Farmer Participatory Training and Research programme

IPM Source Book

Introduction to Coffee Management through Discovery Learning

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Preamble

An integrated pest management (IPM) system, or an integrated crop management (ICM) system can never be a prescriptive, 'off the shelf' package. A grower must look at all the options available to him or her and make an informed decision as to which measures to take. Because each farmer's situation is different, the types of IPM measures they implement may vary between regions and often even from farm to farm.

The farmer participatory approach aims to build farmers' capacities to make their own crop management decisions, based on a better understanding of the agro-ecology of their own fields, and according to their own unique set of circumstances and priorities. With farmer participatory approaches, the role of extension becomes more the facilitation of a learning process by the farming community, and less the teaching of research messages.

A successful farmer participatory coffee IPM programme depends on:
- farmers' sound knowledge of the agro-ecosystem and how this relates to pests, weeds and diseases;
- a practical approach to manipulating the cropping system to manage pests on a cost-effective and sustainable basis;
- willingness and ability on the part of both farmers and support systems (extension, research, others) to experiment, modify and innovate;
- participatory training approaches in coffee extension services;
- promotion of non-chemical methods in coffee management.

This Introduction to Coffee Management through Discovery Learning aims to give some basic information on the options available towards ecological coffee production. It is aimed at extensionists who are involved in farmer participatory coffee IPM. This source book is not intended to be comprehensive. The exercises should be viewed as guidelines and sources of inspiration rather than as rigid instructions.

We hope that this source book will have global relevance, as the exercises can and should be adapted to local conditions, depending on available materials, prevalent pest problems, local knowledge and experience within the farming community. An introductory source book is never complete. It needs to be expanded and updated regularly as practitioners around the world modify existing exercises and develop new ones. As compilers of this source book, we would like to ask for your help in keeping us abreast of new developments and informed of modifications or additional materials.

For further information, additions and updates, please contact us:

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Introduction to the coffee crop

The coffee commodity

Coffee has been drunk for centuries. According to a legend, coffee was discovered by an Alyssinian goatherd who noticed its effect on his goats. Botanical evidence suggests the coffee plant originated in central Ethiopia and was brought to Yemen where it has been cultivated since the 6th century AD. There is indeed evidence that ripe coffee beans were chewed by slaves, taken from present day Sudan into Yemen and Arabia, early in the 15th Century, to keep them awake and active while working under terrible conditions. Coffee drinking was introduced to Europe by the Arabs in the 17th century and consumption has been increasing ever since. Now coffee is drunk widely around the world by an estimated one third of the world's population. Coffee has become a major global commodity. It is one of the topmost valuable primary products in world trade. Its cultivation, processing, trading, transportation and marketing provide employment to an estimated 20 million people worldwide.

Coffee production

There are many species of coffee, but only two are important commercially: *Coffea arabica*, which produces Arabica coffee, and *Coffea canephora*, which produces Robusta coffee. About 60% of the world coffee production is Arabica, which is perceived to be of higher quality, and can fetch much more in the market compared to Robusta. Robusta coffee is better adapted to warm and humid equatorial climates. It is generally more resistant to adverse conditions than Arabica, particularly pest[1] attack. Both species can grow best on deep, free-draining, loamy soils, with a good water-holding capacity and a slightly acid soil (pH 5-6). Soil fertility is important for good production.

Despite a number of serious constraints, discussed in the next section, world production of coffee has increased steadily from about 4 million tonnes in the mid 1960's to about 6.5 million in the 1990's. At least 10 million smallholders produce at least half of world production, growing between 0.5 and 5 ha each, while the remainder is produced on large estates, notably in Brazil, C. America, Indonesia and East Africa.

At the moment, about 40% of coffee is produced in South America, most of which is grown in Brazil and Colombia. Central America is also a major producer, growing 17% of the total, mostly in Mexico and Nicaragua. Asia (Vietnam, India and Indonesia) produces nearly a quarter of the worlds production and Africa (mostly Ethiopia, Tanzania, Kenya and Uganda), nearly a fifth.

Constraints to coffee production

The last 20 years have seen some turbulent times for those who rely heavily, directly or indirectly, on coffee for their livelihoods. Many important changes have taken place in the global coffee market since the late 1980s, the most significant of which has been the liberalisation of markets and the abolition of many government coffee policy organisations. Crucially for small farmers, the role of quasi-state organisations has been greatly reduced as well as subsidies for coffee production and agricultural services. In addition, private exporters have taken a lead role in trading.

[1] Pest = arthropods, vertebrates, pathogens, weeds or other organisms detrimental to agricultural production.

This means that the price farmers get for their coffee is much more closely linked to the world market, which is notoriously volatile, and fluctuates wildly both between and within years, for reasons completely beyond the control of the producer. For example in 1989, the price control clause of the International Coffee Agreement (ICA) was suspended and prices plummeted. The coffee exporting states could not agree on quotas and country after country flooded the market with stocks originally withheld to sustain prices. This kind of uncertainty means that many small farmers, understandably, are not willing to invest time and money in a crop that gives very uncertain returns on investment.

Although price is an important, and perhaps the most visible constraint, it is only one of many problems facing smallholder farmers. For instance, many farmers are isolated from market places, and often have to sell to middlemen, who give them a price below even that of the world market. Lack of access to credit has become one of the key factors undermining the position of small farmers. Without loans at a decent rate of interest, it is impossible for farmers to take adequate care of their crops, or to support their families prior to the harvest. After harvest, they need cash quickly, to clear debts of the previous season, and this means selling the crop quickly, often to the nearest trader, at a time when prices are low anyway. For more information on production constraints on farmers generally, contact the Fair Trade Foundation (see Further reading section).

Other problems include the sensitivity of coffee, particularly Arabica, to extreme weather conditions, such as frost, drought or wetness, which can reduce the quality, volume and value of a crop, as can pests. For example about 50% of Colombia's total coffee area has been infested by the coffee berry borer, a worm that bores into the coffee berry. When the price was low during the early nineties, there was little incentive for farmers to care for their crop.

Coffee berry damaged by coffee berry borer
Photo by P. Baker © CABI Bioscience

Exercise 1 will help you to identify some of the problems facing smallholder farmers in the area you are working in, and to understand farmer's perceptions of those constraints.

Growing Sustainable Coffee

There are no 'silver bullets' or simple solutions to these diverse and complex problems that currently plague the coffee industry. This manual focuses on growing the crop in a sustainable way, utilising management methods that are cheap, practical and sustainable for the small farmer, reducing dependence on often costly inputs such as pesticides and fertiliser.

Growing a healthy crop

A healthy crop is a more productive crop. Growth is more vigorous, yields are generally higher and the plant is better able to resist or compensate for pest attack. In this section, we will look at some of the approaches we can take to improve and maintain the all round vigour of tree, after which attention is paid to specific coffee pests and their management. **Exercise 2** explains the value of monitoring coffee fields, while **Exercise 3** facilitates regular observation of coffee fields using agro-ecosystem analysis (AESA).

Pruning

Pruning is an essential part of coffee production, and basically it involves thinning of branches and removal of old or dead stems. Pruning serves many purposes, including:

- *It determines the shape of the tree.* It is important that the tree is shaped to adapt to the conditions in which they are grown. For example, you may want to prevent the tree from growing to tall to make tasks such as harvesting and spraying easier.

