STUDIES ON BIOLOGY AND SELECTED CONTROL MEASURES OF WEEDY RICE (*Oryza sativa* complex) IN RICE CULTIVATION

by

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ABSTRAK

Survei lapangan telah dilakukan mulai 2003 sehingga 2005 dalam tempoh empat musim berturut-turut menunjukkan terdapat 44 spesis rumpai daripada 29 genera yang tergolong dalam 18 famili dicatatkan di kawasan Muda. Lapan belas spesies daripadanya adalah jenis berdaun lebar, 12 rusiga, 9 rumput dan 5 tumbuhan akuatik. Hierarki bagi lima rumpai yang dominan berdasarkan nilai kepentingan adalah seperti berikut: *Oryza sativa* complex (padi angin) > *Echinochloa crus-galli* > *Ludwigia hyssopifolia* > *Fimbristylis miliaceae* > *Ischaemum rugosum*. Kajian bank benih mendapati sejumlah 577 benih berupaya bercambah yang menyamai 3337 benih m^{-2} (33.37 juta benih ha^{-1}) dalam musim 1/2004, 979 (5659 benih m^{-2} atau 56.59 juta benih ha^{-1}) dalam musim 2/2004, 928 benih (5364 benih m^{-2} atau 53.64 juta benih m^{-2}) dalam musim 1/2005 dan 471 benih (2722 benih m^{-2} atau 27.22 juta benih m^{-2}) dalam musim 2/2005. Kaedah tabur dalam air mampu mengawal serangan padi angin dan seterusnya meningkatkan pengeluaran hasil. Purata bilangan tangkai padi angin berkurangan semasa di luar musim (1/2004) dan semasa musim utama 2004(2/2004), berkurangan sebanyak 15.55% bilangan tangkai padi angin. Purata hasil yang dijangkakan dan hasil sebenar adalah sama bagi semua sawah padi terpilih untuk empat musim berturut-turut. Semasa musim 2/2004 hingga 1/2005 dan musim 1/2005 hingga musim 2/2005, hasil kasar padi masing-masing meningkat sebanyak 6.02% dan 7.94%. Nama-nama varian padi angin adalah: janggut dan tidak berwarna; tangkai terbuka dan tidak berwarna dan tangkai tertutup dan

berwarna diambil dari Guar Chempedak menunjukkan bentuk pertumbuhan dan perbezaan anatomi yang agak sama terutamanya bagi varian tangkai tertutup dan berwarna. Padi angin melengkap kitar hidupnya dalam masa 85-95 hari selepas bercambah. Berdasarkan kajian demografi tumbuhan, kadar penghasilan biji dengan nitrogen adalah 368 biji/tangkai (8464 biji/pokok) dan tanpa nitrogen sebanyak 255 biji/tangkai (2295 biji/pokok). Keputusan dari kajian keupayaan redoks, menunjukkan bahawa nilai keupayaan redoks berkurangan terhadap kedalaman. Berdasarkan dari aspek kawalan dan pengurusan rumpai, padi angin dapat dikawal secara efektif apabila diberi takungan air sedalam 5.0 hingga 10.0 cm pada umur 0 hingga 7 hari lepas cambah. Tanah yang lembap dan tepu membolehkan padi angin berupaya bermandiri dan tumbuh. Kajian kadar nitrogen yang berbeza menunjukkan bahawa saingan padi angin mengurangkan pertumbuhan dan komponen-komponen hasil: bilangan tangkai pokok^{-1} (59.93% kepada 40.07%); peratus pengisian biji (57.68% kepada 42.32%); berat 1000 biji (51.87% kepada 48.13%); dan hasil padi (57.70% kepada 42.32%). Keputusan menunjukkan bahawa 150 – 200 kg ha^{-1} merupakan kadar baja yang disyorkan. Keputusan dari survei petani yang terlibat membuktikan bahawa para petani mempunyai pengetahuan dan pengalaman yang baik dalam aktiviti-aktiviti pertanian untuk mengawal rumpai terutamanya padi angin. Walau bagaimanapun, mereka masih kurang berpengetahuan terhadap pemilihan dan penggunaan herbisid. Tambahan pula, kebanyakan mereka menghadapi masalah yang hampir sama iaitu ketidakcukupan air semasa penyediaan tanah di dalam sawah mereka.

STUDIES ON BIOLOGY AND SELECTED CONTROL MEASURES OF WEEDY RICE (*Oryza sativa* complex) IN RICE CULTIVATION

ABSTRACT

Field survey which was conducted from 2003 to 2005 over four consecutive seasons showed that 44 weeds species in 29 genera belonging to 18 families were recorded in the Muda ricefield. Of these, 18 species were broadleaves, 12 sedges, 9 grasses and 5 aquatic plants. The hierarchy of five dominant weed species based on important value (I.V.) was as follows: *Oryza sativa* complex (weedy rice) > *Echinochloa crus-galli* > *Ludwigia hyssopifolia* > *Fimbristylis miliaceae* > *Ischaemum rugosum*. Soil seedbank study showed that a total of 577 seeds germinated which equal to 3337 seed m^{-2} (33.37 million seed ha^{-1}) in 1/2004 season, 979 seeds (5659 seed m^{-2} or 56.59 million seed ha^{-1}) in 2/2004 season, 928 seeds (5364 seed m^{-2} or 53.64 million seed m^{-2}) in 1/2005 season and 471 seeds (2722 seed m^{-2} or 27.22 million seed m^{-2}) in 2/2005 season. Water seeding method was able to control weedy rice infestation and subsequently produced higher yield. The average number of weedy rice panicles was greatly reduced during off-season (season 1/2004) and during main season 2004 (season 2/2004) the rate decreased by 15.55% number of weedy rice panicles. Average expected and actual yield were relatively similar for all selected farm lands for four consecutive seasons. During season 2/2004 to 1/2005 and season 1/2005 to season 2/2005, the gross yields increased by 6.02%, and 7.94%, respectively. The variants of weedy rice, namely; awn and non-pigmented; open panicle and non-pigmented and compact panicle and pigmented collected from Guar

