

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

by

ZAINAL ABIDIN BIN HJ. ABDUL HAMID

**Thesis submitted in fulfilment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY**

February 2008

ACKNOWLEDGEMENT

In the name of Allah, the most merciful, the most compassionate. I praise Allah the Almighty, for giving me the health, peace of mind and strength to persevere and continue in my struggle for success.

This study would not have been made possible but for the advice, help and cooperation of various individuals. First and foremost, I would like to express my sincere appreciation to my respected main Supervisor, Professor Dr. Hj. Mashhor Mansor and to my co-Supervisor Dr. Hj. Azmi Man (Mardi, Bertam) for their endless help and guidance, encouragement, enthusiasm and unfailing support extended throughout the whole process of completing my thesis. I would also like to take this opportunity to express my gratitude to Universiti Sains Malaysia for all facilities provided to enable me in conducting the field and plant house studies.

My deep indebtedness to the Malaysian Government under Education Ministry for its generous offer of sponsorship during my study at Universiti Sains Malaysia. I would like to express my gratefulness to the Director of Muda Agricultural Development Authority (MADA) and his staff for giving their support and cooperation throughout the duration of my studies. I am indebted to all the many farmers who had spent time and their invaluable participation made this study possible especially Hj. Ibrahim Shaari for providing study sites and cooperation during the study period.

To all members of the Electron microscopy unit, Ms Jamilah, Mr Johari and Mr Ganesh, Mr Saadon, Mr Muthu and Mr Nordin, thank you for your

patience and guidance in the laboratory and fields works. Last but not least, I wish to thank all those who in one way or another contributed to the completion of this thesis.

Finally, this thesis is especially dedicated to my beloved family, for their sacrifice, love and understanding during my study.

TABLE OF CONTENTS

	Page
Acknowledgements	ii
Table of Contents	iv
List of Tables	viii
List of Figures	xiii
List of Plates	xviii
Abstrak	xx
Abstract	xxii
CHAPTER 1 – GENERAL INTRODUCTION	
1.1 INTRODUCTION	1
1.1.1 General Background of the Study	1
1.1.2 Approaches and Objectives of the Study	7
CHAPTER 2 – LITERATURE REVIEW	
2.1 WEED ECOLOGY	10
2.1.1 Changing of weed community	10
2.1.2 Soil and longevity of seedbank	14
2.2 WEED BIOLOGY	20
2.2.1 Roles of weed biology	20
2.2.2 Genetic diversity in weedy rice (<i>O. sativa</i> complex)	20
2.2.3 Weed competitiveness	22
2.2.4 Yield loss due to weeds	25
2.3 WEEDY RICE (<i>Oryza sativa</i> complex)	28
2.3.1 Biology and distribution	28
2.3.2 Dormancy and germination	36
2.3.3 Economic importance of weeds	38

2.4	MANAGEMENT AND CULTURAL PRACTICES OF WEEDS	38
2.4.1	Principles of weed management	38
2.4.2	Selection for control method	40
2.4.3	Effectiveness of using herbicides	41
2.4.4	Nitrogen fertilizer effectiveness	43
2.4.5	Seedbed preparation	45
2.4.6	Water management	46
2.4.7	Approaches for Integrated Weed Management	48
CHAPTER 3	– ECOLOGICAL STUDY	52
3.1	WEED SURVEY IN MUDA RICEFIELDS	52
3.1.1	Introduction	52
3.1.2	Materials and Methods	54
3.1.3	Results	58
3.1.3.1	Survey on <i>O. sativa</i> complex distribution in the Muda area	58
3.1.3.2	Weed distribution in the Muda ricefields area during main season 2003 to off-season 2005	62
3.1.4	Discussion	74
3.2	SEASONAL VARIATION IN THE WEED SEEDBANK OF COMMON WEED SPECIES	78
3.2.1	Introduction	78
3.2.2	Materials and Methods	81
3.2.3	Results	84
3.2.3.1	Seeds emergence	84
3.2.3.2	Weed species density in the soil seedbank	86
3.2.3.3	Weed species composition in the soil seedbank	87
3.2.4	Discussion	99
3.2.4.1	Weed species density in the soil seedbank	99
3.2.4.2	Weed species composition in the soil seedbank	100
3.3	EFFECT OF CULTURAL PRACTICES ON WEEDY RICE POPULATION AND RICE YIELD PRODUCTION	106
3.3.1	Introduction	106
3.3.2	Materials and Methods	107
3.3.3	Results	111
3.3.3.1	Farmers' profile	111
3.3.3.2	Land preparation	113
3.3.3.3	Distribution of weedy rice	115
3.3.3.4	Productivity – grain and yield components	123
3.3.4	Discussion	125