- *It maximizes the amount of new wood for the next season's crop.* By cutting away less productive wood, you encourage the growth of new, vigorous stems and branches.

- *It prevents over-bearing and thus reduces biennial production.* Pruning results in bigger berries of higher quality than small berries that would result from overbearing.

- *It helps prevent some pest and disease problems.* By opening up the canopy so that light can penetrate to the centre of the tree, and air circulates more freely, certain pests and disease problems are reduced or prevented.

There are basically two systems of pruning widely used in Africa, the **single stem** and the **multiple stem** systems. The single stem system involves cutting back older secondary and tertiary branches (Figure 1) that have carried two crops. This encourages the growth of new lateral branches. It also thins the canopy to improve light penetration and air circulation. The Multiple stem system is designed to encourage top, rather than lateral growth, and mainly involves removing the lower primary branches.

In East Africa, farmers have traditionally used the single stem system, but in recent times, more and more are switching to the multiple stem pruning to achieve more regular production and to increase the quantity of coffee produced from decreasing acreages due to sub-division of land.

Exercise 4 investigates the advantages and disadvantages of pruning, using the single stem system.

Mulching and cover crops

Mulching involves covering the soil with a layer of dry vegetation. In East Africa, common materials are napier grass, maize, banana leaves and coffee prunings. Mulching can have many benefits, including:

- reducing the loss of soil moisture
- prevention of soil erosion, which is particularly important where coffee is grown on steep slopes
- increasing soil nutrient levels
- improving the structure of the soil
- suppression of weeds

Alternatively, growing a cover crop ('living mulch') under the coffee trees can give many of these benefits. Cover crops often legumes, which are have a special ability to fix nitrogen from the air in the soil though specialized bacteria that live on their roots, thus indirectly increasing the nitrogen content of the soil.

Soil nutrient management

Soil nutrient management is critical to the general health of the plant, particularly where coffee is grown on poor soils with low nutrient levels. For Arabica in particular, the nutrient that most limits growth is nitrogen, and applications of 50 - 100 kg of nitrogen per ha per year can improve growth. However, the continuous use of inorganic fertilisers has a number of problems associated with it, including the depletion of soil organic matter, the deterioration of soil structure, and the acidification of the soil. The use of organic fertilisers can address many of these problems, and is important for maintaining healthy soils. Organic fertilisers can come from a number of sources including farmyard (cattle, goat, chicken) manure, sludge from methane gas plants, composts and 'plant teas' which can act as liquid manures. **Exercises 5 and 6** cover the production and application of composts, liquid manure and plant teas.

Shading coffee trees

Coffee originated in the forests of East and Central Africa and is therefore well adapted to growing in the shade. Traditionally, coffee is grown under shade, either under other tree crops (e.g. fruit trees), or bananas, or under the shade of trees left standing after land clearance.

In recent years, however, the trend globally has been towards growing coffee without shade, so-called 'sun coffee'. In direct sunlight, coffee yields can be significantly higher compared to shaded coffee. Debt-strapped nations seeking to boost exports have taken deliberate steps to 'modernise' growing practices, and have actively encouraged farmers to grow sun coffee. In Kenya, for instance, it is illegal to grow coffee inter-cropped with other crops even though since recent there is no strict enforcement because of the poor coffee prices.

The problem with sun coffee is that it requires much higher levels of external inputs: The conditions under which sun coffee is grown encourages coffee leaf rust, which has resulted in a large increase in fungicide use. Also, because of the direct sunlight, weeds tend to be more of a problem and grow faster, which leads to increased herbicide use.

Sun coffee also often requires more fertilisers, because of the higher levels of metabolism and production of the crop. Hence, problems arise when sun coffee farmers have to stop fertilising when prices crash. Like legumes, some species of shade trees can fix nitrogen, enriching the soil. Shade trees also provide litter, which can act as a natural mulch, reducing the need for fertilisers and herbicides. They also provide habitats for some natural enemies of pests, and wild life (in particular resident and migratory birds), and help prevent soil erosion.

In the short term, increased costs of inputs needed for sun coffee can mean that the increased yields do not translate into increased profits for the farmer. In the long term, sun coffee is also more costly than shaded coffee because the productive life of the trees is much shorter: Sun coffee trees' productivity declines after 6-7 years, while shade coffee trees have a longer though lower productivity.

Grove in South Kalimantan with coffee, pepper and banana
Photo by E. Boa © CABI Bioscience

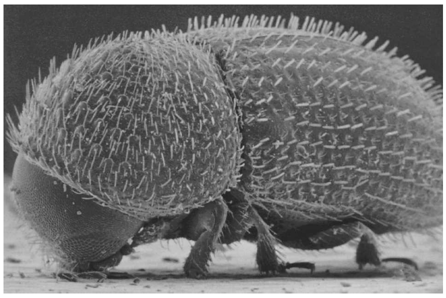
Major coffee pests

Insect pests and their natural enemies

Over 900 insect species are known to infest coffee, however only a tiny fraction of these are economically damaging. **Exercise 7** Assessing farmers' friends in the coffee field and **Exercise 8** Learning more about insects, will help you recognise some of these coffee pests and their natural enemies, and learn about their basic biology.

Coffee Berry Borer (*Hypothenemus hampei*)

The coffee berry borer (CBB) is a black beetle 2mm in length, believed to have originated in Central Africa. It spread from its African centre of origin across Africa, Asia and Central and South America through trade and is considered one of the most significant and widespread insect pests affecting coffee production. Damage is caused by the female, which bores into green coffee berries to lay her eggs, producing legless white larvae that feed on the beans for 3 or more weeks. Economic damage caused is twofold: premature fall of berries and hence total loss of these to production; damaged berries are retained on the tree until harvest, making them of lower commercial value by reducing weight of the bean and downgrading the quality and affecting the flavour of the coffee. The pest is difficult to control by spraying because much of its life cycle occurs deep inside the berry. Manual control (hand picking of berries) is laborious and expensive. Biological control is an obvious alternative, but there are only few known natural enemies of the borer.



Coffee berry borer adult
Photo by P. Baker © CABI Bioscience

Coffee Bug (*Antestia* species)

This bug is a serious pest in many parts of Africa and belongs to the shield bug family. It has striking patterns or markings in black, white or orange. The adults and nymphs feed mostly on immature, green berries, from which they suck the sap, causing the fruits to shrink. The bug may also transmit a fungal disease, which infects developing beans and turns them into a white powdery mass. In Kenya, the disease is known as 'Posho (maize meal) bean'. After harvest, this bug may feed on the tips of coffee branches, stimulating development of shoots, which deplete the plant's resources but bear no fruit. It may also attack flower buds, which turn black and fail to set fruit.

There are over 20 parasitic wasps attacking the coffee bug in East and Central Africa. *Aridelus* spp., for example, attack the nymphs and are particularly important in these regions. *Ascolus* wasps are also important egg parasites and the parasitic fly *Bogosia rubens* attacks the adults. Other important natural enemies of this pest are closely related predatory bugs.

Scales and Mealybugs

Mealybugs are small sap-sucking insects, often covered in a white, waxy coating. The nymphs and adult females may attack leaves, branches, roots or flowers. Scale insects develop a tough, scaly covering and do not move once they have established a feeding site. The most important scale pest is the coffee green scale (*Coccus viridis*) which causes serious losses in many coffee growing regions of the world. There are over 50 species of scale and mealybug pests that attack coffee worldwide, but only a few are important pests.