Chempedak showed that growth pattern and anatomical differences were quite similar particularly on compact panicle and pigmented variant. Weedy rice completes its life cycle within 85–95 days after emergence. Based on plant demography study, under treatment of 150 kg N/ha, the rate of seed production from all survival adult individuals was 368 seeds per panicle (8464 seeds per plant) and without N was 255 seeds per panicle (2295 seeds per plant). Result from redox potential study, showed that the values of redox potential decreased with depth. Based on the control and weed management aspect, the species could be suppressed with the flooding from 5.0 to 10.0 cm water depth at 0 and 7 days after emergence (DAE). Moist and saturated soils favored the survival and growth of weedy rice. Different rates of nitrogen were tested and the result demonstrated that the competition of weedy rice in rice caused reduction of growth and yield components: number of panicles plant^{-1} (59.93% to 40.07%); percentages of filled grains (57.68% to 42.32%); weight of 1000 grains (51.87% to 48.13%); and rice yield (57.70% to 42.32%). The results showed that 150 – 200 kg ha^{-1} is recommended to fertilize. Result from the farm's survey indicated that the farmers who participated in the study had good knowledge and experience of agricultural practices to control weeds especially weedy rice. However, they still lack sufficient knowledge on herbicide selection and application. Besides, the majority of them has almost similar problem in their fields which is insufficient water during land preparation.

CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

1.1.1 General Background of the Study

Rice (*Oryza sativa* L.) is also known as paddy rice is one of the most important crops in the world (Chang and Luh, 1991). It is a major staple food for more than two-third of the world's population (Kim *et al*., 2005), where human activities have led to growing of rice in more than 100 countries across a south to north span from 40^{o}S to 53^{o}N latitude covered the areas from sea level to altitudes of more than 2 500m (Grist, 1986; Chang, 2003). This food grains is primary calorific source which accounts for one-third or more of caloric intake. It provided up to 80% of the calorific intake of nearly three billion people in Asia, Africa and South America. In Asia, it provided an average of 32% total calorie uptake (Maclean *et al*., 2002). As such, it is the most important crop worldwide, particularly in developing countries, where more than 90% of the world's rice is grown and consume (Kim *et al*., 2005). More than 90% of the world's rice is produced and consumed in Asia. In order to meet the demographic demand, the yield of rice production will need to be increased by 35% before 2010 despite a decrease in land, labour and water available for agriculture. IRRI (1989) stated that the demand for rice is projected to increase by 60% over the next 30 years. Then, by 2020, four billion people, or more than half of the world population will depend on rice as a food. Besides, the world's annual rice production will have to increase 70% by the year 2030 to keep up with the demands of a growing population (Xiao *et al*., 1996). This extra production must be met from existing land resources through improved productivity of both transplanted and direct seeded system and through sustainable agricultural practices to ensure long-term food supply as well.

Historically, it is believed rice is an ancient grain crop which has been cultivated for thousand of years. Rice belongs to the genus *Oryza*, tribe *Oryzeae,* subfamily Oryzoideae, and family Poaceae. Generally, there are two cultivated rice species namely, Oryza *sativa* L. (common rice world widely grown in the humid tropics and temperate zones) and *O. glaberrima* Steud. (endemic to West and Central Africa), belong to the *sativa* complex and are diploids with the AA genome (Veasey et al., 2004). The name of genus *Oryza* is derived from the Greek, meaning 'of oriental region' whereas *sativa*, means 'sown' in Latin and *glaberrima*, means 'smooth' and free of hairs (Catling, 1992). Asian cultivated rice has evolved into three eco-geographic races; indica, japonica and javanica. Indica cultivars constitute the majority of rice production worldwide, with estimation of about 80%. Besides these cultivated species, the genus *Oryza* includes approximately 20 wild species (Chang, 1976; Morishima, 1984; Vaughan, 1994; Mackill, 1995) or 21 wild species (Veasey *et al*., 2004). The cultivated rice known today is believed to have occurred via mutations that resulted in awnless, non-shattering grains, and selection for favorable characteristics by the early agricultural inhabitants of Asia (Holm *et al*., 1997). The lineage of cultivated rice is also believed to originate from the wild perennial *O. rufipogon* which became *O. nivara* and eventually, *O. sativa* was derived (Chang, 1976).

Although originally domesticated in Asia, the exact site of origin is uncertain. However, Chang (1976) reported that cultivated rice has been used as food in Thailand since 5000 B.C., but *O. glaberrima* was first domesticated by the Africans around 1500 B.C.. Moreover, Grist (1986) noted that rice was first domesticated in the area between northern India and Pacific coast adjoining Vietnam and China. The cultivated rice believed to have originated in South-east Asia, particularly India and Indo-China, where the richest diversity of cultivated forms has been recorded (Grist, 1986; Catling, 1992). In addition, Catling (1992) and Maclean *et al*. (2002) also reported that the Asian rice culture was established in northern India, Thailand (discovered at Non Nok Tha in the Korat area) and eastern China around 7000 years ago. Then, it spread and diversified to form two ecological groups, *Indica* and *Japonica* northwards in Asia. From the mainland of the continent it also spread south and east through the Malay archipelago with the flow of human culture (Vaughan, 1991). Therefore, in Southeast Asia rice was introduced by the Deutero-Malays when they immigrated into this region about 1599 B.C.

