Integrated Pest Management

Integrated pest management is the key to sustainable, environmentally friendly cacao cultivation that will result in an adequate supply of quality cocoa.

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The concern of every confectioner is to have access to safe and quality cocoa. There can be no question that the production of cocoa and chocolate products free from contamination of pathogens, foreign bodies, residues and other contaminants is of the utmost importance in promoting sustainable cultivation. With the surge of pest attacks on cocoa from the field to the store coupled with the urgent challenge to control them without pesticide residue and other contamination, integrated pest management (IPM) provides the infallible antidote.

IPM DEFINED

Integrated pest management is the careful consideration of all available pest-control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. These control measures keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. Integrated pest management emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest-control mechanisms. It is the key to long-term, sustainable cacao cultivation that will result in an adequate supply of cocoa, enhance quality, improve small-farmer income, address safety issues and alleviate environmental concerns.

FOUR BASIC PRINCIPLES OF IPM

Understanding the basic principles of IPM is important if we are to become comfortable with the IPM philosophy. Whether we are managing pests in canola, cocoa, corn or cotton, we need to abide by these same standard principles that form the basics of an IPM program.

IPM is management intensive, substituting experience and education in place of pesticides. Pesticides are considered a simple control tactic to implement. Although that is an oversimplification, the point is that pesticides are the easy way out. Reliance on pesticides creates problems such as increased input costs, pesticide resistance, secondary pest outbreaks, reduction of beneficial insects, etc. However, to reduce our reliance on pesticides and avoid risk of crop loss, we must know as much about these interrelationships as possible. By understanding how one factor affects the others, we are better prepared to substitute cultural, mechanical or other control methods for a pesticide application.

An effective IPM program for cocoa is designed around four basic components: preparation, prevention, protection and preservation. We will go through each of these principles (pillars), offering explanations and examples. ➤

PREPARATION

Understanding the Crop, Pests and the Environment

Understanding crop growth and development is an underlying principle of IPM. We cannot just focus on the pest. The interactions between crop and pest (as well as the environment) are very important. We must know how to grow a healthy crop. It makes good sense agronomically and economically. However, many people claim that a healthy crop can outgrow pest damage. While this statement can be true, especially for weed management when a healthy crop is more competitive with weeds, it is not a universally true statement. A healthy crop is not immune to pest attack.

The point is that by following the recommendations for crop production, you are better prepared for the highest economic yield. Knowing when a crop is most susceptible to pest damage and/or recognizing stress periods will help fine-tune our pest-management recommendations so that we can avoid treating when crops are not susceptible.

Understanding how the environment affects pest and crop development allows crop advisors to react to changing conditions. Environmental influences like drought stress influence pest-management recommendations. When a crop is under stress it can be less capable of dealing with additional stress caused by insects that extract plant sap (e.g., mirids, stem borers). Weed populations which would not normally cause an economic loss may do so under drought conditions when they compete with the crop for limited water. Also, the weather is notorious for affecting pest development and survival. For example, cool, wet weather is conducive to development of fungal diseases (*Phytophthora* pod rot or black pod disease of cocoa).

Proper Identification of the Pests

Coupled with a basic understanding of the crop, pests and the environment, the first step in developing an effective IPM for cocoa is to identify the pests (diseases included) correctly. The pest-management system cannot be implemented effectively if a farmer does not know the type of pests that are present (or likely to be present) or whether the pest populations pose a significant detriment to the crop. It is essential to note that not all insects and other living organisms require control. Many organisms are innocuous, and some are even beneficial.

Integrated pest management programs work to monitor for pests and identify them accurately. This monitoring and identification reduce the risk that pesticides will be used when they are not really needed or that the wrong kind of pesticide will be used. A misidentification of a pest can lead to erroneous and costly recommendations.

A vivid example is the nematode disease of cocoa caused by root-knot nematodes, *Meloidogyne incognita*. These are microscopic worms that attack young cocoa seedlings, resulting in abnormal swelling of roots (galls) or above-ground hypocotyl swelling, both in the nursery and the field (Figure 1). Farmers are aware of the above-ground symptoms of dieback (yellow discoloration of leaves, wilting, stunted and unthrifty seedlings), but they are generally unaware of the damage done below the ground by these hidden enemies. So thinking it was a fungal infection, they erroneously sprayed pesticides with no satisfactory results.

