Rice Agroecosystem of the Muda Irrigation Scheme, MALAYSIA

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The Muda Irrigation Scheme of Malaysia ecompasses some 126 000 ha of coastal plain of which 97 000 ha are currently under rice cultivation. It is flanked by the Straits of Malacca to the west. The water source of this irrigation scheme is provided by three reservoirs impounded by the Muda Dam, Ahning Dam and Pedu Dam which are situated in the forested catchment area, east of the Muda granary. This book documents results of the ecosystem approach for studying the impact of agriculture, in particular pesticide application, in the Muda Irrigation Scheme. This important book makes a major contribution to the understanding of rice agroecosystem in this massive irrigation scheme, and will be of interest to scientists of Malaysia and other tropical countries, as well as to those specifically concerned with pesticide application.

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PART VI: IMPACT OF PESTICIDES ON THE RICE AGROECOSYSTEM IN THE MUDA AREA

Foreword

Large scale rice double cropping in Malaysia commenced in 1970 and subsequently the scenario of rice cultivation in the Muda area changed dramatically. The rapid adoption of nitrogen-responsive, high yielding rice varieties coupled with the provision of irrigation facilities led to the modification of the ricefield micro-climate and changes in species dominance of rice pests. Furthermore, the widespread transformation from manual transplanting to direct seeding further contributed to more competitive interaction of flora and fauna in the ricefields. Closer canopy and increased plant density have subjected the direct-seeded rice to a wider range of insect pests, disease pathogens and weeds. When adopting the 'direct seeding' technology, the rice soil surfaces are exposed during the entire crop establishment stage, causing grassy weeds and rice seeds to germinate simultaneously. Severe weed infestation has become a major constraint to yield improvement in direct seeded rice. Pest population in the ricefields are generally monitored and managed with minimal usage of pesticides except in cases where the populations have escalated beyond the action threshold.

Realizing the adverse effects of prolonged pesticide usage on the sustainability of rice production, the Muda Agricultural Development Authority (MADA) has embarked on joint studies with regard to the impact of pesticides on the rice agroecosystem in the Muda area. A Memorandum of Understanding between MADA and the Malaysian Institute for Nuclear Technology Research (MINT) was signed in 1992, so as to facilitate the National Technical Committee on Pesticide Residue Research which is under the umbrella of MINT, to undertake the aforementioned studies. The technical committee comprised scientists from MINT, MARDI, DOA, UPM, USM, UKM and MADA. A holistic multi-disciplinary approach was adopted to study various ecological, biochemical, botanical, zoological, microbiological as well as medical aspects related to pesticide usage among rice farmers in the Muda area. These studies have been undertaken since 1992.

This book documents some of the major findings obtained from the joint studies undertaken. Based on the findings, comprehensive and collaborative studies on biodiversity have been initiated for continuous monitoring of the entire rice agroecosystem in the Muda area. I sincerely hope that scientists from these various organisations will continue to make full use of the Muda Irrigation Scheme as their experimental field plots. It is my fervent hope that their endeavour would enable MADA to detect any deviation or abnormality at the incipient stage, hence enabling timely and appropriate action to be taken to counteract any adverse impact to the environment.

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Muda Agricultural Development Authority (MADA)
Alor Setar

10 October, 1997

Preface

This book is a testimony of the success of a Memorandum of Understanding between the Malaysian Institute for Nuclear Technology Research (MINT) and the Muda Agricultural Development Authority (MADA) which was signed in 1992. As part of the agricultural and engineering project contracted out by MADA to MINT under the MoU, pesticide study is unique in that it encompasses a multidisciplinary approach in research. Under the umbrella of MINT, this approach has been undertaken by the National Technical Committee on Pesticide Residue Research to assess the impact of pesticides on the rice agroecosystem in the Muda Irrigation Scheme. The technical committee comprised scientists from various local institutions such as MINT, Malaysian Agricultural Research and Development Institute (MARDI), Department of Agriculture (DOA), Universiti Putra Malaysia (UPM), Universiti Sains Malaysia (USM), Universiti Kebangsaan Malaysia (UKM) and MADA.

Part of the content of this book was published in the Proceeding of the Seminar on Impact of Pesticides on the Rice Agroecosystem in the Muda Area (MINT/P/1995/23). Realizing the constant demand by the masses for a comprehensive compilation of agricultural research findings, this book is materialised. The updated findings are compiled into six parts viz. introduction, weeds, insects, fish, birds, and impact of pesticides on the rice agroecosystem in the Muda area.

The major findings obtained from the holistic studies undertaken by local ecologist, botanist, entomologist, chemist, biochemist, microbiologists, zoologists and also medical practitioners are documented in this book. I sincerely hope that these scientists from various organisations will continue to team up in studying the adverse impact of pesticides to the Malaysian agricultural environment, especially in the major Malaysian rice granary area of Muda.

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Malaysian Institute for Nuclear Technology Research (MINT)
Bangi

10 October, 1997

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List of Abbreviations, Symbols and Codes

A	area infested
≏	approximately
a.i.	active ingredient
AChE	acetylcholinesterase
α	alpha
ANOVA	Analysis of variance
AUFS	absorbance unit full scale
BCF	bioconcentration factor
β	beta
Bhd.	'Berhad'
BL	broad leaf
BLB	bacterial leaf blight
BPH	brown plant hopper
BPMC	fenobucarb
C	Similarity Coefficient
ca.	circa (about)
cfu	colony forming unit
cm	centimetre(s), (0.01 m)
CNS	Central Nervous System
2,4-D	IUPAC name: (2,4-dichlorophenoxy) acetic acid
2,4-D IBE	2,4-D isobutyl ester
D	Dissimilarity Coefficient
D	Simpson's Species Diversity index
D	Dominance index
DAS	days after seeding
DAT	days after treatment
DDD	1,1'-(2,2-dichloroethylidene)-bis(4-=chlorobenzene)
DDE	1,1'-(2,2-=dichloroethenylidene)-bis-(4-chlorobenzene)
DDT	dichlorodiphenyltrichloroethane
DO	dissolved oxygen

