

Paul Van Mele received his first degree in agriculture and ethnobotany from the University of Ghent in 1992. In 2000 he obtained his PhD from Wageningen University, focusing on farmer knowledge and conservation biological control. Having been senior training officer at CAB International, he now heads the Technology Transfer Unit at WARDA. Dr Van Mele edited the books "Way Out of the Woods: Learning How to Manage Trees and Forests" and "Innovations in Rural Extension: Case Studies from Bangladesh".

Nguyen Thi Thu Cuc is professor of Entomology in the Department of Plant Protection at Can Tho University, Vietnam, where she has been working for the past 29 years. Her research field is IPM on fruit plants. She has a special interest in biological control and has been studying the weaver ant *Oecophylla smaragdina* since 1992. Dr Thu Cuc is author of the book "Pests of Major Fruit Plants in Southern Vietnam and their Management".

Tree crops are increasingly being protected by agrochemicals, endangering the environment and human health. This manual provides practical tips to make optimal use of the beneficial weaver ant, based on improved insights of underlying ecological principles. Dr Paul Van Mele, technology transfer specialist at WARDA, and Dr Nguyen Thi Thu Cuc, an entomologist at the Cantho University, have combined the rich sources of scientific and farmers' knowledge into an attractive and colourful manual. It will appeal in particular to university students, NGO workers, extension staff and all those engaged in communicating science to farmers.



CAB International



ISBN 92 9113 3116

Ants as Friends

Paul Van Mele & Nguyen Thi Thu Cuc

Ants as Friends

Improving your Tree Crops with Weaver Ants

Paul Van Mele & Nguyen Thi Thu Cuc

Africa Rice Center (WARDA) aims at enhancing the rice sector in Africa. It also convenes the Inland Valley Consortium (IVC) that coordinates research on sustainable development of inland valleys. IVC pays attention to local innovations and solutions to mitigate negative impacts affecting ecosystem services.

CAB International (CABI) is an international organization dedicated to support the generation, access to and use of knowledge for sustainable agriculture, environment management and human development.

Ants as Friends

Improving your Tree Crops with Weaver Ants

Paul Van Mele

Nguyen Thi Thu Cuc

2007



Credits

CITATION:

Van Mele, P. and Cuc, N.T.T. 2007. Ants as Friends: Improving your Tree Crops with Weaver Ants (2nd Edition). Africa Rice Center (WARDA), Cotonou, Benin, and CABI, Egham, UK. 72 pp.

PHOTOGRAPHS:

Lacewings: Henk van den Berg
Parasitoids: (1) Angela M.I. de Farias; (2, 3 and 4) Nigel Cattlin/Holt Studios International
Others: Nguyen Thi Thu Cuc and Paul Van Mele

ILLUSTRATIONS AND FRONT COVER DESIGN:

Marcella Vrolijk

SPONSORS:

International Fund for Agricultural Development (IFAD)
Conservation, Food and Health Foundation (CFH)

CONTRIBUTORS:

CABI Bioscience (Egham, UK)
Can Tho University (Can Tho, Vietnam)
Fruit farmers (Mekong Delta, Vietnam)
Regional Plant Protection Centre (Tien Giang, Vietnam)
VACVINA (Association of Vietnamese gardeners)

DESIGN AND LAYOUT:

Carmenza Bacca Ramírez

SECOND EDITION PRINTED BY:

Modern Lithographic (K) Limited
Nairobi, Kenya

First English edition (2003); Bahasa edition (2004);
Vietnamese edition (2005)

Contents

About this manual	5
■ PART 1. INTRODUCTION TO NATURAL ENEMIES	7
Natural enemies are friends of the farmer	8
I love predators	10
How to look for parasitoids	15
Can insects also become sick?	17
Do weaver ants differ from other ants?	20
Where can you find weaver ants?	22
Why keep weaver ants?	24
■ PART 2. HOW WEAVER ANTS LIVE	27
Are you as brave as a weaver ant?	28
The weaver ant society	29
When and where can you best find a queen?	31
Do you know what the young of weaver ants look like?	32
Have you ever seen the building constructors at work?	33
How many nests can you find in one colony?	35
A sophisticated alarm system	36
What's up for dinner?	36
Do weaver ants increase honeydew-producing insects?	37
Can we keep ants all year round?	39
Do ants prefer certain plants for making their nests?	40
■ PART 3. HOW TO BEST MANAGE WEAVER ANTS	41
Ant husbandry: is it difficult to learn?	42
How do I prepare my new orchard?	43
How do I get rid of other ants?	44
When and how do I select nests for establishing a new colony?	46
What if I cannot get any nests?	47

Ants as Friends

How do I introduce new nests?	48
How do I take care of newly introduced nests?	50
How can I distribute ants evenly over my orchard?	51
How do I avoid fights between different colonies?	52
I fed my ants and they became so lazy!	53
What happens if I spray chemicals or water on my trees?	54
How can I reduce harm from ant bites?	55
■ PART 4. HOW WEAVER ANTS IMPROVE OUR LIFE	57
Get a healthier environment	58
Save some money	58
Produce organic fruit	59
Share your experiences	59
■ SUGGESTED READING	61
Who to contact?	67

About this manual

This manual offers you a highly exciting discovery voyage about the life of weaver ants, how you can make best use of them to protect your fruit and other tree crops and hence how to save money. Because the focus is on practical aspects based on improved insights of underlying ecological principles, the book will appeal in particular to farmers, university students, NGO workers, extension staff and all those engaged in communicating agricultural sciences to farmers. All the topics covered are based on a huge amount of scientific knowledge and farmers' expertise. Mind you, depending on the crop and climate where you live, slight differences may occur, so it is important to observe for yourself and learn from the local experts such as the farmers.

In the first part you will get an introduction to the role and diversity of beneficial organisms. The second part deals with the life and behaviour of weaver ants. You will learn among other things how the ants grow up from being a larva to a strong worker, how they live in a society where males and females each perform their specific tasks, and how ants for instance react to different factors.



Once you get to grips with this it will be much easier to understand how to best manage the ants throughout the year, as described in part three. In the final part we describe how the weaver ant contributes to improving the life of us all.

Now aren't you getting curious to read the rest of this book? Well, let me tell you one more thing. Did you know that the weaver ant uses a kind of a telephone system to inform the others that an enemy has entered their territory? Or that a delicious meal has been found? Now you can discover many things in this book, but you must know that what is really exciting is that most of it happens in your garden or orchard and that you do not need to buy a ticket to go and watch. Have fun!

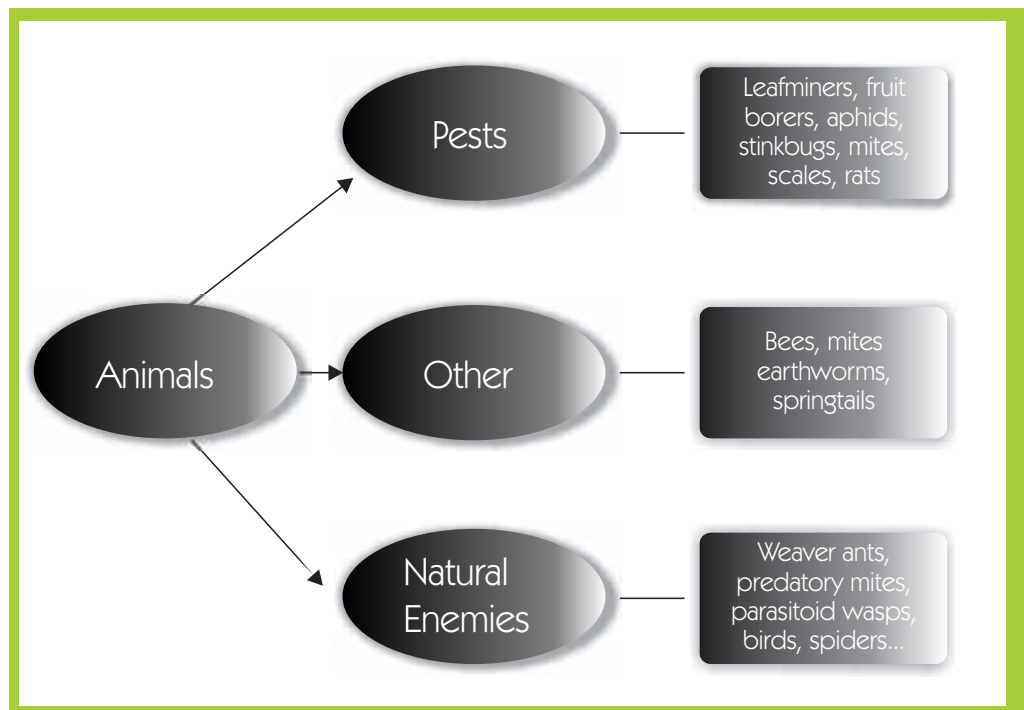
Introduction to natural enemies



Part 1

Natural enemies are friends of the farmer

In general you can classify animals into three broad groups. A first group eats parts of plants or sucks the juice in such a way that it visibly damages your crop. These we call pests. The second group and the majority of animals, however, uses other food available in your field or orchard and is not causing any problems at all. There are for instance pollinating bees, earthworms and many other organisms. The third group consists of animals that eat other animals, including pests. Therefore we call those natural enemies. Some mites¹ feed on plants and are a pest, while others decompose organic matter in the soil. Yet another group of mites preys on harmful mites and hence are natural enemies.



¹Mites are tiny creatures, often difficult to see with the naked eye. Hence, farmers often confuse the damage caused by those mites sucking juice from fruit or other plant parts with a disease.

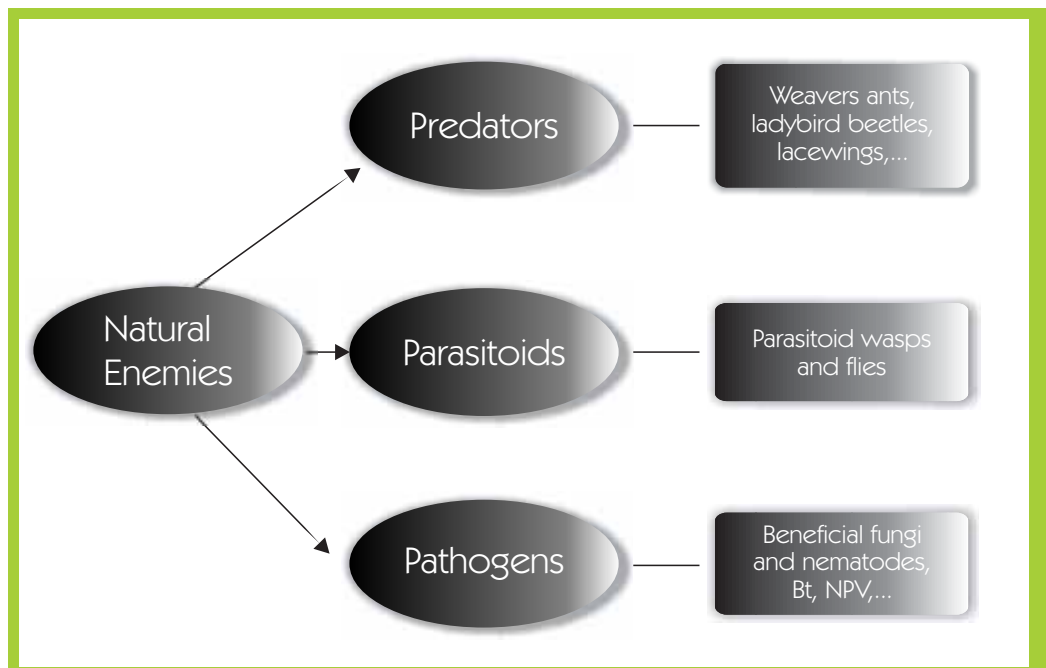
Ants as Friends

If you have a healthy orchard you will find many natural enemies. Although the weaver ant is extremely important, you will learn that other natural enemies are also present and they all contribute to making your life easier.