Effective control of root-knot nematodes by one method is an outdated concept; currently the favored approach is an integrated management strategy comprising several components:

- Preventing the spread of root-knot nematodes through effective quarantine ➤

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There is often a state in the insect's life cycle that is most susceptible to preventive actions. Being familiar with this will assist in developing an appropriate management strategy.

legislation and prophylactic measures at farm level is of vital importance to avoid previously uncontaminated areas becoming infested.

- Commonly used shade plants in cacao fields, such as plantain and banana, may become a source of inocula in the cacao plantation. Plantain and banana suckers should be pared to remove nematode infection.
- Once present in an area, the damage caused by root-knot nematodes can be limited by knowledge of their effects on plant growth, knowledge of nematode population dynamics and distribution patterns, and effective sampling.
- The use of organic amendments to soil (e.g., poultry litter, compost, animal dung, wood ash) is reputed to mitigate the impact of root-knot nematodes on cacao.

Understanding the Pest Life Cycle

Once the pest is identified, it is necessary to have an understanding of its life cycle. There is often a state in the insect's life cycle that is most susceptible to preventive actions. Being familiar with this will assist in developing an appropriate management strategy.

For example, damage by brown cocoa mirids/capsids (*Sahlbergella singularis*) is caused by the feeding activities of the nymphs (1st–5th instar) and adults (Figure 2). Feeding causes characteristic dark markings known as *lesions* on both pods and shoots, which result from the collapse of plant tissue caused by the toxic saliva. Secondary damage by canker and dieback occurs when feeding lesions are infected by parasitic fungi, notably *Calonectria rigidiuscula* Berk.

The population of brown cocoa mirids in mature fruiting farms is usually high during the rainy season. In Nigeria, mirid infestation is usually lowest between February and July, and highest between August and November/December. However, infestation also depends on the availability of an adequate number of suitable pods and young tissues as well as suitable canopy or shade required for resting, feeding and reproduction. Mirids prefer feeding and laying eggs on young and soft shoots (Figure 3) that cocoa trees grow throughout the season.

Managing the Hidden Enemies of Cacao

Enlarged above-ground hypocotyl swelling (at left) of a cacao seedling in the field caused by root-knot nematodes, and dieback condition (at right).

Root-knot nematodes live in the soil, so their management is soil based. Addition of poultry litter (or compost), organic manure or wood ash around the seedlings has been proven to adequately manage the effect of nematodes on cacao, and also provides supplementary nutrients which in turn may have a positive effect on vegetative growth and yield. This has immensely reduced the current level of frustration faced by cocoa farmers in Nigeria when establishing new plantations and/or rehabilitating existing ones.

Figure 1

With this background understanding of the life cycle of mirids, chupons (young vertical stems or shoots) that emerge at the base of trees should be removed regularly, not just during the peak mirid season. Pruning should not be done heavily as this will stress the trees and cause the growth of new chupons, which are a mirid feeding ground. In mature cocoa farms, one should avoid shade or neighboring trees that attract mirids, such as kola trees.

Knowing the Action Thresholds

It is not enough to identify the pest and know its life cycle; we must also know whether the pest population warrants any control. The emphasis is on control, not eradication. Integrated pest management holds that wiping out an entire pest population is often impossible, and the attempt can be expensive and environmentally unsafe.

IPM programs first work to establish an acceptable pest level, called an *action threshold*—the point at which action must be taken to control costs, and controls applied if those thresholds are crossed. For the farmer, the action threshold is the number of pests required to justify control measures. The *economic threshold* is the point at which the cost of potential damage by the pest is more than the cost of control. Crops can tolerate a certain number of pests before economic loss is incurred because all control actions have costs as well as benefits.

