A short guide

Alternatives to Highly Hazardous Pesticides

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PESTICIDE ACTION NETWORK UK · UNEP · IRET · saicm · UNA UNIVERSIDAD NACIONAL COSTA RICA

October 2017

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This document was written as part of the SAICM QSP project on 'Highly Hazardous Pesticides phase out and alternatives in Costa Rica'. The project was kindly funded by the Quick Start Program of the Strategic Approach to International Chemicals Management and coordinated by the Regional Institute of Studies on Toxic Substances (IRET) at the National University of Costa Rica (UNA). PAN UK provided technical support and international liaison.

IRET and PAN UK, 2017.

Preface

This booklet provides readers with information about:

- alternative methods to Highly Hazardous Pesticides for managing pests, crop diseases and weeds in different crops and regions of the world
- phasing out Highly Hazardous Pesticides and replacing them with safer and sustainable alternatives is possible, technically and economically
- how alternatives can be put into practice

The first section provides a very brief introduction to the Highly Hazardous Pesticide initiative from the UN agencies and its support by Pesticide Action Network (PAN) International and others. The second section explains some basic considerations about phasing out HHPs and how stakeholders can support this process. The third section describes examples of alternative methods for specific HHPs and gives several case studies from coffee, cotton, horticulture and cereal production in tropical and temperate regions. These include two pilot trials undertaken in pineapple and coffee farms during 2015-2016 as part of the project **Highly Hazardous Pesticides phase out and alternatives in Costa Rica**. This project is funded by the Quick Start Program of the Strategic Approach to International Chemicals Management (SAICM) and runs from 2015-2017.

Image front cover: Applying pesticide on large coffee farm, Costa Rica. Credit: IRET-UNA

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Introduction to Highly Hazardous Pesticides (HHPs)

The need to take action on HHPs is recognised

While dozens of older, harmful pesticides, such as DDT and lindane, have now been banned or severely restricted, many hazardous substances remain in widespread use. In 2006, the UN organisations on Food and Agriculture (FAO) and World Health (WHO) drew attention to continuing problems of poisoning incidents and pesticide-related ill health and environmental harm, especially in developing countries, despite government controls and agrochemical industry efforts to avoid risky practices and promote so-called 'safe use'. In response, the UN policy makers called for concerted action on Highly Hazardous Pesticides (HHPs), including ways to reduce exposure and risks, as well as further bans.[1] In 2016, FAO and WHO published their *Guidelines on Highly Hazardous Pesticides* under the International Code of Conduct on Pesticide Management.[2]

Also in 2006 the *Strategic Approach to International Chemical Management* (SAICM) set the scene for new concerted actions on harmful side effects of chemicals in general. This global strategy aims to achieve sound management of chemicals throughout their lifecycle. It constitutes a political commitment on the part of governments, chemical and pesticide manufacturers, civil society organisations and others to minimize significant adverse effects on human health and the environment by 2020. The 2015 SAICM meeting recognised highly hazardous pesticides as an issue of concern, acknowledging that they "cause adverse human health and environmental effects in many countries, particularly in low-income and middle-income countries", supporting concerted action to address them, and encouraging an emphasis on promoting agroecologically-based alternatives.[3]

In 2017, UN experts serving as Special Rapporteurs for the right to food and on toxics called for a comprehensive new global treaty to regulate and phase out the use of dangerous pesticides in farming, and move towards sustainable agricultural practices.[4] They noted that "excessive use of pesticides are very dangerous to human health, to the environment and it is misleading to claim they are vital to ensuring food security."

Which pesticides qualify as HHPs?

A definitive list of which pesticides qualify as HHPs has not yet been developed by FAO and WHO. However, UN agencies recognise the need to include not only the most acutely toxic pesticides but also those with chronic effects on human health, or those that are very persistent in the environment or in the tissues of organisms, including humans. There is agreement that pesticides listed in the Stockholm POP and Rotterdam PIC conventions and Montreal Protocol on ozone depletion should qualify, as well as pesticide active ingredients and formulations that have shown a high incidence of severe or irreversible adverse effects on human health or the environment.

PAN International warmly welcomed the HHP initiative and in 2009 published its first *List of Highly Hazardous Pesticides*. In addition to pesticides listed in the international chemical conventions, this includes pesticides classified by internationally recognised authorities under four types of hazard:

- Acutely toxic to humans via swallowing, skin contact or inhalation
- Long-term human health hazards related to cancer, birth defects and reproductive harm, disruption of hormone systems or damage to genetic material
- Environmental hazards (persistent in soil or water; ability to accumulate in the food chain; highly toxic to bees; toxic to aquatic organisms)
- Recognised as causing serious or irreversible harm under actual conditions of use in a particular country

More detailed explanation of the hazard criteria and classifications selected by PAN International is given in the PAN International

HHP List, which has been updated several times.[5] The latest version (Dec. 2016) includes almost 300 pesticides. A short explanatory leaflet on HHPs is available via PAN Germany's web pages on HHPs, along with a list of HHPs banned in different countries and other information.[6]

The Costa Rica project booklet on HHPs includes a detailed explanation of the HHP hazard criteria in the Central American context and the need for national action plans for reducing and eliminating HHPs.[7] It lists 117 HHPs documented as used in Costa Rica during 2009-2015. For example, 23 pesticides in national use are suspected to disrupt hormone signalling; 21 are extremely or highly hazardous due to acute mammalian toxicity; 36 are classified as known or probable carcinogens; and 7 are reproductive toxins and/or damage genetic material (mutagens). For environmental hazards, 1 pesticide in use is bioaccumulative in animal tissues, 5 are very persistent in soil or water, 10 are very toxic to aquatic organisms; and 47 are highly toxic to bees.

Phasing out HHPs makes economic, environmental and social sense

The need to reduce the levels of pesticide-related health caused by HHPs is obvious. The UN's recent report estimates 200,000 acute poisoning deaths each year, with most fatalities occurring in developing countries where health, safety and environmental regulations are weaker.[8] Farmers and agricultural workers, communities living near plantations, indigenous communities and pregnant women and children are particularly vulnerable to pesticide exposure and require special protections. The report highlights that pesticide impacts on health are a human rights concern, as well as a public health issue.

There is scant data on the level of chronic health problems related to pesticide exposure, either directly or via contaminated food and drink, but there is reliable scientific evidence that some cancers, hormonal and neurological disorders such as Parkinson's disease can be linked to the use of certain pesticides in agricultural production.[9] Children are particularly at risk and extremely low levels of pesticide exposure can cause significant harm, particularly during pregnancy and early childhood. Pesticide exposure contributes to some of the rising incidence of childhood cancer, birth defects and early puberty, childhood asthma, obesity and diabetes documented in the US and other developed countries.[10]

Increasing reliance on pesticides is accompanied by environmental contamination problems, acute or chronic harm to exposed wildlife, livestock and beneficial organisms. In 2014 international scientists in the Task Force on Systemic Pesticides concluded that neonicotinoid and other systemic insecticides have serious negative impacts on pollinators and other terrestrial and aquatic invertebrates, amphibians and birds as well as cause significant damage to ecosystem functioning and services.[11] Serious declines in biodiversity are linked with increased use of pesticides, along with other practices in modern, intensive farming.[12] The first comprehensive global evaluation of insecticide contamination data for agricultural surface waters found that more than 50% of samples exceeded legally accepted threshold levels and pose major threats to aquatic biodiversity.[13]

Highly risky pesticide mixing practice by a small-scale coffee farmer. Credit: IRET/UNA, Costa Rica

The hidden costs of reliance on HHPs

Apart from better protection of human health and the environment, there are good economic reasons for looking to phase out specific HHPs in different crops, as well as to reduce pesticide use in general. Farmers and policymakers may not be aware that unintended side-effects of applying pesticides, especially HHPs, generate considerable financial costs. These hidden costs are not reflected in the price of pesticide products and are often 'paid' by exposed communities, farm workers, public health services and society in general. The UN Environment Program estimates that the economic costs related to African smallholder farmers' pesticide use in terms of acute ill health problems will reach US$97 billion by 2020.[14] In the Brazilian state of Paraná, each US$ spent on pesticides is estimated to generate US$1.28 in acute health costs.[15]

Some economic costs of over-reliance on pesticide methods directly harm the farmer's pocket:

Pesticide resistance problems:

Pests, diseases or weeds developing resistance to specific pesticides used against them continues to be a major problem, triggered by over-reliance on chemical control tactics. One notable current example is glyphosate-resistant weeds in US and Canadian genetically-modified herbicide-tolerant crops (maize, soya, cotton) where high levels of glyphosate application for many seasons has provoked a crisis in weed management for many farmers, with control becoming ever more expensive.[16,17] Another current crisis is in Indian and Pakistani cotton where excessive and badly managed insecticide regimes have led to hugely damaging whitefly outbreaks, partly associated with cultivating B.t. cotton cultivars that are very susceptible to sucking pests.[18] Rather than focussing on rotating different chemical groups to try and delay resistance development, reducing reliance on pesticides and phasing in more Integrated Pest Management (IPM) methods is the best way to reduce the risks from and economic costs of hard-to-control pests.