DOA	Department of Agriculture (Ministry of Agriculture, Malaysia)
UPM	Universiti Putra Malaysia
DTNB	5,5'-dithiobis-2-n-nitrobenzoate
DWNP	Department of Wildlife and National Park
e	poorness of fit
E	Equitability index
E.C.	European Community
e.g.	for example
EC	emulsifiable concentrate
ECD	electron-capture detector
ELISA	enzyme-linked immunosorbant assay
EPTC	IUPAC name: S-ethyl dipropylthiocarbamate
EROD	ethoxyresorufin-o-deethylase
et al.	and others (authors)
FAO	Food and Agricultural Organisation (of the United Nations)
G	granular
G	grassess
g	gram (hence also ng, mg, kg, etc.)
g	gravitational constant
GLC	Gas Liquid Chromatography
GST	glutathione S-transferase
H_3PO_4	phosphoric acid
ha	hectare(s) (10^4 m^2)
HPLC	High Performance Liquid Chromatography
hr	hour(s)
H′	Species diversity index
HYV	high-yielding variety
i.e.	that is
i.p.	intraperitoneal injection
IPM	Integrated Pest Management
IU	International unit
IUPAC	International Union of Pure and Applied Chemistry
IV	Importance Value

JE	Japanese encephalitis
Kg.	'Kampung'
kg	kilogram(s)
KII	key informant interview
L	litre (hence also mL, etc.)
λ	wavelength
log	logarithm to the base 10
Ltd.	Limited
M	molarity
m (or μ)	micro, multiplier (10^{-6}) for SI units
m	metre (hence also nm, mm, etc.)
MADA	Muda Agricultural Development Authority
MARDI	Malaysian Agricultural Research and Development Institute
MCPA	IUPAC name: (4-chloro-2-methylphenoxy) acetic acid
mfo	mixed function oxidase
MFO	cytochrome dependent monooxygenase
mg	milligram(s), (0.001 g)
min	minute(s)
MINT	Malaysian Institute for Nuclear Technology Research
MIPC	isoprocarb
mol	mole
MSL	mean sea level
MTMC	metolcarb
N	total number of individual plants
n	number of individual (plants, farmers, birds, fish etc.)
n	nano, multiplier (10^{-9}) for SI units
N	nitrogen
ND	not detectable
ng	nanogram, (10^{-9} g)
NM	not measured
NO	not observed
°C	Celsius or Centigrade temperature
P	probability

PCB	polychlorobiphenyl
pH	$-\log_{10}$ hydrogen ion concentration
PPE	personal protective equipment
r	correlation coefficient
RM	'Ringgit' Malaysia
RTBV	rice tungro bacilliform virus
RTSV	rice tungro spherical virus
S	sedges
s	second(s)
SCI	Sequential Comparison Index
Sdn.	'Sendirian'
SDR	Summed Dominance Ratio
SE	standard error
Sg.	'Sungai'
SI	International System of Units
sp.	species (singular)
SPE	solid phase extraction
spp.	species (plural)
SRP	soluble reactive phosphate
ssp.	subspecies
SU	Sampling Unit
t	time
t	tonne, 1000 kg
UDP-GT	uridine diphosphate-glucuronyl transferase
UKM	Universiti Kebangsaan Malaysia
UNEP	United Nations Environmental Program
USM	Universiti Sains Malaysia
UV	ultraviolet
var	variety
w/v	weight-to-volume-ratio
w/w	weight-to-weight-ratio
WHO	World Health Organisation (of the United Nations)
wt.	weight
YOY	young-of-the year
yr	year(s)

Part I

Background

1 THE RICE AGROECOSYSTEM OF THE MUDA IRRIGATION SCHEME: AN OVERVIEW

Ho Nai-Kin

ABSTRACT

The Green Revolution technologies were introduced to the Muda area of Malaysia in the late 1960s. These technological innovations have resulted in rapid modification of the crop habitat and triggered a chain reaction in the rice agroecosystem. The impact of these technologies on the pest flora and fauna are significant. Indiscriminate use of pesticides causes disruption of natural enemy equilibrium and other undesirable effects to the farmers and the rice environment. The main emphasis of this paper is focused on the interactions between the various biological factors such as pathogenic microorganisms, arthropods, gastropods, fishes, birds, rodents, weeds, and the physical factors in the rice agroecosystem. The impact of double cropping of rice, the provision of irrigation facilities, the changes of crop establishment methods, and the adoption of pesticides on the rice agroecosystem are found to have far reaching effects on the sustainability of rice production in the Muda area.

INTRODUCTION

The Muda Irrigation Scheme is the largest rice granary area in Malaysia. It is situated in the north-west of Peninsular Malaysia, latitude 6° 07' North and longitude 100° 20' East. This irrigation scheme encompasses some 126 000 ha of the coastal alluvial plain of which 97 000 ha are cultivated with rice *Oryza sativa* subspecies *indica*. The coastal plain, 20 km wide and 65 km long is bounded in the east by low hills on the western flank by the Straits of Malacca. At its centre lies Alor Setar, the capital of Kedah State, whilst Kangar the capital of Perlis State, is located at its northern tip.

Large scale rice cultivation in the Muda area began as far back as three centuries ago (Afifuddin, 1975). By 1949, most of the current Muda area was already under rice cultivation (FAO, 1975).

The rice agroecosystem in the Muda area can be considered as an extensive human-manipulated wetland where the rice crops and all other living organisms (biological factors) interact actively with the environment (physical factors). Long term human intervention through continuous activities in rice cultivation has led to complex biotic diversity. Such interaction has far reaching implications on the trophic structures which in turn affect directly or indirectly the stability of the entire rice agroecosystem.

THE PHYSICAL COMPONENTS

The physical factors in an ecosystem encompass the general topography, altitude, soil characteristics (physical and chemical) and climatic factors of the area.

Topography

The Muda Irrigation Scheme area slopes gently from about 4 m above mean sea level (MSL) near the main canal (approximately 20 km inland) to about 1.5 m above MSL near the coast. The terrain is drained by numerous small river channels and creeks, supplemented by excavated canals and drains. Inadequate tertiary drainage system in the past resulted in frequent drainage problems during periods of intense rainfall in the wet season. Salt water intrusion is prevented by tidal gates at the drainage outlets and a system of coastal embankments, a portion of which has been threatened by wave erosion previously.

Although the plain is extremely flat on a macro-level, the micro-topography is very variable. There is a

PLATE 1.1
An aerial view of the Muda area

considerable amount of higher ground surrounded by natural depressions, and complex systems of linked settlements, which partly or entirely hinder the supply of irrigation water to higher or more distant ricefields. This leads to either water shortage or ponding in the problems areas, wastage of irrigation water, and reduced yields.