When pest populations reach a level where the cost of control equals the cost of the damage, the pest population has reached the economic injury level. Then it must be determined whether the benefits derived from control justify the costs incurred. A good farmer will take action to prevent the pest from reaching the economic injury level. Therefore, the action/economic threshold is a little lower pest population than the economic injury level because it takes time to respond to a pest outbreak, especially if there are a lot of acres to be treated and if the pest has a high reproductive capacity.

It is important to note that these action thresholds are pest- and site-specific, meaning that it may be acceptable at one site to have cocoa mirids, but at another site it may not be acceptable. By allowing a pest population to survive at a reasonable threshold (Figure 4), selection pressure is reduced. This stops the pest from gaining

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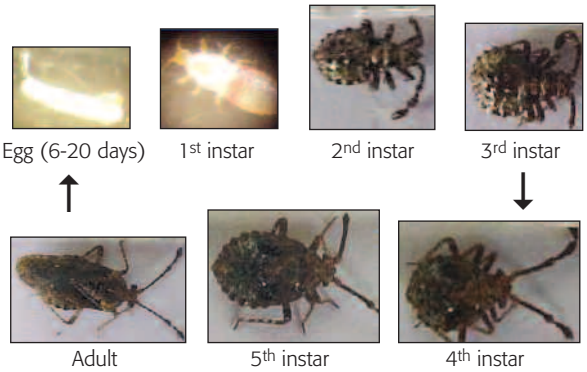
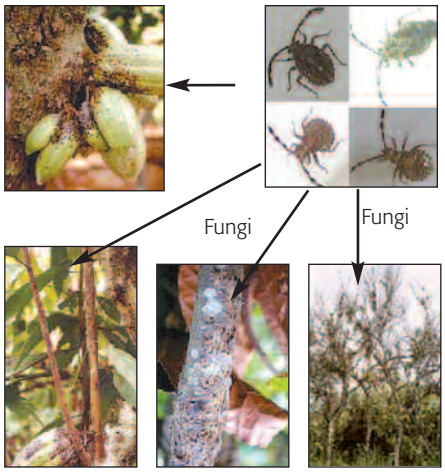
Brown Cocoa Mirid Life Cycle 5–6 wks



The life cycle of brown cocoa mirids commonly found in cocoa-growing areas of West Africa can be disrupted to reduce population buildup.

Figure 2

Infective Stages of Fungi



Damage caused by mirids on cocoa pods and shoots leading to canker and dieback of mature trees.

Figure 3

Preventive measures are the first line of defense in pest control and can be very effective, cost-efficient and of little to no risk to people or the environment.

resistance to chemicals produced by the plant or applied to the crops.

PREVENTION

Keeping the Pest Populations below the Action Threshold

An age-old adage says *prevention is better than cure*. This holds true in developing an effective IPM program. Preventive measures are the first line of defense in pest control and can be very effective, cost-efficient and of little to no risk to people or the environment. Prevention means planning for a potential pest and taking the necessary steps aimed at disturbing the pest's habitat in such ways as erecting a physical barrier and eliminating food or water. These are practices that create unfavorable conditions for pest development and inoculum production, thereby keeping the pests from reaching an action or economic threshold.

These preventive measures include cultural practices such as crop sanitation, soil and nutrient management, traditional methods of pest control and the use of pest-resistant varieties. The choice of pest-resistant varieties that are well adapted to local conditions precludes pest infestation. Weed problems can often be removed by proper preparation of the soil before planting, regular weeding and a healthy plant selection.

Managing Cocoa Pests Using Cultural Practices

Cultural practices seem to be the simplest to apply, both in terms of cost and environmental conservation. These involve the exploitation of the physical or immediate environment of the pest to suppress or manage the pest population using traditional methods and maintenance of farm sanitation. Regular inspection of their farms by cocoa farmers will assist in addressing the pest problems of cocoa.

Phytosanitation is an important cultural method, which involves the removal of diseased parts of the crop. Complete removal or cutting out of trees visibly infected with cocoa swollen shoot virus (CSSV) together with contact and adjacent trees has been the control method advocated in Ghana where the disease has been of economic importance since the 1940s.

Pruning of brooms during the dry seasons when brooms are more visible and before fungal fruiting bodies start producing spores is a major control strategy of witches' broom (caused by *Moniliophthora perniciosa*) in the cocoa-growing regions of Latin America.

