Pesticide Use in Cocoa
A Guide for Training Administrative and Research Staff


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A Guide to Pesticide Use in Cocoa

Foreword

Recent changes to legislation in the European Union (EU) and Japan have concentrated minds over crop protection practices in cocoa and other commodity crops. From the 1st September 2008, assessment of the quality of cocoa imported into the EU included measurement of traces of substances that have been used upstream in the supply chain, including pesticides used on farms or in storage. The crop protection activities of farmers and middlemen will therefore be of increasing concern to all in the cocoa trade, some of whom may have a limited working knowledge of pesticide science.

Pesticides have a poor public image and are known to present dangers to both people and the environment. Nevertheless cocoa, like other tropical crops, is often ravaged by insects, diseases and other pests that must be controlled effectively as well as safely. Pesticides can provide useful control solutions, but must be approved for use on the basis of Good Agricultural Practices (GAP). Unfortunately up-to-date GAP has yet to be established in many cocoa growing areas.

This manual is designed to
1. Summarise important underlying administrative (Section A) and technical issues with pesticides. Sections B and C will be of particular interest to research and extension staff seeking more background information on pesticide science.
2. Help define a “road map” for establishing good crop pest control, storage and distribution practices for bulk cocoa: for the assistance of trainers of trainers and research staff. Those interested in GAP for the field crop may wish to turn directly to Section D, and storage issues are examined in Section E. Finally, a few recommendations are made in Section F, with various terms and lists of key pesticides included in the Appendices.

My approach has been:
• a concise but brief overview of the technical issues leading on to “problem and possible solution” sections
• practicality (focusing on techniques/improvements for cocoa growers and traders)
• specific reference to compounds that are, or may be, used on cocoa
• emphasis on product selection and application by smallholders
• linkages to web-based and other resources - for example, pesticide lists that are only of value if they are regularly updated.

The last point is important. Only by regular interaction between farmers, researchers, extension workers, suppliers, buyers and administrators can the issues confronting the cocoa trade be overcome. Unfortunately, there has at times been confusion about pesticide issues which has led to misuse, safety concerns (or inappropriate lack of concern), poor crop protection and other difficulties. Terms such as “pesticide”, “toxic residue”, “organic”, “environmental impact”, “integrated” and many others are often used in connection with pest management, but these have at times been used loosely, resulting in much misunderstanding.

In this second edition, I have tried to broaden the scope of the Manual, but again find myself having to summarise many important issues, so I strongly encourage reference to further sources of information. I thank all the colleagues who have commented to date and welcome further comments and suggestions, for future versions of this “dynamic document”.

Final revision: 25 March 2010
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A. INTRODUCTION

A1 The need to understand and address pesticide issues in cocoa

Pesticides have been used on cocoa for more than 50 years, with notable early research carried out independently in the former West African Cocoa Research Institute (now the research institutes of Ghana and Nigeria), Brazil, Cameroon, Costa Rica, Côte d'Ivoire, Indonesia, Malaysia and Togo. By the early 1970s a number of effective control techniques had become “established”, and there was little incentive for change until environmental awareness increased in the 1990s. Most notable amongst these were concerns over the use of lindane for the control of cocoa insect pests; this was eventually phased out - but in some countries, not until the early 21st century. Many farmers believe that pesticides work, at least against some cocoa pest problems, and continue to use them - depending on the pest and country (Table A1).

Table A1  A guide to problems against which pesticides may be in current use (based on industry sources and the author’s observations).

<table>
<thead>
<tr>
<th>Cocoa Pest</th>
<th>Region</th>
<th>Use*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black pod rots</td>
<td>Phytophthora spp.</td>
<td>Ubiquitous</td>
</tr>
<tr>
<td>- especially: P. megakarya</td>
<td>W. Africa</td>
<td>1</td>
</tr>
<tr>
<td>Witches’ broom disease</td>
<td>Moniliophthora (Crinipellis) perniciosa</td>
<td>Latin America</td>
</tr>
<tr>
<td>Frosty pod rot</td>
<td>Moniliophthora roreri</td>
<td>Latin America</td>
</tr>
<tr>
<td>Capsids (Miridae)</td>
<td>Sahlbergella singularis, Distantiella theobroma</td>
<td>W. Africa</td>
</tr>
<tr>
<td></td>
<td>Helopeltis spp.</td>
<td>Africa &amp; Asia</td>
</tr>
<tr>
<td></td>
<td>Monalonian spp.</td>
<td>Latin America</td>
</tr>
<tr>
<td>Swollen shoot virus (CSSV)</td>
<td>Vectors: mealy-bugs such as Planococcoides njalensis</td>
<td>W. Africa</td>
</tr>
<tr>
<td>Vertebrates (many spp. depending on region)</td>
<td>Woodpeckers, squirrels, rats and larger mammals</td>
<td>Ubiquitous damage</td>
</tr>
<tr>
<td>Cocoa pod borer</td>
<td>Conopomorpha cramerella</td>
<td>SE Asia</td>
</tr>
<tr>
<td>Vascular streak die-back (VSD)</td>
<td>Oncobasidium theobromae</td>
<td>SE Asia</td>
</tr>
<tr>
<td>Other diseases including</td>
<td>Several spp. including: Ceratocystis &amp; Rosellinia spp Botridiopodia theobromae</td>
<td>Depends on Sp.</td>
</tr>
<tr>
<td>- root diseases</td>
<td>Locally-serious in many cocoa growing areas.</td>
<td>2-3</td>
</tr>
<tr>
<td>- minor pod diseases</td>
<td>Eulophonotus sp. (Africa)</td>
<td></td>
</tr>
<tr>
<td>Insect pests of the cocoa tree, including termites, stembormers, etc</td>
<td>Various spp. including: Zeuzera sp. (S.E. Asia)</td>
<td></td>
</tr>
<tr>
<td>Pests of young cocoa</td>
<td>Many spp., - often polyphagous</td>
<td>Ubiquitous</td>
</tr>
<tr>
<td>Weeds (especially in young cocoa)</td>
<td>Many spp. (includes mistletoe on mature trees)</td>
<td>Ubiquitous</td>
</tr>
<tr>
<td>Insect pests of storage:</td>
<td>Many spp. including: Cryptolestes ferrugineus, Ephestia spp.</td>
<td>Ubiquitous</td>
</tr>
<tr>
<td>- Beetles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Warehouse moths</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Key:
1: Common (although not necessarily ubiquitous) use of pesticides: often dependent on economic circumstances of farmer
2: Localised use of pesticides (may be frequent if cocoa grown commercially)
3: Pesticide use rare or ineffective: cultural and other control methods recommended.
Cocoa has a relatively ‘green image’ and cultural methods (removal of diseased plant parts, etc.) are the most proven and cost effective first line of defence against diseases and insects. However, pesticides are used on cocoa in certain circumstances (cases in category 1 of the table above are of greatest interest). Implementation by farmers of all control methods is often poor, and furthermore …

To adapt an observation in Hamilton & Crossly’s (2004) useful book¹, there are a number of participants in debate on pesticides, each with their own agenda:

- **The Agrochemical (now often called Life Sciences-) industry**: principally the half dozen multinational research-based companies which have invested hugely in new technologies (and wish to protect their investments with patents and confidentiality). They provide Governments with regulatory data to show that their products are safe and effective.

- **Companies producing “generic” products** benefit farmers by pushing down the prices of agrochemical products when patents expire (“off-patent” compounds). In some countries they are owned / supported by Governments. It is not always appreciated by the general public that their interests (and those of their respective sales people) may be different to those of research-based companies.

- **Consumer groups and activists**: who voice concerns, which are often shared by the general public, but which may be taken out of context. Their work was pioneered by Rachael Carson, whose book *Silent Spring* (1962) highlighted the hazards, many now undisputed, of unrestricted use of the older pesticides. It has been argued that they need “regular exposés of unsafe residues in food to maintain their profiles.”

- **The Media** are interested in selling newspapers or television time, with priority given to colourful and sensational stories. It is debatable whether it is in their interests to provide a completely objective balance to such stories, but presenters often guide the debate.

- **National Governments (and increasingly, International bodies such as the European Union)**: have to balance the various interests and provide an appropriate legislative framework for the various players involved. For example, the UK Health and Safety Executive (HSE: formerly Pesticides Safety Directorate - PSD) disclose documents (on the Web pages and elsewhere) emphasising that this framework must be “evidence based”. Governments are also a major source of support to …
- **Research Scientists**: who “seek research grants [and] may try to influence research funding bodies by carefully timed and purpose-designed press releases or may overemphasise a safety concern in order to secure funding.”

The cocoa supply and chocolate industries therefore can expect to receive diverse advice on the subject! Nevertheless decisions must now be made, with minds concentrated by recent regulatory developments, but with incomplete knowledge about the pesticides in question.

### A2 Issues with chemical control:

Chemical control methods have been, at different times and places, considered either as:
- crucial for sustaining a healthy crop or
- expensive and of limited cost efficacy, or
- environmentally unsound in the complex cocoa agro-ecosystem.

Improved crop varieties and various alternative biology-based control techniques may eventually offer sustainable long-term solutions. The major over-arching issues with pesticide use include:
- **Safety** aspects including real and potential risks to growers and consumers (see section C: residues).
- **Cost - effectiveness**: perhaps of greatest interest to many farmers.
- **Technical problems** with pesticide applications: including development of **resistance** by pests (resulting in loss of effectiveness) and **resurgence** where insecticides can actually make minor pest problems worse (see section B6).
- Other sustainability concerns including general **impact on the environment** (*e.g.* the build-up of copper in the soil after long-term use for disease control).

Safety aspects are of course by far the greatest concerns for the general public and thus regulators, but pesticides can be important tools for farmers and cannot simply be wished away. Consumers do not always appreciate the high levels of disease and insect pressure that occur in tropical countries, and solving pest control problems for growers remains a crucial part of the “package”.
A3 The importance of pesticide registration and regulation

National regulations

The Food and Agriculture Organisation (FAO) of the United Nations and other international bodies have consistently encouraged national pesticide registration schemes, which have now been implemented in most countries. However, it is not always easy to implement regulations (especially those that are technical in nature) in remote rural areas, and products may also pass through ‘porous national borders’. The farmer therefore may be faced with a bewildering array of products, with little advice provided on their appropriate use.

In all countries the primary role of registration is to protect human health. The FAO code of conduct on the importation of chemicals is based on the principle of prior informed consent (see below), where importing countries have a right to know about pesticides that have been banned or restricted in other countries. It is the responsibility of Governments to provide appropriate guidance on the use of hazardous compounds, ranging from easily comprehensible labelling to outright banning of the most toxic products.

Prior Informed Consent: pesticides

Prior Informed Consent (PIC) is a convention that was finalised by 50 Governments at a Diplomatic Conference in Rotterdam in September 1998. The Convention creates legally binding obligations for the implementation of the Prior Informed Consent (PIC) procedure. It was initially built on a voluntary PIC procedure, initiated by UNEP and FAO. The Convention entered into force on 24 February 2004 with two major objectives:

- to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm;
- to contribute to the environmentally sound use of those hazardous chemicals, by facilitating information exchange about their characteristics, by providing for a national decision-making process on their import and export and by disseminating these decisions to Parties.

With pressure on global agriculture to increase production, developing countries frequently provide a market for older, cheaper and more hazardous pesticides. They often include generic compounds from producers in expanding economies, which seek less controlled markets. Furthermore in some countries, locally-produced generic products are actively promoted in the interests of industrial development and low prices for farmers.

PIC is a process which identifies and shares government decisions to ban or severely restrict pesticides, and includes dissemination of decisions to importing countries where information may be difficult to obtain. While promoting shared responsibility between importers and exporters, the exporting countries must ensure their industries comply with importing country decisions. Pesticides currently in the PIC Convention include (amongst other substances): 2,4,5-T, aldrin, captafol, chlorobenzilate, chlordane, chlordimeform, DDT, dieldrin, dinoseb, 1,2-dibromoethane (EDB), fluoracetamide, HCH (lindane), heptachlor, hexachlorobenzene, mercury compounds, and certain formulations of parathion, methamidophos, monocrotophos, and phosphamidon. Other pesticides will be included in the PIC Convention if they:

- have been banned or severely restricted on the basis of a science-based risk/hazard evaluation in two regions;
- are “severely hazardous pesticide formulations” which cause health or environmental problems under conditions of use in developing countries. These may be included following a verified incident in a developing country.
**International standards**

The Joint FAO/WHO Food Standards Programme and the *Codex Alimentarius* Commission (often shortened to *Codex*) were set-up to protect the health of consumers and ensure fair practices in the food trade. It was initially believed that, if all countries harmonized their food laws and adopted internationally agreed standards, such issues would be dealt with naturally. Through harmonization, the founders envisaged fewer barriers to trade and more freedom of movement among countries, which would be to the benefit of farmers and their families and would also help to reduce hunger and poverty. The *Codex* committee adheres to a code of ethics for international trade in food, with the following general principles:

1. **International trade in food should be conducted on the principle that all consumers are entitled to safe, sound and wholesome food and to protection from unfair trade practices.**

2. **No food should be in international trade which:**
   - (a) has in it or upon it any substance in an amount which renders it poisonous, harmful or otherwise injurious to health; or
   - (b) consists in whole or in part of any filthy, putrid, rotten, decomposed or diseased substance or foreign matter, or is otherwise unfit for human consumption; or
   - (c) is adulterated; or
   - (d) is labelled, or presented in a manner that is false, misleading or is deceptive; or
   - (e) is sold, prepared, packaged, stored or transported for sale under unsanitary conditions.

The *Codex Alimentarius* has always been a science-based activity. Experts and specialists in a wide range of disciplines have contributed to every aspect of the code to ensure that its standards withstand the most rigorous scientific scrutiny. One scientific committee is the Joint FAO/WHO Meeting on Pesticide Residues (JMPR). JMPR was established in 1963 following a decision by FAO Conference that the *Codex Alimentarius Commission* should recommend maximum residue limits (MRLs) for pesticide and environmental contaminants in specific food products to ensure the safety of foods containing residues. It was also decided that JMPR should recommend methods of sampling and analysis.

- JMPR members are independent scientists who are expert in aspects of pesticides, environmental chemicals and their residues and who are appointed in their own right and not as government representatives.
- JMPR is independent of the Commission.
- FAO appointees draft MRLs for substances under evaluation, based on field trials that are conducted worldwide. WHO appointees conduct toxicological evaluations of the pesticides.
- Reports of evaluations are published.
- There is close cooperation between JMPR and the Codex Committee on Pesticide Residues (CCPR). CCPR identifies those substances requiring priority evaluation. After JMPR evaluation, CCPR discusses the recommended MRLs and, if they are acceptable, forwards them to the Commission for adoption as *Codex* MRLs.

At the time of writing there are only three substances with *Codex* MRLs listed for cocoa beans (the *Codex* MRLs for deltamethrin, fenitrothion and lindane were revoked by 2003 and two of those remaining are subject to review). There is therefore a clear need to update the list for cocoa. Without the prior establishment of workable MRLs or import tolerances for those pesticides likely to be encountered as residues, the new legislation will have a very serious impact on cocoa supply, with significant economic consequences for developing countries as well as Europe’s multi-billion € chocolate industry.
A4 Newer regulations for pesticides and commodities

In 1991, the European Commission started a community-wide review process for all active ingredients (AI - commonly also known as active substances) used in plant protection products within the European Union (EU). A defining moment for the use of pest control products in Europe was the introduction of Directive 91/414/EEC. The process involved evaluation of substances, followed by recommendation on their acceptability to the European Commission. Acceptable substances were included in a positive list of AI known as “Annex I”, if the risk to consumers, workers and the environment was considered acceptable. The original Directive made a distinction between “existing” (on the market before July 1993) and “new” compounds (introduced to the market afterwards). If the compound cannot be included in Annex I, authorisation for products containing that substance must be withdrawn within a period specified in the Commission Directive. This review programme has effectively resulted in a very substantial reduction (>50%) of pesticides available for use in EU countries. Regulation 91/414/EEC will be replaced in June 2011 (see Box A1).

This should be considered as a process under continuous review (see Box A1) since: “… based on scientific assessments, each applicant [has] to prove that a substance could be used safely regarding human health, the environment, ecotoxicology and residues in the food chain. From the end of 2003, the new European Food Safety Authority (EFSA) deals with risk assessment issues and the European Commission retains the risk management decision. The standards of this assessment and the policy of their use are constantly improved in a number of expert groups and documented in guidance documents.”

