormancy density as well. Concerning the study of seedbank, there are many reports on agricultural and silvicultural in applied fields. However, there is limited information on the ecology of seeds and seedling which is very useful weapon to analyze the structure and succession of plant communities.

Weed could produce seeds and subsequently fall to the ground entering the seedbank. Once seedlings are successfully emerged, further interactions with neighbours and their environments will determine whether weeds population can

become a part of the community of rice ecosystem. Before the growing stage, these seeds are stored in the soil as a seedbank. The seedbank is referred to as ‘dispersal in time’ because it provides the same important benefit as dispersal through space. The weed seedbank is known to be as a ‘memory of the land’ and its species abundance and diversity will hence referred as the previous cropping history. In addition, the definition of weed seed bank is the storage of weed seeds in the soil, which emerge in different flushes to compete with the crops. Seed banks are a cluster of non-germinated but viable seeds that are stored in the soil. They can permanently remain dormant in soil for decades till the environment around them are suitable for germination (Lee, Cho, and Lee, 2012). The dormant seed banks play important roles in ecological and evolutionary process which can influence the plants that grow above the soil. Hence, they are well known as critical issues in management plans of certain ecosystem. Furthermore, they play a pivotal role in natural regeneration after an ecosystem being disturbed. The worth of the seed banks restoration is different based on the disruption types and length of the site.

Based on Mashhor et al., (2012), the weed seed bank is known as the memory of the land since species abundance and diversity reflect the previous cropping history. It is crucial things to face weed problems because almost weed species can endure their viability and survival rate in soil for many years. The recruitment of new seedlings from seed bank in different period of time will play a huge role in the compositions, structure, and dynamic of the plant community.

Zainal Abidin (2008) mentioned that soil seed bank or also known as a reservoir of weed seed of plant community that gives significantly to the ability of that community to regenerate and to the distribution pattern of the vegetation, while

the seed production of vegetation affect the composition and abundance of the seed bank. The soil seed bank can be grouped as surface seed bank (active seed bank) and buried seed bank (dormant seed bank).

The weed seed bank containing viable seeds either on the surface or in the soil, is the main source of annual weed infestation in rice ecosystem (Mahfuza et al., 2011). The seed bank comprises of new seeds lately shed by weeds and older seeds that had persisted in the soil for many years. Variation in agronomy management practices can shift the pattern of disruption thus generate changes in seed bank characteristics. The changes in seed bank characteristics can impact the type of species and size composition of weed plants. The seeds stay permanently on the soil surface or are buried after dispersal, through the actions of many biotic and abiotic factors hence composing a seed bank which become the important source of weeds in the ecosystem (Mesquita et al., 2013).

The seed banks composition is usually differed in different rice cultivation fields in term of spatially heterogeneous (Chauhan & Johnson, 2009a; Rao et al., 2007). The variation among the four rice plots in the proportion of weed seeds distribution were similar but showed differences based on hierarchy. Mahfuza et al., (2006) stated that the main weed species in the Muda area based on seedlings emergence in the studied soil seed banks were *L. chinensis* (26.9 %), *F. milliacea* (22.9 %), *C. difformis* (20.2 %), *S. zeylanica* (8.3 %), and *L. octovulvis* (6.3 %). Rao et al., (2007) reported that, there were three dominant weeds species in lowland irrigated rice field which were *C. difformis* (52.0 %), *F. milliacea* (26.0 %), and *M. vaginalis* (18.0 %) covered almost 96.0 % of total emerged seeds.

The main reason that seeds remain viable in the seedbank is because they are usually dormant. Dormancy is a crucial stage in the development of weed seed of a population, and this process will prevent the task of expecting the timing and the emergence of weeds. Proportion of seedbank that has been released from dormancy is strongly related by the number of established weed. In addition, the dynamics of dormancy release of the weed population is largely depended based on the timing weed generally related to crop emergence. Hence, periodicity of germination knowledge clearly shows that the importance of considering dormancy when assessing weed-crop interactions. Furthermore, knowledge of the amount, distribution and dynamics of seeds in soil under different regimes could be used to build up models of seedling emergence that are needed to anticipate the weed infestation pattern mainly in the future crop harvesting.

