Chapter Eight

Ecology of Insect Pests and Natural Enemies

This chapter was adapted from: FAO Inter-Country Programme for the Development and Application of Integrated Pest Management in Vegetable Growing in South and South-East Asia. 2000. *Cabbage Integrated Pest Management: An Ecological Guide.* Vientiane, Lao PDR. However, any errors in this chapter are our responsibility.

CONTENTS:

SUMMARY

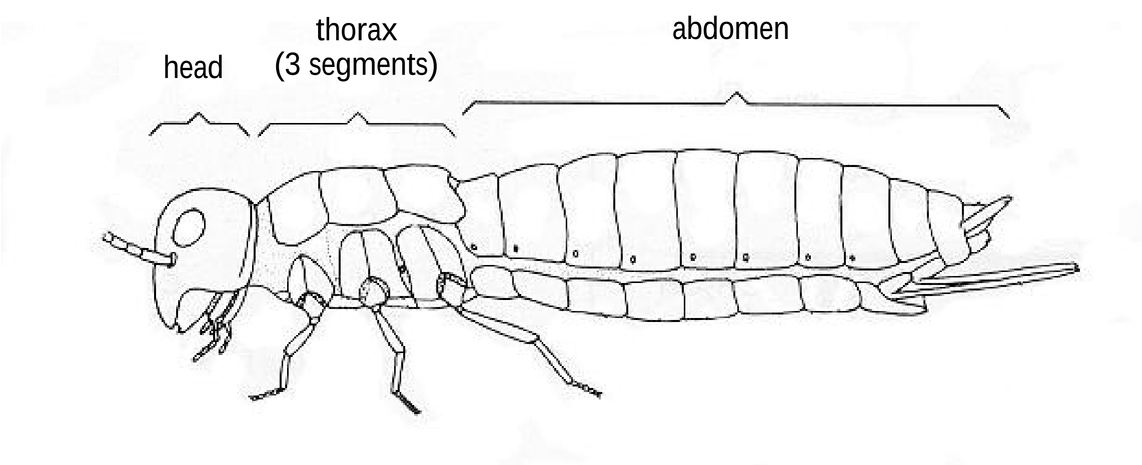
Insect ecology means, the realtionship between insects and their environment. The environment (including weather, food sources, and natural enemies) determines whether or not an insect population causes economic damage. So, learning about ecology enables farmers to make better decisions about mnaging pests.

Insects can damage plants by eating leaves, by sucking plant juices, or by feeding inside the leaves. However, not all insect feeding reduces yield! Plants can tolerate a lot of insect feeding because more leaves and roots are produced than the plant actually needs. So, not all insects that eat tea are “pests”! Actually, some insects are needed to keep the natural enemy population alive. By setting up insect zoos, the functions and life cycles of insects and natural enemies can be studied.

Natural enemies (predators, parasitoids, pathogens and nematodes) reduce pest insect populations. Natural enemies can either live naturally in and around the tea field, or be reared in large numbers to be released into the field. Rearing and releasing natural enemies is becoming an important IPM option in many crops.

8.1 Insect anatomy: what is an insect?

For farmers to be able to recognize natural enemies and pests, they need to know something about how insects are built. Insects are tiny animals that usually have 6 legs and sometimes have wings. The one characteristic that all insects have is three body regions: head, thorax, and abdomen. The **head** functions mainly for food and sensory intake and information processing. Insect mouthparts have evolved for chewing (beetles, caterpillars), piercing-sucking (aphids, bugs), sponging (flies), siphoning (moths), rasping-sucking (thrips), cutting-sponging (biting flies), and chewing-lapping (wasps). The **thorax** provides structural support for the legs (three pairs) and, if present, for one or two pairs of wings. The legs may be adapted for running, grasping, digging, or swimming. The **abdomen** functions in digestion and reproduction.



Typical body of an insect. *The size and shape of the body parts depends on the type of insect. But, all insects have a head, thorax, and abdomen.*

Source: modified from Borror, Triplehorn, and Johnson. 1989. An introduction to the study of insects, 6th edition. Harcourt Brace Johanovich, Fort Worth, Texas, U.S.A.

As simple as it may seem, knowing what type of mouthparts an insect has can be important in deciding on a management tactic. For example, insects with chewing mouthparts can be selectively controlled by insecticides that are stomach poisons (in other words, insecticides that are only effective if eaten). Natural enemies feed on other insects, but not on the crop plant. Therefore, stomach poisons are less likely to harm natural enemies.

