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Pesticide Application in the Oil Palm Plantation

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ABSTRACT

This article attempts to give an overview of the combined practice of pesticide management in oil palm plantations, the types of pesticides commonly used and the method of analysis to determine pesticide residues in palm oil. A brief outline of the regulatory controls for pesticides is also included.

ABSTRAK

Artikel ini memberi suatu peninjauan umum tentang pengurusan perosak bersepadu yang diamalkan di ladang sawit, jenis bahan racun perosak yang lazim digunakan dan kaedah analisis untuk menentukan sisa baki racun perosak dalam minyak sawit. Suatu garis kasar berkenaan peraturan kawalan untuk bahan racun perosak juga diterangkan.

Keywords: pesticide residues, oil palm, herbicides, insecticides, regulatory.

INTRODUCTION

A pesticide is any biological, physical or chemical substance used to control, destroy or repel a pest. Like for any other agricultural crop, oil palm yield can be severely affected by pests that compete against the palm for nutrients, infect or damage the palm. Losses due to pests and efforts to control pests are major obstacles in the cultivation of oil palm. For example, a single bagworm outbreak caused leaf defoliation of 10-year-old palms and reduced the yield to 40%-50% over the next two years (Wood *et al.*, 1973). In order to overcome losses resulting from pest attacks, oil palm plantations practise integrated pest management (IPM) which is a sustainable approach to managing pests. IPM is the coordinated use of pest and environmental information together with available pest control methods to prevent unacceptable levels of pest damage by the most economical means, and with the least possible hazard to people, property and the environment. The control tactics include cultural, biological, genetic and chemical methods. Chemical control in IPM differs from that of a conventional chemical programme in that it involves the judicious use of pesticides. Although IPM approach relies primarily on natural predators to manage pests, the use of selective pesticides remains the most economic and effective pest control method in oil palm plantations.

Pesticides, being toxic must be used with care to avoid accidental contact with people who handle or are exposed to them and to the surrounding environment, which includes plant, fish, certain useful insects as well as the natural enemies of the pests. When pesticides are applied in plantations, they can spread further than where they were applied and can contaminate waterways through run off into rivers.

The degradation and transport of these pesticides in the environment need to be studied to determine the concentrations in water bodies at or near the site of application. Leaching of the pesticides into the waterways may be detrimental to living organisms which may be food for humans or animals. Precautions have to be taken to ensure that the environment is free from pesticide contamination. Another impact of pesticides is that on food safety because pesticides may leave residues in the final product. The edible products of the palm fruit, such as palm oil and palm kernel oil, must be monitored for the residues of the applied pesticides. Therefore, the amount of applied pesticide must be adequate so as to control the target enemies while having minimal effects on the environment and food safety of palm oil. This article outlines agricultural practices and steps in oil palm plantations for crop protection, and monitoring of residue in the environment and oil.

AGRICULTURAL PRACTICES IN THE OIL PALM PLANTATION

Good agricultural practice (GAP) in the use of pesticides (CODEX, 1998) includes the nationally authorized safe use of pesticides under actual conditions necessary for effective and reliable pest control. It covers a range of levels of pesticide applications up to the highest authorized use, applied in a manner in

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the agricultural crops in small amount. Authorized safe use, determined at the national level, includes nationally registered or recommended uses, which take into account public and occupational health and environmental safety considerations. Actual conditions may include any stage in the production, storage, transport, distribution and processing of food commodities and animal feed.

Good Agricultural Practice for Oil Palm

The practices in oil palm plantations seek to address problems caused by some of the weeds, diseases, disorders and pests of the oil palm. Each plantation has its own unique way of handling these problems and they are documented as part of the good agronomic practices manual. Some of the weeds and pests of the oil palm are listed in *Tables 1* to *7*.

WEEDS

The main problem in the oil palm plantation is weeds. During the immature stage, the palm fronds are small and therefore the ground surrounding the oil palm is exposed to sunlight thereby assisting prolific growth of the weeds. However, when the palm is matured, the close canopy prevents sunlight from reaching the ground thus reducing weed growth. Some of the weeds found in oil palm plantations are listed in *Tables 1* to *6*. A brief description of the weed types is as follows:

Grass-type Weeds

Grass weeds from the family of *Gramineae* and *Cyperaceae* have sharp thin leaves. They reproduce by seeds and rhizomes. *Imperata cylindrica* is a common weed, able to produce large amounts of seeds and dormant buds along rhizomes. *I. cylindrica* in sheet form is capable of stunting oil palm growth and yield. Signs of nitrogen deficiency as shown by yellowing can be observed under high weed density.

Other common grass weeds in oil palm plantations include *Paspalum conjugatum* (*rumput kerbau*), *Ottochloa nodasa* (*rumput pahit*), *Ischaemum muticum* (*rumput kemarau*), *Pennisetum polystachion* (*rumput gajah*), *Eleusine indica* (*rumput sambau*) and *Axonopus compressus* (*rumput padang*). *Ischaemum muticum* has the potential to reduce oil palm yield by up to 22%.

Creeper Broadleaf Weeds

The weeds are able to creep on the surface of soil and climb over dead tree stumps or bigger trees. They have wide leaves and small fragile stems. *M. micrantha* is aggressive and grows well in wet, shady and open areas. It affects oil palm growth and yield by competing for nutrients, water and light. Besides that, it also produces an allelopathic compound which may inhibit nitrification by the soil microorganisms.

Non-creeper Broadleaf Weeds

These weeds are the small, erect and succulent herbaceous plants. They are able to flower and produce many seeds. Normally, they can colonize previously chemically treated areas through the rapid germination of seeds. *Asystasia intrusa* is difficult to control due to its ability to spread seeds vigorously and quickly. It grows well on all soil types and even under shade. It competes with oil palm by taking up N, P, and K nutrients efficiently. It grows up to 1 m, competing with palms up to three to four years old.

