IBAR Course

Chapter 3 : Agroecological management of fruit flies on Reunion Island
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**TABLE OF CONTENTS**

A. Agriculture in Reunion Island and constraints on cucurbit crops .................................................................................. 4
   *Agricultural areas in Reunion Island* .................................................................................................................. 4
   *Specific characteristics of the vegetable sector* ...................................................................................................... 7

B. Challenge: before the GAMOUR project .................................................................................................................. 10

C. Crop allocation of Cucurbitaceae among three French Overseas Territories: are the proportions different ? 14

D. Farmers’ opinions on pesticide efficiency: a one-time survey ................................................................................. 15

E. The GAMOUR project: film and quiz ..................................................................................................................... 17

F. Article analysis ......................................................................................................................................................... 21

G. Farmers’ perceptions of the changes to practices and the results ....................................................................... 27

H. Results and economic data ..................................................................................................................................... 29

I. Outlook .................................................................................................................................................................. 34

J. The last word to Sergio and Mireille .................................................................................................................... 37

H. References and links ............................................................................................................................................. 37
Agroecological management of fruit flies on Reunion Island

Chapter 3 of the IBAR course sets out a case study on agroecological management of fruit flies on Reunion Island. Some of these fruit flies are invasive species: invasive species, insects and islands are dealt with in Chapter 1. They affect cucurbit crops but are controlled using biological measures (seen in Chapter 2: Biological control, introduction and acclimatization of auxiliary insects) and other methods. We will then look at the results, farmers’ perceptions and prospects following application of this new agroecological approach.

Summary

Chapter 3, Agroecological management of fruit flies on Reunion Island, with the innovative GAMOUR project in Reunion Island, will highlight links between agroecological practices, ecology and social sciences. The GAMOUR acronym stands for Management ("Gestion" in french), Agroecology, fly ("MOUche", in french), and Reunion Island.
Foreword
How can we manage fruitflies without chemicals? And, by the way, how did farmers perceive chemicals before using other methods?

Chapter 3 will answer to these questions, dealing with a case study of agroecology in Reunion Island. You will find scientific articles to analyze, as well as a socio-economical context and interviews. Have fun!

These days, agroecology is described as a scientific approach devised to promote a form of agriculture that dovetails with the full range of sustainable development strategies. Agriculture in today’s world has to draw on sustainable socio-economic models to meet human populations’ food and non-food requirements while preserving ecosystems and resources as it adapts to the depletion of certain natural resources, minimises the use of inputs and helps stem global warming. To achieve all of this, agroecology uses ecology and its varying levels of understanding of the biological mechanisms, processes and regulations at work in agro-ecosystems and combines this with knowledge on the design and evaluation of innovative agricultural technical systems. The socio-economic and professional dynamics that spur agroecology are therefore quite different but all combine agriculture, science, the natural environment and society.

Chapter 3, with the innovative GAMOUR project in Reunion Island, will highlight links between agroecological practices, ecology and social sciences. The GAMOUR acronym stands for Management ("Gestion" in french), Agroecology, fly ("MOUche", in french), and Reunion Island. As for AMOUR, it signifies "LOVE" in french!

A. AGRICULTURE IN REUNION ISLAND AND CONSTRAINTS ON CUCURBIT CROPS

Agricultural areas in Reunion Island

Reunion Island, 500 miles east from Madagascar in the Indian Ocean, is inhabited since the 17th century by settlers (mostly from France, Madagascar and the African continent). Since then, all of the ethnic groups comprising the island are immigrant populations that have come to
Reunion from Europe, Asia and Africa over the centuries. As a French overseas department since 1946, it is an integral part of the French Republic with the same status as those situated on the European mainland.

With 970 square miles (2512 square km), Reunion Island is located above a volcanic hotspot in the earth's crust, and has still an active volcano, Piton de la Fournaise (http://www.fournaise.info). Reunion is sometimes called a sister to Hawaii, because of the similarity of its climate and its volcanic nature.

The Piton des Neiges volcano, the highest point on the island at 10,070 feet above sea level, is north west of the Piton de la Fournaise. Like Kohala on the Big Island of Hawaii, the Piton des Neiges is extinct. Three collapsed calderas (Cirque de Salazie, Cilaos and Mafate) and canyons are south west of the mountain. Cultivated land and cities are concentrated on the surrounding coastal lowlands. Offshore, part of the west coast is characterised by a coral reef system (https://en.wikipedia.org/wiki/Réunion).

The interactive map of Reunion Island which is displayed online (IBAR course, chapter 3, adapted from DAAF Reunion, 2012) includes its principal locations, land use, as well as a presentation of the farmers interviewed later on. We see three major types of land-use in Reunion Island:
- Agricultural (358.7 square miles, 929 square km, Agreste, 2010)
- Urban (105.8 square miles, 274 square km, Joël Ninon, 2012)
- Natural (388 square miles, 1005 square km, protected area in the National Parc)

With 833 944 inhabitants concentrated on coastal areas, Reunion Island’s population density (862/square mile, 333/square km) is nearly three times the one in mainland France (303/square mile, 117/square km) (INSEE, 2012 (www.insee.fr)).

Most of the island’s ground (79%) has slopes above 10%. This low accessibility has helped to preserve natural spaces, today part of the
National Parc of Reunion Island, established in 2007 (http://www.reunion-parcnational.fr/).