Disruption of beneficial organisms:

Many pesticides (including some fungicides and herbicides) can harm the many different types of insect and other types of natural enemies (spiders, frogs, bats, birds) which prey on or parasitise crop pests. Natural pest control services have been estimated to save $13.6 billion per year in agricultural crops in the US.[19] Pollinators and other beneficial organisms provide essential ecosystem services such as crop pollination and soil nutrient cycling -these are often overlooked but economically valuable for farmers and the longer-term productive potential of their land. Many wild pollinators and beneficial soil-dwelling microbes are very susceptible to pesticides, by direct contact or contamination of their food, shelter or nesting resources.

Negative market consequences:

Consumers and retailers are increasingly demanding safer and healthier food, with zero residues, or at least grown with much less use of pesticides. This has long applied for markets in developed countries, especially for fresh fruit and vegetables, but the same market trend is seen in developing countries, with more studies and media attention to disturbing levels of pesticide residues detected in food and beverage crops.

Growers who rely heavily on HHP pesticides and fail to change practices may risk losing their current and future customers. Conversely, those who are proactive in taking up IPM or organic methods can gain better market prices, more demand for their produce and more supportive relations with buyer companies and the end consumer. A more detailed explanation of the health, environmental and economic rationale for phasing out HHPs is given in the Introduction chapter of PAN International's book on phasing out HHPs with agroecology, with references to recent science studies.[20]

Phasing out HHPs means phasing in safer alternatives

This section covers some practical, policy and farmer support considerations for people interested in replacing specific HHPs with alternative methods for managing the pest, disease or weeds targeted by the relevant pesticide.

The first step, whether at policy level or by a cropping sector, food production company or farmer association, is to identify which HHPs are being used, in which crops and against which particular pest organism. It makes little sense to try and find generic alternatives to, for example, the HHP fungicide carbendazim in Costa Rica. The starting point needs to be pest- and crop-specific, for example, alternatives to carbendazim use in coffee groves to control coffee rust disease.

Successful phase out integrates different methods for the target pest

When planning to replace or phase out a specific HHP, it is important not to assume that use of a particular HHP (for example, carbosulfan use to control whitefly in tomato), can always be simply substituted by either using a less toxic chemical or by a single non-chemical method.

EXAMPLE:
Integrating several methods to achieve effective pest control

The case study on managing coffee berry borer without endosulfan (see section 3.1) highlights how all the farmers studied were using at least two IPM methods: in Colombia, these were intensified cultural controls (field hygiene); regular field monitoring; fortnightly berry picking; and some farmers applied biopesticides. In Central America, farmers undertook pre-harvest field sanitation of bored berries; post-harvest removal of breeding sites; and employed trapping techniques or biopesticides.

Switching to reliance on a single chemical substitute runs the same risk of the pest developing resistance (whitefly, for example, are notorious for their speed of resistance development), while a single non-chemical method may not be able to deliver as much control alone as the former HHP and farmers may be disappointed with the results.

Simple substitutions with readily available alternative products can certainly be a quick and immediate first step, however, to be sustainable in the longer term, additional methods may be needed. Effective and long-lasting control strategies often combine a range of preventative and direct intervention methods – this is the essence of Integrated Pest Management.

Integrated Pest Management (IPM) is an approach that makes use of biological principles and ecological science, rather than the pesticide-dominant strategies which many farmers currently rely on. IPM covers not just insect pests, but also crop diseases, weeds and vertebrate pests (birds, rodents) where these cause problems. It is about managing these organisms to prevent them reaching levels where they cause economic damage, not trying to eliminate them. More information on IPM principles and practices can be found under Useful Resources.

Effective IPM strategies combine a range of different methods or tactics:

a) Methods that prevent the build-up of damaging levels of pests, weeds or diseases

b) Methods that encourage natural pest control processes

c) Direct interventions when tactics under a) and b) fail to deliver adequate control

Table 1 describes successful alternatives for whitefly control in tomato.

EXAMPLE:
IPM alternatives to carbosulfan and lambda-cyhalothrin

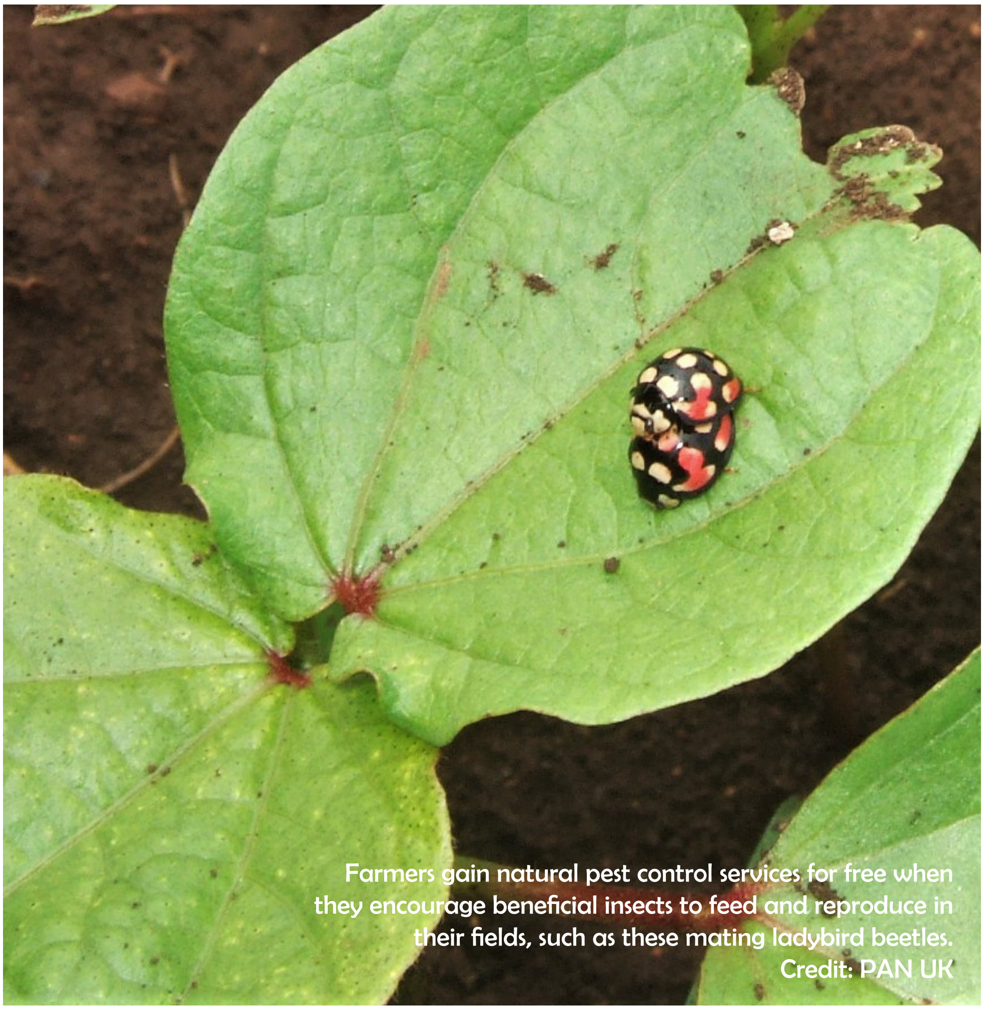
In 2016 the HHP insecticide carbosulfan (in the carbamate family) was recommended for addition to the Rotterdam Convention PIC List by the Convention's Chemical Review Committee. One use is in controlling whitefly in tomato. At high densities, this sucking pest can damage the plant and it can also transmit harmful viral diseases. Other HHP insecticides are also widely used for whitefly control, including the pyrethroid lambda-cyhalothrin. Lambda-cyhalothrin is one of the very few substances to feature on the PAN International HHP List for qualifying under all three hazard groups: acute; and chronic human health hazard; and environmental hazard. It was recently nominated by Georgia as a candidate Severely Hazardous Pesticide Formulation for Rotterdam PIC listing (in 5% formulations). Canada's 2017 re-evaluation of lambda-cyhalothrin concluded that all formulations pose unacceptable cancer and non-cancer risks for children via diet . Canada now proposes to ban all food and feed uses. Table 1 summarises examples of preventative, biological methods and direct control methods for this tricky pest without resort to HHPs.[21]