CHAPTER 4 – BIOLOGICAL STUDY	131
4.1 LIFE CYCLE AND MORPHOLOGICAL CHARACTERISTICS OF WEEDY RICE	131
4.1.1 Introduction	131
4.1.2 Materials and Methods	133
4.1.3 Results	137
4.1.3.1 Morphological and topographical characteristics of weedy rice	137
4.1.3.2 Growth pattern of weedy rice	145
4.1.4 Discussion	154
4.1.4.1 Morphological and topographical characteristics of weedy rice	154
4.1.4.2 Growth pattern of weedy rice	158
4.2 STUDIES ON PLANT DEMOGRAPHY OF WEEDY RICE	162
4.2.1 Introduction	162
4.2.2 Materials and Methods	164
4.2.3 Results	167
4.2.4 Discussion	173
4.3 THE EFFECT OF REDOX POTENTIAL ON THE GERMINATION AND GROWTH OF WEEDY RICE	176
4.3.1 Introduction	176
4.3.2 Materials and Methods	178
Experiment 1: Laboratory Experiment	178
Experiment 2: Plant house Experiment	181
Experiment 3: Field Experiment	183
4.3.3 Results	184
Experiment 1: Laboratory Experiment	184
Experiment 2: Plant house Experiment	190
Experiment 3: Field Experiment	192
4.3.4 Discussion	195
CHAPTER 5 – CONTROL AND MANAGEMENT OF WEEDY RICE	202
5.1 INFLUENCE OF FLOODING ON WEEDY RICE EMERGENCE AND GROWTH	202
5.1.1 Introduction	202
5.1.2 Materials and Methods	204
5.1.3 Results	206
5.1.3.1 Seed germination	206
5.1.3.2 Plant growth	209
5.1.4 Discussion	216

5.2	THE EFFECTS OF NITROGEN ON RICE YIELD	219
5.2.1	Introduction	219
5.2.2	Materials and Methods	221
5.2.3	Results	224
5.2.3.1	Vegetative growth of rice plants	224
5.2.3.2	Yield components and rice yield	235
5.2.4	Discussion	239
5.3	FARMERS' ATTITUDE AND PERCEPTION ON WEED MANAGEMENT	244
5.3.1	Introduction	244
5.3.2	Materials and Methods	246
5.3.2.1	The study area	246
5.3.2.2	Sampling and instruments	246
5.3.3	Results	251
5.3.3.1	Farmer respondents' demographic profile	254
5.3.3.2	Weed management	264
5.3.4	Discussion	271
	CHAPTER 6 – GENERAL DISCUSSION	271
6.1	Ecological and Biological Study	271
6.1.1	Distribution of weed species in the Muda rice granary area	271
6.1.2	Control and weed management	275
6.2	Recommendation for further research	280
	BIBLIOGRAPHY	283
	APPENDICES	311
1	Analysis of total organic nitrogen in soil Semi-Micro Kjeldahl Digestion	311
2	Analysis of total phosphorus	314
3	Analysis potassium	317
4	Analysis of nitrogen from plant samples: A semi-micro Kjeldahl methods	318
5	SEM Tissue Preparation Schedule (HMDS Technique)	321
6	Questionnaire form	323
7	List of published papers from 2003-2006	329

LIST OF TABLES

		Page
Table 2.3.1	Undesirable characteristics of weedy rice including evolutionary characteristics in rice production in Malaysia	34
Table 3.1.1	Occurrence and distribution of weed species in the Muda area from 2/2003 to 1/2005 season	63
Table 3.1.2	Comparison of relative density, relative dominance, relative frequency and importance value index on dominance of weed species in ricefields during rice growing period in Muda area for four consecutive seasons (2/2003 to 1/2005 seasons)	64
Table 3.1.3	Comparison of relative density, relative dominance, relative frequency and importance value index on dominance of weed species in ricefields during rice growing period in Muda area for four consecutive seasons (2/2003 to 1/2005 seasons)	67
Table 3.1.4	Rate scale of I.V. on weed species in ricefields during rice growing period in Muda area from 2/2003 to 1/2005 season	68
Table 3.1.5	Cluster nodes values for the weeds species	71
Table 3.1.6	Cluster nodes values	73
Table 3.2.1	Cluster nodes values	96
Table 3.2.2	Cluster nodes values	98
Table 3.3.1	Comparison of rice varieties in five study sites in Kampung Tandop, Guar Chempedak, Kedah for four consecutive seasons	112
Table 3.3.2	Comparison of crop establishment methods in five study sites in Kampung Tandop, Guar Chempedak, Kedah for four consecutive seasons	112
Table 3.3.3	Lists of farmers' cultural practices on reducing weeds population in ricefields in Kampung Tandop, Guar Chempedak, Kedah	114