The area of Pitons, cirques and remparts (peaks, cirques and ramparts) of Reunion Island coincides with the core zone of La Réunion National Park, and are part of the World Heritage List of UNESCO (United Nations Educational, Scientific and Cultural Organization; http://whc.unesco.org/en/list/1317) since 2010.

A surrounding buffer belt, named free accession area of the Reunion National Park, separates forests from urban zones, and includes agricultural lands. The whole agricultural area covers 359 square miles, among which nearly 50% are cultivated. The 7623 agricultural farms of Reunion Island have a mean surface of 0.022 square miles (570 ares), nearly 10 times less than in mainland France (0.21 square miles/farm; INSEE, 2009).

In mainland France and Reunion Island, a similar proportion of the population (1%) is employed in agriculture. Age and gender differences have been observed. First, the age of 22% of the farmers is less than 40 in Reunion Island, as compared to 17% in mainland France (Agreste, 2010; Graphagri, 2012, départements d’Outre-Mer). Second, in Reunion Island, the gender gap among principal farm operators (only 19% are women) is more important than in mainland France (nearly 30% are women) (INSEE, 2009).

A certain level of training is required to help farmers adapt and overhaul their production systems. Of the five levels of training accounted for in the 2010 agricultural census, more than 80% of the farming population in mainland France and 50% of farmers on Reunion Island are trained to the lowest level (level V, equivalent to a CAPA or BEPA, basic school-leaving certificates in the French system). Nonetheless, for farmers under 30 on Reunion Island, that figure reaches 80%, suggesting that younger farmers are better trained (Agreste spécial, formation en agriculture, N° 72, Novembre 2011).

In all regions of France, farmers looking to convert to organic farming within the next five years have a similar profile to current organic farmers: on average, they are four or five years younger than conventional farmers and their level of pre-service training (in agriculture or otherwise) is
higher. In addition, 20% of conventional farms interested in converting to organic are already diversified (processing farm produce on-site, forestry activities or rural tourism, for example). With 500 to 1,000 potential organic farms by 2015, Reunion Island is on a par (in terms of farm numbers/surface areas) with parts of mainland France. One likely factors contributing to this vibrant growth is the proportion of young farmers on Reunion Island (see above). At the same time, the local farming context may considerably influence the intention to convert (Agreste, 2010; Graphagri, 2012, départements d’Outre-Mer, veille, 2012, Ministère de l’Agriculture, de l’Agroalimentaire et de la Forêt).

**Specific characteristics of the vegetable sector**

With its position in the tropics, its island status and rugged terrain, Reunion Island has an array of microclimates and some extremely diverse wild plants and crops. When it comes to agricultural production, industrial sugar cane plantations dominate, followed by fresh vegetables, meeting 75% of local requirements (59,038 metric tons produced in 2011). In fact, Reunion Island produces a full range of temperate climate vegetables plus a large share of tropical produce. Most fresh vegetables are grown on the uplands to the south of Tampon and St Joseph, the Salazie caldera, and certain regions to the north (from Bretagne to St-Denis and from Dos D’Âne to La Possession). Approximately half of the vegetable-growing areas are found on specialist farms and the other half (52%) are on farms that have diversified, with vegetables grown alongside other crops or livestock. In terms of economic potential, vegetables and flowers are ranked second after field crops, accounting for 18% of gross standard output.

Farms growing vegetables are mainly small: average surface area has remained stable since 2000 at 74 ares. In 2010, fresh vegetable crops accounted for 1,986 ha, a rise of 23% since the previous census in 2000. At the same time, the number of farms has also increased considerably, going up from 2,167 in 2000 to 2,706 in 2010, despite compensation for farmers ceasing operations or taking retirement. This trend illustrates how vibrant the sector is, with new vegetable farmers setting up, often on small-scale farms or creating an additional activity on their existing farm. Alongside
this, in spite of a relatively low level of pre-service training in this sector (70% of farmers have a training level below level V, see definition above), vegetable and flower producers rank first for the number of farmers having taken some form of continuous professional development course over the past 12 months. Certain vegetable crops are, however, threatened and are not included in this upward trend, e.g. tomatoes and cucurbit crops, as we will see later.

Structural weaknesses in the vegetable sector have been observed in most French overseas departments. In 2005, growers had little access to sheltered areas where they could adapt or treat crops, and there were few organisations (cooperatives, farmers’ or wholesalers’ organisations) able to distribute their output. Another issue is the fact that vegetable crops are vulnerable to cyclonic conditions and pests (Graphagri 2012, Départements d’Outre Mer; Agreste DAAF La Réunion n° 81 - Janvier 2013 ; Agreste DOM N°13, février 2006).

**Cyclonic conditions**

Reunion Island’s climate is split between a violent cyclone season from November to April, when most rainfall occurs (especially in the east), followed by a dry season (nearly eight months long in the west). Cyclonic rainfall is considerably intensified by the island’s relief. Reunion Island therefore regularly records high rainfall figures. In fact, it breaks all world records for the rainfall quantities falling in periods of between 12 hours and 15 days. After rainfall deficits followed by cyclones Dinah and Harry in early 2002, fresh vegetable production was down by almost 19% while fresh fruit crops fell by more than 40% (Agreste DAAF La Réunion n° 80, Decembre 2012).