Woody Broadleaf Weeds

Most woody weeds are dicotyledons with strong woody stems. They have a long life of more than two seasons, producing lots of branches. They reproduce by seeds. *Chromolaena odorata* significantly affects inflorescence production, sex ratio and early bunch yield. In most cases, the prolific regeneration into woody shrubs makes them undesirable in oil palm. Besides, *Melastoma* sp. and *Clidemia* sp. are alternate hosts to cockchafer beetles and other leaf eating pests of oil palm.

Sedge-type Weeds

Sedge-type weeds from the family Cyperaceae have sharp thin leaves and angled stems. They reproduce by seeds and rhizomes. *Cyperus iria* and *Cyperus rotundus* are commonly found in the nursery and low lying moist areas. Sedges are common, generally grow well in wet areas and are usually difficult to control with chemicals.

Ferns and Bracken Weeds

These weeds, as saprophytes, do not affect oil palm yield. Instead, they control the water level in the soil. They have short root systems and some even grow in between oil palm fronds as epiphytes. These weeds grow well in wet and shady areas.

GENERAL MANAGEMENT FOR ALL WEEDS

There are various methods of weed control (cultural, biological and chemical), which vary in cost and effects.

TABLE 1. HERBICIDES (active ingredients) SUITABLE TO CONTROL GRASS-TYPE WEEDS

Weed	Active ingredient	Rate of product in 18 litre mixture	Crop stage
Imperata cylindrica	Glyphosate*	180 – 240 ml of 41% product	Outside circles of immature
	Imazapyr*	150 – 225 ml of 10% product	-
Ischaemum muticum	Glyphosate*	160 ml of 41% product	Outside circles of immature
Eleusine indica	Glufosinate-ammonium**	132 ml of 18% product	-
	Imazapyr*	60 – 120 ml of 10% product	Outside circles of immature
	Fluazifop-butyl	60 ml of 26% product	-
Pennisetum	Metsulfuron-methyl	3 g of 20% product	-
	Glyphosate*	60 ml of 41% product	Outside circles of immature
	Fluazifop-butyl	60 ml of 26% product	-

Notes: *Not safe to immature palms; ** Scorching.
Source: Turner and Gillbanks (2003).

TABLE 2. HERBICIDES (active ingredients) SUITABLE TO CONTROL CREEPER-TYPE BROADLEAF WEEDS

Weed	Active ingredient	Rate of product in 18 litre mixture	Crop stage
Mikania micrantha	Fluroxypyr *	15 ml of 26% product	Mature
Passiflora foetida	2, 4-D amine *	56 ml of 70% product	Mature
Momordica charantia	Triclopyr*	60 ml of 32% product	Mature

Notes: *Not safe to immature palms; ** Scorching.
Source: Turner and Gillbanks (2003).

TABLE 3. HERBICIDES (active ingredients) SUITABLE TO CONTROL NON-CREEPER TYPE BROADLEAF WEEDS

Weed	Active ingredient	Rate of product in 18 litre mixture	Crop stage
Assystasia gangetica	2, 4-D amine*	56 ml of 70% product	Mature
	Metsulfuron-methyl	3 g of 20% product	Immature
Passiflora foetida	2, 4-D amine*	56 ml of 70% product	Mature
Mimosa invisa	Glufosinate-ammonium**	180 ml of 18% product	Immature + mature
	Glyphosate*	120 ml of 41 % product	Mature
	Metsulfuron-methyl	3 g of 20% product	Immature

Notes: *Not safe to immature palms; ** Scorching.
Source: Turner and Gillbanks (2003).

TABLE 4. HERBICIDES (active ingredients) SUITABLE TO CONTROL WOODY-TYPE BROADLEAF WEEDS

Weed	Active ingredient	Rate of product in 18 litre mixture	Crop stage
Assystasia intrusa	Metsulfuron-methyl	3 g of 20% product	Immature
	2, 4-D amine	6 – 10 ml of 70% product	Mature
Melastoma malabathricum	Triclopyr	60 – 80 ml of 32% product	Mature
	Metsulfuron-methyl	6 g of 20% product	Immature + mature
Ageratum conzoides	Metsulfuron-methyl	3 g of 20% product	Immature
	2, 4-D amine	6 – 10 ml of 70% product	Mature
Chromolaena odorata	Triclopyr	60 – 80 ml of 32% product	Mature
	Metsulfuron-methyl	6 g of 20% product	Immature + mature

Notes: *Not safe to immature palms; ** Scorching.
Source: Turner and Gillbanks (2003).

TABLE 5. HERBICIDES (active ingredients) SUITABLE TO CONTROL SEDGE-TYPE WEEDS

Weed	Active ingredient	Rate of product in 18 litre mixture	Crop stage
Cyperus iria	Glyphosate*	120 ml of 41% product	Immature + mature
Scleria sumatrensis	Glufosinate-ammonium**	132 ml of 18% product	Mature

Notes: *Not safe to immature palms; ** Scorching.
Source: Turner and Gillbanks (2003).

TABLE 6. HERBICIDES (active ingredients) SUITABLE TO CONTROL FERN AND BRACKEN WEEDS

Weed	Active ingredient	Rate of product in 18 litre mixture	Crop stage
Nephrolepsis biserrata	Metsulfuron-methyl	4-6 g of 20% product	Immature + mature
Dicranopteris linearis	Glufosinate-ammonium** + 2, 4-D amine*	60 ml of 18% product + 60 ml of 70% product	Mature
Adiantum latifolium	Glufosinate- ammonium**	132 ml of 18% product	Mature

Notes: *Not safe to immature palms; ** Scorching.
Source: Turner and Gillbanks (2003).

Cultural Practices

- Mulching with empty fruit bunch (EFB) around the base of palm ;
- Cut fronds placed in the inter-rows;
- Chipped trunk around young palms;
- Legume cultivation; and
- Manual weeding – usually done in nurseries.

These cultural practices benefit the main crop by:
- increasing the organic level in soil;
- maintaining the soil moisture, controlling soil erosion and protecting the physical structure of soil;
- allowing crop integration, thereby increasing area usage and profit; and
- allowing legumes to fix nitrogen from atmosphere as nutrients for palms.