Currently in Malaysia, agricultural areas covered 4.64 million hectares and approximately 14% (622,500 ha) of these areas are dedicated to rice cultivation (Itoh, 1991b). The area planted with rice in Peninsular Malaysia is about 402,800 ha., while in Sabah and Sarawak is about 200,000 ha. (Itoh, 1991b). There are eight granary areas as permanent rice producing areas (Itoh, 1991a; 1991b). Muda area which covers 98,860 ha of wet ricefields is the single largest rice granary area in Malaysia. Kuan *et al*. (1991) and Morooka (1992) reported that this rice granary contributed approximately 25% of total national rice production (Figure 1.1.1). In Malaysia, rice production is not parallel with the increment of country's population (Maclean *et al*., 2002). The country needs about 1.85 million t/ha (tons per hectares) of rice a year in order to fulfill domestic demands. Its resources are from local output of 65% to 70% and additionally from Thailand, Vietnam, Pakistan and India with 30% to 35% but our country can only produce rice yield about 1.2 million tons per hectares. Due to this, increasing rice production will continue to be an important agenda for Malaysia. Therefore, the Department of Agriculture stressed that in order to stop the import of rice from other countries is to increase rice yield to 10 t/ha. In order to achieve sufficient self-consumption of rice, this project had begun in year 2002 as to increase the rice production in Malaysia.

In rice cultures, many constraints are faced by the farmers in gaining high yield. 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

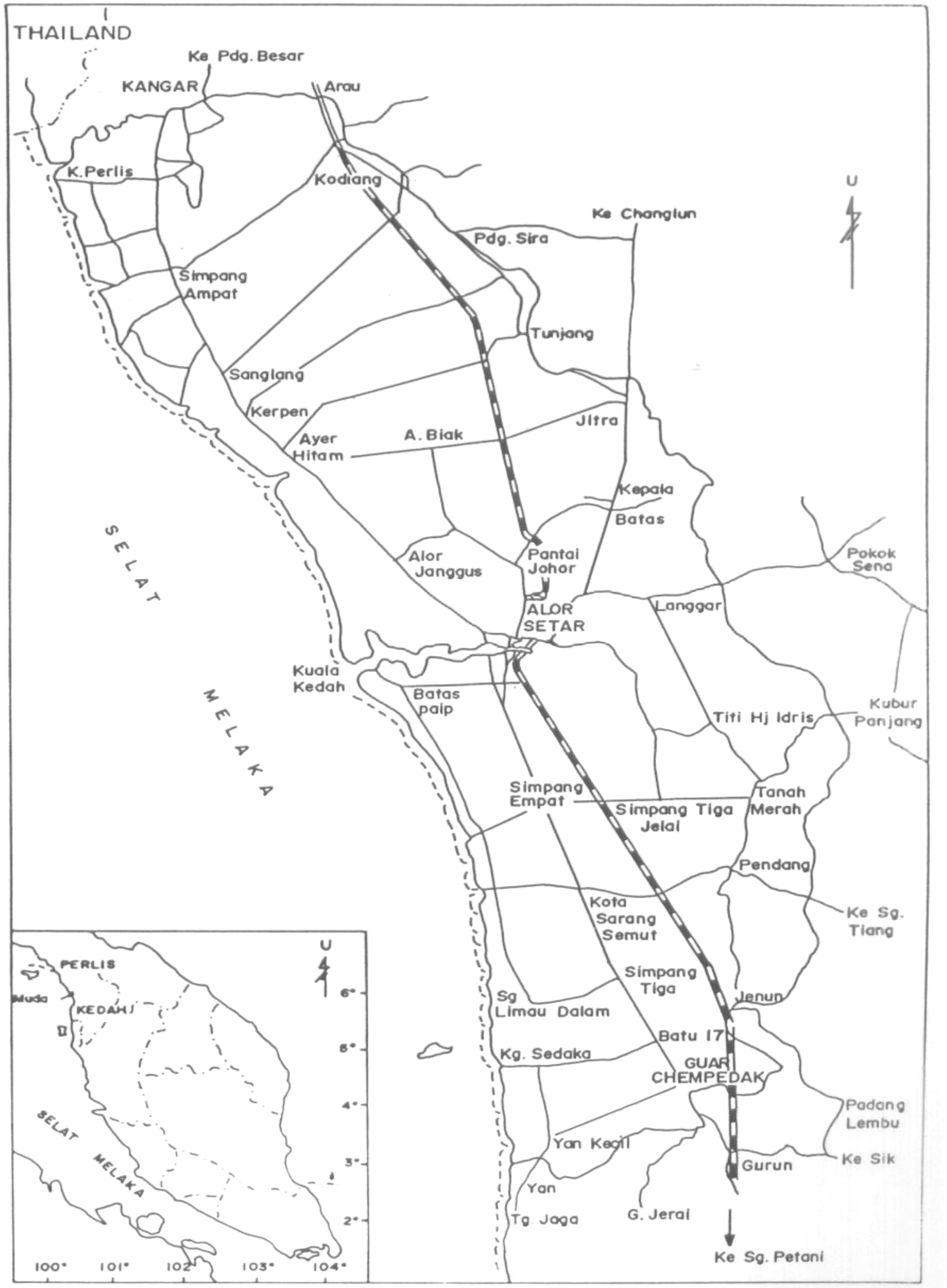

Figure 1.1.1: Muda area in Peninsular Malaysia

method adopted in Malaysia, Thailand, Philippines and Vietnam. This is mainly due to labour shortage and increasing labour cost. The advantages of using this system are able to use modern early rice maturing varieties as well as integrated harvesting activities (Moody, 1995).