Green scale
Photo by P. Baker © CABI Bioscience

Many key natural enemies of scales and mealybugs are parasitic wasps. In many parts of sub-Saharan Africa, ladybird and hoverfly larvae are considered the most important predators. Fungi that cause insect diseases are very important in some regions, for example, the fungus *Cercosporium lecanii*, is considered the most important natural enemy of these pests in parts of Indonesia.

Leaf miners

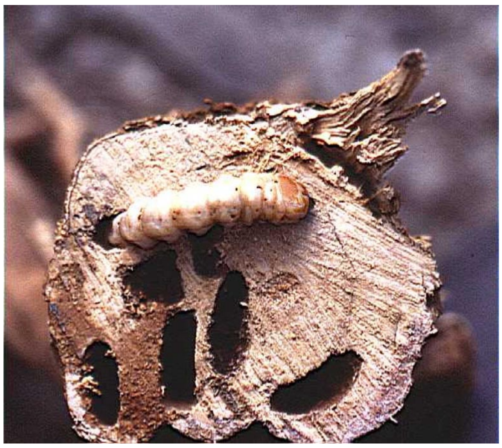
Coffee leafminers are the caterpillars of small *Leucoptera* moths and are now important pests in parts of Africa, mostly as a result of heavy use of pesticides, which have eliminated many of the pest's natural enemies in coffee groves. The caterpillars are white and flattened and grow up to 5 mm long. They burrow inside the leaf and feed on the tissue between the leaf surfaces. Several small mines may run together, causing brown spots to appear and in severe attacks they cause major loss of leaf tissue and premature leaf drop, which reduces plant vigour and yield.

Coffee leafminer: mine with upper epidermis removed to show larvae of L. coffeella
Photo by D. Nestel

The known natural enemies of leafminers are almost entirely parasitic wasps. In Africa, these mainly attack the caterpillar or pupal stage. A few predators have been recorded including two species of predatory thrips, a predatory mite and a species of lacewing.

Coffee Stemborers

The most important coffee stemborers in East and Southern Africa are wood-boring beetles. The beetle larvae bore into the bark and the wood itself. They may tunnel down for up to 20cm into the roots and as much as a metre up into the main stem, causing extensive damage to the lower part of the trunk and the root system. The young larvae of the West African stemborer, an occasional pest in many parts of Africa, may ring-bark the tree, cutting off the supply of



African stemborer
Photo by D. Moore © CABI Bioscience

nutrients to the upper regions of the plant. Young trees up to two years old are frequently killed, and survivors yield little and are unlikely to be worth maintaining.

There is little information on the natural enemies of stemborers. However, a parasitic wasp and a parasitic fly have been recorded on the West African stemborer.

Diseases

Coffee Leaf Rust (*Hemileia vastatrix*)

Coffee leaf rust (CLR) has been studied in great detail since its discovery over a hundred years ago. This fungus only attacks the leaves and the first signs of the disease are orange/yellow circular spots mostly on the lower surface of the leaves. The spores of the fungus are dispersed mainly by wind and infection can progress down a tree via raindrops. In severe cases, coffee trees may suffer premature or complete leaf drop.

Coffee leaf rust
Photo's by J. Waller © CABI Bioscience

Arabica coffee is mostly susceptible, while Robusta is resistant. CLR can be especially problematic on trees under drought stress or where trees are insufficiently fertilised. Mulching and manuring can help minimise CLR impact. The disease causing fungus itself may be attacked by other fungi. For example *Verticillium* species parasitise the leaf rust fungus.

Other leaf diseases

Bacterial blight (*Pseudomonas syringae*), which causes leafspot and die-back of young branches, can be a serious problem where Arabica coffee is grown at high altitudes in East Africa. Cercospora leaf and berry spot (*Cercospora coffeicola*) can be important in coffee nurseries.

Bacterial blight on coffee: die-back
Photo by J. Waller © CABI Bioscience

Coffee Berry Disease (CBD) (*Colletotrichum kahawae)*

Coffee berry disease attacks the berries, at all stages of the crop from flower to ripe berry, although most damage is inflicted when young, expanding berries are infected, which are mostly shed once they become diseased. If the infection reaches the beans, they become black and distorted and are unmarketable. The spores are spread by rain during showers, when spores are washed down from infected berries and bark at the top of the tree to infect berries further down. In addition rain-splash can disseminate spores to adjacent trees when droplets fall into small pools of water on the ground or on the plant.

Coffee berry disease
Photo by J. Waller © CABI Bioscience

To some extent, non-disease-causing fungi, and bacteria present on the plant surface may reduce the population of the CBD fungus, by preventing the pathogen from establishing colonies. The populations of these beneficial microbes may be destroyed by certain fungicides and bactericides. Using more selective chemicals and specific application regimes can reduce impact on these beneficials.

Coffee Wilt Disease, also known as Tracheomycosis (*Gibberella xylarioides*)

This disease can attack almost all above ground parts of the plant, and is most common in young plants. Die back begins with the lower branches but may spread to the whole plant as the disease develops. Stem tissues around the collar the plant are killed, and blue black streaks appear in the wood, under the bark. In severe attacks, trees wilt and collapse. On berries, sunken brown lesions appear at the stalk end of the berry, which can cut off the flow of nutrients to the berries, causing them to die prematurely. Dark brown lesions may also appear else where on the berries, especially where the flower was attached, which turn the infected berries red, so that they appear to ripen early.

Coffee wilt affected plantation in DR Congo
Photo by J. Flood © CABI Bioscience

Diagnostic symptom of coffee wilt: blue-black staining in vessels
Photo by J. Flood © CABI Bioscience

The fungus is soil dwelling and enters the plant through wounds either above or below or below ground. The fungus is apparently not able to survive long in the soil and survival from one season to the next is mainly through seed from infected berries, however, insects and rain splash may also contribute to the spread of the disease.

Root diseases and nematodes

The root rot fungi, *Armillaria* spp. and *Rosellinia* spp., can be serious problems in some coffee growing areas. The leaves rapidly wilt and turn yellow at the tips. Roots and collars crack as the disease develops and fungal growth can be seen on exposed root tissues.

Plant feeding nematodes are tiny worm like organisms that live in the soil. They feed by piercing root cells and sucking the cell contents. In this way they cause damage both by direct feeding and indirectly by providing an entry point for fungal and bacterial diseases. Two main types of nematode attack coffee; the root knot nematode, which form galls or knots on the roots and the root lesion nematode, which feed on the outer layers of the roots causing them to turn yellow or brown.

Coffee root knot nematode symptoms on roots
Photo by J. Bridge © CABI Bioscience

It is extremely difficult to detect the presence of nematodes, simply by looking at the plants. Often there are no visible symptoms of an attack and the only indication is a reduced yield and symptoms that do appear on the above ground parts of the plant are often easily confused with nutrient deficiencies.

Weeds

A range of weeds are associated with coffee, ranging from annual grasses and broad leaved weeds, which are relatively easy to control, to persistent perennials that are more difficult to manage. Perennial grass species reproduce through underground stolons, tubers and rhizomes, such as couch grasses. Sedges can also be a serious problem. They too spread by underground rhizomes and tubers that remain in the soil when the rest of the plant has been destroyed, and are a particular problem in very young coffee. Other perennial grasses that are difficult to control are star grasses, *Paspalum* and *Laporlea* spp. and the annual grasses *Peperomica* and *Synedrella*.