Mirid Action Threshold

The mirid is an important insect pest of cocoa, causing damage lesions on pods, chupons and fan branches.

In many cocoa-growing communities, farmers control mirids by a calendar-based blanket application of insecticides. This practice is often uneconomical and not environmentally friendly.

The use of action thresholds in determining the need for insecticide application ensures that insecticides are applied only when they are needed, thus protecting the environment from avoidable contamination, as well as saving farmers unnecessary expenditure on insecticide.

The mirid action threshold is the cocoa mirid damage level at which it makes sense to control it. The guideline on whether to spray or not, based on the percent of mirid-damaged trees (with the observation of 100 trees in one hectare of a cocoa plantation), is given below.

Threshold key	Decision
0-5% damage	Do not spray
6-25% damage	Do spot application
Above 25% damage	Do blanket spraying
If 70-75% of the pods will be ready for harvest in 2 weeks	Do not spray
If 85% of cocoa pods are already harvested	Do not spray

Figure 4

Phytosanitary pod removal has been found to reduce black pod infection in cocoa farms. This is a preventive method that consists of cleaning trees at the beginning of the season by removing mummified pods left from the previous season, which are a potential source of primary inocula, and then regularly removing diseased pods, which are a potential source of secondary inocula. Removing diseased pods helped to reduce black pod rate by 22 to 31 percent in Cameroon and 35 to 65 percent in Peru. This practice is being advocated in cocoa-growing communities of Ghana, Côte d'Ivoire, Nigeria and Togo. The diseased pods that are removed should be buried outside the farm.

In Indonesia, the practice of regular and complete harvesting reduces levels of cocoa pod borer (*Conopomorphia cramerella*) in the subsequent season. In South America, close monitoring and removal of pods infected with frosty pod (caused by *Moniliophthora roreri*) is likely to be an effective method to manage the problem, although early detection is the key.

To reduce black pod disease incidence, cocoa seedlings should be planted well apart and in well-drained sites. This works because black pod disease needs high humidity for fast development. Cocoa tree canopies should be pruned and shade trees should be removed where necessary to improve airflow and sunlight in the plantation. Care must also be taken to not make gaps in the canopy to avoid attracting mirids. Cocoa trees standing in pools of water will often become unhealthy. Stagnant water may also encourage the spread of black pod disease. Therefore, stagnant water should be removed by digging small drainage canals. This reduces the level of disease in soils. Timely removal of soil tunnels built by ants on the surface of cocoa trunks should be done. This removes two sources of black pod disease: spores carried in infected soil and those carried by the ants themselves.

Furthermore, as part of farm sanitation, dead branches and decaying tree stems should be removed regularly to reduce termite infestation of cocoa farms. Some traditional methods of removing termites include breaking the termite mounds and removal of the queen, pouring locust bean and/or pawpaw leaf extract into the mounds, channeling the drainage into the mounds and applying wood ash around the trees.

Weeding should be done regularly, especially at the beginning of and during the wet season in the cocoa farm. Weeds compete with cocoa trees for nutrients and water from the soil. Weeds also increase humidity on the farm, thereby increasing black pod infection. Too many weeds on a farm make it more difficult to remove dead and diseased pods, branches, etc., that may carry pests and diseases. Regular removal of epiphytes (parasitic plants that grow on cocoa trees, but are not rooted in soil, e.g., mistletoes, ferns, mosses) is encouraged in cocoa plantations to improve tree health, as these parasitic plants reduce the amount of food and water getting to branches and pods. Mistletoes also have indirect harmful effects on cocoa as their presence favors infestation by mirids. Mosses cover the bark and stem of a cocoa tree, stopping flowers from growing and thereby reducing the number of pods produced. They also create high levels of moisture on tree stems which encourage black pod disease.

Physical control practice, which involves poking the holes tunneled by the larvae of stem borer (*Eulophonotus myrmeleon*) at the early stages of attack with a poking stick or wire, carefully done to avoid damage to the tree, would not only kill the larvae but in addition stop further damage by the active stage of the insect pest (Figure 5). Other local practices exist, such as covering the entrance hole with mud or

Phytosanitation is an important cultural method, which involves the removal of diseased parts of the crop.