According to Wah (1998) the proportion of direct seeded land under rice cultivation is believed to be highest in Peninsular Malaysia amongst all the Asian countries and then followed by Thailand, Vietnam (fast adopting this cultural change), Indonesia and Philippines. Direct seeding in other parts of Southeast Asia is thus being practiced to a considerable degree although its proportion to the corresponding total rice area under cultivation is lesser as compared with the Peninsular Malaysia. Generally, direct seeded rice includes both dry and wet seeded methods. In Malaysia, research on direct seeding was first initiated in the early 1970s. In the Muda area, direct seeding method was started in early 1980s. Ho *et al*. (1999) reported that among the various reasons cited by farmers on the adoption of direct seeding were to overcome shortage of labour, to reduce cost of production, to try new technique of planting and water management problem would not arise.

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. Weed control by flooding is quite difficult in seedling rice when it is not managed properly. In recent years in Malaysia, weedy rice

(*Oryza sativa* complex) had been emerging as a serious weed in rice. *O. sativa* complex infestation result in yield loss, harvesting problems, and quality loss through discount. The occurrence of weedy rice was first detected in the southern part of the Muda area in 1990. It was identify that direct-seeding had promoted the spread of weedy rice (Ho *et al*., 1999). As a result, the history and current status of weedy rice has been reviewed extensively (Watanabe *et al*., 2000; Azmi *et al*., 2005). The weed severely infested the fields of direct seeded rice in the Muda area (Md. Zuki *et al*., 1995; Md. Zuki *et al*., 1996; Bakar *et al*., 2000). Therefore, it has been considered as the most dominant and troublesome in most growing areas throughout the world (Watanabe *et al*., 2000).

1.1.2 Approaches and Objectives of the Study

So far the literature on weedy rice studies is still limited. Based on morphological characters of weedy rice, it resembles cultivated rice and therefore difficult to differentiate between weedy rice and cultivated rice. As a result, basic information on this species is needed particularly in deciding an integrated weed management in direct seeded rice. Ecological and biological approaches are mainly focused in order to obtain a specific method which is ecologically and economically sound to farmers in the region. Therefore, knowledge of these approaches is the fundamental concept to enhance the success of weed management and contribute to gain insight into the mechanisms of weed control methods.

Based on the above problem statements, the study was conducted at ricefield of MADA (Muda Agricultural Development Authority), Guar Chempedak and laboratory as well as the plant house of the School of Biological Sciences, Universiti Sains Malaysia, Penang. Scientific discussion for these aspects was presented separately and could be contributed to the farmers and researchers for a good alternative in order to reduced the weeds and gaining high yield to fulfill our needs.

The objectives of this study are to determine:

(a) weedy rice infestation in Muda rice granaries in Peninsular Malaysia;

(b) the population of weed seedbank in the soils with special reference to weedy rice seedbank;

(c) the effects of crop establishment methods and agronomic practices among farmers on weedy rice population and rice yield productions;

(d) the biology of weedy rice (life table, growth pattern and life cycle);

(e) the physical and environment parameters that trigger the occurrence of the species with respect to redox potential;

(f) the influence of flooding on weedy rice emergence and growth at different times and depths of flooding;

(g) the degree of weedy rice competition in direct seeded rice under different nitrogen application rates;

(h) farmers' attitude and perception on weed management with respect to weedy rice infestation.

Scientific comments on the above aspects will be discussed separately in the following topics. This research was conducted so that the data collected can be used as guide to give the best alternative in controlling and managing weeds particularly weedy rice, generally in Malaysia and specifically in the Muda area.

CHAPTER 2

LITERATURE REVIEW

2.1 WEED ECOLOGY

2.1.1 Changing of weed community

Weeds are plants growing where they are not wanted in particular areas. It is widely known that weeds have been efficiently established in a site because of its ideal characteristics. Example of these characteristics are ability to survive unfavorable growing condition, competitive ability, high reproductive capacity, rapid and spontaneous growth, appearing without being sown and aggressiveness. 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 a particular agro-ecosystem community. Thus, Akobundu (1987) believe that weed ecology is associated with the growth characteristics, adaptations and survival mechanisms of weeds that enable them to conquer environmental resources, and successfully colonize new habitats.