Until 2005, pesticide legislation mainly addressed pest control practices on crops that were grown within the EU. More recently, residue legislation was introduced, which applies to imported commodities such as cocoa beans, as well as domestic produce. The issue was laid-out by the ECA/CAOBISCO Pesticides Working Group, with a paper that began with the following statement:

“… The European Union has recently introduced new harmonised pesticide residue legislation (EC No 396/2005), which for the first time applies to imported foods, including cocoa beans as well as domestic produce. This regulation will come into force and introduces limits which could severely affect cocoa imports unless the cocoa sector as a whole acts quickly to ensure that the appropriate Maximum Residue Limits are in place.”

Regulation 396/2005/EC came into force on 1 September 2008 and sets MRLs for pesticide residues in food and animal feed produced, or being imported into, the EU. MRLs were first published as Regulation 149/2008/EC in March 2008 in the form of Annexes to 396/2005/EC; these were updated before they came into force and continue to be subject to review (see section C5). All cocoa beans imported into the EU must conform to the new Regulation, although temporary MRLs (tMRL) may apply to certain AIs for a transitional period. Information is on: http://ec.europa.eu/food/plant/protection/evaluation/index_en.htm - the DG SANCO site which aims to “maximise transparency on the decision making procedure”. NOTE: it is important to differentiate between the MRLs on produce, which are regulated by the annexes of EC 396/2005 and approvals for pesticide use in EU which is

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1 The Joint Pesticides Working Group, is coordinated by the European Cocoa Association (ECA) and CAOBISCO and was tasked to:
- complete a list of pesticides currently used on cocoa in producing countries.
- develop a joint position on pesticides MRLs for cocoa and for cocoa products, with scientific information to support the position.
- adopt an action plan to defend the joint position from a regulatory (EU Commission and EU national authorities) and producing country/field point of view.
- implement a Joint Action plan at EU and national level together with producing countries.
currently regulated by directive 91/414/EEC. However, the two regulations are linked, as described here.

**Box A1**

**Possible future trends in EU legislation - should we be concerned?**

Section C includes a number of issues that might appear to be not directly related to residue tolerances. One of the main objectives of this manual is to guide staff in the cocoa industry through the various, multi-disciplinary aspects of pest management: specifically to ‘stay ahead of the game’ with pesticides and not just try to keep up with existing legislation. To a certain extent, many were taken by surprise by EU regulation EC 396/2005, which itself continues to undergo amendment (i.e. to its Annexes). The original 91/414/EEC regulation, which concerns pesticide use in the EU, was seen by many as just the start of a review process and in July 2008 EU agriculture ministers proposed even stricter controls, with a shift in emphasis from risk to hazard-based assessment of pesticides\(^1\). Regulation 91/414/EEC will be repealed on the 14 June 2011 and replaced by EC 1107/2009, which has now been adopted.

Concerned about possible practical consequences to farmers, the UK Health & Safety Executive (HSE)\(^2\) examined 286 substances included in Annex 1 to Directive 91/414/EEC and existing substances currently under review, including those that are to be withdrawn voluntarily within the near future. In some respects this document is speculative, since the criteria by which further compounds might be withdrawn have yet to be agreed. The criteria **might** include:

- no cat 1 or 2 CMR (substances that are carcinogenic, mutagenic or toxic to reproduction) unless exposure negligible
- no endocrine disruptors unless exposure negligible (HSE point out that a definition of ‘endocrine disruptor’ has yet to be agreed)
- no POPs (persistent organic pollutants: see section A3)
- no PBT (persistent Bioaccumulative Toxic chemicals)
- no vPvB (very persistent, very bioaccumulative)
- withdrawal of substances with an ADI (acceptable daily intake), ARfD (acute reference dose) or AOEL (acceptable operator exposure level) which is significantly lower than those for the majority of approved substances
- no substances considered to cause a risk of developmental neurotoxic or immunotoxic properties
- no substances with a high hazard quotient for bees
- no substances which cause concerns and/or can leach easily into groundwater.

The details of the proposed legislation may take several years to be agreed, but research institutes in cocoa producing countries should now be considering how best to manage key pest species, if substances possibly ‘under threat’ (e.g. certain pyrethroids and neonicotinoids) were to be deemed unsuitable for use with food crops. Further legislative developments in other cocoa consuming regions (especially N. America and Asia) should, of course, also be reviewed constantly.

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\(^2\) Formerly Pesticide Safety Directorate (PSD) UK (December 2008): Revised assessment of the impact on crop protection in the UK of the 'cut-off criteria' and substitution provisions in the proposed Regulation of the European Parliament and of the Council concerning the placing of plant protection products on the market.
The following ICCO map graphically illustrates the complexity of trade in cocoa beans and why emphasis has been placed on European import tolerances. However the USA - and increasingly Asia - are also major consumers.


In the USA, the Environmental Protection Agency (EPA) established the Food Quality Protection Act (FQPA) of 1996 and was considered approximately equivalent to 91/414/EEC ([http://www.epa.gov/opp00001/regulating/laws/fqpa/backgrnd.htm](http://www.epa.gov/opp00001/regulating/laws/fqpa/backgrnd.htm)), but regulates the amount of pesticide residues permitted on food for consumption. The EPA also requires that all approved pesticides are clearly labelled with instructions for proper use, handling, storage and disposal. The EPA produces fact sheets, prepared as part of EPA Registration and Re-registration programmes. Where a Fact Sheet has been issued for a “New” active ingredient (one registered since 1997), this is noted. In addition, the Food and Drug Administration (FDA) provides guidance (2005) on trade policy ([http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/ChemicalContaminantsandPesticides/default.htm](http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/ChemicalContaminantsandPesticides/default.htm)), with specific ‘Level 2’ guidance about dates, affected food commodities with a residue of a given pesticide chemical on: [http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/Pesticides/default.htm](http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/Pesticides/default.htm).

In Japan, the Ministry of Health, Labour and Welfare (MHLW) established new legislation, the Food Sanitation Law, was modified on 29 May 2006, with analysis of cocoa included on a “positive list” published by the Ministry of Health, Labour and Welfare. The MRL list was updated on February 5, 2007 and is on: [http://www.mhlw.go.jp/english/topics/foodsafety/positivenlist060228/dl/index-1a.pdf](http://www.mhlw.go.jp/english/topics/foodsafety/positivenlist060228/dl/index-1a.pdf). Some samples were found to have excessive residue levels and shipments were rejected (although the method of analysis used was different to that proposed elsewhere - see section C5).
A5 Extension: what to say to the farmers?

Cocoa farmers - many of whom are smallholders - when faced with pest problems seek effective solutions and often turn to the use of pesticides to provide remedies. There is a commonly-held view that pest control is best achieved within a framework of “Integrated Pest Management” (IPM) - or more generally “Integrated Crop Management” (ICM). The practical implementation of ‘IPM’, a term first coined in 1967 by R.F. Smith and R. van den Bosch, has been a matter of considerable debate: especially in relation to the use of pesticides. The definition that has been agreed by the UN’s Food and Agricultural Organisation (FAO), and supported by agrochemical bodies, several NGOs, and the International Farmers Organization is that:

“Integrated Pest Management (IPM) means the careful consideration of all available pest control methods and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimise risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro ecosystems and encourages natural pest control mechanisms.”¹

This definition is also reflected in the European Directive on the Sustainable Use of Pesticides. ‘Integration’ therefore implies an optimal mix of pest management techniques including:

- Cultural methods, such as removal and burning of diseased plant parts, pruning, removal of infected/infested pods and regular complete harvesting.
- Clonal selection and other genetic methods that confer resistance to pests; these are long-term measures (much of the research currently taking place is unlikely to be implemented at the farmer level for several years to come).
- The conservation and/or manipulation of biological agents (e.g. biopesticides and insect predators such as ants).
- Application of chemical pesticides, but only on the basis of rational use.

From the farmer’s point of view, (s)he may:

- wish to buy pesticide products for other crops or domestic use, that may be unsuitable for cocoa and leave harmful residues.
- be presented with a bewildering array of products, not to mention sales persuasion, when visiting the agricultural supply store.

Which product to choose? Is it effective? Is it safe? Is it affordable?

¹ Internal Code of Conduct on the Distribution and Use of Pesticides, FAO, November 2002
**A6 Disposal of old stocks**

The withdrawal of recommendations for pesticides often raises questions at Government, distributor, through to farmer levels, about how to dispose of existing stocks. The problem should always be seen as an administrative one: in other words the situation should be avoided in the first place. With sound policy and administration backed up by appropriate scientific support (see recommendations, section F) it is not difficult to foresee trends in pest control methods and, in most cases, it is possible to avoid the use of substances which are subject to concern.

Stocks of older compounds should therefore be used-up, and withdrawn from the market place, long before they are banned. On a small scale, applying older stocks of chemicals to crops is usually considered the most practical way of using them up, provided they are relatively safe and still registered in the country of use. Disposal of obsolete chemicals is very expensive and must take place in one of the limited number of specialist facilities. The comments above only apply when there is a substantial time to go before withdrawal of a given product. In the context any new regulations concerning residues on imports, readers should be aware of the significant time lag (frequently >1 year) between the cocoa farm and the port of entry, so pesticides (or any other practices) that might cause problems, should not be used during the final season (and preferably for 2 seasons) before the deadline.

**A7 Rational Pesticide Use (RPU) as a component of Good Agricultural Practice**

An international meeting: the Round Table for a Sustainable Cocoa Economy (RSCE I), held in Ghana during October 2007, included cocoa farmers, cooperatives, traders, exporters, processors, chocolate manufacturers, wholesalers, governmental and non-governmental organizations, financial institutions as well as donor agencies. Consensus was reached on a number of action points for maintaining sustainable cocoa, and is often called the “Accra Agenda”. Pest management issues featured highly in the list of the priorities, with the following key needs (amongst several others) identified:

- Remunerative prices and increased income for cocoa farmers, including consideration of the impact of fiscal policies;
- Development and promotion of Good Agricultural Practices (GAP) to increase productivity and quality in a manner that respects both the environment and social standards;
- Reduction of losses due to pests and diseases by introduction of integrated pest management;
- Promotion and support of local services providing improved planting materials, fertilizers, pesticides, etc. and provide related training;
- Mechanization of farm operations to reduce costs where possible;
- Increased labour efficiency through better management practices;
- Sustainable commercialization includes the development of efficient supply chains to increase the margin received by farmers, while maintaining cocoa quality and improving traceability in the value chain.

As its name suggests, GAP can encompass a large number of crop production procedures that are safe and effective, recommended (and enforced) either on a national or crop basis. With the use of pesticides, the focus must be on achieving effective pest control, while leaving a minimum amount of pesticide residue on the crop (within practical limits). These limits are
established principally by the agrochemical company wishing to register its products, having carried out a number of rigorous trials.

Insect pest and disease control strategies that rely on the application of a limited number of pesticides are almost certainly not sustainable. A research and extension “vacuum” in appropriate pesticide research since the late 1980s, has combined with years of poor returns for cocoa crops. In consequence, most smallholder farmers are unaware of recent control agents and techniques for pest management, and often apply older, often more hazardous, products.

There is now an urgent need for implementation programmes that transfer rational pesticide techniques in each of the major cocoa growing regions, firstly addressing questions such as:

- What are the true levels of pest control and operational costs (over large areas)?
- Can we replace the currently-used and hazardous (WHO/EPA class I and II) products in the near future?
- Why are older pesticides so popular?
- Are there control techniques that have a minimal environmental impact, yet effectively control target pests?

The term rational pesticide use (RPU) describes the targeted use of pesticides as part of a pest management strategy. Three key elements to mitigate the adverse effects of pesticides are improvements in the selectivity of the products themselves and the precision of their application in both space and time. Other potential benefits include: reduction of costs (for both pesticides and labour), improved safety and reduced environmental impact.

RPU therefore is about the tactics and tools for managing issues such as residues within an IPM strategy which in turn is a component of Good Agricultural Practice. Sections B and C attempt to provide essential background information, leading to a practical description (see C6) of ways in which pesticides should be used; namely:

1. **Diagnosis** of the problem
2. **Product selection**
3. **Good application** techniques
4. **Timing** of application - not only for better pest control, but specifically for residue management communicated to the user via the **Pre-Harvest Interval** (PHI - which is the minimum permitted time between the last spray and harvest).

However, targeting is only possible with accurate understanding about pesticides themselves and their properties; this will be the subject of the next Chapter.
B. PESTICIDES AND THEIR PROPERTIES

B1 What is a pesticide?

The term “pesticide” can be defined simply as any substance which is used to control a pest: at any stage in crop production, storage or transport. It is now generally agreed that the term “pest” applies to any organisms that harm crops, be they insects, diseases, weeds, etc. In the past there has been some confusion with the term “pesticide” - which has at times been applied specifically to insect control agents - and weed-killers (herbicides) that have been managed separately as an agronomy issue.

The major pesticide types

The main pesticide groups include:

- Fungicides - for crop diseases such as black pod
- Herbicides - kill weeds
- Insecticides: control insect pests, but they may also be
  - acaricides: controlling mites
  - nematicides: controlling nematodes (eelworms)
  (Note: not all insecticides kill mites and nematodes; on the other hand, many insecticidal products are sold mainly as acaricides and nematicides).
- Rodenticides - kill rats and mice (they are often much less effective against squirrels)
- Other pesticide types include molluscicides (that kill slugs and snails) and bacteriacides, but they are not usually used on cocoa. Occasionally, some substances have multiple action (e.g. metam is a fungicide, herbicide and nematicide).

Each of these main groups are further classified: either according to their chemical type or by their biological mode of action (MoA): see section B7.

Unfortunately the term “pesticide” is often translated into words that also mean “medicine” or similar. Once again, it is important to be accurate and specific: there is a common misconception amongst farmers that all pesticides do some good, whatever their properties, yet they may actually be harmful.

B2 Names and composition of pesticides

From a legal point of view, one of the main methods of communication between an agrochemical company and the user is the product label. The most noticeable words on the label will usually be the trade name (or brand), and of course in the chemical company’s interest to promote its particular brand of pesticide. However, it is the active ingredient (AI: also called the active substance) and its concentration that is of most interest from the point of view of efficacy, safety and residue tolerances.

Routine use of brand names can cause confusion because:

- Often (and increasingly) the brand name represents a product containing a mixture of active ingredients
- Different brand names may be used for the same product in different countries and languages
- Active ingredients - especially of successful products - may be changed over time
The formulation names (and numbers used in the name) may not conform to international standards.

Labels should also give the chemical name - which follows rules of nomenclature set by the International Union of Pure and Applied Chemistry (IUPAC) as adapted for indexing in Chemical Abstracts. In practice, the common names (for which there are ISO standards) are generally used for describing active ingredients. For example, a commonly used pyrethroid insecticide, used on cocoa is:

**Common Name** (ISO) - lambda-cyhalothrin - which is easier to remember than the …

**Chemical Name** - of two stereo-isomers: (S)-α-cyano-3-phenoxybenzyl (Z)-(1R,3R)-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate and (R)-α-cyano-3-phenoxy-benzyl (Z)-(1S,3S)-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate

**Trade names** are numerous (especially now that the patent for the compound has expired) but they include: ‘Karate’, ‘Kung Fu’ and ‘Matador (as used by the same Company in different countries)§.

A label of another pesticide: the active ingredient and its concentration (in this case a 200 g/l imidacloprid SL formulation) are often in very small writing. Precautions are often described in the form of pictograms (pictures in the bottom right of this label)§.

**Active ingredients (AI), composition, formulation**

For the purposes of toxicology, residue analysis and efficacy, it is the AI, as described by its ISO common name that will be the focus of scientific analysis. However, pesticide products very rarely consist of pure technical material. The AI is usually formulated with other materials and this is the product as sold, but it may be further diluted in use. **Formulation** improves the properties of a chemical for: handling, storage, application and may substantially influence effectiveness and safety.