8.2 *Insect Life Cycles*

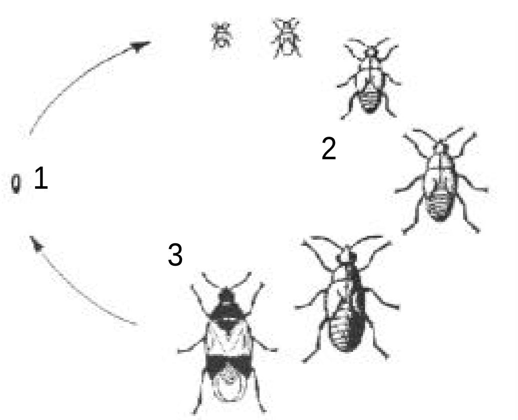
The "life cycle" of an organism means, the way that the organism changes as it grows from the youngest stage into an adult. All animals change their shape a little as they grow. For example, baby chickens do not yet have feathers, and people’s bodies change as they grow from children to adults. But insects are unusual because their shapes change drastically.

As insects grow from eggs into adults, they pass through several forms. Each form has a very different shape and structure. For example, a single species of insect might look like a “ball” one week (an egg), a “snake” the next week (a caterpillar), and a “bird” the week after (a butterfly)! This process of changing from one form to another is called metamorphosis. Farmers need to learn about insect life cycles so that they can recognize pests and natural enemies during all their life stages.

Insect life cycles are classified based on how many forms the insect passes through. There are two main types: (1) life cycles with 3 forms, and (2) life cycles with 4 forms. [Nam: I do not want to change this; in my experience in Central America, this is much easier for farmers to understand than "full change" or "semi-change". Mike]

8.2.1 Life cycles with 3 forms

The 3 forms are (1) egg, (2) nymph or immature insect, and (3) adult. **Eggs** are usually round, and do not move or eat. When the egg hatches, a nymph comes out. **Nymphs** are young insects that look like the adult insect, although they may be colored differently than the adult. They can move and walk, but cannot fly. And they eat the same food and are found in the same places as the adults.



Life cycle with 3 forms (bug):
(1) egg (2) nymph (with five stages, must shed its skin five times) (3) adult

(from: Hoffmann, 1993)

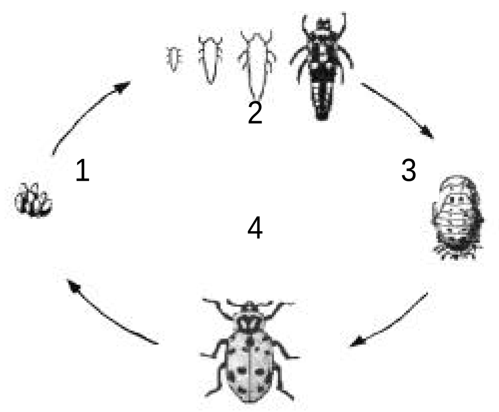
There are usually several nymphal stages (in the drawing to the right, there are five; but the actual number is different for each species). Each nymphal stage is a bit larger than the previous stage. Because insects are covered with a hard stiff skin, nymphs must shed their skin to grow from a smaller stage to a bigger stage. For example, most farmers have probably seen the empty shed skins of cicadas on tree trunks.

The youngest, smallest nymphs do not have any wings. But the older, larger nymphs slowly grow wings that get larger each time the nymph sheds its skin. Nonetheless, nymphs cannot fly. Finally, the largest nymph stage sheds its skin for the last time, and out comes the adult.

Adults have functional wings (can fly), and are sexually mature. Once the insect has become an adult, it does not change its form any more (does not shed its skin, and does not grow much larger). Examples of insects with a 3-form life cycle are bugs (like stinkbugs), grasshoppers, cicadas, aphids, and leafhoppers.

8.2.2 Life cycles with 4 forms

The four forms are (1) egg, (2) larva or caterpillar, (3) pupa, and (4) adult. **Eggs** are usually rounded, and do not move or eat. **Larvae** look something like worms or snakes. They look very different from the adult insect. For example, most farmers have seen caterpillars eating leaves (adult is a butterfly), and legless maggots in rotting fruits (adult is a fly). Perhaps some farmers have seen the larvae of bees?