Carbosulfan is also used in potato against Colorado beetle. Again, a range of IPM methods exist, including physical barriers and manual removal. Hand picking of beetle egg masses can be a viable option for smallholders, while growers in developed countries may use trap crops, field edge traps, mesh row covers, flaming equipment and biopesticides.[22]

Table 1. Different IPM methods for controlling whitefly in tomato

IPM method	Example methods
Preventing build-up of damaging levels of whitefly	• Careful site selection and timing of tomato cultivation - avoid planting next to infested crops! • Grow tomato cultivars resistant to leaf curl virus • Use mesh screening to protect vulnerable seedlings at nursery stage • Carry out good field hygiene, removing infested plants and crop waste after harvest • Plant border crops, e.g. maize, as barriers to flying adults • Use protective soil surface mulches of plastic or straw which make it harder for whiteflies to locate their host plant • Use living cover or companion crops to help keep young tomato plants from attack
Encourage natural pest control processes	• Many naturally occurring beneficial organisms attack whitefly. Help to conserve these by avoiding use of insecticides, especially early season. • Mass-reared natural enemies may be available as commercial biocontrol agents, for release in greenhouses
Direct interventions when prevention and natural control is not enough	• Use yellow sticky traps to monitor when and where adult whiteflies reach problem levels • Use strips of sticky trap plastic for mass trapping adult whiteflies • Apply commercial biopesticides to tomato foliage (products based on fungal agents incl. *Trichoderma*, *Paecilomyces*, *Beauveria* and *Verticillium* species) • Apply soap sprays (commercial or home-made) which suffocate whiteflies on foliage • Apply commercial or home-made botanical extracts • Apply non-HHP insecticides, selecting products with least toxicity to natural enemies

Avoid switching from one problem pesticide to another



Farmers gain natural pest control services for free when they encourage beneficial insects to feed and reproduce in their fields, such as these mating ladybird beetles. Credit: PAN UK

Beware of switching from one HHP to another pesticide, which may pose different problems. For example, when endosulfan insecticide was banned some years ago in Colombia, some coffee farmers simply replaced it with chlorpyrifos against coffee berry borer beetles. Although chlorpyrifos is much less persistent than endosulfan and does not carry the 'fatal by inhalation' hazard, it is also an HHP (qualifying for high toxicity to bees) and is linked with neurological damage to children's brains, reproductive toxicity, skin and eye irritation and is known to harm birds, fish and aquatic invertebrates.[23,24] When assessing alternatives to endosulfan before its listing as a Persistent Organic Pollutant (POP), an analysis of over a hundred potential chemical substitutes found that many of these also had HHP hazard criteria. The Stockholm POP Convention policymakers agreed that priority should be given, instead, to ecosystem approaches in pest management replacing endosulfan, recognising that pesticides are inherently hazardous and that there are better ways of managing pests. This involves rethinking the pest management strategy for the cropping system towards IPM principles and ecological methods.

EXAMPLE:
Eliminating HHP insecticides in coffee

Several large Colombian coffee estates have succeeded in reducing and finally eliminating endosulfan, chlorpyrifos and other insecticides, replacing these with intensive cultural controls and application of Beauveria fungus biopesticides. See video 2 and farm case studies in the 'Growing Coffee without Endosulfan' series.[25]

Government support is needed for HHP phase out

National governments are urged to support the HHP approach with progressive policies, such as banning or restricting specific HHPs, removing any hidden subsidies or financial incentives for pesticide use and actively promoting alternatives.

The FAO/WHO Guidelines on HHPs emphasise that reducing reliance on pesticides is first priority in steps to reduce risks from HHPs, along with maximising non-chemical methods (Box A).

Box A. Steps in pesticide risk reduction

1. **Reduce reliance on pesticides.** Determine to what extent current levels of pesticide use are actually needed and eliminate unjustified pesticide use. Make optimum use of non-chemical pest management practices in the context of sustainable intensification of crop production and integrated vector management (IVM).

2. **Select pesticides with the lowest risk.** If use of pesticides is deemed necessary, select products with the lowest risk to human health and the environment from the available registered products of those that are effective against the pest or disease.

3. **Ensure proper use of the selected products** for approved applications and in compliance with national regulations and international standards.

The HHP Guidelines give brief examples of policy or administrative measures to support more uptake of sustainable pest management which does not involve HHP use, such as:

- Promote IPM and IVM through investment in training, communication and further research, and monitoring of their effectiveness
- Improve the availability and distribution of low risk biological alternatives
- Use good agricultural practice schemes and other non-regulatory options to promote substitution of HHPs by pest management approaches and products that pose less risk
- Consider using financial incentives (e.g. subsidy or taxation instruments) to favour low risk products, such as biological control agents and most biopesticides, over high risk products.

Some countries are starting to take action on addressing HHP issues at regulatory level and/or via practical policy support for safer alternatives.

EXAMPLE:
HHP bans and risk reduction in Mozambique

In 2014, the government of Mozambique cancelled registration of 61 pesticide products containing 31 HHP active ingredients.
It also set risk reduction measures for a further 52 products.

Bans or severe restrictions included insecticides methamidophos and dichlorvos, widely used in vegetable production, and herbicides 2,4-D, diuron and paraquat, mainly used in sugar cane.

These regulatory decisions were made jointly by the Ministries of Agriculture and Environment as part of a SAICM project identifying HHPs in use in the country and developing a risk reduction plan.

A case study describes the steps in the process and positive results obtained.[26]

EXAMPLE:
Supporting safer alternative products in Kenya

The government of Kenya was one of the first in developing countries to establish a fast-track system for registration of biological pesticides.

This was partly in response to the need of the country's valuable export horticulture sector for safer alternatives, which could help reduce pesticide residues in their produce and avoid rejection of shipments by EU importers.

Technical guidance was provided by the Real IPM Company Kenya, with local experience in development of biopesticides and biocontrol strategies. Guidance frameworks for registration of biological control agents now exist for several regions.[27]

This positive policy support helps more companies to supply the rapidly increasing market for biological products, now growing much faster than demand for synthetic pesticides.[28]

EXAMPLE:
Phasing out carbofuran use in Costa Rica

In 2014, the government of Costa Rica decided to prohibit use of carbofuran, due to its high toxicity and potential risk to people exposed occupationally and to consumers via residues in food and the fact that carbofuran was one of the major causes of pesticide poisoning cases in the region.[29]

Carbofuran's persistence in soil and water and environmental risk via run-off was also a factor in the decision and its high toxicity to mammals, birds, fish and aquatic organisms.

The policy makers also assessed that for almost all crops, substitutes for carbofuran already existed, either other chemicals or non-chemical methods, with the exception of snail pests in pineapple and nematodes in banana.

To enable producers of these important export crops time to find safer alternatives, a 23 month period of grace was given for use of granular carbofuran products in these two crops, under certain restrictions.

Supply chains can play a major role in phasing out HHPs

Numerous private label sustainability standards and food retail companies have prohibited certain hazardous pesticides in recent years, often starting with the former PAN 'Dirty Dozen' and some older pesticides long banned in Europe and the US. Many now prohibit pesticides listed not only on the Stockholm POP Convention but also those on the Rotterdam Prior Informed Consent (PIC) List and the fumigant methyl bromide (subject to banning under the Montreal Protocol on ozone depletion). Several standards, plus some retailer companies, now actively address HHP issues in the latest versions of their individual pesticide policies, by prohibiting, restricting or monitoring specific HHPs. Table 2 summarises prohibitions and restrictions of three global standards certifying tropical export crops and one British fresh produce retail company in relation to different hazard criteria used in the PAN International HHP List.

