National Strategies and Action Plans on Agricultural Biodiversity Conservation and Sustainable Utilisation

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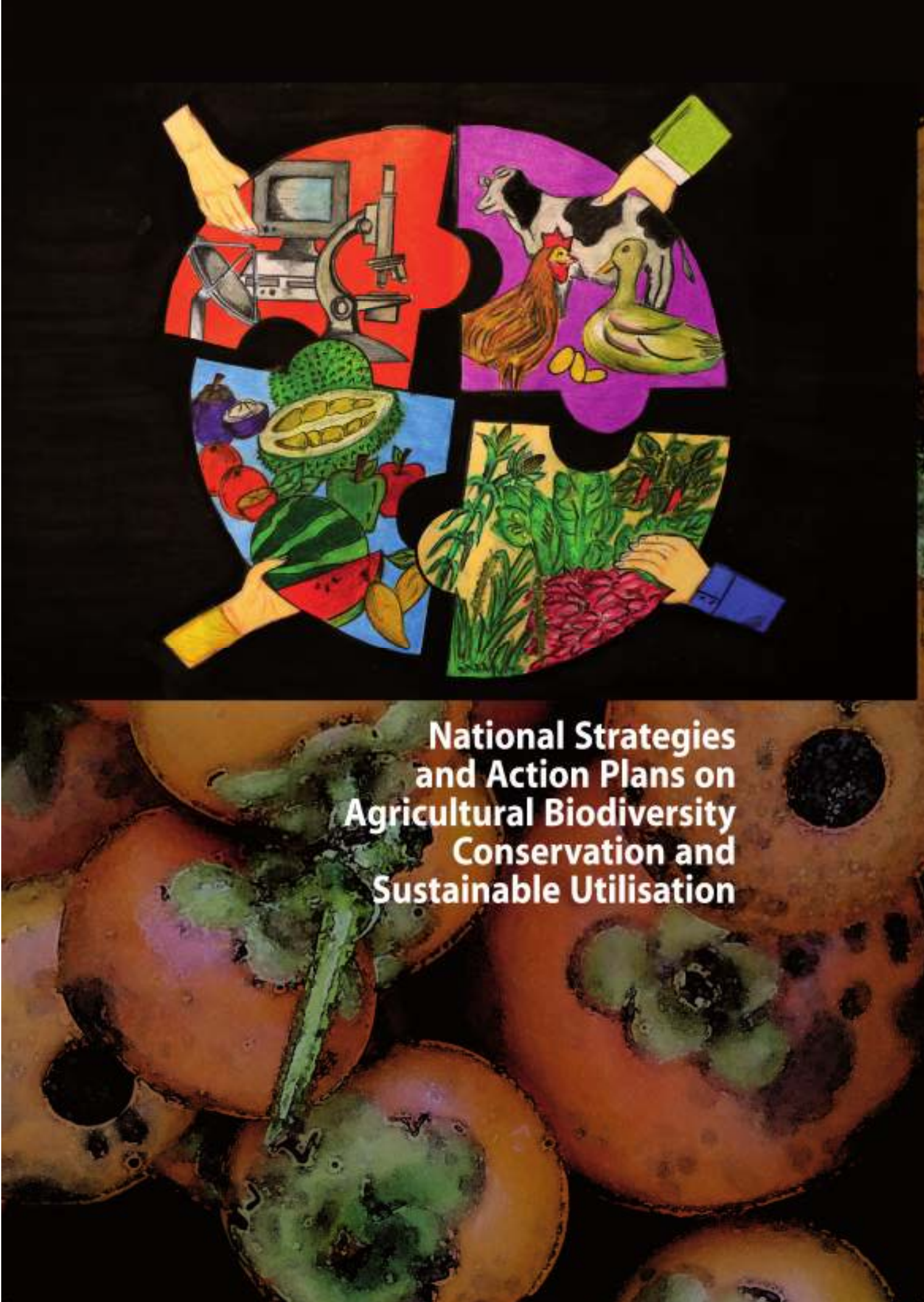
Flower of torch ginger, *Etlingera elatior*

Expedition into Royal Belum State Park of Perak



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Foreword by the Minister of Agriculture and Agro-based Industry Malaysia

Agricultural biodiversity is one of the most valuable features of sustainable agricultural development. It is the fundamental feature of farming systems that encompasses many types of biological resources tied to agriculture, including genetics, edible plants and crops, livestock, soil organisms, arthropods and agro-ecosystem components. It provides farmers with various options to produce and manage crops, land, water, insects and biota under different production scenarios and systems.

Agricultural biodiversity is one of the six thematic work programs of the Convention on Biological Diversity (CBD). It is also an important element in the FAO's Global Plan of Action (GPA) for the Conservation of Plant Genetic Resources for Food and Agriculture (PGRFA), the International Treaty on Plant and Genetic Resources for Food and Agriculture (ITPGRFA), crop genetic resources as well as genetic resources for animals.

Agricultural biodiversity is currently threatened by human activities in various forms. The process of urbanisation, unsustainable agricultural development and excessive logging activities are inevitable factors that lead to the gradual loss of traditional varieties, pollinators and beneficial microbes. The destruction of agricultural biodiversity can undermine agricultural development since the development of new crops and increase in productivity relies substantially on agricultural biodiversity.

The publication of this document, *National Strategies and Action Plans on Agricultural Biodiversity Conservation and Sustainable Utilisation,* serves as an important national document for the Ministry of Agriculture and Agro-based Industry (MOA) together with other related ministries and agencies, to conserve and judiciously manage our agricultural biodiversity. The document provides detailed breakdown of what needs to be done to safeguard the agricultural biodiversity in Malaysia.

I would like to take this opportunity to congratulate the National Technical Committee on Agricultural Biodiversity for their success in producing and publishing this important document.

Thank you,

YB Datuk Seri Noh bin Haji Omar

Foreword by the Minister of Natural Resources and Environment Malaysia

Malaysia is a biodiversity hotspot and one of the 12 mega biodiversity countries in the world. Malaysia's rich biodiversity has shaped our agricultural sector with a huge variety of food crops, fruits, plantation crops, vegetables and livestock. The National Policy on Biological Diversity (NPBD) adopted in 1998 has given a clarion call for the conservation and management of biodiversity among others to ensure food security. This is especially important as our rich biodiversity holds the reservoir for future food as many species are yet to be fully explored for its usage as food and to generate new sources of wealth for the nation. Our biodiversity is also the natural gene bank which harbours the key ingredients for the development of new varieties for better yield and also to meet the potential impacts of climate change.

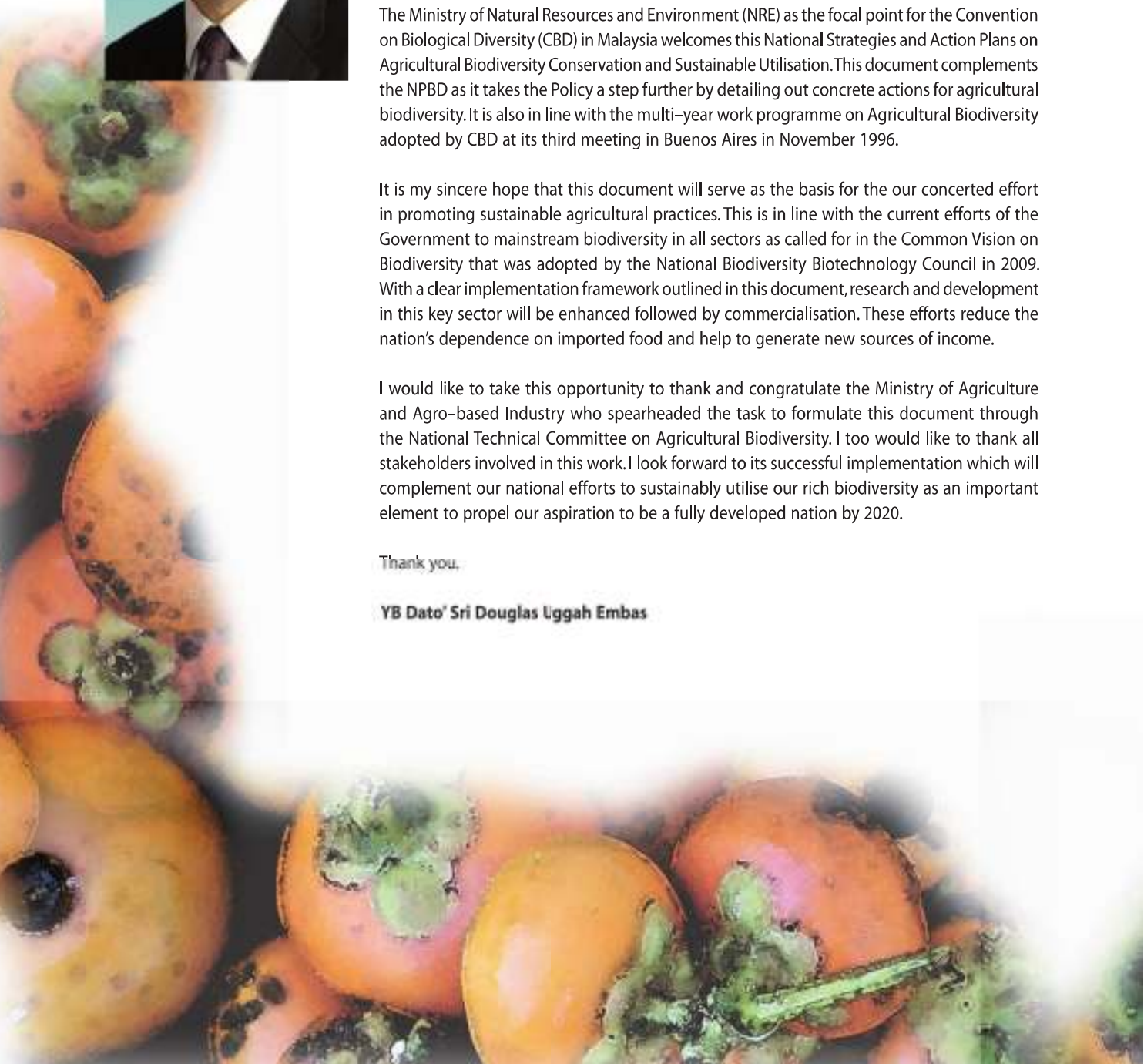
The Ministry of Natural Resources and Environment (NRE) as the focal point for the Convention on Biological Diversity (CBD) in Malaysia welcomes this National Strategies and Action Plans on Agricultural Biodiversity Conservation and Sustainable Utilisation. This document complements the NPBD as it takes the Policy a step further by detailing out concrete actions for agricultural biodiversity. It is also in line with the multi–year work programme on Agricultural Biodiversity adopted by CBD at its third meeting in Buenos Aires in November 1996.

It is my sincere hope that this document will serve as the basis for the our concerted effort in promoting sustainable agricultural practices. This is in line with the current efforts of the Government to mainstream biodiversity in all sectors as called for in the Common Vision on Biodiversity that was adopted by the National Biodiversity Biotechnology Council in 2009. With a clear implementation framework outlined in this document, research and development in this key sector will be enhanced followed by commercialisation. These efforts reduce the nation's dependence on imported food and help to generate new sources of income.

I would like to take this opportunity to thank and congratulate the Ministry of Agriculture and Agro–based Industry who spearheaded the task to formulate this document through the National Technical Committee on Agricultural Biodiversity. I too would like to thank all stakeholders involved in this work. I look forward to its successful implementation which will complement our national efforts to sustainably utilise our rich biodiversity as an important element to propel our aspiration to be a fully developed nation by 2020.

Thank you.

YB Dato' Sri Douglas Uggah Embas



Foreword by the Chairman of National Technical Committee on Agricultural Biodiversity

The National Technical Committee on Agricultural Biodiversity has completed the preparation of the document National Strategies and Action Plans on Agricultural Biodiversity Conservation and Sustainable Utilisation. It is aimed to look after the nation's biological resources which are important to food and agriculture. This imminent step is crucial for conservation and sustainable use of agricultural biological diversity.

Agricultural biodiversity has long been recognized as the most valuable part of our national resources. It is critical for food security and its rare and wild species of food crops can be utilised as sources of new industrial crops. The Strategies and Action Plans are formulated to create awareness among the public and policy makers, increase capacity building, enhance research and development on conservation and utilisation, improve *in situ* and *ex situ* conservation and strengthen policy and regulations. It is my ultimate hope that these strategies and action plans will be able to promote and encourage better understanding of conserving our agricultural biodiversity.

On behalf of the technical committee and the editors, I would like to take this opportunity to express our gratefulness to the Ministry of Agriculture and Agro-based Industry for entrusting MARDI as the secretariat of the National Technical Committee on Agricultural Biodiversity. I would also like to thank all those involved in the preparation of the document.

It is my sincere hope that the document will be adopted by various agencies and stakeholders related to agricultural development in Malaysia.

Thank you.

YH Dato' Dr. Sharif Haron

Preface

Malaysia signed the Convention on Biological Diversity (CBD) on 12th June 1992 and ratified it in 1994. The Ministry of Natural Resources and Environment (NRE) is the national focal point to CBD. As a party to the CBD, Malaysia undertakes to incorporate CBD objectives in its national policies. Malaysia launched the National Policy on Biological Diversity (NPBD) in April 1998. The policy aims to transform Malaysia into the world centre of excellence in conservation, research and sustainable utilisation of tropical biological diversity by the year 2020. It has 15 strategies, and it is an enabling move for implementing the CBD agenda in the country.

The NRE has mandated the Ministry of Agriculture and Agro-based Industry (MOA) to mainstream CBD objectives into the development of the agricultural sector in Malaysia. In response, MOA has established the Steering Committee for Food & Agriculture. The committee requested MARDI to form the National Technical Committee on Agricultural Biodiversity that is chaired by the Deputy Director General (Research) of MARDI. One of the functions of this technical committee is to formulate the national strategies and action plans specific for agricultural biodiversity and to assist in the implementation of the various action plans. The technical committee organized three consultative workshops to prepare the National Strategies and Action Plans on Agricultural Biodiversity Conservation and Sustainable Utilisation. The workshops were attended by eighty three participants from various government and non-government organizations (See Appendix I). The strategies and action plans in the document are meant to ensure that the agricultural sector in Malaysia uses its biological resources as recommended in NPBD.

The strategies strive for coordinated and holistic ways to identify, conserve and optimize the use of agricultural biodiversity in Malaysia. They are meant to enhance productivity, improving human and environmental safety and quality of life. We would like to encourage all stakeholders involved in agricultural development in Malaysia to incorporate relevant strategies and action plans in their planning programmes.

Editors

Local people selling their indigenous products by the road side in Sarawak

Executive summary

The term *agricultural biodiversity* encompasses all the biological diversity that contributes to food production at the genetic, species and ecosystem levels. At the genetic level, diversity in plants and animals is particularly important for adaptation to a wide range of environmental stress, such as climate change. At the species level, the diversity of the organism population in the agroecosystem contributes to the ecosystem functions, such as nutrient cycling, pest and disease regulation and pollination. At the ecosystem level, the resilience of agroecosystems is dependent on biodiversity to reduce its vulnerability and enhance the adaptability of the ecosystem to the changing environment. In short, agricultural biodiversity is a vital component for food security and sustainable agriculture.

However, agricultural biodiversity is currently threatened by some agricultural practices. For instance, more than 90% of crop varieties are no longer planted and half the breeds of livestock lost. The destruction of agricultural biodiversity by agricultural practices occur in a vicious cycle that undermines agriculture, as its long-term productivity relies on having a minimum biodiversity. For example, the decline in bee populations in North America and Europe has threatened orchards. Likewise, microbes are important to food industries and biofertilisers that generate much of our national income.

Thus, even as the world needs increasing food, agricultural productivity will be curtailed if its biodiversity continues to further diminish. Strategic practices should be adopted to increase agricultural biodiversity as properly managed agricultural land use systems can benefit society through conserving a variety of wild plant and animal species and habitats, which have not just economic or scientific value, but also recreational and even aesthetic advantages. The challenge is to expand agriculture without depleting our planet's biological interdependence.

In recognition of this monumental task, the Convention of Biological Diversity (CBD) of the United Nations Environment Programme (UNEP) has established the Programme of Work (POW) of Agricultural Biodiversity at the Third Conference of the Parties (COP3), November 1996. The objectives of POW for agricultural biodiversity are to promote the positive effects and mitigate the negative impacts of agricultural practices on biological diversity, conservation and sustainable use of genetic resources important to food production, and fair and equitable sharing of the benefits arising from the use of genetic resources. It comprises four mutually reinforcing elements: (1) assessment; (2) adaptive management; (3) capacity building; and (4) mainstreaming.

The strategies and action plans in the document are meant to ensure that the agricultural sector in Malaysia uses its biological resources as suggested in NPBD.