Weed population shifts are due to the changes in the individual organisms that make up the population of a locality. This is often caused by changes in weed management practices (Mortimer, 1996; Rao, 2000). A farmer and an individual field play a role in adapting the subsequent changes. Similar findings have been reported in rice fields where weeds are dynamic and they changed in abundance and dominance according to changes in the rice agroecosystem (De Datta, 1981; Azmi, 1994; Tomita *et al*., 2003; Karim *et al*., 2004; Begum *et al*., 2005a; 2005b). Furthermore, Kim *et al*. (1983) stated that the occurence of weed vegetation of a particular area is determined with biotic (plants, microorganism) and abiotic (temperature, edaphic and climatic conditions) factors. The occurrence of weed vegetation is strongly affected by cultural practices such as irrigation, fertilizer, cultivar grown, tillage, herbicide used and crop rotation (Rao, 2000; Poggio *et al*., 2004). Edaphic factors such as soil physical structure, pH, nutrient and moisture status also strongly affect the weed vegetation. Ho (1998) also stated that the weed distribution is always affected by human and environmental factors. The weed spectrum and the degree of infestation in the rice agroecosystem are often determined by the types of rice culture (irrigated, rainfed lowland, upland, deepwater, and tidal wetland), crop establishment method (transplanted or direct seeded), moisture regime (irrigated and rainfed), land preparation (lowland or upland) and cultural practices (flooding, fertilizer application, cultivar types) (De Datta, 1981). Mercado (1979), Zanin *et al*. (1997), Poggio *et al*. (2004) and Yin *et al*. (2005) added that, the plant composition of the biosphere keeps on changing particularly in cultivated areas. There are also major factors that influences weed population in rice fields such as control method used, rice cultivar planted and changes in soil and water management (De Datta, 1988). The continuous adoption of any particular rice production practice frequently causes a shift in dominance of the weed population.

Switching from transplanted to direct seeded rice cultivation has changed the population, distribution and intensity of weeds abruptly (Azmi and Baki, 1995). Thus, groups of species which grow in the same area must possess common environmental tolerance which enables them to survive the hazards of the area. There may however be different strategic solutions which accomplish the same tolerances. In this case, weed community must also differ in ways which permit them to escape from an exclusive struggle for existence. 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 grasses in direct seeding (Azmi and Hussin, 1995; Azmi *et al*., 2000; Bakar *et al*., 2000; Karim *et al*., 2004; Begum *et al*., 2005a; 2005b).

Studies of these cases have been carried out by several researchers in Muda area showed that in early 1970s during direct seeding technique being introduced (less than 1% of cultivation area), there are 21 species in 13 families was recorded (Watanabe *et al*., 1996; Watanabe *et al*., 1999). The sequence of hierarchy according to the dominance weeds are *Monochoria vaginalis* > *Ludwigia hyssofolia* > *Fimbrystylis miliaceae* > *Cyperus difformis* (Ho and Md. Zuki, 1988). In the first season 1989 (82% of the Muda area), 57 species of weeds in 28 families was recorded. The most troublesome weeds are *Echinochloa crus-galli* > *Leptochloa chinensis* > *F. miliaceae* > *Marsilia crenata* > *M. vaginalis* (Ho and Itoh, 1991). Azmi *et al*. (1993) indicated that the most dominant weed species are *Echinochloa crus-galli* > *F. miliaceae* > *L. chinensis*

> *Scirpus grossus*. *M. vaginalis* > *E. crus-galli* > *Bacopa rotundifolia* > *Cyperus iria* > *L. chinensis* (Azmi, 1994). Pane (1997) and (Pane *et al*., 1998) recorded the highest weed species are *L. chinensis* > *F. miliaceae* > *E. crus-galli* > *L. octovalvis*. Whereas, Begum *et al*. (2005a; 2005b) observed the weed vegetation in terms of percentage field infestation were *O. sativa* complex (weedy rice) > *L. chinensis* > *E. crus-galli* > *I. rugosum* > *F. miliaceae* > *L. hyssipoflia*. Thus, widespread transformation of rice cultivation method from manual transplanting to direct seeding has created a rapid change in weed spectrum in Muda area. Changing of distribution of weeds species has occurred problems to select the suitable management of weeds on how to overcome this problem. Recently, weedy rice (*Oryza sativa* complex) is considered a new weed species has established and emerging threat to rice production in certain rice areas of Peninsular Malaysia (Azmi *et al*., 1994). Weedy rice infestation was indicated as early as in 1988 in Projek Barat Laut Selangor (PBLS) and Muda area in 1990 (Azmi and Abdullah, 1998).

Generally, the existing of several weeds from different habitats varied in term of growth strategy in order to survive with other species. Most plant ommunities exhibit both vertical and horizontal differentiation. For example, different species occur at various height above ground and also distributed differently along the ground surface (Radosevich and Holt, 1984). Kershaw and Looney (1985) also mentioned that pattern in vegetation is the spatial arrangement of individuals of a different species. This phenomenon consists of morphological pattern controlled by its morphological characteristics, for example roots, shoots and rhizomes with respect to its growth development, environmental pattern developed in vegetation in response to a general and overall variation of one of the major environmental factors and producers a pattern of density distribution and sociological pattern caused by the effect of an individual on environment which can be quite independent of the age of the individual. Knowledge about the weed community emergence pattern could suggest planting dates for annual crops with limited herbicide option that may minimize weed interference and also benefit growth simulation models that have been developed for crops grown in this region (Kiniry *et al*., 1992). Indeed, management and planning of weeds program are associated with planting activities. Weeds control program is not only to eradicate weeds species but it might be changed their distribution and relationship between species due to disturb their nature ecology, competition interaction, weeds suppression as well as form of growth development in community.

2.1.2 Soil and longevity of seedbank

Most agricultural soils contain a large reservoir of weed seeds which germinate over time (Navie *et al*., 2004). 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 (Zimdahl *et al*., 1988).