Life cycle with 4 forms (ladybird beetle):
(1) Eggs (2) Larva (with four stages, must shed its skin four times)
(3) Pupa (4) Adult

(from: Hoffmann, 1993)

Larvae also behave differently from the adults; they are found in different places, and eat different food. For example, even though caterpillars eat leaves, adult butterflies do not damage plants (they just eat honey from flowers). There are generally several larval stages (in the drawing to the right, there are four; but the actual number is different for each species). Each larval stage is a bit larger than the previous stage, requiring a shedding of the skin between the stages. Larvae never have any wings (unlike nymphs).

Because larvae are so different from adults, the insect needs an extra form to change itself from a larva to an adult. The third form is called a **pupa**. It is usually hard, and does not eat or walk (although it may wriggle if you touch it). Pupae can be found “glued” onto leaves, or inside a “nest” of silk, or in the soil. Inside the pupa, the insect is growing its wings and changing into an adult. When it is finished, the adult crawls out of the pupa.

Adults have functional wings (can fly), and are sexually mature. Once the insect has become an adult, it does not change its form any more (does not shed its skin, and does not grow much larger). Examples of insects with a 4-form life cycle are moths, butterflies, beetles, flies, wasps, bees, and ants. Yes, ants have larvae that look like worms! Thrips have a lifecycle similar to the 4-stage cycle, but the “larvae” of thrips have small wings (see Chapter Nine).

The growth rate of insects depends on the temperature of their environment. Generally, cooler temperatures result in slower growth; higher temperatures speed up the growth process. If a season is hot, more generations of an insect may occur than during a cool season.

Every insect species will have its own optimum temperature for development. Some insects can live and reproduce only at lower temperatures whereas others need high temperatures. That is why you will often find different insect species in the tropics than in temperate regions. This also applies for plant pathogens.

Understanding how insects grow and develop will help farmers manage them. First, some natural enemies are active predators or parasitoids during only one specific stage of their life. For example, the larvae of hover flies are voracious predators, but the adult flies only feed on nectar from flowers. Second, some pest insects are susceptible to control only during one specific stage. For example, scale insects are much easier to kill during the first nymph stage, which walks around actively. Later in their life cycle, the scale insects are protected underneath a hard waxy “shell” or shield. Likewise, each stage of a pest insect may have a very different set of parasites, which are often specifically adapted to only one particular growth stage of the pest.

There are two ways that you can study the life cycle of an insect. First, if the insect is relatively large, you can rear the insect in an insect zoo (see the box below). However, tiny insects like thrips or mites are difficult to observe in an insect zoo. For tiny insects, it is easier to study the life cycle by collecting them from the field. In other words:

- Once a week, collect samples from the field of all the life stages that are present (for example, collect buds or stems, bring them inside, and search them carefully using a magnifying glass).
- Sort the life stages according to size and form. Again, you will need to use a magnifying glass to decide how many different sizes or forms there are.
- Write down how many of each size or form you found. And, write down the rules that you used for telling the forms apart (for example, small nymphs were 1-2 mm long, medium nymphs were 3-4 mm long, etc.) Save a few examples of each form (for example, in small bottles of alcohol, or glued onto stiff cards).
- Repeat the same steps the following week, using the same rules for separating the forms or stages in the life cycle.

By repeating this procedure for 3-5 weeks, you should be able to see the entire life cycle.

Insect Zoo: studying life cycles of insects that are relatively big

To study different stages of a life cycle of insects, try rearing the insects in an insect zoo. Although it may not be easy to study a full life cycle, it is possible to study some stages, for example the stages that cause plant damage.

Collect some adult insects or eggs, or larvae or nymphs, from the field and put them in a glass or plastic jar with some fresh leaves from an unsprayed field. The leaves will stay fresh for longer if you put a wet piece of cotton around the cut end of the stem. Add water to the cotton as needed to keep it wet. When studying the life cycles of predators (insects that eat other insects), you should also put some appropriate prey into the insect zoo as food for the predators. Put some tissue paper in the bottom of the jar to absorb excess water. Close the jar with fine netting that permits air circulation, and keep the jar in the shade.

Insect zoos are also suitable to find out what insects are emerging from egg masses; are they pests, or parasitoids (natural enemies)? It is also useful to rear larvae or pupae that you find in the field but don’t know what species they are.