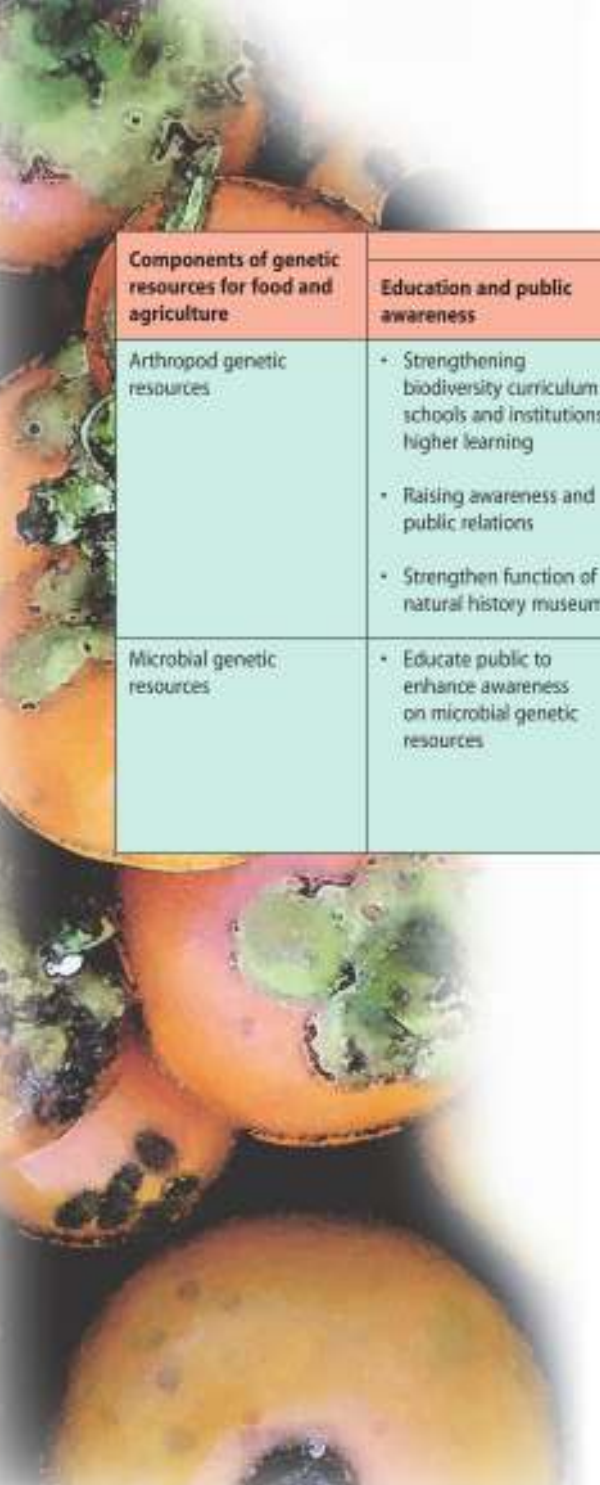
The National Strategies and Action Plans on Agricultural Biodiversity Conservation and Sustainable Utilisation was drafted through three consultative workshops attended by various governmental and non governmental organisations. The document has five chapters – General Introduction, Plant Genetic Resources for Food and Agriculture, Farm Animal Genetic Resources for Food and Agriculture, Arthropod Genetic Resources for Food and Agriculture and Microbial Genetic Resources for Food and Agriculture.

The chapters were organised based on the components of dimension of genetic resources for food and agriculture. The components are: 1) Plant genetic resources for food and agriculture, including pasture and rangeland species and forest genetic resources of trees that are an integral part of farming systems, 2) Animal genetic resources for food and agriculture, including fisheries as part of the farming system, and insect genetic resources, and 3) Microbial and fungal genetic resources. However, fishery genetic resources are not discussed, being instead covered under the inland water ecosystem programme.

In each components, four issues are identified – education and public awareness, capacity building, research and monitoring and legal and institutional framework. The issues are in line with the four elements of the POW of agricultural biodiversity. Table 1 summarizes the various strategies for each issue of each dimension. The strategies strive for coordinated and holistic ways to identify, conserve and optimize the use of agricultural biodiversity. They mean to enhance productivity, improving human and environmental safety and quality of life.

Table 1. Strategies for conservation and sustainable utilisation of agricultural biodiversity in Malaysia

Components of genetic resources for food and agriculture	Issues			
	Education and public awareness	**Capacity building**	**Research and monitoring**	**Legal and institutional framework**
Plant genetic resources	• Strengthen education and public awareness in PGRFA conservation and sustainable use	• Strengthen institutional framework and capacity building • Establish funding for PGRFA activities • Promote international cooperation in PGRFA conservation and utilisation • Strengthen legal framework of in situ conservation areas for crop relatives and wild species for food and agriculture • Utilisation of PGRFA	• Promote and strengthen on-farm conservation • Sustain and expand *ex situ* conservation • Promote and enhance sustainable use of plant genetic resources	• Strengthen national policy on PGRFA conservation and sustainable use • Promote implementation of international treaties and conventions related to PGRFA
Farm animal genetic resources	• Enhance institutional and public awareness • Develop the focal point for FAnGR	• Improve scientific knowledge base and skill • Enhance sustainable use of FAnGR components • Develop centres of excellence for conservation of FAnGR • Provide knowledge and understanding on diversity for its effective conservation and management	• Establish inventory of local FAnGRs • Expand conservation and sustainable use of FAnGRs • Strengthen breed endangerment early-warning and response systems for FAnGR	• Strengthen institutional framework for FAnGR • Integrate FAnGR management and sustainable utilisation considerations into livestock development policies and programmes • Review legislation to reflect domestic animal diversity needs and to promote agroecosystems approaches to the management of FAnGR • Strengthen and integrate conservation programmes • Promote international cooperation and collaboration • Strengthen efforts to mobilize resources, including financial resources for the conservation, sustainable use and development of FAnGR



Components of genetic resources for food and agriculture	Issues			
	Education and public awareness	Capacity building	Research and monitoring	Legal and institutional framework
Arthropod genetic resources	• Strengthening biodiversity curriculum in schools and institutions of higher learning • Raising awareness and public relations • Strengthen function of natural history museum	• Build up national capacity in arthropod systematics and biodiversity-trained personnel • International cooperation & networking in consideration of necessity to coordinate actions and set priorities • Establishment of modern research facilities	• Conservation and utilisation of arthropod genetic resources	• Review and update existing legislation on conservation of arthropod biodiversity
Microbial genetic resources	• Educate public to enhance awareness on microbial genetic resources	• Build national capacities and link them • Capacity building at international level and interlinkage of the capacities built	• Scientific study of microbial genetic resources and its conservation and utilisation • Establish a continuing funding mechanism • Management, updating and maintenance of databases	• Biosafety guidelines • Strengthen implementation of legislation on import and export of microbes

Acronyms

Binjai, *Mangifera caesia*

10th MP	Tenth Malaysia Plan
11th MP	Eleventh Malaysia Plan
AGC	Attorney General's Chamber
ATCC	American Type Culture Collection
CABI	Centre for Agriculture and Biosciences International
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
DOA, Peninsular	Department of Agriculture, Peninsular
DOA, Sabah	Department of Agriculture, Sabah
DOA, Sarawak	Department of Agriculture, Sarawak
DOF	Department of Forestry
DOVSAI	Department of Veterinary Services and Animal Industry, Sabah
DSMZ	German Collection of Microorganisms and Cell Cultures
DVS, Peninsular	Department of Veterinary Services, Peninsular
DVS, Sabah	Department of Veterinary Services, Sabah
DVS, Sarawak	Department of Veterinary Services, Sarawak
DWNP	Department of Wildlife and National Parks
EPU	Economic Planning Unit
EurepGAP	European Retailers Produce Working Group-Good Agricultural Practise
FAMA	Federal Agriculture Marketing Authority
FAO	Food and Agricultural Organization of the United Nations
FELDA	Federal Land Development Authority
FRIM	Forest Research Institute, Malaysia
FOA	Farmers' Organization Authority
GAP	Good Agriculture Practice
MRB	Malaysian Rubber Board
MARDI	Malaysian Agricultural Research and Development Institute
MCB	Malaysian Cocoa Board
Nuclear Malaysia	Malaysian Nuclear Agency
MACRES	Malaysian Centre for Remote Sensing
MOA	Ministry of Agriculture and Agro-based Industry
MOE	Ministry of Education
MOF	Ministry of Finance
MOHE	Ministry of Higher Education
MOI	Ministry of Information, Communication and Culture
MOSTI	Ministry of Science, Technology and Innovation
MOTour	Ministry of Tourism
MPOB	Malaysian Palm Oil Board
NGO	Non-Governmental Organisation
NITE	National Institute of Technology and Evaluation, Japan
NIVB	National Institute of Veterinary Biodiversity
NRE	Ministry of Natural Resources and Environment
PSD	Public Service Department
RECSEA	Regional Co-operation in Southeast Asia for Plant Genetic Resources
R&D	Research and Development
SaBC	Sabah Biodiversity Center
Sabah MOAFI	Ministry of Agriculture and Food Industry Sabah
SBC	Sarawak Biodiversity Center
SALM	Good Agriculture Practice Scheme Malaysia
TFNet	Tropical Fruit Network
TOR	Term of Reference
TWN	Third World Network
UKM	Universiti Kebangsaan Malaysia
UM	Universiti Malaya
UMS	Universiti Malaysia Sabah
UMT	Universiti Malaysia Terengganu
UNIMAS	Universiti Malaysia Sarawak
UPM	Universiti Putra Malaysia
USM	Universiti Sains Malaysia
UiTM	Universiti Teknologi Mara

Chapter 1

INTRODUCTION

Rokam, *Flacourtia inermis*

1. INTRODUCTION

1.1 Malaysian landscape

Located in the tropics, Malaysia consists of two major land masses, straddling across the South China Sea. Peninsular Malaysia is at the southern tip of mainland Southeast Asia while East Malaysia is on the island of Borneo. The area of the country is 329,847 km^2, of which 40% is in Peninsular Malaysia and 60% East Malaysia. The population is about 28.3 million in 2010. About 80% of total population resides in Peninsular Malaysia. The country has an equatorial climate with fairly uniform temperatures throughout the year.

Agriculture is an important sector for Malaysia development. Out of the total land mass, about 16% is used for agriculture. In 2010 the sector was dominated by plantation crops, of which oil palm (6.50 million ha) was the major crop followed by rubber (1.50 million ha). Of the food crops, rice (0.40 million ha) is the most important followed by fruit (260,000 ha) and vegetable cultivation (38,000 ha) (DSM, 2010).

1.2 Megadiverse country

Malaysia is blessed with an extremely rich and very diverse biological resources. It is one of the 12 megadiverse countries in the world harbouring more than 170,000 species of flora and fauna or about 16% of the world's classified species (NRE 2006). These flora and fauna are listed below:

Mokara Tengku Anis

Malaysia's known flora and fauna species diversity

Organisms	Total number of species
Mammals	306
Birds	742
Reptiles	567
Amphibians	242
Marine fishes	4,000
Freshwater fishes	449
Invertebrates	150,000
Flowering plants	15,000
Palms	536
Orchids	3,000
Fern and fern allies	2,012
Fungi	700
Mosses	832

Source : NRE (2006)

1.3 Convention on Biological Diversity

Malaysia signed the Convention on Biological Diversity (CBD) on 12th June 1992 and ratified it in 1994. As a party to the CBD, Malaysia has the responsibility to incorporate CBD objectives into its national policies. According to Article 6 of CBD every contracting party shall either develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity, or adapt its existing strategies, which any case are to reflect the measures set out in the Convention.

Decision III/11 agreed at the Third Conference of the Parties (COP), November 1996 recognizes that although there is much evidence of the loss of agricultural biodiversity and the continuing threats to its development and use, there is very limited understanding of the measures that are needed to develop work programmes that will address these problems. Other COP decisions that are relevent to agricultural biodiversity can also be found on different programmes including inland waters biodiversity, ecosystem approach, access and benefit sharing and Article 8(j).

The objectives of the Programme of Work (POW) on agricultural biodiversity are to promote the positive effects and mitigate the negative impacts of

Chicken poultry

Misai kucing, *Orthosiphon stamineus*

agricultural practices on biological diversity, the conservation and sustainable use of genetic resources and the fair and equitable sharing of benefits arising out of the use of genetic resources. The POW comprises four mutually reinforcing elements: (i) assessments; (ii) adaptive management; (iii) capacity building and (iv) mainstreaming.

1.4 National Policy on Biological Diversity

The Malaysian government launched the National Policy on Biological Diversity (NPBD) in April 1998. It is a major milestone towards implementing CBD agenda in Malaysia. This policy sets the vision of transforming Malaysia into a world centre of excellence in conservation, research and utilisation of tropical biological diversity by year 2020. The policy for effective management of biodiversity includes 15 strategies as follows:

i. Improving the Scientific Knowledge Base;
ii. Enhancing Sustainable Utilisation of the Components of Biological Biodiversity;
iii. Developing Centre of Excellence in Industrial Research on Tropical Biological Biodiversity;
iv. Strengthening the Institutional Framework for Biological Diversity Management;
v. Strengthening and Integrating Conservation Programmes;
vi. Integrating Biological Diversity Considerations into Sectoral Planning Strategies;
vii. Enhancing Skill, Capabilities and Competence;
viii. Encouraging Private Sector Participation;
ix. Reviewing Legislation to Reflect Biological Biodiversity Needs;
x. Minimizing Impacts of Human Activities on Biological Biodiversity;
xi. Developing Policies, Regulations, Laws and Capacity Building on Biosafety;
xii. Enhancing Institutional and Public Awareness;
xiii. Promoting International Cooperation and Collaboration;
xiv. Exchanging of Information; and
xv. Establishing Funding Mechanisms.

Stingless bee, Trigona itama

Josapine

1.5 Agricultural biodiversity for human well-being

Agricultural biodiversity is a broad term that refers to all components of biological diversity of relevance to food and agriculture. It also refers to all components of biological diversity that exist in an agroecosystem which include the variety and variability of animals, plants and micro organisms which are necessary to sustain key functions of the agroecosystem, its structure and processes.

Therefore, apart from producing food and income, agricultural biodiversity also provides raw materials for clothing, shelter, medicines, genetic resources to breed new varieties and performs services such as maintenance of soil fertility and biota, soil and water conservation and pollination, all of which are essential to sustain the country's agricultural and economic growth.

However, the world agricultural biodiversity is currently threatened by some agricultural practices. Many crop varieties have disappeared from farmers' fields; half of the breeds of many domestic animals have been lost. In fisheries, the main fishing grounds are now being fished at or above their sustainable limits. Agriculture cannot be curtailed, nevertheless if strategic actions are not taken, agricultural biodiversity will diminish significantly in the next 50 years. The destruction of agricultural biodiversity by agricultural practices creates a vicious cycle that actually undermines agriculture because agricultural biodiversity are essential to agricultural productivity.

Conservation of agricultural biodiversity is a major challenge in securing and providing well-being for future generations. The conservation effort shall not be emphasized only on the conservation of crop genetic resources but also the other biodiversity related to it. The ecosystem approach provides a platform to effectively conserve and sustainably use biodiversity.

1.6 Dimensions of agricultural biodiversity

Other dimensions of the agricultural biodiversity include:

i. genetic resources for food and agriculture, e.g. rice variety;
ii. components of biodiversity that support ecosystem services, e.g. nutrient cycling;
ii. abiotic factors, e.g. climatic factors; and
iv. socio-economic and culture, e.g. traditional knowledge.

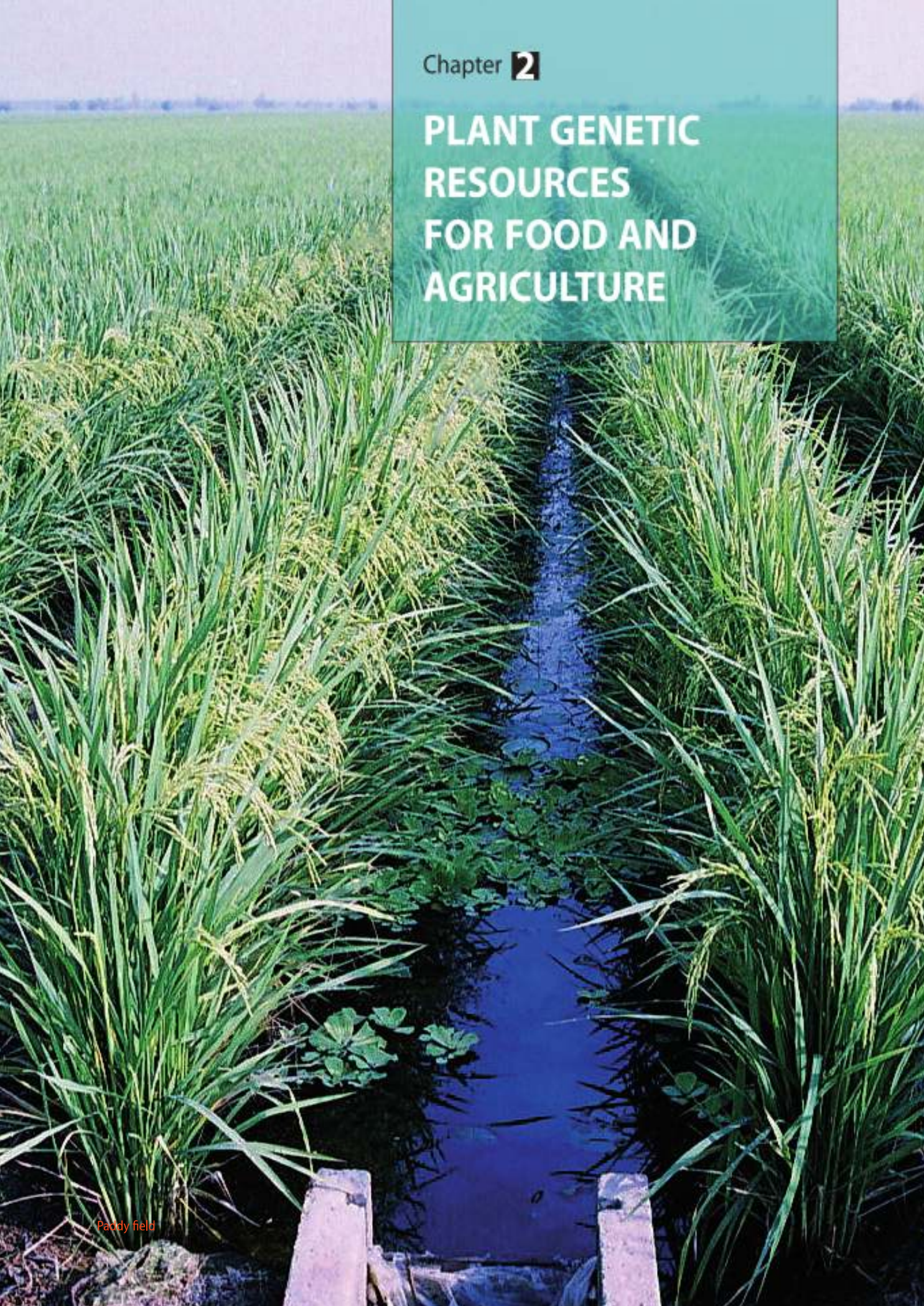
The dimension of genetic resources for food and agriculture constitutes the main units of production in agriculture and it can be identified as the following three components:

i. Plant genetic resources for food and agriculture including pasture and rangeland species and forest genetic resources of trees that are an integral part of farming systems;
ii. Animal genetic resources for food and agriculture including fishery genetic resources, in cases where fish production is part of the farming system, and arthropod genetic resources; and
iii. Microbial and fungal genetic resources.