Formulation terminology should follow a 2-letter convention: e.g. GR (granules), DP (dusts) listed by CropLife International (formerly GIFAP then GCPF) in the Catalogue of Pesticide Formulation Types (http://www.croplife.org/monographs.aspx?wt.ti=Technical%20monographs -

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§ Inclusion of compounds or products are for illustration only and does not imply recommendation or otherwise.
By far the most frequently used products are formulations for mixing with water then applying as sprays. Water miscible, older formulations include:

- Emulsifiable concentrate (EC)
- Wettable powder (WP)
- Soluble (liquid) concentrate (SL)
- Soluble powder (SP)

Newer, non-powdery formulations with reduced or no use of hazardous solvents and improved stability include:

- Suspension concentrate (SC)
- Capsule suspensions (CS)
- Water dispersible granules (WG)

The major groups of pesticide formulations can be illustrated as follows:

Very occasionally, some pesticides (e.g. malathion) may be sold as technical material (TC - which is mostly AI, but also contains small quantities of, usually non-active, by-products of the manufacturing process).

**B3 Biological activity of pesticides**

The purpose of applying a pesticide is to achieve a biological effect on the target pest. This effect is often described by scientists as a **response** and it is **dose dependent** - which usually means that the higher the dose, the more individuals in a **population** of organisms will be affected (and ultimately killed). The population in question could be the **target pests**, but also unintentionally exposed human beings or other **non-target organisms** (beneficial or harmless animals and plants). This is assessed in laboratory experiments called **bioassays**, where response is measured over a range of doses (different quantities of pesticide [AI] delivered individually to target organisms).

Described on a graph, the response is **non-linear** *(i.e. not in a straight line)*, but usually in the form of a **sigmoid** (‘S’ shaped) curve - see illustrations. The first diagram shows that this sigmoid curve has been derived from the **normal distribution** - the bell shaped curve that
describes natural variability which is widespread in living organisms (e.g. the height of people, the weight of cocoa pods, the ability of animals to withstand drought). By analysis of this dose response line, an estimate can be made of the median lethal dose or LD₅₀ of a pesticide to a group of organisms (i.e. the exact dose which would kill 50% of a test population of pests).

Origin of the sigmoid dose-response curve from the normal distribution curve (above) accumulated on a 0-100% scale. The doses are on a logarithmic scale (without which the ‘S’ curve would be extremely asymmetrical).
The LD$_{50}$ is derived from the dose-response curve and represents the dose at which 50% of test organisms (such as pests) are killed. In practical experiments, there is often considerable variability in measured mortality at different dose rates and statistical methods (called logit or probit analyses) are used to determine LD$_{50}$.

Other levels of response can be used such as LD$_{10}$ and LD$_{90}$ (i.e. the 10% and 90% level of control respectively) but LD$_{50}$ is most commonly used since it represents the point at which the dose can be estimated most accurately. In some bioassays, the pesticide is not administered directly to the target, so the true dose applied to a given individual is not known. Different dosages (see below) may have been applied (e.g. different rates of surface deposit from various concentrations of pesticide mixtures) in which case the median lethal concentration or LC$_{50}$ will be quoted.

**B4 Application rate (the theory and the label)**

Only in the most sophisticated spray operations is any attempt made to control the various factors that affect spray deposition on the crop. In practice, the small-holder cocoa farmer can best assess the number of trees per tank-full (see section D5). It is rarely appreciated just how inefficient normal existing application practices are in crops. Winteringham’s work highlighted the inefficiency of dose transfer to the biological target; when lindane sprays were applied to cocoa mirids, only 0.02% of the total leaving the tank reached the biological target. Exceptionally, efficiency may reach 30% for herbicide sprays on grass weeds; thus, even in better cases, approximately 70% of the pesticide mixture is wasted.

In general, experience has shown that for most spray operations, calibration is most effective when it focuses on the **volume application rate (VAR)**. By mixing in a known quantity of pesticide formulation, an accurate dosage is applied to the target area (a group of trees, a field, etc.). It is important to distinguish dosage from dose: which is an exact quantity of substance delivered to an individual organism (e.g. in a bioassay). VAR in itself makes little difference to the quality of deposit, which is dependent on the various interacting factors shown below. From this, an appropriate formulation dilution rate could be calculated to accurately achieve a certain dosage per tree or per hectare.
During any spray operation, the amount of pesticide landing on the biological target depends on a number of factors, often resulting in complex interactions.

In practice, such calculations are only rarely made by operators. Attention to product labels is far from general practice, but labels remain the most available source of information to farmers and spray operators. However, even label application rates can be flawed if more than one type of sprayer is used in an area, since typically they assume a given (often very high) VAR will be used. For tree crops such as cocoa, the pesticide label will give application rate in the form of a recommended tank mix concentration; good labels may also give useful application advice...

This shows a (sadly rare) example of clear application instructions being provided on a pesticide label.

Unfortunately, this is displayed on a bottle containing a hazardous (Class I) insecticide that has now been superseded. Although the pictograms (at the bottom of the label) indicate the need for protective equipment, the operator illustrated just above is using a motorised mistblower, but wearing neither a face visor nor ear defenders (see section D3).
Consumer protection, operator safety and GAP

Before finishing the description on pesticide labels, it is important to stress the need for rigorous registration and label approval processes for permitted products. National pesticide guides that focus on locally recommended plant protection products are increasingly being published and are an important source of information on trade names, recommended application rates for different crop uses, etc. Where they are not available (or difficult for farmers to obtain), provision of such guidance in a user-friendly form, is an important role for Government and NGO extension agencies.

B5 Mode of Dose Transfer (residual, systemic, vapour acting, etc.)

There are many pesticides that work in various ways, and the different types of control action affect the amount, efficiency and speed of dose transfer to the target pest. The cartoon below shows some of the insecticide dose transfer mechanisms.

Farmers (and researchers) may not always appreciate that, except in certain circumstances, direct contact with spray is a relatively unimportant dose transfer mechanism. Many insecticides rely on pests picking up a lethal dose after crawling over deposits (secondary contact) or by ingestion. Fungicides such as copper, which only have protectant action, must similarly be well distributed on the surface of the plant, in order to prevent infection by fungal diseases. In practice, contact insecticides and protectant fungicides must be applied with a good coverage of spray droplets in order to make contact with the target (although copper deposits may redistribute over the surface of the plant by rainwater). Fumigant action is especially important for control of storage pests. Certain older insecticides (e.g. lindane, endosulfan: see Box B1) were especially effective, since fumigant action often helped to compensate for inadequate application in the field (difficult at the best of times with cocoa). Repellency may not always be beneficial - especially if deposits are short lived or if pests consequently pick up sub-lethal doses. However the concept of lure and kill (where an insecticide is mixed with an attractant) has been used very successfully for control of pests such as fruit-flies.
Box B1
IRAC MoA groups 1 and 2 insecticides and DDT: notorious but still useful - why?

The acronym 'DDT'\(^8\) conjures up many of the (often negative) perceptions about pesticides. The first major synthetic insecticide, introduced in the 1940s, this compound was accompanied by others in the group of chemicals called organochlorines. By the 1960s, Rachael Carson\(^*\) and others were pointing out their negative side-effects, particularly associated with over-use in agriculture (environmental impact, resistance and resurgence). Perhaps the greatest alarm amongst the general public was caused by residues on food, which resulted in detection of DDT and its breakdown products in mothers’ milk. It was one of the first compounds to be classified as a ‘persistent organic pollutant’ (POP). However, DDT has undoubtedly saved millions of lives: it is cheap and provides long-term control of malaria mosquitoes, with has “a remarkable safety record when used in small quantities for indoor residual spraying (IRS) in endemic regions”\(^**\). It is now never recommended in agriculture, but there are reports of misuse, with IRS insecticides being diverted onto crops, so residues on food continue to be monitored.

DDT actually belongs to the same IRAC group (3) as pyrethroids (see box E1) - all these chemicals attack the insect nervous system, but in different ways. Group 2 compounds are called GABA\(^4\)-gated chloride channel antagonists and include two sub-groups:

- other older organochlorine compounds: gamma HCH\(^8\) (also called lindane and BHC) and the cyclodiene group of compounds called, that includes endosulfan. Both HCH and endosulfan have historically been very important insecticides in cocoa, but are now obsolete and have been withdrawn. Their high vapour action was a useful property for farmers - substituting for poor application - but is now considered environmentally unacceptable; in 2009 the production and agricultural use of lindane was banned under the Stockholm Convention on persistent organic pollutants (see section A3 and: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=579&ArticleID=6144&l=en).
- a relatively new (reported in 1992) chemical called fipronil. This is highly potent against a wide range of insects and can be used at very low rates of application and formulated into products that can be classified into toxicity class III. Nevertheless, fipronil has a toxic sulfone metabolite (MB46136) and, unusually, it has been assigned a MRL of 0.005 (which is below the ‘default’ LOD value). Also, with a known high impact on non-target organisms, it should be deployed with great care and is primarily used to protect seedlings (and wooden structures) from termite attacks.

Group 1 insecticides inhibit the Acetylcholinesterase (AChE) pathway at nerve junctions. Because the AChE mechanism in insect synapses is similar to that of mammals, many group 1 compounds are extremely or highly hazardous, although there are several exceptions (e.g. malathion, temephos). This group contains a number of systemic compounds (e.g. carbofuran, carbosulfan, dimethoate, monocrotophos) and are divided into two chemical sub-groups:

- **organophosphorous (OP)** insecticides such as malathion, chlopyriphos and pirimiphos
- **carbamates** such as promecarb and propoxur that have been used on cocoa, but are now withdrawn in the EU. Fenobucarb (BPMC) and isoprocarb (MIPC) are still widely used against sucking pests in Asia, but not in Europe, so residue tolerances above LOD for these compounds in the EU are bound to be temporary.

DDT and most compounds in groups 1-2 represent “old insecticide chemistries” and have been most heavily decimated by regulatory and commercial factors over the past two decades. The few that remain (mostly OPs) are usually “softer” representatives of their class. They are considered practical and attractive to farmers because they are cheap, fast acting and have a broad spectrum of action. In terms of pest management strategy they help maintain diversity of MoA for resistance management (IRM), OPs in particular do not build-up in the environment and some have such a short persistence that they rarely present residue problems. Nevertheless, many are suspected endocrine disruptors (see box C1) and have tMRLs that are unlikely to remain permitted for long into this decade.

\(^*\) Rachael Carson

\(^**\) Stockholm Convention on persistent organic pollutants

\(^4\) GABA = gamma-aminobutyric acid
Ingestion of insecticides may occur via various routes: either from a residual deposit (as illustrated) or by translocation - where pesticides have an ability to be absorbed into the plant and are redistributed, including to the site of attack. Depending on their physical-chemical properties (see below) some pesticides may be trans-laminar (travelling short distances through the surface of leaves into the tissues) or systemic (where the insecticide, fungicide or herbicide is translocated over greater distances).

Systemic action is an important feature of many modern fungicides and herbicides, besides being often effective for control of sucking insects (aphids, capsids, mealybugs, etc.) and ‘cryptic’ pests (e.g. insects that are unlikely to come in contact with a pesticide spray by burrowing into the plant). Systemic translocation is usually acropetal, moving up the plant from the point of application, or towards the edges of leaves if these are sprayed. Only herbicides (and the rare example of phosphonate fungicides and possibly one recently introduced insecticide) move down the plant (basipetal translocation) towards the roots.

**Box B2**

**Neonicotinoid insecticides: relatively new and successful, but controversial**

Nicotine, the ‘active ingredient’ for smokers; it is also a very potent insecticide. Being a natural product, ‘tobacco tea’ has been permitted for organic pest management, but purified nicotine would be classified as most toxic (class 1) if sold commercially. As with pyrethrum and the pyrethroids (see box E1) the commercialised synthetic analogues, called ‘neonicotinoid’ or ‘nicotinyl’ insecticides (and placed in IRAC class 4A) are more stable than their natural progenitors in sunlight. Unlike pyrethrum and pyrethroids but in common with other ‘new chemistries’, neonicotinoids typically have relatively low mammalian toxicities compared with their natural analogue, with several products available in toxicity class III.

The first compound in this group, imidacloprid, was introduced in 1990 and is now off-patent, so it has become relatively cheap for farmers to buy. Neonicotinoids now account for the greatest sales in the insecticide sector (more than a third of insecticides, compared with pyrethroids which occupied 17% of the market in 2006). Typically they are systemic insecticides with trans-laminar activity and with contact and stomach action. They are readily taken up by the plant, including from the root-zone, and are used for control of sucking insects such as cocoa mirids. Some neonicotinoids have low mammalian toxicities compared with other insecticides on the market (e.g. thiamethoxam in class III) and new AIs in the group are under development for cocoa (see Appendix 3c). This is a highly competitive sector in the market, with mixtures of AI (controversially) becoming more frequently marketed.

Probably the most controversial aspect with these compounds is their relatively high toxicity to bees (in spite of having passed through a whole raft of environmental testing before registration). In Europe, the problem is being managed by engineering controls that greatly reduce drift: of spray droplets and dust from seed dressings.

Cocoa farmers that also manage hives should take great care about exposing bees to trees that are sprayed with neonicotinoids.
Physical and chemical properties (and where to obtain information)

Readers wanting to know more about pesticides can consult the Pesticide Manual, which is available either as a book or electronically (the latter is updated annually). Again, the importance of accuracy cannot be over-emphasised, and a reference work such as this is an essential tool for policy makers, senior crop protection scientists, etc. The Pesticide Manual includes information on:

- Names: both international nomenclature and common product brand names
- Physical chemistry and methods of analysis
- Commercialisation and toxicological reviews (now including 91/414/EEC status)
- Mode of action, common uses and formulation types
- Mammalian toxicology
- Ecotoxicology and environmental fate

Although much of this information is specialist in nature, anyone advising on pesticides should become familiar at least with the function of certain entries. For example, information on properties such as:

- vapour pressure (v.p) indicates how likely a compound is to have fumigant action
- solubility and partition coefficient (between water with an organic solvent - log P) can give important clues on whether the compound has systemic action, or can be leached into groundwater, etc.

B6 Technical problems with pesticides

Two phenomena are classed here as ‘technical issues’, in that they relate to the effectiveness of pest control rather than the toxicological and environmental risks associated with pesticide use. However, in both cases one of the practical consequences is that some farmers, by not understanding these phenomena, may be encouraged to apply more pesticides in the short-term, thus increasing the risk of high crop residues.

1. Development of resistance: where pests adapt over time after exposure to control agents, which become ineffective (e.g. loss of effectiveness of certain fungicides for the control of Phytophthora spp.). Among the first cases of insecticide resistance detected was against organochlorines by cocoa mirids.

Resistance is an evolutionary process that has been defined as:

“a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species” (source: IRAC - see B7).

Furthermore, the problem may be compounded by cross-resistance: where resistance to one pesticide confers resistance to another pesticide, even if the pest has not been exposed to the latter product. Because insect and fungal populations are usually large in size and reproduce quickly, the rate at which resistance evolves is greatest when fungicides and insecticide are over-used.

2. Pesticide induced resurgence: especially following the use of insecticides that cause a ‘flare up’ of pests that were previously of minor importance; this is sometimes called the “pesticide treadmill”. An example of resurgence in cocoa was the dramatic increase in populations of the trunk borers Eulophonotus myrmeleon (Cossidae) and Tragocephala castinia theobromae (Ceramicidae), which were previously considered to be minor pests, following destruction of their natural enemies with applications of BHC and dieldrin - applied to control insects such as mirids.
**B7 Mode of Action (MoA) groups**

Historically, pesticides have often been classified according to their chemical groups and this is useful for understanding the properties of a given compound (as above). However, the first entry given for most compounds in the *Pesticide Manual*[^1] is the mode of action (MoA) group: which possibly represents the most useful pesticide classification for biologists.

MoA entries may be something like: ‘FRAC G1’, ‘IRAC 2A’ or HRAC G’. From a pesticide industry point of view, one of the most important threats to product sustainability and innovation is the onset of resistance (see section B6). Research-based companies collaborate (under the auspices of *CropLife International*) in order to develop better understanding of MoA mechanisms and thus create a “common good” by mitigating the onset of resistance. Currently, there are four specialist committees:

- Fungicide Resistance Action Committee (FRAC)
- Insecticide Resistance Action Committee (IRAC)
- Herbicide Resistance Action Committee (HRAC)
- Rodenticide Resistance Action Committee (RRAC)

MoA describes the way a pesticide attacks some biological process (often a certain biochemical pathway in a particular kind of living cells) within the pest. For example:
- Selective herbicides might attack specific photosynthetic process in the chloroplasts of susceptible plant cells (*i.e.* weeds not crops).
- Pyrethroid and neonicotinoid insecticides attack nerve cells (and have a fairly broad spectrum).
- Phenylamides that attack specific nucleic acid synthesis pathways in Oomycetes such as *Phytophthora* (see Box B3).