Table 3.3.4	Comparison of grain yield (expected yield) in the five study sites in Kampung Tandop, Guar Chempedak, Kedah for four consecutive seasons	124
Table 3.3.5	Comparison of grain yield (actual yield) in the five study sites in Kampung Tandop, Guar Chempedak, Kedah for four consecutive seasons	124
Table 4.1.1	Comparison of growth pattern of weedy rice sown in plant house condition	147
Table 4.1.2	Summary of roughness present on the leaf surface	156
Table 4.2.1	Life table of the weedy rice (<i>Oryza sativa</i> complex) treated without nitrogen planted in plant house	169
Table 4.2.2	Values of L_x , T_x , and e_x (mean expectation of life)	169
Table 4.2.3	Life table of the weedy rice (<i>Oryza sativa</i> complex) treated with 150kg N/ha planted in plant house	170
Table 4.2.4	Values of L_x , T_x , and e_x (mean expectation of life)	170
Table 5.1.2	Percentage (%) of <i>O. sativa</i> complex seed emergence under different times and depths of flooding	207
Table 5.1.2	Effect of plant heights (cm) of <i>O. sativa</i> complex under different times and depths of flooding	210
Table 5.1.3	Effect of root lengths (cm) of <i>O. sativa</i> complex under different times and depths of flooding	211
Table 5.1.4	Effect of dry weight (g) of roots of <i>O. sativa</i> complex under different times and depths of flooding	213
Table 5.1.5	Effect of dry weight (g) of shoots of <i>O. sativa</i> complex under different times and depths of flooding	214

Table 5.1.6	Effect of total dry weight (g) of <i>O. sativa</i> complex under different times and depths of flooding	215
Table 5.2.1	Plant height of rice as affected by nitrogen fertilization and weedy rice competition at 30 DAS	226
Table 5.2.2	Tiller numbers of rice as affected by nitrogen fertilization and weedy rice competition at 30 DAS	226
Table 5.2.3	Chlorophyll contents of rice leaves as affected by nitrogen fertilization and weedy rice competition at 30 DAS	227
Table 5.2.4	Plant height of rice as affected by nitrogen fertilization and weedy rice competition at 60 DAS	227
Table 5.2.5	Tiller number of rice as affected by nitrogen fertilization and weedy rice competition at 60 DAS	228
Table 5.2.6	Chlorophyll contents of rice leaves as affected by nitrogen fertilization and weedy rice competition at 60 DAS	228
Table 5.2.7	Plant heights of rice as affected by nitrogen fertilization and weedy rice competition at harvest	229
Table 5.2.8	Tiller numbers of rice as affected by nitrogen fertilization and weedy rice competition at harvest	229
Table 5.2.9	Chlorophyll contents of rice as affected by nitrogen fertilization and weedy rice competition at harvest	230
Table 5.2.10	Dry weights of rice straw as affected by nitrogen fertilization and weedy rice competition at harvest	232
Table 5.2.11	Dry weights of rice plant as affected by nitrogen fertilization and weedy rice competition at harvest	232

Table 5.2.12	Nitrogen contents of rice as affected by nitrogen fertilization and weedy rice competition at harvest	234
Table 5.2.13	Number of panicles per plant as affected by nitrogen fertilization and weedy rice competition at harvest	236
Table 5.2.14	Percentage (%) of filled grain of rice as affected by nitrogen fertilization and weedy rice competition at harvest	236
Table 5.2.15	Weights of 1000 grains of rice as affected by nitrogen fertilization and weedy rice competition at harvest	237
Table 5.2.16	Grain yield of rice as affected by nitrogen fertilization and weedy rice competition at different rates of nitrogen fertilization	237
Table 5.3.1	Detail number of farmers distributions out of 244 farmers from 27 localities of Mada area	253
Table 5.3.2	Frequency distribution of farmers' demographic profile of the surveyed farmers (total respondents = 244)	253
Table 5.3.3	Frequency of farmers' cultural practices on reducing weeds population cited in 244 interviews in ricefields in Muda area	255
Table 5.3.4	The most dominant herbicide usages based on 244 farms' surveyed in the Muda area, Kedah	256
Table 5.3.5	Farmers perception of important dominant weeds species out of 244 farms' surveyed in the Muda area, Kedah	257
Table 5.3.6	Farmers perception of important dominant weeds species resistant out of 244 farms' surveyed in the Muda area, Kedah	257
Table 5.3.7	Comparison of means of the different aged groups across rice yield during main season 2004 (2/2004)	259
Table 5.3.8	Cross tabulation between Age and Grain Yield for 1/2005 season	259