A number of broad leaved species such as *Oxalis* spp. and *Parthenium* spp. are also important in coffee, although most species are less harmful than perennial grasses and sedges. *Commelina* weeds are also important in many coffee growing areas of the world. Modern weed control techniques try to select for broad-leaved species to create ground cover.

Managing coffee pests

Making the most of natural enemies

In the coffee agrosystem, there is a large complex of natural enemies, including predators, parasites, insect diseases and nematodes, attacking insect pests. One of the most fundamental, ways in which farmers can reduce their reliance on chemical pesticides is to make the most of the natural enemies already present in the field. This **conservation** of natural enemies is a very important form of biological control.

Perhaps the most important way in which you can conserve natural enemies is to minimise the number of pesticide applications you make. The decision whether or not to apply pesticides should always be based on the findings of detailed observations of the crop, taking into account pest and natural enemy levels and the general health of the crop (see **Exercise 3** AESA). To learn about spray drift effects, **Exercise 9** is recommended.

When pesticide applications are justified, there are a number of approaches to minimise the impact they have on natural enemies:

- Some insecticides are intrinsically less harmful to natural enemies than others. As a rule of thumb, one can consider biopesticides (such as *Bacillus thuringiensis,* a bacteria that produces a powerful but selective insect toxin) are safer to natural enemies than synthetic chemicals.

- Chemical control methods can also be made to act more selectively by the way in which they are applied. A good example of this is stem treatment of coffee bushes against ants. Most ants are not a problem in themselves, in fact some are extremely important predators, but certain species, such as *Pheidole punctulata*, feed on the sugary waste that mealybugs excrete and will therefore protect them from many natural enemies. Ants can be effectively controlled by painting a band of insecticide, about 10cm wide around the lower part of the coffee stem. Of course, physical barriers created by applying a band of non-toxic insect glue or fluffed wool would be more environmentally sound whilst having a similar effect. Ants foraging from the ground fail to cross these barriers, but predators that live in the leaf canopy and flying insects such as parasitic wasps are left completely unharmed!

- Sometimes, you may have scope for timing sprays when they do not affect the critical stage of natural enemy activity. In pest populations with distinct generations, natural enemies may be active at particular times in the pests life cycles. For example, coffee leafminers are most effectively controlled by spraying when the adult moths are emerging and egg-laying. At this time, important parasitoids are protected inside leaf mines in their pupal stage. If sprays are carried out while leafminer larvae are still inside their mines, the pesticides merely kill adult parasitoids as they at that stage search for hosts and are vulnerable to pesticide applications.

Adding more natural enemies

Sometimes, even when you have tried to conserve natural enemies, they are still not effective enough to prevent economic damage. In this situation it is sometimes possible to boost the populations of natural enemies that are already in the ecosystem, by mass rearing them in laboratories or rearing units and then releasing them into the field. This approach to biocontrol (**augmentative** biological control) is not widely used for coffee.

Introducing new natural enemies

Sometimes there simply are no natural enemies that are effective against a pest in a particular system. This situation usually arises when exotic pests have been introduced to a new region leaving their natural enemies behind and as a result their numbers increase rapidly. One approach is to go back to the area where the pest originated, find natural enemies attacking the pest, and import them into the new region to redress the balance. The coffee mealy bug *Plannococcus kenyae* was introduced to Kenya from Uganda in the early 1920's, and outbreaks of this pest occurred shortly afterwards. A parasitic wasp, *Anagyrus kivensis* from Uganda was released in 1939 and it achieved good control of the mealybug by 1949. Although the idea is simple, a substantial amount of research and money is involved in developing this type of biological control. Therefore it is undertaken by government and international research organisations, rather than by farmers. However, farmers can actively participate in a release programme and contribute to its success by minimising pesticide use, thus giving the introduced natural enemy the best chance of becoming established and controlling the pest.

Cultural methods

Sometimes you can manage pests by changing the way in which you grow the crop. Methods based on this idea are called **cultural methods**. As pointed out earlier, growing a healthy crop can help the plant resist or compensate for pest and disease attack.

Most of the recent coffee research on cultural methods has been in relation coffee berry borer (CBB), which is a problem in South America, but not in Africa. The CBB survives from one cycle to the next in berries that have either dropped on the ground or left on trees after harvest. One of the most effective ways to control this pest is to pick up and destroy any ripe, over-ripe or dry berries either on the ground or on the trees at the end of the season. Picking berries off the ground is very labour intensive, and therefore to keep berry drop to a minimum, mature berries should be harvested frequently. If practical, the trees should be stripped completely bare of berries as soon as possible after harvest. Coffee growers, through experimentation and record keeping, need to establish the economic benefit of investing in the extra labour required in order to reduce CBB damage in the next season.

The use of clean (pest-free) seed at planting is an important strategy for controlling seedborne diseases, such as coffee wilt disease. Seed from disease free sources should always be used.

As pointed out earlier, pruning increases the vigour of the plant by cutting away unproductive vegetation and opening up the leaf canopy to allow more light to penetrate and air to circulate, thus reducing the humidity and temperature. These conditions are less favourable to many pests and diseases, for example, coffee berry disease and coffee bugs (*Antestia spp)*. Kenyan farmers in a pilot coffee IPM training project observed higher parasitism rates of *Antestia* bugs in pruned, compared with unpruned, trees (verbatim from Thayu, Wundnyi, Kariguini and Othaya Farmer Field Schools). **Exercise 4** looks at the role of pruning in pest and disease management in more detail.

Pest Resistant Coffee Varieties

The use of pest and disease resistant varieties is a very valuable IPM strategy, and various resistant varieties of coffee are now available, for example, resistance to coffee berry disease was bred into 'Ruiru 11' variety, developed in Kenya. Most varieties resistant to coffee leaf rust disease are only resistant to one, or a few strains of the fungus, however, a natural hybrid from 'Timor' is resistant to most major strains of coffee leaf rust. This hybrid has been used in breeding programmes with 'Caturra' varieties in Brazil and Colombia to develop 'Catimor' varieties resistant to all major strains. These are now used in many countries to produce locally-adapted rust resistant cultivars.

Resistance is also considered an important strategy for coffee wilt disease although previously resistant varieties developed during the 1950's and 1960's are succumbing in the current East and Central African coffee wilt epidemic; yet the reasons for this remain unclear. Grafting is another valuable technique for the production of resistant plants, on a shorter time-scale than growing from seed. 'Ruiru 11' cultivars may be grafted onto growers' existing rootstock to confer coffee leaf rust resistance. Arabica coffee stems, which produce coffee of high quality, can be grafted onto rootstocks of Robusta coffee which is more resistant to root-knot nematodes, to produce a bush that is both more resistant to nematodes and yielding a high quality product.

Weed Control

A number of weed control strategies are available to smallholders. Cultural and mechanical controls include weed slashing, using a machete, and the use of a mulch or cover crop which can be effective for many grass weeds such as couch and star grass. Hoeing may be used in some systems, but is not recommended where coffee is grown on slopes, as it may increase soil erosion.

As mentioned earlier, growing a cover crop can also help to smother weeds. One option is to grow a cover crop under the coffee bushes. This gives plenty of ground cover, and can be very effective in smothering a range of weeds. Some cover crop species, such as the legume *Cassia* spp. actually produce chemicals, which prevent the germination of some weed seeds.