Stem Borer

Stem borer larva at the entrance/exit hole (top) and a newly emerged adult (above).

Figure 5

Good soil and nutrient management produces strong plant vigor that will help to ward off disease, insects and competition with weeds.

black soap to cut off the oxygen to the stem borer caterpillar. The adults can be picked off by hand and killed, but this must start as soon as infestation is spotted.

Finally, good soil and nutrient management produces strong plant vigor that will help to ward off disease, insects and competition with weeds. The soil on cocoa plantations should be tested, at a minimum, once every three to four years. These tests provide soil pH and plant nutrient levels on which recommendations for fertilizer and organic material for producing a healthy and vigorous crop are based. The use of organic fertilizers (poultry litter, cattle or goat manure, composts) has been effective in maintaining healthy soils for healthy cocoa plants.

Pest-Resistant Cocoa Varieties

The use of pest-resistant cocoa varieties is an important preventive measure for managing certain pests and to keep crop injury below the economic threshold. The development of high-yielding and pest-resistant materials becomes imperative in the light of current low cocoa yields obtained by farmers (estimated at approximately 450–520 kg/ha), old age of trees and farms in need of rehabilitation, high incidence of *Phytophthora* pod rot and mirid attack, dwindling forest areas, population growth, land-tenure system making less land available for cocoa farming and climate variability.

There is also the need for cocoa intensification to increase yield per unit land area rather than opening new land areas. The Cocoa Research Institute of Nigeria (CRIN), since its establishment in 1964, has actively engaged in cocoa breeding in fulfillment of its mandate to develop improved materials. CRIN participated in a Global Cocoa Breeding Initiative within the CFC/ICCO/IPGRI Project, which lasted for 10 years in two phases from 1998 to 2003 and 2004 to 2009. With sustained funding and support from international partners (in analyzing the chocolate flavor profile) over this period, we were able to work within our set objectives to develop new cocoa varieties that meet the following criteria:

- High yielding and early bearing.
- Resistance to *Phytophthora* pod rot.
- Resistance to mirids (*Sahlbergella singularis*).
- Physical and chocolate flavor quality acceptable in the world market.

Recently, CRIN has officially released and registered eight new hybrid cocoa varieties (CRIN Tc–1 to CRIN Tc–8). In general and as a minimum standard, these hybrid materials have the following characteristics:

- Outstanding high yield at 1.5 to 2 t/ha compared to 520 kg/ha average yield obtained in farmers' fields.
- Early bearing (precocious) from two years (24th month) after field establishment compared to three to four years of earlier and older varieties.
- Resistance to *Phytophthora* pod rot (black pod disease) and mirid (*Sahlbergella singularis*) attack.
- High butter fat content, at least 55 percent.
- Superior cocoa base (flavor) chocolate quality.
- Excellent physical bean quality (>1.0 g) according to the world market standard.

It is hoped that these hybrids, when utilized by cocoa farmers, will assist in preventing *Phytophthora* pod rot and mirid attack, which are common in the cocoa-growing communities of West Africa, thereby bringing the long-awaited revolution in the cocoa economy and ensuring adequate income and food security to our farming families. These hybrids also hold the key to increased volume of cocoa beans for export and processing, and sustainability of agricultural commodities' contribution to the West African nations' gross domestic product.

Breakthrough: New Phytophthora Pod Rot- and Mirid-Resistant Cocoa Varieties

The Cocoa Research Institute of Nigeria recently released and registered eight pest-resistant hybrid cocoa varieties (CRIN Tc–1 to CRIN Tc–8). The specific attributes of CRIN Tc–3 are stated in Figure 6a and shown in Figure 6b.

PROTECTION

The Call for Drastic Action

Once the action threshold has been reached and preventive measures are not yielding required results, there is the need to protect the crop from more damage. If action is called for, control measures that optimize cost and effect while minimizing adverse effects should be chosen.