Table 5.3.9	Cross tabulation between Age and Grain Yield for 1/2004 season	260
Table 5.3.10	Cross tabulation between Age and Grain Yield for 2/2004 season	260
Table 5.3.11	Cross tabulation between age and the highest yield achieved	261
Table 5.3.12	Grain yield among farmers as for three consecutive season in Muda areas	261
Table 5.3.13	Farmers' perception of the general identification method of weedy rice	263

LIST OF FIGURES

		Page
Figure 1.1.1	Muda area in Peninsular Malaysia	5
Figure 2.1.1	Diagrammatic flow chart for the dynamics of the population of weed seed bank in the soil	17
Figure 2.2.1	Interacting forces in weed-crop competition	24
Figure 2.3.1	Geographical distribution of weedy rice (<i>Oryza sativa</i> complex) in the world (adapted from Baki, 2005)	33
Figure 2.4.1	Research strategy for the development of an integrated weed management system	51
Figure 3.1.1	Map of sampling sites at Muda area	55
Figure 3.1.2	Percentage of area infested by weedy rice (<i>Oryza sativa</i> complex) in Muda area from 1993 to 2004 (Mada's data)	59
Figure 3.1.3	Area infested pattern by weedy rice during 12 year (1993-2004) in Muda area (source: Mada's data)	60
Figure 3.1.4	Mean monthly rainfall distribution in Muda area from 1993 to 2004	60
Figure 3.1.5	Rainfall distribution in Muda area in 1996 and 2004	61
Figure 3.1.6	Importance value of five dominance weeds species in Muda area during period studied (main season 2003/04, off-season 2004, main season 2004/05 and off-season 2005)	69
Figure 3.1.7	A dendrogram resulting from cluster analysis of the weed species distribution. The most similar weed species are clustered together	72
Figure 3.1.8	Dendrogram of the cluster analysis for the difference planting season in Muda area for four consecutive seasons	73
Figure 3.2.1	Number of seedlings of eight dominant weed species from Kampung Tandop, Yan, Kedah ricefields soils (from 5 sampling sites) for four consecutive seasons	85

Figure 3.2.2	Number of individual seedlings of each species at every temporal observations which germinated from soil seedbank at Kampung Tandop, Guar Chempedak, Kedah for four consecutive seasons (season 1/2004 to 2/2005)	88
Figure 3.2.3a	Average number of individuals and total accumulation of dominant weed seed germination from Kampung Tandop, Yan, Kedah ricefield for off-season 2004 (1/2004) (mean of 5 replications)	90
Figure 3.2.3b	Average number of individuals and total accumulation of dominant weed seed germination from Kampung Tandop, Yan, Kedah ricefield for main-season 2004 (2/2004) (mean of 5 replications)	91
Figure 3.2.3c	Average number of individuals and total accumulation of dominant weed seed germination from Kampung Tandop, Yan, Kedah ricefield for off-season 2005 (1/2005) (mean of 5 replications)	92
Figure 3.2.3d	Average number of individuals and total accumulation of dominant weed seed germination from Kampung Tandop, Yan, Kedah ricefield for main-season 2005 (1/2005) (mean of 5 replications)	93
Figure 3.2.4	Importance value (%) of eight common weed species which were found in the soil seedbank at Kampung Tandop, Guar Chempedak, Yan, Kedah ricefield	95
Figure 3.2.5	A dendrogram resulting from cluster analysis (UPGMA) of the common weed seedlings in soil seedbank using Pearson's similarity coefficient	96
Figure 3.2.6	PCA biplot of distribution of weed seeds emergence and growing seasons based on the scores Eigenvalues	97
Figure 3.2.7	Dendrogram representing an unweighted pair group mean cluster analysis (UPGMA) for weed species and planting seasons in soil seedbank. The most similar seasons are clustered together	98
Figure 3.3.1	Map of the five sampling sites in Kampung Tandop, Guar Chempedak. A, B, C, D, and E represents the study sites	110