Table 2. Summary of how hazard criteria are used by selected supply chain organisations for prohibiting or restricting HHPs

Hazard group	HHP hazard criteria and classifications	Rainforest Alliance 2017	Fairtrade 2017	UTZ Certified 2015	UK retailer 2015
International Conventions	Montreal Protocol	P	P	P	P
	Rotterdam PIC	P	P	P	P (R)
	Stockholm POP	P	P	P	P
Acute Toxicity	Extremely hazardous (WHO Ia)	P	P (R)	P	R (M)
	Highly hazardous (WHO Ib)	P	P (R)	P	R (M)
	Fatal by inhalation	<u>*R*</u>	P (R)	R	R (M)
Carcinogenic	EPA highest cancer hazard	P	P		R
	IARC highest cancer hazard	P	P		R
	EU/GHS highest cancer hazard	P	P	P	R
Probably carcinogenic	IARC 'probable' cancer hazard		M		M
	EPA 'probable' cancer hazard		M	P (R)	M
Chronic toxicity	Mutagenic (EU/GHS)	P	P (R)	P (R)	M
	Reproductive toxin (EU/GHS)	P	P (R)	P (R)	M
	Known or potential endocrine disruptor (EU/GHS)		P (R)	P (R)	M
Environmental concern	very bio-accumulative		*P* <u>*(R)*</u>	R	M
	very persistent in water, soil or sediment		*P* <u>*(R)*</u>	R	M
	very toxic to aquatic organisms	<u>*R*</u>	*P* <u>*(R)*</u>	R	M
	highly toxic to bees	<u>*R*</u> + a few P	M + a few R	R	M

KEY: **P = Prohibited; R = Restricted; M = Monitored; P (R)** = prohibited but some restricted where use cannot be stopped immediately; <u>*R*</u> = partly restricted. Dates show latest version of pesticide lists published. Policy details for each standard can be found via Useful Resources.

While these four organisations have decided on different priorities for which pesticides to prohibit or restrict and how producers need to comply with these requirements, this comparison makes clear that:

(i) all now address not only the international conventions and well known acute toxicity hazards but several chronic human health and environmental hazards too

(ii) all take pragmatic approaches, recognising that specific HHPs may be in widespread use in particular crops or supply sources and immediate prohibition could risk serious economic losses for producers

For HHPs on their restricted or monitored lists, organisations may require producers to: report on volumes used; take additional safety measures to reduce risk and exposure; request prior permission to use (giving justified reasoning); or take action on residue levels in food.

Several aim for medium term (3-5 years) phase out of priority HHPs currently in use, starting with developing farm or grower group plans for reducing use and phasing in safer alternatives.

Success in phasing out HHPs is closely linked with support from supply chains in the form of training and advice for producers, rather than simply imposing compliance with requirements. Actively involving producers, researchers and others in trying out different IPM methods and developing effective IPM strategies for specific crops is very important.

Recognising common challenges in phasing out some widely used HHPs, in 2016 sustainability standard members of the ISEAL Alliance created an IPM coalition, to collaborate on building expertise and experience in IPM alternatives, via an HHP database under development and training materials shared on the Sustainability Xchange website.[30]

EXAMPLE:
Supporting coffee farmers to phase out endosulfan

When Fairtrade prohibited endosulfan use by certified farmers (from 2005) and Rainforest Alliance and Utz Certified (from 2011), coffee growers using this HHP and their exporter companies faced considerable challenges to comply with the prohibition requirement.

In Nicaragua, agronomists from Fairtrade coffee co-operative SOPPEXCA worked with 650 farmer smallholder members to trial trapping techniques for coffee berry borer, using ethanol attractant.

In El Salvador, exporter Coex tested the trapping method firstly on its own estates and found the costs and effectiveness compared very favourably with chemical control. Coex agronomy team then promoted trapping and biopesticide use among its 2,000 supplier estates, enabling some to phase out endosulfan use within one season and to gain Rainforest certification for their coffee.

Farm entrance poster for a medium size coffee farm in Colombia, certified under Rainforest Alliance and trained in IPM methods by local organisations. Credit: PAN UK

Case studies and examples of alternatives to HHPs

Case study on endosulfan alternatives for coffee berry borer in Latin America

The *Growing Coffee without Endosulfan* project was conducted jointly by PAN UK and the Global Coffee Platform, with other ISEAL member standards, and funded by FAO, IDH's Sustainable Coffee Program and ISEAL. It specifically aimed to document experiences of coffee growers in certified standards in replacing endosulfan use for coffee berry borer (CBB) *Hypothenemus hampeii*, an economically damaging pest which reduces quality and yield of coffee beans. The project interviewed farm owners and managers and agronomists in countries with (a) continuous flowering and harvesting (Colombia), and (b) defined flowering and one main harvest period (El Salvador and Nicaragua) to identify the different cultural, physical, biological and chemical controls reported in use, along with pest monitoring and decision-making tools. Farms ranged from 2 to 200ha, shaded and sun systems and five different certified standards, including organic.

A range of IPM methods in use

The field visits showed clearly that it is perfectly possible to manage CBB well without endosulfan, on small and large farms, using safer, IPM methods. They countered the myth that alternatives to endosulfan are always more expensive and demonstrated that considerable reduction in other Highly Hazardous Pesticides can be achieved too. The comparative assessment asked six key questions about the pros and cons of each of the different IPM methods farmers reported for managing CBB:[31]

- o How effective is it in controlling CBB?
- o How much does it cost?
- o How much labour time does it need?
- o How easy is it to implement?
- o Does it need much training before it can be used?
- o Other key points or farmer recommendations

Technical, economic and implementation information collected was synthesised into guidance documents on how farmers were putting the methods into practice and farm case studies. A set of videos illustrate farmers' experiences with cultural controls, biopesticides, trapping methods and pest monitoring and decision making.[32] Table 3 summarises IPM methods used on the 22 farms visited.

In Colombia, several of the farms visited are managing CBB very well almost without insecticides in areas where 10-12 years ago this pest was very problematic and many farmers were still using endosulfan. Successful IPM methods are being used by smallholders, medium scale farms and large estates, making use of research and extension advice from the National Coffee Growers' Federation (FNC).

In Nicaragua and El Salvador, apart from the organic farms, several other farms are able to manage CBB without insecticides, or with much reduced use. There is increasing use of Beauveria biopesticides and of ethanol-baited traps. In all cases, either the producer co-op or the export association or other technical support provider is working closely with these farmers to promote these alternatives. Farmers are adapting some of the methods to suit their own situation, e.g. using empty soft drink containers to hold the ethanol attractant, rather than more expensive commercial traps, and increasing the number of traps set per hectare.

Key lessons

Key lessons were identified with stakeholders from both regions and shared with the coffee sector and with policy makers:[33]

(1) CBB control without endosulfan is perfectly feasible: Farms have achieved good control across a range of farm sizes, climate zones and altitudes, pest pressure levels, coffee production systems, farmer ages and educational levels. Several farmers who were using endosulfan routinely three years earlier have succeeded in eliminating its use.

Table 3. Summary of IPM methods used for Coffee Berry Borer on farms visited

IPM method	Colombia (9 farms)	Central America (13 farms)
Pest monitoring and decision making methods		
Regular plot sampling to estimate CBB incidence	9	2
Plot observation to identify 'hotspots'	9	11
Dissecting bored berries to identify pest position, for accurate timing of controls	7	0
Using methanol-baited traps to monitor pest levels and time controls	2	1
Physical methods		
Physical trapping using methanol-baited traps for mass-trapping	1	6
Physical trapping at pulping stations and berry collection points using greasy tarpaulins or 'trap' trees	3	0
Preventative methods (grove management and field sanitation)		
Cultural control by collecting fallen berries and unpicked berries after harvest	2	13
Cultural control by picking bored early ripening berries between harvest periods	9	11
Regularly replanting or pruning coffee bushes to make cultural controls easier	6	4
Biological methods		
Biological control applying *Beauveria* fungus biopesticide	4	5
Biological control via release of parasitic wasps (one or two releases in the past only)	1	1
Chemical methods		
Chemical control using insecticides other than endosulfan	5	5
Chemical control using endosulfan	0	1

Table indicates number of farms in each region which report using a particular IPM method.