Proper selection of plants for integration is crucial to avoid competition between the plants and oil palm. Legume cultivation is beneficial and the mixture recommended for oil palm are *Calopogonium mucunoides*, *C. caeruleum*, *Centrosema pubescene*, *Pueraria phaseoloides*, *Desmodium ovalifolium*, *Mucuna bracteata* and *M. cochinchinensis*.

Weeds are controlled through biological and chemical means. Biological control through animal integration, such as cattle, goat, sheep and deer rearing, has been effective in controlling weeds in the mature plantation. Chemical control is carried out by spraying herbicides on these weeds. Knowledge on spraying techniques and types of weed and herbicides is important. Systemic herbicides provide longer control compared to contact. The types of herbicides according to the type of weed are summarized in *Tables 1* to *6*.

PESTS: INSECTS AND VERTEBRATES

Basic Elements of Pest Management

Oil palm is prone to several species of defoliators, bunch, fruit and stem attackers. Growers should be able to define conducive environments to the breeding of pests and the threshold levels of pests. Chemicals should be used only after the pest numbers exceed a certain population level. Census and monitoring of pest population are essential to determine that the population level of the pests does not exceed the economic injury level.

Once a pest is detected, growers should be able to identify it and the category of infestation, whether it is a low, moderate, serious or outbreak situation. During an outbreak, the proper technique, timing and correct choice of chemicals are essential to bring the population to a tolerable level.

The IPM is combination of both chemical and biological means. In this concept, the use of chemicals is strictly for reducing the pest population if it exceeds a certain threshold. Once it is reduced, establishment of a self-propagating, integrated biological control agent is encouraged for long-term control.

Biological control agents can be in the form of insect predators and parasitoids, fungi, bacteria and virus which are host specific to the pests. These natural enemies contribute to the long-term control of pests and reduce the reliance on chemical insecticides. Theories as well as field training are essential in order to introduce and implement the concept to the growers. Some of the pests of oil palm are listed in *Table 7*.

Choice of Control (chemical and biological)

Growers should only use chemicals which are registered in the country. Chemicals should be selectively chosen to control certain kinds of pests. The correct technique of application needs to be considered when using a certain formulation of chemicals.

The choice of chemicals should be based on whether it is a stomach poison (specific for leaf eaters) or contact poison (for general control). Generally, a contact poison is less selective as it will harm the beneficial insects and organism as well. A systemic chemical, which goes into the plant system, is very selective towards leaf eating pests. Wax baits are useful for mammalian/rodent pests.

Knowledge in biological control is essential for growers to ensure long-term control of pests. Biocontrol agents can be enhanced by having suitable and conducive environments, *e.g.* insect parasitoids and predators require food and shelter in certain flowering, nectariferous plants. The planting of these beneficial plants is greatly encouraged.

Protective Clothing and Method of Application

Growers should wear protective clothing when diluting and spraying the chemicals. The operators should have proper knowledge on handling pesticides and the correct method to apply the chemicals, either by spraying, trunk injection or baiting. The types of chemicals, supplies and usage need to be properly recorded. The chemicals need to be stored in a safe place.

DISEASES

Besides weed and pest problems, the oil palm is also prone to several diseases. The major diseases are vascular wilt, basal stem rot, bud and spear rot, red ring disease and sudden wilt. Of the five diseases mentioned, basal stem rot is the major disease in Malaysian oil palm plantation.

TABLE 7. PESTS AND DISEASES OF THE OIL PALM (*Elaeis guineensis*)

Stage	Diseases, disorders and pests
Nursery	Anthracnose, leaf spot disease, aphids, cockchafers
Mature leaf	Crown disease, white stripe, patch yellow, leaf eating caterpillars, bagworms, nettle caterpillars
Stem and root	*Ganoderma* trunk rot/basal, stem rot, upper stem rot, termites
Bunch and fruit	Bunch and fruit rot, *Marasmius palmivorus*, bunch moth (*Tirathaba rufivena*)
Young palms	Grasshoppers, rhinoceros beetle
Mature palms	Beetles, termites
Fruits	Rat (*Ratticus tiomanicus*), birds (*Psittacula longicanda, Psittinus cynurus* and *Loriculus galgulus*)

Source: Turner and Gillbanks (2003).

Vascular Wilt

Vascular wilt, or Fusarium wilt, is caused by the fungus *Fusarium oxysporum f.* sp. *Elaeidis*. It is a soil borne disease and the fungus attacks the xylem. Once established the disease causes the vascular strands in the stem to turn dark brown and, finally, black. This will impede the transportation of water and nutrients in the stem, thus killing the oil palm.

Basal Stem Rot

This is a disease caused by several species of *Ganoderma* and is a major disease in Malaysia. Oil palm planted after coconut, especially on coastal marine clays, is susceptible to this disease. However, the disease also occurs on peat and inland soils. Even though there are several species of *Ganoderma*, the species commonly found in Malaysia is *Ganorderma boninense.* Control of the disease is by application of the triazole group of fungicides and fumigant methylisothiocyanate. One of the fungicides being tested against *Ganoderma*, in MPOB, is hexaconazole. Hexaconazole is not registered for use on palm oil yet; however, trials are being carried out to generate residue trial data which will be used for registration and establishment of maximum residue limits (MRL) in palm oil.

Bud and Spear Rot

This disease causes chlorosis of the fronds, especially the youngest fronds of 1-10. The actual causal agent has yet to be identified. The disease also causes the roots to rot and the rotting tissue can emit characteristic putrid odour. The disease is rampant in areas of high rainfall and low sunshine. The incidences are reported to be high during the rainy season with remission in the dry season. The disease is reduced through improved agronomic practices, such as improved drainage, reduced soil compaction and improved aeration.