Figure 3.3.2(a)	Comparison crop establishment method on distribution of weedy rice for four consecutive seasons	116
Figure 3.3.2(b)	Comparison crop establishment method on distribution of weedy rice for four consecutive seasons	117
Figure 3.3.2(c)	Comparison crop establishment method on distribution of weedy rice for four consecutive seasons	118
Figure 3.3.2(d)	Comparison crop establishment method on distribution of weedy rice for four consecutive seasons	119
Figure 3.3.2(e)	Comparison crop establishment method on distribution of weedy rice for four consecutive seasons	120
Figure 3.3.3	Distribution of weedy rice panicles/m ² for 50 sampling points from Kampung Tandop, Yan, Kedah ricefields for four consecutive seasons (season 1/2004 to 2/2005)	121
Figure 3.3.4	Comparison the distribution of weedy rice panicles among the farmers for four consecutive seasons. Vertical bars represent \pm S.E	122
Figure 4.1.1	Comparison of tiller production of variants of weedy rice planted in plant house condition. Vertical bars represent \pm S.E	149
Figure 4.1.2	Linear regression of number of tiller production by variants of weedy rice	150
Figure 4.1.3	Comparison of plant height of variants of weedy rice planted in plant house condition. Vertical bars represent \pm S.E	151
Figure 4.1.4	Relationship between plant heights of weedy rice variants and days after seeding	152

Figure 4.1.5	Schematic representation of the life cycle of weedy rice (open panicle variant). A = seed; B = pregerminated seed (3-8 days after seeding, DAS); C = 2-3 leaf-stage (7-10 DAS), D = 1-2 tillers stage (15-20 DAS), E = active tillering stage (25-30 DAS), F = maximum tillering/booting stage (40 – 50 DAS), G = Heading stage (55-60 DAS), H = Flowering/maturation stage (60-95 DAS). A-E = Vegetative phase; E-F = Reproductive phase; F-H = Ripening phase	153
Figure 4.2.1	Life expectancies (e_x) for weedy rice. Vertical bars represent \pm S.E	171
Figure 4.2.2	Survivorship curves for population of weedy rice. Vertical bars represent \pm S.E	171
Figure 4.2.3	Diagrammatic life-table for weedy rice which was treated with (A) 0 kg N/ha and (B) 150 kg N/ha, in plant house condition. By convention, rectangles represent stages of the life-cycle; inverted triangles represent transition probabilities between stages and the diamonds represent seed production	179
Figure 4.3.1	The physical set up of the redox potential experiment under room condition. Redox potential and dissolved oxygen reading were taken from A, B, and C for both tubes	185
Figure 4.3.2 (A and B)	Changes of redox potential readings taken at the surface; middle surface; bottom from substrate. Vertical bars represent \pm S.E. A = aerobic condition, B = anaerobic condition	186
Figure 4.3.3	Changes in redox potential and dissolved oxygen. Vertical bars represent \pm S.E	187
Figure 4.3.4	Changes of redox potential and plant growth under Vertical bars represent \pm S.E Vertical bars represent \pm S.E. (A) aerobic and (B) anaerobic condition	188
Figure 4.3.5	Relationship between redox potential (mV) and dissolved oxygen (mg/L)	191
Figure 4.3.6	Changes in redox potential of difference water depth planted in plant house condition. Vertical bars represent \pm S.E	191

Figure 4.3.7	Changes in dissolved oxygen of difference water depth planted in plant house condition. Vertical bars represent \pm S.E	193
Figure 4.3.8	Changes of redox potential, dissolved oxygen, pH and water temperature during rainy season for five field plots in Guar Chempedak, Yan, Kedah. Vertical bars represent \pm S.E	194
Figure 4.3.9	Changes of redox potential, dissolved oxygen, pH and water temperature during dry season for five field plots in Guar Chempedak, Yan, Kedah. Vertical bars represent \pm S.E	194
Figure 5.1.1	Effect of water depth and time of flooding on seed emergence and total dry weight of weedy rice at 28 DAS	208
Figure 5.2.1	Chlorophyll content of the leaves of rice plant and weedy rice at different rates of nitrogen fertilization	230
Figure 5.2.2	Dry weights of the plants of rice and weedy rice at different rates of nitrogen fertilization	233
Figure 5.2.3	Nitrogen contents of rice plant and weedy rice at different rates of nitrogen fertilization	234
Figure 5.3.1	Map of sampling sites based on MADA-localities in the Muda rice granary area	247
Figure 5.3.2	The structure of the questionnaire	252
Figure 6.1	Diagrammatic presentation of the life cycle of weedy rice-crop association, illustrating the temporal development of the surface and buried seedbanks in the soil with respect to direct seeded rice	277
Figure a	Sketch of Markham apparatus	313