Protective methods are action-oriented measures targeting a particular pest population with a bid to control or manage them to reasonable levels, with no adverse effects on the crop or the environment. It is noteworthy to state that protective measures are never intended to stand alone, but are rather integrated into the two IPM pillars (preparation and prevention) discussed earlier. Protective measures include biological, pheromonal and chemical pest-control strategies.

Biological Pest Control

Biological control refers to the release and/or establishment of predators or parasites that can effectively reduce pest populations. This involves the introduction of the natural enemy of the pests to control them. Although this management technique can be done on a large scale through mass rearing, it is most effective for small crop units, such as greenhouses or nurseries, where one particular pest can be targeted. Introducing predators and parasites with multiple host or prey preferences may reduce the effectiveness of the biological control agent.

Growing concern about pesticide toxicity and food safety has led to a call for reduced pesticide use. The need for alternative control measures has increased interest in the use of biological control agents. Biological control is deemed to be a more natural or environmentally friendly

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CRIN Tc–3 Variables

Pedigree: pound7 x PA150
Genetic base: Amazon hybrids
Adaptation: moist savanna and humid forest
Disease tolerance: highly resistant to *Phytophthora* pod rot and mirids
Yield potential: 1.7 to 2.0 tons/ha (mean – 1.85 tons/ha) dry bean
Pod characteristics
Pod size: large
Pod shape: elliptic to oblong with prominent bottleneck
Pod apex form: acute to acuminate
Pod rigosity: slightly rough, pod slightly ridged
Pod basal constriction: intermediate to intense
Pod index: 22.5
Mean number of pods per tree: 41 (up to 144/tree)
Bean Characteristics
Mean number of beans per pod: 41
Bean size (mean weight of one dry bean): 1.1g
Bean Quality
Quality rating: "superior cocoa base and flavor" quality
Average butter fat content: 56.6 percent

Figure 6a

Hybrid Cocoa Variety CRIN Tc–3

Variety CRIN Tc–3 with anthocyanin-pigmented flush leaves, green, smooth-textured and slightly ridged long pods, and prominent bottleneck.

Figure 6b

One of the fundamental ways in which farmers can reduce their reliance on chemical pesticides is to make the most of the numerous natural enemies already present in the field.

method of disease control. This can be implemented into IPM strategies and reduce the amount of pesticides applied in the farm.

Conserving Natural Enemies of Cocoa Pests

Maintaining a healthy and balanced ecosystem is an important aspect of IPM practices, and this helps to conserve the natural enemies of cocoa pests. One of the fundamental ways in which farmers can reduce their reliance on chemical pesticides is to make the most of the numerous natural enemies already present in the field.

Conservation of these beneficial organisms is a cornerstone of IPM. To conserve natural enemies, farmers will need to minimize the number of pesticide applications.

For instance, there are various natural enemies that kill mirids. These are usually not so well known to farmers. The better-known example is the weaver or tailor ant (*Oecophylla longinoda*). There are two types of weaver ant, the red and the black; the black is commonly thought to be the more aggressive. This weaver ant makes nests in the cocoa canopy and protects cocoa pods from mirids. Farmers regard the ant as both unwelcome, because of its painful bite, and beneficial, because its appearance coincides with reduction in pest damage. Weaver ants have been exploited to control cocoa mirids in Ghana, Nigeria, Indonesia and Vietnam, thus reducing pesticide use and its associated impacts on human health and the environment (Figure 7). Weaver ants have also been used as natural enemies to reduce the incidence of cocoa pod borer (*Conopomorpha cramerella*) in Malaysia and Indonesia where they prey on the larvae.

Managing Witches' Broom with a Biocontrol Agent

The discovery of a saprophytic natural biological control agent, *Trichoderma stromaticum*, in Para State, Brazil, has given new impetus to the integrated management of witches' broom (*Moniliophthora perniciosa*) with potential for nonchemical intervention. *T. stromaticum* is a newly discovered species found in association with the brooms and infected pods. The

Success Story: Weaving Ants into Pest Control

The pods are shiny and beautiful with the ants taking care of them.
—Nguyen Khac Thuoc

Nguyen Khac Thuoc (at right) lives in Binh Phuoc Province in the highlands of southern Vietnam where cocoa mirid (*Helopeltis theivora*) is a common pest on cocoa farms.