2.3 Weed Classification

In Malaysia, generally weeds in rice ecosystem are classified into four type which are grasses, sedges, broadleaved, and aquatic weeds. Graminae (Poaceae) is the most common weed with the highest number of weeds species followed by sedge for example Cyperaceae.

2.4 The Overview of Rice

Rice (*Oryza sativa*) is one of the most crucial staple food in Asian countries for more than 50 % of human population in the world (Joshi et al., 2013; Krishna Dhital, 2011; Mann, et al., 2007). Based on Krishna Dhital (2011) it is estimated that

by the year of 2025, rice farmers in all over the world need to produce 60 % more rice than at recent production to give an enough food demands to human population. It is a commodity that can be export. In the past, rice was cultivated by using traditional method, or also known as transplanting rice cultivation culture. Thirty days old of rice nursery seedlings was transplanted into puddle and continuous flooded soil. Nowadays, the rice granary area become expanded to million hectares, which puddling is not a suitable to be practiced based on worst water shortage (Mann, 2006). Hence, direct seeding, a new rice cultivation culture being suggested to replace the conventional transplanting rice cultivation culture. Direct seeding rice cultivation culture is being introduced in order to overcome high production cost mainly on water usage and labor demand.

2.4.1 Direct seeding

Farooq et al., (2011) define direct seeding as the crop establishing process form seeds sown in the rice field rather than by nursery. Direct seeding rice cultivation culture can be divided into four types which are dry seeded (sowing dry seeds into dry soil), wet-seeded (sowing pre-germinated seeds on wet puddle soils), water seeding (seeds sown into standing water), and volunteer seedlings (Joshi et al., 2013). In dry seeded fields, the soil was ploughed only once which is a week before seeding whereas the soil was ploughed twice in both wet-seeded and volunteer seedlings, about two weeks and one week before seedling (Juraimi et al., 2013). Wet direct seeding rice mainly applied especially during situation of labour limited, and recently being practiced by farmers in Malaysia, Vietnam, Thailand, Philippines, and Sri Lanka (Pandey & Velasco, 2002; Weerakoon et al., 2011). On the other hand, the shortage of

water supply causes increasing in practicing dry direct seeded rice. The yields from dry direct seeding rice is small in irrigated areas but it is being practiced traditionally in rainfed upland ecosystem in many Asian countries. Meanwhile, water seeding is practiced to manage weed problems especially from weedy rice infestation, and it is widely applied in the United states.

The advantages of direct seeding rice cultivation culture are maintaining continuous moist soil and hence water demand being reduced. Direct seeded rice cultivation culture being practiced on terraced and sloppy lands by farmers in South Asia especially in Bangladesh and Western Himalayan region in India (Gupta et al., 2006). Reports showed that the rice yields from direct seeding rice cultivation culture always lower than transplanting rice cultivation culture due to the lacking in a proper weed management. Before 1950s, direct seeding rice cultivation culture was predominant but later, the cultivation method has been changed to puddle transplanting (Pandey 2005; Rao et al.,2007).

Nowadays, many of Southeast Asian countries applying direct seeding rice cultivation culture as a result of shifting from traditional transplanting rice cultivation culture (Pandey 2002). The decision on shifting rice cultivation culture from transplanting to direct seeding is made due to the water scarcity and also costly issues on labour intake (Chan and Nor, 1993). The advantage of direct seeding is helping in reducing water usage by about 30 % as it removes seedlings raising in nursery.