**Pests**

We have already looked at insects (Chapter 2). Chapter 3 will focus on three vegetable fly species that affect cucurbit crops.

Considered native to India, *Bactrocera (Zeugodacus) cucurbitae (Coquillett)*, the melon fly, is now found in more than 40 countries
Its worldwide distribution includes North America (localised), South and East Asia, East and West Africa, Hawaii, as well as Oceania and Indian Ocean islands. In the Mascareines (Mauritius and Reunion islands), *B. cucurbitae* has been detected in Mauritius in 1960, and has probably reached Reunion from Mauritius in 1972. In La Reunion Island, this thermophilous species is abundant up to an altitude of 2000 feet (600 meters), but no longer seen above 2625 feet (800 meters).

*Dacus (Didacus) ciliatus (Loew)* is distributed from Egypt to South Africa, in the Indian Ocean (Reunion, Mauritius and Mayotte) and Oriental Asia (Pakistan and India). It has also been reported in the Middle East (Iran, Saudi-Arabia, Yemen, amongst others), with a recent spread in the last twenty years to Israel and Oman (http://www.cabi.org/isc/datasheet/17682, updated June 2016). As the common name, Ethiopian fruit fly, suggests, *D. ciliatus* is native to East Africa. Detected in La Reunion Island since 1964, it is seen up to an altitude of 3940 feet (1200 meters).

*Dacus (Dacus) demmerezi (Bezzi)*, the Indian Ocean Cucumber fly, has a limited distribution. Native from the Indian Ocean region, it was described in Mauritius in 1923 by Bezzi (Orian and Moutia 1960), then in Madagascar (Paulian, 1953) and La Reunion (Etienne, 1982). In La Reunion Island, *D.demmerezi* can be found from the coastal area, where it coexists with *D.ciliatus* and *B.cucurbitae*, to 4900 feet (1500 meters), where *D.ciliatus* and *B.cucurbitae* are no longer seen (Vayssières and Carel 1999).

Text modified from the PhD thesis of C. Jacquard (2012), and references herein:


The areas in which these various pest species are found are mainly related to environmental factors and host plants. The distribution of the host plants
(farmed crops or otherwise) is itself dependent on climate and altitude. Therefore, depending on altitude and season, each of these three vegetable fly species may coexist on Reunion Island.

B. CHALLENGE: BEFORE THE GAMOUR PROJECT

These three species cause a lot of damage to cucurbit crops and no sustainable solution had been introduced. As described in Chapter 2, the parasitoids *Psyttalia fletcheri* (Silvestri) and *Fopius arisanus* (Sonan), which were introduced in the 2000s and which have since settled on the island, have not had a significant impact, partially because of the high levels of insecticide used in horticultural systems. Likewise, insecticide treatments are affected by resistance among Tephritidae species in general, as described in the scientific literature (e.g. Vontas et al., Insecticide resistance in Tephritid flies, Pesticide Biochemistry and Physiology 100 (2011) 199–205). This in part explains why cucurbit crops have not undergone the same expansion as other vegetable crops. We will first look at an interview conducted with farmers who encounter difficulties growing cucurbits. Then a set of exercises will help further your understanding of the figures on the proportion of farmed areas given over to cucurbits in the French overseas departments, and on opinions of farmers who grow these crops.

**Farmer's interviews and birth of the GAMOUR project**

In order of appearance:

Mireille Jolet, founding member of the Organic Farmers Group of La Reunion, “Lou Cachet” educational farm, La Riviere-St-Louis, La Reunion

Sergio Victoire, producer of chayote in Salazie and Secretary of the Chamber of Agriculture (since 2003)

Video transcript:

Mireille Jolet, founding member of the Organic Farmers Group of La Reunion, “Lou Cachet” educational farm, La Riviere-St-Louis, La Reunion
“Hello, my name is Mireille Jolet, I come from La Reunion island. I became a farmer in 2003. Specific courses led me to organic farming. First involved in disability education, I followed a professional retraining. We founded an organic farmers’ group in 2005, at that time we were only a dozen. We were contacted by Mr. Deguine to participate in a research project on cucurbits and fruitflies. In our educational farm, we talk to children about agroecology but focus on specific examples such as bees, It is important to inform the young generation about the importance of insects”.

Sergio Victoire, producer of chayote in Salazie and Secretary of the Chamber of Agriculture (since 2003) “I am producer of chayote since 20 years. In the last ten years, we saw fruit flies attacks on chayotte getting worse. The CIRAD contacted us, proposing a sustainable solution to control the fruit fly. One morning, we were a dozen of farmers, gathered for a meeting, and were invited to try a new method of fruit fly control. The farmers only believe what they see, they have to meet production quotas, should they stay or should they go? None of us accepted this first day. 2 days later Mr. Deguine calls me and suggests a three-month trial, to see how it works out. I considered this possibility.”
I had experienced a lot of fruit flies attacks, affecting up to 80% of my crops. So, I accepted.

My father was a farmer,
I started from scratch,
but I've always dreamed about becoming a farmer.
When I started I had no diploma,
Technicians I meet today say I have a Master’s degree

I'll still have to take courses,
even if I stay a farmer until I get 60 or 70 years old.
I always follow an ongoing professional learning.