Understanding pesticide MoA is important for:
- Resistance management
- Describing the symptoms and physiology of the method by which a substance is effective, thus …
- Determining its likely effects (and often speed of action) on the target pest.
- Providing a convenient classification of pesticides for biologists

Within organisms, pesticides are metabolised – or changed - into one or more different chemicals. The metabolites (changed products) may be either more toxic or less toxic than the original pesticide ingredient. Given enough time, an organism may be able to metabolise certain pesticides to non-toxic metabolites and survival or death may depend on the rate of metabolism before the toxic activity is complete or irreversible. On the other hand, some pesticides are effective only after they have been metabolized to a lethal compound in the organism.

**Spectrum of action**

The MoA will often determine the degree to which a pesticide discriminates between target and non-target organisms. A selective pesticide affects a very narrow range of species other than the target pest. The chemical itself may be selective in that it does not affect non-target species or it may be used selectively in such a way that non-target species do not come into contact with it. Non-selective pesticides kill a very wide range of weeds, insects, plant disease organisms, *etc.*
Box B3
Black pod control with fungicides

In many years, the black pod pathogen *Phytophthora megakarya* causes the greatest crop loss in W. Africa: the World’s most important cocoa growing region. Fungicides are widely used for control of the disease, so the choice of control agents is therefore worthy of special attention and provides a useful case study on MoA and selectivity.

The most widely used fungicides are various copper and phenylamide compounds. Copper is more likely to be a soil/environmental issue, and since these compounds are essentially contact fungicides, it would be difficult to distinguish exogenously applied sprays from back-ground levels in residue tests. The MRL set for copper ions, is 50 mg/kg. Organic producers are still permitted to use copper, albeit on a restricted basis (see B7). The MoA of copper compounds is described as multi-site (FRAC group M1), therefore the risk of fungicide resistance is considered to be low.

Residue analysis has recently focused on metalaxyl and benalaxyl, especially since farmers might spray within its one month pre-harvest interval (PHI: one of the principal means of mitigating high residue levels). These are phenylamide compounds with protective, curative and systemic properties. *Phytophthora* is not strictly a fungus, but belongs to a group called the Oomycetes - and phenylamides disrupt their unique nuclear RNA synthesis pathways (FRAC group A1).

Metalaxyl was discovered by Ciba Geigy (now Syngenta) in 1977. It consists of a number of isomers and it was later discovered that one in particular, metalaxyl-M, showed greatest biological activity. In 1996 the company re-patented the latter as mefenoxam (marketed as ‘Ridomil-gold’) thus doubling the patent life. Residue studies and submissions for registration in the EU refer strictly to this isomer, which is on EU/91/414 Annex 1 effectively a new substance (confirmed under legislation 02/64/EC). Supervised GAP residue trials for the latter were carried out by Syngenta on fermented dry beans and using the local processing methods, in order to obtain MRLs. Residue trials included rates of 90 g mefenoxam/ha (2 x normal rate).

The status of (chemically) unresolved metalaxyl under EU legislation will remain unresolved until 30th June 2010 when a final decision will have been taken. In the mean time, a temporary MRL (tMRL) for sum of metalaxyl-M plus other isomers, of 0.1 mg/kg, has been set at the lower limit of analytical determination according to regulation 149/2008. This is effectively half the old *Codex* MRL for metalaxyl (*i.e.* 0.2 mg/kg).

![Metalaxyl and Mefenoxam](image)

It is thought that there is a high risk of resistance to metalaxyl by *Phytophthora* spp and agrochemical companies are currently assessing modern alternatives. These include Carboxylic Acid Amide (CAA) fungicides which disrupt cell wall deposition (the cell walls of Oomycetes differ from the fungi, and contain glucan-cellulose rather than chitin). However, it may be several years before these become commonly used for cocoa.
B8 Biological control methods, organic production and the search for “sustainability”

The precautionary principle is an especially strong concept in Europe (as opposed to the caveat emptor approach often found elsewhere) and often has been used as a guiding principle to constrain the use of pesticides. There is no reason why the precautionary principle cannot be consistent with GAP, as explained in sections A5 and A7. Leading proponents in Europe for the IPM approach (as opposed to organic agriculture) are a group of national organisations linked by the European Initiative for the Sustainable development in Agriculture (EISA - http://www.sustainable-agriculture.org/start.html).

Associated with concerns about pesticides, cocoa that is certified as being ‘organic’ carries a substantial price premium. One of the issues for organic cocoa may be the withdrawal of permission to use copper fungicides, which are already on ‘restricted’ lists. In the EU, it was proposed that use of copper should be below 8 kg/ha/year after 2002, and the International Federation of Organic Agriculture Movements (IFOAM: www.ifoam.org) proposed that it should be withdrawn altogether by 2010. This probably represents a maximum of 5 sprays per season, which probably approaches the economically viable limit at normal application rates and cocoa prices.

Research efforts have focused on biology-based (i.e. “natural”) technologies such as the use of pheromones to lure insects such as mirids and pod borers. Biological control (biocontrol) has been promoted frequently and, amongst the various strategies, three are of potential importance in cocoa:

- **Classical biological control**: a co-evolved natural enemy from the area of origin of the target pest (weed, pathogen or invertebrate) is released, reproduces and feeds on the pest population, which is suppressed.
- **Conservation of natural enemies**: activities which enhance the activity of indigenous natural enemies, in contrast to the use of broad spectrum pesticides and their potentially negative impact.
- **Biopesticides** are one example of inundative biological control in which beneficial microbial organisms are often applied in the same way as their chemical equivalents.

Two recent perspectives on pesticide related issues are shown here:
The underlying issues have been somewhat politicised, with certain organic movements even rejecting some biological control interventions; the research and debate will continue. One of the principles of organic agriculture (OA) is of course to minimise external inputs, but with many tropical crops - not least cocoa - crop losses can be extremely high (>50%) if pests remain unchecked.

Amongst the practical issues in OA, is establishing precisely which pest management interventions are permitted or otherwise. Advice can even be conflicting as the editors of the Manual of Biocontrol Agents have found. A useful guide to the compatible management methods is on http://www.nysaes.cornell.edu/pp/resourcguide/index.php, and EU Regulation No 889/2008 lays down detailed rules for implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products.

**B9 Certification**

Worldwide there are many systems and marks for certifying organic produce …

Examples of organic certification marks

Within the EU, logo bearing the words “Organic Farming” or translations thereof (bottom right and centre) can be used on a voluntary basis by producers whose systems and products have been found to satisfy Council Regulation (EEC) No 2092/91. The ‘Euro-leaf’ logo (bottom right) became compulsory from 1 July 2009 for pre-packaged organic food produced in any of the 27 EU member states.

Most of this manual focuses on bulk cocoa, with appropriate pesticide use in a GAP/IPM context that might be used in the farm, or in storage and transport.

Many of the major chocolate manufacturers now emphasise the need for traceability along supply chains and collaborate with various certification organisations, three of which are
described below. However, a recent television documentary (http://news.bbc.co.uk/panorama/hi/front_page/newsid_8583000/8583499.stm) has revealed how difficult even maintaining labour standards (let alone less ‘visible’ phytosanitary standards) can be in the often remote and complex, cocoa supply chains.

Examples of marks used by certification bodies involved with cocoa traceability and GAP

The Fairtrade Foundation (http://www.fairtrade.net): sets labour and economic as well as environmental and phytosanitary standards: “Fairtrade Standards include requirements for environmentally sound agricultural practices. The focus areas are: minimized and safe use of agrochemicals, proper and safe management of waste, maintenance of soil fertility and water resources and no use of genetically modified organisms. Fairtrade Standards do not require organic certification as part of its standards. However, organic production is promoted and is rewarded by higher Fairtrade Minimum Prices for organically grown products.”

The Rainforest Alliance (http://www.rainforest-alliance.org) “works to conserve biodiversity and ensure sustainable livelihoods by transforming land-use practices, business practices and consumer behaviour.” Working with a network of environmental groups, farmers must comply with appropriate standards for protecting wildlife, wild lands, workers’ rights and local communities in order awarded the certified seal (illustrated).

UTZ CERTIFIED (http://www.utzcertified.org/index.php?pageID=224) producers comply with the Code of Conduct covering good agricultural practices, social and environmental criteria. Their compliance is checked yearly by an independent auditor. The developmental stage of its programme will be completed by the end of 2009 with the first certified cocoa expected in early 2010. The initial focus is on Côte d’Ivoire, but the intention is to expand to other cocoa producing countries.
C. SAFETY AND RESIDUES

Pesticide residues are a matter of great concern since members of the general public perceive a risk but feel it is a matter over which they have little control. In response, authorities attempt to regulate by setting standards and monitoring exposure. This results (necessarily) in an arcane set of procedures and terminologies. A full list of terminologies and acronyms can be found on www.dropdata.org/download, with some of the more common ones listed in Appendix 1. Again, this booklet can only summarise these complex issues but full accounts can be obtained from Hamilton & Crossly (2004) and Matthews (2006).

C1 Classifying the hazards of pesticides

There are at least four aspects to pesticide safety:
- acute (short-term) risks to farmers and other spray operators
- impact of pesticides on the environment
- residues remaining on food (and animal feed) and related to this…
- real and perceived concerns about longer term effects of pesticides (including combinations of substances)

Acute Hazards and Operator Safety

See: DROPDATA.org/RPU/tox_classification.htm and Appendix 2

The World Health Organisation (WHO) provides an internationally recognised system for classifying the acute hazard of pesticides. They are grouped in terms of their median lethal dose (LD₅₀; see Appendix 1) from Class I (most toxic) to Unclassified (unlikely to cause harm with normal use) with each class bounded by a 10-fold range of dose (in mg/kg body weight). The WHO system recognises a 4-fold reduced hazard with solid formulations, in comparison with liquids. The classification was further developed by the US Environmental Protection Agency (EPA), which also recognises inhalation, eye and skin sensitisation effects. These classifications should be based on formulations (where such information is available), but unfortunately, detailed information on individual products is often difficult to obtain, and many entries in the Pesticide Manual are estimated from AI values. Member countries of the EU evaluate each product on a case-by-case basis and, if necessary, assign one of nine risk symbols and a large number of associated risk phrases (see: http://europa.eu/scadplus/leg/en/lvb/l21273.htm); this scheme also has been adopted by the International Labour Organisation.

In some countries toxicity classification is illustrated by a colour coded stripe or triangle indicating the hazard of the product. This is excellent, but unfortunately not universal. To summarise, for farmers and operators that do not have access to good protective equipment, the guiding rule should be:

- Class I pesticides extremely / highly hazardous DO NOT USE
- Class II pesticides moderately hazardous take great care
- Class III pesticides slightly hazardous take care
- Unclassified / Class IV pesticides unlikely to be hazardous still take care

NOTE: the terms “hazard” and “risk” are often used loosely. They have specific meanings:

RISK = (INTRINSIC) HAZARD x EXPOSURE

Exposure may have two elements: time and level of contact with the hazard. This is an important concept and has been (mis)used in the past to suggest that “there are no hazardous substances, just dangerous ways of using them”. An analogy may be useful here. Motor
vehicles are intrinsically hazardous (some cars more so than others and note that far greater numbers of people die in motor accidents every year than from all forms of pesticide poisoning). We only take a risk when we get inside, or in the path of, a vehicle - and most people are prepared to take-on that risk. When a person is a long way from a motor vehicle, the risk is zero. Since for most people economic life must continue, the concept of reducing risk to levels that are As Low as Reasonably Achievable (ALARA) is considered more practical than eliminating risk - which may be impossible.

Certain pressure groups, including the Global IPM Facility (supported by FAO and other organisations working with Farmer Field Schools) have suggested that Class I and II products should be withdrawn from general use, since smallholder farmers are unlikely to use appropriate personal protective equipment (PPE). With the development of new insecticide products there are now only a very few cases where Class I pesticides can be justified at all, let alone for smallholder agricultural problems. However, complications could occur if all Class II products were to be withdrawn immediately. The problem here is especially with insecticides, where there is often a need for resistance management strategies involving alternations in the use of different groups of compounds. Therefore, a phased restriction / withdrawal of the more hazardous compounds may be more appropriate, before safer products become available.

EC Directive 67/548/EEC and subsequent amendments provide a harmonised basis for the classification and handling of hazardous substances. Operator risk (via inhalation, dermal and oral routes) is often quantified by a measure called the Acceptable Operator Exposure Levels (AOEL: see section C5).

Other measures of toxicity and implications

From an operational point of view, acute toxicity is paramount, but other criteria are important - especially in food safety assessments. In order to register a pesticide, other toxicological information is required including:

- Chronic (sub-acute) toxicity over long periods (years) that include generation studies to find out if fertility has been impaired
- Carcinogenicity - whether the substance is likely to cause cancers
- Teratogenicity - whether the substance can damage embryos
- Genotoxicity - whether the substance damages genetic material
- Irritancy (especially for spray operators) and
- Metabolism - it is important to know how the substance is metabolised, into what (metabolites may be more toxic than the original pesticide) and how all metabolites are excreted.

Two important measures (and their associated terms) are especially prominent in legislation and debate. They are actually not linked to one another, but in some ways can be thought of as reflecting hazard and risk.

- ‘Toxicological measures’ based on known safety limits: including Acceptable Daily Intake (ADI: a key indicator for pesticide approval)
- Measures and limits of actual residues based on field studies: including Maximum Residue Levels (MRLs: practical specifications for food producers) for a given crop.
Testing for residues is carried out following internationally agreed and validated methods (and good laboratory practice [GLP] standards apply in some countries). Procedures include extraction and “clean-up” from samples, followed by analysis using various instruments, depending on the residue being analysed. Appropriate equipment for individual compounds is included in Pesticide Manual entries. Analysis techniques include: gas chromatography (GC), gas-liquid chromatography (GLC), gel permeation chromatography (GPC), high-pressure liquid chromatography (HPLC) and various mass spectrometry techniques, so such laboratories are expensive to set-up and maintain.

(photos: Jean Ponce Assi, SACO-CHOCODI)

C2 What are MRLs?

Pesticide residues on crops are monitored with reference to Maximum Residue Limits (MRL) and are based on analysis of quantity of a given AI remaining on food product samples. The MRL for a given crop/AI combination, is usually determined by measurement, during a number (in the order of 10) of field trials, where the crop has been treated according to GAP and an appropriate pre-harvest interval (see section C5) has elapsed. For many pesticides, however, this is set at the Limit of Determination (LOD) – since only major crops have been evaluated and understanding of ADI is incomplete (i.e. producers or public bodies have not submitted MRL data – often because these were not required in the past). LOD can be considered a measure of presence/absence, but true residues may not be quantifiable at very low levels. For this reason the Limit of Quantification (LOQ) is often quoted in preference (and as a ‘rule of thumb’ is usually approximately 2X the LOD). Further information on detection limits is on http://en.wikipedia.org/wiki/Detection_limit. For substances that are not included in any of the annexes in EU regulations, a default MRL of 0.01 mg/kg normally applies (but note that an even lower MRL applies for one AI: fipronil and its metabolite).

It follows that adoption of GAP at the farm level must be a priority, and includes the withdrawal of obsolete pesticides. With increasingly sensitive detection equipment, a certain amount of pesticide residue will often be measurable following field use. In the current regulatory environment, it would be wise for cocoa producers to focus on pest control agents that are permitted for use in major importing countries.

It should be stressed that MRLs are set on the basis of observations and not on ADIs and it is also generally understood that MRLs would considerably over-estimate actual residue intakes. MRL studies take place after years of initial development and it is most unlikely that an agro-chemical company would even carry them out (with a view to registering the product), were toxicological studies to raise serious question marks about a new compound.
C3 Safety: Acceptable Daily Intake (ADI) and ArFD, OELs, etc.

A pesticide can only be approved for use if the risk to consumers, based on potential exposure, is acceptable. The limit set for a pesticidal active ingredient (AI), the ADI, is an estimate of the amount that can be consumed daily, for a lifetime, without harm to the person. The term “acceptable” is considered to involve a 100 fold safety factor from a measure called the No Observed Effect Level (NOEL) obtained in laboratory studies (section C1), which is 10 times lower than the Lowest Observable Effect Level (LOEL).

![Graph showing the relationship between NOEL, LOEL, and LD50.]