2.4.2 Transplanting

In rabi period, transplanting rice cultivation culture is the most popular rice establishment technique. It needs more extensive and expensive labours and thus increases the production cost and always result in delay in planting because of limited labours (Johnkutty, 2002). Recently, factors like urbanization and industrialization worldwide causes limited specializes labour for transplanting and this situation becomes a big problem to many rice farmers. In some of Asian countries, rice is mainly being cultivated by transplanting 30 days-old seedlings into soil with wet tillage land preparation. The advantages of traditional transplanting rice cultivation culture are increasing availability of nutrient, like (phosphorus, iron, and zinc), suppression of the weeds, seedlings establishment easily, and producing anaerobic conditions to increase availability of nutrient. Traditional transplanting also had some of the disadvantages instead of advantages itself including losses of water through puddling and also evaporation and percolation of surface.

2.4.3 Switching from transplanted to direct seeded rice cultivation

Farmers faced many problems in gaining high yield of rice. Weeds are a constant problem in all rice growing areas especially in direct seeded rice. For example, for the past 10 to 15 years in Southeast Asia, there has been a significant shift in the rice production system from transplanting methods to direct seeding methods of which wet seeding (pregerminated seed usually broadcast on puddle soil) has been the main method adopted in Malaysia, Thailand, Philippines, and Vietnam. This is mainly due to labour shortage and increasing labour cost. The demand of transplanting,

manual weeding, and increasing of labour have encouraged the move to direct seeding in irrigated and rainfed lowlands. Weeds become a major issue in this system because rice and weeds emerge at the same time. Furthermore, weeds population, weeds distribution, and weeds intensity changed abruptly when transplanted rice cultivation is switched to direct seeded rice cultivation. The widespread adoption of direct seeding has occurred changes in weeds flora (from predominance of broadleaved weeds and sedges in transplanted crop to the more competitive grassy weeds in direct seeding). Changing of distribution of weeds species has occurred problems to select the suitable management of weeds on how to overcome this problem.

2.5 Water Management

Germination and survival of weeds in rice are considerably effected by water management and leveled field. Germination of sedges and grasses are reduced by the deep water of irrigated rice but it does not limit regrowth of perennial sedges and broadleaved weeds. Hence, water management is difficult without levelling of fields. The success of seedling establishment is determined by the depth of water. The most effective method of cultural control of weeds in rice is the flooding of the fields. Flooding is an effective ways of weed control under certain conditions (seeding, soil type, climate, crop rotation, diseases, and insects). In the most growing seasons, flooding causes environment that inconducively for germination of sedges and grassy weeds. In addition, flooding is effective when the roots and/or the shoot of the weeds are completely submerged by water for a long period of time.

Formation of productive tillers is suppressed and low rice yields obtained during early flooding to a depth of 5 cm to 8 cm. Meanwhile, germination of the most weeds seeds is prevented and majority of weed seedlings is killed by flooding to a depth of 10 cm. Six to nine days after sowing are the safe limit for flooding where farmers only control the weeds during critical period to obtain optimum yields (Juraimi et al., 2012). In the United States, most direct seeded fields are drained three to four weeks after flooding and soil is allowed to dry for several days. Maximum yields and minimum losses are produced at 5 cm to 10 cm of water depth.

CHAPTER 3

METHODOLOGY

3.1 General Description of the Study Site

Penang or 'Pulau Pinang' is a state which located in Northwest Coast of Peninsular Malaysia. It is divided into two sections by the Strait of Malacca. This island got its name from a tree called as 'Pokok Pinang' or its scientific name is *Areca catechu*. Penang state is one out 14 states in Malaysia, which consists of island (Penang Island) and mainland (Seberang Perai) (Figure 3.1). Penang island covers 285 km² which is fully separated from Seberang Perai. Both of this area is connected by 13.5 km of Penang Bridge and 24.0 km of Penang Second Bridge. The temperature of Penang Island is about 27.0 °C - 30.0 °C in a day time and about 22.0 °C - 24.0 °C in a night time. The total precipitation is about 2,670 mm and the humidity is about 70.0 % - 90.0 %.