Soils

In the Muda rice agroecosystem, geological evidence has revealed that the Muda plain is predominantly blanketed by marine sediments deposited during the rise of the sea level in the Pleistocene time. Further inland in the flood plain, the marine alluvium is mixed with fluviatile sediments. Nearer to the eastern low hills, the marine influence diminishes and the deposits are mainly fluvial and colluvial in origin. After the recession of the sea, these sediments were subjected to the soil forming processes. Upon all these factors, an evolutionary sequence of soil profiles was generated (Soo, 1972). The soils in the Muda area are classified into 16 soil series which in turn are grouped into various soil classes, based on their limitations to the growth of rice plants as the principal criterion (Fig. 1.1). The bulk of the soils are derived from marine alluvium (range of clay content: 49% to 83%) with poor drainage and slightly acidic. The Muda soils in general are considered suitable for rice cultivation. Before the introduction of rice double cropping in 1970, some 27% of the Muda area comprised natural depressions with no free drainage. The depressions were blanketed with acid sulphate soil, the dry soil pH of which is in the range of 3.0 to 4.3. The very high sulphate content and poor drainage were limiting factors to rice cultivation. Nevertheless, the continuous flushing effects of irrigation water coupled with liming over the past two decades have ameliorated the acute acidic condition. The productivity of acid sulphate soils in the Muda area has improved significantly in recent years.

Climate

The climate is tropical and the area is shielded from the direct rain-bearing winds of the north-east and the south-west monsoons by the main range to the east and Sumatra to the south-west. The bulk of the rain in the project area is brought by the inter-monsoon rains. Based on the annual rainfall pattern the area has three seasons, namely the dry season from December to March (average rainfall less than 100 mm per month), the moderate season from April to July (average rainfall 200 mm per month) and the wet season from August to November (average rainfall 200 to 300 mm per month). The long term average annual rainfall is 2100 mm. With the exception of the wet season, rainfall is erratic, often occurring in high intensity downpours of short duration. The annual rainfall in an average year is in the range of 1900-2400 mm. When the annual rainfall is less than 1900 mm, it is considered a dry year. A wet year has an annual rainfall of more than 2400 mm (Jegatheesan and Morooka, 1996). Dry periods of up to ten days in the wet seasons and 30 days in the dry seasons are not uncommon.

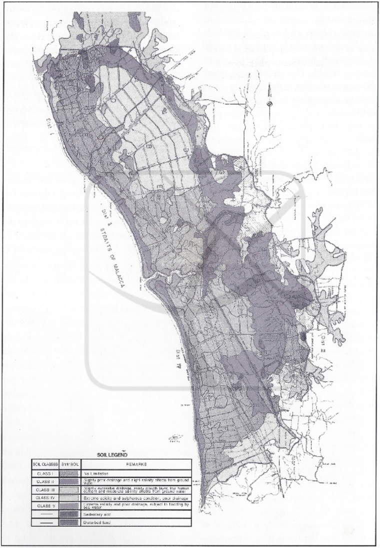

FIGURE 1.1
Soil classes map of the Muda area

Rainfall during the wet season is usually sufficient to maintain one crop of paddy ('padi') per year. However, the off-season (first season) crop from February/ March to August/September depends to a large extent on irrigation water which is impounded in the three dams some 100 km miles east of the Project Area.

There is very little variation in the day length and temperature. Mean temperature values range from 26°C to 28°C and relative humidity fluctuates between 70% and 95%.

THE BIOLOGICAL COMPONENTS

The biological factors comprise the flora and fauna in the rice agroecosystem including the pathogenic microorganisms, arthropods, gastropods, fishes, birds, mammals and the weed flora within the vicinity of the rice crops.

Pathogenic microorganisms

The pathogenic microorganisms in the Muda rice agroecosystem encompass three main categories; namely, fungi, bacteria and viruses.

Among the fungal pathogens, *Pyricularia oryzae* which caused severe seedling and foliar blast as well as neck rot in the 70s and early 80s is now under control. Currently, the most important fungal pathogen in the direct seeded rice environment is *Rhizoctonia solani*, the causal agent of sheath blight disease. This pathogen is transmitted by water, soil, air, straw and stubbles. The alternative hosts include most weeds in the rice agroecosystem. Other fungal pathogens include *Cercospora oryzae* (narrow brown

PLATE 1.2
Paddy harvesting by a combine harvester

spot), *Cochliobolus miyabeanus* (brown spots), *Rhynchosporium oryzae* (leaf scald), *Gibberella fujikuroi* (bakanae disease) and *Ustilaginoidea virens* (false smut). However, most of these diseases are sporadic in occurrence and seldom culminate into epidemics.

Among the pathogenic bacteria, the most important pathogen is *Xanthomonas oryzae* pv *oryzae* (*X. oryzae*) the causal organism of bacterial leaf blight disease. The entry of bacteria into the vascular system of rice plants is through hydathodes or wounds. In severely infected fields, bacterial ooze can be detected as milky drops on infected leaves in early morning. Systematic infection by this bacterial pathogen causes 'kresek' in which the entire rice plant wilts and collapses after disease attack. The other common bacterial pathogen is *Xanthomonas oryzae* pv *oryzicola* (*X. oryzicola*) which causes bacteria leaf streak disease. Infected rice plants have distinct linear, water soaked lesions between leaf veins. Under humid condition, bacterial exudates in the form of amber beads are often formed on the lesions.

The most important virus in the Muda area is tungro virus. In the early 1980s, tungro disease ('penyakit merah') inflicted severe damage to the rice crops in the Muda area. The value of crop loss from 1981-3 was estimated to be US$10 million (Heong and Ho, 1987). Tungro disease is caused by a complex of rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV). The virus is transmitted by the green leafhoppers (*Nephotettix* spp.) in a semi-persistent manner.

In the 1990s, the four most commonly found pathogenic microorganisms in the Muda area have been: *Xanthomonas oryzae* pv. *oryzae*, *X. oryzae* pv. *oryzicola*, *Cercospora oryzae* and *Rhizoctonia solani*. The tungro virus can still be detected by the use of enzyme-linked immunosorbant assay (ELISA), however, no disease outbreaks have been reported in the Muda area since the mid 80s.