Using a hand lens to observe the white fungal mass indicating a coffee berry borer beetle killed by a biopesticide application containing *Beauveria bassiana*. Credit: PAN UK

(2) Cultural controls form the backbone of good CBB management: All farmers met are doing some form of field sanitation as the backbone of CBB IPM. These practices are essential to reduce the amount of pest breeding sites and reduce CBB levels in the following season.

(3) Field monitoring is an important tool for CBB decision-making: Most farmers carry out some form of field observation for monitoring pest presence and level, identifying 'hotspot' areas on their farm and for optimum timing of any control activities.

(4) Some farms have greatly reduced or eliminated insecticide use for CBB: This is due to careful planning and organisation of IPM tasks, along with worker training and incentivisation, as much as the IPM methods themselves.

(5) It is a myth that endosulfan alternatives are always more expensive: Trapping and use of *Beauveria* biopesticides can be cheaper than endosulfan application or similar in cost. Central American farmers using methanol traps found it much cheaper and less laborious than organising workers to spray insecticide - and far less risky to worker health.

(6) Investing in IPM brings numerous benefits: None of the farms considered IPM methods to be too costly. Instead, they viewed labour costs of cultural controls and other IPM methods as a necessary investment to guarantee good coffee quality and which can deliver benefits including: higher price for coffee beans; expanded and more rewarding market options; improved farmer and worker welfare; wildlife protection and less environmental pollution.

Case study on alternatives to HHP insecticides for cotton pests in Ethiopia

Larvae of the African bollworm moth *Helicoverpa armigera* form one of the most serious pests affecting cotton in Africa and Asia, along with whiteflies and other sucking pests. These are often targeted by farmers with frequent spraying of broad-spectrum and hazardous insecticides. In Ethiopia, large

Rows of sunflowers planted within this cotton field provide a refuge for useful natural enemies early in the season. Credit: OBEPAB, Benin

cotton farms may apply three to five rounds of HHP insecticides, such as endosulfan, malathion and dimethoate, against bollworm. Insecticide use has been fairly common too among smallholder farmers, until falling cotton prices forced many to cut back on agrochemical inputs. Pesticide handling practices are very poor on large and small farms, lacking adequate protective equipment, and there are anecdotal reports of ill health among spray operators.

Use of the food spray method for increasing natural biological control

Safer IPM options exist for managing bollworm, including an innovative method for enhancing biological control by attracting predatory insects into cotton fields to feed on pests. First developed by entomologist Dr Robert Mensah in Australia 20 years ago to reduce hazardous insecticide use in large-scale cotton, the 'food spray method' has now been taken up by several thousand smallholders in Benin and Ethiopia. Food sprays are made from ground maize or waste brewers' yeast, and attract predatory insects, such as ladybird beetles, lacewings and hoverflies, by mimicking the chemical cues they use to locate prey. These predators are important natural enemies of soft-bodied insect pests, such as aphids, and of bollworm eggs and very small larvae. Where these predators are numerous, cotton farmers can often avoid pest populations from reaching damaging levels or reduce the number of chemical applications needed to control them.

Sprayed onto the cotton foliage early in the season, the odour plume from the food spray attracts these predators into the cotton rows so they are 'ready and waiting' before the first bollworms and other major pests arrive when the crop begins flowering. Farmers then need to monitor their cotton fields at least once a week, preferably twice, to check if they have a favourable balance of predators to pests present. Research experience from Australia and Africa has confirmed that if fields contain at least one arthropod natural enemy individual for every two pest individuals counted (a Predator: Pest ratio of 0.5 or higher), then small bollworms and other pests can usually be kept in check for the next few days. Further food sprays can be applied as needed, when pests start to outnumber natural enemies and tip the balance below this 0.5 ratio.

The method also involves sowing 1-3 rows of sorghum or maize between every 8-10 rows of cotton. Bollworm female moths prefer to lay eggs on these plants at flowering stage than on cotton, so they serve as a 'trap crop' to lure this pest away from the cotton. The foliage also provides a refuge for natural enemies. For the food spray method to work well, broad-spectrum insecticides which can kill the predators must be avoided, hence the need to use it as part of organic or IPM systems.

Field trials and farmer training deliver economic and other benefits

The food spray method was first adapted to the context of resource-poor African smallholders in an organic cotton project in Benin but it was not clear whether it would work in the Ethiopian context too.[34] The method was therefore tested and refined as part of a Farmer Field School (FFS) training project for sustainable cotton conducted during 2013-2016 by PAN Ethiopia and PAN UK in collaboration with entomologists from the Arba Minch Plant Health Clinic and extension experts from the regional Board of Agriculture. Trial results over four seasons proved that the food spray method could deliver successful pest control with yields similar or higher than conventional chemical control on large farms and much improved yields in smallholder farms. Net profits were also higher than current farm practice on large and small farms. Table 4 shows pest control treatments, yield and profit data for two FFS village demonstration sites and two large farms.

Success in combining the food spray method with other cotton IPM methods has enabled over 2,000 farmers in Ethiopia's southern Rift Valley to stop using endosulfan and other HHPs and change to a production system based on agroecological principles. Thanks to the set of IPM practices introduced via FFS training (e.g. optimum sowing density, methods for growing a healthy crop which can better withstand pest and disease attack, careful and timely weeding, good field hygiene), farmer groups have succeeded in increasing substantially the yields (Fig. 1) and income from their cotton and no longer risk exposure to harmful pesticides. Cotton lint from IPM trained farmers has been classed as top quality grade for two consecutive seasons and the combination of high quality with zero pesticide use is helping farmer groups to access new and more profitable market options, including organic buyers.

Figure 1. Yield increases obtained by IPM trained farmers compared with untrained farmers in Arba Minch area, Ethiopia (cotton seed in quintals (100kg) per ha)

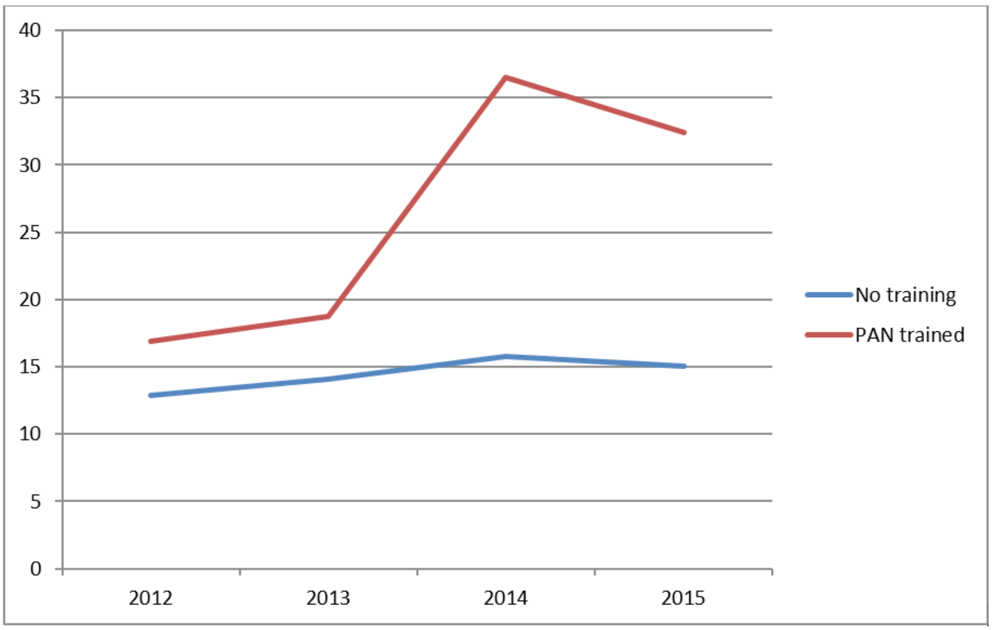


Table 4. Comparison of treatments, yields and profits at four sites in Arba Minch area in 2015 (costs in Ethiopian birr, ETB)