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 the distribution 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 aboveground plant community (Swanton and Booth, 2004). As a result, seedbanks are very important to the ecology of communities and to recruitment of species, particularly those that rely mostly or totally on non-vegetative means of reproduction (Navie *et al*., 1996). Thill *et al*. (1985) and Zamora and Thill (1989) also stated that the soil seedbanks are important 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 nondormant seeds. Furthermore, an important element in seedbank dynamics is seedbank depletion (Westerman, 2003; van Mourik *et al*., 2005), unsuccessful germination (Grundy *et al*., 2003), seed movement (Lonsdale, 1993; Colbach *et al*., 2000; Forcela, 2003) and seed mortality as a result of ageing and attack by pathogens (Lonsdale, 1993; Forcela, 2003). The soil seedbank divided into surface seedbank (active seedbank) and buried seedbank (dormant seedbank). Rao (2000) stated that seedbanks are composed of numerous species belonging to three groups. The first group includes a few dominant species accounting for 70 to 90% of total seedbank. These species represent 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 geographic area however not to current production practices. The third group accounts for a small percentage of the total seed and includes recalcitrant seeds from previous seedbanks of the previous crop (Wilson *et al*., 1988). This group undergoes constant change due to seed dispersal by humans, other animals, wind and water. Buhler *et al*. (1997) mentioned that weed seedbank characteristic influence both the weed populations that occur in a field and the success of weed management. Weeds produce a lot of seed. Most of the seeds entering the seedbank come from annual weeds (Rao, 2000). New seeds may enter the seedbank through many sources, but the largest source is plants producing seed within the field (Cavers, 1983). Mortimer (1990) stated that comparatively there are between 100 and 1000 seeds m^{-2} in forest soils, 100 and 1000000 m^{-2} in grassland and arable soils 1000 and 100 000 m^{-2}. Generally, the size of seedbank in agricultural land ranges from near zero to as much as 1 million seed m^{-2} (Fenner, 1987). Many processes are involved in the generation and regulation of the seedbank in the soil as illustrated in Figure 2.1.1.

Management practices have major impacts on these processes (Mulugeta and Stoltenberg, 1997a; 1997b; Webster *et al*., 2003). Evidently, farming practices influence the quantities of seeds returned to and removed from the soil. Therefore, cultural practices can have a substantial effect on species composition and seed density in agricultural fields. In addition, depending on agronomic management practices used (tillage), buried seed stays viable for several years and different types of tillage systems also may affect weed seed population. For example, after 7 to 8 years of standard chemical and mechanical weed control, from 1500 to 3000 weed seeds per m^2 (to a 10 cm depth) were found in continuous corn using a ridge tillage systems,

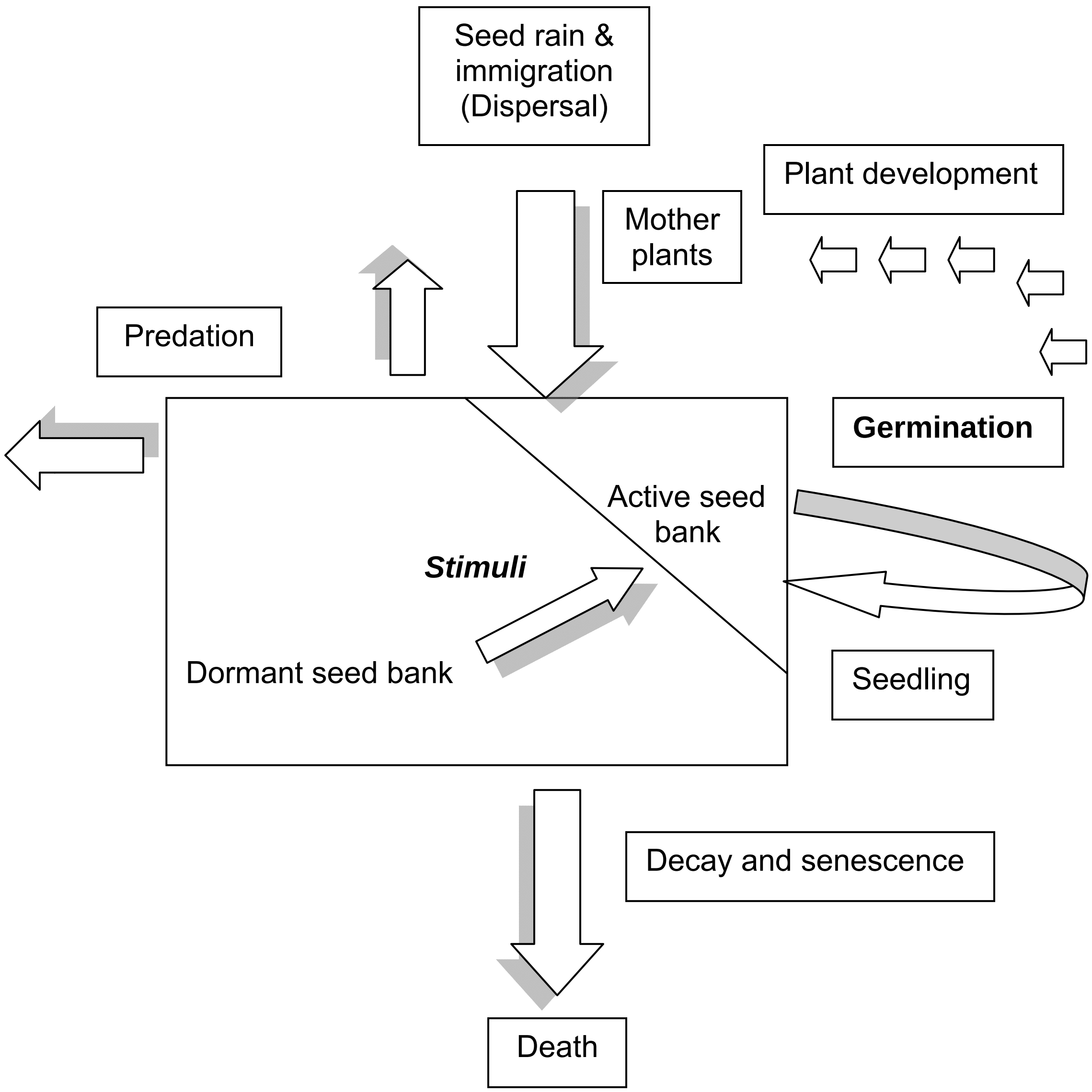

Figure 2.1.1: Diagrammatic flow chart for the dynamics of the population of weed seed bank in the soil (adapted from Harper, 1977)