In this strategy and action plan, agricultural biodiversity components are discussed under four major groups: plants, farm animals, arthropods and microbes. Fish component is reported under inland water ecosystem programme of work.

Chapter 2

PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE



Paddy field


1


2


3

2. Plant Genetic Resources for Food and Agriculture

2.1 Rationale

Plant genetic resources (PGR) means any materials of plant origin containing gene(s) of actual or potential value to mankind. If the plant produces food or any other useful product(s), it is referred to as a plant genetic resource for food and agriculture (PGRFA). PGRFA is a source of genes, which provides the basic raw materials required by breeders to continue improving crop plants. For example, double cropping has been made possible in Malaysia by improved rice varieties such as Malinja, Mahsuri, Bahagia and Ria which have short-maturity periods. These varieties have the semi-dwarf gene (sd1) introgressed from variety Dee-geo-woo-gen (Athwal, 1971; Khush & Virk, 2005). So far, more than 30 improved rice varieties have been released in Malaysia as a result of continuous exploitation of the available local and foreign germplasm conserved in the MARDI Rice Genebank (Abdullah et al. 2003). Another example is Josapine, a new high yielding pineapple developed by MARDI from two local cultivars - Sarawak and Johor.

MARDI Rice Genebank

Apart from contributing genes for crop improvement, PGR has the potential to generate income to the country by providing raw materials in the manufacturing of food, herbal medicines, dietary supplements, protein, industrial chemicals and many others. Many countries have benefited from the commercialisation of their PGR for these purposes.

At least 1,200 Malaysian plant species are known to have medicinal properties. A number of them contains high antioxidants (e.g., ulam raja *(Cosmos caudatus)*, terung pipit *(Solanum torvum)*, bebuas *(Premna foetida)*), oils and chemicals used to manufacture pesticide (e.g., akar tuba *(Derris elliptica)* for rotenone), veterinary medicines (e.g., patawali *(Tinospora crispa)*, gelenggang *(Cassia alata)*), as starting materials for some drugs, (e.g., kemunting cina *(Catharanthus roseus)* for anticancer, keladi *(Caladium* spp.*)* for contraceptive) (Rasadah & Li, 2009). Through genetic enhancement, many indigenous fruit species can be improved and commercialised (e.g., cerapu *(Garcinia prainiana)*, kundang *(Bouea macrophylla)*, kuini *(Mangifera odorata)*, binjai *(Mangifera caesia)*, salak *(Salacca glabarescens)* and the wild durians of Sarawak). Many wild plant species are grown as ornamentals.

Plants with high antioxidant,
1. Bebuas (*Premna foetida*),
2. Terung pipit (*Solanum torvum*),
3. Ulam raja (*Cosmos caudatus*)

Kacip fatimah, *Labisia pumila*

Conserved in field genebank, binjai (*Mangifera caesia*) and kuini (*Mangifera odorata*)

The most important reason for conserving PGRFA is because the diversity of a number of our PGRFA species are already under threat of being eroded or loss and the potential of some are unknown. There are more than 500 tree crop species currently considered endangered, including some rare fruits and edible plants such as cerapu *(Garcinia prainiana),* binjai *(Mangifera caesia),* tampoi *(Baccaurea macrocarpa),* rambai *(Baccaurea motleyana),* kundang *(Bouea macrophylla),* bacang *(Mangifera foetida)* and several wild relatives of the crops (Mohd. Shukor et al., 2007).

The threat is more serious on the landraces of crops. For example, traditional rice varieties have been replaced by modern varieties.

2.2 Current status

2.2.1 *In situ and on farm conservation and development*

So far, not much has been studied about on farm conservation in Malaysia. There have been several studies by MARDI and DOAs of Peninsular Malaysia, Sabah and Sarawak on traditional fruits in home gardens and orchards. In several villages in the Peninsular, Sabah and Sarawak, there are still many important landraces of traditional fruits (Salma et al., 2006). Therefore, home gardens and orchards can be excellent repositories for traditional fruit germplasm if a proper system can be established. Sabah Parks has inventorised important crop species in several community farms around Taman Kinabalu and in the Crocker Range (Mohd. Shukor et al., 2007).

One good example of on farm conservation is the conservation of rice in Bario in the Kelabit Highlands at 3,600 feet above sea level. The quality and authenticity of Bario rice is guaranteed by the Bario Rice Certification Programme which ensures the seed quality and good agricultural practices (GAP) conformed to standards (Jamadon et al., 2007).

2.2.2 *Ex situ conservation*

Ex situ conservation is one of the areas where most of the country's PGRFA activities are focused. The conservation is in the form of seeds stored in genebanks and continuously regenerated in the field and arboreta. More than 370 tropical fruit species are found in Malaysia and 16 of them have been cultivated commercially (Rukayah, 2002). There is still a lack of *ex situ* conservation for many fruit species. However, some of the fruit species are being conserved in the field genebanks of MARDI, DOAs and universities. Among the species are durian *(Durio* spp.*),* mango *(Mangifera indica),* rambutan *(Nephellium lappaceum),* ciku (*Manilkara zapota*), kuini *(Mangifera odorata),* binjai *(Mangifera caesia),* bacang *(Mangifera foetida),* duku *(Lansium domesticum),* salak *(Salacca* spp.*),* pulasan *(Nephellium ramboutan-ake),* manggis *(Garcinia mangostana),* cerapu *(Garcinia prainiana),* pisang *(Musa* spp.*),* nangka *(Artocarpus heterophyllus),* cempedak *(Artocarpus chempeden),* coconut *(Cocos nucifera),* limau *(Citrus* spp.*).* In Sabah, *ex situ* collections of fruits, herbs, medicinal and ornamental plants can be found in Kinabalu Park, Poring Rafflesia Farm, Kinabalu Mountain Botanical Garden and Poring Orchid Conservation Center. MARDI and DOAs Sabah and Sarawak maintain some vegetable germplasm collections.

Seed storage in genebank

Seeds of more than 12,000 accessions of rice, about 100 accessions of chili and eggplant, and more than 500 accessions of landraces of the traditional vegetables are kept in MARDI's medium and long term seed genebank (Jamadon et al., 2006). However, more accessions still need to be collected so that the conserved germplasm is endowed with many useful traits, which may not be found in the current collection for future utilisation in breeding programmes.

2.2.3 *Institutions and capacity building*

Activities under the Global Plan of Action (GPA) priority area include establishing national programme on PGRFA, promoting and establishing a PGRFA Network, construction of a comprehensive PGRFA Information System, developing an early warning system for loss in PGRFA, education and training in PGRFA conservation and use, promoting awareness of the importance of PGRFA and last but not least, establishing the needs for genetic resources plant conservation and sustainable use.

In the regional PGRFA networking activity, MARDI has been participating with RECSEA (Regional Co-operation for Southeast Asia) and Bioversity International.

Several PGRFA information systems have been developed separately by agencies such as MARDI, Forest Research Institute Malaysia (FRIM), Malaysian Agency for Control Remote Sensing (MACRES), MIMOS, UPM and TFNet. Therefore, there is a need to establish a national PGRFA information system.

2.2.4 *Utilisation of PGRFA*

Characterisation and evaluation of conserved genetic resources are very important to allow breeders, geneticists, genebank curators and other users, to identify accessions or lines with specific interests/traits. Some of crop species have been characterised and evaluated. Characterisation and evaluation are continuously being carried out by relevant agencies. Characterisation using molecular markers is also being done by some institutions and private sectors (Mohd. Shukor et al., 2007).

Some accessions of underutilised plant species have been identified and developed into new crops. Some examples are accessions of pulasan (*Nephellium ramboutan-ake*) and kuini (*Mangifera odorata*) (Salma, 2005). Traditional vegetables and ulam such as peria pantai (*Colubrina asiatica*), bebuas (*Premna foetida*) and gajus (*Anacardium occidentale*), with high antioxidant and iron contents have been identified (Erny Sabrina et al., 2005; Mohd. Shukri & Alan, 2009). Many species of medicinal plants and ulam still remain underutilised.

2.3 Way forward

Conservation and sustainable utilisation of PGRFA are important for the benefit of the present and future generations. Genes which are useful, must be introgressed into cultivar to develop new varieties. Underutilised fruits, such as kuini *(Mangifera odorata),* pulasan *(Nephellium ramboutan-ake)*, cerapu *(Garcinia prainiana)* and binjai *(Mangifera caesia),* can be developed into potential crops. This, partly has been achieved for nyekak (*Durio kutejensis*), dabai (*Canarium odonthopyhllum*) and isau (*Dimocarpus longan* var. *malesianus*) in Sarawak and bambangan (*Mangifera pajang*) and tuhau (*Etlingera punicea*) in Sabah. Many herbal, medicinal plant and ulam species are being promoted for cultivation. There are many independent collections of germplasms being kept by institutions, organisations and individuals. Ideally, these collections and their records should be deposited and registered in a formal entity as custodian for the national PGRFA. The records should be placed on the PGRFA national network to make them accessible to all relevant stakeholders. High priority should be accorded to the programme to enhance national capacity

Ulam gajus, *Anacardium occidentale*

Underutilised fruit, bambangan, *Mangifera pajang*

Cerapu, *Garcinia prainiana*

in PGRFA conservation and sustainable utilisation to maximise socio-economic benefits.

More emphasis should be given to the utilisation of PGRFA in the implementation of the Global Plan of Action (GPA) in Malaysia. Many PGRFA activities of indigenous species involve mainly collection and characterisation. The potential of the PGRFA can only be realized through their utilisation such as the development of new varieties for farmers.

Conservation and sustainable utilisation of PGRFA require effective information system, consultation and collaboration between relevant agencies/ individuals. In order to strengthen all these activities at the national level, substantial investment in human resource, funding, infrastructure and equipment for the development, management and maintenance of *ex situ* and *in situ* genebanks are required. In education and training, relevant learning institutions should include PGRFA conservation and sustainable utilisation in their curriculum.

2.4 Strategies and action plans for plant genetic resources for food and agriculture

2.4.1 *Education and public awareness*

One of the strategies of the National Policy on Biological Diversity is to promote and encourage understanding and participation by the public and institutions for effective conservation of PGRFA. In line with this, PGRFA conservation and sustainable use will be incorporated into local training, education and public awareness activities.

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry /Implementing Agency	Impact
1	Strengthen education and public awareness in PGRFA conservation and sustainable use	1. Incorporate PGRFA conservation and sustainable use in local trainings, education and public awareness	1. Train local communities to identify, catalogue and manage wild crop relatives and wild food crops	Number of communities trained	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC & SaBC	Improve public understanding on importance of PGRFA
			2. Conduct talks/ seminars/conferences/ courses	5 sessions of talk/ seminar/conference/ course conducted or 200 participants involved	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC & Universities. **NRE**/FRIM	
			3. Produce short documentary	Number of documentaries produced	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC & Universities. **NRE**	
			4. Produce articles in newspapers	Number of articles produced	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC & Universities. **NRE** /FRIM	

Cili padi Semerah, *Capsicum frutescens*

2.4.2 *Capacity building*

The strategies outlined under capacity building include:

i. strengthen the institutional framework through improved capacity in PGRFA R&D, building strong national programmes, information system and established networks for PGRFA;
ii. ensure stable and adequate funding for implementing the national action plan by, *inter alia*, encouraging private sector participation in PGRFA conservation and use;
iii. promote international cooperation in PGRFA conservation and use by improving the international network on PGRFA conservation and use, and improving the country's compliance to international treaties and conventions related to PGRFA;
iv. increase *in situ* conservation areas of crop relatives and wild species for food and agriculture;
v. develop facilities and train trainers in *ex situ* conservation, as well as develop funding mechanism and human capital for PGRFA collection and conservation; and
vi. increase the capacity to use Plant Genetic Resources by strengthening characterisation, evaluation and genetic enhancement, promoting development and commercialization of underexploited crops and species, and creating new markets for products from farms using diverse varieties and crops.

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry /Implementing Agency	Impact
1	Strengthen institutional framework and capacity building	1. Improve R&D capacity in PGRFA	1. Establish National genebank	National Genebank established and functional	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), Universities, other relevant agencies & Organisations	Increased used of conserved genetic resources by breeders and crop scientists
			2. Establish Plant Breeding Institute	Plant Breeding Institute established and functional	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), Universities, other relevant agencies & Organisations	
		2. Build strong national programmes, information system and establish networks for plant genetic resources for food and agriculture	1. Review and improve existing National programmes	Programmes reviewed and improved	12 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) & Universities **NRE**	Better use of genetic resources, increased public awareness
			2. Establish PGRFA information system	PGRFA information system established	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) & Universities **NRE**	
			3. Establish PGRFA networks	PGRFA networks established	12 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), Universities. and **NRE**	
			4. Participate in regional and international collaborations	Regional and international contacts established	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), Universities & other organisations. **NRE**/FRIM	
		3. Human resource development	1. Provide financial support for training related to PGRFA conservation and sustainable utilisation	Number of scholarships awarded	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), Universities. **NRE**	More scientists trained in Geographical Information System (GIS), taxonomy, population biology, agronomy, agroecology and genetic resource collection
			2. Provide financial support for on job trainings related to PGRFA conservation and sustainable utilisation	Number of grants for on job trainings provided	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), Universities, **NRE** /FRIM **MOF**	
2	Establish funding for PGRFA activities	1. Secure funding from goverment for PGRFA management	1. Prepare and submit proposals to goverment	Size of fund allocated	12 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), Universities, **NRE** /FRIM **MOF**	Enhance contribution of government and encourage private sectors to contribute

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry /Implementing Agency	Impact
3	Promote international cooperation in PGRFA conservation and utilisation	1. Enhance international network on PGRFA conservation and utilisation	1. Establish and participate in new international network in PGRFA conservation and utilisation	PGRFA International networks established	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC, Universities. **NRE**/FRIM	International linkage and collaboration established
		2. Improve country's compliance to international treaties and conventions related to PGRFA	1. Develop mechanism to ensure country's compliance with the various treaties and conventions related to PGRFA	Country's compliance to PGRFA	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC & Universities. **NRE**	Fulfill international obligations, genetic resources better conserved and benefits shared
		3. Effective monitoring system	1. Establish monitorings by organizing workshops and discussions	Number of monitorings established	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC Universities & other relevant organisations **NRE**/FRIM	Country's obligation on report submission fulfiled
4	Strengthen legal framework of *in situ* conservation areas for crop relatives and wild species for food and agriculture	1. Safeguards and increase *in situ* conservation areas	1. Review existing laws and propose new legislation *in situ* conservation areas for PGRFA	PGRFA *in situ* and *ex situ* conservation areas gazetted	36 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC & Universities. **NRE**/DOF	Plant genetic resources conserved *in situ* as resources for new crops
5	Utilisation of PGRFA	1. Strengthen existing major crop breeding programmes	1. Identify, screen and utilise useful genes or traits	Number of accessions used in breeding programmes	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC & Universities. **NRE**/FRIM	Strengthen linkages and networking for better use of plant genetic resources
		2. Promote exploitation of underutilised crops and species	1. Characterise and evaluate germplasm	Percentage of accessions characterised and evaluated	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak), SBC, SaBC & Universities. **NRE**/FRIM	Supply and distribution of seeds for underused crops established
			2. Marketing new products from underutilised crops	Number of marketable products	60 months	**MOA**/DOA (Peninsula, Sabah & Sarawak) FAMA, FOA), FELDA, Private sectors & related organisation.	Marketing of local products established in domestic and international markets

Coconut, *Cocos nucifera*

2.4.3 *Research and monitoring*

Not much has been studied about on farm conservation in Malaysia. The efforts to collect, describe and document PGRFA will be promoted and strengthened through survey and *in situ* inventory of farms. There is a need to develop management, conservation and improved technologies for PGRFA as well as *in situ* conservation techniques for crop relatives and wild species. *Ex situ* conservation will be sustained and expanded through improved technologies and collection of more PGRFA. To promote and enhance sustainable use of PGR, characterisation, evaluation and genetic enhancement will be expanded; adoption of sustainable agriculture practices through diversification of crop production and encouragement on broader diversity in crops and

commercialisation of underexploited crops and species promoted. The global plan of action will be monitored to allow preparation of country reports and organisation of workshops and discussions.