Now, if we can learn how to treat these natural enemies in the right way, they can do a really great job for us by protecting our crop. This will not only save us a lot of money, but is also good for our health, for our family and for the environment. Are you interested to find out more about the farmers' friends?

There are actually three types of natural enemies that help us protect our crop, namely predators, parasitoids and pathogens. As opposed to parasitoids which are often very tiny creatures, most people are aware of predators as they are easy to observe.

Besides, few people know that not all fungi, bacteria and viruses damage our crops, but that quite some are beneficial to us by attacking pests. We will describe all three types of natural enemies briefly in the following sections.

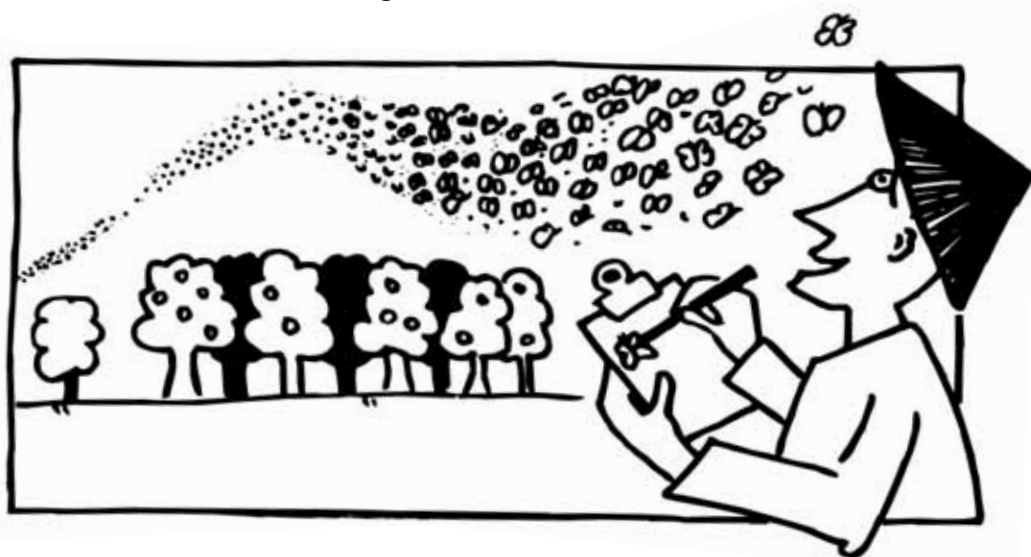


I love predators

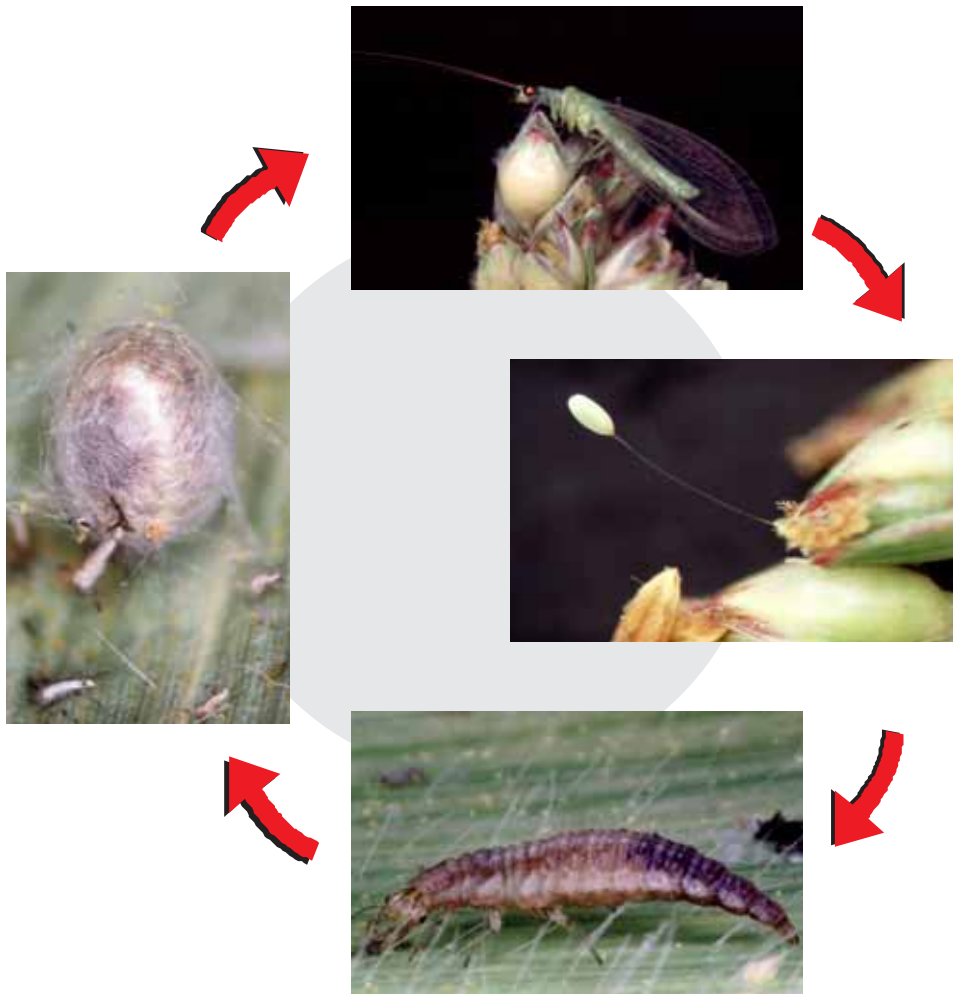
Those natural enemies that actively hunt their prey are called predators. They are really fascinating to observe in your orchard. Have you ever come across any of the ones mentioned below? Walk through your orchard and see if you can find any. Mind you, when you do this in the early morning you will probably get a different picture than when you do this at noon. Can you observe what they feed on?

To give you an indication, some photos are given of common predators. Predators in your orchard may look a bit different as there are so many different species in each family. If you see any other predator that does not look like the ones below, go and grab a pencil and draw it on a piece of paper to discuss with your friends! If you want, you can also collect some and ask your colleagues if they know this natural enemy.

Often you will know how the adults look, but bear in mind that also the larvae or young stage of predators such as beetles, hover flies and lacewings eat a lot of pests. The larvae often look quite distinct from the adult stage.








Life cycle of a lacewing



Eggs of lacewings are typically laid on long stalks. Once the larva emerges from the egg, it starts feeding mainly on aphids and mites. A mature larva produces a cocoon [in reality less than 1 centimetre (cm) long] and pupates on the plant. The adult that emerges from the cocoon only flies by night and feeds on plant pollen and nectar.






Ants as Friends

Name Family	Adult	Description
Ladybird beetles (Coccinellidae)		Larvae ² and adults feed on aphids, lepidopteran eggs and other soft-bodied insects. Adults may also feed on pollen and nectar of flowers to get extra energy.
Ground beetles (Carabidae)		Adults and larvae of ground beetles feed on a range of eggs, larvae, pupae (in or on the soil), and soft-bodied insects.
Rove beetles (Staphlinidae)		Both larvae and adult rove beetles feed on eggs and soft-bodied insects. Adults often drop from the plant when disturbed.
Assassin bugs (Reduviidae)		Assassin bugs have an elongated neck and curved mouthparts held under their body. They feed mainly on aphids, small caterpillars and insect eggs.
Praying mantids (Mantidae)		Praying mantids are up to 10cm long and feed mainly on larger insects such as grasshoppers and bugs.

Some common predators

²Larvae are the growing 'worm-like' stage in the life cycle of many insects.

Ants as Friends

Name Family	Adult	Description
Hover flies (Syrphidae)		Hover flies look like bees, but they maintain a stationary position in flight. The larvae feed on aphids, while the adults visit flowers for their nectar.
Ants (Formicidae)		Many ant species are important predators attacking insect eggs, larvae, pupae and adults.
Lacewings (Chrysopidae)		Lacewing larvae feed mainly on aphids and mites, while adults only eat nectar and aphid honeydew. Eggs are typically laid on long stalks.
Earwigs (Dermaptera)		Most earwigs hide in the soil or in enclosed spaces during the day. At night they search plants for eggs, larvae and nymphs of smaller soft-bodied insects.
Spiders (Araneae)		All spiders, whether web spinners or hunting species, are active predators. They attack a wide range of insect prey, including pests and beneficial insects.

Some common predators

Ants as Friends

Development stages of ladybird beetles and hover flies



Larva of ladybird beetle



Larva of hover fly



Pupa of ladybird beetle



Pupa of hover fly



Mating adults of ladybird beetle



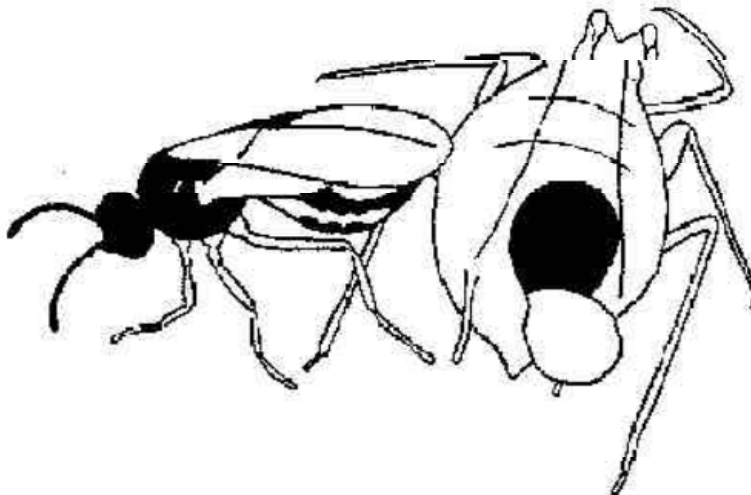
Adult of hover fly

How to look for parasitoids

This group of insects is generally less known than predators as they are more difficult to observe: most parasitoids are often less than two millimetres (mm) long. However, this doesn't mean that they are less important in helping you to protect your crop. While predators often feed on a large range of prey, parasitoids are often very selective. Did you know that parasitoids are very important to keep aphids, leafminers, scales, mealybugs and many other pests under control? As such they perfectly complement the work of predators.

Parasitoids are called that because they lay their eggs in, on or near an insect host. When a young parasitoid larva emerges it will feed on its host often killing it. You can easily recognise parasitised eggs or larvae because they often change colour and die quickly.