while about two-third fewer seeds were found in conventionally tilled corn (Forcell and Lindstrom, 1988).

The seedbank is a function of the longevity of seeds in the soil and determined by the inherent viability of seeds and dormancy mechanisms (Maillet, 1991). 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 ricefields in the Muda area (Ismail *et al*., 1995). Considerable longevity of seeds is a widespread characteristic. Some seeds could be buried up to 10" (26 cm) deep and do not surface for years. Therefore, 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/m) even greater than in the other two plantation crops. These seeds had a high germination rate of about 80% (Ismail, 1989). In Brazil, de Avila *et al*. (2000) reported that red rice (*Oryza sativa* complex) is one of the most important weeds of lowland rice, causing yield and quality losses and rendering land usable for rice production due to the buildup of a persistent seed bank. It has seed longevity in the soil. Seed longevity in the soil is ecotype-dependent and is also affected by burial depth, soil type and moisture, and dormancy density as well (Noldin, 2000).

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 (Holzner, 1982). Therefore, an in depth study on ecology of weeds weedy rice have to proceed particularly on management of its seed bank during pre-planting period (Watanabe *et al*., 1999; Abdullah and Mohamed, 2002). In Korea, Pyon *et al*. (2000) stated that 2.7% - 3.7% emergence of cultivated rice and 17.0% - 26.3% emergence of weedy rice occurred during planting before winter. Besides, emergence percentages were higher at shallower depth than in deep soil. Weedy rice can be emerged (60% and 100% germination) at the 9 cm water depth but cultivated rice did not emerge at the same depth.

Although seed of many weed species have the potential for long-term survival in the seed bank, most seeds have a short life span (Murdoch and Ellis, 1992). Factors accounting for the loss of weeds in the soil include germination, decay, predation, and physical movement. The relative importance of these mechanisms varies with species and environmental conditions (Buhler *et al*., 1997). Anderson (1996) also indicated that some seeds will be lost to predation by insects, arthropods, rodents, and birds.

2.2 WEED BIOLOGY

2.2 1 Roles of weed biology

Weeds are group of plants of which are neither desirable nor economical values to surroundings. They have special characteristic such as tolerance to environmental changes, production of large numbers of seeds and high competitive ability (Ismail, 1989), rapid growth through vegetative phase to flowering, discontinuous germination (internally controlled) and great longevity of seed (Monaco *et al*., 2002). Therefore, an understanding of the biology of weed is very useful due to improve weed management strategies. In the rice cropping system, knowledge on the biological identification (morphology and anatomy), distribution and life cycle as well as ecological aspect should be taken into consideration during planning on how to decrease the population of weeds.

2.2.2 Genetic diversity in weedy rice (*O. sativa* complex)

The evolution of weeds is a complex phenomenon. Baker (1974) and De Wet and Harlan (1975) discussed the weeds evolve within the man-made habitats in three principal ways: (a) from wild colonizers through selection toward adaptation to continuous habitat disturbance; (b) as derivatives of hybridization between wild and cultivated races of domestic species; and (c) from abandoned domesticates through selection towards a less intimate association with man. Moreover, Mortimer (1990) has reviewed that the evolution of weeds may be seen at three levels: (a) speciation; genetic change in a taxon and the evolution of a species with characters favouring growth in disturbed an unpredictable habitat; (b) race formation in which locally adapted races of a weed species occur; and (c) crop mimicry where the association of crop and weed is so intimately associated with man that it has led to the evolution of mimetic weeds. Weedy rice is considered to have various origins. Weedy rice found in regions where no wild rice occurs is probably derivatives of cultigens.

Weedy rice usually involves hybridization and/or selection of shattering types within the primary gene pools of the two rice cultigens, *O. sativa* and *O. glaberrima*, and their close relatives that share the AA genome (Vaughan, 1994; Vaughan *et al*., 2001). However, Abdullah *et al*. (1996a; 1996b) reported that there are two possible ways that weedy rice in the Malaysian granaries evolved from cultivated rice either by spontaneous mutation of genes controlling shattering or by hybridizing among cultivars and subsequent selection favoring shattering phenotypes.

According to Azmi and Abdullah (1998), the origin of weedy rice has been very speculative because of two reasons. Firstly, the grain features of weedy rice and its variant strains are similar to the modern cultivated rice and secondly, a similar observation of annual weedy types or intermediate types (genotypes believed to be natural hybrids) has been reported in countries.

Based on these reasons, there are indications that gene(s) introgression has taken place in the past between cultivated rice and O. *rufipogon*, a wild rice commonly found in the Muda area. DNA analysis using randomly amplified polymorphic DNA (RAPD) markers confirmed that the genetic structure of weedy rice plants was also of close similarity to cultivated rice, shows that the Malaysian weedy rice could have originated from cultivated rice (Vaughan *et al*., 1995a; 1995b; Abdullah *et al*., 1996a; 1996b).