Balik Pulau or literally known as 'The Village Behind the Island' is a town located in Southwest District of Penang Island (Daerah Barat Daya Pulau Pinang). Balik Pulau is a smaller area in Barat Daya District. Barat Daya District cover almost 200 km² area, which means it is more than a half of Penang Island (excluded Seberang Perai) or around 20.0 % of area in Penang state. It include Balik Pulau , Teluk Bahang, and Bayan Lepas. The minimum and maximum temperatures of Balik Pulau area are about 24.5 °C and 39.0 °C respectively and the mean humidity is about 89.0 %. Economic activities by Balik Pulau residents include agriculture, fishery, and entrepreneurship. Rice cultivation is one of the main agriculture activities in Balik Pulau.

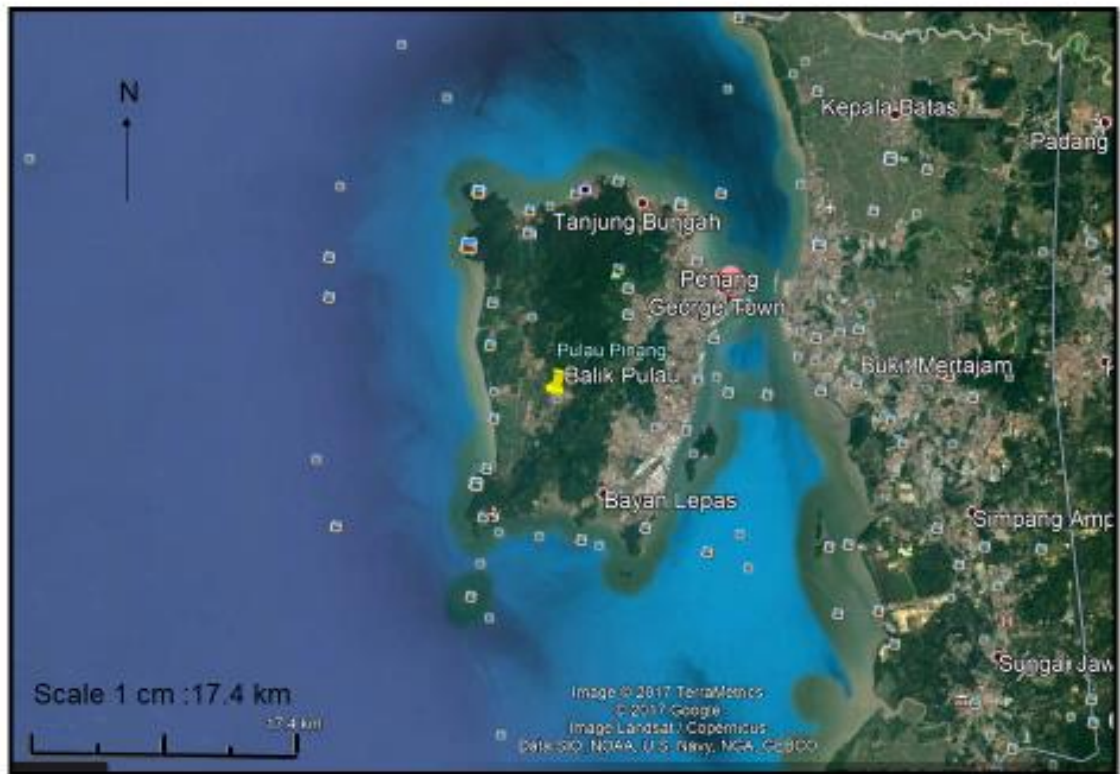


Figure 3.1 : Map of Penang State including Penang Island and Seberang part (Source : Google Earth)

3.2 Location of Study Area

This study was carried out at Balik Pulau rice ecosystem near Department of Agriculture (DOA) District of Southwest, Penang. The farmers in this area practicing direct seeding rice cultivation by using MR 220CL2 rice variety. There are four rice field plots which is studied such as Pokok Kenanga Plot, PPK Fasa 3 Plot, PPK Fasa 1 Plot, and Sungai Burung Darat Plot (Figure 3.2).