Related exercises from CABI Bioscience/FAO manual:

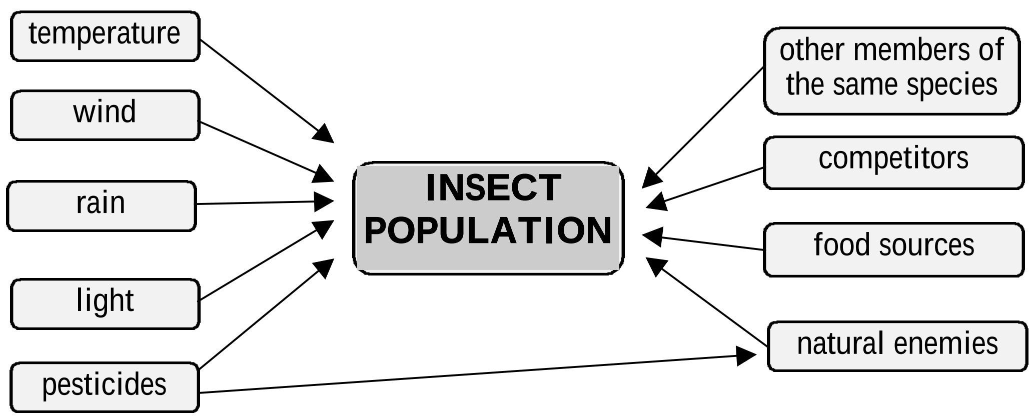
4.1 Insect zoo

4.A.1. Life cycle of caterpillar pests

8.3 *Why learn about insect ecology?*

Ecology means the relationships between organisms and their environment. In Agro-Ecosystem Analysis, insects are considered as populations rather than individuals. One single thrips that eats a tea leaf will never cause yield loss, but a population of ten thousand thrips might. The environment of an insect population consists of:

- *Physical factors* such as temperature, wind, humidity, light, and pesticides; and
- *Biological factors* such as other members of the same insect species; food sources; natural enemies (including predators, parasitoids, and diseases); and competitors (other organisms that use the same space or food sources).



Insect ecology: the relationships between an insect population and the environment

These relationships are a reason that insect pests don't always grow to large populations and damage crops. There may be large numbers of predators that eat the pest insects. Or, the weather conditions may be unfavorable (insects usually like warm, dry weather). Or, the plant variety may not be very attractive for the pest insects to eat. And there may be many more reasons.

Farmers can make much better decisions about managing pests once they learn how the environment affects pests. For example, it is important for farmers to recognize natural enemies, and to decide whether or not the natural enemies will be able to control the pest population. Natural enemies are called the "Friends of the farmer", because they do nothing but reduce pest populations! The work of natural enemies can reduce the need for pesticides. This saves money and time, and possibly the environment and human health.

In many areas, the use of pesticides is still a common practice for insect and disease control. Most pesticide sprays are very toxic to natural enemies. The death of natural enemies means that insect pest species can increase in number very rapidly. Normally, natural enemies will kill a large number of the pest insects, but when there are no natural enemies, the pest insect population can grow rapidly. Life cycles of natural enemies usually take longer than those of pest insects. So, once insecticides are used, it is difficult to bring back the natural enemies within one season. Insecticides should be used only when there are no other options for control and there is a definite and visible need.

8.4 How can an insect damage a plant?

A plant needs its leaves to absorb sunlight to make sugars for energy and growth (this process is called *photosynthesis*). The sugars are transported through the veins of the plant to other parts like roots and stems (see Chapter Four).

When an insect feeds on the leaves and reduces the leaf area, like some caterpillars do, less sugar is produced and the plant has less energy for growth and development. When insects are sucking on the leaves of the plant, like aphids or thrips or scales, they are sucking the sugars out of the plant cells or the veins. This leaves less sugar available for the plant for its growth and development. In addition, some sucking insects excrete sugary wastes (honeydew) onto the leaves. Fungi can grow on this honeydew. Leaves become black with these fungi and as a result, photosynthesis is reduced.

Other insects like red borers and termites feed inside the stem and destroy the tubes (xylem and phloem) that the plant uses to transport water from the roots to the leaves, and sugar from the leaves to the roots. This may eventually lead to lower yield.

It is important to note that **not all insect feeding reduces yield!** This is especially true for insects that feed on leaves or on roots. Tea plants are able to compensate for feeding because more leaves and roots are produced than are actually needed. However, for some insects like thrips, even a small amount of feeding can reduce tea **quality**.