I travel a lot with members of an agricultural group I preside,
we've been to China, Vietnam ....
and I come back from every trip
with a bit of new knowledge to share
on our tiny rock in the Indian Ocean
for the farmers of La Reunion
and for my own farm.
My fellows asked me to keep on,
and to become the secretary of the chamber of agriculture !”

**QUIZ**

*Which one of the farmers, Mireille or Sergio, has been involved ahead of the project?*

**Explanation:** Mireille Jolet has been contacted by the CIRAD to participate in a research project on cucurbit farming in 2003.
What do Mireille and Sergio have in common? More than one answer is expected.

Correct answers are:

- are ready to operate changes in their professional activity

Explanation: Mireille Jolet, at first specialized educator, has undergone professional retraining to establish a pedagogic farm in 2003. Sergio Victoire was the first farmer to test the GAMOUR method, thus providing evidence of its efficacy on cucurbits in Reunion island.

- are (or have been) institutional representatives in Reunion island

Explanation: Mireille Jolet has co-founded the Organic Farms Group of Reunion island in 2005. Sergio Victoire is president of a farmer's association and has been elected Secretary of the Chamber of Agriculture in 2013.

- have interest in on-going professional learning

Explanation: Mireille Jolet has, for example, undergone a professional training in organic farming. Sergio Victoire learns regularly from on-going training and from travels abroad.

Uncorrect answers are:

- have had serious complaints about fruitflies

Explanation: Only Sergio Victoire mentions an increase of fruit flies attacks over the last ten years.

- had an initial agricultural proficiency

Explanation: Unlike Mireille Jolet (holder of a professional certificate in farming), Sergio Victoire started from scratch.
C. CROP ALLOCATION OF CUCURBITACEAE AMONG THREE FRENCH OVERSEAS TERRITORIES: ARE THE PROPORTIONS DIFFERENT?

This exercise needs you to understand the **Chi-square Test for Independence**. You may for example visit this tutorial:


The tropical islands of Martinique, Guadeloupe (Caribbean) and of La Reunion (Indian Ocean) are French Overseas Territories. *Cucurbitaceae* (or Cucurbits) are cultivated on all three islands. Three genera of *Tephritidae* flies (*Dacus, Bactrocera, Ceratitis*) are pests for *Cucurbitaceae* cultures in La Reunion island since the 1960s. These three genera have not yet been documented in Martinique and Guadeloupe, where only one species of *Tephritidae* is established (*Anastrepha obliqua* (Macquart), pest of mango and other fruits, http://www.cabi.org/isc/datasheet/5659; see also, in French: https://www.anses.fr/fr/content/avis-et-rapport-de-lanses-relatifs-à-une-demande-de-réalisation-d’une-hiérarchisation-des). *Cucurbitaceae* may also be affected by other pests in tropical zones, such as the aphid-transmitted *Papaya ringspot virus* (PRSV), fungi (*Pyrenochaeta lycopersici*, *oidium*), the bacteria *Raslonia solanacearum* ...

According to data from 2000, the main cucurbit crop grown in La Reunion island (with 49554 ha of agricultural land) was the cucumber (with 123 ha); the other cucurbits represented 359 ha. For the islands of Martinique and Guadeloupe, with 33390 and 48881 ha of agricultural land respectively, the main cucurbit grown was melon (490 and 360 ha respectively). The other cucurbits were grown on 877 and 537 ha respectively. Agricultural land allocated to legumes and tubers (including cucurbits) reached 2151, 4192 and 2842 ha in Reunion, Martinique and Guadeloupe islands respectively. Below, you will fill in a table which will help you to evaluate the proportion of crops allocated to *Cucurbitaceae* in the three islands (data from year 2000, http://agreste.agriculture.gouv.fr/). You will see if there are significant differences, or not, among the three islands. Surface conversions: 1000 ha = 3,86 square miles = 2471 acres.
Results of the exercise and conclusion:
Different economical/environmental/ecological factors (among which, possibly, fruitflies) could be involved in the relative poor surface allocation to cucurbits in La Reunion.

D. FARMERS' OPINIONS ON PESTICIDE EFFICIENCY: A ONE-TIME SURVEY

Among the three pilot villages chosen at the beginning of the GAMOUR project, "L'Entre-Deux" ("In-Between" could be its name in english) is located at almost 2000 feet (600 meters) above sea level, between two river arms. Its protection from any potential environmental contamination is ideal for an agroecological study zone. Farming represents its first economical activity, with 188 acres (76 ha) allocated to legumes and tubers in 2000 for 509 acres (206 ha) of agricultural land (Agreste, 2000). B.cucurbitae summer outbreaks have been reported (GAMOUR, 2011), in line with the description of this fruitfly in the island of La Reunion up to almost 2000 feet (Etienne, 1982). Pesticides have been used, to try to get rid of B.cucurbitae. A one-time survey has been conducted on the farmers' opinions on pesticide efficiency, by students of the Master of Urban Engineering and Environment, University of La Reunion (Aubry et al., 2009).

Among the estimated 131 farm leaders from L'Entre-Deux (including retirees), 29 have been interviewed: 24 (83%) say they use pesticides, whilst 12 (41%) believe that pesticides are inefficient.