3.2.1 Pokok Kenanga Plot

Pokok Kenanga Plot is located near to the Politeknik Balik Pulau which is a new educational institute that was built in Balik Pulau. It is the biggest rice field in Balik Pulau located in the district of Southwest. The size of this rice field is about 34 hectares (34 ha.), which is about 11.0 % out of 310 hectares (310 ha.) of rice field area in Balik Pulau. Pokok Kenanga irrigation scheme got the water supply from Sungai Titi Teras which flow through Pokok Kenanga irrigation canal (Plate 3.1).

3.2.2 PPK Fasa 3 Plot

The second plot is Pertubuhan Peladang Kawasan Fasa 3 plot (PPK Fasa 3 Plot) (Plate 3.2). It is located along Tok Kiat Road in Balik Pulau rice ecosystem. This plot is using pump system for irrigation scheme which, the water flow

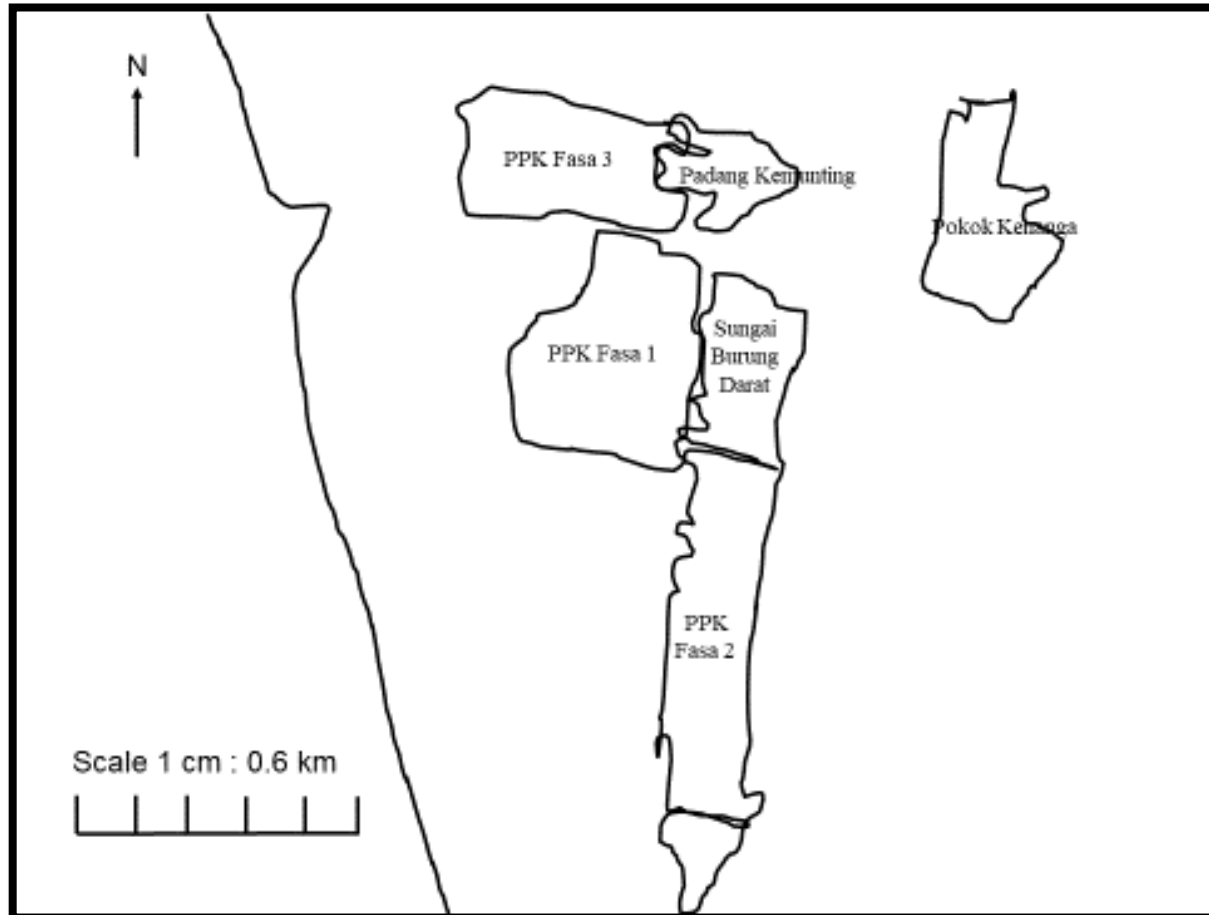


Figure 3.2 : Map of Balik Pulau rice ecosystem (source : Department of Agriculture in Barat Daya, Balik Pulau, Pulau Pinang)



Plate 3.1 : Pokok Kenanga rice field plot which is located near to the Politeknik Balik Pulau



Plate 3.2 : PPK Fasa 3 rice field plot

through Sungai Burung irrigation canal. Rice farmers in Balik Pulau reported that the soil from this plot is the best soil for rice cultivation. Rice grows healthier due to the soil fertility. Furthermore, the rice yield from this soil is very high. However, sometimes the rice cannot be harvested due to the soil sink causes harvesters cannot harvest the rice. In this situation, farmers lose money.

3.2.3 PPK Fasa 1 Plot

Plate 3.3 showed Pertubuhan Peladang Kawasan Fasa 1 plot (PPK Fasa 1 Plot), which is also located along Tok Kiat Road. This plot located just 200 metres (200 m) from the second plot, which is assigned as PPK Fasa 3 Plot. In PPK Fasa 1 Plot, the irrigation scheme is similar as irrigation scheme of PPK Fasa 3 Plot, by applying pump system, which the water flows through Sungai Burung irrigation canal.

3.2.4 Sungai Burung Darat Plot

The fourth plot is Sungai Burung Darat Plot. This plot get water supply directly from Sungai Burung by using gravity system from Sungai Burung Irrigation Scheme. In this study, this plot is indicated as the last plot to sample the soils. It is located behind the Department of Agriculture (DOA) District of Southwest in Balik Pulau and also in front of farmers' residents (Plate 3.4).