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry /Implementing Agency	Impact
1	Promote and strengthen on-farm conservation	1. Survey and inventory PGRFA on farms	1. Survey distribution and inventory PGRFA on farms	Survey distribution and inventory PGRFA on farm established	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) & Universities	Information on distribution, characteristics, values and threats, and population genetics of PGRFA on farm available
			2. Survey traditional knowledge on use of PGRFA for food and agriculture in selected farms	Survey on traditional knowledges in selected farms established	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC & Universities	
			3. Identify, inventorize and characterise PGRFA on farms in selected survey locations	PGRFA on selected farm identified, inventorised and characterised	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) & Universities	
			4. Assess the value of PGRFA in farms in selected survey sites	PGRFA in selected survey site evaluated	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) & Universities	
			5. Develop indicators and survey threats to on-farm PGRFA	Indicators and threats identified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) & Universities	
		2. Identify traditional technology used for on farm PGRFA conservation	1. Survey traditional farmer practices in management of PGRFA	Traditional farmer practices for on farm conservation identified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) & Universities	Information on farmer best practices, improved varieties, sustainable agriculture practices, enhanced crop heterogeneity established
2	Sustain and expand *ex situ* conservation	1. Develop technologies and manage the current *ex situ* conservation	1. Conduct research in conservation technologies for different species and genotypes	Cost effective *ex situ* conservation technologies developed	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC & Universities	Technologies for cost reduction, increased seed life and shorter generation cycles
			2. Continuous monitoring of viability of regenerated accessions	Percentage of accessions regenerated for regeneration	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC & Universities	
			3. Duplicate PGRFA as per international genebank management standard.	Percentage of accessions multiplied for multiplication	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC & Universities	

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry /Implementing Agency	Impact
		2. Collect new PGRFA to fill gaps and expand *ex situ* conservation	1. Identify gaps in collection of selected PGRFA	Gaps in collections identified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations	Broader genetic base for crop development
			2. Collect and conserve new PGRFA to fill gaps	Percentage of the identified PGRFA collected	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations	
			3. Collect local varieties in potential disaster prone areas	Percentage of the identified varieties collected	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations	
3	Promote and enhance sustainable use of plant genetic resources	1. Expand characterisation, evaluation and genetic enhancement	1. Identify gaps and priorities in characterisation and evaluation on *ex situ* materials	Priorities and gaps established	12 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations **NRE**/FRIM	Increased use of genetic resources for crop improvement
			2. Characterise, screen and evaluate PGRFA	Percentage of accessions/ species evaluated	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations **NRE**/FRIM	
			3. Conduct hybridization involving wild genotypes to transfer trait(s) of interest	Number of hybridizations	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations **NRE**/FRIM	
		2. Develop practices to promote broader use of genetic diversity in cropping systems	1. Assess the ideal equilibria between genetic uniformity and diversity in cropping system	Methodology developed and ideal equilibria established	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations **NRE**/FRIM	Best management practices adopted by farmers
		3. Promote underutilised crops and species	1. Identify species with potential and develop sustainable practices for their production	Number of underutilised species promoted	60 months	**MOA**/MARDI, FAMA, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations **NRE**/FRIM	Increased farmer's income
			2. Prospecting underutilised species for useful compounds	Number of potential species identified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC, Universities & other relevant organisations **NRE**/FRIM	

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry /Implementing Agency	Impact
			3. Develop post-harvest processing and improve marketing	Number of products from underutilised species developed and commercialised	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) SBC, SaBC Universities& other relevant organisations **NRE**/FRIM	

2.4.4 *Legal and institutional framework*

Malaysia acceded to the International Treaty on PGRFA (ITPGRFA) on 5th May 2003. As a contracting party, Malaysia has to ensure the conformity of its laws, regulations and procedures to its obligations in the treaty. It is important to strengthen the policy on PGRFA conservation and sustainable use at the national level. Equally important is to promote implementation of international treaties and conventions on PGRFA with activities leading to compliance to ITPGRFA to ensure facilitated access and benefit sharing.

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry /Implementing Agency	Impact
1	Strengthen national policy on PGRFA conservation and sustainable use	1. Establish policy and advisory panels on PGRFA in key areas	1. Identify and appoint personnel for advisory panels	Advisory panels appointed	12 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) **NRE**/ FRIM, Local Councils, State Governments	Better protection and systematic management of plant genetic resources
			2. Formulate TOR of advisory panels	TOR formulated	12 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) **NRE**/ FRIM, Local Councils, State Governments	
			3. Legislate Policy on conservation and management of PGRFA	Policy established	24 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) **NRE**/ FRIM, Local Councils, State Governments	
			4. Formulate policies on incentives for crop diversification and creation of markets for biodiverse food crops	Policy on incentives in place	24months	**MOA**/MARDI, FAMA, DOA (Peninsular, Sabah & Sarawak) **NRE**/ FRIM, Local Councils, State Governments	
2	Promote implementation of international treaties and conventions related to PGRFA	1. Ensure PGRFA activities compliance to Treaties and Conventions related to PGRFA	1. Review existing legislations, procedures and regulations to identify potential gaps	Legislations, procedures and regulations reviewed and gaps identified	24 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) **NRE**/ FRIM, **AGC**, Local Councils, State Governments	Fulfill international obligations and safeguard local plant genetic resources according to national interest
			2. Formulate, amend and implement legislations, procedures and regulations	Legislations, procedures and regulations formulated/ amended	24 months	**MOA**/MARDI, DOA (Peninsular, Sabah & Sarawak) **NRE**/ FRIM, **AGC**, Local Councils, State Governments	

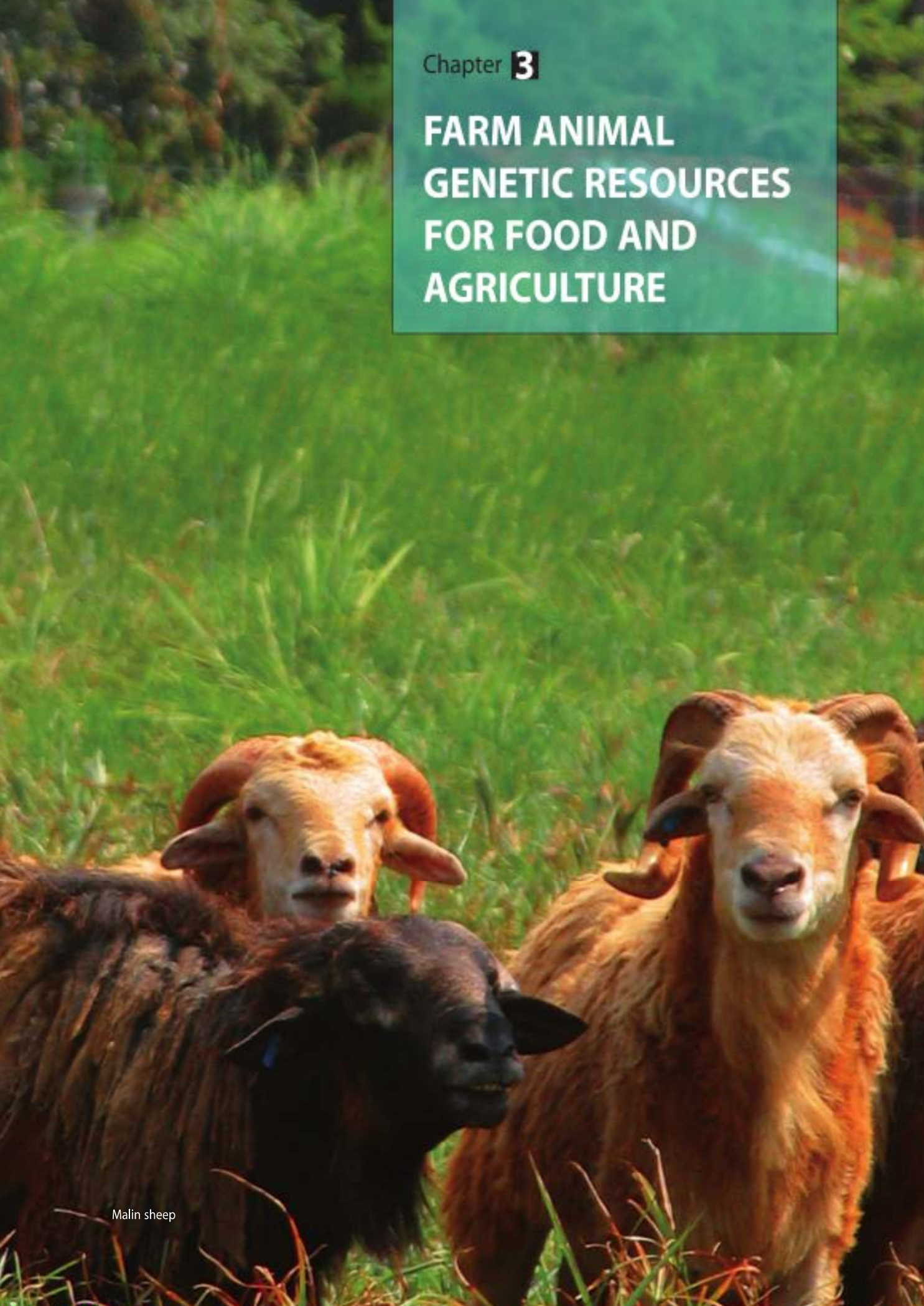
Pulasan, *Nephellium ramboutan-ake*

Tampoi, *Baccaurea macrocarpa*

Durian Nyekak, *Durio kutejensis*

Chapter 3

FARM ANIMAL GENETIC RESOURCES FOR FOOD AND AGRICULTURE



Malin sheep

Jermasia goat - a synthetic Malaysian breed

Mafriwal - Malaysia's dairy cattle

Kampong chicken

3. Farm Animal Genetic Resources for Food and Agriculture

3.1 Rationale

Farm Animal Genetic Resources (FAnGR) are defined as those animal species which are or maybe used for food and agriculture. Breeds are distinct populations whithin a species and have definable and identifiable external characteristics which give them a separate identity (FAO, 2007b).

According to the Global Plan of Action for Animal Genetic Resources for Food and Agriculture (FAO, 2007a), continued indiscriminate breeding and crossbreeding may result in loss of genetic diversity and risk endangering of breeds presently considered to be undesirable. Hence, breeds that comprise the nation's farm animal genetic resources should continue to be comprehensively studied and documented for better management and utilisation of these genetic resources.

Farm animals genetic diversity have important economic, technological, ecological and social implications for the nation (Raymond et al., 2008).
Of particular significance are:

i. economic benefits;
ii. food security;
iii. nutritional value;
iv. national heritage;
v. animal and public health;
vi. biological science;
vii. ecological benefits;
viii. educational value;
ix. biosafety; and
x. recreational and therapeutic value.

3.2 Current status

3.2.1 *Farm animals biological diversity*

The farm animals genetic resources (FAnGR) of Malaysia, consisting mainly of cattle, buffalo, sheep, goats, swine, poultry, horses and deer are quite diverse with a known total of 101 breeds and breed crosses (AnGR Technical Team, 2003). The breeds can be classified as indigenous, recently introduced or continually imported (the latter two comprising 65 breeds). Indigenous breeds include Kedah-Kelantan cattle, Katjang goat, Malin sheep, South China pig, local Indian dairy cattle, Bali cattle, Swamp buffalo, Murrah buffalo, Kuda Padi (Local ponies) and Kampong chicken. 25% of the indigenous breeds and 46% of the other breeds are widely used (AnGR Technical Team, 2003). There are also farmed 'wild' species, such as swiftlet, Sambar deer, mouse deer, soft-shell turtle, porcupine, crocodile and frog.

The various breeds have been evaluated, particularly the ruminants, mostly by baseline breed surveys, genetic characterisation and to a lesser extent by molecular genetic characterisation. The species studied include beef and dairy cattle, buffaloes, goats, sheep and poultry. Molecular characterisation has been done for various breeds and strains of cattle, buffaloes, goats and chicken (AnGR Technical Team, 2003).

Purebreeding and crossbreeding are commonly practiced in the country (DVS, 1980; DVS, 1986; Raymond and Ratnakumar, 1997 & Ibrahim et al., 2006). The main reasons for crossbreeding in ruminants are to exploit heterosis and for introgression of desirable traits. Crossbreeding has been used in the development of new breeds, such as the Mafriwal cattle, Brakmas cattle (Brahman x Kedah-Kelantan), Charoke cattle (Charolais x Kedah-Kelantan) and Jermasia goats (German Fawn x Katjang). The Mafriwal is now a stable dairy-

beef cattle breed comprising 60-75% Holstein and 25-40% Zebu inheritance. Brakmas (50% Brahman, 50% Kedah-Kelantan), and Charoke (50% Charolais, 50% Kedah-Kelantan) are beef breeds. Other breeds being locally developed include the MARDI Kampong chicken and IKTA quail. For swine, a 3-way cross is practiced for heterosis in a structured mating system.

Kedah-Kelantan bull undergoing semen collection at NIVB

Malaysian Brahman bull

Conservation programmes are managed mostly by the DVS (Mustaffa, 1994), MARDI, DWNP and DOVSAI. For example, Kedah-Kelantan cattle are conserved at Tanah Merah Livestock Station, Kelantan; Bali cattle at the Malaysian Veterinary Institute, Kluang, Johor and Livestock Breeding Centre, Tawau, Sabah; Brakmas cattle and Kampong chicken at MARDI Muadzam Shah, Pahang; Charoke cattle at MARDI Kluang, Johor; Swamp buffalo in Buffalo Project, Telupid, Sabah; Jermasia goats at University of Malaya, Kuala Lumpur; mouse deer in Sungai Batu Pahat Wildlife Conservation Centre, Perlis; and porcupine in Sungai Dusun Wildlife Conservation Centre, Selangor. There are also genebanks managed by NIVB, Jerantut, Pahang; National Animal Embryo Centre (NAEC), Kluang, Johor and Biotechnology Centre, Keningau, Sabah (Raymond & Krishnalingam, 1996, 1997; Raymond, 1998, 1999; Raymond & Fauzi, 2001).

3.2.2 *Utilisation of farm animal genetic resources*

FAnGR have contributed significantly to the national economy and the socio-economic well-being of individuals, particularly in the rural areas (FAO, 2007a,b). Humans have utilized FAnGR by consuming their products in the form of meat, milk, and eggs. In a recent FAO'S pamphlet on animal diversity (FAO, 2008), it is stated that, "Maintaining the diversity of animal genetic resources is essential to enable farmers, pastoralists and animal breeders to meet current and future production challenges resulting from changes in the environment, including climate change; to enhance resistance to diseases and parasites; and to respond to changes in consumer demand for animal products. Livestock contributes to and will be affected by climate change. Livestock producers will have to cope with both slow climatic changes and frequent extreme climate events. It is expected that climate change will affect livestock production and productivity both directly and indirectly." (Delgado et al., 1999; Aziz & Raymond, 2009; Raymond & Ibrahim, 2002).

With regards to the relative importance of the contributions of the different breed groups to food and agriculture, the continually introduced breeds (such as those supplied by international breeding companies to the local poultry

Livestock under palm oil plantation


A Bali bull at a traditional farm in Jengka, Pahang


Barbados Blackbelly sheep at the conservation herd


Charolais crossbred cattle are very popular in Kelantan and Terengganu


Semen being collected from a Duroc boar

and swine industries) contributed the most, followed by recently introduced breeds and locally adapted breeds (AnGR Technical Team, 2003). Livestock are mainly raised to produce protein in the form of meat, milk or eggs (Raymond, 2004; Raymond & Aziz, 2009). Other value products from livestock production include chicken litter (sold as organic fertiliser) and hides.

Farmers generally match their breeds to their resources. The hardy Kedah-Kelantan cattle and their crosses are grazed on marginal land and the vegetation under tree crop plantations, while imported feeder cattle are fattened in feedlots. Pure Friesian dairy cattle are used in the sub-tropical conditions in the highlands of Ranau, Sabah for their high milking potential. Friesian, Jersey and Jersey x Friesian dairy cattle are farmed in environmentally controlled housing systems in lowland areas.

Market demand strongly influences the development of different FAnGRs, e.g. Saanen goats, a reintroduced breed, to supply the niche demand for goat milk for healthy consumption, therapeutic value or as an ingredient in cosmetic products. As for sheep, there is a demand for mutton but not for the coarse wool of the local breeds. Hence, while sheep are bred for meat, there is a preference for hair sheep breeds, as these are more adaptable to the tropics besides being easier to manage (Ernie Muneerah et al., 2009).

3.3 Way forward

Generally, the objectives for breed conservation are similar for all breeds, namely to establish a stable herd (*in situ*) with wide gene pool, preservation of genetic material (*ex situ*), genetic improvement of the breed and marketing of the breed products in a niche market. Activities include bioprospecting, individual animal identification, performance recording, genetic evaluation and selection, semen processing, embryo production and marketing. Conservation priorities will be guided by the National Policy on Biological Diversity (MOSTE, 1998). Awareness and understanding of the roles and values of FAnGR will be enhanced among stakeholders to facilitate their involvement in sustainable development and use of FAnGR. Existing legislation, regulatory and management frameworks to strengthen and integrate conservation programmes of livestock breeds will be reviewed. The overall objectives would be to:

i. **Maintain,** conserve and sustainably propagate animal genetic resources for the present and future, taking into consideration the various challenges, including climate change;
ii. **Optimize** economic benefits from sustainable use of the components of domestic animal diversity;
iii. **Ensure** long-term food security for the nation;
iv. **Increase** the economic production of animal protein;
v. **Enhance** scientific and technological knowledge, educational and socio-cultural values of domestic animal diversity; and
vi. **Emphasize** biosafety considerations in the development and application of animal biotechnology in line with ethical and religious needs.

In managing FAnGR in the country, three priorities have been identified: human resource development in all aspects of FAnGR conservation and sustainable development, effective programmes to conserve and use selected FAnGRs identified to be at risk, and development of the National Focal Point NIVB as a reference centre for FAnGR conservation and utilisation (AnGR Technical Team, 2003). In line with these priorities, a comprehensive programme will be initiated to increase the competency of FAnGR professionals and technicians, strengthen *in situ* and *ex situ* conservation programmes, increase public awareness and enhance strategic international partnerships to drive the conservation initiative (CBD, 1992).