While herbicides are widely available in coffee growing areas, the use of broad-spectrum products and blanket application techniques may also promote soil erosion and dessication by removing ground-cover.

Selective weeding practices are directed at the most problematic weed types such as vines, grasses and tall broad leaved weeds, while less damaging species are left to provide ground cover, while not having a significant effect on the yield of coffee. The problem weeds may be controlled either by slashing or by spot application of a herbicide. This approach has been tested in Nicaragua where training was provided to help farmers recognise the most damaging weed species.

Discovery based learning exercises for coffee

Exercise 1. Appraisal of coffee production constraints

Objectives

- To obtain information on farmers' coffee management practises and identify the major problems encountered by farmers
- To prepare a seasonal calendar as a guideline for farmer field school study plots

Procedure

In the meeting place:
Facilitate a general interactive discussion session to discuss the kind of information that needs to be gathered from coffee farmers. Work through the entire coffee production cycle, including land preparation, seedling management, planting, flowering stage, fruiting stage, picking, etc. At each step, decide what kind of information that needs to be gathered from coffee farmers, in terms of production constraints and the management practices associated with each stage of the crop, including pest and disease management (e.g. spraying, cultural controls), pruning practices, fertilisation practices, etc.

In the field:
In small groups of 4-6 participants, visit different coffee fields. Discuss farmers' practices and problems with each farmer and visit the fields to observe and verify some of the problems.

Observing coffee constraints in the field

Back in the meeting place:
Each small group prepares posters to present their findings to the rest of the group. After the discussions, develop a seasonal calendar, which is a record of crop growth and development stages plus, per stage, what is done, by when, by who and for what reason. This becomes a guideline for the farmers' practice treatment in comparative experiments to test alternative, IPM management options in a field school set-up.

Guide questions for discussion

1. What do farmers see as the main constraints to coffee production?
2. At what stage(s) of the cropping season is each constraint important?
3. What options do farmers perceive they currently have to overcome these constraints? Are there other ICM options available?
4. Which of the constraints could be addressed in a farmer field school programme? How?

Exercise 2. Monitoring coffee fields

Objective

To understand the importance of field monitoring

Materials

Polythene sheets, vials, polythene bags, hand lens, coffee field (preferably unsprayed), flip charts, colour pens

Procedure

In small groups, visit different coffee fields (preferably those that haven't been sprayed recently) and make observations on insects, diseased leaves, branches, stems, berries etc that are known or can be recognised by the participants.

In each field, each group selects and tags one or more coffee bushes. Each tagged bush is observed systematically through detailed observations of bottom, middle and top branches.

Spread a polythene sheet on the ground below the tree. Beat / shake tree stems so that the insects, diseased berries, and leaves fall on the sheet. Gather the polythene sheet carefully and observe its content: how many different types of insects are found, which of these are known as pests, how many berries and leaves are found and why did they drop off the tree?

To record the results, draw a large picture of the coffee plant in the correct colours and draw the major pests and other constraints that were observed. Present the results per group.

During the discussions, establish the local names of insects and diseases observed and the difference between the different fields. Arrive at a consensus on why coffee fields should be observed. As much as possible differentiate insect pests from natural enemies (farmers' friends)

Guide questions for discussion

1. Which pest problems were found and what are the local names for these?
2. Can you differentiate those insects that are pest insects and those that are natural enemies ('friends of the farmers')?
3. Was there a difference in results between the various fields? Why (/why not) and what can we learn from this observation?
4. Is there a need to observe coffee fields regularly? Why (/why not)?

Exercise 3. Observing coffee fields through Agro-Ecosystem Analysis (AESA)

Objectives

- Analyse the field situation by making observations, drawing findings and discussing potential management actions needed
- Study the coffee agro-ecosystem for informed decision making
- Understand the various interactions that occur amongst the components in the coffee ecosystem and demonstrate their balance

Materials

- ✔ Coffee field
- ✔ Vials
- ✔ Polythene bags
- ✔ Cotton wool
- ✔ Methyl alcohol (70%)
- ✔ Sweep nets
- ✔ Hand lenses
- ✔ Notebooks, pencils and erasers, colour markers and crayons
- ✔ Poster paper (flip charts / newsprint)
- ✔ Meter rule

Procedure

AESA data are normally collected from various treatments (e.g. IPM versus Farmers' Practice) to learn about the impacts of those treatments.

Preparation:

In groups of 3 or 4 participants (if possible with one facilitator each), visit a different coffee field. Each group selects one person to record all data (Recording can be rotated amongst group members). Each group should move diagonally across the field and select and tag at least 5 coffee bushes for observations.

Making observations (use attached data sheet for recording):

For each coffee bush/tree:

- Measure the height of the tree (cm), the canopy diameter (cm) and the No of cycles (*number of seasons the tree has passed through).*

- Spread the polythene sheet on the ground below the trunk of the tree. Shake or beat the trunk vigorously, so that insects, diseased berries and leaves fall on the polythene. *Make sure your first shake/beat is a good one, so that you catch the insects by surprise. If the first shake does not knock them down, many insects will cling tightly to the plant and won't fall off, no matter how much you try to dislodge them subsequently!*

- For each bush, observe and record the numbers of the insects you recognise on the polythene sheet, and whether they are a pest or a beneficial. Collect any insects that you do not recognise in the vials. Take them back to the meeting place to see if any of the other groups can help you.

- After beating the tree, select branches, 1 from the top, 1 from the middle, and 1 from the bottom of the tree. Carefully observe 5 leaves on each of these branches and the branches themselves, recording numbers and species and insects remaining on the branches. Observe and record how many of the leaves and berries are diseased. If you recognise the diseases, record them. If you don't recognise them, collect them in vials and take them back to the meeting place.

- Count on how many bushes the major pests and diseases are found.

- Record the number and species of any weeds on or around the tree. If you are not sure whether a plant is a weed, collect it in a polythene bag, and take it back to the meeting place. The other groups may be able to help you decide.

- Record the general condition of the plant (Healthy, Moderately Healthy, Weak).

- Record the soil moisture levels (High, medium, Low). Check whether there are signs of soil erosion. What is the health of the soil (structure, organic matter)?