In Surinam, Watanabe *et al*. (2000) recognized two types of weedy rice; one type was resulting from dropped seeds from previous harvests and red rice. Whereas in Korea, Tang and Morishima (1997), found that weedy rice strains may be originated from wild vs. cultivated type variation and from indica-japonica variation. Generally, weedy rice is a hybrid between wild rice and cultivated rice. Several studies have done concerning with the origin of weedy rice (Noldin, 2000; Sato, 2000; Song *et al*., 2002; Chen *et al*., 2004; Arrieta-Espinoza *et al*., 2005).

2.2.3 Weed competitiveness

In general, among annual weeds, broadleaved weeds are more competitive than are grass weeds (Anderson, 1996). Competition between weeds and rice is a negative interaction that minimizes rice yield. The degree of competition is closely associated to the life cycle of the crop. Keeping annual crops weed-free during the first third of their life cycle is critical, since that is the period when weed competition is the most damaging (De Datta, 1981). Competition that occurs later in the crop life cycle usually results in minimal yield loss, although seeds from late-season weed infestations can become a problem in subsequent crops. Competitive ability of rice is measured in terms of weed effects on yield and other plant characters that contribute to yield. In any case it is clear that weeds reduce yields by competing with the crops for light, water and nutrients as well as by exerting a negative influence through (active or passive) emission of different substances (Holzner, 1982). Weed competition is complicated because of several factors affected and influenced by the degree of competition encountered by weeds and crop, a s shown in Figure 2.2.1. Aldrich (1984) and Akobundu (1987) mentioned the competitive interactions are influence by several morphological and physiological characteristics of the crop and the weed species, related to rate of growth, leaf area development and light absorption capacity of the leaves.

Generally, competition begins as soon as the root system of one plant invades a feeding area of another (Pavkycheno, *cited in* Radosevich and Holt, 1984). According to De Datta (1981) the greatest competition occurs when the plants are similar in their growth habit, for example root growth and foliage characteristics because they make nearly the same demands on the environment. Weed competition is more severe during the early stage of plant growth where difficult to distinguish between some grasses and rice plants (Chandler, 1979). Reduction in height, tiller number, leaf area, dry weight shoot weight and seed yield (Fischer *et al*. 1995) can result in low yield. Competition of weeds are well documented and increased in fallow ricefields,

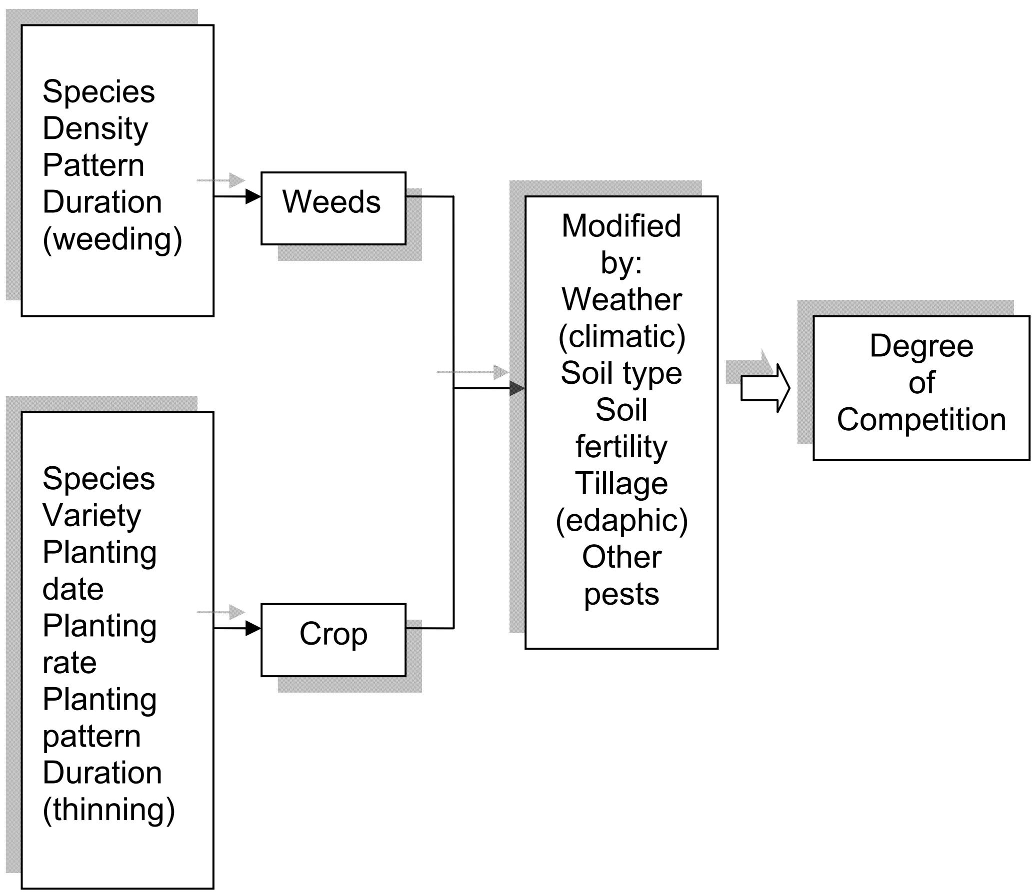

Figure 2.2.1: Interacting forces in weed-crop competition
(adapted from Aldrich, 1984)