A lot of parasitised insects like aphids, psyllids, scales and mealybugs mummify, leaving only the empty skin of the insect behind. No matter which stage is affected, after a while small parasitoid wasps or flies will emerge. You can clearly see the exit hole. Have you ever observed any mummified insects in your orchard? It really shows you have a healthy orchard and that some friends are helping you.



Some common parasitoids



Parasitoid wasp (in reality only a few mm long) laying an egg in the body of an aphid.



Swollen aphid mummies due to parasitisation. Some have a hole through which the parasitoid has left the host.



Small parasitoid wasp (in reality only a few mm long).



Parasitoid wasp emerging from nymph (the immature growth stage) of whitefly that looks like a scale.

To find out about parasitoids by yourself, collect some relatively young leaves with leafminer damage and put them in a transparent container with a perforated lid and lined with some tissue paper. When daily observing, you can see either that the leafminer develops normally into a small moth, or that a small wasp or fly has emerged.

Can insects also become sick?

Yes indeed, just like humans they can become sick, because in nature there are many diseases that can attack them. Isn't nature helping us a lot in many ways?

These beneficial diseases for us may be fungi, bacteria, viruses, protozoa or nematodes (Table 1). Most of you may be familiar with the bacterium Bt and the virus NPV. Once inside the insect pest, the pathogen³ multiplies rapidly, killing the host within a short time (Figure 1). As with humans, healthy individuals may become easily contaminated by one sick individual or by eating infected food. Pathogens are invisible to the naked eye, but you can often observe the damage symptoms they cause.

Have you ever seen any thrips, mites, hoppers, scales or caterpillars that have been attacked by a fungus? Very typically these pests become covered with fine fungal threads, which in a later stage get a powdery layer. The colour of it depends on the type of fungus.





As with vegetables, you may also find caterpillars in your orchard that have been attacked by viruses like NPV. A very clear symptom is that the affected caterpillar or pupa changes colour, often whitish at first then turning dark.



Caterpillar infested by fungus

³Pathogens are any organisms like fungi, bacteria, viruses, etc. able to cause disease in a particular host or range of hosts. If the host happens to be a harmful pest, the pathogens are considered beneficial to us.

Table 1. Characteristics of pathogen groups that kill insects

Pathogens	Host range	Mode of entry	Speed of kill
Viruses 	Mainly caterpillar Often specific to one genus or a single species	By mouth	3-10 days
Bacteria 	Mainly caterpillar, diptera (mosquitos and flies) and larvae of coleoptera (beetles) Particular strains specific to different species	By mouth	30 minutes 3 weeks
Fungi 	Very broad Many individual strains are host specific	Through the cuticle ⁴	4-7 days
Nematodes 	Very broad	Through the cuticle	6-10 days

The skin of the slightly swollen host breaks easily when touched, releasing the liquid that contains many viruses, and as such further spreading these beneficial organisms. Infected caterpillars may hang by their 'legs' from foliage.

⁴ The cuticle is the hard skin of insects.

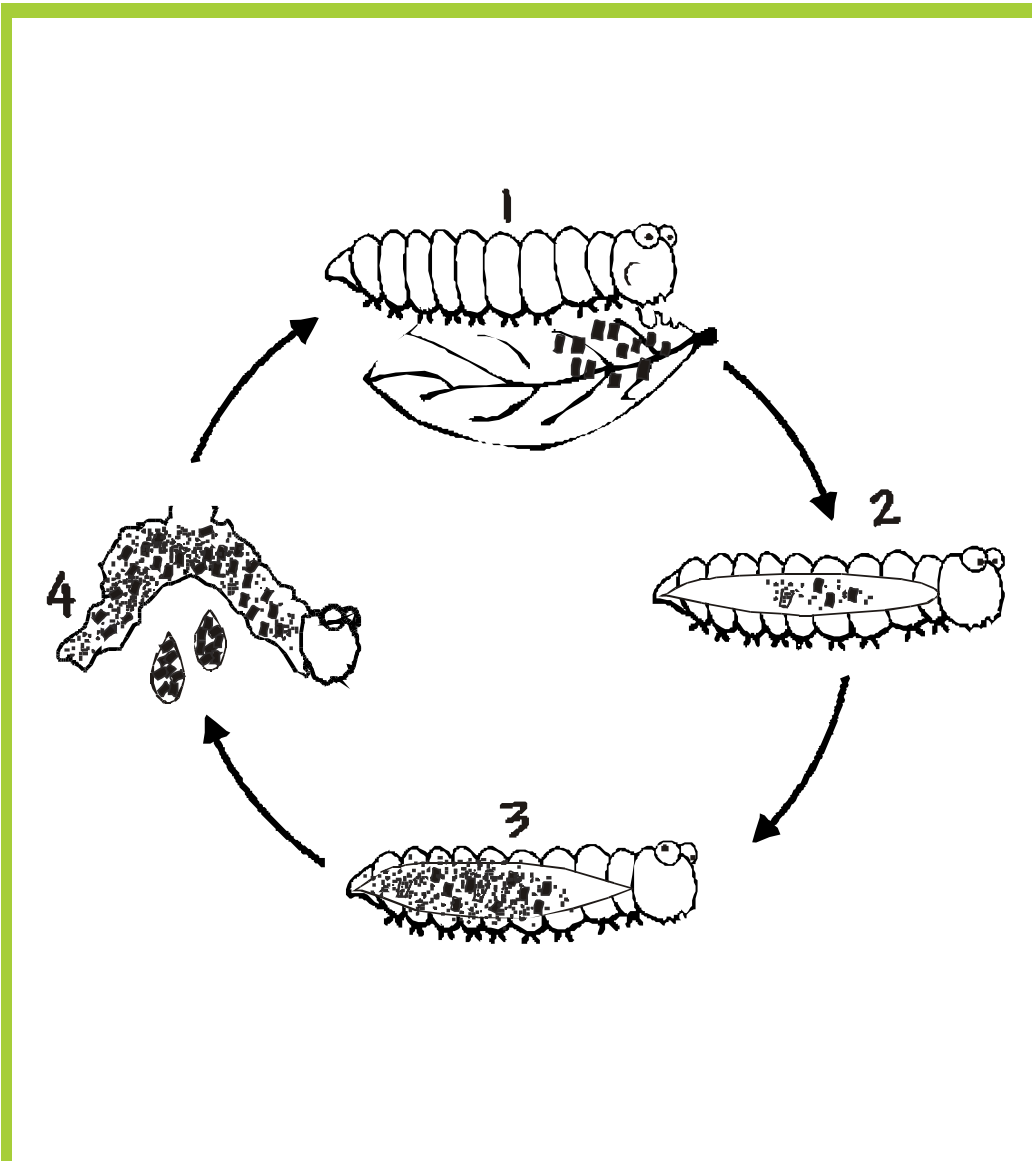


Figure 1. Life cycle of a typical virus that kills a caterpillar. Mind you, in reality viruses cannot be seen by the naked eye. Viruses enter caterpillars through contaminated food (1), the digestive juices release virus particles which multiply in the stomach (2), virus particles infect other organs and multiply (3), and within 3 to 10 days the liquified caterpillar releases fluid that contains millions of viruses (4).

Mind you, in reality viruses cannot be seen by the naked eye. Viruses enter caterpillars through contaminated food (1), the digestive juices release virus particles which multiply in the stomach (2), virus particles infect other organs and multiply (3), and within 3 to 10 days the liquified caterpillar releases fluid that contains millions of viruses (4).

Do weaver ants differ from other ants?

Weaver ants are very special in that they actually weave leaves together to make their nest. They are given many different names depending on the country, ranging from yellow ants (Vietnam, China), to red ants (Thailand) and green ants (Australia) just to give you a few examples. Despite its usefulness in a local context, the description based on colour does not seem to give us a satisfactory classification when we start comparing ant species within or between countries, or even more between continents.

Are we talking about the same ant or not? In Vietnam, for instance, what people commonly call yellow ants actually comprise many different species with a yellow appearance, some of which can be a real nuisance in the house.

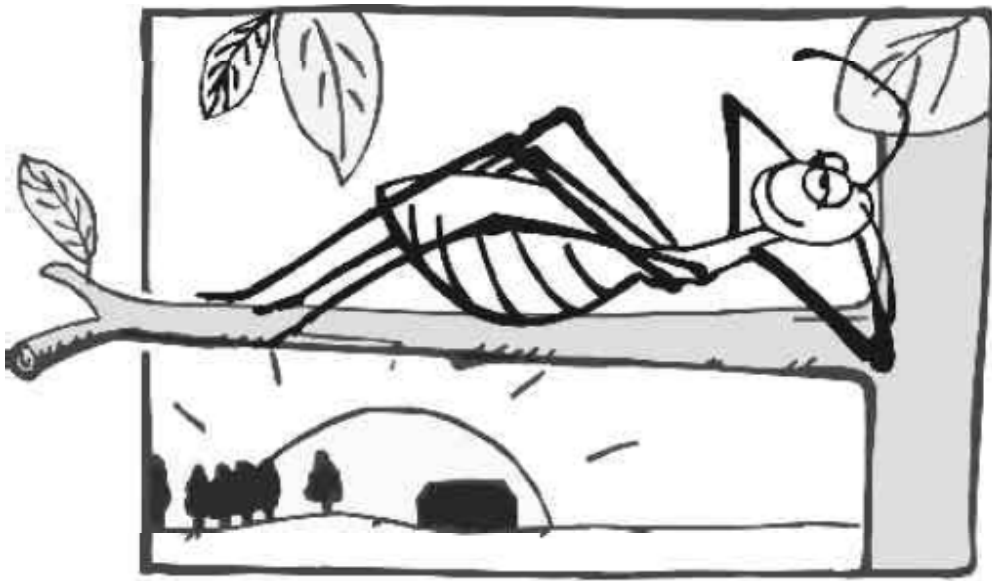
To distinguish weaver ants from other ants, scientists gave them a separate name, namely *Oecophylla*, irrespective of the country where they occur. Weaver ants are further specified as *Oecophylla smaragdina*, which occurs in Asia, whereas the African species has been given the name *Oecophylla longinoda*.

When we talk about weaver ants in this book, we thus mean both the Asian and African ant that makes nests in trees. You will never find weaver ants in your house, because they like to live outside in the fresh air. That is also why they don't make nests under the ground, but high up in the trees.

Apart from their nesting behaviour, comparing them with other ants is quite simple: weaver ants are bigger than most other ones, and they are more aggressive. Luckily the pain of their bites disappears very fast.

Ants as Friends

Like other common ants which you see in or around your house, weaver ants also like something sweet, but actually they prefer to eat other insects and small animals. Imagine what an army of ants can do with their strong teeth to protect your crop from harmful insects! Therefore, it is important to learn how to live peacefully together with them and make them your friends.



Where can you find weaver ants?

The weaver ant can be found in many different countries from Africa to Asia (Table 2). As far as history books are concerned, the Chinese people were the first to make weaver ants their friends in citrus more than 1000 years ago, but of course not everything has been recorded in history.