Red Ring Disease

This disease is usually observed in oil palm older than five years and is characterized by progressive yellowing of the fronds from the oldest to the youngest. Other symptoms observed are production of very short fronds, compact appearance of the crown, followed by necrosis of the leaflets. The disease is attributed to the nematode, *R. cocophilus,* and the vector for this nematode is *R. palmarum*. Other vectors reported include *Metamasius hemipterus, Dinamis borassi, Limnobaris calandriformis* and *Strategus aloes.*

CHEMISTRY OF PESTICIDES

Several pesticides are applied to control pests and diseases of oil palm. These pesticides are classified into herbicides, insecticides, rodenticides and fungicides. The list of pesticides registered for use in oil palm is shown in *Table 8*. All pesticides are toxic and therefore should be applied according to the instructions on their labels. These pesticides at low dosage are used to kill agricultural pests while at high dosage can be fatal to humans.

Herbicides

Chemicals used for destroying weeds are referred to as herbicides. Herbicides can be classified in several ways depending on their chemical structure, effect on weeds, functional group or field use. They are also grouped based on their action on foliage or through the soil. Their effects on foliage can be by contact (selective or non-selective) or translocation (selective or non-selective). A selective herbicide is one that retards or kills the growth of an unwanted plant, or weed, while causing little or no injury to desirable species. On the other hand, a non-selective herbicide kills every plant it comes into contact with. Herbicides that act through the soil (soil-borne) are taken up through the roots of the target plant. They have either short or long residual and selective or non-selective effect. Pre-emergent herbicides are applied to the soil and prevent germination or early growth of weed seeds. Post-emergent herbicides are those applied when the weeds are fully grown.

In the oil palm plantation, herbicides are applied to control weeds in competition with the oil palm. These herbicides are regularly applied to the area surrounding immature palms to prevent weed growth. However, when the trees mature the canopy prevents sunlight reaching the weeds. This reduces prolific growth of the weeds, allowing for minimal herbicide application.

Most herbicides are applied as water-based sprays using ground equipment. Even though a number of herbicides are registered for use in oil palm plantations, the commonly used herbicides are paraquat, glyphosate, glufosinate ammonium and metsulfuron methyl. However, paraquat's mode of action differs from the other three because it destroys weeds on contact. The other three are systemic herbicides and therefore are slower in showing results. Systemic herbicides are absorbed by the foliage or roots and translocated to other parts of the plant.

Paraquat is a bipyridal herbicide and the commercial forms are the dichloride and bis(methyl sulphate). It is deliquescent and very soluble in water. The salts are stable in neutral and acid media but are oxidized under alkaline condition and decompose in ultraviolet light. Autoxidation or reduction of paraquat solutions produces an intensely purple

TABLE 8. MAXIMUM RESIDUE LIMITS OF AGROCHEMICALS IN SCHEDULE SIXTEEN OF THE PESTICIDE ACT 1985 AND REGULATIONS

Pesticide	Type	National MRL (mg kg^{-1})
Captan	F	10
Cyproconazole	F	0.1
Dithiocarbamates	F	1
Difenoconazole	F	0.1
2, 4-D	H	0.05
Ametryn	H	0.2
Cinosulfuron	H	0.1
Dicamba	H	0.1
Diuron	H	0.1
DSMA	H	0.1
Fluazifop-butyl	H	0.2
Fluroxypyr	H	0.1
Glufosinate ammonium	H	0.5
Glyphosate	H	0.1
Imazapyr	H	0.1
Imazethapyr	H	0.05
Metsulfuron methyl	H	0.02
MSMA	H	0.1
Paraquat	H	0.1
Sethoxydim	H	0.05
Triclopyr	H	0.1
Butocarboxim	I	2
Chlorpyrifos	I	0.5
Cypermethrin	I	0.5
Deltamethrin	I	0.2
Gamma HCH	I	2
Lambda cyhalothrin	I	0.1
Methamidophos	I	0.1
Methidathion	I	0.1
Monocrothophos	I	0.05
Acephate	I	0.5

Notes: F = fungicide, H = herbicide, I = insecticide, MRL = maximum residue limit, ADI = acceptable daily intake.
Source: Food Act 1983 (Act 281) and Regulations (2005b).

water-soluble, relatively stable free radical. This solution of free radical absorbs at 396 nm while the unreduced form absorbs at 256 nm. The unformulated salts are corrosive to common metals but the diluted forms are less corrosive and do not affect the spray equipment (EXTOXNET; The Pesticide Manual, 1991).

When sprayed on weeds, on contact, it rapidly scorches and kills the weeds. It is used for land preparation in combination with 'no-till' agricultural practices. It is particularly important to growers in peat areas where woody weeds, like bracken and ferns dominate the vegetation. Paraquat is the chosen herbicide during rainy season because it is rain-fast and kills weeds within 15-30 min. In comparison, the efficacy of glyphosate and glufosinate may be reduced to 40%-70% if heavy rain comes after application.

Paraquat, a non-selective herbicide, used to be the major pesticide applied in the oil palm plantations because of its effectiveness in killing *Nephrolepis biserrata*. However, paraquat usage in the agricultural sector in Malysia was banned in July 2003; but usage was reinstated for oil palm in 2005 for two years. In December 2006, paraquat was allowed to be used for other crops until November 2007. Hence, an alternative is needed to destroy this dominant vegetation in oil palm plantations. Glyphosate is the next major herbicide used followed by others such as metsulfuron methyl, 2,4-D, glufosinate ammonium, diuron, fluroxypyr, *etc*.

Glyphosate is a phosphonic acid herbicide acting as an aromatic acid synthesis inhibitor. Pure glyphosate has a zwitterions structure and is corrosive to iron, steel and aluminium. It is a broad-spectrum, non-selective systemic herbicide used for control of annual and perennial plants including grasses, sedges, broad-leaved weeds and woody plants. On application to the foliage, it is absorbed and rapidly translocated throughout the plant. It acts by preventing the plant from producing essential amino acids. This reduces the production of protein in the plant and inhibits plant growth. Due to the absorption being limited to foliage, soil bound glyphosate is effectively inert. Glyphosate is metabolized or broken down by some plants. Aminomethylphosphonic acid is the main metabolite of glyphosate in plants (EXTOXNET; The Pesticide Manual, 1991).