LIST OF PLATES

		Page
Plate 2.3.1	Serious infestation of weedy rice in Guar Chempedak, Yan, Kedah's ricefield	35
Plate 2.3.2	Lodging caused by weedy rice infestation in Guar Chempedak, Yan, Kedah's ricefield	35
Plate 4.1.1	Variants of weedy rice which are used in the study. A = open panicle, non-pigmented; B= compact panicle, pigmented; and C = awned, close panicle, non-pigmented	134
Plate 4.1.2	Scanning electron micrographs of weedy rice shows morphological of seed surface with microhairs. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 200 μ m	138
Plate 4.1.3	Scanning electron micrographs show of morphological of weedy rice seed glume. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 100 μ m	139
Plate 4.1.4	Morphological of seed surface with gemmate papillae regularly arranged. Close-up of parallel rows of tubercles/trichomes. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 10 μ m	140
Plate 4.1.5	Morphological of seed surface with gemmate papillae regularly arranged. Close-up of parallel rows of tubercles/trichomes. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 10 μ m	141
Plate 4.1.6	Morphological of adaxial leaf surface views of weedy rice, with epicuticular cell layers which is covered waxes and microhairs/spines shatteringly locate and the rows of silica knobs can be distinctly seen. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 20 μ m	142

Plate 4.1.7	Morphological of weedy rice abaxial coleoptile surface sizes with the parallel rows of various of papillae stomata and microhairs, and generally covered with wax. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 10 μ m	143
Plate 4.1.8	Morphological structure of weedy rice stomata on abaxial surface covered with the dense wax deposits and with many silica knobs excluded the surface of guard cells. Four knobs except (c) locate at the four corners of peristomatal rims. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 2 μ m	144

KAJIAN BIOLOGI DAN KAEDAH KAWALAN TERPILIH PADI ANGIN (*Oryza sativa* kompleks) DALAM PENANAMAN PADI

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°S to 53°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