Table 2. Countries where weaver ants have been reported

Africa	Asia-Pacific
Benin	Australia
Burkina Faso	Bangladesh
Burundi	Borneo
Cameroon	Cambodia
Congo Democratic Republic	China
Côte d'Ivoire	Indonesia
Equatorial Guinea	India
Gabon	Laos
Ghana	Malaysia
Guinea	Papua New Guinea
Kenya	Singapore
Mali	Solomon Islands
Mozambique	Sri Lanka
Nigeria	Thailand
Rwanda	Vietnam
Senegal	
Tanzania	
Togo	
The Gambia	
Uganda	
Zambia	

Oecophylla smaragdina prefers environmental temperatures between 26 and 34°C and relative humidities between 62 and 92%.

Ants as Friends

Apart from protecting *Eucalyptus*, mahogany, red cedar and other timber trees, just have a look at the following to see in which other tree crops weaver ants have been used. In citrus and cashew, for instance, these ants control all major pests and also improve the yield and quality of the fruits and nuts. And besides protecting coconuts and cocoa from bugs, they also deter rats. African mango growers, on the other hand, often cite that, in orchards with weaver ants they do not have problems with snakes. Isn't that wonderful?



Why keep weaver ants?

While examples of the benefits of weaver ants have been described for many crops and in many countries, most citrus farmers in the Mekong Delta of Vietnam will tell you how the ants also improve their fruit quality. Not only do their fruit shine more, they are also juicier!

Do you want to find out how efficiently weaver ants can protect your crop from pests? Just put a living caterpillar under some leaves in any tree with a lot of weaver ants and then see in what time the ants have discovered and taken it away. Be ready for a surprise!

If you observe carefully, you will see that weaver ants either disturb, deter or directly prey on a multitude of pests such as the citrus green bug, leaf feeding caterpillars and many fruit attacking insects. Besides this, in orchards with a good weaver ant population there are less problems with mites, leafminers and even fruit flies!



Mite damage



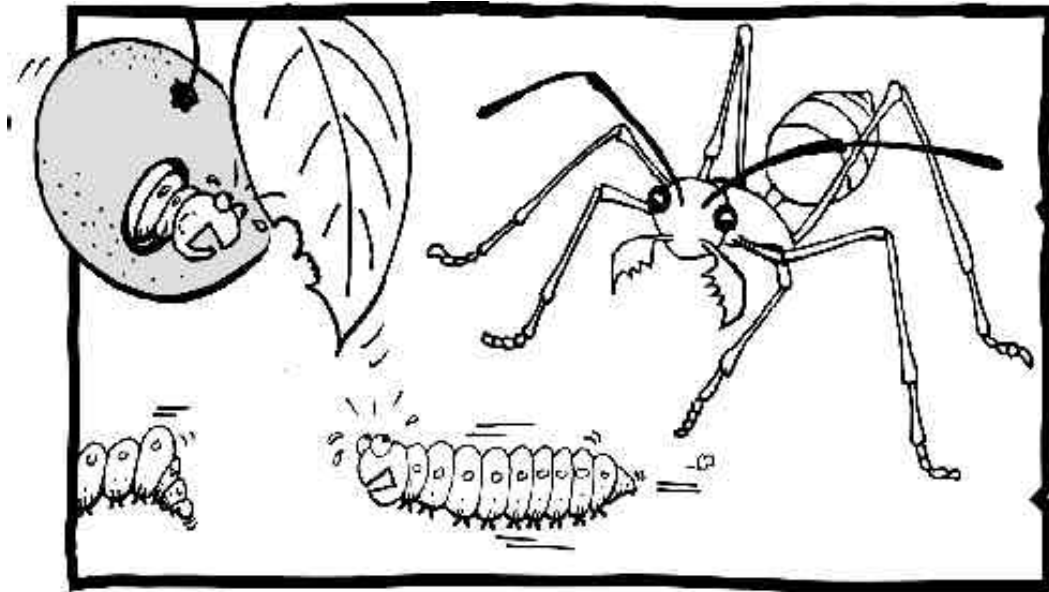
Citrus leafminer damage



Fruit fly

Ants as Friends

To find out how you can make best use of them, let's first have a look at how the ants live. You will not only find this useful when you want to make them your good friends, it even might open a new world for you.



How weaver ants live



Part 2

Are you as brave as a weaver ant?

Interestingly, weaver ants behave a lot like humans do, or at least some of us. Although you will find out more throughout this book, we can give you an early taste of it.

■ *Fearless*

If you think that small creatures are afraid of anything bigger than themselves,

you are wrong. Weaver ants attack any intruder, even those that are more than 100 times bigger than themselves.

■ *Energetic*

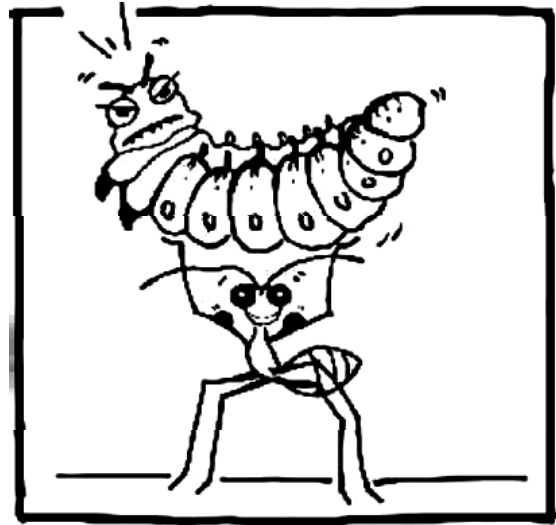
Just observe one ant for a while and you will see how active it is. Indeed, these weaver ants can run up and down all day long. Any human being trying to do the same amount of activities would be completely exhausted. Did you say you want to compete?

■ *Disciplined*

No one escapes from it. When something needs to be done in the ant society, all will participate in the activities. Just try to observe when the ants build a nest.

■ *Intelligent*

Did you know that by producing certain odours and by touching the others in a specific way, weaver ants have developed their own communication system? Within the shortest time all will know where something is happening and what needs to be done.



The weaver ant society?

Like most other ants weaver ants live in a society where work is well divided among the different types of individuals. It is by working closely together in a well organised and disciplined way that they can achieve a lot of things. The society, also called a colony, can live in either a few or many nests.

■ *Queen*

In each colony you can find one or several queens in one nest (dry season) or in more nests (rainy season). They are easy to recognise as they have the biggest size and a green to brown body with a big belly to produce many eggs. At the beginning they have wings just like the males, but after the mating flight they lose their wings.



Winged queens inside a nest during rainy season

■ *Males*

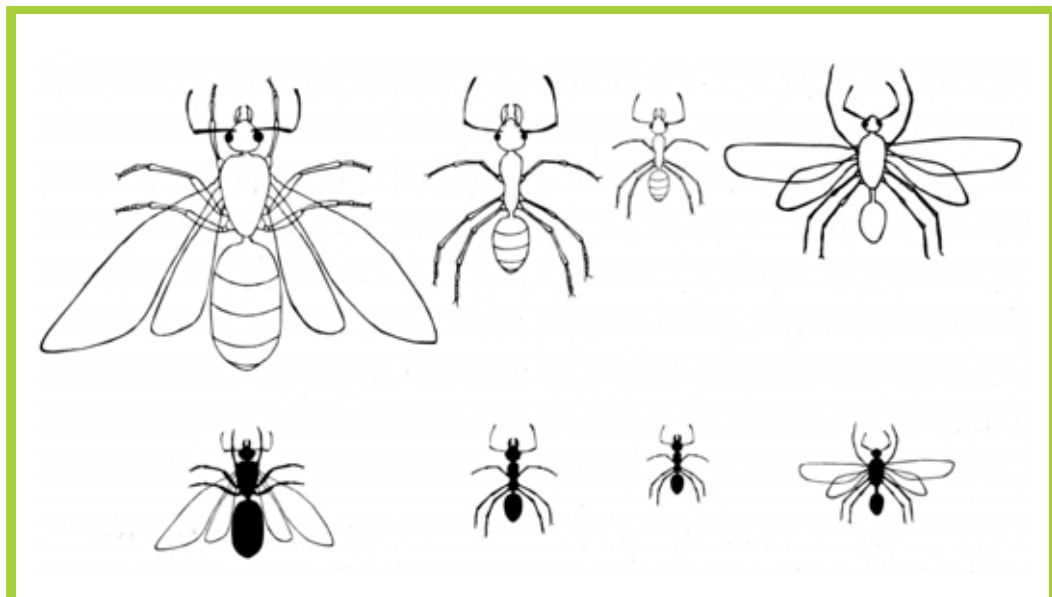
Males are much smaller than the queen, and have a blackish body. Their only task is to mate with the queen after which they die. They only live for a short time: reared in a laboratory a lot of them died within 1 week, while the queen and workers lived for several months!

■ *Small workers*

The small workers are like nannies. They stay mainly inside the nest and take care of the young.

■ *Large workers*

These individuals are the most numerous in the colony and are responsible for a whole range of activities. They guard against intruders, collect and bring home food for the whole colony, and construct nests. But that is not all. Have you ever seen when a nest is disturbed that they take the young from that nest in their strong teeth and transport them to a safe place? Under certain conditions they can also lay eggs, just like the queen.



From left to right winged queen, large worker, small worker and male.
Shown enlarged above, true size below.

When and where can you best find a queen?

In natural conditions, the number of individuals in a colony can increase rapidly depending on the availability of food and plants for making nests. You will find more ants and nests in the rainy season, and if you have tried to look for a queen during this time of the year, you have probably been more lucky than when looking in the dry season. In the Mekong Delta of Vietnam, for instance, you will have most chance of finding a lot of queens in the rainy season from July to October.



Large nests with queens can also be found low above the ground, but only if the place is undisturbed.

Because the queen prefers not to be disrupted while laying eggs, you have more chance of finding queens in undisturbed places. Truly, in case you frequently walk or work in the orchard to irrigate, prune, harvest or spray the trees, the queens will look for a nesting place in plants that are not disturbed in or near your orchard.

Queens can be mainly found in nests that are not so small, but mind out: the leaves of the nest should still be fresh and green, otherwise it is likely that most ants have already moved on to a new nest, the queens as well.

Do you know what the young of weaver ants look like?

In the nests, queens lay many eggs which develop into worm-like larvae. The eggs are very small and elliptical (0.5 mm x 1 mm), whereas the larvae are 5 to 10 times bigger and look like small white worms. Despite this, larvae are easily confused with eggs, because without a magnifier you cannot see their eyes or mouth.



Worm-like larvae of the weaver ants. The large pupae will become queens, while the smaller ones will develop into males. If you look hard, you can already see their wings.

People in the Mekong Delta will often tell you that they use ant eggs as fishing bait, whereas in reality these are already well developed queen-larvae which are regularly fed by smaller workers.

Larvae are also very different from their parents as they have a smooth skin white as milk and do not yet have any legs or wings.

The larvae grow and throw off their old skin several times, just like the snake does. After some time they will change into adults with clearly visible legs, eyes and a mouth, and wings for the males and queens. At first they are still white and non-active, this form is called a pupa (see photo), but later on each will take on its own colour.

Have you ever seen the building constructors at work?

Talking about team work! These small creatures manage to make large nests (as big as palaces for humans) within a couple of days, because all work together from sunrise to sunset.