Plate 3.3 : PPK Fasa 1 rice field plot



Plate 3.4 : Sungai Burung Darat rice field plot which is located behind the Department of Agriculture (DOA) Barat Daya, Balik Pulau

3.3 Seed Bank Method

An experiment of soil seed bank was run at plant house of School of Biological Sciences, Universiti Sains Malaysia (USM) for 6 months from December 2013 to May 2014. The soil that was used in this experiment were from Pokok Kenanga Plot, PPK Fasa 3 Plot, PPK Fasa 1 Plot, and Sungai Burung Darat Plot. These soils were sampled originally from Balik Pulau rice field on 26th October 2013. The soils were sampled randomly by using 1 m x 1 m quadrat and were dig from 0 cm to 20 cm in depth (0 cm - 20 cm) (Mashhor et al., 2012). The soil series data (secondary data which was collected from Department of Agriculture, Teluk Chengai, Kedah) were shown in (Appendix 1), (Appendix 2), and (Appendix 3).

In this experiment, two factors were applied which were different water level conditions and using soils from different plots. There were four types of water levels namely control water level condition (0 cm water deep), saturated water level condition (3 cm water deep), partially flooded water level condition (5 cm water deep), and flooded water level condition (10 cm water deep). Three replicates were prepared for each water level conditions. 48 plastic trays were prepared. Furthermore, the plastic trays were measured with the same water level and soil depth measurements and were marked with liquid paper in each level that was needed.

On the experiment day, the plastic trays were filled with water and the water levels were observed daily to make sure that the water depths were kept constant from the beginning until the end of the experiment. Therefore, the water was added when it was needed. Then, the dry soils were transferred into plastic trays with the size of (23 cm x 18 cm x 10 cm). The volume of soil which 2,070 cm³ was mix thoroughly