To estimate the confidence interval of the global opinion of the 131 farm leaders of L'Entre-Deux, according to our sample and population size, what probability distribution can we use ? The answer is: the hypergeometric distribution.

The hypergeometric distribution is used to calculate probabilities when sampling without replacement (one farm leader can only be interviewed once!). It is a discrete probability distribution that describes the probability of k successes (here, 12 negative opinions) in n draws (here, 29 interviewed farm leaders), without replacement, from a finite population of size N (here, 131
farm leaders) that contains exactly $K$ farm leaders with a negative opinion, wherein each farmer's answer is either a negative or a positive/neutral opinion. In contrast, the binomial distribution describes the probability of $k$ successes in $n$ draws with replacement. When $N>10n$, i.e. when the population size is more than ten times the sample size, we can use the binomial distribution as an approximation of the hypergeometric distribution.

In our example, the population $N$ is small, $N=131$, while the sample $n$ (number of interviews) is 29, with $10n = 290$ and, thus $N<10n$. Hence, it is not the binomial distribution, but the hypergeometric distribution, which will be used to estimate the confidence interval of the global opinion of the 131 farm leaders of L'Entre-Deux. The probability $p$, to be wrong (if the average is NOT included in the obtained confidence interval), has been chosen at a level of $p<0.05$. In other words, if we reproduce the sampling and analysis independently a 100 times, then 95% of the confidence intervals will include the true value of the average.

Using the hypergeometric distribution, the confidence interval of the global percentage of the 131 farm leaders of L'Entre-Deux with a negative opinion on pesticide efficiency has been calculated, and can be seen if you click on the error bar of the graph: between 26% et 58.8%. In this example, 12 farmers believed that pesticides were inefficient, out of 29 interviewed farmers.

**Question:** up to how many farmers may state a negative opinion about pesticide efficiency, without however allowing us to draw the conclusion that a majority of farmers do not believe in pesticides?

**Answer:** if up to 19 farmers believe pesticides are inefficient, the lowest value of the confidence interval is still below 50% (between 48.1% and 80.2%). Thus, even if 19 (out of 29) farmers believe pesticides are inefficient, we still are not confident that a majority of farmers have a negative opinion on pesticide efficiency. The lowest value of the confidence interval is above 50%, when at least 20 farmers believe pesticides are inefficient.
E. THE GAMOUR PROJECT: FILM AND QUIZ

GAMOUR PROJECT
Christian Sanchis, Bourbon Images Production
Terres d’ici – Antenne Réunion

Jean-Philippe Deguine, initiator of the GAMOUR project
Victor Duffourc, communications officer at FDGDON
Pascal Rousse, coordinator of the GAMOUR project at the Chamber of Agriculture
Victor Duffourc, communications officer at FDGDON
Pascal Rousse, coordinator of the GAMOUR project at the Chamber of Agriculture
Jean-Philippe Deguine, initiator of the GAMOUR project

Transcripts of this translated video (a combination of two films about GAMOUR) are below:

Jean-Philippe Deguine:
To recover from the disturbance we got into, (with flies in large numbers.
imbalance between flies and their natural enemies, imbalance between flies and their host plants):
this approach is called agroecology.

Voice-over:
Conceived by the CIRAD and coordinated by the Chamber of Agriculture since 2009,
the GAMOUR project federates a dozen of different stakeholders of La Reunion island.
Together, they will develop, during 3 years, new methods designed to control fruit flies.
The aim is to propose operational methods to farmers, without applying pesticides directly to the cultures.

Victor Dufourc:
the aim is to implement, working together, a project to control the fruit fly.
We were in a technical deadlock,
the pesticides were not efficient,
we had to find a solution,
we implemented a process involving different methods,
avoiding the application of pesticides to the cultures.

Voice-over:
Since more than a year (the video is realized in 2010),
the GAMOUR project is in its development phase.
The CIRAD, with its partners,
implements a program to control this pest,
which has become the worst enemy
of the legume growers of La Reunion island.
Three methods have shown, on pilot sites,
their efficiency against the fruit fly.
Let's begin with the augmentorium:

Pascal Rousse:
First, an augmentorium, it is this net-covered,
tent-like structure.
We will put the attacked fruits in it.
The mesh size of the nets has been chosen,
so that fruit flies emerged from pupae
are sequestered and will eventually die.
On the contrary, the parasitoids,
the natural enemies of fruit flies,
which will develop
at the expense of the fruit fly larvae,
are smaller and can escape
of this augmentorium.

Voice-over:
Second, a trap with a sexual attractant
also eliminates a large number
of male flies on the plot.

Here we can see the result,
hundreds of flies are trapped,
these males will no longer reproduce.

Voice-over:
the third method is
the application of toxic baits to border plants.

Pascal Rousse:
Attractive plants are grown
on the border of the attacked plot;
the bait applied on them is composed of 99.9% proteins.
Bees, parasitoids ... all the beneficiary insects,
will not eat this bait.
The bait is eaten by the flies only,
which will eventually die
because of a biopesticide included in it.

JP. Deguine:
In summary, we use PROPHYLAXIS
(a regular pick-up of attacked fruits,
fallen on the ground),
BAIT PLANTS
(attraction of fruit flies outside the plot),
and MASS TRAPPING
(attraction of male fruit flies
by sexual baits placed around the plots).