What is really exciting is that several large workers pull leaves together, and while they keep them in the same position, other workers stitch the leaves together mainly from the inside. So do they use needles and threads? Well you could say so: in fact they take their larvae between their teeth and use them as a shuttle.

The larvae then continuously produce thin threads of silk from one leaf to the other. Imagine how many times they are taken back and forth before a strong enough silk web has been produced!

As nest building is a very laborious task, the weaver ants have become experts in finding the most suitable leaves to construct a nest.

When the leaves are very small like with the *Murraya* shrub, a huge amount of silk is required (see photo in section 'Do ants prefer certain plants to make their nest?').

These energetic workers not only construct nests, they are also called upon to repair damage. Now, if you don't believe it, check it out yourself: slightly lift one leaf from a nest and you will see how quickly they start repairing it!

Ants as Friends

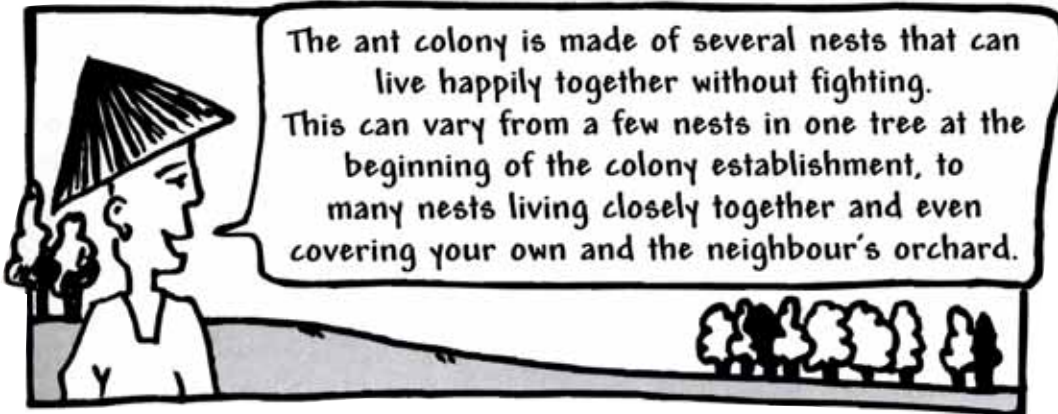


Weaver ants build their nest by folding leaves and using the silk of their larvae to stitch the leaves together.

How many nests can you find in one colony?

The number of ants in one nest on average varies between 4000 and 6000 individuals, and the whole colony can have as many as 500,000 adult workers! The ant colony is like an extended family with many nests and individuals who all know each other and who work closely together in a certain area.

How many nests you can find in one colony depends on many different factors such as availability of food and level of disturbance, but it can reach up to 100! These nests may be found in over 15 trees, and over an area bigger than 1000 square metres.



■ A sophisticated alarm system

As we mentioned before, the large workers are the guards of the society. At any time they will alarm the others when an intruder enters their territory. Just try to climb in one of the trees with a nest, or even just slightly touch one of their nests and you will be amazed in how short a time a whole army is raised and ready to come after you!

When a prey is found, the large workers use some odours and they touch their colleagues in a special way to indicate where they have found a prey and how big it is. While a couple of ants pin down the intruder, help is on its way. Isn't that really incredible!

■ What's up for dinner?

Dinner for the ants is very diverse, and could be classified into two big groups: proteins and sugar. Unlike any other ants, their main preference is for proteins rather than sugar. Proteins can be found in meat, fish, chicken, rats and most importantly for us, insects.

As we mentioned earlier, weaver ants actively search for food, and they will bring this back home to their nest to feed themselves as well as the larvae and others in the nest. They prey directly on a multitude of pests. Even moths, which fly during the night and



hide under the leaves during daytime, often fall prey to these hungry creatures. Weaver ants will supplement their proteins with something nicely sweet, for instance with honeydew from sap-sucking insects or with plant nectar. Rather than actively searching for sugar, weaver ants prefer to keep their 'sugar pot' close to their house. Therefore you will always find some insects like aphids, scales or mealybugs near and sometimes even inside their nests!

Do weaver ants increase honeydew-producing insects?

Although in citrus this is often stated as a problem caused by the weaver ant, this contradicts our findings and those of many experienced citrus farmers: outbreaks of honeydew-producing insects never occur when you take good care of the weaver ants and avoid the use of pesticides. On the contrary, if the amount of sugar produced by these insects is bigger than the amount required by the colony, the ants will even kill some of them.

The main reason for this misperception is that the weaver ants prefer to keep their 'sugar pot' close to their house, and that this can be easily observed. When a new nest is made, weaver ants will look for and prefer young leaves that have some honeydew-producing scales and often include these in their nest. This will give them some sugar and thus energy for the construction of their nest during the initial period. Therefore it



Ants keep honeydew-producing mealybugs on a hibiscus shrub close to the orchard, reducing their need to tend mealybugs on your fruit trees.

Ants as Friends

might be good to have a few plants in or around your orchard that honeydew-producing insects prefer more than your fruit trees.

As we mentioned in the introduction, weaver ants are not the only beneficial organisms in your orchard. A wide range of predators and parasitoids keep the population of insects like aphids, scales and mealybugs under control. You can therefore expect an outbreak of these insects not because you have weaver ants, but more likely because you have sprayed some toxic chemicals that killed all the other beneficials! Even if the weaver ant may recover soon from certain chemicals, most other friends of the farmer are less strong and this should always be kept in mind.



Ants with honeydew-producing scales on a hibiscus shrub close to the orchard. Outbreaks of scales or mealybugs will only occur when you use toxic pesticides.

Can we keep ants all year round?

Two things we have to understand about weaver ants is that they adapt well to changing conditions, and that they always try to optimise food and housing conditions.

Ideally, a good place to set up a colony will have:

- *Enough prey, possibly with honeydew-producing insects;*
- *Plants with large, flexible leaves or with abundant smaller leaves;*
- *Limited human disturbance.*

Now, why do you think ants regularly abandon a nest to go and build one in another place? Right, for one reason or another the conditions are not ideal anymore: either food has become scarce, nesting conditions become poor, or they are disturbed above their tolerance level.

They might set up a new nest in the same position in the tree when the only reason for discomfort is that the leaves of their former nest have become dry. However, other factors will determine whether they will move their nests up and down the tree, change tree, or even move to another orchard.

In the dry season for instance the sun is so hot, that all nests in the top of trees are abandoned and new nests are built lower down in the canopy. On the other hand, regular disturbance by people will make ants move higher up in the trees, or in the worst case the whole colony will move to another orchard. As you can see, the latter is something we better try to avoid.

Do ants prefer certain plants for making their nests?

As we mentioned above, to make nests the weaver ant prefers plants with large, flexible leaves or with abundant smaller leaves. Apart from banana, papaya and most palm trees, you can imagine that a lot of plants qualify for this. Mind you: some plants lose all their leaves in the dry season or in winter time.



Tall trees like *Spondias* are preferred nesting sites. As some trees lose their leaves in the dry season, a good mixture of plants is recommended.



Small shrubs like *Murraya* are preferred nesting sites if left undisturbed. Ants like it because the flowers provide them with sweet nectar.

To avoid disturbance, ants often prefer higher trees such as the coc tree (*Spondias dulcis*) or mango trees in the Mekong Delta. When left undisturbed, however, also smaller trees or shrubs may be preferred. As such you may find nests in the wild annona trees (*Annona glabra*) along the canals of your orchard, or even in hibiscus shrubs in your garden. The latter is mainly preferred because the ants have easy access to the honeydew from the scales or mealybugs feeding on this plant.

How to best manage weaver ants



Part 3

■ Ant husbandry: Is it difficult to learn?

Well, ants are living creatures and like all animals we have to learn how to best treat them if we want to make them our friends. Now that you know how they live and behave, you are already a long way to achieving this. It will help you a lot in deciding how to act best and under which circumstances.

In the following section you will learn some basic tools to make best use of the weaver ants, and you will see that they are quite easy to learn.

Taking each of these topics into account will definitely increase your rate of success. The topics covered are:

1. How do I prepare my new orchard?
2. How do I get rid of other ants?
3. When and how do I select nests for establishing a new colony?
4. What if I cannot get any nests?
5. How do I introduce new nests?
6. How do I take care of newly introduced nests?
7. How can I distribute ants evenly over my orchard?
8. How do I avoid fights between different colonies?
9. Do I need to feed my ants?
10. What happens if I spray chemicals or water on my trees?
11. How can I reduce harm from ant bites?

How do I prepare my new orchard?

As you remember, weaver ants prefer to have an undisturbed place and plenty of good leaves to make their nests. If you convert your paddy or vegetable field into an orchard, it is quite unlikely that you can meet these requirements. Two scenarios are possible:

If you have some older trees around your field: do not cut them down as these are good shelter places for the ants. Older trees can ensure that a new colony will establish much faster.

If you do not have any older trees, a golden rule is to plant some non-crop trees or shrubs for shelter in or around your new orchard as soon as possible. Remember that certain plants like banana, papaya and sapodilla are less suitable. Maybe you can add some other examples from your own experience.



Keep or plant high-growing trees like mango in or around your orchard as refuge for the ants.

How do I get rid of other ants?