Arthropods

In the Muda rice agroecosystem, three categories of arthropods are present. The first category comprises pests which attack various parts of the rice plants. The status of these pests are influenced by many biotic and abiotic factors such as the presence of parasites, predators and pathogens, the occurrence of prolonged drought, the changes in agronomic practices and the modification of habitats. In terms of area of infestation, the hierarchical list of dominance in the early nineties (1990-4) was in the descending order of brown planthopper (*Nilaparvata lugens*) > rice stemborers (*Scirpophaga incertulas, Chilo polychrysus* and *C. suppressalis*) > white-backed planthopper (*Sogatella furcifera*) > rice thrip (*Stenchaetothrips biformis*) > rice bug (*Leptocorisa oratoria*) > rice leaf folder (*Cnaphalocrocis medinalis*) > case worm (*Nymphula depunctalis*). The rice thrip and the case worm are becoming more widespread in recent years. Consecutive dry years in the early 1990s and severe moisture stress during off seasons probably have an adverse impact on the natural enemies, and hence created favourable conditions for these two previously minor pests to emerge from an innocuous position to become more dominant (Ho *et al.,* 1995).

The second category includes insects and spiders that are natural enemies to the rice pests. These beneficial species parasitize or predate and suppress or regulate the pest species. Without these natural enemies, the rice pests would multiply so quickly that complete destruction of the rice crops may occur after severe pest infestations. In the Muda rice agroecosystem, the common insect predators are ladybird beetles (*Micraspis* spp. and *Harmonia* spp.), ground beetles (*Ophionea nigrofasciata*), grasshopper (*Conocephalus longipennis*), water bug (*Microvelia douglasi*), plant bug (*Cyrtorhinus lividipennis*), and damselflies (*Agriocnemis pygmaea*). Among the spiders, the common predators include the wolf spider (*Lycosa pseudoannulata*), orb spider (*Argiope catenulata*), and long-jawed spider (*Tetragnatha maxillosa*). Among the parasites, wasps such as *Telenomus* spp., *Anagrus* spp. and *Oligosita* spp. are commonly found.

The third category consists of all the neutral insect species in the rice as well as non-rice habitats in the agroecosystem. These groups of insects serve as alternative hosts for the natural enemies. For instance, the Chironomidae insect larvae of the Dipteran midge are often abundant in huge swarms as scavengers in the rice agroecosystem. These delicate mosquito-like insects are important food items for the predators (Abdullah *et al.,* 1994).

Gastropods

In the rice agroecosystem, Gastropoda is considered the most important class in the phylum Mollusca. Studies conducted by the Universiti Sains Malaysia (USM) in the late 1970s recorded ten species in the Muda area. One of the most common snails found in the ricefields was *Bithynia pulchellum*. Other gastropods included: *Pila ampullacea, Melanoides tuberculata, Thiara scabra, Lymnaea rubiginosa, Indoplanorbis exustus, Gyraulus convexiusculus* and *Ferrisia javana*. Two other species: *Filopaludina javanica* and *F. martensi* were common throughout the entire Muda area including the Pedu Reservoir, Pedu River and Kedah River. Many of the gastropod species which occur in the Muda area are known to be the intermediate hosts for trematode that parasitize human beings. For example *P. ampullacea* is the intermediate host for *Fasciolopsis buski* (large intestinal fluke) (Chambers, 1980).

The exotic golden apple snail (*Pomacea canaliculata*) was first detected in the Muda area in 1992. It was first confined to the Wan Mat Saman Irrigation Canal. The population of the snail and the egg clusters were drastically reduced after the application of tea seed cake by MADA. However, the remnants of the golden apple snails managed to survive and later encroached into the ricefields. In 1997, some 30 hectares of rice lands were infested by the golden apple snails (Ho and Zulkifli, 1997).

Fishes

Studies conducted by the USM in the early 1990s recorded 36 species of fish from 21 families in the ricefields as well as irrigation canals and drainage channels in the Muda area. Cyprinidae is the most dominant family with eight species detected in the Muda agroecosystem. The diversity of fish was greater in the north (22 species) as compared to the south (16 species) of the Muda area. A longer history of direct seeding and exposure to herbicides could be one of the main factors affecting fish distribution in the southern Muda ricefields. Ricefield fish that are commonly found in the Muda area include: *Channa striata* ('haruan'), *Trichogaster pectoralis* ('sepat siam'), *T. trichopterus* ('sepat kedah') and *Anabas testudineus* ('puyu'). The common catfish (*Clarias* spp.) population has declined drastically in recent years. Overfishing of breeding adults could be one of the causes of poor recruitment of this fish species (Ali, 1994).

Birds

Studies conducted in 1993 and 1994 by the Universiti Kebangsaan Malaysia (UKM) detected birds from the families of Columbidae, Ploceidae, Turtidae, Motacillidae, Alcedinidae, Apodidae and Caprimulgidae in the Muda agroecosystem. The main groups captured were grainivores such as the baya weaver or 'ciak tempua' (*Ploceus philippinus*) and scaly-breasted munia or 'pipit pinang' (*Lonchura punctulata*). The non-pest birds captured were white throated kingfishers (*Halcyon smyrnensis*), magpie robin (*Copsychus saularis*) and greater painted snipe (*Rostratula benghalensis*) (Abdullah and Ho, 1994).

Rice is the most dominant food item for the grainivores. Barnyardgrass (*Echinochloa crus-galli*) has been recorded as a food source for the sharp-tailed munia (*Lonchura striata*) (Avery, 1978).

In the 80s, the chemical bird repellent methiocarb was tested in the Muda area. Methiocarb causes severe nausea to the affected birds but does not result in bird mortality. Theoretically, the experience of nausea caused by methiocarb could be transmitted from adult to young and from experienced adult to newly arrived birds. Field evaluations showed that the methiocarb treatment was only effective for a period of 3-5 days. More studies on dosage, timing, frequency and method of application, in relation to wind speed and rainfall should be investigated to enhance the efficacy of bird repellants.

Rodents

In the rice agroecosystem, rodents generally reside and breed on high grounds. The favourite sites are field levees, irrigation embankments, bushes and scrub adjacent to the farmyards. Studies conducted by the Malaysian Agricultural Research and Development Institute (MARDI) in the late 70s indicated that *Rattus argentiventer* was the dominant species. Other rodents detected were *Mus caroli* and *Bandicota indica* (Lam, 1978).

In the 70s and 80s, rat occurrence was observed to reach epidemic proportion once every three years in the Muda area. Complacency and lack of vigilance after rodent control was considered one of the root causes of regular outbreaks. Staggered planting and continuous presence of food sources in the fields are the main factors leading to the build-up of rat populations. The most severe rat damage in the Muda area occurred in 1984. Owing to water scarcity, only half of the Muda area was planted with rice in the first season of 1984. As food source became scarce due to the decline in planted hectarage, rats started migrating from the fallowed fields to the planted areas and attacked the standing rice crops. Almost all the nursery plots of the early season crops were ravaged by rats. Some of them suffered up to 60% damage. Affected farmers had to resow three times to re-establish their nurseries. In 1984, more than a metric ton of zinc phosphide was distributed to the Muda farmers to keep rice rats at bay (Ho, 1986).