☞ Spraying for insects that are not actually reducing yield or quality is a waste of money and time, and exposes the environment and your family's health to needless risk. Farmers should do experiments to find out how many insects their tea can tolerate. As a guide, use Field Study #1 from the from the Tea IPM Field Guide. The study is entitled **"Effect of different management methods on tea ecosystem"**.

Related exercises from CABI Bioscience/FAO manual:

4.A.3. Plant compensation study

8.5 A pest or not a pest insect: how to find out!

Many insects can be found in a tea field. Not all of them can be called "pests"; in fact, very few insects have the potential to cause yield loss to tea. There are many potential "pest insects" that do not build up in populations large enough to cause economic yield loss. They may chew a few leaves here and there but this does not affect the yield or quality of the tea. These plant-eating insects have an additional function: they serve as food for natural enemies. In fact, their presence keeps the population of natural enemies alive so one could almost say at that time they are "beneficial"!

The goal of growing tea is to produce as much yield as possible without spending a lot of money. If there are no pests that are causing economic damage, then do not waste money on pesticides that can damage the natural enemy population.

When you find insects in the field, it is sometimes difficult to judge whether they are actually damaging the plants or not. Some insects may just be *crop visitors* passing by and resting on the plants or on the soil, or *neutrals* that live in the crop but do not eat from the plants nor influence the pest populations as natural enemies directly. Neutrals can be a food source for natural enemies.

If you find insects and you are not sure what they are (pests, natural enemies, or crop visitors/neutrals), take some time to observe their behavior in the field. What are they eating? Another way is to set up an *insect zoo* to find out what the function of that insect is. See box below.

Whether or not a plant-eating insect is a pest depends not only on the population of that insect but also on the growth stage of the crop in which it occurs. For example, red borer damage can kill tea seedlings, but mature bushes can tolerate the damage.

Insect Zoo to check the role of insects

To check whether an insect could be a pest, take a few glass/plastic jars, or plastic bags, and put in some fresh stems and leaves from an unsprayed field. Add the insects that you want to study. Close the jar with fine netting that permits air circulation and keep it in the shade. Watch to see if the insect starts feeding on the leaves in the next hours, up to 2 days. If the insect did not eat the leaves, it may not be a pest insect. If the insect does not eat, don't keep it in the zoo for more than 3 days. Remember that when a person is locked in a room with nothing but a book, he or she may get so hungry after a few days that he or she will start chewing the book.... but that does not prove that humans eat books....!.

Remember, even if the insect eats a few leaves, it may not be a pest capable of causing economically-important damage.

To find out if the insect is a predator, put it in a jar and give it some soft-bodied insects (aphids or small caterpillars) with some leaves. Observe if it feeds on the food insects in the next hours up to about 2 days. If the insect eats other insects, you can be sure that it is a predator. But if you do not see the insect eating other insects, perhaps it eats plants, or perhaps the conditions inside the zoo were so strange that the insect didn't want to eat anything! Try several zoos, and several types of food insects, before deciding that your insect is not a predator.

Related exercises from CABI Bioscience/FAO manual:

1.6. Show effects of beneficials incl. natural enemies

4.1. Insect zoo

4-A.4. Assessment of impact of ground-dwelling predators

4-A.5. Measuring the parasitism level of caterpillars

8.6 Non-chemical methods for managing pest insects

This section discusses some non-chemical methods that are useful for managing many pest insects. In addition, Chapter Nine discusses management and control practices for each pest insect individually. Insecticides are discussed separately, in Chapter Twelve.

The four basic principles of IPM are:

1. **Grow a healthy plant.** Strong, vigorous plants are better able to tolerate insect damage.

2. **Protecting and helping natural enemies.** Many natural enemies live naturally within the tea field, and in wild plants in nearby fields. Just like the crop and pest insects are managed, natural enemies also must be managed so that they become abundant and effective. As was discussed in Chapter Two, making the tea ecosystem more diverse and more stable often helps natural enemies. Additional information about how to protect and help natural enemies is given later in this chapter.

3. **Regular field observation and analysis** using Agro-Ecosystem Analysis. Farmers can only make good decisions if they have good information. In other words, farmers must monitor what is happening in the field now, and compare it to what has happened during the past few weeks, to understand the tendency or trend. Pest insects, natural enemies, the growth stage of the crop, and weather are among the factors that should be observed and analyzed.