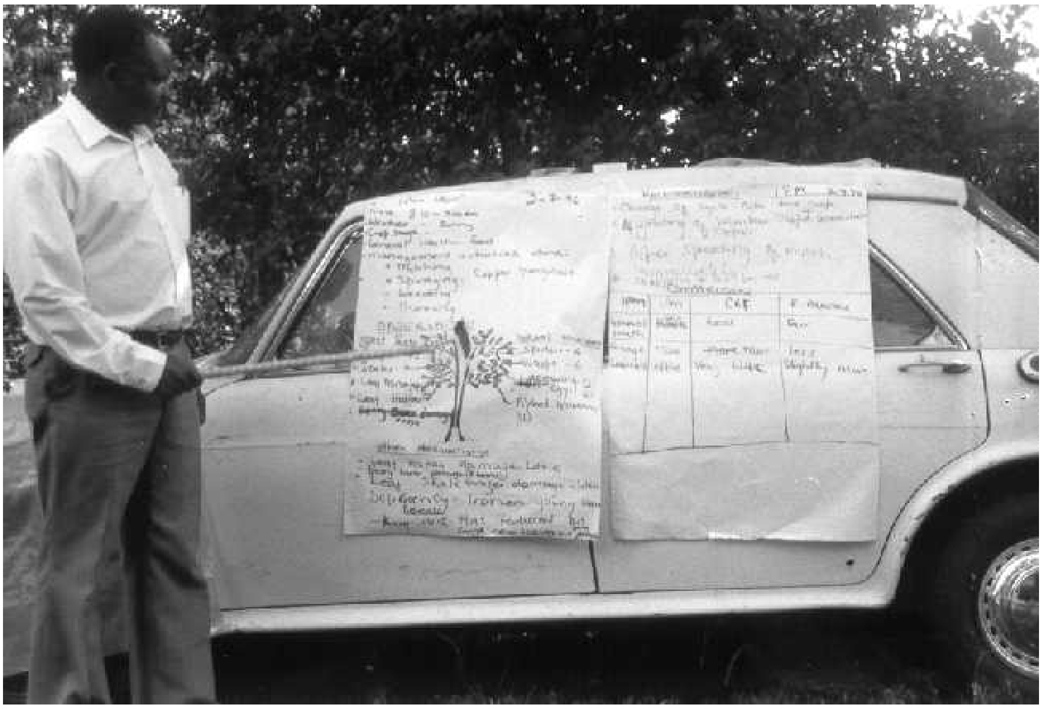
- Record the weather conditions at the time when you made your observations.

Drawing the Agro-Ecosystem, Kenya coffee farmer field school in Kariguini, 1996
Photo by S. Williamson © CABI Bioscience

Presenting your findings:

Present your results on flip charts or posters. Prepare them as follows:

- Draw a large picture of a coffee plant in the centre of the page, using the right colours
- On the left-hand side of the plant, draw the insect pests and disease symptoms found and, indicate how many you found, and where on the plant you found them.
- On the right, draw the beneficials. Indicate how many you found, and where on the plant you found them.
- Around the base of the plant, indicate the number and the species of the weeds you found.
- Somewhere on the chart, also indicate weather conditions, soil moisture, general plant health and any other general observations you made.
- Present and explain the chart to the other groups.



Presenting the Agro-Ecosystem, Kenya coffee farmer field school in Kariguini, 1996
Photo by S. Williamson © CABI Bioscience

Making management decisions:

Discuss as a group what management decisions to take. For example, given the relative pest and natural enemy populations, diseases levels, do we need to spray or are there other management options?

If you do need to do something, how and when and what will be the impact on the agro-ecosystem. E.g. if you opt to spray a pesticide, what chemical should you use? Is it necessary to spray the whole field? Is it necessary to spray the whole plant? What will happen to the natural enemies if you spray? And what knock-on effect would you expect if natural enemies would be killed by spraying?

What is the condition of the soil? Do we need to irrigate? What is the structure of the soil? If it is poor, can we improve it? Do we need to take measures against soil erosion? If so, what? Etc.

How can AESA be used?

You don't need to answer all these questions straight away. You can use the AESA to identify topics you need to study or to give you some ideas as which IPM/ICM methods you would like to try out.

AESA can be modified and used as a system for collecting data in simple farmer experiments. For example, comparing IPM and Farmer practise plots, or testing different crop varieties, or evaluating different fertilisation regimes.

TYPICAL FIELD DATA COLLECTION SHEET FOR AESA

Group Name: AESA No. Plot Name: Date:
Crop:

Insect pests, natural enemies and diseases

Organisms / Conditions	Tree Number										Total
	1	2	3	4	5	6	7	8	9	10	
Insect pests and mites 1. 2. 3. 4. 5. 6.											
Natural Enemies 1. 2. 3. 4. 5. 6.											
Diseases We need to specify how we do this: see questions in text.* 1. 2. 3. 4. 5. 6.											
Weeds 1. 2. 3. 4. 5. 6.											

Agronomic Data

Parameter	Bush No.						
1. Plant Height (cm) 2. No. of Cycles* 3. Canopy diameter (cm) 4. Soil moisture	1	2	3	4	5	Total	Average

D General Field Conditions / Problems

Weather

Erosion?

Others?

Exercise 4. Coffee pruning

Objectives

- To learn how to do proper pruning
- To investigate how proper pruning may reduce common coffee diseases, especially leaf rust

Materials

- ✔ Un-pruned coffee bushes
- ✔ Secateurs or whatever farmers use as pruning tools

Procedure

Be careful if coffee canker is present as you could spread it on the pruning tools from infected to healthy trees!

- Work in groups of two participants per coffee bush, carefully pruning off suckers and branches with die back diseases. Remove secondary branches in an alternate pattern.

- Make field observations of pruned and un-pruned trees over time. Use the observation and presentation methods described in Exercise 3 (AESA). Pay particular attention to disease levels, and to populations of insect pests and natural enemies.

- At the end of the season, measure and compare yields from pruned and un-pruned trees.

Guide questions for discussion

1. Did you observe any differences in disease levels (increase or decrease) between pruned and un-pruned trees? If so, why?
2. Did you observe any differences in insect pest levels (increase or decrease) between pruned and un-pruned trees? If so, why?
3. Did you observe any differences in natural enemies (increase or decrease) between pruned and un-pruned trees? If so, why?
4. Where they any differences in any other measurements you made, e.g. general plant health, numbers of berries per branch, weed infestation.
5. Considering the labour involved in pruning, do you think this is a worthwhile exercise? Why / why not?

Exercise 5. Compost preparation

Objectives

- To learn how to prepare compost for application on coffee fields

Materials

- ✔ Plenty of plant material both dry and green
- ✔ Ordinary top soil
- ✔ Animal manure or old compost
- ✔ Wood ashes and charcoal dust
- ✔ Several jars of water

Procedure

- Select a location close to the place where the compost will be used. Make sure it is sheltered from the wind, rain and sun. The compost pile must not get too hot or dry.

- Measure an area one-and-a half meters to two meters wide and any convenient length depending on the available composting materials. It must be possible to work on the compost pit without actually stepping on it.

- Loosen the ground where the compost pile will be. The materials need close contact with the loose soil at the bottom. It is best to make a shallow trench about 30cm deep. In dry areas the trench or pit can be as much as one metre deep. The topsoil obtained will be used in the compost. Therefore, put it on one side beside the trench.

- The bottom layer should be of rough vegetation such as maize stalks or hedge cuttings. This layer should be about 30cm thick. Chop maize stalks etc into shorter lengths.

- The second layer should be manure or old compost or slurry. It should be about 10cm thick.

- Sprinkle some of the topsoil on top of this layer so that it just covers the material. Do not put on too much soil, and only use topsoil.

- The next layer should be made up of green vegetation about 15-20cm thick. Use green weeds, grass, hedge cuttings or kitchen waste.

- If you have wood ashes, sprinkle some on top of the green vegetation. If wood ash is not available, use topsoil.

- Add water to the pit. Use a watering can or any other convenient container, but make sure the pile is well watered.

- Repeat the whole process again, starting with rough vegetation then manure or old compost, top soil, green vegetation, ash or soil and finally water again. Repeat this process until the pile is 1-1.5m. A well-made pile has almost vertical sides and a flat top. If you have a lot of material to compost, build several smaller piles (about 2 m in length).