Glufosinate ammonium is derived from phosphinothricin, a natural microbial toxin isolated from two species of Streptomyces fungi. It is a phosphorus-containing amino acid that inhibits the activity of the enzyme, glutamine synthetase, which is necessary for the production of the amino acid glutamine and ammonia detoxification. The application of glufosinate ammonium leads to reduce glutamine and increased ammonia levels in the plant. This causes photosynthesis to stop and the plant dies within a few days (EXTOXNET; The Pesticide Manual, 1991).

Uptake of glufosinate ammonium is through the leaves and stem and damage is restricted to those parts of the plants which are in direct contact with the spray. The active ingredient can move within leaves but cannot move to other parts of the plant such as underground rhizomes or stolons. Long-term control of perennial weeds is therefore limited. The main metabolite of glufosinate ammonium in plants is 3-methyl-phosphinicopropionic acid and other metabolites are 4-methyl-phosphinico-butanioc acid and 2-methyl-phosphinico-acetic acid. The anionic surfactant, sodium polyoxyethylene akylether sulphate (AES), is added to enhance the plant's absorption of glufosinate.

Metsulfuron methyl is a sulphonylurea herbicide which is stable in air. It hydrolyses in acid solution at 25°C with a half-life of 15 hr at pH2, 33 days at pH15, greater than 41 days at pH7 and pH9 and rapidly decomposes at 45°C. It is used as a selective herbicide primarily for pre- and post-emergent control of annual biennial and perennial broadleaf weeds and some annual grasses. It is a systemic compound with foliar and soil activity and enters the plant through the roots and foliage, inhibiting synthesis of key amino acids thereby inhibiting cell division. It is biologically active at low rates of usage (EXTOXNET; The Pesticide Manual, 1991).

The 2,4-D, abbreviated from 2,4-dichlorophenoxyacetic acid, is a chlorinated phenoxy compound and is used as a systemic herbicide to control broadleaf weeds, grasses and other monocots, woody plants, aquatic weeds and non-flowering plants. When applied on foliage, it is absorbed and translocated throughout the plant. It is selective and weeds can be treated while the crop is not affected or only minimally injured. It is the most widely used herbicide in cultivated agriculture, in pasture and rangeland applications, forest management, home gardens and to control aquatic vegetation. As a plant-growth regulator, it stimulates nucleic acid and protein synthesis and affects enzyme activity, respiration and cell division. On absorption through the leaves, stems and roots, it moves throughout the plant and accumulates in the growing tips (EXTOXNET; The Pesticide Manual, 1991).

Diuron is a urea herbicide used to control a wide variety of annual and perennial broadleaf and grassy weeds. It is used to control weeds and mosses on non-crop areas and among many agricultural crops. It works by inhibiting photosynthesis. It decomposes at 180°C-190°C. At ordinary temperature and neutral pH, hydrolysis is negligible but under acidic and alkaline conditions or higher temperatures hydrolysis is greater. Diuron degrades by N-demethylation under aerobic conditions to metabolites such as *N'*-(3,4-dichlorophenyl)-*N*-methylurea; 3,4-dichlorophenylurea and 3,4-dichloroanaline, while under anaerobic conditions a dechlorinated product, N'-(3-chlorophenyl)-*N*-methylurea, is formed (EXTOXNET; The Pesticide Manual, 1991).

Fluroxypyr belongs to the pyridinoxy acid family. It is readily translocated and effective by post-emergence foliar application, controlling a range of broadleaf weeds. It is also applied directly on herbaceous and woody broadleaf weeds in orchards and plantation crops such as rubber and oil palm.

Dicamba belongs to the benzoic chemical class and can be applied to the foliage or soil. It is readily absorbed by the foliage and roots and translocated throughout the plant. While 2,4-D can be used to control most weeds, dicamba can be used for tough-to-control weeds. Dicamba controls annual and perennial broadleaf weeds, brush and bracken. It can also kill broadleaf weeds before and after they sprout. Dicamba combined with phenoxyalkanoic acid or other herbicides is used in pastures, range land and non-crop areas. In some plants, it may accumulate in the tips of leaves. Dicamba acts as an auxin-like growth regulator and some plants can metabolize or break it down (EXTOXNET; The Pesticide Manual, 1991).

Triclopyr is a herbicide belonging to the pyridine (picolinic acid) family. It is a selective systemic herbicide used to control woody and herbaceous broadleaf plants and has little or no impact on grasses. As an auxin mimic or synthetic auxin, the herbicide kills by mimicking the plant growth hormone auxin (indole acetic acid). When administered at effective doses, it causes uncontrolled and disorganized plant growth that leads to death. Both the salt and ester are readily hydrolysed to the acid form in the environment and plant.

INSECTICIDES

The use of insecticides in oil palm plantations is minimal as they are only applied when there is an insect attack. The major problem in Malaysian oil palm plantations is bagworm and a number of studies have been carried out to control this infestation. The insecticides applied for this purpose are phosphorus-based, or organophosphorus, compounds which are applied through trunk injection. Under the 16th Schedule of the Food Regulations, the use of organophosphorus compounds such as monocrotophos, methamidophos and acephate is restricted. They can only be applied on oil palm and coconut. Synthetic pyrethroids such as cypermethrin, lambda-cyhalothrin and deltamethrin are also used to control *Oryctes* attack on immature palms.

Organophosphorus Compounds

One of the groups of insecticides with wide ranging toxicity is organophosphorus compounds. They can be absorbed dermally, orally or through inhalation of the vapours. This group of insecticide attacks cholinesterase, which is necessary for proper functioning of the nerve. It acts by inhibiting or poisoning cholinesterase causing the nerve impulse transmission to race out of control due to a build-up of acetylcholine at the end of the nerve fibres. This will result in convulsions, muscle twitching and even violent muscular action.