Data from laboratory studies is expressed as a dose (usually mg/kg bodyweight) and it is necessary to extrapolate these data for human exposure (be it dermal toxicity for AOEL or ADI for dietary safety). Dietary intake is often based on the National Estimated Dietary Intake (NEDI) estimate of a given foodstuff using surveys by national food standards agencies. Ideally, judgements would be carried out on Theoretical Maximum Daily Intake (TDMI), but there may be substantial variations between infants, children and adults even after adjusting for body weight. Another often quoted parameter, the Acute Reference Dose (ARfD), which is similar to the ADI, refers to short-term intake of an AI.

C4 Pesticide breakdown

After application, pesticides are degraded by chemical and physical processes in the environment such as sunlight, soil and water (called abiotic degradation) or metabolised within living organisms (see section B6). Breakdown of a pesticide (and many other substances) in the environment can be thought of as following a decay curve. This is a function of the chemical’s half-life, which is the time (most usually expressed in days) required for half of the applied pesticide to become converted into degradation products (which may in turn be biologically active and have substantial half-lives).

The rate of break-down depends on many factors, not least the chemical stability of the pesticide in question, but factors such as temperature and pH are extremely important, so the half life may be expressed as a range (e.g. 3-10 days). Probably the most important mode of pesticide degradation is oxidation: especially by activated oxygen (e.g. ozone and hydroxyl radicals generated by sunlight, hydrogen peroxide generated in plants, etc.) rather than O2 in the atmosphere.
Allowing sufficient time to elapse between application and harvest enables any residue to degrade to acceptable levels (*i.e.* the MRL) and the Pre Harvest Interval (PHI) has a built-in safety factor. Reducing the dosage reduces the time to which acceptable levels are reached, but pest control may be impaired. Excessive residues occur with short harvest intervals, overdosing, or worst of all both of these.

Implications for application and environmental impact

Improved (as opposed to just competent) application techniques are an especially promising way of mitigating residues and lowering environmental impact, but unfortunately research in this field has been very limited. Targeted dose-transfer[^9] can increase pest mortality for a given level of application to the crop, while maintaining equivalent pest control[^7].
Environmental safety

This is a huge subject which is summarised here in the form of a diagram. Agrochemical companies are now obliged to allocate substantial resources to assess the environmental fate of compounds (and their metabolites). Even after registration, environmental concerns can be raised that may threaten the future of successful compounds (e.g. box B2). The environmental impact of a given pesticide treatment is a function of its properties and the way that contamination takes place.

Screening of new compounds includes risk assessment of both ground and surface water contamination, involving computer modelling. A number of standard tests take place on non-target organisms including birds (such as mallard ducks), fish (including rainbow trout), algae, water fleas (Daphnia spp.), bees and other beneficial species.

Inappropriate application can lead to off-target contamination due to spray drift, and “run-off” from plants causing contamination of the soil. Several studies have concluded that point source contamination (entry of pesticides to water courses/groundwater following spillage of concentrate or after washing equipment) often causes the greatest harm - especially to waterways. During training sessions, time should be allocated to considering crop protection activities relative to the positions of water courses and wells. For example, in order to protect water sources, it is especially important that farmers consider waste flows when washing out sprayers.
**C5 MRLs for cocoa: what will be assessed in practice?**

In the EU and USA, samples of cocoa beans are first de-husked before residue analysis takes place, whereas at the time of writing, whole beans are analysed in Japan (“beans without pods”), which is more likely to result in residue violations.

Commission Regulation 396/2005/EC of the European Parliament and of the Council proposed maximum residue levels of pesticides for food products applied from 1st Sept 2008. This was amended by regulation EC 149/2008 by establishing Annexes II, III and IV setting maximum residue levels for products previously covered by Annex I: at:


Annex III includes so-called temporary MRLs for cocoa (many subject for review within 4 years) and is split into two parts as follows:

- **Part IIIA:** Temporary MRLs for substances being in the approval circle for use in EU or substances that are no longer approved for use in EU.
- **Part IIIB:** Temporary MRLs for all active substances for new commodities (including cocoa) introduced under 396/2005/EC. These MRLs are based on national MRLs, where a risk assessment has been performed by the European Food Safety Authority (EFSA).
- **Annex IV** contains plant protection products already evaluated at EC level for which it is not necessary to set MRLs (because of their low risk).

This 398 page document is arcane and difficult to read, but easier access (with a download facility), under “cocoa (fermented beans)” and “tea, coffee, herbal infusions and cocoa”, is available at: [http://ec.europa.eu/food/plant/protection/pesticides/database_pesticide_en.htm](http://ec.europa.eu/food/plant/protection/pesticides/database_pesticide_en.htm)

A description of regulations in Japan and the USA was given in Section A4. MRLs for cocoa imports into Japan can also be found on:

C6 What can be done to mitigate residue problems?
Essentially there are three measures that can be taken at the farmer-operator level:
- apply the right substance(s),
- in the right way,
- at the right time.

It follows that there are four important practical ways to avoid residue violations:

1. **Establish whether pesticide application is the most appropriate way to solve the problem:**
   - Will it be cost effective?
   - Are there viable alternatives?

2. If it is appropriate, select the right pesticide for the problem:
   - Am I using a suitable product for cocoa?
   - Is it on the recommended list for controlling the problem?
   - Is it safe for me to use?
   - How would I need to use it?

3. **Apply pesticides in the right way to achieve effective pest control**

   Good application includes control of the amount of product delivered to the crop. This means good nozzle selection, calibration and application technique (see section D).

   A frequently encountered misconception is that “Adding a little extra will make sure of good control”

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1 Inclusion of compounds or products is for illustration only and does not imply recommendation or otherwise.
4. **Apply pesticides at the right time - before the Pre-Harvest Interval (PHI):** which is the minimum permitted number of days between the last spray and harvest. This can be one of the most important considerations for avoiding harmful residues on produce.

For example, the product shown is an effective and widely-used fungicide for the control of black pod disease. The label ("Use recommendation") states that the recommended PHI is **one month**, but this may not always be adhered-to by farmers during peak-season disease attacks.
D. GOOD AGRICULTURAL PRACTICES FOR COCOA

DROPDATA reference: the contents of this section have been summarised in the leaflet: Spraying Cocoa: 10 Essentials, which is now available in Bahasa, English, French, Spanish, Tok Pidgin and Vietnamese versions.

Download these from: www.dropdata.org/cocoa/training.htm.

This is only a summary - each sub-section could be applied as individual training sessions. I suggest here some of the “key messages” and explain why they should be prioritised.

**D1 Matters to think about before picking up a sprayer**

This manual is not about promotion of pesticides and it must be emphasised that pest management measures have little or no relevance, if the nature of the pest attack is not understood or if the crop is poorly managed.

**Crop architecture**

Good IPM usually means that farmers must inspect crops regularly, and may involve sanitary harvesting to remove diseased infested pods. It is virtually impossible to do this well in very tall crops. Good spraying, to maximise coverage on the biological target, likewise needs well managed trees.

The first message for cocoa farmers …

Tall trees are very difficult:
- to monitor
- to spray
- to harvest

(Cartoon courtesy J. Cooper, NRI)

Prune trees regularly: reducing the height of tall trees (to 3-4 metres) will make spraying easier: but you may lose a season of crop! This is probably the most important pre-condition for implementing GAP, and there are various methods to rehabilitate very tall cocoa, as described below.
Drastic but necessary: cocoa rehabilitation

*Top row:* simple tree height reduction; cuts are made at approximately 1.5 - 2 metres above the ground then treated with copper fungicide. In order to maintain some production, this must be carried out in stages over 4-5 years (*i.e.* with only 1/4 of the farm cut in any one year).

*Second row:* rehabilitation after grafting …

*above* - chupon grafting
*above right and right* - side grafting
Weed control and herbicides

Herbicides, or weed killers, occupy the largest global share of the pesticide market, although their use by smallholders is limited in comparison with intensive farming, amenity weed control, etc. Perhaps their greatest use in cocoa is in larger-scale, commercial plantings. They are most typically applied at an early stage to prevent young plants from being choked by weeds. Control is rarely required once the canopy closes (although mistletoes may become a problem in poorly managed cocoa).

Herbicides have been classified in several ways and, as with other pesticides, a number of chemical families can be grouped by their modes of action (using letters in the HRAC nomenclature). In practice, herbicides are often grouped according to their mode of use:

- **contact** herbicides, where only the part of the plant sprayed is killed, such as the photosynthesis inhibitor paraquat (MoA group D)
- **systemic** - pre-emergent and post-emergent herbicides include compounds that:
  - disrupt amino acid synthesis in chloroplasts e.g. glyphosate (group G)
  - disrupt cell division in broad-leaved weeds: including synthetic auxins such as 2,4-D and picloram (group O).

During recent surveys in cocoa, glyphosate and paraquat have been quoted as widely used on cocoa. However another herbicide, 2,4-D has caused perhaps the greatest concern, appearing as residues in cocoa beans from more than one country. In some cases, it transpired that the residues originated from the ground on which cocoa beans had been dried (roadsides, courtyards, etc.) that had been treated with herbicides, or had been exposed to run-off after rain. The use of drying mats for cocoa beans, elevated off the ground, is therefore an important recommendation for quality in the supply chain.

Recommendations:

- Approved herbicides present a minimal risk when used judiciously for weed management in establishing trees
- … which especially means care in application: avoiding the production and drift of small droplets onto non-target areas.
- Care and oversight is needed along the whole cocoa bean production and supply chain
- … herbicide residues may originate from outside the cocoa garden.
Identification of pest problems
Application of pesticides is costly and may be risky, so farmers should always ask the question “What am I trying to control?”
This will affect selection of the product and how it will be applied.

Examples of West African problems that may be treated with pesticides include:

**In younger cocoa**
- Weeds
- Defoliating insects (grasshoppers, beetles, etc.)

**Principal crop production**
- Black pod disease (*Phytophthora* spp. - especially *P. megakarya*) - see Box B1, p.21
- Mirid (capsid) bugs (mostly *Sahlbergella singularis* and *Distantiella theobroma*)
- Cocoa swollen shoot virus (CSSV*)
- Termites

**Storage pests** (see section E)

* CSSV is transmitted by mealybugs (Pseudococcidae) which are tended and redistributed on plants by black ants. Systemic organophosphate insecticides (that are no longer permitted under EU regulations) have been tested for control of the mealy bugs, but they were hazardous and had little effect. Although modern insecticides are under test, it is too early recommend them as an effective control technique, and current research on managing this virus is focused on breeding resistant varieties.
2008 marked the centenary of cocoa mirids (Sahlbergella singularis and Distantiella theobromae: also known as capsids) in West Africa. These insects have become the most damaging insect pests in the region and are thought to cause annual crop losses in excess of 200,000t. They are an example of ‘new encounter’ pests - cocoa originated in the Amazon region of South America, and having been introduced to W. Africa in the 19th century, became infested with local insects that adapted to a new food source. Similarly, a complex of true bug pests (called Hemiptera) adapted to cocoa in S.E. Asia, including a number of mirid species in the genus Helopeltis.

Entwistle’s book gives an excellent description of the early development of mirid control measures. Insecticide application techniques on cocoa remain essentially based on experiments that were carried out in the 1960s when the organochlorine gamma-HCH (also called BHC and lindane) was the AI of choice. Two properties, persistence and fumigant action, helped to overcome inadequacies in application and HCH remained in widespread use until the 1990s.

Resistance (see section B5) to organochlorines by cocoa mirids was detected in the 1950s and, as with other pests, necessitated the development of an Insecticide Resistance Management (IRM) strategy. A successful technique has been to interchange the compound with other insecticides, belonging to different MoA groups, in order to reduce selection pressure on a single biochemical pathway. Early screening of chemicals from the 1960s to the early 1990s focused on carbamates (IRAC group 1A) and organophosphorus (OP) compounds (group 1B). Examples of widely used AIs included the carbamates: propoxur and promecarb; the OPs: chlorpyrifos, diazinon and pirimiphos methyl and the organochlorine (IRAC group 2) endosulfan. Several of these, like HCH, have some fumigant action but many are now withdrawn (see Box B1).

Pyrethroids (see Box E1) have been widely used against cocoa insects, especially mirids in West Africa (also Helopeltis and cocoa pod borer in SE Asia). They belong to IRAC MoA group 3 and commonly-used examples include: bifenthrin, deltamethrin, cypermethrin and lambda-cyhalothrin. Neo-nicotinoids (see Box B2) such as imidacloprid and thiamethoxam, are of interest since they have systemic action and relatively low mammalian toxicities.

Other concerns have been raised about these compounds, including possible impact on bees and other pollinators, and the search for alternative control methods continues. Two current lines of research are manipulation of mirid pheromones (mating attractants) and mycoinsecticides. Pest outbreaks often occur when a species is no longer controlled by its natural enemies (which in the case of Hemipteran insects include specific fungi that are diseases of insects). Mycoinsecticides are often formulated spores of such fungi and can be applied in a similar way to chemicals. If shown to be effective, they would be both environmentally-friendly and contribute to mirid IRM.
Managing the Cocoa Pod Borer in SE Asia

The cocoa pod borer (CPB) *Conopomorpha cramerella* (Snellen) is considered to be one of the most serious cocoa pests in South East Asia since it not only causes crop loss but also greatly reduces cocoa quality. The spread of this apparently invasive pest species was a major setback for Malaysian cocoa production. Although it has been argued that its pest status resulted from more than one new encounter with cocoa by this insect, which is endemic on rambutan and other species, recent research at USDA indicates that CPB in S.E. Asia is genetically very uniform.

Chemical insecticides became widely adopted as CPB control methods in estates until the 1990s, and when the majority of SE Asian production shifted to Sulawesi, they continued to be used by small-holder farmers. Extensive work was done during the Malaysian “CPB crisis” in the 1980s, but there has been an almost complete hiatus in pesticide research and development for well over a decade. Since then, agricultural chemistry companies have introduced a number of new molecules, belonging to novel modes of action (MOA) against Lepidoptera, but cocoa is not one of their priority crops for development.

Previously, CPB infestations were sprayed with gamma HCH (BHC) and subsequently endosulfan. As with cocoa mirids, the efficacy of these compounds was partly due to fumigant action, which compensated for inadequacies of application. Compounds currently registered in Indonesia (the greatest user of CPB insecticides by far) include: pyrethroids (alpha cypermethrin, beta cyfluthrin, deltamethrin, lambda cyhalothrin, etc.), chlorpyrifos and, most recently, fipronil. Many farmers in Sulawesi, where most cocoa is grown there, typically apply insecticides 3-5 times per year.

Top: a moderately infested pod

Bottom: an adult moth. The biological target has been broadly defined and targeted spraying of pods and the undersides of branches is a preferred method of application for smallholder farmers.

Ideally, management of this insect would focus on crop sanitation and regular complete harvesting (RCH) of pods, but the level of labour and supervision required prevents successful implementation in many areas. Promising alternative techniques include the use of plastic sleeves to protect pods and the use of pheromones.

A very useful guide for identifying many of the major cocoa diseases and insect pests is available to download from both the CABI and WCF web sites (see: Appendix 4). Since the time of writing, some of the pesticides listed have now been superseded.

There are Bahasa, English, French, Portuguese, Spanish and Vietnamese versions of this guide.

**Level of attack - is it worth spraying?**

Make sure that it is worth applying a pesticide. Specifically that:

- the infestation is above an appropriate action threshold
- it is not too late to spray (*i.e.* if too much damage has already been done - as in this severe attack of *P. megakarya* black pod disease). With infestations such as the one shown here, the only useful control measure would be to remove and destroy the infected pods and bury them if possible, in order to reduce the release of spores.
**D2 Pesticide selection**

Choose and use the right pesticide:
- think safety first …
- …and ask yourself “Will it be effective?”…

The lists given in Appendix 3 will help you make your decision.

**Read the label or find out:**

- Is this the right product for the job?
  - will it really control the problem?
  - cheapest is not always best!

- How much will I need to apply?

- What is the **Pre-Harvest Interval? (PHI)**

These signs mean:

- very toxic
- harmful/irritant
- danger to the environment
- corrosive

If you do not have special personal protective equipment (PPE - see D3 below)
… **Do NOT use hazardous products**

**D3 Personal Protective Equipment (PPE)**

PPE (mask, goggles, gloves* etc ) are not always available in rural, cocoa growing areas and are only of value if they are well maintained and worn properly.

* NOTE: it is safer to use no gloves at all than gloves with holes in them.