He first planted cocoa in 2005 using 200 seedlings he received from SUCCESS Alliance Vietnam. As the trees began to grow, he started to notice damage to the cherelles and small, growing pods caused by the feeding mirids. To control the pest, Thuoc turned to a natural means of pest control that has been in use for over 3,000 years on a variety of tree crops—weaver ants.

Thuoc established several ant colonies on the mirid-infested trees. The weaver ants build nests in the trees (at right) and feed on the mirids. Within a few weeks, mirids were no longer a problem on his farm.

Thuoc's adoption of weaver ants with ease and enthusiasm is characteristic of his innovative spirit. By 2006, he had expanded his cocoa production from 200 to 1,000 trees using seedlings produced in his own nursery. Today, he has expanded his nursery and will supply 10,000 seedlings to other farmers in the cocoa club through which they receive training and technical support.

Figure 7 Courtesy of SUCCESS Alliance Vietnam funded by World Cocoa Foundation

fungus has mycoparasitic activity against *M. perniciosa*, possibly due to production of hydrolytic enzymes and antifungal metabolites. It colonizes the necrotic tissue of the brooms and suppresses the production of fruiting bodies, thereby interrupting the disease cycle and lowering the source of inocula. This mode of action is referred to as biological pruning or biological phytosanitation. Thus the use of this biocontrol agent (BCA) could potentially allow farmers to eliminate expensive phytosanitary pruning of brooms, a step that is presently required for management of this disease. This BCA is currently marketed as Trivocab and is available to cocoa farmers in Bahia, Brazil.

A noteworthy fact is that natural enemies can help reduce cocoa pests, but these friendly beneficials can't survive when pesticides are used intensively.

Pheromonal Pest Control

Pheromones are chemicals emitted by an animal that signal another animal of the same species. Pheromones can be utilized to catch or deter insect pests with the aim of disrupting the mating cycle. For example, pheromone traps that contain the synthetic pheromone emitted by the female cocoa pod borer have been used to catch male moths in Malaysia. Pheromone techniques are currently being explored for use with brown cocoa mirids in Nigeria, West Africa.

Chemical Pest Control

Integrated pest management does not exclude the use of chemical control methods which involve the use of pesticides. However, pesticides are a part of an IPM program only as a last resort and only when all other management techniques, including preventive techniques, have failed or are no longer economical or practical. IPM can help prevent stockpiles of pesticides as it can reduce the overuse of and dependency on pesticides. Pesticides are to be used when there is no risk of environmental damage or when benefits outweigh the risks. We should never forget the fact that IPM is an environmentally sensitive and effective approach to pest management that relies on a combination of common-sense practices.

If properly used, pesticides are very effective in reducing pest populations and the potential harm they represent. The demand for materials that are safer and that have limited lifespans has helped to create new pesticides that are generally safer for handlers and consumers, and require small amounts of active ingredient per acre which are less damaging to the environment. In addition, botanicals and biopesticides composed of bacteria, nematodes or plant derivatives (such as neem oil) are used whenever possible.

Integrated pest management allows for more efficient and effective use of pesticides. It reduces or minimizes the use and application of synthetic pesticides, protects the environment, reduces health risks for the farmers and secures the quality of agricultural products (with no pesticide residues). The grower should use the safest, most effective pesticide available for the particular pest. Spot treating, rather than blanketing the entire crop, is usually both more environmentally sound and economically efficient. The type and quantity of the material to be used is critical, because an inappropriate choice of pesticide may kill beneficial biological control agents (natural enemies of the pest), harm the crop or reduce market yield and/or quality. Pest populations must be monitored in the field before pesticide application. Prior to using any pesticide, fields must be monitored (as earlier discussed) to make sure of the following:

- The pest is properly identified. ➤

Pesticides are a part of an ipm program only as a last resort and only when all other management techniques, including preventive techniques, have failed or are no longer economical or practical.