Site	Treatments	Seed cotton yield (Kg/ha)	Total revenue from seed cotton	Total production cost	Net revenue
Genta Kanchama FFS group	Food Spray (1 round)	4,385	65,775	9,650	56,126
	Insecticide (3 rounds Malathion 50% EC @ 2l/ha)	1,497	22,460	4,832	17,627
	Untreated	3,262	48,930	7,324	41,606
Kolla Mulato FFS group	Food Spray (3 rounds)	2,380	35,696	5,688	30,007
	Insecticide (2 rounds Malathion 50% EC @ 2l/ha)	1,497	22,460	4,567	17,893
	Untreated	1,979	29,679	4,757	24, 922
Large Farm A	Food spray (2 rounds)	2,126	31,896	8,306	23,590
	Insecticide (2 rounds endosulfan 25%ULV @ 2.5l/ha)	2,016	30,173	8,592	21,581
	Untreated	1,954	29,310	7,805	21,505
Large Farm B	Food spray (3 rounds)	4,259	63,888	12,562	51,326
	Insecticide (4 rounds endosulfan 25%ULV @ 2.5l/ha)	4,329	64,931	13,611	51,320
	Untreated	1,042	15, 626	11,804	3,822

US$ = 21 ETB Dec. 2015. Seed cotton price = 15 ETB/kg

Success factors

One of the success factors for Ethiopia was conducting detailed and robust field trials at different sites over three seasons to try out different food spray 'recipes', combinations with neem seed extract and to find out which predator groups were attracted and how well they could keep bollworm and sucking pests under control.

Another factor was training effort dedicated for farmers and extension staff to learn how to:

- prepare and apply the food spray
- identify cotton pests and natural enemy groups
- scout fields to assess the balance between predators and pests and work out if and when a further food spray was needed

A simpler technique for insect scouting for farmers with limited literacy was introduced, using maize kernels to represent predators and stones to represent pests. Detailed instructions on how to put the components of the food spray method into practice, how to set up and evaluate pilot trials and an explanation of the ecological science underlying the method have now been compiled in a trainers' guide, with successful case study material.[35]

Good results were also obtained in trial IPM plots on two large farms, with yields and net revenue significantly higher than those on the main fields under conventional chemical practice. At large scale, one or more direct IPM intervention methods are likely to be needed in addition to the food spray method and the project aims to experiment with light traps for bollworm adults and with a new botanical extract product for cotton pests.

Alternatives to HHP herbicides for weed control in coffee

Pesticide use surveys of coffee farmers in Costa Rica conducted under the HHP project identified several HHP herbicides in use, including diquat, glyphosate, oxyfluorfen and paraquat. Recently, more growers are using paraquat, raising concerns for worker health, especially if casual workers are engaged in poor practices. Paraquat is reported in use by 25% of coffee farmers surveyed during 2015-2016, spraying this acutely toxic substance from one to three times a year.

However, there is useful experience in the Central American region of effective alternative approaches, based on integrated weed management. The key to reducing or eliminating herbicide use in coffee groves is to integrate a variety of physical, cultural and ecological methods, to achieve short term control of the most harmful weeds and over time to alter the vegetation balance to favour more beneficial and neutral plants. Understanding which weedy plants are most harmful and which pose no problem for the coffee bushes is essential, along with regular field monitoring and knowing when and how to manage different weed types. The following summarises the main methods, more details are provided in the project briefing.[36]

Good cultural controls: Growing healthy coffee plants, with well-balanced fertilisation, helps vigorous growth in the early years, enabling the young bushes to compete better with weeds for space, light, nutrients and water. Planting at high density with improved varieties aids the coffee canopy to close quickly and limit aggressive weed growth.

Use of shade trees: These help to reduce weed growth and the organic matter generated by leaf litter and pruning forms a mulch cover which further inhibits weeds. While coffee grown under full sun will need weeding 4-6 times per year, groves with shade trees need only 2-3 sessions.

Dead mulches: Dead mulches, composed of crop waste (maize, beans, etc), grass cuttings or other plant material, can be scattered over the soil and helps to inhibit weed development.

Living mulches or cover crops:
Selected ground cover plants can be sown between coffee rows for multiple benefits: soil protection, conservation of nutrients and water, biodiversity and natural control of pests and weeds. Suitable species should be low-growing with shallow rooting, which will not compete with the coffee bushes. Leguminous species are good as they can improve soil fertility too.

Controlled grazing: Livestock (mainly sheep) are used by some coffee growers as a weed control method. Care needs to be taken to rotate their grazing around the different plots.

Manual or mechanical control (by hand tools or motorised equipment):
Coffee bushes are least able to compete with weeds in recently planted groves and in the period before harvesting. Manual weeding operations need to focus on (a) complete removal of weeds in the 75cm diameter 'drip circle' around the bush stem and (b) selective weeding (hand pulling or slashing by machete) between rows. This practice is very important in the first two years. It also makes compost/ fertiliser application easier and reduces the number of weeding sessions needed throughout the year. Weed material removed can be left on the ground as a protective cover for the soil.

Modifying the weed community:
This longer term method involves changing the composition of the weed communities, by leaving those plant species which provide more benefit than harm while eliminating those that are more harmful. It aims to encourage plants with a creeping growth habit, which don't have deep roots and which quickly cover the soil. Illustrated guides to useful and harmful weeds are available.

Timely control is very important - if weeding operations are carried out when vegetation is already thick and high, it becomes more difficult, takes longer and incurs more expense, whether this is done manually, mechanically or using herbicides.

Trials on alternatives to HHP nematicides in pineapple

Pineapple production in Costa Rica can be prone to serious infestations of soil-dwelling nematode worms, which can damage the root system of young pineapple plants or open wounds which can allow attack by serious rot diseases. To avoid nematode problems, many pineapple farms rely on HHP nematicides ethoprophos or oxamyl, applied as granules to the soil just before, or shortly after, planting, followed by a second application, around 2-3 months later.

Both these nematicides are extremely toxic to humans and known to harm non-target soil organisms. Ethoprophos is reported as one of the commonest causes of acute poisoning in Costa Rica and found to contaminate surface water and drinking supplies.

Nematodes can be controlled without HHPs via:

- **good cultural controls,** e.g. careful soil preparation before planting to expose nematodes to sunlight, along with good crop rotations (continuous monoculture makes nematode problems worse)
- **biological control,** mainly via the use of products based on fungal species which feed on nematodes
- **chemical control** using new nematicide products which do not contain HHPs

As part of the project on *Phasing out HHPs*, the IRET team decided to explore non-chemical alternatives to the commercial standard nematicide based on ethoprophos. A small pilot trial was conducted at a large farm belonging to pineapple company Fertinyc, in San Carlos district, Alajuela, in central Costa Rica. This company is keen to reduce pesticide and fertiliser applications and the farm manager has already experimented with biopesticide products based on the fungus *Paecilomyces* and succeeded in reducing HHP nematicide applications.

Treatments tested

Three alternative methods were tested, comparing the results with the current nematicide use and a totally untreated control:

1. Commercial practice standard *Mocap 10G* (ethoprophos) (dose rate: 35kg/ha)
2. *PA-ECO* biopesticide based on the fungal biocontrol agent *Paecilomyces lilacinus* (4 kg/ha)
3. 'Wood vinegar' extract distilled from wood smoke (40 litres/ha)
4. *Klamic* biopesticide based on the fungal biocontrol agent *Pochonia chlamydosporia* (0.83 kg/ha)
5. Untreated control (zero nematicides or alternatives)

Both biopesticide products are commercially available in Costa Rica. Pyroligneous acid or 'wood vinegar' contains over 300 constituents, some of which have bactericidal and fungicidal properties, while others stimulate plant growth. Wood vinegar is known to be very effective against nematodes, by direct toxicity, as well as encouraging microbes that feed on them. In Costa Rica its application has given good results in vegetables and it can be easily prepared by collecting the distillate from burning soft wood species. Trial treatments were applied as a soil drench at 15 days after planting and nematodes were counted in samples of soil and within pineapple roots at 75 and 135 days after planting. Details of the trial, technical results and cost comparisons are given in the project briefing.[37]

Trials on alternatives to HHPs in pineapple.
Credit: IRET/UNA, Costa Rica

Key findings

Nematode levels and plant weight: Numbers of pathogenic nematodes (*Pratylenchus and Helicotlyenchus spp.*) increased over the study period (Nov. 2015 to Feb. 2016), however there were no significant differences in nematode levels between any of the treatments. A likely reason was that the nematode populations in all the treatment plots turned out to be unusually low- well below the root damage threshold of 1,000 *Pratylenchus* nematodes per 10g roots. The trial fields were previously under grazing pasture and cassava, which may explain the very low nematode populations found, and none of the plots reached levels which would have justified treatment, either with synthetic nematicides or alternatives.