Zinc phosphide was the most popular rodenticide in the 70s and early 80s. As most of the Muda farmers applied zinc phosphide individually without the practice of prebaiting, bait shyness often took place. As zinc phosphide is an acute poison without an antidote, indiscriminate use can lead to hazards to the farmers and the environment. In the late 80s, MADA withdrew the distribution of zinc phosphide to the farmers. Anticoagulants such as warfarin, chlorophacinone, brodifacoum, bromadiolone are now included in the recommendations for rat control in the Muda area.

Weeds

Field surveys conducted by MADA in 1989 indicated that 57 weed species belonging to 44 genera and 28 families were recorded (Ho, 1991). Eighteen of these species or 31.6% of the weeds were encountered in less than 5% of the fields covered by this study. From the remaining 39 species, nine occurred in 5% to 10% of the fields. In other words, the occurrence of 27 species or 47.4% of the weeds recorded could be considered as minor in the first season of 1989. On the other hand, eleven species or 19.3% of the weed conglomeration in this study were detected in more than 50% of the fields surveyed. These weeds are considered widespread in terms of coverage (Table 1.1).

The family Cyperaceae topped the list with twelve species. This was followed by Poaceae with ten species. *Cyperus* was the largest genus with seven species that were predominant. This was followed by the genus *Scirpus* and *Echinochloa*, each of which had three species listed, respectively.

The weed spectrum in the coastal ricefields was broader compared to those in the inland areas. Thirty seven weed species under transplanted rice culture and 53 species under direct seeded rice culture were listed in the coastal ricefields; whilst in the inland areas, only 29 and 43 species were recorded under transplanted and direct seeded rice cultures, respectively. Weed species such as *Enhydra fluctuans, Cyperus imbricatus, Spirodela polyrhiza, Nelumbo nucifera, Nymphaea lotus, Crotalaria quinquefolia,*

TABLE 1.1
Changes of weed flora and dominance from transplanting to direct seeding in the Muda area (1979-89)

Results of weed survey	Season 2/79	1/82	1/84	2/84	1/87	1/89
Number of species	21	34	42	45	50	57
Number of genera	18	18	30	30	38	44
Number of families	13	14	19	17	22	28
% Direct seeded area	0.2	20.7	53.0	24.0	98.9	81.7
Dominant weed species*	M. vag L. hys F. mil C. dif L. fla	M. vag L. hys F. mil L. hex S. gro	F. mil M. vag E. cru S. gro M. cre	E. cru S. gro L. hys P. amp L. chi	E. cru E. col L. chi S. gro F. mil	E. cru L. chi F. mil M. cre M. vag

The dominant weed species*

M. vag	- *Monochoria vaginalis*	S. gro	- *Scirpus grossus*
L. hys	- *Ludwigia hyssopifolia*	E. cru	- *Echinochloa crus-galli*
F. mil	- *Fimbristylis miliacea*	M. cre	- *Marsilea crenata*
C. dif	- *Cyperus difformis*	P. amp	- *Panicum amplexicaule*
L. fla	- *Limnocharis flava*	L. chi	- *Leptochloa chinensis*
L. hex	- *Leersia hexandra*	E. col	- *Echinochloa colonum*

Echinochloa stagnina, Oryza rufipogon and *Paspalum distichum* were only detected in the coastal ricefields in this survey. It is noteworthy that all except *Spirodela polyrhiza* and *Crotalaria quinquefolia* are perennial weeds. *Enhydra fluctuans* is a perennial marsh herb often gregarious in nature. Propagation is by vegetative means from stem fragments and also by seeds. *Cyperus imbricatus* is a coarse, erect, tufted perennial which thrives in wetland and swampy places. *Nymphaea lotus* and *Nelumbo nucifera* are perennial aquatic herbs with stout creeping underground rhizomes. The perennial grasses, namely *Echinochloa stagnina, Oryza rufipogon* and *Paspalum distichum* thrive well in aquatic sites such as swamps, ditches and streams and also along field levees and dykes. They reproduced almost entirely by vegetative means and spread by stolons. The formation of secondary shoots from axillary buds that produce adventitious roots is a prerequisite for spreading. These three perennial weeds were rarely seen in the transplanted fields. However, with the widespread adoption of direct seeding culture, infestations have escalated in recent years.

Weeds which appeared ubiquitous throughout the Muda area were *Monochoria vaginalis* (100%), *Fimbristylis miliacea* (97.5%), *Sagittaria guayanensis* (81.3%), *Cyperus difformis* (73.8%), *Marsilea minuta (M. crenata)* (72.5%), and *Scirpus grossus* (70%). All these weeds were common to both types of rice culture, but the order in which they were ranked varied. Regardless of location, more weed species were encountered in the direct seeded ricefields than in transplanted fields. The major weeds under direct seeded condition were *Echinochloa crus-galli, Fimbristylis miliacea, Leptochloa chinensis* and *Sagittaria guayanensis* (Ho, 1991).

IMPACT OF DOUBLE CROPPING ON THE RICE AGROECOSYSTEM

The expansion of rice production through double cropping technology has resulted in distinct changes in the ricefield environment. Before the introduction of double cropping in 1970, stemborers were considered to be the most important insect pest in the Muda area. However, in recent years, stemborers have not been as important as they used to be. This is attributed to the modification of the microclimate and habitat favouring the beneficial organisms in exerting more efficient biological control on stemborers (Hirao and Ho, 1987). Currently, the yellow stemborer (*Scirpophaga incertulas*) is dominant, followed by the dark-headed striped borers (*Chilo polychrysus).*

Before the introduction of rice double cropping, rice blast (*Pyricularia oryzae*) was considered by Muda farmers as the most important disease. This is because the humid conditions during the wet (rainy) seasons were very conducive to blast conidia dissemination. After double cropping, rice blast continued to be the most important disease in the 70s until cultivars with host plant resistance to blast were introduced in the early 80s.

The replacement of numerous traditional rice varieties planted in a single area by a few dominant high yielding, nitrogen responsive but poor disease resistant varieties also changed the scenario of pest infestation. The planting of the variety 'Seribu Gantang' over 50% of the Muda area in the late 70s was one of the contributing factors which led to the outbreak of the tungro epidemic in the Muda area.