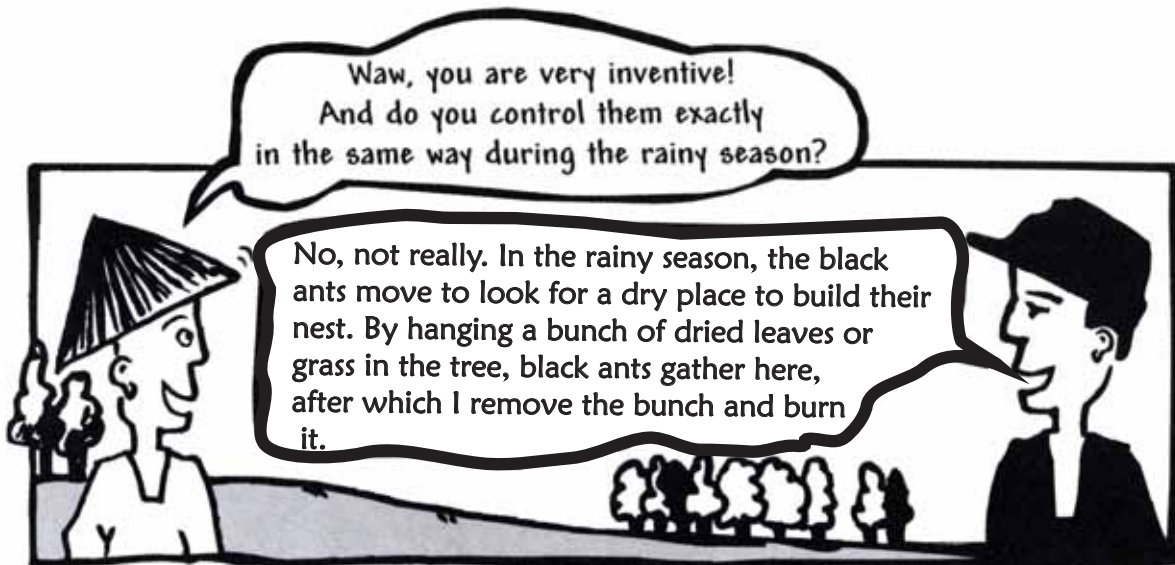
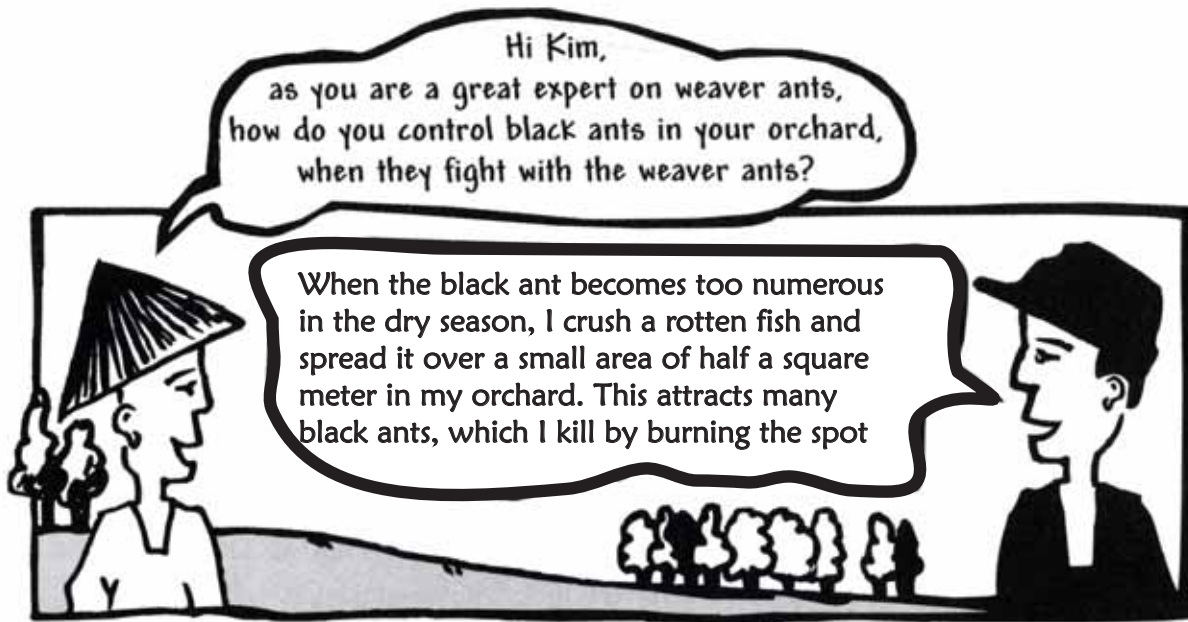
Because ants of different species, or even the same ants of different colonies like to fight each other, it is important to get rid of or strongly reduce these ants before you introduce weaver ant nests from another place.

A major competitor of the weaver ant is the black ant (*Dolichoderus thoracicus*): these ants do a good job in protecting sapodilla fruit. However, in citrus they are considered a pest as farmers say they reduce the fruit quality.

Through his life-long experience, Mr. Nguyen Van Cung from Giong Trom district, Ben Tre province had to intervene several times to keep the black ant population under control. He has developed two different strategies depending on the season, both based on studying ant behaviour. Just have a look at the conversation on the following page.

Maybe you can come up with some other methods that are compatible with integrated pest management (IPM). Once you have reduced the other ants, your chances of success for establishing a new colony of weaver ants will increase again.

Ants as Friends



When and how do I select nests for establishing a new colony?

Basically you can take nests any time of the year, although the best time is in the rainy season between July and October. Why is that? As we saw earlier on, this time of the year a lot of egg-laying queens are present in the nests, and we know that without a queen, the newly introduced colony will disappear fast.

And as you can imagine, the more nests you can introduce the better your chance of a successful colony establishment. However, make sure all nests come from one and the same colony otherwise they will start fighting each other. Therefore it is best to take as many nests from one single tree or from neighbouring trees and preferably from an undisturbed place.

Of course you do not want to collect nests with only a few ants inside. The best is to go for medium to large nests that still have fresh green leaves. Once leaves from the nest get older, they become dry and the ants abandon this nest. A good tip is to lightly knock on a nest with a stick: you will soon see if there are

many ants inside or not. If you want to avoid becoming covered with ants, better wait a while until they settle down again before you cut off the nest and put it in a bag.



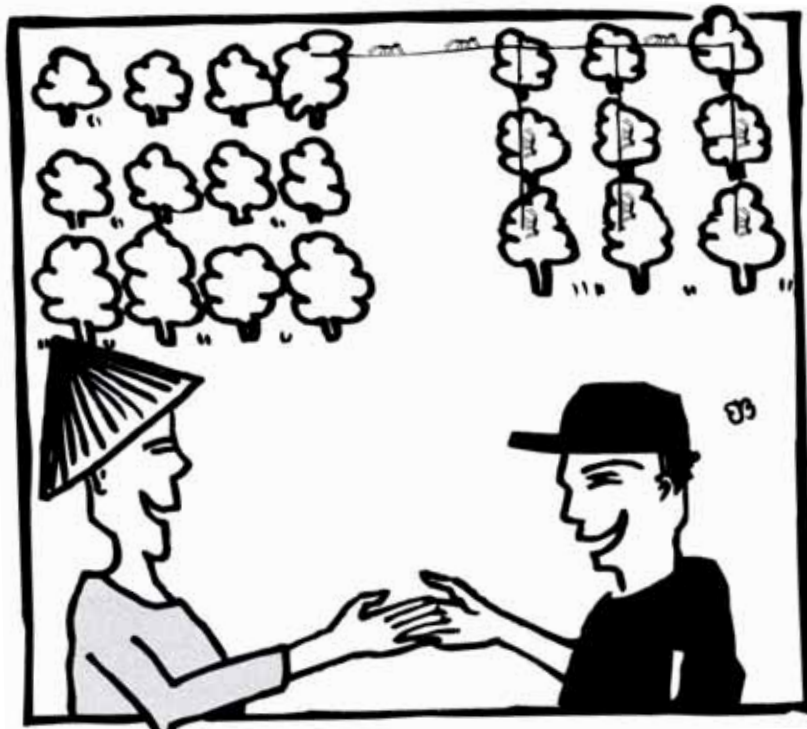
Lightly tapping the nest will soon tell you whether the nest is still inhabited or not.

What if I cannot get any nests?

Because the native vegetation has decreased tremendously in many places due to increased cultivation pressure, it may be difficult to find nests in nature. Besides, many farmers are not always willing to hand out nests to others as they believe this will weaken their own colony.

So how to get around this? Simple, if your neighbour has a well established colony, just ask for permission to make a connection between the canopies of his or her orchard and yours. Ants can then easily walk to your trees and set up nests by themselves. The ants will get a bigger territory to search for food and this will strengthen the colony. Not only you, but also your neighbour will benefit from this!

Initially it might be good to put some food at your end of the 'ant bridge' to attract them over.



How do I introduce new nests?

Again, you can use many of the things you have learned about how ants live and behave. For instance, whenever you decide to introduce nests, either in a new orchard or in a different part of your established orchard, it is important to put the nests in trees with young leaves. If possible, you could also put them in high trees that have many flexible leaves.

Now, do I put the nests in the top, middle or bottom of the tree? Again, careful observation will tell you a lot. In the dry season, ants do not like to stay high up in the trees as it is too hot, so at this time of the year it is better to put them in the middle of the tree. And the same is true in periods of heavy rain.

If there still are some black ants in your trees, Mr. Cung has over the years developed a very successful strategy to introduce weaver ant nests, which is illustrated in figure 2.

When you take one nest of the weaver ant and introduce it in a tree where the black ant lives, this is not good. The nest contains babies and the soldiers available in the nest have no food and have to take care of the babies. Therefore they cannot fight the black ant.

Better is first to lure the strong soldier weaver ants by putting a rope from one of the trees with nests to a container with food such as shrimps (figure 2a).

After the container is full of strong soldier ants you put a bag over it and transport it to the place where you want to establish a new colony, he explains. Once on the spot, you climb the tree high up where you then release the soldier ants (figure 2b). This approach guarantees better success than when you just release it at any other place in the tree.

Ants as Friends

Once the black ants are defeated you then introduce a complete nest (figure 2c). The best time to do this is at the beginning of the rainy season as ants are then very active. They finish a new nest within a very short time, sometimes in less than one hour, because they want to protect themselves from the coming rain.

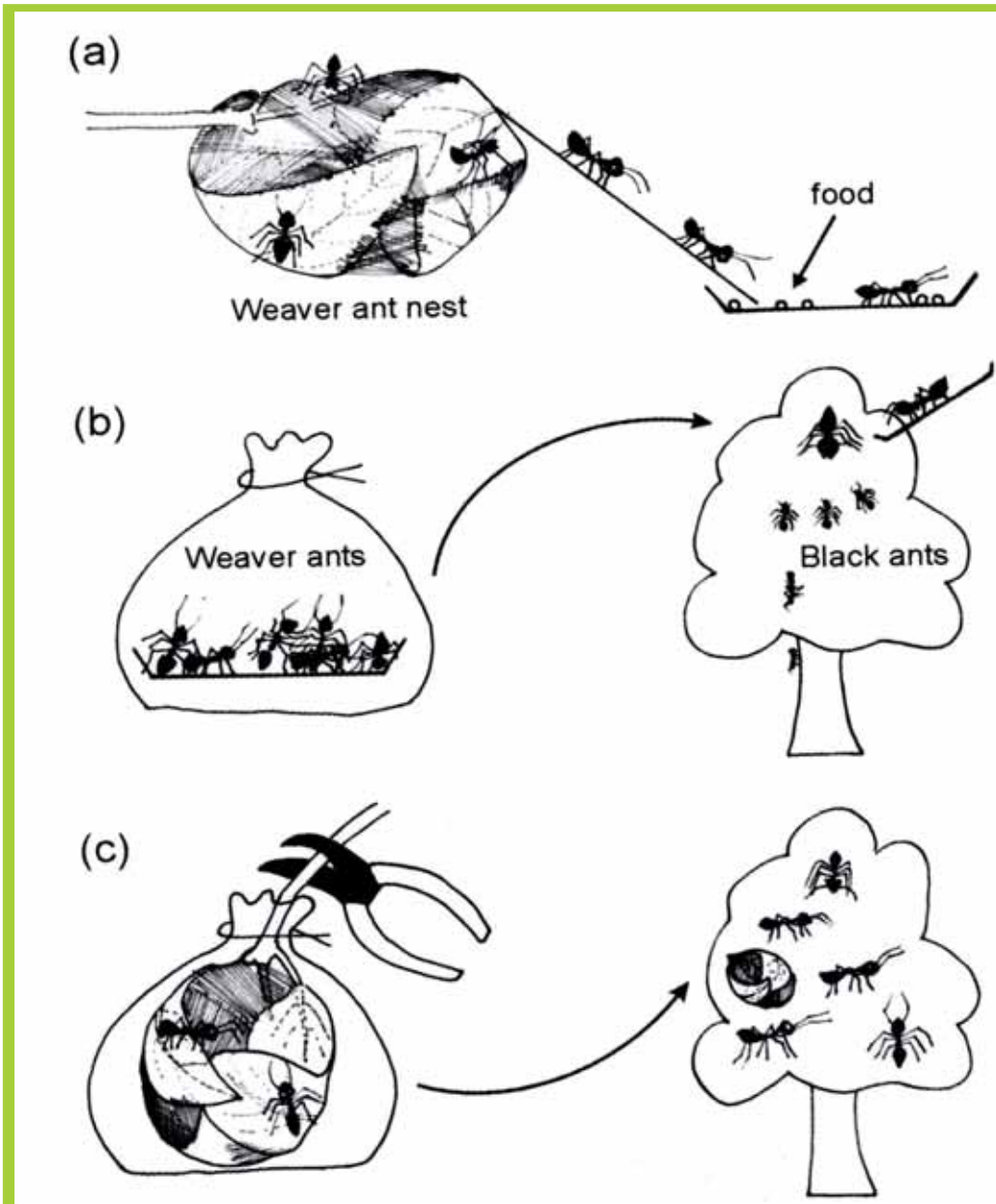


Figure 2. Introducing a new nest of weaver ants in a tree where black ants live requires a special strategy. It involves luring large workers of weaver ants (a), getting rid of the black ants (b), and finally introducing the weaver ant nest (c), for the full explanation, see text in the previous box.