Since it may also be too hot to wear heavy protective gear, we therefore recommend:
- Selection of less toxic products (see above)
- Minimum personal protection
- Appropriate techniques for avoiding exposure when spraying
- Hygiene and cleanliness (see below)
Minimum Personal Protection Measures

- **Wear a hat** to protect against falling droplets
- Wear comfortable clothing that protects as much of the body, arms and legs as possible.
- ... but never put on previously contaminated overalls or other clothing
- A face visor is especially important if you are using irritant or harmful pesticides (see box below).
- Wear trousers on outside of boots

If you use a **motorised mistblower** ear defenders are essential.

**Box D4**
**An economic way to protect of the face**

Face visors protect the face from irritating or toxic sprays, but commercial equipment is expensive and may cost more than €20. The INIAP face visor (as shown here) was developed as a very low-cost alternative. It can be made from a 2 L plastic (not ribbed) soft drinks bottle, tied on with strings.
IMPORTANT

Children must not take part in spray operations: pesticide application must always be treated as potentially hazardous and children are especially sensitive to pesticides.

D4 Maintenance of equipment is vital

The notes on the following three pages refer mostly to manual, knapsack sprayers, as used by most smallholder farmers (further notes on motorised mistblowers can be found on DROPDATA/DD). Firstly, it usually pays to choose a good quality, robust sprayer and always ask the question “Will I be able to find spare parts for it?”

- Is your sprayer working properly?
  Before each spray operation check equipment using clean water only

- Are there any faults or blockages?
  Check pump, valves, filters and nozzle.

- Are there any leakages?

If spare parts are not available, joints can be repaired with white (plumber’s PTFE) tape or rubber seals (can be made out of old tyre inner tubes). Replace worn and leaking hoses.

Leaking sprayers are bad because of:
- operator exposure to tank mixture
- under-estimation of application rates
- possibility of increased environmental contamination

D5 How to spray cocoa

- The method of application is crucial, but it is often the most neglected aspect of pesticide use. Together with attention to PHIs and number of sprays, careful application is one of the important ways in which pesticide residues can be controlled, as it determines the dosage delivered to the crop.

Having made sure your equipment is in good working order, there are four steps to application:

- Assessing the target
- Nozzle selection and setting
- Calibration
- Application technique

How not to spray!
(courtesy H. Dobson & J. Cooper, 2005 - Vegetable production and pest management calendar).

How to treat the target?
Where must the spray deposit be put …
   → pods & trunks ?
   → shoots ?
   → whole tree ?

**Select the right nozzle**: if your sprayer has a variable hollow cone nozzle, what setting should be selected? Remember that “overkill” will result in high residues as well as wasting money and harming the environment …

**Know your spray nozzles:**

**Common types of hydraulic nozzle** and the pattern of spray produced

Top: **cone nozzle** (most commonly used, for fungicides & insecticides)

Middle: **flat fan nozzle** - general purpose and spray booms

Bottom: **deflector (anvil) nozzle** - for herbicides

**Types of cone nozzle**

The right combination of disc and core nozzle (*e.g.* D1.5-25) can be pre-fixed to maximise the spray deposited on pods and branches.

Unfortunately, many sprayers are fitted only with **variable cone nozzles**, but few farmers know which setting to use.
Squirting with a jet as above is usually wasteful. **Remember:** high flow rates mean
→ bigger droplets
→ greater risk of run-off
→ wasted money!

A wide spray cone (above) is good for general canopy treatment, but can be wasteful for pods and narrow branches

For narrow targets like pods and branches you need a narrow angle of spray (left).

**It pays to Calibrate**
Use the right amount of water (volume rate) and pesticide mixture.

Ask yourself the questions:

- how many litres can my sprayer tank hold?
- how many trees are treated per tank load?
- how many tank loads are required to spray the whole farm?
**Application technique**

Only mix as much pesticide as you need for the day

Be systematic: spray evenly and make sure you don’t miss any target areas… …or spray them twice!

Are all the target pests being sprayed effectively?

Is a lot of spray landing in areas that it shouldn’t be? Specifically … … is there dripping from the pods or leaves? … if so, you are **spraying too much** - reduce your volume application rate.

**D6 Containers and Hygiene**

- If you use sachets - dispose of them carefully
- If you must recycle pesticide bottles: rinse at least 3 times before disposal. If possible, use the water for rinsing in the next spray tank load
- **Never** use your **mouth** to clean nozzles … or to prime your sprayer
- **Never** eat, drink or smoke while spraying
- After spraying: - clean out the sprayer first - then wash yourself and your clothes, but …
- **Never dispose of washing water near water sources** (use waste ground or discard beneath the cocoa crop, away from children and animals)

**D7 Post-spray Evaluation**

After spraying, ask yourself:
- Did you spray the number of tank loads expected? If not, why?
- Was it difficult to reach high pods and branches? If so - start pruning your trees
- Did the spray operation work? … continue monitoring pests on your crop … … if not, change your pesticide, timing or improve your application technique.
E GOOD CROP STORAGE PRACTICES

FAO gives useful guidance on management of storage pests, but in light of new regulations, specific control agents may need to be updated (http://www.fao.org/docrep/x0039e/X0039E00.htm).

The Federation of Cocoa Commerce Ltd. (FCC) has issued and updated a *Statement of Best Practice for Managing Infestation and Fumigation* (latest version 2003). This is a useful document that provides information on techniques for improving cocoa quality.

**E1 Important storage pests**

Storage pests likely to infest cocoa beans include:

**Warehouse moths** (Lepidoptera) especially:
- Cocoa moth (= Warehouse moth)
- Tropical warehouse moth (= Almond moth)  
  - *Ephestia elutella* (Pyralidae)
  - *E. cautella*

**Beetles** (Coleoptera) such as:
- Cigarette beetle
- Corn sap beetle
- Rusty grain beetle
- Coffee bean weevil  
  - *Lasioderma serricorne* (Anobiidae)
  - *Carpophilus dimidiatus* (Nitidulidae)
  - *Cryptolestes ferrugineus* (Cucujidae)
  - *Araecerus fasciculatus* (Anthribidae)

**Rodents**  
- *Rattus spp.*

*Right* - beans infested with warehouse moth larvae

*Left* - Rusty grain beetle  
- *Cryptolestes ferrugineus*

*Right* - Warehouse moth  
- *Ephestia elutella*


**E2 The significance of non-chemical controls**

Infestations of stored produce can be reduced dramatically by:

**General sanitation:** as with most pest control, basic measures must be taken to prevent the carry-over of infestations by cleaning and clearing up debris that can harbour pests.

**Maintaining a low moisture content:** In most stored crops, if moisture content is reduced to below 8%, all metabolic activity of any organisms present practically ceases. Drying is therefore a standard treatment before storage, but may require external energy and air movement to evaporate the moisture and remove the resultant water vapour. The energy may be derived from burning fossil fuel or wood, or from solar energy, as in sun-drying. Drying processes are well documented and results can be reliably predicted.

**Other methods:** such as the use of modified atmospheres (MA): where oxygen availability is reduced and temperature is well controlled (insect activity rises with increasing temperatures up to 42°C). These methods were rarely used in cocoa until steps were taken to withdraw the important fumigant methyl bromide (restricted under the international Montreal Protocol agreement because of concerns about ozone depletion). Treatments involving MAs have been investigated by the Central Science Laboratory in the UK and are now seen as acceptable and viable alternative treatments for further development in the immediate future.

**E3 Application and timing of insecticide treatments in storage**

Insecticides, including fumigant treatments, are chemical methods for controlling storage insects. The most common methods of application have included:

**Admixture of insecticidal dusts with the produce before loading it into the sack.** Mixing is carried out in various ways, such as shovel mixing on a tarpaulin or, for large-scale operations, mixing in dust formulations in rotating drums or on conveyor belts. However, these techniques are likely to give rise to potential health hazards and are no longer recommended (except for seed treatments where they can be highly efficient).

**Applying liquid insecticide sprays or dusts to successive layers of sacks as the stack is built.** Spraying or dusting successive layers of sacks with insecticides (as shown below) is less likely to build up residues, but is not always effective and there is always a danger in applying undiluted insecticides.

**Enclosing a fumigant with the sacks under a gas-proof sheet.** This is usually the most effective method of insect control and when used correctly is safe and least likely to lead to residue problems. Phosphine (phostoxin) is a toxic gas that is generated from sachets containing metal phosphides. It is slowly released among bags covered by a gas-proof sheet: which is held down by “sand snakes” or similar weights. With phosphine, the covered stack is typically left for between 5 and 16 days, and then opened up to allow the gas to escape. The time depends on the temperature and the commodity, but is never less than 96 hours (whereas methyl bromide was popular because it was effective in less than 3 days). The Federation of Cocoa Commerce Statement of Best Practice provides further details of procedures.

**Introduction of fogs into enclosed spaces such as containers.** The application of insecticides (e.g. synergized pyrethroids) using thermal foggers is primarily designed to kill flying insects such as warehouse moths that might escape or hatch inside containers.

An issue that appears to have been overlooked in the past is the treatment of the wooden pallets on which cocoa sacks are stored - especially for the control of termites. Termite insecticides are often, out of necessity, persistent and toxic and have included chemicals such
as chlorpyrifos and fipronil, together with other now obsolete organochlorines. It is thought
that some occurrences of high insecticide residues in produce have arisen from indiscriminate
treatment of pallets, and that greater care will be needed in future.

a. Treating successive layers of sacks as the stack is built (see text)

b. Space treatment with a pyrethroid UL formulation: using a thermal fogger before closing a container
c. Fumigating sacks under sheets with phostoxin generating sachets (aluminium phosphide)
Box E1
Pyrethroid Insecticides

Previously the most important proportion, now the second largest sector of the synthetic insecticide market includes a class of compounds called the pyrethroids, which are highly effective against agricultural and public health major pests. They were introduced thirty years ago by a team of Rothamsted Research scientists led by M. Elliott, and represented a major advancement in activity and relatively-low mammalian toxicity. Their development was especially timely with the identification of problems with DDT use.

Their work consisted firstly of identifying the most active components of pyrethrum, extracted from East African chrysanthemum flowers and long known to have insecticidal properties. Pyrethrum rapidly knocks down flying insects, but has a low mammalian toxicity and negligible persistence - which is good for the environment but gives poor efficacy when applied in the field. Pyrethroids are essentially chemically stabilized forms of natural pyrethrum and belong to IRAC MoA group 3 (they interfere with sodium transport in insect nerve cells).

The 1st generation pyrethroids, developed in the 1960s, include bioallethrin, tetramethrin, resmethrin and bioresmethrin. They are more active than the natural pyrethrum, but are unstable in sunlight. Activity of pyrethrum and 1st generation pyrethroids is often enhanced by addition of the synergist piperonyl butoxide (which is not itself biologically active). With the 91/414/EEC review, many 1st generation compounds have not been included on Annex 1, probably because the market is simply not big enough to warrant the costs of re-registration (rather than any special concerns about safety).

By 1974, the Rothamsted team had discovered a 2nd generation of more persistent compounds notably: permethrin, cypermethrin and deltamethrin. They are substantially more resistant to degradation by light and air, thus making them suitable for use in agriculture, but they have significantly higher mammalian toxicities. Over the subsequent decades these were followed with other proprietary compounds such as fenvalerate, lambda-cyhalothrin and beta-cyfluthrin, but most patents have now expired, making them cheap and therefore popular (although permethrin and fenvalerate have not been re-registered under the 91/414/EEC process). One of the less desirable characteristics, especially of 2nd generation pyrethroids is that they can be irritant to the skin and eyes, so special formulations such as capsule suspensions (CS) have been developed.

Pyrethroids have been widely used against cocoa insects in the field (Box D1). Synergized tetramethrin has been applied extensively for control of warehouse pests - partly due to its low persistence and irritancy, but (together with permethrin) it has not been included on Annex 1 of 91/414/EEC. Now only natural pyrethrum (usually synergized) may be used. Substitutes should be sought, but other, permitted “knock down” insecticides including 2nd generation pyrethroids, would have to be used more carefully due to greater persistence and the general risk of insecticide resistance. Substitute MoA groups to consider might include juvenile hormone analogues (IRAC group 7).
**E4 Pesticide Selection**

In the EU, fumigants and rodenticides are regulated by the Biocidal Product Directive (98/8/EC) aims to harmonise the European market for biocidal products and their active substances (Directive 91/414/EEC served as a model in its drafting). It is environmental legislation (http://ec.europa.eu/environment/biocides/index.htm) and “aims to provide a high level of protection for humans, animals and the environment”.

The following pesticides are known to have been used recently in cocoa warehouses:

<table>
<thead>
<tr>
<th>1. Fumigants (on 91/414/EEC Annex 1)</th>
<th>Precursors of the fumigant phosphine: aluminium phosphide, magnesium phosphide</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Fumigants in IRAC group 8: (miscellaneous group of multi-site MoA)</td>
<td>Methyl bromide: is no longer permitted in the EU and still in the process of being ‘phased out’ in N America and SE Asia. Sulfuryl fluoride: a proposed alternative, is now included in Annex 1 of 98/8/EC (Directive 2009/84/EC)</td>
</tr>
<tr>
<td>3. Surface treatments: currently on 91/414/EEC Annex 1 - but <strong>must be used with great care</strong> to avoid high residue levels. <strong>Note:</strong> approvals for certain products (including pirimethos-methyl) for structural treatments are being revoked in the EU.</td>
<td>OPs (IRAC group 1B): chlorpyrifos, pirimiphos-methyl Pyrethroids (IRAC group 3): natural pyrethrum, cypermethrin, deltamethrin</td>
</tr>
<tr>
<td>4. Surface and fogging treatments: Recorded, but <strong>not included in Annex 1</strong></td>
<td>fenithrothion, malathion, isoprocarb (MIPC), permethrin, tetramethrin</td>
</tr>
</tbody>
</table>

Following the withdrawal of methyl bromide in the EU and concerns over residues of non-fumigant insecticides (*i.e.* groups 3 & 4 above), there will inevitably be increasing reliance on the use of phosphine with associated concerns about the onset of resistance. This subject has been reviewed by Chaudry\(^{10}\), who recommends that phosphine fumigation should only be carried out by trained staff to ensure:

- Acceptable standard of gas-tightness of the area under fumigation
- Appropriately-timed application of optimal doses, and maintenance of the exposure over a minimum required length of time
- Regular monitoring of gas concentrations, to ensure maintenance of effective levels
- Post-fumigation assessment of the effectiveness of each treatment
- Integration with other methods (*e.g.* surface treatments with approved residual insecticides, or provision of a physical barrier) to reduce the risk of re-infestation during subsequent storage. The withdrawal of a number of previously used compounds (see Appendix 3b) may become a matter for concern.
E5 Inspection, sampling, documentation and traceability

The introduction of residue monitoring will clearly add a major new aspect to the implementation of cocoa quality standards. A summary of the complexities of the supply chain can be found on http://www.icco.org/about/shipping.aspx and improved inspection and monitoring procedures are primarily a matter of concern for cocoa traders and their associations (such as the FCC and CMAA). Reference is made here to rules for sampling and quality§ as defined by the FCC (http://www.cocoafederation.com/).

In order to pass as high quality fermented beans, an assessment is firstly made of cocoa bean numbers for a given weight and the proportion of foreign matter. A ‘cut test’ follows by bisecting them lengthwise through the middle, in order to assess the proportion that are mouldy, slaty (indicating under-fermentation), purple (over fermented), insect damaged, germinated or flat beans. In addition there are standards for content of moisture (typically below 7.5-8%: as determined by International Confectionary Association [ICA] analytical method No. 43), free fatty acids (FFAs: ICA analytical method No. 42) and ‘off flavours’ (ICA analytical method No. 44).

‘Contamination’ is currently defined as “cocoa which has smoky, hammy or other off-flavour taste or smell, or which contains a substance not natural to cocoa”. In the past therefore, the focus has been on contaminants associated with artificial drying of cocoa, but consideration is now being given to other sources that might be introduced at any stage along the supply chain. Beside pesticide residues, monitoring may take place for other contaminants, including presence of:

- mycotoxins, including ochratoxin-A (OTA) - are produced by fungi (and are usually orders of magnitude more toxic than pesticides and may therefore be due partly to failures in pest management),
- poly-aromatic hydrocarbons (PAH) - which can result from cocoa beans coming into direct contact with smoke, for example during artificial drying using badly designed or poorly maintained driers
- heavy metals (rare and usually associated with cocoa grown on volcanic soils).