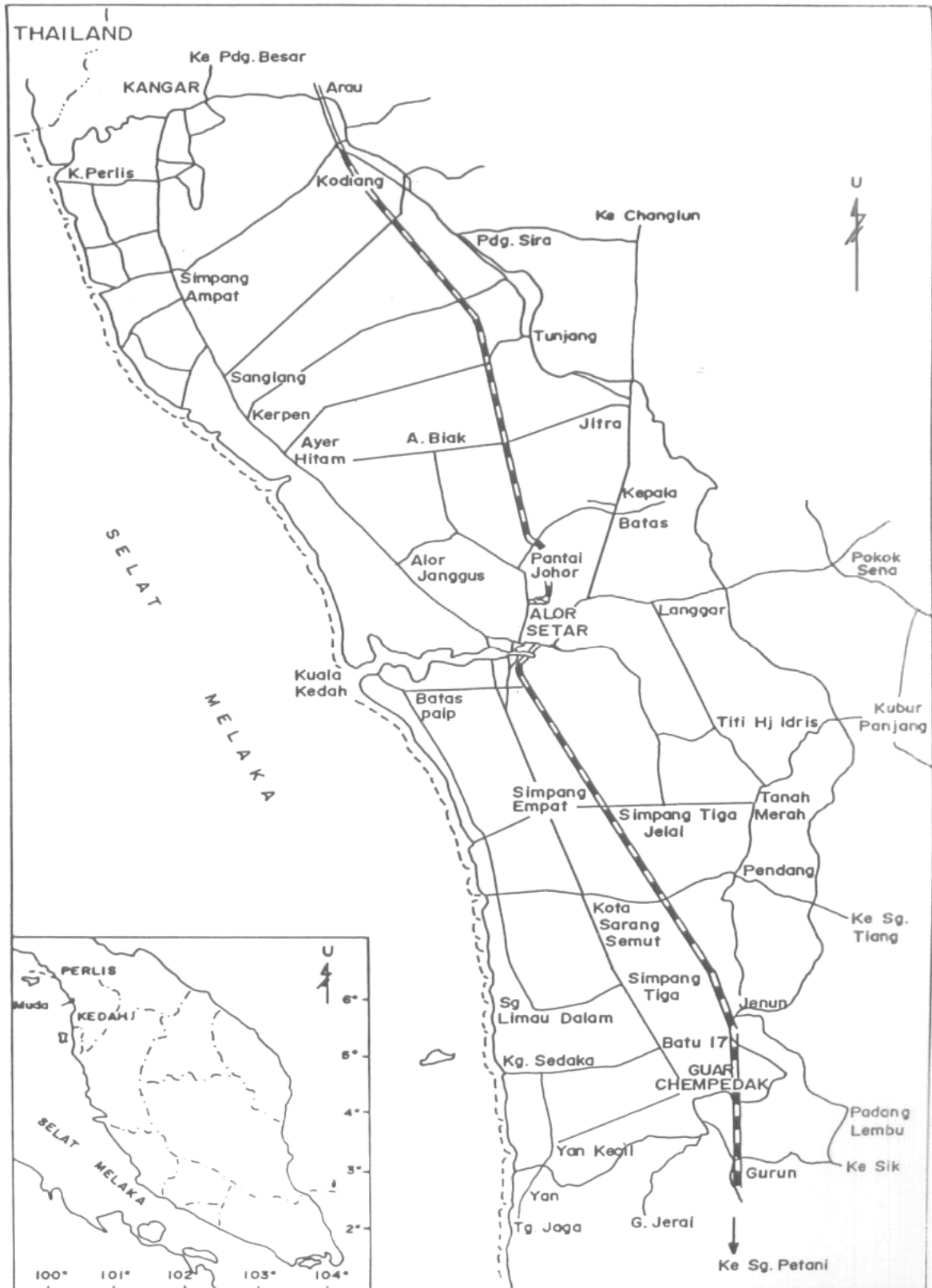


Figure 1.1.1: Muda area in Peninsular Malaysia

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 occurrence 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 hyssifolia* > *Fimbristylis 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 communities 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 produces 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 m² (to a 10 cm depth) were found in continuous corn using a ridge tillage systems,