Monocrotophos is one of the organophosphorus insecticides which acts both systemically and through contact. It penetrates plant tissues rapidly and is used against a wide range of pests. In Malaysia, it is only formulated as a systemic chemical for trunk injection and a purchase permit from the Pesticides Board is required. It is restricted to use for oil palm and coconut only. This compound is used to address the bagworm problem in oil palms. When it is injected into the oil palm trunk, the transpiration pull transmits the compound to the fronds where the bagworm population concentrates. Application of monocrotophos is confined to serious infestation of this pest, which exceeds the threshold level (EXTOXNET; The Pesticide Manual, 1991).

Methamidophos is another organophosphorus compound used on oil palms to control bagworms. It is a broad-spectrum systemic and contact insecticide and acaricide. It is absorbed by the roots and leaves. In Malaysia, it is formulated for trunk injection. The systemic effects of methamidophos remain up to two weeks after initial application (EXTOXNET; The Pesticide Manual, 1991).

Acephate is the third organophosphorus compound used to address bagworms. It is a systemic insecticide with contact and stomach action. It is of moderate persistence with residual systemic activity of about 10-15 days. Acephate emits toxic fumes of phosphorus, nitrogen and sulphur oxides when decomposed under heat. Symptoms of exposure to acephate include a slight irritation of the eyes and skin. In Malaysia, acephate is also formulated for trunk injection and it is also a restricted compound used for oil palm and coconut tree (EXTONET; The Pesticide Manual, 1991).

Chlorpyrifos belongs to the organophosphorus family with the phosphate group attached to the pyridine ring. It is also a cholinesterase inhibitor as it disrupts the activities of the enzyme which is essential for proper working of the nervous system of both humans and insects. It is a broad range, non-systemic insecticide which is effective by contact, ingestion and respiratory action. It is effective against a wide range of plant eating insects. It is used to control the rhinocerous beetle (*Oryctes rhinocerous*) in oil palm plantations (Basri and Norman, 2000) and termites. The primary chlorpyrifos breakdown product is 3,5,6-trichloro-2-pyridinol (EXTONET; The Pesticide Manual, 1991).

Synthetic Pyrethroids

Insecticides belonging to this group have similar properties as the naturally occurring pyrethrins. They are stable compounds and are used against a wide variety of pests. Two synthetic pyrethroids used for oil palm are cypermethrin and deltamethrin.

Cypermethrin is easily hydrolysed but is more stable in acid than in alkali. It is available as an emulsifiable concentrate or wettable powder. Technical cypermethrin is a mixture of eight different isomers, each of which may have its own chemical and biological properties. The mode of action is through contact or by ingestion, by which the insect nervous system is paralysed (EXTONET; The Pesticide Manual, 1991).

Deltamethrin also belongs to the synthetic pyrethroid family insecticides that kill insects on contact and through digestion. It is stable at ≤ 190°C and more stable in acid than in alkaline medium. It acts in the same way as the natural pyrethrins, which paralyze the insect nervous system rapidly and kill the insects due to irreversible damage to the nervous system. It is also a broad spectrum insecticide and the most powerful synthetic pyrethroid (EXTONET; The Pesticide Manual, 1991).

RODENTICIDES

Roenticides are chemicals used to kill rodents (rats). Anticoagulant rodenticides are probably the most commonly used rodenticides today. These rodenticides exert their effect by interfering with the recycling of vitamin K1, an active form of vitamin K. When vitamin K cannot be regenerated, clotting factors cannot be activated and coagulapathy results leading to uncontrollable haemorrhage and death.

Anti-coagulants

Anti-coagulants are compounds commonly used to control rodents. These compounds initiate blood clots and damage capillary blood flow in the body. Some of these anti-coagulants are warfarin, bromodiolone and brodifacoum. They are used against rodents in oil palm plantations. Besides these chemicals, barn owls are the biological agent for controlling rats.

Warfarin is odourless, tasteless and effective in very low doses, and is used for controlling rats and mice around homes, animal and agricultural premises, and commercial and industrial sites. Warfarin does not act rapidly and a marked reduction of rodent population can be observed usually in about a week after application. Once warfarin is taken by rodents, they continue to consume it until the anti-clotting property of the compound produces death through internal haemorrhaging (EXTONET; The Pesticide Manual, 1991).

Brodifacoum is a second generation rodenticide of exceptional activity which is effective against rodents that are resistant to conventional anti-coagulants. Death of the rodents occurs only after a single feeding. It is so potent that, unlike other anti-coagulants, a rodent may absorb a lethal dose by taking a 50 mg kg^{-1} bait as part of its feed intake on only one occasion (EXTONET; The Pesticide Manual, 1991).

Bromodialone provides excellent control for warfarin-resistant rodents with mortality occurring within 48 hr. Its mode of action is disruption of the normal blood clotting mechanism. It is so effective against rats and mice that a single dose of a 50 mg kg^{-1} bait can kill *Rattus norvegicus* and *R. rattus* from the fifth day. Bromodiolone is used in the form of ready-to-use baits and is particularly palatable to rodents (EXTONET; The Pesticide Manual, 1991).

FUNGICIDES

Fungicides are used to destroy or inhibit growth of fungi. In the past, incidences of pesticide poisoning occurred because of mistaken consumption of seed grains treated with fungicides such as organic mercury and hexachlorobenzene. However, pesticide regulations are already in place today to ensure that fungicides control the disease without injuring the plant and leave no poisonous residue in edible crops.

Benomyl is a systemic, benzimidazole fungicide that is selectively toxic to microorganisms and to invertebrates. It has low acute toxicity. However, benomyl may irritate the skin of the workers exposed to it. It is also readily absorbed by the body through inhalation of the dust but there are no reports of toxic effect on humans. Benomyl is used against a wide range of fungal diseases and is formulated as wettable powder, dry flowable powder or dispersible granules. It is rapidly degraded to carbendazim which has similar toxicological properties as benomyl. Benomyl decomposes when in contact with water and moisture (EXTOXNET; The Pesticide Manual, 1991).