The grower should use the safest, most effective pesticide available. Spot treating, rather than blanketing the entire crop, is usually more environmentally sound and economically efficient.

- The pest is present in economical proportions (above the action/economic threshold).
- The pest is at a life stage that is susceptible to the pesticide.
- The pest is present at a crop stage when there is preventable yield loss, i.e., if the pest has not totally overtaken the crop and it is not close to harvest.

Responsible Pesticide Use in Cocoa

Responsible pesticide use (RPU) is an important tool of IPM which is a subset of good agricultural practices. It involves applying pesticides in a legal manner (rate, application type, target crop, target pest, etc.). Pesticide residues, which are a concern to confectioners and consumers of chocolate, for the most part come from improper application of pesticides in the cocoa field. Rpu answers the questions of what to apply, how to apply and when to apply. This means that to effectively lessen pesticide residue problems, farmers must apply the right pesticide in the right way and at the right time.

It follows that there are four important, practical ways (adapted from the *Pesticide Use in Cocoa* training manual by Roy Bateman) to avoid pesticide residue violation on cocoa:

- Establish whether pesticide application is the most appropriate way to solve the problem. Will it be cost effective? Are there viable alternatives?
- If it is appropriate, select the right pesticide for the problem: Am I using a suitable product for cocoa? Is it on the recommended list for controlling the problem? Is it safe for me to use? How would I need to use it?
- Apply pesticides in the right way to achieve effective pest control. Good application includes control of the amount of the product delivered to the crop. This means good nozzle selection, calibration and application technique.
- Apply pesticides at the right time, before the preharvest interval, which is the minimum permitted number of days between the last spray and harvest. It could be one month, etc., but most farmers don't always adhere to it, especially during peak-season disease attacks. This can be one of the most important considerations for avoiding harmful residues on produce.

PRESERVATION

Evaluation of an IPM Program

Evaluation is often one of the most important steps in the preservation of an IPM program. This is the process to review an IPM program and the results it generated. Asking the following questions is useful:

- Did actions have the desired effect?
- Was the pest prevented or managed to the farmer's satisfaction?
- Was the method itself satisfactory?
- Were there any unintended side effects?
- What can be done in the future for this pest situation?

Understanding the effectiveness of the IPM program allows the site manager to make modifications to the IPM plan prior to pests reaching the action threshold and requiring action again.

Agriculture is a dynamic system that continually changes in response to changing crop production practices and the environment. Likewise, IPM must continually change to meet pest-management challenges. IPM is a continuum (and not an end) that will change with time. For example, host-plant resistance is a very important IPM tool, but it is not always permanent. Pests change over time and become resistant to these crop varieties. Also, there may be some new pests or new races/strains of pests that need new integrated management strategies to combat them. Therefore, there is the need to periodically review and re-evaluate the IPM program.

The backbone of any IPM program requires routine monitoring of pest pop- ➤

ulations and crop conditions. Without this information one cannot make an intelligent pest-management recommendation, or evaluation. If one is not monitoring pest populations, how will one know if one is at the economic threshold? How will one know which is the best crop stage to treat? How will one know if one has pests at all? Maybe one will have high pest populations and not even realize it until it is too late. So this takes us back to the first pillar of IPM, preparation. All of the four pillars of IPM are interwoven.

Every farmer practices some type of IPM. Some are further along than others, but continual progress is the key. As new pest-control techniques are discovered, the farmer and crop advisor must adapt their pest-control program to reflect these changes. What is considered a good IPM program today may be considered a chemical-intensive program in a few years. Additionally, some good advice to the farmer and crop advisor is to try these new changes on a limited scale, becoming comfortable with the suggested practices before wide-scale changes are made. Therefore, to preserve the gains of IPM, evaluation is the key.

CONCLUSION

Integrated pest management stresses reliance on preventive practices and balances the strengths of one practice against the weaknesses of another to provide a more complete or holistic pest-management approach. Pesticides should be used responsibly and only if the preventive practices fail. Therefore, with the adoption of IPM in its entirety there will be less concern about pesticide residue and contamination of cocoa beans. There will be access to safe and quality cocoa for the production of chocolate. □

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