The adoption of double cropping and the continuous presence of food sources in the rice agroecosystem has created an environment more conducive to the multiplication of rats. Lam (1978) noted that in double cropping areas reproductive activities were bimodal as compared to unimodal in the single cropping areas.

When rice was grown only once a year, weed infestation was seldom reported by farmers as a problem. This was because thorough land preparation and extensive hand weeding greatly reduced the chances of weed infestation. After the commencement of double cropping, modern varieties with shorter stature and erect leaves allowed more light penetration creating a field condition conducive to weed multiplication. Broadleaved weeds such as *Monochoria vaginalis, Ludwigia hyssopifolia* and sedges such as *Scirpus grossus* and *Fimbristylis miliacea* have become dominant after widespread adoption of double cropping in the Muda area (Ho, 1991).

IMPACT OF IRRIGATION ON THE RICE AGROECOSYSTEM

The provision of irrigation infrastructure is an important pre-requisite for the success of rice double cropping. In the Muda area, the civil engineering works involved the construction of three reservoirs, namely Muda, Pedu and Ahning. The reservoirs were created by damming up the Muda, Pedu and Ahning rivers. Other irrigation facilities include a primary conveyance system of 146 km of canals, a distributing system of 930 km of secondary canals; a drainage system of 240 km primary drains and 883 km secondary drains. In addition, more than a thousand kilometres of tertiary canals and drains have been constructed.

Field levees or irrigation dykes overgrown with weeds are favourite nesting sites of rodents. The construction of irrigation facilities results in the increase of canal density and the corresponding increase of dyke density which leads to the escalation of rodent nesting sites. In recent years, rat damage was high in ricefields adjacent to poorly maintained dykes which served as undisturbed breeding grounds for rodents to multiply.

Proper operation and maintenance of the waterways are crucial for the improvement of water management and water use efficiency. Ever since the implementation of the fertiliser subsidy scheme in 1979, widespread usage of fertilisers has created substantial impact on the rice agroecosystem. Accumulation of fertilisers in drains, coupled with hot and humid tropical climate and slow water flow enhance luxuriant weed growth in the waterways. Water hyacinth (*Eichhornia crassipes*), knot grass (*Polygonum barbatum*), water convolvulus (*Ipomoea aquatica*), water primrose (*Ludwigia adscendens*) are the dominant weeds in the irrigation canals. Delayed weed control in the waterways often leads to clogging of the drainage channels and results in severe flooding. Besides, it was reported that larvae of *Mansonia* mosquito, vector of filariasis, are found breeding on water hyacinth, water convolvulus and water lettuce (*Pistia stratiotes*) (Ho, 1981).

In addition, improving water use efficiency through recycling water from the drains back to the irrigation canals also facilitated the spread of aquatic weeds such as *Salvinia molesta, Pistia stratiotes* and other floating weeds. Residues of pesticides are also being reintroduced into the irrigation system through recycling (Cheah and Lum, 1994).

IMPACT OF CROP ESTABLISHMENT ON THE RICE AGROECOSYSTEM

Changing the crop establishment method from transplanting to direct seeding causes habitat modification. In the Muda area, it is noted that the practice of direct seeding has created field conditions favouring outbreaks of certain rice pests. There are indications that more pest problems caused by planthoppers, leaffolders, Malayan black bug, stinkbug and stemborers occur in direct seeded rice as compared with transplanted rice. Direct seeded crops tend to develop abundant foliage and earlier closure of crop canopy. This is further aggravated by high seed rates and more nitrogenous inputs. Studies by Hirao *et al.* (1988) revealed that the brown planthoppers (BPH) usually complete two generations in transplanted crops, and three generations in direct seeded crops. BPH adult populations generally reach their peak at 80-90 days after transplanting. However, in direct seeding, the peak often occurs earlier at 50 to 70 days after sowing (DAS). In addition, Wada *et al.* (1994) found that a crop-free fallow period or a prolonged dry spell is detrimental to both the planthoppers and their natural enemies, whereas continuous planting favours the activities of natural enemies. In the tropical rice agroecosystem, the initial density of BPH is not a determinative factor of pest infestation. The interaction of BPH with its natural enemies is more crucial in influencing outbreaks (Wada *et al.*, 1994).

The widespread transformation of crop establishment method from transplanting to direct seeding also creates ideal field conditions for the development of rice diseases, particularly bacterial leaf blight (BLB) and sheath blight. The problem of BLB becomes more acute in locations where the susceptible variety MR 84 is direct seeded continuously over an extensive area. Fields with high seeding rate (more than 100 kg/ha) coupled with high nitrogen fertiliser (more than 120 kg N/ha) show more severe BLB symptoms.

The weed-rice ecological relationship is complex and dynamic. Weed distribution is always affected by human and environmental factors. The weed spectrum and the degree of infestation in the rice agroecosystem is often determined by the types of rice culture and crop establishment. The continuous adoption of any particular rice production practice frequently causes a shift in dominance of the weed population.

In 1979, when transplanting was still the predominant rice culture in the Muda area, 21 species from 19 genera, within 13 families were recorded. Broadleaved species such as *Monochoria vaginalis, Ludwigia hyssopifolia, Limnocharis flava* and sedges such as *Fimbristylis miliacea, Cyperus difformis* and *Scirpus grossus* constituted more than 80% of the weeds. Grasses such as *Echinochloa crus-galli, E. colonum, Leersia hexandra* and *Isachne globosa* were found growing sporadically along the edges of direct seeded fields. Their occurrences were considered minor (Ho, 1980).

In 1984, when direct seeding became the dominant crop establishment method (53% of the total planted area), *Echinochloa crus-galli* and *Leptochloa chinensis* became more predominant. The water fern *Salvinia molesta* was detected for the first time in the Muda area. In the zero tillage-volunteer seedling ricefields, *Melochia corchorifolia* and *Aeschynomene indica* were abundant. Field studies indicated that the average number of weeds was 5 species/m^2 (ranging from 3-7 species) under transplanted condition compared with 8 species/m^2 (ranging from 5-12 species) under direct seeded culture (Ho, 1986).

In 1987, severe drought resulted in drastic depletion of water in the reservoir storage, and irrigation to the Muda area was rendered impossible. In order to overcome this adverse situation, the Muda farmers resorted to dry ploughing their fields and dry seeding their rice crops. Field surveys recorded 50 weed species belonging to 38 genera classified under 22 families in the direct seeded fields, whilst under transplanted conditions, only 32 species were listed (Ho and Md. Zuki, 1988).