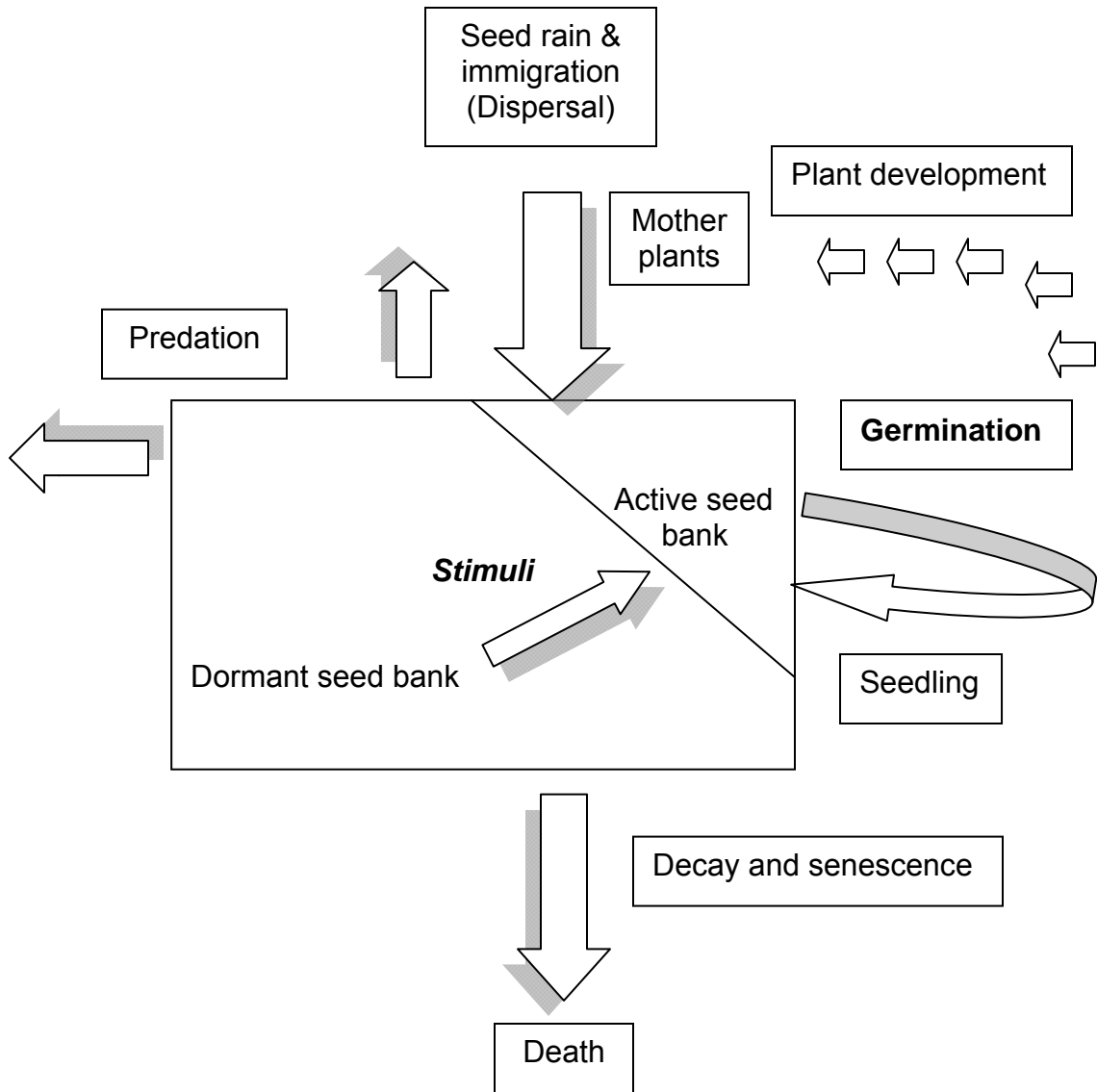


Figure 2.1.1: Diagrammatic flow chart for the dynamics of the population of weed seed bank in the soil (adapted from Harper, 1977)

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, as shown in Figure 2.2.1. Aldrich (1984) and Akobundu (1987) mentioned the competitive interactions are influenced 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,

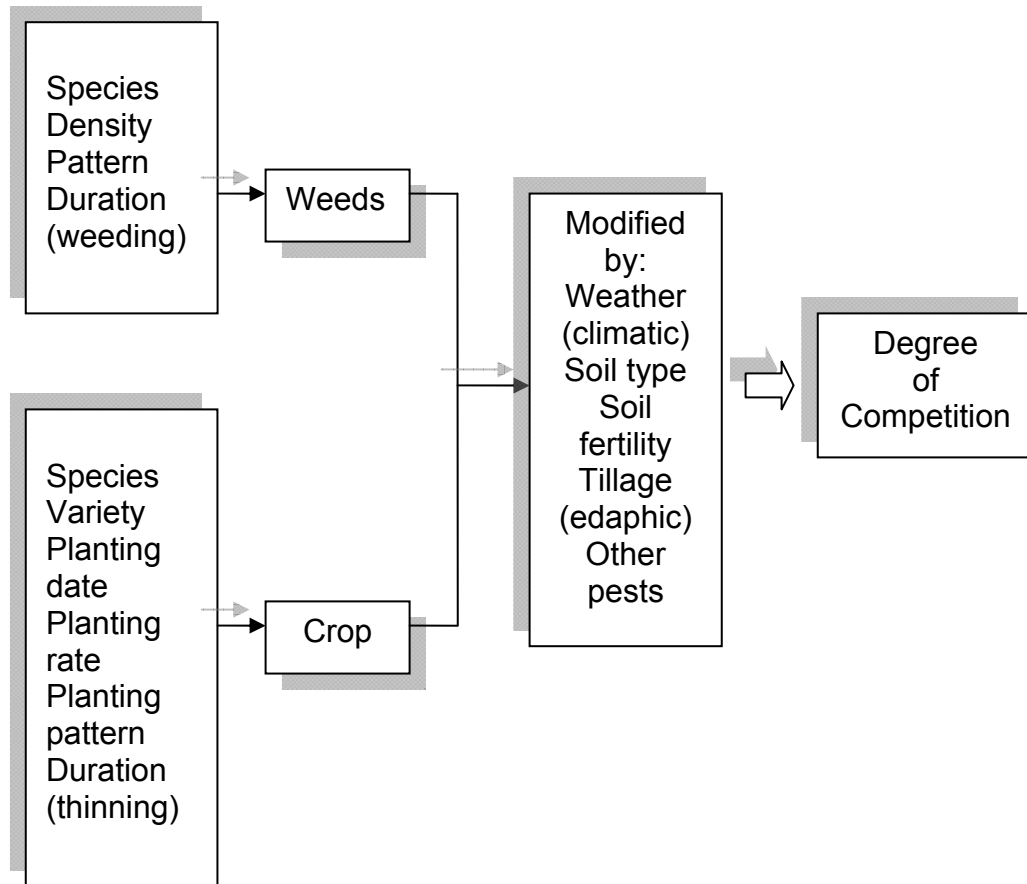


Figure 2.2.1: Interacting forces in weed-crop competition (adapted from Aldrich, 1984)