The trial was terminated before fruit harvest (18-24 months after planting) so final yield could not be assessed. Nevertheless, measuring plant size at 75 days after planting, the team noticed that the smallest plants were those on the plots treated with the HHP nematicide and this difference was statistically significant. One explanation could be that ethoprophos was causing harmful effects not only to the target nematodes but to beneficial microorganisms in the soil, with adverse consequences for biomass production by the pineapple plants. HHP nematicides are very potent, with broad spectrum activity and known to cause damage to a wide range of non-target organisms living in the soil, including those that contribute to soil health, nutrient cycling and biological control of soil-dwelling pests and diseases.

Treatment costs: Contrary to widely held perceptions that alternatives to synthetic pesticides are always more expensive, all three non-chemical methods used in this trial were considerably cheaper than the HHP nematicide (Table 5). The cheapest treatment was for *Klamic* biopesticide based on *Pochonia chlamydosporia*. Costs were calculated for a single soil drench treatment although most pineapple growers usually make two applications.

Preliminary conclusions: Although it is hard to draw firm conclusions from this short duration trial under very low nematode infestation levels, these preliminary results suggest the following considerations:

- alternatives could be as effective as HHP nematicides and cheaper
- alternatives do not require specialised equipment, expert advice nor intensive training.
- combining one application of conventional nematicide and one non-chemical treatment may also be an option for growers to reduce HHP use and costs, without the perceived risks of completely changing their usual practice.
- good IPM growers will sample fields to monitor nematode levels before planting pineapple, to avoid unnecessary applications when numbers are low
- HHP nematicides may do more harm than good in situations where they disrupt beneficial soil microbes important in growing a healthy crop

Table 5. Comparison of nematode treatment costs (in Costa Rican colones)

Treatment	Unit cost	Cost per hectare
1. HHP nematicide Mocap ® (ethoprophos)	7,570 per 1.5kg	176,633
2. Fungal biopesticide *(P. lilacinus)*	5,000 per kg	20,000
3. Wood vinegar	5,000 per gallon	52,910
4. Fungal biopesticide *(P. chlamydosporia)*	5,500 per kg	4,565
5. Untreated control	0	0

US$ = 526 colones in Nov. 2015


Coffee rust disease caused by the fungal pathogen *Hemileia vastatrix*

Trials on alternatives to HHP fungicides for coffee rust disease

Coffee rust disease, caused by the fungal pathogen *Hemileia vastatrix*, is an important disease of Arabica coffee and in recent years has reached outbreak levels in Central American countries, causing severe economic losses for many farmers. High infection levels can harm coffee through reduced photosynthesis and excessive leaf fall, leading to yield losses, and sometimes killing bushes. In Costa Rica, inappropriate and excessive use of fungicides to try and control the disease has increased coffee growers' production costs and risks the development of fungicide resistance in the coffee leaf rust pathogen.

Conventional coffee growers spend considerable money on trying to prevent any yield losses due to coffee rust attack, often spraying fungicides eight times per season. Some of the commonest fungicides used qualify as HHPs, including epoxyconazole, validamycin A and carbendazim.

While not acutely toxic to humans, they are classified as chronic health hazards, including probable carcinogens, mutagenic, reproductive toxins or endocrine disruptors.

Coffee rust attack levels and economic damage to coffee groves can be reduced by:

- Careful and timely management of groves, with regular pruning and replacement of old bushes
- Replanting with coffee varieties bred for resistance to coffee rust disease
- Good, balanced nutrition to produce healthy coffee bushes more resilient to attack, with attention to soil and moisture conservation in the groves
- Growing coffee in partly shaded and biodiverse groves, which encourage the many beneficial microorganisms which act as biological control agents of disease
- Well-timed and well-targeted application to coffee foliage of either synthetic fungicides and/or biofungicides and traditional mineral mixtures

Treatments tested

As part of the project on *Phasing out HHPs,* the IRET team tested several non-chemical products and combinations, as alternatives to a widely used product containing the HHP fungicide epoxiconazole. Small pilot trials were conducted at a commercial coffee farm and a research farm during 2016. The specific products tested were:

- **HHP fungicide epoxiconazole + pyraclostrobin** (Opera ®)
- **Non-HHP fungicide trifloxystrobin + cyproconazole** (Esfera ®)
- **Non-HHP fungicide triadimenol**
- **Sulphur + calcium hydroxide mixture.** A traditional mineral method for treating plant diseases.
- **Bordeaux mixture** (copper sulphate + calcium oxide). Another traditional mineral method.
- **Biofungicide** based on the fungus Lecanicillium lecanii.
- **Botanical fungicide**, tea tree Melaleuca alternifolia oil extract (Timorex ®).
- **Biofungicide/botanical combination** product, based on three microbial control agents+ neem tree Azadirachta indica oil extract (Roya-OUT ®)

All products are readily available in Costa Rica, except Roya-OUT ®, which is currently under commercial trial. The treatment regimes planned for both sites were:

T1= negative control (no fungicides)

T2= HHP fungicide epoxiconazole + pyraclostrobin (Opera ®)

T3= sulfo-calcic mixture, alternated with Lecanicillium biofungicide

T4= Bordeaux mixture, alternated with Lecanicillium biofungicide

T5= botanical extract Timorex ® + reduced rate non-HHP fungicide (Esfera ®)

T6= biofungicide/botanical combination product Roya-Out ®

T7= non-HHP fungicide (Esfera ®)

Rust incidence percentage was assessed every month (Mar-Nov.2016) and severity on a five point scale in the last 3 months before harvest (Dec. 2016), using national sampling protocols.

At the commercial farm site, initial disease incidence was very low but when the rainy season began, rust incidence and severity steadily increased, reaching 32% incidence in Sept. At this stage the farm owner decided to apply the HHP fungicide (Opera®) in the control and RoyaOut ® treatment plots. At the research farm site, coffee rust reached such high levels in all plots that the trial had to be abandoned and no yield data was collected. Synthetic fungicide and alternative treatments all failed to reduce the disease to acceptable levels or prevent serious defoliation. These unplanned interventions need to be taken into account when interpreting the results. Treatment details and results are given in the project briefing.[38]

Key findings

Disease levels and yield: At the commercial site, the treatment with the lowest disease incidence and severity was the non-HHP fungicide (T7), significantly different from the other treatments, with incidence remaining below 7% for the duration and severity under 1.05 out of 5. Among the treatments containing non-synthetic alternatives, the botanical extract combined with reduced rate non-HHP fungicide (T5) had the lowest disease levels, with incidence under 20% and severity below 1.33.

Although disease incidence and severity varied considerably between treatments at the commercial site, a different pattern emerged at harvest (Table 6). While the highest yield was obtained with the sulphur-calcium hydroxide mix alternated with *Lecanicillium* biofungicide (T3), yields did not differ significantly between any of the treatments. The treatments based solely on synthetic fungicides were the cheapest, with the HHP fungicide product a little cheaper than the non-HPP option. Amongst the treatments containing non-synthetic alternatives, the cheapest were the mineral mixes alternating with *Lecanicillium* biofungicide, at almost identical cost.