A subsequent weed survey in 1989 indicated that the weed spectrum further expanded to 57 species after the widespread adoption of direct seeding in the Muda area (Table 1.1). Comparative ecological studies on weed flora in irrigated ricefields revealed that weed infestation was more severe in direct seeded than in the transplanted areas. The most significant contributory factor towards the increase of weed weight in direct seeded fields came from prolific growth of the grassy weeds. There is also a much wider range and intensity of weed problems in rice crops sown in dry soil than those sown on puddled soil. The composition of the weed flora is strongly influenced by the landscape position and degree of submergence. It is observed that the coastal areas of the Muda scheme have a wider weed spectrum compared with the inland areas. This is because the heavy marine clay soils and flat topography give rise to a higher ponding incidence in coastal ricefields, and hence create more conducive conditions for the growth of aquatic weeds. Perennial weeds such as *Echinochloa stagnina, Paspalum distichum* and *Cyperus babakan* are more frequently encountered after continuous adoption of direct seeding (Ho, 1991).

IMPACT OF PESTICIDES ON THE RICE AGROECOSYSTEM AND THE FARMING COMMUNITY

Three key factors are considered to be of the utmost importance in influencing the interaction between rice pests and their natural enemies in the rice agroecosystem. These factors are:

- The availability of susceptible host plants,
- The climatic conditions conducive to pests but unfavourable to their natural enemies,
- The indiscriminate application of pesticides.

Intensive applications of broad spectrum insecticides have been observed to be one of the major factors causing acute reduction of arthropod diversity in the rice agroecosystem. It was reported in the Muda area that BPH outbreaks often took place after widespread chemical application to control thrips or leaffolders. The resurgence of BPH is primarily due to the diminution of natural enemies, especially predators e.g. spiders and egg parasites, *Cyrtorhinus* spp. The major outbreak of BPH in 1991 has been attributed to repeated application of insecticides such as endosulfan, cypermethrin and monocrotophos to control leaffolders at 25-45 DAS in 1991. It is noteworthy that BPH population was low and incidence of hopperburn was absent in adjacent ricefields where insecticides were not applied at all (Ito *et al.*, 1992).

The misuse of pesticides is another factor capable of creating a far reaching adverse impact on the rice agroecosystem. The typical example is the misuse of endosulfan by farmers for rodent control in the Muda area. In the early 90s, although the application of zinc phosphide had declined drastically and the usage of anticoagulants had increased, many farmers were not satisfied with the slow action of anticoagulants. Through their own ingenuity, the Muda farmers started using Endosulfan EC for rodent control. Endosulfan was usually mixed with used engine oil before application. The mixture was later poured along the field levees, so that rodents entering the ricefields would get their fur contaminated with endosulfan. The rodents subsequently were poisoned through the habit of fur licking. A MARDI/MADA joint study on pesticide residues in the Muda area in 1992/3 revealed that the cyclodiene endosulfan was a ubiquitous contaminant of the water resources, especially in the recycled irrigation water. Residues of this insecticide were detected in most of the water samples at level ranging from < 0.005 ng/mL to 25.5 ng/mL (Cheah and Lum, 1994). The European Community (E.C.) drinking water standard for endosulfan is 0.1 ng/mL. MADA's study indicates that the misuse of endosulfan by farmers for rodent control might be the main contributing factor to the high level of endosulfan residue in the rice agroecosystem. A key informant interview (KII) conducted in 1994 revealed that 91.7% of the respondents mentioned that they have used endosulfan for crop protection. About 6.8% of them used endosulfan exclusively for rodent control and 60.7% of them used it for the control of rodents as well as other insect pests such as stemborers and leaffolders.

As far as weed management is concerned, continuous adoption of a single weed control method has resulted in a distinct weed shift in the Muda area. The use of 2,4-D applied as post emergence control has caused the suppression of the easy-to-control weeds such as *Monochoria vaginalis* and *Fimbristylis miliacea*, resulting in a distinct dominance of *Echinochloa crus-galli, Sphenoclea zeylanica, Marsilea minuta, Cyperus iria* and *C. babakan*. The application of pretilachlor with fenclorin as safener has shown remarkable crop selectivity and bio-efficacy in grassy weed suppression, but provided a conducive environment for *Sagittaria guayanensis* and *M. minuta* to prevail. Molinate suppresses *E. crus-galli*, but results in escalated infestation of *Leptochloa chinensis* and *Ischaemum rugosum* (Ho, 1991).

Herbicide-tolerant strains or resistant biotypes could evolve through repeated use of the same herbicide over a long period. In the Muda area, a 2,4-D resistant biotype of *Fimbristylis miliacea* was first detected in 1989 in a farmer's field where 2,4-D has been seasonally applied since 1975 (Ho, 1992). Subsequent studies conducted by Watanabe *et al.* (1994) indicated that the resistant biotype recovered after the application of 2,4-D amine at 16 times strength over the recommended dosage. This resistant biotype showed cross-resistance to other phenoxy compounds such as 2,4-D isobutyl ester, 2,4-D sodium salt and MCPA.

In recent years, increasing use of herbicides in rice cultivation has created concern regarding the hazards to the health of rice farmers. In Malaysia, a recent survey on pesticide usage and associated incidence of poisoning in the Muda area indicated that herbicides were most frequently used when compared with insecticides, fungicides and rodenticides. Approximately 51.3% of the responding farmers reported that they had experienced symptoms associated with pesticide poisoning. The highest incidence was due to herbicide application alone (24.8%), followed by insecticides (14.7%). Farmers rarely experienced poisoning symptoms due to rodenticides or fungicides. Headache and dizziness (71.6%) were most commonly experienced by the respondents. The types of herbicide identified by farmers and spray operators were 2,4-D, paraquat, molinate and metsulfuron methyl (Ho *et al.*, 1990).

CONCLUSION

With their farmyards surrounded by immense ricefields, the Muda farmers and their families are indeed an integral component of the entire rice agroecosystem. Over the past two and a half decades, the shift from single to double cropping (1970s) followed by the subsequent transformation from transplanting to direct seeding (1980s) has created a significant impact on the rice environment. The Green Revolution brought along with it technological advances such as: the large scale introduction of high yielding, semi-dwarf cultivars; the widespread adoption of nitrogenous fertilizers, and the provision of irrigation facilities. These technological innovations have resulted in rapid modification of the crop habitat and subsequently triggered a chain reaction in the rice agroecosystem. The impact on the populations of pest flora and fauna was so tremendous that pesticides usage was widely adopted by farmers to minimise crop damage and yield losses in their farms (Table 1.2-Table 1.4). Indiscriminate use of pesticides causes disruption of the pest-natural enemy equilibrium and other undesirable effects to the farmers and the rice environment. Pest resurgence, pesticide resistance, weed shift, pesticide poisoning and environmental pollution are of major concern to the Muda Agricultural Development Authority (MADA).