Voice-over:
By picking up regularly the attacked fruits,
fallen on the ground,
we avoid the proliferation of the fruit flies.
A fruit fly can have a progeny of hundred flies
in less than a month, one month later
there will be thousands of them.
Attacked fruits favor their development;
placing the fruits in the augmentorium,
in which the fruit flies will be trapped,
and where only the parasitoids can escape,
will stop the reproduction cycle of the fruit fly. The advantages of this system relies on an adapted net mesh size which will sequester the flies but will let the natural enemies, smaller, escape. Fruit flies spend less time than thought on the cultures; most of the time, they rest, eat and reproduce on border plants; this is why we use the bait plant technique. The trapping of males impairs the reproduction of fruit flies, and thus, their proliferation. The pheromone used, the Cue-lure, is efficient on 2 of the 3 target fruit fly species; it will not attract any other pollinator or natural enemy.

JP. Deguine :
If we do not follow these techniques, which are not difficult, but new, we may be disappointed by uncontrolled fruit fly attacks. Constant monitoring, perseverance, humility and finesse are required. We have to continue what has been started, and show that we can be committed to sustainable and healthy agriculture, as we would like it to be in La Reunion island in the coming years.

QUIZ:
In less than one month, up to how many fruit flies can be found on a sole attacked zucchini? Answer: We can find thousands of them, one month after initial egg laying.

Which negative aspects of insecticide usage are presented in the film?
a. their use is expensive to the farmer
b. insecticides are also a threat for auxiliary insects (beetles, parasitoids ...)
c. insecticides are not efficient on fruit flies
d. insecticides may provoke leukemia among farmers
e. insecticides may contaminate lagoons after heavy rainfalls in Reunion Island
f. insecticide use may have negative impacts on human health and environment
g. insecticide application is more time-consuming than collecting contaminated cucurbits from the ground

**Answer:** although all statements above are correct, only b and c are cited in the film.

*Why did we use border plants?*

**Answer:** Because fruit flies spend most of their time resting on them

*How are used the bait plants?*

**Answer:** Another plant species surrounds the field and harbours a food attractant.

*Which method is effective?*

**Answers:** The augmentoria, for the sequestration of fruit flies but not of natural parasites; baits with sexual attractants in plastic bottles, to capture male fruit flies; bait plants with food attractants/insecticides, to kill the fruit flies

**F. ARTICLE ANALYSIS**

The different methods used in the GAMOUR project were first born in Hawai, and had to be adapted to the context of Reunion Island (climate, host-plant species, fruit fly species, available material ....). The three following articles include some of the experiments used to implement and adapt the "Hawaian methods" in Reunion Island.
Article 1 (Deguine et al., 2011): Net choice is key to the augmentorium technique of fruit fly sequestration and parasitoid release

In Reunion Island, tephritid fruit flies are the main pests of fruit and vegetable crops, causing severe yield losses. Instead of the curative approach to reducing populations, this study focused on a particular sanitation technique, which forms the basis of Integrated Pest Management (IPM) in this context, using a tent-like structure called an “augmentorium”, the aim of which is to contribute to controlling these pests. This structure sequesters adult flies emerging from infested fruit while allowing the parasitoids to escape, via a net placed at the top of the structure. The size of four nets was tested in the laboratory in order to include the most effective one in an augmentorium prototype adapted to the conditions of Reunion Island. The mesh finally selected (hole area 3.00 mm²) proved to be perfectly effective with 100% sequestration of adult flies (Ceratitis capitata, Bactrocera cucurbitae, Bactrocera zonata). In addition, 100% of the parasitoids (Fopius arisanus and Psyttalia fletcheri) were able to escape from the cage through the mesh if they chose to do so. Farmers were enthusiastic about using the augmentorium prototype. Implications for the use of this technique in Reunion Island are discussed.

Further explanations for article 1:

The explanations given on the statistical tests are not intended as a lesson on statistics but are simply given to help understanding. You are not required to be familiar with or proficient in the various functions referred to; your aim is to be able to identify the results that were obtained using statistical testing. Table 3: to compare the escape rates for parasitoids, the response variable number
of parasitoids having escaped from the cage/emerged in the cage was studied. Firstly, the ‘Probit Link’ function was used to link the variable to a Generalised Linear Model. The explanatory variables tested (the parameters that can affect the response variable) are: mesh size and repetitions. For each mesh size and repetition variable, the number of degrees of freedom (ddl1 (French abbreviation) or df1 in the article) is representative of the number of groups for each variable, minus the number of relations among them. For example, for the ‘mesh’ variable, bearing in mind that the total number of individuals counted is known, only three groups out of four can be freely selected. Df1 for the ‘mesh’ variable is therefore equal to 4-1=3. Df2 is representative of the error or residuals: it is the number of observations (3x4=12 in the case of P. fletcheri), minus the number of independent groups (repetitions), and minus the df of the variable considered. For example, here we have, for the ‘mesh’ factor, df2 = 12 – 3 – 3 = 6 in the case of P. fletcheri. If the variable alone has an effect, then the probability indicated in the last column (P) is less than 0.05. We can see that for P. fletcheri and F. arisanus, the ‘mesh’ variable has an effect on the parasitoid escape rate. For P. fletcheri alone, the repetitions do not produce comparable results: the ‘repetition’ variable also has an unexpected effect on the parasitoid escape rate. Comparisons were then made for the ‘mesh’ variable (with a significant effect on the parasitoid escape rate, regardless of the parasitoid), for each mesh size (Table 4). Table 4: For each parasitoid, pairwise comparisons (Tukey test) were done for each of the four mesh sizes (see the results in the article text, final paragraph before the discussion). The effectiveness of the mesh sizes was then ranked (letters a, ab, b). There is a significant difference between the two groups when the letter (a or b) differs from one group to another. Conversely, a group rated ab will be no different to either a or b. For each mesh, table 4 represents: the average parasitoid escape rate and standard deviation (sd) for that rate. For example, mesh 4 lets 68 +/- 3% of emerged P. fletcheri parasitoids escape.