Thiram is a dimethyl dithiocarbamate compound used as a fungicide to prevent crop damage in the field and to protect harvested crops from deterioration in storage or transport. Thiram is also used to protect seeds, fruits, vegetables, and ornamental and turf crops from a variety of fungal diseases. At high dosage, thiram is used to repel birds, deer and rodents. The fungicide deteriorates on prolonged exposure to air, heat and moisture. The dry powder of the compound when in contact with human skin can produce very slight erythemia (EXTOXNET; The Pesticide Manual, 1991).

Captan is a non-systemic phthalimide fungicide used to control diseases of many fruits and ornamental and vegetable crops. It is also used to spray root tips and for seed treatment to protect young plants against rot and damping off. The fungicide is also used to improve fruit finish by giving it a healthy, bright coloured appearance. Toxicology studies have not shown any tetragenic, carcinogenic or mutagenic effect (EXTOXNET; The Pesticide Manual, 1991).

Hexaconazole belongs to the family of azole fungicides. It is a systemic fungicide with protective and curative functions. This compound is used to treat and control *Ganoderma* in oil palm. The mode of action is through inhibition of ergosterol biosynthesis and thus, it is used for control of many fungi especially ascomycetes and basidiocetes. If hexaconazole were ingested, oral washing with water and induced vomiting must be effected within an hour of ingestion. Hexaconazole is also a mild eye irritant (EXTOXNET; The Pesticide Manual, 1991).

PROCESSING PALM FRUITS FOR OIL

Palm fruits harvested from the trees are transported to the mills to be processed for crude palm oil. The fruits are steam sterilized to deactivate the enzyme which causes hydrolysis of the triglycerides, for easy fruit detachment from the bunch and to soften the fruits to facilitate pressing of the oil out of the fruits. The crude oil also undergoes water washing before finally being dried and polished. The crude oil is then transported to the refinery for further processing to produce refined, bleached and deodorized (RBD) palm oil.

One of the steps in the processing of the crude oil to RBD palm oil involves water washing and this will remove most of the water soluble pesticides from the oil and degrade some of the pesticides to smaller molecules which are easily removed by steam (especially if these molecules are volatile). Most of the herbicides used on oil palm trees or in the oil palm plantation are very or moderately soluble in water. *Table 9* shows the amounts of pesticides commonly used in a plantation in Malaysia. Based on this survey, the amount of herbicides used top the other pesticides. Some of the insecticides used against pests of the oil palm trees are also slightly water soluble. Therefore, it is correct to assume that most of the pesticides are removed during processing of the palm fruits to RBD palm oil.

ANALYSIS OF RESIDUE IN OIL

Pesticides play an important role in the well being of food crops. However, the application of pesticides can result in the risk of residues in the food consumed. One of the food crops is oilseeds and oil bearing fruits. In order to obtain high yields of the oil, pesticides are applied to protect the crop against insects, weeds, rodents, fungi, *etc*. Oil, being a traded commodity, needs to be analysed for the residues of pesticides used. *Table 10* summarizes the analytical methods developed in MPOB for analysing various pesticide residues in oil matrix. Using the methods developed in MPOB, pesticides can be monitored in palm oil and its products. To date, based on more than 100 samples of palm oil analysed, no residue of the pesticides used in oil palm plantations have been detected.

REGULATORY

Monitoring the residue level of pesticides in palm oil is one of the reasons for developing methods. This is important because it will ensure that palm oil is free from chemical residues and is safe for human consumption. Another important aspect of analysing the product is to ensure that palm oil can meet the pesticide residue regulatory requirements of importing countries.

Palm oil and its products have always been categorized as food or raw materials for food products. Ninety percent of palm oil is still used for food purposes and therefore is subject to the Food Regulations of importing countries and the requirements differ from country to country. These differences can give rise to trade problems. In order to harmonize the different requirements, CODEX Alimentarius Commission proposed that standards be set up to facilitate trade and most countries are now following these standards. One of the standards is the MRL for pesticides used in agricultural commodi-

TABLE 9. AGROCHEMICAL USED IN AN OIL PALM PLANTATION IN MALAYSIA (1999-2020)

	1999	2000	2005	2010	2020
Oil palm area (1000 ha)	2 742	2 874	3 192	3 518	4 251
Herbicides (million litres)					
Glyphosate	7.7	8.0	8.9	9.9	11.9
Paraquat	4.8	5.0	5.6	6.1	7.4
2,4-D amine	1.0	1.0	1.1	1.2	1.5
Spray adjuvants	0.5	5.2	5.7	6.3	7.7
Rodenticides (t)					
Warfarin	2.8	2.9	3.3	3.6	4.3
Bromadiolone	0.5	0.5	0.6	0.7	0.8
Insecticides					
Cypermethrin (1000 litres)	1 974	2 069	2 298	2 533	3 061
Carbofuran	1 398	1 466	1 628	1 794	2 168
Sime RB Pheromone (1000 sachets)	129	135	150	165	200
Fungicides (kg)					
Thiram	4 524	4 742	5 267	5 805	7 014
Benomyl	2 550	2 673	2 968	3 272	3 953

Source: Sime Darby forecasts.

ties by the CODEX Committee on Pesticide Residue (CCPR).

According to CODEX (1998), pesticide is defined as any substance intended for preventing, destroying, attracting, repelling or controlling any pest including unwanted species of plants or animals during the production, storage, transport, distribution and processing of food, agricultural commodities or animal feeds, or which may be administered to animals for the control of ectoparasites. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant, fruit thinning agent, or sprouting inhibitor and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. The designation normally excludes fertilizers, plant and animal nutrients, food additives and animal drugs. Pesticide residue is any specified substance in food, agricultural commodities or animal feed resulting from the use of a pesticide. The term includes any derivatives of pesticides, such as conversion products, metabolites, reaction products and impurities considered to be of toxicological significance (CODEX, 1998).

What is MRL? CODEX defines MRL as the maximum concentration of pesticide residue (expressed as mg kg^{-1}) recommended by the CODEX Alimentarius Commission to be legally permitted in or on food commodities and animal feed (CODEX, 1998). It is the pesticide residue level in food based on Good Agricultural Practices (GAP).