- To complete the pile, cover it with a 10cm layer of topsoil. This layer prevents fermentation gases escaping from the pile. *But make sure that the cover doesn't shut off any air circulation as that would promote rotting rather than composting of the organic material inside the pile.* Finally, cover the whole pile with dry vegetation to prevent loss of moisture through evaporation. Take a long, sharp stick ('thermometer') and drive it into the pile at an angle.

- Water the compost occasionally, about every 3 days depending on weather conditions. (If it is raining there is no need to water). The compost should be kept moist, but not too wet, angle, and use the stick to monitor the moisture levels in the pile. To monitor the moisture content, drive a stick long, pointed stick into the pile. The stick, when removed, will be warm. The stick also helps to check the condition of the pile from time to time. It will show whether the pile is dry or wet.

- After two to three days, decomposition will have started in the pile, and this decomposition will start to generate a lot of heat. Use the stick ('thermometer') to ensure that the compost is hot, i.e. that decomposition is in progress by pulling out the stick and checking the lower part for its humidity and warmth (feel with your bare hands – wash hands afterwards). Check the stick regularly, not only for temperature, but also for the presence of a fungus called "fire fang". Fire fang destroys the compost when the pile once the compost becomes dry. Fire fang turns the stick white, and if you detect it you should add water immediately. Once there is no more heat generation, the decomposition process is slowing down and it's time to turn the pile.

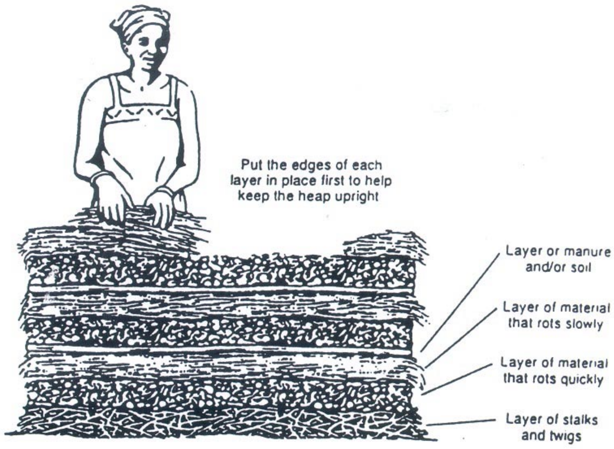
- If all goes well, the pile should be turned after three weeks. Do not add any fresh material during turning, except water if "fire fang" has developed. Make sure that while turning the bottom part of the pile ends up on the top. This is necessary because decomposition at the bottom goes slower than at the top.

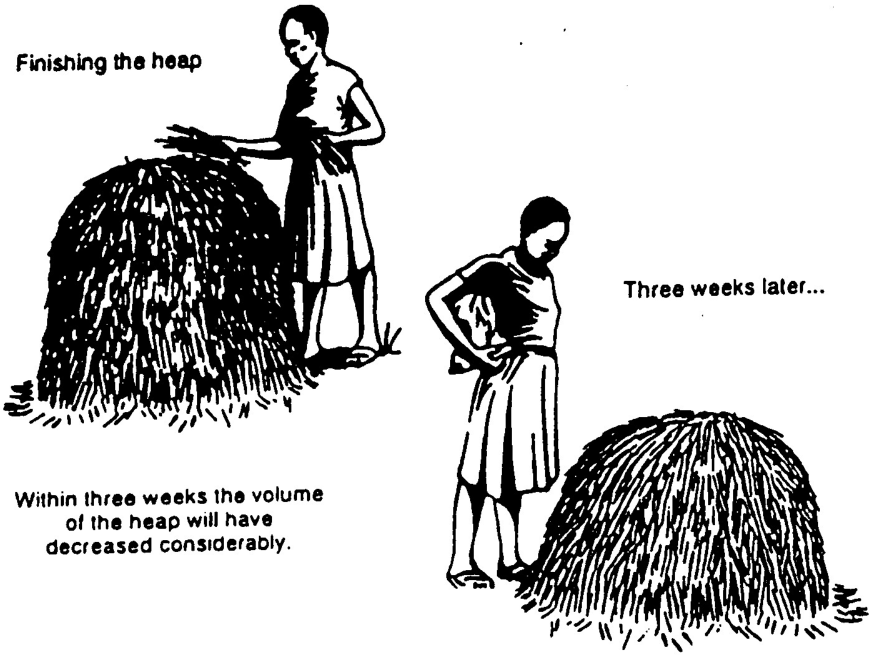
- After three more weeks the pile should be turned a second time. The pile should stay moist, not wet. When the pile has been taken care of well, there is no need for further turning. By now the compost should have a fresh earth smell and no grass, leaves or animal droppings should be visible. Some woody branches or stalks may still be present as they take a long time to decompose.

- Three weeks after the second turning, the compost should be ready for use. If the planting season is still some time away, leave the pile where it is. Keep it well covered and moist, but not wet (*compost is wet when water drips-out of a handful which is squeezed tightly*).

Guide questions for discussion

1. What happens with weed seeds, pupa of pest insects and disease spores inside the compost heap?
2. When is it better to compost crop residues rather than digging in crop residues (as e.g. in a smallholder coffee garden where there is mixed cropping with vegetables)?
3. Do farmers in your area make compost? If not, why not? If yes, do they have alternative methods for doing so (e.g. discuss: '*above procedure looks complicated, do the odd alternating of layers of vegetatation, soil and manure work as well?')*?
4. What are the costs / benefits of making and utilising compost?





Source: Henry Double Day Association

Exercise 6. Making liquid manure and plant teas

Objectives

The aim of making liquid manure and plant teas is to quickly provide a crop with adequate natural plant food during the growing season. Liquid manure and plant teas are ready for use after two or three weeks, as compared to six weeks or more for compost.

Materials

- ✔ Manure – e.g. chicken or rabbit or a mixture of both
- ✔ A container – either a drum / half a drum for small quantities
- ✔ A strong sack or gunny bag
- ✔ A strong pole and rope

Procedure

Liquid manure:

- Put the manure in a strong sack or gunny bag with 50 kg of manure for one drum of water. Fill it in such a way that you can tie the top of the bag securely.

- Suspend the bag containing manure in a drum full of clean water. The bag should be tied securely with a rope and suspended on a strong pole placed across the top of the drum.

- Leave the manure to stand for 15 days. Cover the drum to prevent excessive evaporation.

- After three days and every other day thereafter, stir the drum contents by lifting the bag several times using the pole.

- After 15 days the water will have turned blackish and most of the plant food in the manure will have been washed into the water. Remove the bag.

- Dilute the contents of the drum 1:2 (to one part of the liquid manure add two parts of clean water). Spray the crop at the stem and not at the leaves. Alternatively water around the roots near the stem.

Plant teas:

- When preparing plant teas, branches and green sappy leaves are chopped up and placed in a drum full of clean water. It is not necessary to put the leaves in a bag.

- Leave the chopped leaves to stand for 15 days. Cover the drum to prevent excessive evaporation.

- After three days and every other day thereafter, stir the drum contents.

- After 15 days the water will have turned blackish. Dilute the contents of the drum 1:2 (to one part of the plant tea add two parts of clean water). Spray the crop at the stem and not at the leaves. Alternatively water around the roots near the stem.

Water with this liquid manure or plant tea for two or three weeks. It is effective as top dressing after planting the crop using compost.

Guide questions for discussion

1. Do farmers in your area make liquid manure / plant teas? If not, why not? If yes, do they have alternative methods for doing so?
2. What are the costs / benefits of making and utilising liquid manure / plant teas?