How do I take care of newly introduced nests?

As soon as you have put some nests in a new place, and the ants like this new environment, you will notice that they will start making a new nest very soon. Imagine how you would feel yourself, when you have to build a new house, wouldn't you appreciate it if someone prepared and presented you some food? So will the ants. By putting some food in the new tree during the first week, they will more likely stay there.

But food is not the only thing in life! If you keep on disturbing their new environment by weeding, spraying, pruning or whatever, they will soon decide to move to a quieter environment.

Be honest, wouldn't you prefer a peaceful neighbourhood yourself?



Providing some food like chicken intestines is common practice to increase the success rate of establishing a new colony.

How can I distribute ants evenly over my orchard?

As with people, ants like to keep their feet dry. Therefore in the dry season you will see them walking over the ground without problems, but once it starts raining they prefer to walk over the branches.

Especially when trees are young and their branches do not touch, you have to give the ants a hand by putting bamboo sticks or a nylon rope between the trees. Once trees are old enough, their canopies will touch one another and ants can freely move from one tree to another.

Remember, there is one condition when you better avoid connecting trees, that is in the 'no-mans land', or better 'no-ants land' between two colonies. You can even prune some branches to keep two colonies separated if you see a fight might start.



Mr. Tran Van Buu from My Khanh in Can Tho province uses bamboo to facilitate ants moving in his orchard.

How do I avoid fights between different colonies?

Especially when you want to introduce nests in a new area, the most important thing to remember is that individuals of different colonies do not really like each other. When collecting nests for a new introduction, you therefore have to make sure they all come from one and the same colony, as we described earlier on.

When weaver ants from different colonies meet, it results in huge fights with many deaths on both sides. A good way to distinguish two colonies is therefore to look for a territory between nests that is not occupied by weaver ants, the no-ants-land. You often find more than one colony within the same orchard and if you don't want your orchard to turn into a battle field, it is definitely recommended to keep different colonies separated, and not mix nests from different colonies. You can try to keep two colonies separate by pruning the branches or twigs of those trees where the colonies run into one another. One farmer even told us once that he threw water over the fighting ants to 'cool their temper'.

When a battle between two colonies has taken place you will find many dead ants on the floor, and a few twigs may even die because of the large amounts of formic acid released by the ants during the fight.



Dead twig due to large amounts of formic acid released by ants during a large battle between two colonies.

I fed my ants and they became so lazy!

Yes indeed, if you feed your ants then why should they still make the effort to go searching for prey? And that is finally what you want them to do, isn't it? After all, a lazy guard isn't a good guard!

It is important to observe the weaver ants in your orchard, and by doing this you will notice that at a certain time in the dry season food may be a bit scarce. At this stage, and if you want to avoid the ants moving to another place or that the population reduces, it can be good to give them some food. Two or three times per year should be sufficient, don't exaggerate.

Most farmers use waste products, such as chicken intestines or a few small fishes, as this costs absolutely nothing. To keep the ants more evenly distributed over the orchard, you must put the food in different parts of your orchard.



Providing food during the dry season should be kept to a minimum or the ants will stop preying on insect pests.

What happens if I spray chemicals or water on my trees?

There are a few things you must consider, and having read all the previous pages, the following will now sound very logical to you.

Firstly, and as we mentioned before, ants do not like to be disturbed. So whatever you do, you should know that this will influence their activity. Especially when establishing a new orchard and having just introduced some nests, you should absolutely avoid to spray pesticides, growth regulators or even water at least for the first month after introducing the nests. Otherwise they will immediately take their belongings, move elsewhere and all your efforts to establish a colony will be for nothing. Secondly, weaver ants are not the only friends of the farmers. In orchards with established colonies, the ants may recover quickly from chemical sprays, but the other beneficial organisms may take longer to do so.

Only less toxic and highly selective pesticides should be used in case of emergency as appropriate in IPM. Organophosphates and pyrethroids should be avoided at all times! This will be better for your own health as well.

Explore how to best control diseases in an ant-friendly way. Thirdly, the nests are the houses of the ants where they keep their young. Therefore it is better to avoid spraying trees with nests at any time.



Spraying pesticides is better avoided unless compatible with integrated pest management.

How can I reduce harm from ant bites?

So far you have only read nice things about the weaver ant, not all of these are known by a lot of farmers. But if they are so useful, why do not more people make use of them?

Indeed, ants not only actively hunt and deter harmful insects, but they also bite people who come near their nest or too close to their trails. Especially those people who do not know all the good things of the weaver ant consider this a problem. In reality, the bite isn't so painful and the pain disappears fast. Therefore, experienced farmers are less troubled by a few bites and can reduce potential harm when they must go in the orchard for harvesting or pruning.

Certain methods can be used to temporarily reduce the number of ants if necessary. All ant bridges could be removed early in the morning. Or you can lure the ants away by putting food in another part of your orchard where you will not work at that time. Especially during harvest some farmers remove all nests from their fruit trees to other non-crop plants around their orchard.



A lot of farmers take a bag full of wood ash and throw a handful of it on the branches of the tree they want to climb. The ants then fall down from the branches and have difficulties to return. Interestingly, a similar traditional technique has been developed independently by people in Vietnam, Gabon and many other African countries. They rub their hands and arms with wood ash, so that the ants do not attack them.

People in Africa also rub their arms and feet with certain repellent products before climbing trees; use protective clothing; or harvest at times of the day when the ants are least active.

As you can see the bites are only a small problem, while the ants give us so many benefits. So why shouldn't you try to keep them in your orchard?

How weaver ants improve our life



Part 4

Get a healthier environment

By making best use of the weaver ant, you need less chemicals which pollute the air and soil, and poison the water. Your orchard will be more in harmony with nature: birds and bees will be attracted and other beneficials like parasitoids will come to help protect your crop.

Save some money

In the Mekong Delta of Vietnam, extensive studies have shown that orange and mandarin farmers who take care of weaver ants spend only 25 to 50% of the amount of money on chemicals as compared to those without ants, while average yield is maintained, leading to a higher net income (Figure 3). Imagine what you can do with all the extra money saved!

Not only have weaver ants been used successfully in fruit crops. In Australia, cashew quality and yield was higher when weaver ants were present and no chemicals were used as compared to chemical pest control.

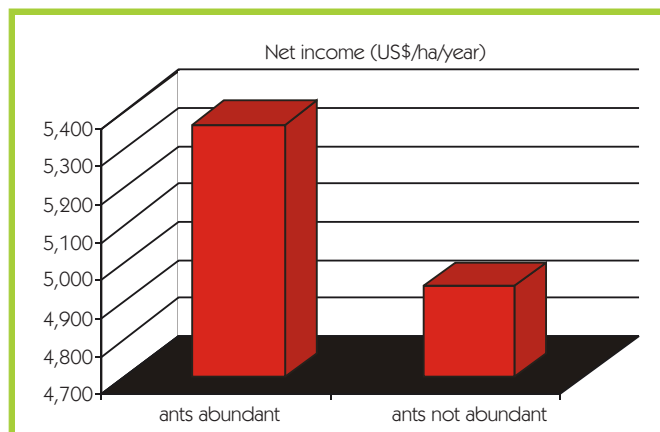


Figure 3. Average net income of mandarin farmers in the Mekong Delta, Vietnam, 1997-1998.

Produce organic fruit



A rich harvest of shiny oranges and mandarins produced with the help of weaver ants.

Organic fruit is increasingly sought after and catches a higher price at the market. In cases where there is no suitable infrastructure in place yet, you can already start improving your skills in growing high quality organic citrus. In the near future a recognised labelling mechanism and proper marketing structures should be in place.

In the meantime, however, you can explore how the local market reacts to weaver ant fruit. Just put up a big signboard saying: "These beautiful fruits have been produced with the help of weaver ants!" People can clearly see that fruit grown with ants has higher quality as it shines more and is more juicy.

Share your experiences

Wow, didn't you find it extremely interesting to learn about all these topics? Not only do you know now what are the benefits of keeping weaver ants, and how they live and behave, but also how to make best use of them. Knowing all these things, you can actually start observing the walk-about of the weaver ant and other beneficial organisms in your orchard with more

Suggested reading



The following represents a selection of articles related to weaver ants in Africa and Asia. Most abstracts of these papers are available on CAB Abstracts.

Barzman, M. S., Mills, N. J. and Cuc, N. T. T. 1996. Traditional knowledge and rationale for weaver ant husbandry in the Mekong Delta of Vietnam. *Agriculture and Human Values*, 13(4), 2-9.

Cuc, N.T.T. 1994. Study on the relationship between the presence of the yellow ant *Oecophylla smaragdina* and greening disease on citrus. *Plant Protection Bulletin of Vietnam*, No 6, 16-19 (in Vietnamese).

Cuc, N.T.T. 2001. Study concerning the yellow ant *Oecophylla smaragdina* on citrus in the Mekong Delta of Vietnam. Proceedings of the final symposium on fruit production in the Mekong Delta focusing on integrated pest management. Can Tho, Vietnam, 29 March 2001, (in Vietnamese).

Cuc, N.T.T., Mai, V., Chien, and Van Mele, P. 2001. Yellow ants: techniques to use yellow ants in citrus. Agricultural Publishing House, Ho Chi Minh City, pp.15 (in Vietnamese).

De, K. and Pande, Y. D. 1988. Bionomics and some behavioural aspects of the mango stone weevil, *Sternochetus gravis* (Fabricius) (Coleoptera: Curculionidae). *Entomon*, 13(1), 17-24.

Dejean, A. 1991. Adaptation of *Oecophylla longinoda* (Formicidae - Formicinae) to spatio-temporal variations in prey density. *Entomophaga*, 36(1), 29-54. Dejean, A. 2000. Ant protection (Hymenoptera: Formicidae) of two pioneer plant species against the variegated locust. *Sociobiology*, 36(1), 217-226.

Dejean, A., Djieto Lordon, C. and Durand, J. L. 1997. Ant mosaic in oil palm plantations of the Southwest Province of Cameroon: impact on leaf miner beetle (Coleoptera: Chrysomelidae). *Journal of Economic Entomology*, 90(5), 1092-1096.