4. **Farmers become the experts.** Farmers must have confidence in their own knowledge and their ability to make their own decisions. If not, they will often use too many pesticides out of fear. The goal of IPM training should be to eliminate IPM training! Farmers should become as independent as possible of trainers, extension personnel, and pesticide vendors.

For IPM to be successful, all four of these principles must be applied. Principle #1 (growing a healthy plant) has already been covered in Chapters Five, Six, and Seven. Principle #2 (protecting and helping natural enemies) and Principle #3 (field observation and analysis) will be discussed in this chapter. Principle #4 (farmers become the experts) is the goal of the entire IPM training programme, including this *Ecological Guide*.

8.6.1 Regular field observation and analysis

Farmers should carefully observe their field each week, using the Agro-Ecosystem Analysis techniques that they learned in Farmers Field School. For a good sample, farmers should observe in each of three levels of the tea plant: (1) on top of the canopy, (2) inside the canopy, and (3) at the bottom of the tea plant. That way, farmers will have a more complete picture of what is happening in their field. Farmers should observe (and take notes about) pest insects, natural enemies, the growth stage of the crop, plant diseases, plant health including water and fertilizer needs, and the weather.

Methods for Agro-Ecosystem Analysis are discussed in the *Tea IPM Field Guide*. Using Agro-Ecosystem Analysis to decide whether a pesticide application is needed is discussed in Section 12.1 of this *Ecological Guide*.

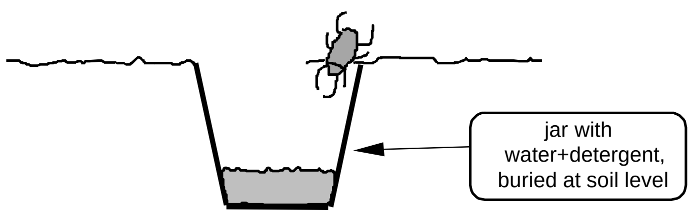
As part of weekly monitoring, insect traps can help provide information about what is happening in the field. Farmers can count the number of insects caught in traps, and analyze if the numbers are going up or down. Also, traps located on different borders of the field can help show if insects are coming into the field from the outside. Some common traps are discussed in the next section.

Use of traps for sampling and control

There are several types of traps to catch insects. Most traps will catch adult insects. These traps are often used for monitoring the populations rather than actual control. However, since some traps catch large quantities of insects they are often considered as control measures in addition to monitoring. For best results, several traps should be used in each field (for example, one trap on each side of the field). This makes it easier to detect from which direction the insects are coming. Some common types of traps include:

Light traps: Light traps are usually made of a light (can be electric, a candle, or a wick in kerosene or oil) and either a sticky plate or a basin filled with soapy water. Insects (mainly night-flying moths or beetles) are attracted to the light, and are caught on the sticky plate or fall into the water and die. However, natural enemies may also be attracted to light traps. When large numbers of natural enemies are caught it may be better to remove the traps.

Pitfall traps: are plastic or glass jars, half-filled with soapy water and buried into the soil up to the rim of the jar. These traps are good for catching ground-dwelling insects like ground beetles. Purpose of these traps is purely for monitoring as many ground beetles are active during the night and you may miss them when monitoring the field during the day. Pitfall traps may also be used without water and detergent, to catch living insects for insect zoos. However, good climbers will escape.



A pitfall trap

Yellow sticky traps: these are often made from yellow colored pieces of plastic or cardboard. They can also be made from empty yellow plastic bottles in which engine oil is sold, or even from pieces of bamboo or wood that have been painted yellow. Ask farmers for their ideas about how to make inexpensive traps from local materials. The trap should be painted or smeared with something sticky. Often glue or grease is used, but why not try sap from trees? Again, the goal is to make a cheap but effective trap.

The yellow color attracts some insect species like aphids, whiteflies, and thrips. The trap is especially useful for monitoring the adult population (what direction they are coming from, and how abundant they are). To a lesser degree, it can be used as a control measure, to catch adult pest insects. However, not only pest insects are attracted to the yellow sticky traps but also some beneficial natural enemies. Thus, it would be advisable to place just one trap as a trial and monitor in detail which insects are caught. If large numbers of natural enemies stick to the glue it might be better to remove the traps.