§ FCC Sampling Rules, FCC Quality Rules: applicable to contracts made after March 2008
The initiatives being put in place to improve traceability were described in Section B9. The structure and length of the cocoa supply chain differs from region to region within the same producing country as well as across producing countries. Methods of warehousing and shipping also vary, which will inevitably influence the point and level of sampling. Not every possible pesticide will be examined in every shipment of course. Different levels of sampling will take place, according to different criteria (e.g. see section C5), but inevitably it will be necessary to improve traceability of cocoa consignments.

For example, anecdotal reports suggest that the need to control insects has encouraged “risk averse” traders and middlemen to apply pesticides un-necessarily before intermediate points of sale, and thus raise the risk of residues being detected. It follows that review of procedures along the supply chain in cocoa growing countries will be required, in order to avoid a record of ‘positive’ residue tests.
F. RECOMMENDATIONS

F1 General
The overall aim of this manual is to raise awareness of general and specific issues relating to pesticide use in cocoa. Certain issues will be country specific, some will also involve commercially sensitive information, but it is generally agreed that much needs to be done to improve general knowledge of pesticide science and actual pest management practices.

In particular, the need for accuracy cannot be over-emphasised (e.g. the use of International standards, focusing on AI’s and not trade names and, at the farm level, calibration etc.). There is much scope for collaboration within cocoa growing regions and for sharing knowledge of pest management practices. The choices may be bewildering at times, but the pest problems are often common to adjacent countries. Throughout this manual, I have recommended the need for improved:

- choice of plant protection products
- application method and timing
- communication of the above

Establishment of GAP is obviously not just about ensuring correct pesticide use and phasing out obsolete and problematic compounds. There are usually reasons for existing practices (be they good or otherwise) and it is very important to learn by whom and why they are used. The lists of compounds in Appendix 3 will continue be reviewed. The need for specific guidance, for farmers and warehousemen cannot be over-emphasised, but the method of communicating such messages will be crucial.

F2 The need for ‘strategic cocoa pesticides’
The approach suggested here is to identify a positive list of ‘Strategic cocoa pesticides’ (see Appendix 3a) that can be recommended for specific important pests and stages in the supply chain. Extra special care is needed for pesticides used against storage pests, in warehouses and in cocoa transport, for reasons described in section E.

F3 The need for practical research on pesticide application
‘Strategic cocoa pesticides’ addresses only the qualitative issue of AI selection, but levels of residue require more attention to application methods and timing. Application techniques and pesticide selection received much attention and extensive research in the 1970s and 80s, but then went out of favour. There is now high-level recognition that supply problems of agricultural commodities in general (not just cocoa) are partly due to neglect of research for at least 15 years11. Your attention is drawn to comments made in sections B and C4.

F4 Better communication
Pesticides have been “off the agenda” not only in research, but also in many farmer training initiatives. Rational and scientific pesticide use must be put back on these curricula. Although the de-emphasis of pesticides in publicly-funded programmes is highly understandable, the loss of pesticide-use skills at the farm and extension service levels has been alarming. Booklets such as this and farmer training programmes can only provide guidance - they will only be truly effective under a proactive implementation policy framework in cocoa growing countries.
Box F1
Criteria for listing pesticides in Appendices 3a-d

In the first edition, pesticides were divided into ‘positive’ and ‘negative’ lists, with reference to the new EU legislation. This has proved over-simplistic and impossible to maintain with the new wider geographical scope. For this and future editions Appendix 3 will therefore be divided into four categories:

A. Lists of strategic/recorded pesticides for use in cocoa which:
   - are known to be on 91/414/EC Annex 1 and have Japanese/US import tolerances; EU MRL’s (mg.kg⁻¹) remain tMRLs and their status should be checked regularly; those listed here refer to “Cocoa (fermented beans)” as in Reg. (EC) No 396/2005.
   - show acceptable levels of low mammalian toxicity and environmental impact and do not belong to the highest toxicity group WHO/EPA Class I.
   - have proven efficacious against an important pest species of cocoa, as published in (preferably refereed) literature

B. Compounds to be used with great CAUTION (limited time span, etc).
These active substances:
   - have MRLs in some markets, but not others and/or …
   - are likely to be phased out within 2–3 years, but …
   - have shown demonstrable efficacy in at least one regional cocoa growing country
   - do not belong to WHO/EPA toxicity Class I

C. Lists of experimental control agents for possible future inclusion in category ‘A’.
These control agents:
   - are known to be on 91/414/EC Annex 1 pending, or likely to be submitted;
   - are subject to current field testing and may well conform to criteria in category ‘A’
   - do not belong to WHO/EPA toxicity Class I and are preferably in Class III or better

D. Pesticides that MUST NOT BE USED FOR COCOA
These have been recorded as used on cocoa (e.g. by the ECA/CAOBISCO project), but have been rejected by major importing countries (usually for toxicological/ ecotoxicological reasons) and have no residue tolerances in major markets.

Notes:
1. Trade names are not used in this edition and several products contain mixtures of AI.
2. Compounds for inclusion continue to be reviewed, and special care should be taken with any compound that remains on the “pending” list.
3. For historical reasons, a number of compounds are recorded as being used on cocoa and have MRL values that are above the default value, yet are not on the list of substances on Annex 1. It is important to appreciate that the authorisation of a pesticide on the EU market (Dir. 91/414/EEC) and the harmonised pesticide residue legislation (396/2005/EC, which includes MRLs for imported cocoa) are essentially two separate legal issues.
4. In principle, procurement agencies and cocoa growers are encouraged to consider carefully any products containing any AI listed in Appendix 3B and they should not be developed for new markets. However this list is a “mixed bag” of compounds that include those:
   - that have import tolerances in some markets
   - for which no company has considered it economic to prepare and submit an adequate dossier for inclusion in Annex 1 in the EU.
   - which have been rejected, but tMRL have been set in the interests of cocoa production and market competition, where a case has been made for continued use of compounds that are popular amongst farmers (e.g. unresolved metalaxyl products¹⁰, which are known to be very useful for control of cocoa black pod).
F5 National and regional action

In this edition reference is specifically made to West African problems. There is clearly a need to strengthen procedures and recommendations with producer country registration authorities. Specific guidelines on the distribution and use of pesticides are freely available from organisations such as FAO (http://www.fao.org/ag/AGP/AGPP/Pesticid/p.htm). Cocoa growing countries need pesticide scientists with up-to-date training, capable of foreseeing issues before they arise.

National organisations understood to be primarily responsible for pesticide registrations are:

Brazil: Ministério da Agricultura, Brasília
Cameroon: Ministry of Agriculture and Rural Development (MINADER) (Department of Regulation and Quality Control of Inputs and Agricultural Products)
Côte d'Ivoire: Direction de la Protection des Végétaux, du Contrôle et de la Qualité, Ministère de l’Agriculture (DPVCQ/MINAGRI), Abidjan
Dominican Republic: Mostly organic production
Ecuador: Programa Nacional de Sanidad Vegetal, Ministerio de Agricultura y Ganadería, Quito
Ghana: Environmental Protection Agency (Ministry of Food and Agriculture), Accra
Indonesia: Direktorat Jenderal Perlingdungan Tanaman Pangan, Departemen Pertanian, Jakarta
Malaysia: Pesticides Board, Ministry of Agriculture, Kuala Lumpur
Nigeria: National Agency for Food and Drug Administration and Control (NAFDAC) HQ: Abuja; cocoa issues: Lagos office
Togo: Laboratoire de l’Institut Togolais de Recherche Agronomique (ITRA)

Your attention is drawn to comments made in section A6 concerning the avoidance of obsolete pesticide stocks. You are reminded that, for cocoa to be exported to the EU and elsewhere, the use of inappropriate pesticides must be phased-out as quickly as possible.

ACKNOWLEDGEMENTS

Several diagrams in this manual are courtesy of CropLife International - the industry association that places information on PPE, safe use of pesticides, storage, etc. in the public domain (http://www.croplife.org). I also thank Jean-Ponce Assi, Jerry Cooper, Hans Dobson, FERA UK, Marc Joncheere and Graham Matthews for other illustrations.

I am most grateful for all the helpful advice and suggestions that I have received to date from: Jean Marc Anga, Isabelle Adam, Victor Adjei, Pénélope Alexandre, Colin Campbell, Henri Diserens, Hans Dobson, Michelle End, Martin Gilmour, Helmut Guenther, Prakash Hebbar, Marc Joncheere, Marianne Lindblom, Graham Matthews, Mike Rutherford, Phil Sigley and Claudine van de Meulebroucke.

Our sponsors have provided funds for this work in order to promote international development and cocoa sustainability. The views and recommendations expressed here are given in the spirit of free exchange of information and ideas. Whereas every care has been taken to ensure accuracy throughout, we cannot take any legal responsibility for any errors or omissions in this manual. Any such errors are the sole responsibility of the author, who would of course welcome any comments and suggestions for use in future editions.
# APPENDIX 1

## Acronyms

The following table lists some technical terms and abbreviations used in pesticide science. A more comprehensive list is given in “Understanding the Acronyms” in the DROPDATA download section.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADI</td>
<td>Acceptable Daily Intake</td>
</tr>
<tr>
<td>AI, ai</td>
<td>active ingredient</td>
</tr>
<tr>
<td>ALARA</td>
<td>As Low As Reasonably Achievable</td>
</tr>
<tr>
<td>AOEL</td>
<td>Acceptable Operator Exposure Level</td>
</tr>
<tr>
<td>ARfD</td>
<td>acute reference dose</td>
</tr>
<tr>
<td>as</td>
<td>active substance</td>
</tr>
<tr>
<td>c</td>
<td>centi-(x 10^{-2}) – as in centimetre (cm)</td>
</tr>
<tr>
<td>CDA</td>
<td>controlled droplet application</td>
</tr>
<tr>
<td>CNS</td>
<td>central nervous system</td>
</tr>
<tr>
<td>CMR</td>
<td>substances that are carcinogenic, mutagenic or toxic to reproduction</td>
</tr>
<tr>
<td>CXL</td>
<td>Codex Maximum Residue Limit (Codex MRL)</td>
</tr>
<tr>
<td>DT_{50}</td>
<td>period required for 50 percent dissipation (define method of estimation)</td>
</tr>
<tr>
<td>g</td>
<td>gram</td>
</tr>
<tr>
<td>GAP</td>
<td>Good Agricultural Practice(s)</td>
</tr>
<tr>
<td>GMP</td>
<td>Good Manufacturing Practice(s)</td>
</tr>
<tr>
<td>GWP</td>
<td>Good Warehouse Practice(s)</td>
</tr>
<tr>
<td>GLC</td>
<td>gas liquid chromatography</td>
</tr>
<tr>
<td>GLP</td>
<td>good laboratory practice</td>
</tr>
<tr>
<td>GMO</td>
<td>genetically modified organism</td>
</tr>
<tr>
<td>GSP</td>
<td>good storage practice</td>
</tr>
<tr>
<td>ha</td>
<td>hectare (10^4 m^2)</td>
</tr>
<tr>
<td>HACCP</td>
<td>Hazard Analysis Critical Control Point (usu. food processing)</td>
</tr>
<tr>
<td>HPLC</td>
<td>high performance liquid chromatography (sometimes high pressure ~)</td>
</tr>
<tr>
<td>HV</td>
<td>high volume</td>
</tr>
<tr>
<td>IPM</td>
<td>integrated pest management</td>
</tr>
<tr>
<td>IRM</td>
<td>insecticide resistance management</td>
</tr>
<tr>
<td>JMPR</td>
<td>Joint FAO/WHO Meeting on Pesticide Residues (Codex Alimentarius)</td>
</tr>
<tr>
<td>k</td>
<td>kilo (10^3) thus Kg - kilogram</td>
</tr>
<tr>
<td>K_{oc}</td>
<td>organic carbon adsorption coefficient</td>
</tr>
<tr>
<td>K_{OH}</td>
<td>hydroxyl radical rate constant</td>
</tr>
<tr>
<td>K_{om}</td>
<td>organic matter adsorption coefficient</td>
</tr>
<tr>
<td>K_{OW}</td>
<td>octanol water partition coefficient</td>
</tr>
<tr>
<td>L</td>
<td>Litre</td>
</tr>
<tr>
<td>LC_{50}</td>
<td>lethal concentration, median</td>
</tr>
<tr>
<td>LD_{50}</td>
<td>median lethal dose; \textit{dosis letalis media}</td>
</tr>
<tr>
<td>LOAEL</td>
<td>lowest observable adverse effect level</td>
</tr>
<tr>
<td>LOD</td>
<td>limit of determination - has also been used for “limit of detection”</td>
</tr>
<tr>
<td>LOEC</td>
<td>lowest observable effect concentration</td>
</tr>
<tr>
<td>LOEL</td>
<td>lowest observable effect level</td>
</tr>
<tr>
<td>LOQ</td>
<td>limit of quantification</td>
</tr>
<tr>
<td>LV</td>
<td>low volume</td>
</tr>
<tr>
<td>µg</td>
<td>microgram (10^{-6} g)</td>
</tr>
</tbody>
</table>
APPENDIX 2

Acute Toxicity Classification

i. The World Health Organisation (WHO) classification

(LD$_{50}$ to rats mg/kg body weight: of formulations where information is available)

<table>
<thead>
<tr>
<th>Class</th>
<th>Solids Oral</th>
<th>Solids dermal</th>
<th>Liquids oral</th>
<th>Liquids dermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia</td>
<td>≥ 5</td>
<td>≤ 10</td>
<td>≤ 20</td>
<td>≤ 40</td>
</tr>
<tr>
<td>Ib</td>
<td>6-50</td>
<td>11-100</td>
<td>21-200</td>
<td>41-400</td>
</tr>
<tr>
<td>II</td>
<td>51-500</td>
<td>101-1000</td>
<td>201-2000</td>
<td>401-4000</td>
</tr>
<tr>
<td>III</td>
<td>≥ 501</td>
<td>≥ 1001</td>
<td>≥ 2001</td>
<td>≥ 4001</td>
</tr>
<tr>
<td>(U)</td>
<td>&gt; 2000</td>
<td>-</td>
<td>&gt; 3000</td>
<td>-</td>
</tr>
</tbody>
</table>

ii. The US Environmental Protection Agency (EPA) system

<table>
<thead>
<tr>
<th>Class</th>
<th>All formulations: LD$_{50}$ (mg/kg) oral</th>
<th>Inhalation: LC$_{50}$ (mg/l) dermal</th>
<th>Eye effects</th>
<th>Skin effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>≤ 50</td>
<td>≤ 20</td>
<td>Corrosive, corneal opacity not reversible within 7 days</td>
<td>Corrosive</td>
</tr>
<tr>
<td>II</td>
<td>51-500</td>
<td>201-2000</td>
<td>Corneal opacity not reversible within 7 days, irritation persisting for 7 days</td>
<td>Severe irritation at 72 hours</td>
</tr>
<tr>
<td>III</td>
<td>501-5000</td>
<td>2001-20,000</td>
<td>No corneal opacity, irritation reversible within 7 days</td>
<td>Moderate irritation at 72 hours</td>
</tr>
<tr>
<td>IV</td>
<td>&gt; 5000</td>
<td>&gt; 20,000</td>
<td>No irritation</td>
<td>Mild or slight irritation at 72 hours</td>
</tr>
</tbody>
</table>
APPENDIX 3

3A Lists of strategic / recorded pesticides for use in cocoa

All these AIs:
- are known to be on 91/414/EEC Annex 1 ($^Y$, or pending - P); see box F1
- EU MRL$^\alpha$ (mg.kg$^{-1}$) remain tMRL$^\alpha$ and their status should be checked regularly; those listed here refer to “Cocoa (fermented beans)” as in Reg. (EC) No 396/2005.
- have shown demonstrable efficacy in at least one regional cocoa growing country
- do not belong to WHO/EPA toxicity Class I

(i) black pod diseases

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>benalaxyl</td>
<td>A1</td>
<td>$^Y$</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>copper hydroxide</td>
<td>M1</td>
<td>$^Y$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>copper oxide</td>
<td>M1</td>
<td>$^Y$</td>
<td>50.0</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>copper oxychloride</td>
<td>M1</td>
<td>$^Y$</td>
<td></td>
<td>$\alpha$</td>
</tr>
<tr>
<td>fosetyl aluminium</td>
<td>P</td>
<td>$^Y$</td>
<td>2.0</td>
<td>0.05</td>
</tr>
<tr>
<td>metalaxyl-M (mefenoxam)</td>
<td>A1</td>
<td>$^Y$</td>
<td>0.1</td>
<td>0.02</td>
</tr>
</tbody>
</table>