Seladang, *Bos gaurus hubbacki*


Kuda padi (local ponies)

In today's context, conservation of FAnGR has to evolve into a dynamic venture as it entails not only the preservation of genetic diversity but also the economic valuation, use and genetic development of breeds to ensure that conservation is both profitable and sustainable. The systematic implementation of these strategies and action plans will ensure that the erosion in FAnGR is contained, so that these resources will continue to be available for posterity and the benefit of the nation for generations to come.

3.4 Strategies and action plans for animal genetic resources for food and agriculture

3.4.1 *Education and public awareness*

There is very limited awareness on issues involved with FAnGR conservation and its sustainable utilisation among various stakeholders such as policy makers, livestock entrepreneurs, farmers, educators and the general public. This has resulted in low priority being given to conservation projects, lack of funding to support FAnGR with critical population levels, and in some cases the almost complete loss of diversity. Awareness and understanding of FAnGR diversity and its importance will lead to better appreciation to safeguard farm animals diversity. The following measures are recommended for enhancing overall awareness and understanding: incorporation of FAnGR conservation issues in courses in schools and higher education institutions; regular articles in local mass media on the importance of FAnGR diversity; establishment of a focal point, incorporating an information centre, for FAnGR.

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing agency	Impact
1	Enhance institutional and public awareness	1. Identify and determine FAnGR awareness status*	1. Conduct KAP study (Knowledge, Attitudes, Practices)*	KAP initial and final study report	10th MP & 11th MP	**MOA**	Higher awareness among public
		2. Inculcate FAnGR conservation values in schools and higher learning institutions*	1. Organise awareness activities for schools and educational institutions*	Number of activities conducted	10th MP & 11th MP	**MOA** **NRE** **MOE** **MOHE**	
		3. Improve public awareness on the roles and values of animal genetic resources**	1. Organise seminars, workshops and publicity events (including media)**	Number of activities conducted	10th MP & 11th MP	**MOA** **NRE** **MOI**	
			2. Develop and distribute information materials on FAnGR**	Number of brochures and information materials produced	10th MP & 11th MP	**MOA**/DVS	
2	Develop the focal point for FAnGR	1. Establish a national educational and information centre***	1. Advise public, establish good public relations and disseminate information***	Educational and information centre established	10th MP & 11th MP	**MOA**/DVS, NIVB	Enhanced networking in animal industry
			2. Disseminate FAnGR information through information and communication technology*	Number of FAnGR information articles disseminated	10th MP & 11th MP	**MOA**/DVS, NIVB	
			3. Access and update global FAnGR database***	Yearly update of DAD-IS (Domestic Animal Diversity Information System-FAO)	Annually	**MOA**/ DVS	

NB: Asterisks denote priority with 3 asterisks having highest priority

A Bali cross Kedah-Kelantan bull in Kedah

3.4.2 *Capacity building*

Currently the nation lacks competent human capital in the field of FAnGR management. Related to this, there is limited institutional development to support conservation and utilisation programmes. This has led to inadequate planning and implementation of FAnGR projects. The development of human resource expertise in all aspects of FAnGR conservation, use, development and characterisation is a priority in capacity building need. To increase research capacity, it would involve training of scientists in these areas, in courses at tertiary and higher levels. To enhance sustainable use of the components of FAnGR, NGO's and private sector participation/investment will be encouraged. Traditional knowledge, practices and lifestyles that contribute to conservation efforts will be supported. Other areas of capacity building include establishing centres of excellence for development and conservation of FAnGR, enhancing national and international collaboration in developing educational and training programmes and improving management, research and institutional capacity for inventory, monitoring and characterisation of FAnGR.

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing agency	Impact
1	Improve scientific knowledge base and skill	1. Develop technical expertise in various aspects of FAnGR management - inventory, monitoring and characterisation***	1. Attach dedicated officers and scientists to international centres of excellence	Number of officers trained	10th MP & 11th MP	**MOA** **MOSTI** **PSD** International agencies	Better management of FAnGR
			2. Engage scientists from international centres of excellence **	Number of scientists engaged	10th MP & 11th MP		
			3. Organize courses in capacity building**	Number of international level courses conducted	10th MP & 11th MP	**MOA** & International agencies	
			4. Participate in international conferences/ workshops/ courses**	Number of officers participated	10th MP & 11th MP	**MOA** & International agencies	
2	Enhance sustainable use of FAnGR components	1. Encourage private sector (including GLCs) participation/ investment**	1. Promote viable economic packages to private sector**	Number of packages promoted	10th MP & 11th MP	**MOA** & Private sector companies	Increased FAnGR business
		2. Encourage NGO participation in FAnGR conservation and use**	1. Establish and develop smart partnerships with NGOs for involvement in FAnGR conservation and use**	Number of NGOs engaged	10th MP & 11th MP	**MOA**/MARDI, DVS, DOVSAI Sabah & DOA Sarawak	Proliferation of FAnGR Genetic improvement of breeding stock Increased self sufficiency for FAnGR products Better management of FAnGR Preserve and use traditional knowledge (IP Preserved)
		3. Encourage establishment of breed societies**	1. Develop and promote breeding schemes to farmer groups**	Number of breed societies established	10th MP & 11th MP	**MOA**/MARDI, DVS, DOVSAI Sabah & DOA Sarawak	
		4. Upgrade existing breeding structures**	1. Develop breeding strata (nucleus and multiplier) and establish or strengthen data recording schemes**	Breeding structures for 5 breeds developed	10th MP & 11th MP	**MOA**/MARDI, DVS, DOVSAI Sabah & DOA Sarawak	
		5. Promote traditional knowledge, practices and lifestyles that support conservation efforts*	1. Cultural shows and agro tourism fairs related to local FAnGR*	Number of shows/fairs conducted	10th MP & 11th MP	**MOTour** **MOI** **MOA**/DVS/ Sabah MOAFI **NRE**/DWNP	

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing agency	Impact
3	Develop centres of excellence for conservation of FAnGR	1. Identify centres of excellence and strengthen the National Focal Point***	1. Establish and upgrade centres of excellence***	Number of centres of excellence established / upgraded	10th MP & 11th MP	**MOA**/MARDI, DVS, DOVSAI Sabah, DOA Sarawak **NRE**/ DWNP	Better conservation and use of FAnGR
4	Provide knowledge and understanding on diversity for its effective conservation and management	1. Compile available knowledge on FAnGR **	1. Coordinate, collate and synthesize available data and information from collections, surveys and geographic information systems**	National Focal Point (NIVB) strengthened	10th MP & 11th MP	**MOA**/DVS	Better understanding of research needs and priorities

NB: Asterisks denote priority with 3 asterisks having highest priority

3.4.3 *Research and monitoring*

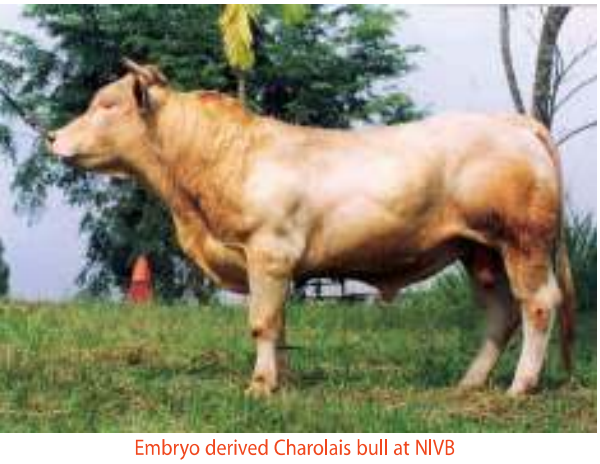
There is a general lack of focus and priority on research and monitoring in conservation and utilisation of FAnGR. This may be attributed to unawareness of its importance, lack of information on its potential economic use, the general perception that exotic germplasm is superior, and poor uptake of technologies involved with FAnGR. Research and development on conservation and sustainable utilisation of FAnGR should concentrate on the economic and social implications. The benefits that would accrue from using FAnGR include food security, environmental stability, national FAnGR heritage, and scientific and educational values. The immediate need is to prepare an inventory of local FAnGRs and expand their potential uses. Activities will include breed surveys, breed characterisation, monitoring of existing FAnGRs and research on use of FAnGRs and their products.

Muscovy ducks

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing agency	Impact
1	Establish inventory of local FAnGRs	1. Develop and maintain breed database***	1. Design survey protocol and conduct breed survey***	Survey report completed	From 2013	**MOA**/DVS,MARDI, NIVB , EPU **MOHE** **NRE**/DWNP & Department of Statistics	Better decision making due to comprehensive information available on breeds and breed crosses More focused breeding activities Ability to develop breed types adapted to specific ecosystems Enhanced breeding methodology
			2. Design and update FAnGR breed database ***	FAnGR breed database established	From 2013		
		2. Enhance breed characterisation (Case studies of individual breeds)**	1. Genetic evaluation of breeds under various ecosystems**	Number of breeds evaluated	From 2013		
2	Expand conservation and sustainable use of FAnGRs	1. Genetic improvement of selected FAnGRs of importance to national heritage**	1. R&D to improve selected FAnGRs for productivity, disease resistance and fecundity**	Number of breeds genetically enhanced	10th MP & 11th MP	**MOA**/MARDI, DVS	Improved breeds for higher productivity under selected production systems
			2. Enhance and establish gene banks for FAnGR breeds***	Number of genebanks established	10th MP & 11th MP	**MOA**/NIVB, MARDI **MOHE** **NRE**/DWNP	
		2. Ascertain breeds for future environments**	1. Breeding and selection using FAnGR adapted to challenging production environments (climate change)**	Number of breeds of high economic importance identified	10th MP & 11th MP	**MOA**/NIVB, MARDI **MOHE** **NRE**/DWNP	
		3. R&D on use of FAnGRs and their products**	1. Undertake research collaboration with international centres of excellence**	Number of research projects undertaken	10th MP & 11th MP	**MOHE** **MOA**/MARDI, NIVB **NRE**/DWNP	Improved use of livestock and their products Improved rural socio-economic status
			2. Evaluate important/ unique characteristics of individual livestock breeds**	Number of research projects undertaken	10th MP & 11th MP	**MOA** /DVS, MARDI & Goverment linked companies	
			3. Product development of local FAnGRs**	Number of products developed per animal species	10th MP & 11th MP	**MOHE** **MOA**/MARDI	
			4. Analyse the socio-economic impact **	Number of impact studies conducted	10th MP & 11th MP	**MOA**/MARDI **MOHE**	

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing agency	Impact
3	Strengthen breed endangerment early-warning and response systems for FAnGR	1. Establish early-warning and response plan**	1. Design and develop early warning and emergency response plan***	Early-warning and response plan documented	10th MP & 11th MP	**MOA**/DVS **NRE**/DWNP	Safeguard indigenous FAnGR
		2. Implement early-warning and response plan**	1. Continuous monitoring of breed population statistics and threats. ***	Annual reports produced on status of FAnGR	10th MP & 11th MP	**MOA**/DVS **NRE**/DWNP	
			2. Undertake simulation exercise	Number of simulation reports produced	10th MP & 11th MP	**MOA**/DVS **NRE**/DWNP	

NB: Asterisks denote priority with 3 asterisks having highest priority



Embryo derived Charolais bull at NIVB

3.4.4 *Legal and institutional framework*

The erosion of FAnGR biodiversity is one of the most serious challenges to sustainable livestock development. Currently the Animal Act 1953 (revised 2006) and Sabah Animal Ordinance 1962 (amended 1998) provide some legislation on livestock conservation. However, specific regulations regarding biodiversity conservation have not been formulated or updated, leading to weaknesses in their enforcement. The Wildlife Act 1972 only covers protection for wildlife species including those introduced as farm animals but there is no regulations to addres issues on sustainable management of farmed wildlife species. Strengthening the laws on the conservation and sustainable use of FAnGR is much needed. The critical needs are to review legislation to reflect domestic animal diversity needs and strengthen the institutional framework for FAnGR. In addition, it is also important to reinforce and integrate conservation programmes into animal health and disease control programmes, as well as livestock development programmes. Other important aspects would be the framework for funding mechanisms, genetic resources management, information exchange as well as international cooperation and collaboration.

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing agency	Impact
1	Strengthen institutional framework for FAnGR	1. Establish National FAnGR Technical Working Group**	Set up Secretariat for National FAnGR Technical Working Group (TWG)**	TWG established and operational	10th MP	**NRE** **MOA**/DVS, MARDI **MOHE**	Better networking and coordination of FAnGR activities
2	Integrate FAnGR management and sustainable utilisation considerations into livestock development policies and programmes	1. Establish National Livestock Breeding Policy***	1. Prepare National Livestock Breeding Policy***	National Livestock Breeding Policy launched	10th MP	**MOA**/DVS, MARDI **MOHE** **NRE**/DWNP	Well coordinated breeding plan and programme Breed certification and disease control Better utilisation of exotic genetic material
			2. Implement National Livestock Breeding Policy***	Programmes implemented in line with breeding policy	10th MP	**MOA**/DVS, MARDI **MOHE** **NRE**/DWNP	
		2. Establish identification and traceability mechanism together with performance recording*	1. Implement National Registration and Identification System for existing and imported breeding stock***	Percentage of nucleus breeding animals registered Percentage of imported breeding animals registered	10th MP	**MOA**/DVS, MARDI & DOVSAI Sabah	

No.	Strategy	Action plan	Proposed Activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing agency	Impact
			2. Development and implementation of breeding plan ***	Breeding plan implemented	10th MP	**MOA**/DVS, MARDI & DOVSAI Sabah	
3	Review legislation to reflect domestic animal diversity needs and to promote agro-ecosystems approaches to the management of FAnGR	1. Further development and revision of relevant laws**	1. Review legislation related to FAnGR**	Review report completed	On-going	**MOA**/DVS	Safeguard indigenous FAnGR Optimize conservation and use of FAnGR
4	Strengthen and integrate conservation programmes	1. Establish national *in situ* and *ex situ* conservation programmes***	1. Coordinate and implement National Conservation Programme for FAnGR ***	Conservation programme documented	2013	**MOA**/DVS, MARDI, **MOHE**	
		2. Improve biosecurity and SPS (Sanitary and Phytosanitary Status)***	1. Implement National Animal Disease Control and Eradication Plan ***	Programme implemented as planned	On-going	**MOA**/DVS	Economic value of FAnGR preserved
5	Promote international cooperation and collaboration	1. Strengthen regional and international networking**	1. Active involvement in international projects and initiatives**	Number of projects completed	10th MP & 11th MP	**MOA**/DVS, MARDI, **NRE**/DWNP **MOHE**	Improved synergies in FAnGR conservation for mutual economic benefit
			2. Active participation in international meetings, seminars and workshops**	Number of international events hosted Number of delegates participated in international events	10th MP & 11th MP	**MOA**/DVS, MARDI, **NRE**/DWNP **MOHE**	
			3. Support establishment of Asian regional focal point in Malaysia**	Asian regional focal point establishment approved by government	10th MP & 11th MP	**MOA**/DVS, MARDI, **NRE**/DWNP **MOHE**	
6	Strengthen efforts to mobilize resources, including financial resources for the conservation, sustainable use and development of FAnGR	1. Establish funding mechanism (Dedicated funds for FAnGR conservation)***	1. Establish specific clusters for FAnGR conservation projects i. Identify priority areas*** ii. Prepare application format** iii. Set up review panel iv. Approve projects and disburse funds**	Number of conservation projects Size of funds disbursed	10th MP & 11th MP	**EPU** **MOSTI** **MOA** **NRE**	Greater economic and social benefits through FAnGR conservation and use
			2. Provide incentives for FAnGR heritage conservation projects.	Size of funds disbursed for FAnGR heritage conservation projects	10th MP & 11th MP	**NRE** **MOSTI** **MOA** **EPU**	

NB: Asterisks denote priority with 3 asterisks having highest priority

Chapter 4

ARTHROPOD GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Stingless bees, *Trigona itama* an indigenous pollinator

Oomyzus as tiger moth parasite

Sago grubs, *Rhynchophorus ferugineus*

4. Arthropod Genetic Resources for Food and Agriculture

4.1 Rationale

Arthropods are the most diverse group of animals on earth, majority of them are found in the tropics, particularly in the rainforests. Apart from herbivores, most of the arthropods are beneficial organisms providing various ecosystem services, such as predator, parasitoid, pollinators, nutrient recyclers and food, etc.

i. **Predator and parasitoid**. Arthropods kill other arthropods. About 50% of known insects are parasitic or predatory, most preying on other insects. The major predatory arthropods include parasitic wasps, spiders and scorpions (Daily et al., 1997).

ii. **Pollinators**. Arthropods, especially insects, pollinate about 80% of flowering plants, or 60% of all known plants. Many plants have evolved intricate relationships with their insect pollinators, without which they would not reproduce and/or maintain their genetic diversity (Daily et al., 1997). Insects also play a major role in maintaining indigenous plants, hence, in their conservation.

iii. **Nutrient recyclers**. Arthropods facilitate the decomposition of organic debris, releasing the nutrients held to the plants. In consuming woody debris, their digestion breaks down the particles, facilitating the subsequent action of bacteria and fungi in mineralizing them (Andersen, 1997). Arthropods also aerate the soil and incorporate humus into it as they burrow for their homes or to find food. Ants and termites fertilise poor soils as their nests are rich in minerals from their droppings, decaying food and debris.

iv. **Food**. Arthropods, especially insects, process carbohydrate and nitrogen into protein, which are then eaten by higher animals. Insects alone are reckoned to consume more plant materials than herbivores (Daily et al., 1997). They are an important source of protein, perhaps even a better option for commercial production. Bees produce honey and wax that are widely used in medicines, as health foods, and for traditional crafts such as candle making and batik.

v. **Tourist attractions**. The major entotourism attractions in Malaysia are butterfly parks, honeybee hives and firefly colonies. Preserved arthropod specimens (butterflies, moth and beetles) are also sold as souvenirs. In butterfly parks, the butterflies are bred and the adults released in large walk-in net houses.