☞ **Related exercises from CABI Bioscience/FAO manual:**

4.2. Sampling for arthropods with light trap

4.3. Sampling for arthropods with sticky board

4.4. Sampling for arthropods with water pan trap

4.6. Soil-dwelling predators

8.6.2 Protecting and helping natural enemies

Just as the farmer manages the crop and pest insects, so the farmer must also manage natural enemies. Insecticides kill pests but also kill natural enemies. Management practices for natural enemies should focus on protecting them and as much as possible helping them increase their numbers. Natural enemies that live naturally in and around the field are adapted to the local environment and to the target pest. So, it is relatively simple and inexpensive for farmers to help these local natural enemies become abundant. Another way to make sure that natural enemies are abundant is to rear (or buy) large numbers of natural enemies, then release them into your field. This option is discussed in a separate section, below.

Some tactics for protecting and helping the natural enemies that live in your field:

1. **Learn to recognize the natural enemies** during all of their life stages. The first step towards taking care of natural enemies is knowing where they are. To monitor natural enemies, farmers need to be able to recognize them. Some of the most important natural enemies in tea are described at the end of this chapter.

2. **Allow some insect pests to live in the field:** these will serve as food for natural enemies. Of course, you cannot allow huge populations of pests. But remember, not all insect feeding on plants results in yield loss! Tea plants can tolerate quite a bit of injury.

3. **Do not use insecticides before there is a serious infestation of a pest insect.** Don't apply "just in case" or "because my neighbor is also spraying". This is not only a waste of money but may actually result in MORE problems with pest insects, because they can increase their population quickly when there are no natural enemies around. Monitor the field regularly to avoid unnecessary spraying. And, use non-chemical control methods (like planting shade trees or using traps) to reduce the need for insecticides. See Chapter Nine for non-chemical methods to manage specific pest insects.

4. **If an insecticide is needed, try to use a selective insecticide in a selective manner** (apply to a very localized area, only on the most-infested plants). Be extremely careful in choosing a pesticide. Most pesticides (even several fungicides!) are toxic to natural enemies. Even pesticides that claim to be very selective and harmless to natural enemies may still cause problems. You can test this yourself! See box below.

Effects of pesticides on natural enemies: a study example

1. Prepare hand sprayers with the pesticide to be tested.
2. Select a few plants in the field. Label plants with name of treatment and spray them with the pesticide. Let leaves dry on the plant.
3. Pick one or several leaves from each labeled plant and place these in jars (use gloves!).
4. Collect predators, e.g. spiders or lady beetles from the field (use a small brush).
5. Place predators in the jars, close the lid and place a piece of tissue paper between the lid and the jar to avoid condensation inside.
6. Check condition of predators after 8 and 24 hours.

Note: instead of leaves, a piece of cloth can be sprayed with pesticides. Rest of study as above.

5. **Provide flowering wild plants (food and shelter for natural enemies).** When the borders of the field have some weeds, especially when they are flowering weeds, these borders can provide a shelter for natural enemies. Mixed plantings such as intercrops or green manure plants can have a similar effect. Many natural enemies (for example hover flies and parasitoid wasps) live longer, and are therefore more effective, when there are sufficient flowers to feed on. Even though they eat "meat" (pest insects) for protein, they still need nectar from flowers for energy. Unfortunately, some pest insects also live in flowering weeds.

How can farmers take advantage of helpful weeds while minimising their harmful effects? Farmers need to study the weeds in their fields to learn which weeds are used by pests, and which weeds help natural enemies. Farmers should do Study #7 from the Tea IPM Field Guide (study entitled **"Effects of different weed management methods on tea ecosystem and yield"**).

Related exercises from CABI Bioscience/FAO manual:
4.9. and 4.10. Importance of flowers as food source to adult parasites.

8.6.3 Purchase and Release of Natural Enemies

In several countries in Asia, commercial or government "zoos" rear and sell a variety of natural enemies including several species of parasitoids; predators such as predaceous mites, lady beetles, lacewings, and praying mantis; and pathogens such as NPV (virus) and *Beauveria* (fungi). Availability of commercial natural enemies in a country also depends on the regulations of this country.

Numerous examples from Asia exist on the use of reared natural enemies for release in vegetable crops. For example, farmers in Dalat (Viet Nam) are studying the use of parasitoid wasps to control cabbage pests. Introduction of natural enemies is often a long process that includes training in parasitoid rearing, establishing an efficient rearing facility, setting up (field) experiments, and training farmers (Ooi, Dalat report, 1999).