Exercise 7. Assessing farmers' friends in the coffee field

Objective

- To discover the impact of farmers' friends in the coffee field by examining pest populations on coffee trees with and without predators

Materials

- ✔ Unsprayed coffee trees infested by pests
- ✔ Nylon mesh
- ✔ Long sticks (about 2 m each)

Procedure

- Prepare 10 nylon mesh cages (2m x 2m x 2m) supported by 4 sticks to cover individual coffee trees
- Identify and select 10 coffee trees highly infested by pests e.g. antestia bugs, aphids or mealy bugs.
- Clear all predators from the selected trees and from the soil underneath and then cage trees. The nylon mesh should be properly buried into the soil to block the way for insects. Randomly label 5 of the caged trees 'without predators' and 5 'with predators'.
- Collect 40 active predators, e.g. Lacewings or Ladybird beetles, and introduce them to each of the cages labelled "with predators".
- After 5 days remove the cages carefully and count the number of pests on each tree in each of the treatment. Note whether the introduced predators are alive.
- Calculate the average number of individual insect pests in each treatment.

Guide questions for discussion

1. What was the impact of farmers' friends in the coffee field?
2. How can you conserve farmers' friends in the coffee field?

Exercise 8. Learning more about insects

Objectives

- To become aware of beneficial insects in coffee fields as well as their food range
- To learn more about insect life cycles

Materials

- ✓ Coffee fields
- ✓ Vials / glass or plastic jars
- ✓ Cotton wool / fine mesh screen
- ✓ Hand lenses
- ✓ Polythene sheets

Procedure

Finding out who eats what

In the field:

- Select and tag 10 coffee bushes at random.

- Lay the polythene sheet out under the stem, and beat/ shake the stem as described in Exercise 3 (AESA).

- Collect several specimens of each insect you find, and place each species in a separate vial. Close the vial with some cotton wool or fine mesh screen.

- Collect plant material including berries, leaves, and anything else you think the insects might be feeding on.

In the meeting place:

- Introduce a range of different food types to each vial, including plant material e.g. coffee berries, coffee leaves, and some insect prey including the pests you identified in the previous step.

- Observe the insects at regular intervals for as long as possible. You may be able to see it feeding on its preferred food. If this is not possible, observe the vials daily and record which food types have been eaten, or disappeared.

- You may find that the insect does not eat any of the food items you have offered. It is possible that the insect is in fact a predator, but you just haven't offered it the right prey. In this case, collect more insects using the beating or shaking the stem as described in Exercise 3 (AESA).

- Offer the insect a wider range of insect prey. Observe the vials as often as you can to see you can observe the insect feeding on a particular prey species. If you don't actually see the predator feeding, observe the vials as often as you can and. Count the numbers of each prey species and try and work out what has disappeared (been eaten), and what has been left.

Learning more about insects

In this part of the exercise we examine the insects that we experimented with in the first part.

- Collect the insects that you are interested in at different stages of development (eggs, larva, nymph or pupae) by beating/ shaking the trees as described in Exercise 3. Put each individual in a separate vial. To avoid condensation in the vial, line the bottom with some tissue (toilet) paper. Place it in a shaded, cool place.

- Feed each insect on an appropriate food source according to your findings in the first part of the exercise.

- Observe the insect as often as possible, or at least once every 2 days. Observe and draw each different stage of development, as you observe it passing though the different stages of its life cycle. Also make notes on what it is doing, for example is it moving, is it still feeding, is it laying eggs and if so, how many and where?

Guide questions for discussion

1. Which of the insects, that you didn't know before, feed on plants and which of them feed on insect prey? If you do not know the name, make one up, based on its behaviour! For example, farmers in Kenya named hoverflies 'Helicopter Insects', because of the way they fly.
2. What can you say about these insects from a pest management point of view? (Remember, just because an insect feeds on the plant, it doesn't necessarily mean it is causing economic damage).
3. How do the studies of the insect life cycles help in making pest management decisions?

Exercise 9. Learning about spray drift

Objectives

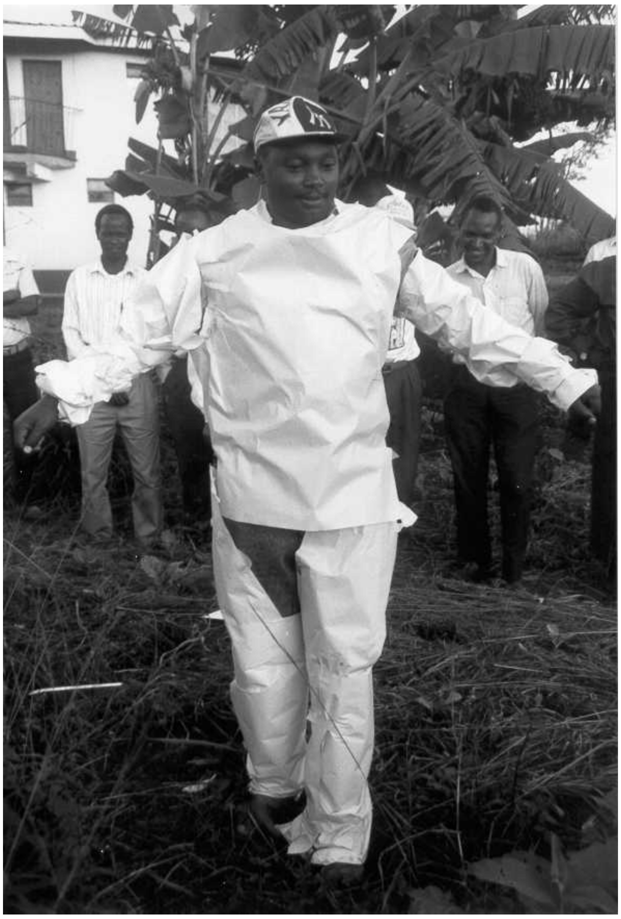
- To demonstrate spray drift to other crops when spraying coffee.
- To create awareness of the direct exposure to pesticides when spraying.

Materials

- ✔ Knapsack sprayer
- ✔ Non-toxic dye
- ✔ White flip charts
- ✔ Coffee bush with surrounding crops/vegetation (other crops should be over one meter away from the coffee bush to be sprayed)
- ✔ A volunteer!

Procedure

- Prepare 5-10 litres of dye solution in the knapsack.
- Wrap up the volunteer completely (apart from the eyes!) in white flip chart paper.
- Ask the volunteer to spray the tree as though were using a pesticide, i.e. for about 5 minutes at different heights and from different wind directions.
- After spraying, remove the sprayer and observe how much dye is on each part of the body (none, a little, a lot).
- Examine the surrounding vegetation surrounding the coffee bush, and observe how far the spray has drifted and whether or not is on crop plants.



Getting prepared for the spray dye exercise, Othaya Farmer Field School 1996 Photo by B. Nyambo © CABI Bioscience

Guide questions for discussion

1. How much spray ended up on the operator?
2. What are the hazards that pesticide contamination might pose to pesticide sprayers' health?
3. What sort of protective clothing do you think sprayers should use?
4. How far did the spray drift? Under what conditions would the drift be greater? Under what conditions would it be less?

5. Did the spray drift on to neighbouring crops? If so what are the implications for health? What are the implications for the agro-ecosystem, in particular the pests and natural enemies in the contaminated crop?