Rhinoceros beetle, *Oryctes rhinoceros*


Collection of butterflies


Rajah brooke, *Trogonoptera brookiana* and Atlas moth, *Attacus atlas*


Ladybird beetle as predator

Other potential services: Some insects, such as ants, are important agents of seed dispersal. They collect seeds of various trees and disperse them further from the mother trees. Flies disperse spores of fungi (Daily et al., 1997). Some arthropods are used as indicators of the impact of disturbances, such as human activities and climate change on the environment (Andersen, 1997). Maggots are used in patient care to remove necrotic tissues. Enzymes can be extracted from flies and termites as anti-coagulants and cellulases (Fan et al., 2005). Spiders produce toxins with potential as biopesticides (Tedford et al., 2004).

4.2 Current status

4.2.1 *Arthropods for human well-being*

Biological control. Biological control can be practiced with parasitoids and predators. Insects as biological control in agroecosystems in Malaysia were elaborated in detail by Ooi et al. (1979 & 1990). Efforts to increase efficacy of the biological control insects on their prey (harmful insects) are on going.

Parasitoids are insects parasitising eggs, larvae, pupae or adults of other insects during their reproduction. In Malaysia, the most widely studied parasitoids are Ichneumonidae and Braconidae (Hymenoptera) (Idris et al., 2001). Out of an estimated 8,000 species, only less than 500 have been identified in Malaysia. Among the successful attempts of using parasitoids as biological control are *Trichogrammatoidea nana*, an egg parasitoid of the sugarcane borer, and *Diadegma semiclausum* (= eucerophaga), *Diadromos collaris* and *Cotesia* (= *Apanthales*) *plutella* (Kurdjumov) against the larvae and pupae of the diamondback moth (DBM), *Plutella xylsotella*. There are many more parasitoids yet to be identified and evaluated for their potential in biological control.

Predators are arthropods that are preying on other arthropods. Some of the common predators are from the Order Hymenoptera, Coleoptera, Neuroptera, Diptera and Hemiptera. In Malaysia, two species, *Sycanus dichotomus* (Hemiptera: Reduviidae) (Sajap et al.,1999) and *Oecophylla smaragdina* (Hymenoptera: Formicidae), have been investigated for their potential as biological control agents against lepidopteran pests (Lim et al., 2008). Ladybird beetles such as *Cheilomenes sexmaculata* are common aphid predators that have yet to be fully studied.

Insects as pollinators. Pollinators provide an essential biological service to flowering plants. In nature, poor pollination has been blamed for the extinction of several plants, seed-eating animals, loss of vegetation and, eventually, demise of whole healthy ecosystems. In agriculture, poor pollination may lead to decrease yield and deform fruits. Many fruits - star fruit, guava, mango, melons, passion fruit, soursop, cocoa and oil palm - are dependent on insects for their pollination, and assisted pollination may have to be done when natural pollination is insufficient. For example, introduction of the oil palm weevil, *Elaeidobius kamerunicus*, from the Cameroons to pollinate the oil palm has increased the yield with, additionally, over RM400 million cost savings for dispensing with artificial pollination

There is, however, mounting evidence of pollinator decline globally with potential dire consequences for many agroecosystems. In Malaysia, the demand for pollinator services has increased due to greater fruit cultivation. However, studies on the pollinator status are limited, especially on the decline in pollinator abundance, pollinator-plant relationships and the factors affecting the effectiveness of pollinator services. Stakeholder awareness, capacity building and the legal framework are important for sustainable conservation of pollinators. For example taxonomists are essential for correct identification of pollinator species for a particular plant species and empowerment of pesticides control usage to enhance the pollinator contribution to high yield, quality and safe agricultural produce.

Termites as nutrient recycler

Cricket, *Teleogryllus occipitalis* as animal feed

Praying mantis, a predator

Although Malaysia is rich in pollinator species, previous studies indicated that only stingless bees, blue butterflies and carpenter bees are used to pollinate fruit trees.

Nutrient recycling. Although arthropods are known to be important in nutrient recycling, very few studies have been done on the subject in Malaysia. The studies have been on termites, collembolan and dung beetles.

Insects as feed. Insects can be used as animal feed. Termites have traditionally been harvested from their nests as poultry protein supplement (Farina et al., 1991). Maggots of *Musca domestica* and *Sarcophaga* sp. flies raised on animal droppings in West Africa are fed to chickens (Soukossi, 1992). Chironomid larvae are raised on chicken manure, harvested, cleaned and sold as fish feed in Hong Kong (Armitage et al., 1995). In Malaysia, the grub of the sago beetle (*Rhynchophorus ferrungineus*) is not only fed to animals but also consumed by humans (Dentan, 1991). MARDI has found the cricket, *Brachytrypes portensus*, to have 61.6% crude protein, of which 43.4% are amino acids, with 2.74% lysine, 0.77% methionine and 0.87% cysteine – sufficient contents for poultry nutrition.

Arthropods in eco-tourism. The major entomological tourist attractions in Malaysia presently are butterfly parks, honeybee hives and firefly colonies. Preserved arthropod specimens (butterflies, moths and beetles) are sold as souvenirs to tourists. In butterfly parks, the butterflies are bred in breeding houses and the adults released in large walk-in net houses. The butterflies include the Rajah Brooke, Malayan bird wing, blue bottle, five-bar sword tail, orange albatross and danaid tigers. Natural occurrences of certain insects, for examples, nightly aggregations of fireflies and butterflies attract tourists. One of the most popular firefly parks is Kampong Kuantan in Kuala Selangor. Another area with fireflies and potential for tourism development is Larut in Perak. In Pasir Putih, Kelantan, chirping bush crickets, *Mecopoda elongata*, are entered in singing competitions, which attract both the locals and non-locals, even some foreigners. The gathering of honey from wild hives also has ecotourism potential.

Enzymatic conversion of cellulose to fuels. All organisms secrete enzymes to help in their digestion. The enzymes, *inter alia*, break down carbohydrates into simpler sugars for absorption through the gut. Wood digesting insects, such as beetles and termites, are able to digest cellulose with the help of symbiotic microbes in their gut. However, termites do not necessarily depend on symbiotic microorganisms for cellulose digestion. For example, *Nasutitermes takasagoensis* secrete cellulases, mainly endo-1, 4-glucanase and 1, 4-glucosidase. These enzymes have been used artificially to convert cellulose to ethanol (Tokuda and Watanabe, 2007). However, although termites abound in Malaysia, there has been no attempt to isolate any of their enzymes.

Arthropod toxins for biopesticides. Arthropods, such as spiders and scorpions, produce toxins for paralyzing their prey. Their peptide-producing genes have been inserted in nucleopolyhedrosis virus to enhance its infectivity. Even though these arthropods are abundant in agroecosystems, the species are mostly unknown.

Medicines and pharmaceuticals. Insects play importance roles in the wellness of human beings. Some insect-related medicinal products are honey bee pollen, royal jelly and an entomopathogenic fungus, *Cordyceps sinensis*, from infected subterranean caterpillar larvae.

Indicator species and fundamental disturbances. Arthropods are often vulnerable to environmental disturbances, including climate change. Sensitive species can have their populations rise and fall with the environmental impacts. In Malaysia, insects, particularly ants and dung beetles, are widely

Trigona sp. on *Manilkara zapota*

Diamondback moth, *Plutella xylostella,* is a pest of crucifers

Diadromos sp. parasitising diamondback moth pupae

used as indicator species in forest disturbances. Tropical insects are known to be sensitive to climate change as they can only tolerate a narrow range of temperatures because they have adapted to a rather constant climate deep in their nests.

4.2.2 *Database development*

A database on arthropods is being compiled in many institutions. Part of its functions is to be a centre for reference on a common platform with all the other databases on biodiversity in Malaysia. Many research institutes and universities already have their own arthropod databases, e.g., MARDI with its Agrobiodiversity Information System (AgrobIS).

4.2.3 *Legislation*

The laws (Plant Quarantine Act, Food Act) and guidelines (SALM, EurepGAP) on arthropod diversity are vague.

4.3 Way forward

In the past, arthropod research was accorded low priority despite the importance and abundance of insects. Collecting, documenting and preserving agriculturally important insects will be a continuing exercise to compile more and more useful information for reference. Thus, development of databases and bioinformatics is an important task for a national referral centre. To strengthen the taxonomic studies, additional manpower (taxonomists and parataxonomists) is essential. Research on arthropods will focus on strategic conservation of their diversity in agroecosystems (*in situ/ex situ*), use of arthropod resources and evaluation of the ecological services provided by arthropods (e.g., as pollinators, parasitoids and predators, bioindicators). Enhancing awareness and understanding of arthropod diversity can bring about better appreciation of biodiversity and its importance in sustaining agriculture, especially by those directly involved in crop protection. To reduce the loss in biodiversity, the legal and institutional framework has to be strengthened.

4.4. Strategies and action plans for arthropod genetic resources for food and agriculture

4.4.1 *Education and public awareness*

An awareness and understanding of biodiversity, as well as public and institutional participation in effective conservation and protection of biodiversity, are part of the strategies of the National Policy on Biological Diversity. The public understanding and awareness will be enhanced by;

i. Strengthening the biodiversity curriculum in schools and institutions of higher learning;
ii. Publication of brochures, information materials and popular scientific books; and
iii. Preparation of multimedia presentations on arthropods.

No.	Strategy	Action plan	Proposed activities	Key Performance Indicator	Duration	Lead Ministry/ (Implementing Agency)	Impact
1.	Strengthening biodiversity curriculum in schools and institutions of higher learning	1. Addressing the issue of arthropod biodiversity in teacher's training for secondary schools and universities	1. Review curriculum on biodiversity (pollinators, parasitoids and predators, protein, food, medical and pharmaceutical applications)	Curriculum review completed	60 months	**MOA** **MOE** Universities	Awareness of benefits of arthropod diversity in fruit industry, pharmaceuticals, animal feeds and food safety
			2. Organise training including fieldwork on arthropod biodiversity (pollinators, parasitoids and predators; protein, food, medical and pharmaceutical applications)	Number of training organised	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Best management practices for arthropod conservation and lessons learned
2.	Raising awareness-and public relations	1. Prepare brochures, information materials, documentaries	1. Select resource personnel for production of information materials on various arthropod groups (pollinators, parasitoids and predators; protein, food, medical and pharmaceutical applications)	Number of resource persons identified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Quality information materials produced
			2. Gather information on arthropod diversity, ecological services and effects of agricultural activities and climate change on beneficial arthropods	Number of brochures/booklets prepared	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Awareness of benefits of arthropod diversity by stakeholders
			3. Organise seminars and training programmes	Number of seminar conducted	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Towards good agricultural practice
			4. Conduct training for farmers	Number of trainings conducted Number of farmers trained	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak) and Universities	Awareness of benefits of arthropod diversity by stakeholders
		2. Produce multimedia presentations on arthropod diversity	1. Production of film, cd, dvd or website	Number of multimedia presentations produced	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Awareness of benefits of arthropod diversity by stakeholders

No.	Strategy	Action plan	Proposed activities	Key Performance Indicator	Duration	Lead Ministry/ (Implementing Agency)	Impact
3.	Strengthen function of natural history museum	1. To liase and enhance Malaysian Natural History Museum (MNHM) activities	1. Widening the collection of arthropods related to agricultural production	Percentage of arthropods in MNHM increased	60 months	**MOA**/MARDI, DOA **NRE**/FRIM Universities	Custodian for reference materials on biodiversity in Malaysia Crucial to preserve and keep arthropod, parasitoids and predators for future reference Reference collection for studies and scientific evidence
			2. Development of database on arthropod diversity (pests, pollinators, parasitoids and predators; protein, food, medical and pharmaceutical applications) in every institution and establishment on a common platform for information sharing	Database with common platform developed	12 months	**MOA**/ MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Information sharing

4.4.2 *Capacity building*

The priority in capacity building in the field of arthropod biodiversity is to increase the competency and the number of taxonomists and parataxonomists (conventional and molecular). It is also important to enhance networking and international cooperation while improving the infrastructure needed. There is a great need to enhance research in strategic conservation of arthropod diversity in agroecosystems (*in situ*/*ex situ*), bioprospecting and use of arthropod resources and evaluation of ecological services provided by arthropods (e.g., as pollinators, parasitoids, predators and bioindicators).

Taxonomists sorting and identifying insect collection

No.	Strategy	Action plan	Proposed activities	Key Performance Indicator	Duration	Lead Ministry/ (Implementing Agency)	Impact
1.	Build up national capacity in arthropod systematics and biodiversity-trained personnel	1. Increase number and enhance competency of taxonomists, parataxonomists (conventional & molecular) and biodiversity-trained personnel	1. Strengthening existing programme on arthropod systematics and taxonomy	Number of taxonomists and parataxonomist appointed	60 months	**MOA**/MARDI and Universities	Cost and time saving in identification through well trained local taxonomists and biodiversity-trained personnel
			2. Provide scholarships for study	Size of fund allocated	60 months	**MOA** **MOHE** Universities	
			3. Taxonomist attachment at renowned institution	Number of taxonomists attached at renowned institution	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	
			4. Conduct training for biodiversity-trained personnel	Number of training programmes	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Awareness of benefits of arthropod diversity by stakeholders
2.	International cooperation & networking in consideration of necessity to coordinate actions and set priorities	1. Enhance bilateral & multilateral cooperation between research institutions	1. Established linkages with international centres	Number of linkage Number of visits	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Sharing and exchange of information and expertise development in arthropod diversity Fostering global co-operation in arthropod research
		2. Improve international networking	1. Organise international workshops and seminars	Number of international workshops and seminars organised	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	
3.	Establishment of modern research facilities	1. Upgrading of existing and installing new facilities	1. Procurement of the facilities	Facilities procured	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Well equipped and up-to-date facilities for faster and more accurate identification of species

Tephritidae pest of fruits

4.4.3 *Research and monitoring*

Research should focus on assessment of arthropod biodiversity, strategic conservation of arthropod diversity in agroecosystems (*in situ*/*ex situ*), use and management of arthropod resources and evaluation of ecological services/ functions contributed by arthropods.

No.	Strategy	Action plan	Proposed activities	Key Performance Indicator	Duration	Lead Ministry/ (Implementing Agency)	Impact
1	Conservation and utilisation of arthropod genetic resources	1. Assessment of arthropod biodiversity	1. Survey arthropod diversity in natural and agro ecosystems	Number of expeditions organised	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Ensured food security
			2. Studies on pollinator and plant relationships	Number of crop ecosystems surveyed	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	
			3. Domesticate indigenous pollinators (*ex situ*)	Number of indigenous pollinator species conserved	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	
		2. Determine the impact of agricultural activities and climate change on arthropod diversity	1. Survey impact on arthropod diversity in natural and agro ecosystems due to agricultural activities and climate change	Number of projects conducted Bio indicators (arthropod) for ecosystems identified and evaluated	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Sustainable management of agroecosystem
			2. Forecast and monitor arthropod diversity in relation to agricultural activities and climate change in natural and agro ecosystems	Early warning system developed for paddy, vegetables, oil palm and forest	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Sustainable management of agroecosystem
		3. Bio prospect and use arthropod diversity to generate sustainable agricultural practices	1. Screen potential arthropods for economic purposes (biological control, as food/feed, pharmaceutical applications, biopesticides)	Number of potential species identified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Reduction in imports of protein for feed (fish meal, animal feed) and increase yield and quality of agricultural produce
		4. Quantify ecological services/ functions by arthropods	1. Screening and evaluate potential arthropods for economic purposes (biological control, pollination, pharmaceutical applications, biopesticides)	Number of potential species identified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Resilient agroecosystems developed
			2. Valuation functions & effects of beneficial arthropods	Services of beneficial arthropod on crops evaluated Number of crops quantified	60 months	**MOA**/MARDI, DOA (Peninsular, Sabah and Sarawak), Universities and other related agencies	Economically viable, safe and high quality agricultural produce

Hoverfly adult

4.4.4 *Legal and institutional framework*

The threat to loss of arthropod biodiversity is one of the most serious challenges in sustainable agriculture. Indiscriminate pesticide use is one of the main factors disrupting the equilibrium of arthropod populations in agroecosystems. Strengthening the law on pesticide use may help. The Plant Quarantine Act 1976 consolidates the laws on control, prevention and eradication of agricultural pests and encourages prudent management and conservation of biological diversity in agricultural systems. However, the Act and other guidelines (SALM, EurepGAP) on arthropod diversity remain vague. The enactment/establishment of the National Biological Diversity Policy and the National Council for Biological Control may provide a better platform for the use of biological diversity sustainably for the continued progress and socio-economic development of the nation.