The result is that mesh 4 is the only one that is effective for both parasitoids in question.

Conclusion: This study helped define the best conditions for use of an augmentorium on Reunion Island, a prototype of which has already been developed. The augmentorium can therefore play a decisive role in controlling fruit and vegetable fly populations. In addition to their primary role, the presence of augmentoria in the field may provide an important visual reminder
to pick up the infested fruits that have dropped to the ground. It is also the first step towards an integrated control programme and the method may also contribute to the management of other categories of pests. The article mentions two other advantages of augmentoria: they could be used as a site for hatching parasitoids and producing compost. One drawback from this technique is that it can provide a reservoir of fungal spores so fungicides may be required.

Article 2 (Atiama-Nurbel et al., 2012): Maize more attractive than Napier grass as non-host plants for Bactrocera cucurbitae and Dacus demmerezi

Some species of fruit flies (Diptera: Tephritidae) shelter and roost in non-host plants surrounding crops. The aim of this study was to compare the attractiveness of two plants (Poaceae): maize, Zea mays (Linne) and Napier grass, Pennisetum purpureum (Schumacher) for two species of Dacini damaging cucurbits in Reunion Island: Bactrocera cucurbitae (Coquillett) (Diptera: Tephritidae) and Dacus demmerezi (Bezzi) (Diptera: Tephritidae). Plants of the two plant species were established in pots and presented to adult flies in field cages. In each cage, a cohort consisting of adults of a given species, of known sex and age, was released. For each species, the experiment was replicated four times. The number of adult flies on the different plants as well as their location on the plant was recorded. Maize was more attractive to adults of B. cucurbitae and D. demmerezi than Napier grass irrespective of sex and sexual maturity. Most adults of both species were found under the leaves of maize and Napier grass. The effects of the date, time of day, age, and sex of flies on their attraction to plants are discussed. An application of this study would be to use maize as a border plant, with applied bait sprays for the control of fruit flies.

Further explanations for article 2:

The explanations given on the statistical tests are not intended as a lesson on statistics but are simply given to help understanding. You are not required to be familiar with or proficient in the various functions referred to; your aim is to be able to identify the results that were obtained using statistical testing.

Table 1 first shows the variables that have a significant effect on the proportion of the two fly species on maize: the stage and date are taken individually, along
with the time/date and life stage/date interaction. Only the time of observation has an effect where *Dacus demmerezi* is present. The significance of the different proportions on maize/elephant grass was therefore tested according to these explanatory variables and, depending on date and life stage, is shown for *B. cucurbitae* (Figure 1) and *D. Demmerezi* (Figure 2).

For *B. cucurbitae*, the analyses (Table 1, Figure 1 and text) indicate that: for the explanatory variable ‘date’ only: maize is the plant selected by more than 50% of flies on most of the dates considered (p<0.001). However, there are a few exceptions: 22 April, when three life stages (all except mature males) of *B. cucurbitae* preferred elephant grass. The assumption put forward to explain this difference is disruptive rainfall in the afternoon. Furthermore, the explanatory variable ‘date/time interaction’ indicates a clear preference for the elephant grass at 12:00 (p<0.05); for the explanatory variable ‘life stage’ taken alone: maize is the plant selected by more than 50% of the flies at most life stages considered (p<0.001), with one exception: mature females (c). Likewise, immature flies (males on 22 and 29 April, and females on 22 April) do not go for maize (an example of ‘date/life stage’ interaction). The proportions observed for the full set of immature fly groups are between 45–82%. For mature flies, 6 May was quite unusual: it was the only date on which more than 50% (p<0.05) of females preferred the maize and the only date on which more than 50% of males preferred not to go to the maize.

For *D. demmerezi*, the analyses (Table 1, Figure 2 and text) indicate that: for the explanatory variables ‘life stage’, ‘time’ and ‘date’ only: maize is the plant significantly selected by over 50% of the flies in most of the cases considered. Nonetheless, there are a few exceptions: 30 April, when only mature *D. demmerezi* females preferred the maize, while for mature males (c) there was a preference for the maize on 6 May only (‘date/life stage’ interaction). 6 May is also the only date on which there was a preference for maize, at all times of the day (a case of ‘date/time’ interaction).