8.7 Natural enemies: The Friends of the Farmer

Natural enemies are the friends of the farmer because they help the farmer to control insect pests that eat plants. Natural enemies are also called *beneficials*, or *biocontrol agents,* and in case of micro-organisms, *antagonists*.

8.7.1 Major groups of natural enemies

Natural enemies of insect pests can be divided into a few large groups: predators, parasitoids, pathogens, and nematodes. Some of their main characteristics are listed in the table below. The major natural enemies of tea insect pests are described in more details at the end of this chapter. Antagonists (the natural enemies of plant diseases) are discussed in Section 10.9.

CHARACTERISTICS OF NATURAL ENEMIES OF INSECT PESTS:

Predators	• Predators usually hunt or set traps to catch a prey to feed on. • Predators can feed on many different species of insects. • Both adults and young insects (larvae or nymphs) can be predators. • Predators follow the insect population by laying more eggs when there is more prey available. • Common predators are spiders, lady beetles, ground beetles, syrphid flies, and large stinging wasps.
Parasitoids	• Attack only one insect species or a few closely related species. • Only the larvae are parasitic. One or more parasitoid larvae develop on or inside a single insect host. • Parasitoids are often smaller than their host. • Comon parasitoids are tiny wasps or flies.
Pathogens	• Insect pathogens are fungi, bacteria or viruses that can infect and kill insects. • Pathogens require specific conditions (e.g. high humidity, low sunlight) to infect insects and to multiply. • Most insect-pathogens are specific to certain insects groups, or even restricted to certain life stages of an insect. • Commonly used insect pathogens are *Bacillus thuringiensis* (Bt), and NPV virus.
Nematodes	• Nematodes are tiny worms (about 1 mm long) that naturally live in soil. • *Entomopathogenic* nematodes attack and kill insects, and do not harm plants. • Entomopathogenic nematodes are usually only effective against pests in the soil, or in humid conditions.

Natural enemies of insect pests do not damage plants and they are harmless to people!

8.7.2 What kind of natural enemies are most efficient?

A successful natural enemy should

- Have a high reproductive rate, so that populations of the natural enemy can rapidly increase when hosts are available.
- Have good searching ability. Ladybird beetles, for example, are effective predators when pest populations are high. They are thought to be less effective at lower pest densities.
- Eat just one (or a few) types of insect pests, so that they dedicate all their effort to helping control that pest.
- Be able to tolerate different environmental conditions.
- Occur at the same time as the pest.

It is probably impossible for any one natural enemy to have all these characteristics, but those with several of them will be more important in keeping pest populations low.

For predators, efficiency is also determined by their appetite. For example, ladybeetle adults may eat as many as 50 aphids per day. To check the appetite of predators, the following experiment is easy to do:

☞ **The Predator Appetite Test!**

Catch a predator, such as a ladybird beetle or a syrphid larva. Place it carefully in a jar, together with some fresh leaves and a paper tissue to avoid condensation of water. Put a leaf with a known number of prey in the jar (for example, 20 aphids). Take another jar and place a leaf with the same number of aphids inside, but without the spider or ladybeetle. This is the control, to see how quickly a group of 20 aphids can multiply (or, how many die from being moved out of the field and imprisoned in a jar!). After 2 or 3 days, count the number of aphids alive in both jars. Discuss if the predator has eaten the prey and how effective it will be in field situations.

For parasitoids, effectiveness is also determined by the number of adult parasitoids that emerge from one host (the pest insect). Many adults emerging from a pest insect can each again parasitize a new host. This way the parasitoid population builds up more rapidly than when only one adult emerges from a host.

☞ **Related exercises from CABI Bioscience/FAO manual:**

4-D.1.	Predation on sucking insects in insect zoo
4-D.2.	Cage exclusion of natural enemies in the field
4.7.	Direct observations of consumption rates of predators in the field
4.5.	Studying predators in the field.
4-A.5.	Measuring the parasitism level of caterpillars
4-A.6.	Parasitisation on diamondback moth of cabbage
4-A.7.	Effect of parasitisation on feeding behavior of diamondback moth
4-A.17-20.	Life cycle and biology of parasites
4-A.21.	Preference of host stages by *Diadegma semiclausum* (or *Cotesia plutellae*)