No.	Strategy	Action plan	Proposed activities	Key Performance Indicator	Duration	Lead Ministry/ (Implementing Agency)	Impact
1	Review and update existing legislation on conservation of arthropod biodiversity	1. Strengthen the law on pesticides use (Pesticides Act)	1. Review the existing law	Law amended	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak) **AGC**	Arthropod diversity conserved for sustainable agro ecosystem
			2. Create awareness on pesticide application & safety	Number of pesticide applicators trained	36 months	**MOA**/DOA (Peninsular, Sabah and Sarawak)	
		2. Plant Quarantine Act	1. Review existing law	Review Plant Quarantine Act	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak) **AGC**	
		3. Wildlife Act	1. Review existing law	Review Wildlife Act	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak) **AGC**	
		4. CITES	1. Review existing lists related to arthropods	Review CITES	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak) **AGC**	

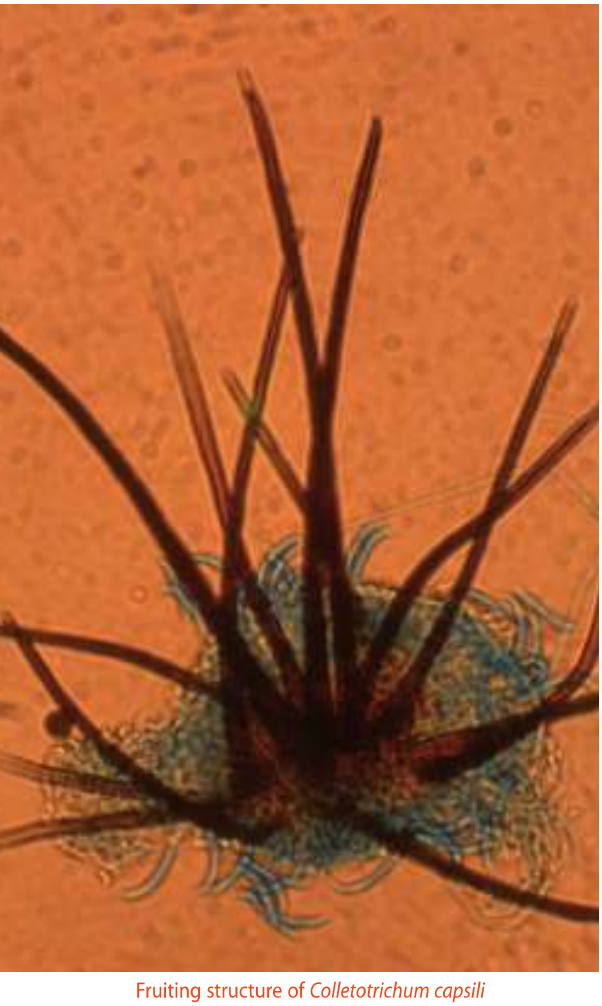
Apis mellifera

Chapter 5

MICROBIAL GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Cantharellus sp.

Trichoderma viride colonising the seed surface of soybean



Fruiting structure of *Colletotrichum capsili*

5. Microbial Genetic Resources for Food and Agriculture

5.1 Rationale

Microorganisms are a vital yet often neglected component of the world's biodiversity. Worldwide, they stand out as the major building blocks for biotechnology-related industries. However, the role of microbial genetic resources in bio-industries, especially in Malaysia is not fully acknowledged and thus needs to be nurtured. There is an urgent need for information and better understanding of our microbial diversity for increased investment in microbial resources by both local and international entrepreneurs. Harnessing microbial genetic resources will provide solutions to many problems in agriculture, forestry, the environment, healthcare and food and make available valuable resources for the development of bio-industries. However, microbes also exist as pathogenic forms, contributing to losses in yield and quality of produce, post harvest losses, contamination and food spoilage.

Microbes play important roles in the biogeochemical cycles of carbon, nitrogen, sulphur and other elements enabling ecosystems to recycle these substances for living organisms. Agriculture, forestry and fisheries are examples of commercial activities dependent on and sustained by basic microbial activities. Recycling of waste water, solid waste treatment and bioremediation are other examples of the use of microorganisms to transform wastes into non-toxic, reusable materials. In addition, the vast genetic diversity of microbial life provides a resource for many pharmaceutical and biotechnology industries. Microbes are also used in the development of biofertilisers, bioenhancers, biopesticides and bioherbicides.

While the developing nations host much of the world's biodiversity, including microbial genetic resources, they have insufficient capacity to fully document it (catalogue, isolate, characterise, identify and preserve). CABI reported around 90,000 species of fungi already described but estimates 1.5 million in total, mostly awaiting discovery. Therefore, there remains great potential for new species and strains with beneficial properties to be found.

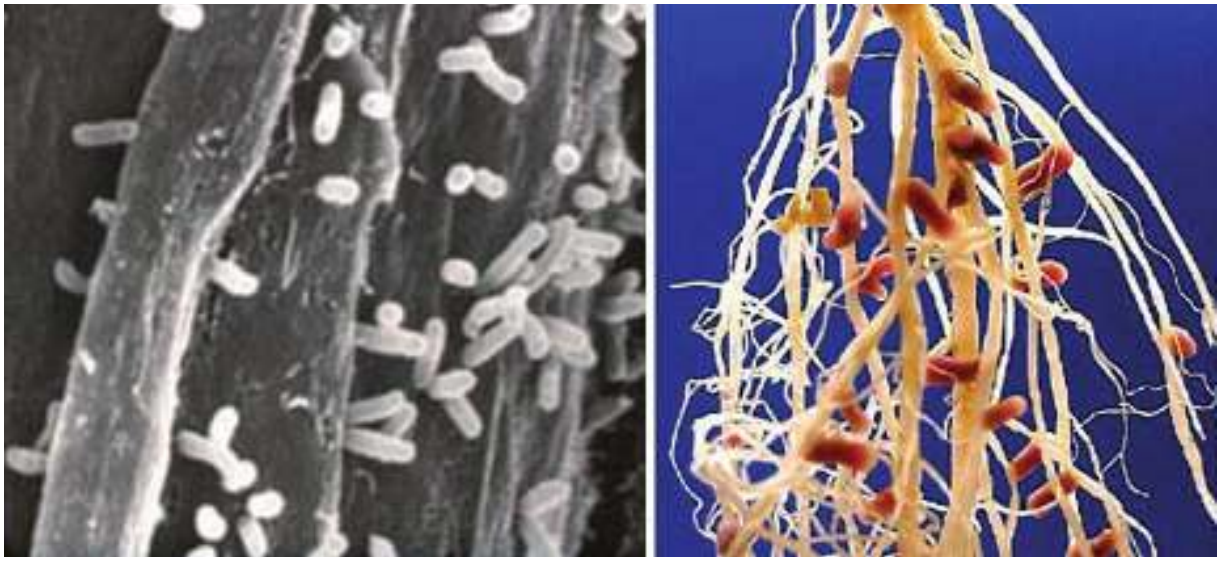
5.2 Current status

5.2.1 *Microbial database*

The World Data Centre for Microorganisms (WDCM) reports 601 culture collections in 68 countries registered with it. These have a total of 1,809,534 microbes – 782,813 bacteria, 528,038 fungi, 32,678 viruses, 8,703 cell lines and 457,302 other kinds of microbes (http://wdcm.nig.ac.jp/statistics.html). As much as half of the 204 collections in Asia registered with WDCM are in Thailand, China and India, and over 317,636 of the 571,156 strains are held in China and Japan. In Malaysia, only 6 culture collections comprising 2,910 culture were recorded.

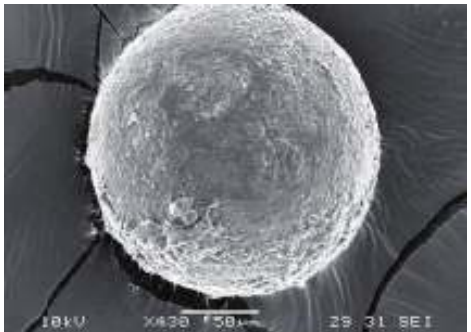
5.2.2 *Microbial utilization*

The use of microbes in Malaysian agriculture is still new. Some research on N_2-fixing bacteria, e.g. *Bradyrhizobium*, has been done on groundnuts (Shamsuddin et al., 1992) and vegetable soybeans (Shamsuddin et al., 2003). *Azospirillum brasilense* Sp 7 and a locally isolated PGPR strain, UPMB 14, have shown potential as biofertiliser for sweet potato on tin tailings (a sandy soil) (Saad et al., 1999). Inoculation of the PGPR strain of *Klebsiella* sp. UPMSP9, *Erwinia* sp. UPMSP10 and *A. brasilense* Sp 7 in sweet potato has shown that several bacterial strains can colonize the roots of sweet potato plantlets to enhance their growth (Farzana et al., 2009). They are thus potential biofertilisers as they can colonize the roots and multiply in them to promote plant growth.



Nitrogen-fixing *Rhizobium* bacteria colonizing the root hairs of leguminous plants. Source: Effects of Microbes on Their Habitat 2009, Kenneth Todar (eds)

Saprophytic basidiomycetous fungi growing on palms



Mycorrhizal spore (*Glomus spp.*)

In oil palm, the use of diazotrophic rhizobacteria as biofertiliser reduces the requirement for nitrogen and lowers the production cost. For examples, inoculation with *A. brasilense* Sp 7 and *Bacillus* sp. UPMB 10 and 13 have significantly increased total leaf N, leaf chlorophyll content and enhanced the growth and root development of oil palm plantlets. *Bacillus sphaericus* UPMB 10, has shown potential as biofertiliser with the ability to fix 28% of nitrogen from the atmosphere (Amir et al., 2002). Inoculation of PGPR strains with minimal fertilizer-N supply are effective as biofertiliser to fix N_2 and increase plant growth, nutrient uptake, yield and fruit quality of bananas (Mia et al., 2005).

Phosphate-solubilising bacteria from the rhizosphere of oil palm are important in maintaining the availability of P for the crop productivity (Radziah and Lizawati, 2005). Several species such as *Pseudomonas aeruginosa, P. fluorescens, Staphylococcus saphophyticus* and *Aspergillus* sp. isolated from compost were found to be phosphate solubilisers (Phua Choo, 2004).

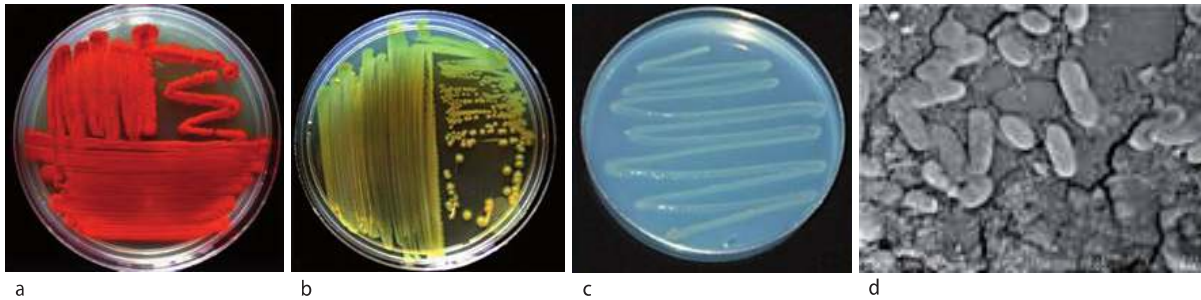
Malaysia currently produces an annual quantity of 1.4 million tonnes of palm kernel cake (PKC) as a by-product in the milling of palm kernel oil. PKC is considered a medium grade protein feed (Chin, 2002). Since the fibre in PKC is mainly in the form of ß-mannan type hemicellulose (Mohd. Jaafar and Jarvis, 1992), the intended product of its degradation should be mannose when it is subjected to ß-mannanase that is produced by microbial cells. It is known that ß-mannanases are derived from plants, fungi and bacteria. Some of the potential isolates include *Trichoderma koninggi, T. viride, Aspergillus niger, A. terreus* and *Trichosporon beigelii* B (Marini et al., 2002; Ibrahim, 2008).

Mycorrhizal research in Malaysian agriculture began in 1967 with the first report of endomycorrhizas in the roots of rubber (*Hevea brasiliensis*) trees (Wastie, 1967). The research on various indigenous and exotic forest trees in Malaysia intensified in the 1970s with the aim of applying the fungus for better plant growth in plantations and in reforestation efforts, and in the rehabilitation of degraded sites (Lee, 2006). Inoculation of vesicular arbuscular mycorrhizas (VAM) resulted in better fertiliser use efficiency by teak seedlings and improved root development and, subsequently, seedling growth (Mohd. Ghazali et al., 2005).

(a) SEM micrograph of *Trichoderma harzianum*,
(b) Antibiosis against *Fusarium*
(c) Mycoparasitic activities against *Ganoderma*

Microorganisms can also be used as biopesticides, as safe, biological active ingredients. *Bacillus thuringiensis* is a commercially available biopesticide against lepidopterous larvae (Sivapragasam et al., 1996). *Pseudomonas aeruginosa, P. fluorescens, P. putida* biotype B, *Staphylococcus saphophyticus, Aspergillus* sp., *Penicillium* sp. and *Trichoderma* sp., all isolated from compost, have shown potential as biocontrol agents against bacterial wilt of tomato by *R. solanacerum* (Phua Choo, 2004). Formulations of *Trichoderma* and *Burkholderia* have been tested and found effective as potential biocontrol products for controlling seed-borne pathogens in soybean and sclerotial diseases of vegetables (Jinantana and Sariah, 1998; Begum et al., 2008)

Antimicrobial substances produced by *Sternotrophomonas maltophilia, Agrobacterium agropyri, B. gladioli, P. aeruginosa, Microbacterium testaneum* and *B. multivorans* were found to inhibit *Schizophyllum commune* Fr., the causal agent of brown germ and seed rot of oil palm (Dikin et al., 2005). Endophytic *Pseudomonas* and *Burkholderia* have been shown to have a suppressive effect on the spread of *Ganoderma* in oil palm, suggesting their potential as biocontrol agents against basal stem rot (Zaiton et al., 2008).



(a) *Serratia marcesens* (b) *Burkholderia cepacia* (c) *Pseudomonas* sp. (d) SEM micrograph of *Pseudomonas* sp.

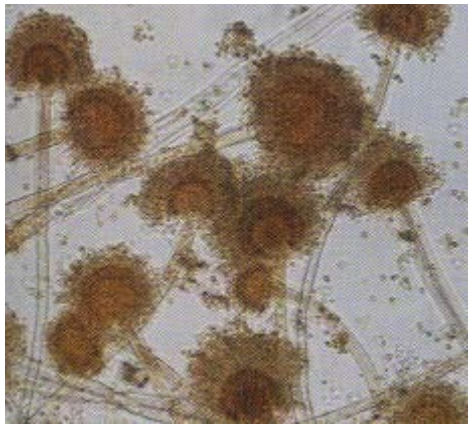
Lactobacillus plantarum I-UL4 isolated from Malaysian fermented food was shown to produce *bacteriocin*, widely used as a commercial preservative in food industries (Ng et al., 2005). The strain also has a broad inhibitory spectrum with potential as a probiotic (Lim et al., 2005). Mirfat et al. (2005) studied the medicinal properties of the fungus, *Schizophyllum commune* Fr., and found extracts to be potential nutraceuticals with therapeutic properties. Fungi from *Polyporus* species, including *Pycnoporus sanguineus*, were shown to be potential bioremediators of effluent from the textile industry (Umi Kalsom et al., 2008).

Bioherbicides are biocontrol agents applied to weeds as conventional herbicides. The active metabolites produced by *Exserohilum prolatum* were found to have potential bioherbicidal properties against itchy grass in sugarcane plantations (Hala Eltahir, 2006).

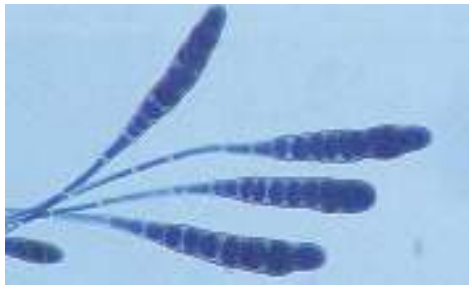
MICROBIAL GENETIC RESOURCES FOR FOOD AND AGRICULTURE

No.	Functional Group	Targeted Industries	Microbial Use In Malaysia
1.	Fungi	Agriculture (biofertilisers, biopesticides), food, animal feed and other biotechnological industries (e.g. about 48 companies for biofertiliser,10 for fermented foods, 1 for animal feed)	*Mycorrhiza* as plant growth enhancers *Trichoderma* spp. as biocontrol agents for plant diseases *Exserohillum longirostratum* as bioherbicides against plantation weeds *Aspergillus, Trichoderma* for PKC and silage production Edible mushrooms *Rhizopus oligosporus* in food industry *Aspergillus niger* for fermentation
2.	Bacteria	Agriculture (biofertilizers, biopesticides), bioremediation, food, bio-fermentation (probiotics) and other biotechnological industries (e.g. about 48 companies for biofertiliser,10 for fermented foods, 1 for animal feed, 4 for probiotic foods)	*Azospirillum brasilenses and Rhizobium* as nitrogen fixers Phosphate solubilizing bacteria for nutrient recycling *Bacillus thuringiensis, Burkholderia* sp. as bioagents in plant diseases, *Lactobacillus* spp. in health drinks and probiotics Yeasts in food fermentation *Agrobacterium* as source of transgenes
3.	Virus	Agriculture (biopesticides) and other biotechnological industries	Nucleopolyhedrosis Virus (NPV) against *Spodoptera litura* Oryctes virus against Rhinoceros beetle

Mushroom-based food products



Aspergillus candidus



Alternaria sp.

Conidia of *Curvularia eragrostidis*

5.3 Way forward

The Action Plan on microbial genetic resources strives to develop and implement coordinated and holistic strategies/approaches with the intention of identifying, conserving and optimising the use of microbial genetic resources as enablers to enhance productivity, improve human and environmental safety and the quality of life. The microbes referred to in the Action Plan encompass the spectrum of variability (morphology, structure, metabolism and behavioural differences) among all types of microorganisms (fungi, bacteria, mollicutes and viruses) in the natural world and as altered by human intervention. Microbial genetic resources has important economic, technological and social implications, in particular, for sustainable agriculture.

In implementing the Action Plan, activities will be targeted to cover areas pertaining to conservation of microbial resources for the present and future, optimisation of the economic benefits from sustainable use of microbial genetic resources, enhancement of scientific and technological knowledge, educational and socio-cultural values of microbial genetic resources, and biosafety considerations in the development and application of microbial biotechnology.