Table 6. Yield and cost data from commercial farm trial site
(kg coffee berries picked per bush and costs in Costa Rican *colones*)

Treatment	Unscheduled changes to treatment	Yield	Treatment cost per ha
T1. Control (untreated)	substituted with 3 applications of HHP fungicide in Aug-Oct	3.14	*not calculated*
T2. HHP fungicide		3.06	59,409
T3. Sulpho-calcium mix + *L. lecanii* biofungicide		3.39	116,000
T4. Bordeaux mix + *L. lecanii* biofungicide		3.02	116,730
T5. Botanical fungicide + reduced rate non-HHP fungicide		2.64	247,000
T6. Biological/ botanical product	substituted with 2 applications of HHP fungicide in Sep-Oct	3.15	*not calculated*
T7. Non-HHP fungicide		2.78	71,212
US$= 543 colones March 2017			

Key findings

Replacing HHP fungicides with non-HHP synthetic products appears to be a feasible option, technically and economically. The trifloxystrobin + cyproconazole product produced the best results in terms of coffee rust levels at the site with low disease pressure, and at the high disease levels it was second best (before the trial was cut short). Its cost is a little higher than the HHP product but it could be a viable option for conventional coffee growers.

The two treatments combining mineral mixtures with *Lecanicillium* biofungicide were the cheapest among non-chemical products and could be a good option for organic growers.

The lack of any significant difference in yields between the treatments suggests that chemical and non-chemical alternatives to HHP fungicides can work to deliver decent yields, although the unscheduled addition of HHP fungicides to two of the non-chemical treatments probably contributed to the similar yields.

The project team observed that bushes at the commercial site in plots treated with biological products retained far more leaves and with a healthier, green colour than in plots treated with azole fungicides and hypothesise that the fungicides could be negatively affecting leaf retention.

Some fungicides are known to upset the balance between beneficial and harmful fungi and bacteria in coffee groves and may disrupt beneficial processes in the micro-ecosystem, aggravating rather than aiding disease control and plant health.

The project work with conventional, IPM and organic growers has learnt of several good experiences with the tea tree oil extract, enabling users to reduce from four fungicide applications per season to just one or even a half dose. Some organic farms report good results with biofungicides when applied regularly (up to six sprays). For biofungicides to work best, background levels of the beneficial fungi need to build up over several seasons.

Alternatives to endocrine disrupting pesticides in European agriculture

As more regulatory agencies start to prohibit or restrict pesticides with specific HHP hazard criteria, more attention is focussing on alternatives, to feed into the policy process. The definition of what constitutes an endocrine disrupting chemical (EDC) pesticide in the context of the European Union's pesticide authorisation regulation 1107/2009 remains controversial and contested, with agrochemical companies and some producer groups arguing loudly that banning widely used EDC pesticides will bring major economic losses to the farming sector. These arguments often fail to make a valid assessment of the benefits of reducing human or environmental harm or of the technical and economic feasibility of safer alternatives.

With the help of independent experts in IPM and biological control, PAN Europe assessed the feasibility of available chemical and non-chemical alternatives to 13 of the most debated endocrine disrupting pesticides, using data from different crops and EU countries. These experts concluded that proposed regulatory bans on these EDCs would not lead to substantial yield losses. Furthermore, IPM alternatives can deliver benefits from reducing further development of pest, weed or disease resistance problems, make better use of natural pest control processes and reduce environmental contamination. Table 7 gives three examples from the alternatives assessment.[39]

One lesson from this work is that policymakers in chemicals management, especially those without an agronomic background, often lack awareness of IPM methods available or are under the misconception that these are less effective or much more expensive than conventional chemical control. PAN Europe is collaborating with the European branches of the International Organisation for Biological Control (IOBC) and the International Biocontrol Manufacturers Association (IBMA) to inform EU and national policy makers, via booklets and a portable exhibition on IPM principles and methods in important crops (wheat, maize, grapevine, tomato, apples, potato, brassicas and salads).[40] To persuade policymakers, farmers and the general public that safer alternatives already exist and should be actively promoted, in 2017 PAN Europe launched its educational website on Low Impact Farming, featuring case studies and videos from Italian vineyards and French cereal farms with successful experience in reducing

Table 7. Alternatives available for selected pesticides subject to potential bans under EU regulatory hazard cut-off criteria for endocrine disruption

Pesticide with EDC hazard	Main targets	Chemical alternatives	Non-chemical alternatives
Azole fungicides, e.g. **cyproconazole** **epoxiconazole**	*Septoria tritici* disease in cereals	SDHI fungicides e.g. boscalid Strobilurin fungicides e.g. azoxystrobulin	***Preventative methods***: Avoid early planting Grow less susceptible cultivars ***Biological methods***: bacterial seed treatments
ioxynil herbicide	Broad-leaved weeds in onions & leeks	bromoxynil fluazifop-P-butyl pyridate pendimethalin oxyfluorfen clethodim	***Preventative methods***: Use of 'false' seed bed technique Soil solarisation ***Direct control methods***: Mechanical weeders Thermal weeders
thiacloprid insecticide	Aphids in strawberries	pirimicarb, pymetrozine	***Biological methods***: Commercial biocontrol agents (parasitic wasps, lacewings, ladybirds) Fungal biopesticides ***Direct control methods***: Soap or fatty acid based insecticides Natural pyrethrins

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Useful Resources

Information on IPM and agroecological alternatives for specific crops

Ecological Pest Management Guides by CABI/FAO and CIP, developed from years of FFS training experience and expert inputs. Include: Tomato; Cabbage; Potato; Disease Management. Available via the 'Crops' page of the FAO Asia Vegetables IPM website, along with other guidance on alternative methods for a variety of crops, relevant to developing country agriculture:
http://www.vegetableipmasia.org/crops

On-line Information Service for Non-chemical Pest Management in the Tropics (OISAT).
Via: http://www.oisat.org/what_is_oisat.html A database from PAN Germany describing a variety of non-chemical methods, mainly using botanical extracts and other simple preparations, suitable for smallholder production. Also contains useful info on IPM principles and putting these into practice. OISAT Field Guides to Non-Chemical Pest Management now available for 16 different crops, via:
http://www.oisat.org/fulltext_docs.php?category=field_guides

Plantwise website, CABI. Contains a wealth of information on IPM methods for managing pests, diseases and weeds in dozens of different crops worldwide, with a focus on developing countries. The 'Knowledge Bank' tab allows you to search for hundreds of technical factsheets and farmer leaflets. Pest Management Decision Guides are available for dozens of crop/pest combinations, summarising preventative methods and direct interventions, with a preference for non-chemical methods. Via:
http://www.plantwise.org/

Infonet Biovision website. Via: http://www.infonet-biovision.org/
Contains practical info on ecological principles and non-chemical pest management for numerous tropical crops. Web sections also cover pest management of human and livestock disease vectors, plus broader aspects of human nutrition, healthy soils and environmental management.

Agroecology Knowledge Hub. Via: http://www.fao.org/agroecology/en/
New FAO website explains the ten elements of agroecological practices, plus case studies and links to resources on external sites. Also contains reports from regional conferences organised by FAO with policymakers.

International People's Agroecology Multiversity (IPAM) is a research-learning-action approach to agroecology that focuses on small-food producers and farming communities, mainly in Asia, and developed by a network of farmers and women's organisations, NGOs, researchers and academic institutions. Useful resources on agroecological methods and alternative farming systems can be found via: http://library.ipamglobal.org/jspui/handle/ipamlibrary/366

Videos on IPM of different crop pests available via:
AgTube http://www.agtube.org/en/categories/integrated-pest-management
Access Agriculture http://www.accessagriculture.org/home

Links to pesticide lists and policies of selected standards

Fairtrade Hazardous Materials List Version 1 Dec. 2016:
https://www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/Hazardous_Materials_List_EN.pdf or via http://www.fairtrade.eu/ under Standards

Rainforest Alliance SAN List for pesticide management. Version July 2017:
https://dl.dropboxusercontent.com/u/585326/2017SAN/Certification%20Documents/SAN%20Lists%20for%20Pesticide%20Management.pdf or via http://san.ag/web/2017-san-standard-raising-the-bar-on-sustainability-standards/

Utz Certified List of Banned Pesticides & Pesticides Watch List Version 1.0 via
https://utzcertified.org/en/ndp?article=&id=26584902 and Pest and disease management & pesticide handling Position Paper (via Resource Library https://utz.org/resource-library/)

Pesticide Action Network UK

PAN UK is based in Brighton. We are the only UK charity focused solely on addressing the harm caused by pesticides.

We work tirelessly to apply pressure to governments, regulators, policy makers, industry and retailers to reduce the impact of harmful pesticides.

Find out more about our work at:
www.pan-uk.org

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