(ii) insects

As sprays (mostly against mirids)

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetamiprid</td>
<td>4A</td>
<td>$^Y$</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>beta-cyfluthrin</td>
<td>$\beta$</td>
<td>3</td>
<td>$^Y$</td>
<td>0.1</td>
</tr>
<tr>
<td>cypermethrin ($\alpha$ isomer - $\beta$)</td>
<td>3</td>
<td>$^Y$ *</td>
<td>0.1</td>
<td>0.03</td>
</tr>
<tr>
<td>deltamethrin ($\beta$)</td>
<td>3</td>
<td>$^Y$</td>
<td>0.05</td>
<td>0.05 $\delta$</td>
</tr>
<tr>
<td>dimethoate</td>
<td>1B</td>
<td>$^Y$</td>
<td>0.05</td>
<td>0.05 $\delta$</td>
</tr>
<tr>
<td>imidacloprid</td>
<td>4A</td>
<td>$P$</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>lambda-cyhalothrin</td>
<td>$\beta$</td>
<td>3</td>
<td>$^Y$ *</td>
<td>0.05</td>
</tr>
<tr>
<td>thiamethoxam</td>
<td>4A</td>
<td>$^Y$</td>
<td>0.05</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Termite control

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>fipronil $\gamma$</td>
<td>$^\beta$</td>
<td>2</td>
<td>$P$</td>
<td>0.005 $\gamma$</td>
</tr>
</tbody>
</table>

(iii) weeds

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D dimethylamine salt</td>
<td>O</td>
<td>$^Y$</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>glyphosate trimesium</td>
<td>G</td>
<td>$^Y$</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>glyphosate isopropylamine</td>
<td>G</td>
<td>$^Y$</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

(iv) stored produce

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminium phosphide</td>
<td>24</td>
<td>$^Y$</td>
<td>0.05</td>
<td>0.01 (as hydrogen phosphide)</td>
</tr>
<tr>
<td>magnesium phosphide</td>
<td>24</td>
<td>$^Y$</td>
<td>0.05</td>
<td>0.01 (as hydrogen phosphide)</td>
</tr>
<tr>
<td>pyrethrins (pyrethrum) for fogging</td>
<td>3</td>
<td>$^Y$</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>pyrethroids (treating sacks, etc.)</td>
<td>3</td>
<td>if Yes as above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* High residue levels have been found in imported produce to the EU and/or Japan
$\alpha$ No MRL given in Japan and copper is exempt in the USA: see box B1
$\beta$ Registered (widely used) for cocoa pod borer control in Indonesia
$\gamma$ Fipronil (sum fipronil + sulfone metabolite [MB46136] expressed as fipronil)
$\delta$ Includes deltamethrin and tralomethrin (as total)
**3B Compounds to be used with great CAUTION (limited time span, restricted markets, etc.)**

These AIs:
- have permitted MRLs in some markets, but not others and/or …
- many of these are temporary (tMRL\(^2\)) and are likely to be phased out within 2-3 years, but …
- have shown demonstrable efficacy in at least one regional cocoa growing country
- do not belong to WHO/EPA toxicity Class I

(i) black pod diseases

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>metalaxyl (unresolved)</td>
<td>A1</td>
<td>Y</td>
<td>0.1 (T)</td>
<td>until 06/2010 (all isomers)</td>
</tr>
</tbody>
</table>

(see Box B1)

(ii) insects

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>bifenthrin</td>
<td>3</td>
<td>N</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>diazinon</td>
<td>1B</td>
<td>N</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>chloryprifos (ethyl)</td>
<td>1B</td>
<td>Y *</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>fenithrothion</td>
<td>1B</td>
<td>N</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>fenvalerate</td>
<td>3</td>
<td>N *</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>fenobucarb (BPMC)</td>
<td>1A</td>
<td>N *φ</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>isoprocarb (MIPC)</td>
<td>1A</td>
<td>N ø</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>malathion</td>
<td>1B</td>
<td>N *</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>pirimiphos methyl</td>
<td>1B</td>
<td>Y *ε</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

(iii) weeds

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU tMRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>picloram</td>
<td>O</td>
<td>Y</td>
<td>0.01 (T)</td>
<td></td>
</tr>
</tbody>
</table>

(iv) stored produce

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>bioresmethrin</td>
<td>3</td>
<td>N</td>
<td>0.01</td>
<td>0.1</td>
</tr>
<tr>
<td>methyl bromide</td>
<td>8</td>
<td>P µ</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

(as inorganic bromide ion) 70.0

* High residue levels have been found in imported produce to the EU and/or Japan

β Registered for cocoa pod borer control in Indonesia

ε Use of pirimiphos methyl in cocoa is not defended by Syngenta. Zero tolerance (LOD) for this AI in Australia; EU MRL is 0.05 mg.kg\(^{-1}\)

μ Restricted under the Montreal Protocol
### 3C Lists of experimental control agents for possible future inclusion under Appendix 3A

All these AIs:
- are known to be on 91/414/EEC Annex 1 (Y, or pending - P).
- are subject to current or recent field testing and may well conform to criteria in category ‘3A’, when it is established that they conform to criteria in box F1
- do not belong to WHO/EPA toxicity Class I

#### (i) black pod diseases

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>dimethomorph</td>
<td>F5</td>
<td>Y</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>iprovalicarb</td>
<td>F5</td>
<td>Y</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>mandipropanamid</td>
<td>F5</td>
<td>P</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

Other MoA groups to consider testing:
- B3, B5, C3 (strobilurins), C4 (QiI fungicides), U5
- MCAs such as *Trichoderma* spp.

#### (ii) insects

**a. mirids (including *Helopeltis* spp.)**

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU status</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>emamectin benzoate</td>
<td>6</td>
<td>P</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>thiacloprid</td>
<td>4A</td>
<td>Y</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>clothianidin</td>
<td>4A</td>
<td>P</td>
<td>0.05</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**IGRs:**
- novaluron: 15 P 0.01 0.02
- teflubenzuron: 15 Y 0.05 0.02
- spiromesifen: 23 P 0.02
- spirotetramat: 23 P 0.1

**b. cocoa pod borer**

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>emamectin benzoate</td>
<td>6</td>
<td>P</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**IGRs:** novaluron, teflubenzuron, methoxyfenozide: 18 Y 0.05
- granulosis viruses? MCA -

#### (iii) weeds

**Active ingredients**

<table>
<thead>
<tr>
<th>MoA group</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Safer contact herbicides required?

#### (iv) stored produce

**Active ingredients**

<table>
<thead>
<tr>
<th>MoA group</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sulfuryl fluoride</th>
<th>EU MRL</th>
<th>JP MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>
# 3D Pesticides that MUST NOT BE USED for cocoa

<table>
<thead>
<tr>
<th>Active ingredients</th>
<th>MoA group</th>
<th>EU, MRL status § and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insecticides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>acephate</td>
<td>1B</td>
<td>N</td>
</tr>
<tr>
<td>amitraz</td>
<td>19</td>
<td>N Ј</td>
</tr>
<tr>
<td>aldrin</td>
<td>2</td>
<td>N Class 1</td>
</tr>
<tr>
<td>azinphos-methyl</td>
<td>1B</td>
<td>N Class 1</td>
</tr>
<tr>
<td>cabaryl</td>
<td>1A</td>
<td>N</td>
</tr>
<tr>
<td>carbosulfan</td>
<td>1A</td>
<td>N</td>
</tr>
<tr>
<td>cartap</td>
<td>4C</td>
<td>N</td>
</tr>
<tr>
<td>cyhalothrin (unresolved)</td>
<td>3</td>
<td>N α</td>
</tr>
<tr>
<td>cyhexatin (acaricide)</td>
<td>12B</td>
<td>N Ј</td>
</tr>
<tr>
<td>DDT</td>
<td>3</td>
<td>N І (may be used for IRS)</td>
</tr>
<tr>
<td>dichlorvos (DDVP)</td>
<td>1B</td>
<td>N Class 1</td>
</tr>
<tr>
<td>dieldrin</td>
<td>2</td>
<td>N Class 1</td>
</tr>
<tr>
<td>dioxacarb</td>
<td>1A</td>
<td>N</td>
</tr>
<tr>
<td>endosulfan</td>
<td>2</td>
<td>N (MRL 0.1 mg/kg) * Class 1</td>
</tr>
<tr>
<td>lindane, gamma BHC, HCH</td>
<td>2</td>
<td>N * І</td>
</tr>
<tr>
<td>methyl-parathion (= parathion-methyl)</td>
<td>1B</td>
<td>N * І Class 1</td>
</tr>
<tr>
<td>methomyl</td>
<td>1A</td>
<td>N І Class 1</td>
</tr>
<tr>
<td>monocrotophos</td>
<td>1B</td>
<td>N І Class 1</td>
</tr>
<tr>
<td>profenfos</td>
<td>1B</td>
<td>N</td>
</tr>
<tr>
<td>promecarb</td>
<td>1A</td>
<td>N Class 1</td>
</tr>
<tr>
<td>propoxur</td>
<td>1A</td>
<td>N</td>
</tr>
<tr>
<td>terbufos</td>
<td>1B</td>
<td>N Class 1</td>
</tr>
<tr>
<td><strong>Herbicides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ametryn</td>
<td>C1</td>
<td>N</td>
</tr>
<tr>
<td>atrazine</td>
<td>C1</td>
<td>N</td>
</tr>
<tr>
<td>diuron</td>
<td>O</td>
<td>N*</td>
</tr>
<tr>
<td>fomesafen</td>
<td>E</td>
<td>N</td>
</tr>
<tr>
<td>MSMA (methyl arsenic acid)</td>
<td>Z</td>
<td>N</td>
</tr>
<tr>
<td>2,4,5-T</td>
<td>O</td>
<td>N І</td>
</tr>
<tr>
<td><strong>Fungicides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>benomyl</td>
<td>B1</td>
<td>N δ</td>
</tr>
<tr>
<td>captafol</td>
<td>M4</td>
<td>N І Ј</td>
</tr>
<tr>
<td>hexaconazole</td>
<td>G1</td>
<td>N</td>
</tr>
<tr>
<td>pyrifl演示n</td>
<td>G1</td>
<td>N</td>
</tr>
<tr>
<td>triadimefon</td>
<td>G1</td>
<td>N</td>
</tr>
<tr>
<td>tridemorph</td>
<td>G2</td>
<td>N</td>
</tr>
<tr>
<td>zineb</td>
<td>M3</td>
<td>N</td>
</tr>
</tbody>
</table>

Appendix 3b (continued)
 Stored produce

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Code</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>allethrin (esbiothrin)</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>fenitrothion</td>
<td>1B</td>
<td>N</td>
</tr>
<tr>
<td>isoprocarb (MIPC)</td>
<td>1A</td>
<td>not listed Ø</td>
</tr>
<tr>
<td>permethrin</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>resmethrin</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>tetramethrin</td>
<td>3</td>
<td>N</td>
</tr>
</tbody>
</table>

* High residue levels have been found, within the last 5 years, in imported produce to the EU and/or Japan

Cocoa growers are strongly advised to stop using any products containing any AI listed here. Where they have been used in the past for cocoa pests, there should be satisfactory substitutes for them now recommended: if this is not the case please notify the author.

They include:
- obsolete and banned compounds (e.g. aldrin, lindane).

α Note: as with metalaxyl, unresolved cyhalothrin is not included on Annex 1, but the isomer lambda-cyhalothrin (used for mirid control) is included.

§ compounds not included on 91/414/EEC Annex 1 and are not thought to be essential for cocoa production.

Ĵ Compounds specifically listed at LOD for cocoa in Japan

Φ Pesticides listed in the PIC Convention

Ø P pesticides are used outside the EU but for which no toxicological data and no MRLs have been notified for inclusion in 396/2005/EC Annex III (neither by the member states, in the form of import tolerances, nor by third countries). Such compounds may have a clear purpose outside Europe (e.g. fenobucarb and isoprocarb: which are widely used for control of hemipteran pests of rice in Asia, and have also been applied to cocoa in certain countries).

β Also breakdown product of thiodicarb

δ Breaks down into the permitted compound carbendazim

These lists may not be exhaustive: they have been based on ICCO records and the findings of the ECA/CABI/CAOBISCO project (Global Research on Cocoa, June 2008).
APPENDIX 4

Web sites of organisations providing further information

CAB International http://www.cabi.org/index.asp
Certification bodies involved with cocoa traceability and GAP:
The Fairtrade Foundation http://www.fairtrade.net
The Rainforest Alliance http://www.rainforest-alliance.org
UTZ CERTIFIED http://www.utzcertified.org

Codex Alimentarius official standards http://www.codexalimentarius.net/web/standard_list.jsp
pesticide MRLs http://www.codexalimentarius.net/mrls/pestdes/jsp/pest_q-e.jsp

Cocoa Merchants Association of America (CMAA) http://www.cocoamERCHANTS.com/
COLEACCP (horticultural GAP project) http://www.coleacp.org/
CropLife International http://www.croplife.org/
European Cocoa Association (ECA) www.eurococoa.com

European Commission (Directorate General for Development and Directorate General for Health and Consumer Affairs [DG SANCO])
EU Food safety http://ec.europa.eu/food/index_en.htm
EU Agriculture: http://ec.europa.eu/dgs/agriculture/index_en.htm
EU legislation on MRLs: http://ec.europa.eu/food/plant/protection/pesticides/index_en.htm

USDA Foreign Agricultural Service report
(useful overview about implementation of 396/2005 - 17 January 2008).
http://useu.usmission.gov/agri/pesticides.html#New%20EU%20Maximum%20Residue%20Legislation

European Food safety Agency http://www.efsa.eu.int/
European Initiative for the Sustainable development in Agriculture (EISA)
http://www.sustainable-agriculture.org/start.html

European and Mediterranean Plant Protection Organization (EPPO) http://www.eppo.org/
Food and Agriculture Organisation (FAO) http://www.fao.org/
Understanding the Codex http://www.fao.org/docrep/w9114e/W9114e04.htm
Global Forum on Agricultural Research (GFAR): (enhancing national capacities to adapt and transfer knowledge: hosted by FAO) http://www.egfar.org/
JMPR: technical monographs http://www.inchem.org/pages/jmpr.html

Federation of Cocoa Commerce (FCC) http://www.cocoa federation.com/
Health & Safety Executive (UK - formerly PSD)
http://www.pesticides.gov.uk/food_safety.asp?id=726

International Cocoa Organisation (ICCO) http://www.icco.org/
International Pesticide Application Research Centre (IPARC)  http://www.dropdata.org
Guidelines on cocoa pests and IPM:  http://www.dropdata.org/cocoa/cocoa_prob.htm
Japan MRL list was (updated February 2007):  
Mars Inc. (sustainability team)  http://www.cocoasustainability.mars.com
Organic production - IFOAM  http://www.ifoam.org/
Pesticide residue analysis (contract) available from:  
http://www.cemas.co.uk/residues.html  
http://www.csl.gov.uk/aboutCsl/scienceGroupsAndTeams/fsg/pesticides/index.cfm
Resistance Action Committees: useful for MoA classification & information about resistance  
Fungicides  http://www.frac.info/frac/index.htm 
Herbicides  http://www.plantprotection.org/HRAC 
Insecticides  http://www.irac-online.org/ 
Rodenticides  http://www.rrac.info/
Roundtable for Sustainable Cocoa (RSCE-3)  http://www.roundtablecocoa.org
Sustainable Tree Crops Programme (STCP)  http://www.treecrops.org/crops/cocoa.asp
USA: Food and Drug Administration (FDA) - guidance (2005) on pesticide residues:  
http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/Pesticides/default.htm 
Environmental Protection Agency (EPA) Food Quality Protection Act (FQPA, 1996):  
http://www.epa.gov/opp00001/regulating/laws/fqpa/backgrnd.htm
World Health Organisation (WHO)  http://www.who.int/en/ 
Guidelines for predicting dietary intake of pesticide residues  
http://www.who.int/foodsafety/publications/chem/pesticides/en/

Selected References

4 Tomlin, C (Ed. 2007) The Pesticide Manual 14th Ed. BCPC, Alton, UK
6 Entwistle, PF, Johnson, CG, Dunn, E. (1959) Nature (Lond) 184: 2040