5.4 Strategies and action plans for microbial genetic resources for food and agriculture

5.4.1 *Education and public awareness*

Awareness and understanding of microbial genetic resources and its importance can bring about a better appreciation of biodiversity by the general public and stakeholders. Communication on technical issues to the policy makers and administrative authorities will be essential for efficient awareness-raising. This has to be provided at different levels to individuals and groups. In many cases, an introduction to the subject and awareness-raising could be done through established information centres, workshops and seminars, as well as by regular distribution of brochures, manuals and books, and training of multipliers.

Cultivated commercial mushroom

No.	Strategy	Action plan	Proposed activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing Agency	Impact
1	Educate public to enhance awareness on microbial genetic resources	1. Awareness-raising and public relations work	1. Produce information brochures, pamphlets, etc.	Number of brochure / pamphlet	60 months	**MOA**/Research organisations & Universities	Integrated microbial genetic resources in sectoral planning strategies, e.g., Environmental Impact Assessment (EIA) monitoring, national estate policy, sectoral and cross-sectoral development programmes
			2. Participate in exhibitions	Number of exhibition participated	60 months	**MOA**/Research organisations & Universities	
			3. Disseminate information through electronic media	Number of information through electronic media disseminated	60 months	**MOA**/Research organisations & Universities	
			4. Stronger participation in international seminars and meetings	Number of participation in international seminars and meetings	60 months	**MOA**/Research organisations & Universities	
			5. Invite private sector agencies to participate in promotional activities	Number of private sector agencies participated	60 months	**MOA**/Research organisations & Universities	Greater private sector contribution and involvement in microbial diversity conservation
		2. Train, enhance skill and competency of stakeholders	1. Conduct workshops, seminars and short courses	Number of workshops/ seminars/ short courses conducted	60 months	**MOA**/Research organisations & Universities	Educate stakeholders on the role of microbes in sustainable agriculture and environment, e.g., EIA monitoring, bioremediation, biopesticides, biofertilizers and food industry
			2. Hold lectures/public seminars on issues related to microbial genetic resources	Number of public seminars conducted	60 months	**MOA**/Research organisations & Universitiess	
		3. Establish an information centre	1. Offer advice and consultancy to interested parties	Key institute named as the co-ordinating centre	12 months	**MOA**/Research organisations & Universities	Availability and increased access to information on microbial genetic resources and information sharing
			2. Set up interactive website and microbial forum	Website and microbial forum established and maintained	60 months	**MOA**/Research organisations & Universities	
			3. Serve as microbial reference centre	Microbial reference centre for plants, animals and arthropods established	60 months	**MOA**/Research organisations & Universities	
		4. Promote interaction and networking between professional bodies dealing with microbes	1. Dialogues and jointly organised meetings	Number of dialogues and meetings organised	60 months	**MOA**/Research organisations & Universities	

Environmental Scanning Electron Microscope (ESEM)

5.4.2 *Capacity building*

The issue of conservation and utilisation requires committed cooperation by experts, authorities and all interested parties at both the national and international levels. When action plans to identify and conserve microbial species are to be implemented in an efficient and purposeful way, reliable, speedy and accurate information exchange is a necessity. A focal point for identification and conservation of the microbes, which also serves as a resource base and contact point at both national and international levels, is to be established. Researchers should familiarise themselves with mainstream global themes relevant to microorganisms and microbial genetic resources and get a better understanding and appreciation of the implications of the CBD and its Program of Work, as well as the World Trade Organisation/Sanitary and Phytosanitary (WTO/SPS) Agreement. In particular, national weaknesses in identification, documentation and conservation of microbial genetic resources, isolation and characterisation protocols, as well as any lack of taxonomic expertise and reference collections must be addressed.

To achieve the above, the action plans will have to cover areas such as strengthening institutional programmes on microbial genetic resources and related issues, developing centres of excellence, national cooperation, discussion and networking with different user groups and stakeholders and international cooperation and networking.

No.	Strategy	Action plans	Proposed activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing Agency	Impact
1.	Build national capacities and link them	1. Strengthen institutional programmes on microbial genetic resources and related issues	1. Offer holistic programmes on microbial genetic resources	Programmes reviewed	60 months	**MOA** **MOHE** Universities	Enhanced skills, expertise and competency, and developed human resources in the appropriate areas
			2. Reinforce existing programmes in centres of higher learning in specific areas of expertise – mycology, taxonomy, bacteriology, virology, etc.	Number of research activities on microbial genetic resources at undergraduate and postgraduate	Annual	**MOA** **MOHE** Universities	
			3. Include / increase courses on microbial systematic and conservation in the curriculum (in Schools and Universities)	Microbial systematic and conservation courses included/ increased	60 months	**MOA** **MOHE** Universities	
			4. Obtain funding from relevant agencies	Number of projects Size of fund alllocated	60 months	**MOA**/Research organisations & Universities	
			5. Establish databases on scientists	Databases on scientists in the areas related to microbial genetic resources established	12 months	**MOA**/MARDI	Enhanced research and expert sharing
			6. Establish Chair for microbial genetic resources	Chair for microbial genetic resources at any IPTA established	60 months	**MOA** **MOHE** Universities	Enhanced skills, expertise and competency, and developed human resources in the appropriate areas

No.	Strategy	Action plans	Proposed activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing Agency	Impact
			7. Offer attachment training to scientists in industry, research organisations and universities	Number of training attachments	60 months	**MOA**/Research organisations & Universities	
		2. Develop centres of excellence	1. Establish and fund national focal point and centres of excellence for microbial genetic resources	National focal point and centres of excellence established	60 months	**MOA**/MARDI (focal point) & other agencies	Accessible information, and collaboration in research with relevant agencies and industries
			2. Offer in-service training on isolation, identification, characterisation and preservation protocols for microbes	Number of training programmes	60 months	**MOA**/Research organisations & Universities	
		3. National cooperation, discussion and networking with different user groups and stakeholders	1. Stronger incorporation of the issues on microbial genetic resources in expert committees and working groups	Expert committees and working groups established	Once a year	**MOA**/Research organisations & Universities	Enhanced collaboration in scientific research between industry and research institutes
			2. Conduct interdisciplinary seminars and events for scientists, user groups and stakeholders	Number of seminar conducted	60 months	**MOA**/Research organisations & Universities	
2.	Capacity building at international level and interlinkage of the capacities built	1. International cooperation and networking	1. Enhance bilateral and multilateral cooperation between neighbouring countries	Number of visits abroad	60 months	**MOA**/other private agencies	Sharing and exchange of information and expertise development in microbial genetic resources International cooperation and collaboration promoted
			2. Enhance international harmonisation and further develop education and training programmes	Number of international speakers/ facilitators invited	60 months	**MOA**/Research organisations & Universities	
			3. Stronger participation in international workshops and meetings	Number of participation in international workshops and meetings	60 months	**MOA**/Research organisations & Universities	

Mushroom found in Kenyir Lake, Terengganu

Bacteria colonies on agar medium

5.4.3 *Research and monitoring*

Although research in microbial genetic resources has increased in Malaysia over the past few years, our knowledge remains inadequate. Many of the nation's species have yet to be discovered, investigated and documented. This lack of data impedes efforts to harness the resource. However, new methods now enable information to be obtained merely from establishing the type of microorganism (diversity) – by trawling databases for molecular and macromolecular information on the microorganism. New technologies based on diverse organisms - from diagnostics to biosensors and biocatalysts – are also being developed. However, they can only succeed with a better understanding of the microorganisms, and knowledge on their diversity from establishment and maintenance of reference cultures.

No.	Strategy	Action plans	Proposed activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing Agency	Impact
1.	Scientific study of microbial genetic resources and its conservation and utilisation	1. Bioprospecting for microbes in natural and disturbed environments	1. Survey, isolate, identify, document and maintain the cultures in referral centres	Number of studies on oil palm ecosystem (coastal, peat and inland) under different management Number of studies on 2 vegetable ecosystems –in the highlands and lowlands; organic and conventional farm Number of studies on effect of climate change on microbial genetic resources in agriculture ecosystem Number of studies on agrowaste management Number of studies on utilization of microbes in food industry	60 months	**MOA**/Research organisations & Universities	Minimized impacts by human activities on microbial genetic resources. Enhanced information base for sustainable use of microbial genetic resources (conservation, development of biopesticides, bioremediation, biofertilisers and food industry)
			2. Establish national database on culture collections	A central coordinating agency established	36 months	**MOA**/MARDI & other research/ organisation **MOHE**/UPM & other universities	Enhanced information base for sustainable use of microbial genetic resources (conservation, development of biopesticides, bioremediation, biofertilisers and food industry)
				Databases for taxonomic groups established: i. Bacteria ii. Viruses iii. Fungi	36 months	**MOA**/MARDI & other research/ organisation **MOHE**/UPM & other universities	
			3. Set up network of databases for accessibility	A central portal for microbial genetic resources established	12 months	**MOA**/MARDI **MOHE**/UPM	

No.	Strategy	Action plans	Proposed activity	Key Performance Indicator	Duration	Lead Ministry/ Implementing Agency	Impact
		2. Formulate concrete measures for selected species	1. Screen and select species with potential economic importance	Number of products produced	24 – 60 months	**MOA**/Research organisations & Universities	Identification of selected species for R&D in agriculture and food industry
			2. Survey market potential for microbes and microbial products	Number of survey conducted	24 – 60 months	**MOA**	Identification of microbial products for agricultural and food industry
			3. Adoption of microbial products for food and agriculture	Number of products produced	24 – 60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak) & MARDI	
		3. Mitigate impacts of agricultural activities	1. Analyse the impacts and monitor effects of agricultural activities on microbial genetic resources	Number of analyses conducted	24 months	**MOA**/Research organisations & Universities	Enhanced capacity in bioremediation and soil health
			2. Implement remedial measures	Number of remedial measures implemented	36-60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak), Research organisations & Universities	Restoration of soil health for agriculture and food
2.	Establish a continuing funding mechanism	1. Guaranteed funding	1. Source funding from national and international bodies	Size of fund allocated for i. recruitment of personnel; ii. equipment; iii. maintenance of databases, culture collection etc.; and iv. R&D	60 months	**MOA** **NRE**	Availability of continuous funding for research and development (R&D)
			2. Collaborative research with national and international agencies	Linkages with related agencies dealing with microbial genetic resources (NITE, ATCC, DSMZ, CABI etc.) established	60 months	**MOA**/Research organisations & Universities	Networking for conservation of microbial genetic resources and R&D for food and agriculture
			3. Private sector participation in microbial genetic resources, exploration and use	Linkage with private organisations (Petronas, Shell, etc.) established	60 months	**MOA**/Research organisations & Universities	Reliable funding from private sectors for conservation, and R&D on microbial genetic resources
3.	Management, updating and maintenance of databases	1. Guaranteed continuing management and interlinkage of data on microbial genetic resources	1. Assign personnel and establish databases in line with identified research projects	Number of scientists appointed for each taxonomic category: i. Curation verified ii. Maintenance of databases	36 - 60 months	**MOA**/ Independent institution	Established permanent and sustainable data base management centre (data storage, mining and capture)
		2. Update the databases, improve the data quality and data management	1. Regular updating and continuing management of databases on microbial genetic resources	Annual updates by participating organisations	Annually	**MOA**/Research organisations & Universities	

5.4.4 *Legal and institutional framework*

To mitigate the present, and avoid future negative impacts of import, export and use of microbes, legislation and enforcement of the laws are of utmost importance. The activities are to be carried out on the basis of the key technical data and in compliance with national and international requirements. Biosafety guidelines on the use of microbes will be formulated and the existing legislation on import and export of microbes strengthened through harmonization of national and international practices on sanitary and phytosanitary (SPS) measures.

No.	Strategy	Action plans	Proposed activity	Key Performance Indicators	Duration	Lead Ministry/ Implementing Agency	Impact
1.	Biosafety guidelines	1. Formulate biosafety guidelines on use of microbes	1. Hold meetings and dialogues between policy makers and related agencies	Biosafety guidelines/ Act for use of microbes	48 months (Act) and 12 months (Guidelines)	**MOA**/DOA (Peninsular, Sabah and Sarawak) & other related agencies **NRE**	Information contributed for development of biosafety policies, regulations and laws
		2. Provide funds	1. Source funding from relevant agencies	Size of fund allocated	36 months	**MOA** **NRE** **MOSTI** **MOH** & other related agencies	
		3. Recommend action by associations of interest and political decision makers	1. Formulate recommendations for action from research results and cost-benefit analyses	Number of dialogues conducted	36 months	**MOA** **NRE** **MOSTI** **MOH** & other related agencies	
2.	Strengthen implementation of legislation on import and export of microbes	1. Harmonize national and international practices on implementation of sanitary and phytosanitary (SPS) measures	1. Strengthen enforcement through awareness programmes and education	Number of awareness programmes conducted	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak) & other related agencies **NRE** **MOH**	Effective monitoring and regulation of import and export of microbes Legislation reviewed to reflect microbial genetic resources needs
			2. Organise training for customs and quarantine authorities	Number of training programmes conducted	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak), MARDI & Universities	
			3. Organise special awareness programmes for decision and policy makers	Number of training programmes conducted	60 months	**MOA**/DOA (Peninsular, Sabah and Sarawak), MARDI & Universities	

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APPENDIX I. List of participants involved in workshops of preparation of National Strategies and Action Plans of Agricultural Biodiversity Conservation and Sustainable Utilisation

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7	Ms. Zamzurina Zulkifli	NRE
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9	Datin Jatil Aliah Timin	DOA, Peninsula
10	Mr. Mohamad Ramdzan	DOA, Peninsula
11	Mr. Mohd. Yusof Othman	DOA, Peninsula
12	Mr. Wan Darman b. Wan Abdullah	DOA, Peninsula
13	Dr. Jenny Lee	DOA, Sabah
14	Mr. Chong Tan Chun	DOA, Sabah
15	Dr. Abu Hassan Muhammad Ali	DVS, Peninsula
16	Dr. Kamarudun Md. Isa	DVS, Peninsula
17	Mr. Adrien Kumar Raymond	DVS, Peninsula
18	Mr. Mohd. Hafiz Abdul Rahman	DVS, Peninsula
19	Ms. Ernie Muneerah Mohd. Adnan	DVS, Peninsula
20	Ms. Shariffah Nazari	DVS, Peninsula
21	Dr. Punimin Abdullah	DVS, Sabah
22	Dr. Humrawali Khan	DVS, Sarawak
23	Ms. Syarifah Khadiejah Syed Mohd. Kamil	DWNP
24	Mr. Abdul Rahman Ahmad	FELDA
25	Mr. Mohd. Saidee Salleh	FELDA
26	Dr. Lee Su See	FRIM
27	Dr. Masahuling Benong	MRB
28	Dr. Siti Arija Mad Arif	MRB
29	Dr. Abd. Rahman Milan	MARDI
30	Dr. Jasmi Yahya	MARDI
31	Dr. Johari Jiken Abdullah	MARDI
32	Dr. Mohamed Rani Mat Yusoh	MARDI
33	Dr. Mohd Norowi Hamid	MARDI
34	Dr. Mohd Shukor Nordin	MARDI
35	Dr. Musaddin Kamaruddin	MARDI
36	Dr. Rosliza Jajuli	MARDI
37	Dr. Salma Idris	MARDI
38	Dr. Tan Geok Hun	MARDI
39	Dr. Tosiah Sadi	MARDI
40	Mr. Azuan Amron	MARDI
41	Mr. Hj. Ithnin Badri	MARDI
42	Mr. Jamadon Bahari	MARDI

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46	Mr. Muhammad Shafie Md. Sah	MARDI
47	Mr. Razali Mirad	MARDI
48	Mr. Zulhairil Ariffin	MARDI
49	Ms. Khadijah Awang	MARDI
50	Ms. Maya Izar Khaidizar	MARDI
51	Ms. Nor Ayshah Alia Ali Hassan	MARDI
52	Ms. Razean Haireen Mohd. Razali	MARDI
53	Ms. Site Noorzuraini Abd Rahman	MARDI
54	Ms. Stella Mathews	MARDI
55	Mr. Musa Yaacob	MARDI
56	Mr. Haya Ramba	MCB
57	Ms. Meriam Mohd. Yusof	MCB
58	Ms. Nuraziawati Mat Yazik	MCB
59	Dr. Maizura Ithnin	MPOB
60	Dr. Norman Kamarudin	MPOB
61	Ms. Shakinah Salleh	Nuclear Malaysia
62	Dr. Sahilah Abdul Mutalib	UKM
63	Prof. Dr. Idris Ab. Ghani	UKM
64	Prof. Dr. Mohd. Osman Mohamad	UIAM
65	Mr. Jupikely James Silip	UMS
66	Prof. Madya Abdullah Md. Zain	UMT
67	Prof. Dr. Sepiah Muid	UNIMAS
68	Prof. Dr. Fatimah Abang	UNIMAS
69	Assoc. Prof. Dr. Jothi Malar Panandam	UPM
70	Dr. Nur Azura Adam	UPM
71	Prof. Dr. Ahmad Said Sajap	UPM
72	Prof. Dr. Raha Abd Rahim	UPM
73	Prof. Dr. Sariah Meon	UPM
74	Assoc. Prof. Dr. Mohd. Said Saad	UPM
75	Assoc. Prof. Dr. Umi Kalsom Md. Shah	UPM
76	Assoc. Prof. Dr. Latiffah Zakaria	USM
77	Prof Dr. Abu Hassan Ahmad	USM
78	Dr. Mohd Yusoff Abdullah	UITM
79	Mr. Abdul Manab Hj. Khalid	Felda Farm Products
80	Dato' Dr. Vincent Ng In Hooi	KOTERNAK
81	Mr. Lim Eng Siang	Bioversity International
82	Ms. Lim Li Ching	TWN
83	Dr. Suhaimi Masduki	Biofusion Sdn Bhd