Douaho, A. 1984. Pests and diseases of oil palm and coconut. Biological control of *Pseudotheraptus* and related species. *Oleagineux*, 39(5), 257-262.

Greenslade, P. J. M. 1971. Phenology of three ant species in the Solomon Islands. *Journal of the Australian Entomological Society*, 10(4), 241-252.

Holldobler, B. and Wilson, E. O. 1977. Weaver ants: social establishment and maintenance of territory. *Science, USA*, 195: 4281, 900-902

Holldobler, B. and Wilson, E. O. 1983. Queen control in colonies of weaver ants (Hymenoptera: Formicidae). *Annals of the Entomological Society of America*, 76(2), 235-238.

Huang, H. T. and Yang, P. 1987. The ancient cultured citrus ant. *Bioscience*, 37, 665-671.

Julia, J. F. and Mariau, D. 1978. The coconut bug: *Pseudotheraptus* sp. in the Ivory Coast. I. Studies preliminary to the devising of a method of integrated control. *Oleagineux*, 33(2), 65-75.

Liang, W. and Huang, M. 1994. Influence of citrus orchard ground cover plants on arthropod communities in China: a review. *Agriculture, Ecosystems and Environment*, 50, 29-37.

Löhr, B. 1992. The pugnacious ant, *Anoploplepis custodiens* (Hymenoptera: Formicidae) and its beneficial effect on coconut production in Tanzania. *Bulletin of Entomological Research*, 82, 213-218.

Macfarlane, R., Abington, J. B. and Walton, P. D. 1987. Control of the coconut nutfall bug (*Amblyopelta cocophaga*). Ministry of Agriculture and Lands, Solomon Islands. Annual Report 1985, 19-20.

Peeters, C. and Andersen, A. N. 1989. Cooperation between dealate queens during colony foundation in the green tree ant, *Oecophylla smaragdina*. *Psyche*, 96(1-2), 39-44.

Peng, R. K., Christian, K. and Gibb, K. 1995. The effect of the green ant *Oecophylla smaragdina* (Hymenoptera: Formicidae), on insect pests of cashew trees in Australia. *Bulletin of Entomological Research*, 85, 279-284.

Peng, R. K., Christian, K. and Gibb, K. 1998a. How many queens are there in mature colonies of the green ant, *Oecophylla smaragdina* (Fabricius)? *Australian Journal of Entomology*, 37, 249-253.

Peng, R. K., Christian, K. and Gibb, K. 1998b. The effect of non-crop vegetation on the insect pests and their natural enemies in cashew (*Anacardium occidentale* L.) plantations. *Plant Protection Quarterly*, 13, 16-20.

Peng, R. K., Christian, K. and Gibb, K., 1999. The effect of colony isolation of the predacious ant, *Oecophylla smaragdina* (F.) (Hymenoptera: Formicidae), on protection of cashew plantations from insect pests. *International Journal of Pest Management*, 45, 189-194.

Peng, R., and Christian, K. 2004. The weaver ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), an effective biological control agent of the red-banded thrips, *Selenothrips rubrocinctus* (Thysanoptera: Thripidae) in mango crop in the Northern Territory of Australia. *International Journal of Pest Management* 50(2), 107-114.

Peng, R., and Christian, K. 2005a. The control efficacy of the weaver ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), on the mango leafhopper, *Idioscopus nitidulus* (Hemiptera: Cicadellidea) in mango orchards in the Northern Territory. *International Journal of Pest Management* 51(4), 297-304.

Peng, R., and Christian, K. 2005b. Integrated pest management in mango orchards in the Northern Territory Australia, using the weaver ant, *Oecophylla smaragdina*, (Hymenoptera: Formicidae) as a key element. *International Journal of Pest Management* 51(2), 149-155.

Perfecto, I. and Castiñeiras, A. 1998. Deployment of the Predaceous Ants and their Conservation in Agroecosystems. In: P. Barbosa (ed.) Conservation Biological Control. Academic Press, New York, pp. 269-289.

Phukan, E., Khound, J.N., Bhagabati, K. N. and Dutta, S. K. 1995. Predators of citrus borer complex in Assam. *Plant Health*, 1, 83-85.

Rajapakse, R. 2000. The management of major insect pests *Bactocera cucurbitaceae* and *Aulacaphora* spp. in cucurbits under 3 intensive systems: integrated chemical and organic agriculture in Southern Sri Lanka. The BCPC Conference: Pests and diseases, Volume 3. Brighton, UK, 981-985.

Rastogi, N. 2000. Prey concealment and spatiotemporal patrolling behaviour of the Indian tree ant *Oecophylla smaragdina* (Fabricius). *Insectes Sociaux*, 47(1), 92-93.

Seguni, Z.S.K. 1997. Biology and control of *Pheidole megacephala* (Hymenoptera: Formicidae, Myrmicinae) especially in relation to use of *Oecophylla longinoda* (Formicidae, Formicinae) for biological control of *Pseudotheraptus wayi* (Heteroptera, Coreidae) in Tanzanian coconut cropping systems. Ph.D. dissertation, University of London.

Smith, D., Beattie, G.A.C. and Broadly, R., 1997. Citrus Pests and Their Natural Enemies. Integrated Pest Management in Australia. Department of Primary Industries, Brisbane, Queensland, pp. 272.

Sporleder, M. and Rapp, G. 1998. The effect of *Oecophylla longinoda* (Latr.) (Hym., Formicidae) on coconut palm productivity with respect to *Pseudotheraptus wayi* Brown (Hem., Coreidae) damage in Zanzibar. *Journal of Applied Entomology*, 122(8), 475-481.

Stapley, J. H. 1980. Coconut leaf beetle (*Brontispa*) in the Solomons. *Alafua Agricultural Bulletin*, 5(4), 17-22.

Stapley, J. H. 1980. Using the predatory ant, *Oecophylla smaragdina*, to control insect pests of coconuts and cocoa. Information Circular, South Pacific Commission, No. 85, 5 pp.

Van Mele, P. 1999. Living fences around orchards in southern Vietnam. Non-Wood-News, FAO, Rome, 48-49. <http://www.fao.org/docrep/x1022e/x1022e05.htm#22>

Van Mele, P., 2000. Evaluating farmers' knowledge, perceptions and practices: a case study of pest management by fruit farmers in the Mekong Delta, Vietnam. PhD thesis, Wageningen University, the Netherlands, pp. 225.

Van Mele, P. and Cuc, N.T.T. 2000. Evolution and status of *Oecophylla smaragdina* as a pest control agent in citrus in the Mekong Delta, Vietnam. International Journal of Pest Management, 46(4), 295-301.

Van Mele, P., Cuc, N.T.T. and Van Huis, A. 2001. Farmers' knowledge, perceptions and practices in mango pest control in the Mekong Delta, Vietnam. International Journal of Pest Management, 47(1), 7-16.

Van Mele, P. and Cuc, N.T.T. 2001. Farmers' perceptions and practices in use of *Dolichoderus thoracicus* (Smith) (Hymenoptera: Formicidae) for biological control of pests of sapodilla. Biological Control, 20(1), 23-29.

Van Mele, P. 2001. Sustainable Fruit Production. Pest Management Notes, No.11 (Briefing for IPM in Developing Countries Project funded by EC DGVIII), PAN-UK, pp.4. <http://www.pan-uk.org/Internat/IPMinDC/pmn11.pdf>

Van Mele, P. 2001. Farmer Participatory Training and Research: Potential for Promoting and Sustaining Citrus IPM. Paper presented at the Golden Ant Awareness Meeting, February 21, 2001, at the Southern Fruit Research Institute (SOFRI), Long Dinh, Vietnam, pp. 7.

Van Mele, P., Mai, V., Chien, H.V. and Cuc, N.T.T. (Eds.). 2001. Weaver Ants: A Golden Opportunity. Proceedings of Citrus Farmer Workshop, February 2001, Tien Giang, Vietnam. CABI Bioscience, pp. 25.

Van Mele, P. 2001. Weaver Ants in Citrus: a Revival. Biocontrol News and Information, 22(2), p. 40-42. <http://pest.cabweb.org/Journals/BNI/Bni22-2/Train.HTM>

Van Mele, P. and Van Lenteren, J. 2002. Habitat manipulation for improved control of citrus leafminer and mite pests in a mixed orchard-ricefield landscape, Mekong Delta, Vietnam. Agriculture, Ecosystems and Environment, 88 (1), 35-48.

Van Mele, P., Cuc, N.T.T. and Van Huis, A. 2002. Direct and indirect influences of weaver ant *Oecophylla smaragdina* husbandry on citrus farmers' pest perceptions and management practices. International Journal of Pest Management, 48 (3), 225-232.

Van Mele, P. and Truyen, V. T. 2002. Observations and farmer experimentation with predatory ants. LEISA, 18(1), 28-29 pdf. [Http://www.ileia.org/2/18-1/28-29 pdf.](http://www.ileia.org/2/18-1/28-29.pdf)

Van Mele, P., and Chien, H.V. 2004. Farmers, biodiversity and plant protection: developing a learning environment for sustainable tree cropping systems. *International Journal of Agricultural Sustainability* 2(1), 67-76.

Varela, A.M. 1992. Role of *Oecophylla longinoda* (Formicidae) in control of *Pseudothraupis wayi* (Coreidae) on coconut in Tanzania. PhD dissertation. University of London.

Way, M. J., 1963. Mutualism between ants and honeydew producing Homoptera. *Annual Review of Entomology*, 8, 307-344.

Way, M. J. and Khoo, K. C., 1991. Colony dispersion and nesting habits of the ants, *Dolichoderus thoracicus* and *Oecophylla smaragdina* (Hymenoptera: Formicidae) in relation to their success as biological control agents on cocoa. *Bulletin of Entomological Research*, 81, 341-350.

Way, M.J. and Khoo, K.C., 1992. Role of ants in pest management. *Annual Review of Entomology*, 37, 479-503.

Way, M.J., Cammell, M.E., Bolton, B. and Kanagaratnam, P. 1989. Ants (Hymenoptera: Formicidae) as egg predators of coconut pests, especially in relation to biological control of the coconut caterpillar, *Opisina arenosella* Walker (Lepidoptera: Xyloryctidae), in Sri Lanka. *Bulletin of Entomological Research*, 79(2), 219-233.

Yang, P. 1984. The application of *Oecophylla smaragdina* Fabr. in South Fujian. *Fujian Agricultural Science and Technology*, 5, 23-25. (in Chinese)

Yang, P. 2002. Historical perspective of the red tree ant, *Oecophylla smaragdina* and its utilization against citrus insect pests. *Chinese Journal of Biological Control*. 2002, 18: 1, 28-32. (in Chinese)

Who to contact?

For advice on weaver ants, or to report your experiences please contact the following:

Dr. Nguyen Thi Thu Cuc

Department of Plant Protection Can Tho University
Can Tho
Vietnam
Tel. 838 513
nttcuc@ctu.edu.vn

Dr. Paul Van Mele

Technology Transfer Unit
Africa Rice Center (WARDA)
01 BP 2031, Cotonou, Benin
p.vanmele@cgiar.org