How are the MRL of crops established? In CODEX, the process of setting MRLs requires adherence to the following:

- intended registered use of pesticide following the principles of GAP;
- supervised residue trials according to the principles of GAP with pesticide applied at the recommended dose to address the pest problem;
- toxicological evaluation: Acceptable Daily Intake (ADI) for chronic exposure and where necessary, Acute Reference Dose (ARfD) for acute exposure;
- estimation of daily consumer intake (chronic and, if applicable, acute) using representative diet data for average population and children; and

TABLE 10. METHODS USED TO ANALYSE PESTICIDE RESIDUES IN PALM OIL AND PALM OIL PRODUCTS

Pesticide	Amount of standard spiked in the oil matrix (mg kg^{-1})	Recovery of standard from oil matrix (%)	Methods of test/analysis	Limit of detection
Paraquat	0.05 – 1.5	56 - 84	Column clean-up; spectrophotometric	0.01μg g^{-1}
Glyphosate	0.01 – 1.00 0.01 – 1.00	75.3 – 95.5 73.5 – 84.5	Pre-column HPLC Post-column HPLC Column clean-up, HPLC fluorescence detector	0.02 μg g^{-1}
Glufosinate ammonium	0.01 – 1.00	82 - 105	ASE clean-up, liquid chromatography-mass spectrometry (MS) - MS	5 μg g^{-1}
Metsulfuron methyl	0.01 – 1.0	75 - 82	HPLC-DAD	Ongoing
Methamidophos Monocrotophos Acephate	0.08 – 1.20	74 - 102	Gel permeation chromatography (GPC) clean-up, GC-FPD	4.0 μg kg^{-1} 5.0 μg kg^{-1}
Chlorpyrifos	0.04 – 0.10	88 - 100	Liquid extraction GC-μ-ECD	0.005 μg g^{-1}
Deltamethrin	0.02 – 1.0	73.5 - 97	GPC clean-up, GC-μ-ECD	0.023 μg kg^{-1}
Organochlorines	0.1 – 1.0	55 - 107	GC -ECD	0.003-0.1 μg ml^{-1}
Hexaconazole	0.2 – 1.0	50 – 70	Possibly GPC/SPE; GC-ECD	0:2 μg g^{-1}

Sources: Ainie *et al*. (2005a,b,c); Ainie and Tan (2005); Halimah *et al*. (2005a,b); Pesticide Analytical Manual (1967); Yeoh *et al*. (2005); Yeoh and Ainie (2005a,b).

- setting MRLs when ADI, ARfD are not exceeded.

MRL is determined by conducting supervised residue trials using the pesticide concerned on the specific crop to address the pest problem and in compliance with GAP. The crop is harvested at the post-harvest interval and the residue determined. The residue level may be the MRL if the Theoretical Maximum Daily Intake (TMDI) is not exceeded. However if the total residue of this pesticide used on all crops exceed the TMDI, then the residue limit for the pesticide for each crop has to be reduced; thus GAP needs to be changed accordingly. TMDI is a gross overestimate, but is a cheap screening instrument.

MRLs are available at the global, regional and national level. At the global level, CODEX is harmonizing the MRLs of various regions and this is the basis for settlement of trade disputes as allowed for by the WTO. The Joint FAO/WHO Meeting on Pesticide Residue (JMPR), an independent advisory body to the CCPR, draws CODEX MRLs from proposals on pesticide residues. JMPR consists of scientific experts responsible for the evaluation of pesticide residue and toxicological data. However, the CODEX standards are now mostly only set for crops grown in developed countries. To date, there are no CODEX standards for pesticides in palm oil and this warrants ongoing work to generate baseline data for the establishment of MRLs for CODEX. MPOB has initiated supervised residue trials to generate the data for establishment of MRLs for three pesticides. The data are being collected, collated and compiled according to CODEX protocols.

Even though CODEX standards are generally accepted by every country, there are some standards which are still not accepted at the regional level and which have become non-tariff barriers (NTBs). Every country has national MRLs which are based on the GAP of the country. However, MRLs can vary from country to country due to climatic differences, agricultural practices and the methodologies applied in setting the limits. The differences can cause trade barriers or problems leading to trade differences even among countries within the same region. Hence, ASEAN regional efforts are being made to harmonize the pesticide MRLs with the objective of facilitating intra-ASEAN trade as well as to protect consumers' health.

In Malaysia, national MRLs are documented in the Food Act 1983 (Act 281) and Regulations (as at 25th June 2004) (Food Act 1983 and Regulations, 2005a,b). All the agrochemicals registered for usage in the agricultural sector can be found under Regulation 41 of Schedule Sixteenth. In this schedule, 31 compounds are registered for use in oil palm plantations to address pest problems. *Table 8* is a list of agrochemicals approved by the Pesticide Board for use on oil palm trees and this list can be found in Schedule Sixteen of the Pesticide Act 1985 and Regulations. The national MRLs are based on data submitted by the company which produces the pesticide. The data are based on the results from two supervised residue trials using the recommended dosage and double recommended dosage. The data are evaluated by a scientific working group to derive MRLs which are not detrimental to human health.

CONCLUSION

The oil palm industry in Malaysia practises IPM where there is a balance between chemical pesticide application and biocontrol. This practice is target oriented and IPM procedures developed accordingly to address them. With the implementation of IPM, the chemicals used are selective, of low toxicity and used judiciously. Under IPM, beneficial plants, parasitoids/predators are established for long-term control of the targeted pests.

All the application of chemicals on oil palm in plantations is according to the label instructions and the harvesting according to GAP. A standard on the GAP for oil palms has been drafted by the Department of Standards and is awaiting public comment. MPOB will continuously develop methods for determination of residue of pesticides used by the oil palm industry. The oils derived from the fruit is monitored regularly to ensure that it is safe for human consumption. In line with food safety, MPOB will also develop MRLs for pesticides used in oil palm plantations.

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