Realising the far reaching effects of continuous pesticide use on the sustainability of rice production, MADA has embarked on studies with regard to the impact of pesticides on the rice agroecosystem. A holistic multi-disciplinary approach was adopted to study the various ecological, biochemical, botanical, zoological, microbiological as well as medical aspects related to pesticide usage among rice farmers in the Muda area.

In addition, a participatory oriented extension program has been formulated to educate farmers on the importance of the ecological approach in addressing environmental problems at the farm level. MADA believes that the farmer-to-farmer approach can help to establish, maintain, strengthen and sustain a long-term ecological monitoring program in the Muda area.

TABLE 1.2
Estimated insecticide usage in the Muda area, Malaysia (in metric tons)

	Year						
Types of insecticide	1980	1986	1990	1992	1994	1995	1996
Gamma BHC (granulated formulation)	200	80	-	-	-	-	-
Endosulfan (granulated formulation)	280	60	15	5	4	-	-
Endosulfan (EC formulation)	10	20	40	40	20	10	5
MTMC + phenthoate	120	25	20	12	2	20	11
Cartap	-	-	-	-	-	4	7
Imida cloprid	-	-	-	-	-	0.5	1
Carbofuran	100	200	350	150	120	150	89
Propoxur	10	2	-	-	-	-	-
BPMC	10	20	20	3	3	5	3
MIPC	-	5	3	1	1	5	2
Monocrotophos	NA	2	20	-	-	-	-
Methamidophos	NA	1	10	-	-	-	-
IGR	-	-	-	2.5	2.8	2	2
Synthetic pyrethroid	-	-	-	-	-	9	9
Others	3	5	8	5	5	3	8
Total	733	420	486	218.5	157.8	208.5	137

NA = not available

TABLE 1.3
Distribution of rodenticides in the Muda area (1981-96)

Types of rodenticide		Year					
		1981	1985	1990	1994	1995	1996
Zinc phosphide	(kg)	2129	2255	-	-	-	-
Coumatetralyl	(kg)	355	1275	-	-	-	-
Brodifacoum (Matikus®)	(kg)	745	1862	2380	456	1666	600
Warfarin (Yasomin®)	(kg)	-	-	350	250	-	-
Warfarin (Tikumin dust®)	(kg)	-	250	150	-	-	250
Chlorophacinone (Drat EC®)	(litre)	-	55	16	-	-	-
Chlorophacinone (Drat Bait®)	(kg)	-	-	300	713	487.5	322.5
Bromadiolone (Ebor 401®)	(kg)	-	-	638	370	355.2	784
Total		3229	5697	3834	1789	2508.7	1956.5

TABLE 1.4
Estimated usage of herbicides in the Muda Irrigation Scheme, Malaysia (in metric tons)

Types of herbicide	Year												
	1980	1983	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
2,4-D IBE	100	180	250	280	250	250	200	160	150	150	150	140	145
2,4-D Sodium Salt	50	20	NA	NA	NA	30	10	8	5	4	4	4	4
2,4-D Amine	5	20	150	150	140	130	60	50	40	30	30	30	30
MCPA	1	NA	1	1	1	-	-	-	-	-	-	-	-
Molinate	-	10	110	195	265	380	600	500	550	250	240	70	50
Molinate & Propanil	-	-	-	-	-	8	10	10	10	5	6	5	5
Oxadiazon	-	-	10	10	6	6	6	2	2	-	-	-	-
Propanil	-	-	-	2	14	20	22	26	25	20	25	20	15
Thiobencarb	-	-	-	-	-	50	50	10	-	-	-	10	5
Thiobencarb + Propanil	-	-	-	-	-	-	-	-	-	6	8	30	45
EPTC	-	-	-	-	-	-	20	19	20	50	58	40	40
Pretilachlor	-	-	-	-	-	-	5	6	5	5	7	8	8
Paraquat	10	80	300	320	320	320	330	300	270	250	225	250	240
Glyphosate	-	-	-	-	-	-	-	-	-	20	25	30	40
Fenoxaprop	-	-	-	-	-	-	-	-	7	5	8	6	6
Sethoxydim	-	-	-	-	-	-	-	-	-	8	3	2	-
Quinchlorac	-	-	-	-	-	-	-	-	-	2	2	1	1
Others	NA	NA	1	2	3	6	5	6	8	9	9	10	12
Total	166	310	822	960	999	1200	1318	1097	1092	814	800	656	646

NA = not available

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THE NATIONAL WORKING COMMITTEE (TECHNICAL) ON THE APPLICATION OF NUCLEAR TECHNIQUES IN PESTICIDE RESIDUE RESEARCH

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Jacket illustration:

Front cover:
I. Bird's eye view of the ricefields of the Muda Irrigation Scheme, Malaysia
II. The Muda Reservoir in the forested catchment area.

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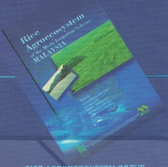

RICE AGROECOSYSTEM OF THE MUDA IRRIGATION SCHEME, MALAYSIA

Pesticides have become one of the major components of modern farming practice. However, their usage needs to be properly carried out and regulated. Farmers need to be made aware of the potential hazards arising out of improper use of pesticides, to them as well as to the environment.

This book presents the results of a comprehensive study on the impact of pesticide usage in the largest rice agroecosystem in Malaysia, the Muda Irrigation Scheme. The study, carried out by a group of local scientists, covers the impact of pesticide usage on biodiversity and bioresources (forest, weed, insect, fish, and bird). In addition to farmers education, it shows the potential of crop establishment, irrigation method and double cropping of rice as useful factors that can be employed in minimizing the impact.

The book also provides good foundation for future work and points out areas for further studies. It is a valuable reference to policy makers, researchers, regulators, agriculture-related agencies, chemical/fertilizer companies as well as those concerned with sustainable farming.

The ecologists, chemists, biochemists, entomologists, zoologists, botanists, microbiologists, agronomists and medical practitioners involved in this study are congratulated for their efforts.

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