Table 2 shows the preferred resting sites: overall, regardless of life stage, both fly species are found, in order of preference, as follows: inner leaf surface > upper leaf surface > trunk > male inflorescences. Exceptions to this rule concern: the trunk and upper leaf surface of elephant grass, with no differentiation among immature *B. cucurbitae*; the upper leaf surface, trunk and male inflorescences of maize, split into two significant groups among *D. demmerezi*. Figure 3 shows the preferences of flies regarding the height of host
plants they visit (upper, middle and lower zones). The upper zone is preferred for elephant grass (apart from among immature B. cucurbitae, which prefer the middle and lower zones and mature male B. cucurbitae which show no preference). For maize, the middle zone is mainly preferred, except for certain D. Demmerezi (immature females and mature males), which prefer the middle and upper zones.

**Article 3 (Deguine et al., 2012): Cage Study of Spinosad-Based Bait Efficacy on Bactrocera cucurbitae, Dacus ciliatus, and Dacus demmerezi (Diptera: Tephritidae) in Reunion Island**

On Reunion Island, *Bactrocera cucurbitae* (Coquillett), *Dacus ciliatus* (Loew), and *Dacus demmerezi* (Bezzi) cause severe damage to cucurbit crops. The aim of the study was to test in field cages the effectiveness of Syneis-appat (Dow AgroSciences), a spinosad-based bait (0.02% of spinosad) on both attraction and mortality of young adults (6-9 day old) of these three species. The effects of gender were also evaluated for all species whereas the effects of protein deprivation were tested with *B. cucurbitae* only. For the first 15 min after application, significantly more *B. cucurbitae* adults were attracted to the bait than *D. demmerezi* and *D. ciliatus*; the subsequent response (30-75 min after bait application) of *D. demmerezi* was statistically similar to that recorded for *B. cucurbitae*; whereas the response of *D. ciliatus* to the bait was consistently significantly lower. Adult mortality was significantly higher for *B. cucurbitae* than for *D. demmerezi*, and was significantly higher for the latter than for *D. ciliatus*. Sex had no significant effect on the mortality rate for each species. The efficiency of the bait was the same for *B. cucurbitae* adults regardless whether or not the diet included proteins. Overall, Syneis-appat appears to be more effective against *B. cucurbitae* and *B. demmerezi* than against *D. ciliatus*. In Reunion Island, this bait could constitute a useful component in the framework of Integrated Pest Management.

**Some further data for article 3:**

For the first 15 min after application, significantly more *B. cucurbitae* adults (21.7 +/-1.8%) were attracted to the bait than *D. demmerezi* (7.6 +/-2.4%) and *D. ciliatus* (2.7 +/-1.4%); the subsequent response (30-75 min after bait application) of *D. demmerezi* was statistically similar to that recorded for
B.cucurbitae; whereas the response of D. ciliatus to the bait was consistently significantly lower. Adult mortality was significantly higher for B. cucurbitae (94.6 +/- 0.7%) than for D. demmerezi (85.7+/−2.1%), and was significantly higher for the latter than for D. ciliatus (60.4+/−4.4%).

G. FARMERS’ PERCEPTIONS OF THE CHANGES TO PRACTICES AND THE RESULTS

Mireille Jolet: ‘… what we noticed, overall, is that it is a big step forward for us, because we didn’t grow cucurbits any more, because we had so many problems with them. We would have needed to grow them in glasshouses but on La Reunion island, we don’t all have large glasshouses for crops so we now have an opportunity for more diversification with our crops, now that we can grow cucurbits out in the field.

With GAMOUR, the most difficult aspect is having to think about the entire project, in other words when you plant a crop, you also have to plant a tight couple of maize rows all around the field, so you have to irrigate behind that to make sure everything grows and the whole system works. So that is the hardest part, but then the time you spend doing that is made up for later on and you gain financially; you harvest bigger quantities, so it’s worth it in the end.’

‘Afterwards, we apply the bait. We go round every five days to apply a new batch, but that’s all part of farming. You have to keep a close eye on things and apply all the right treatments if you want to get on.’

Sergio Victoire: ‘…For me, it’s about 5% of what I used to spend. Before, there were more inputs, but now I buy Synéis and pay for labour. Before, we spent two half-days a week treating the crops but now it’s ten minutes a week, so I’m more than aware of the time and money saved.’
Mireille Jolet: ‘For organic farming, it is a bonus for cucurbits, but as a Reunion Island native, I’m really pleased that this is happening because even conventional farmers are coming on-board. When he carried out the trials, Mr Deguine [behind the GAMOUR project] contacted conventional farmers growing chayote intensively, for an output of several metric tons/year and using large quantities of products.

The GAMOUR method helped all those fields switch to organic farming.

Often, the thinking among farmers is: “let’s see if it works, we’ll let the others try it out first and if the losses aren’t too high, we’ll follow”. One of the largest producers [Sergio Victoire] tried; symbolically, it’s important that these people act as pioneers. The others follow behind. In just three to four years, we have seen an increase from 50 to 150 organic farmers. This is one way to help us to produce more and increase our revenues. It’s given us a practical way of moving forward.’

**QUIZ**

_In your opinion, are the savings made via the GAMOUR project higher for one particular category of farmer?_

Yes, for organic farmers

Explanation: Sergio Victoire explains that work time and spending on insecticides have both been reduced. Organic farmers had virtually abandoned cucurbit crops.

Over the last three to four years, the number of organic farmers on Reunion Island has been multiplied by: 3

Explanation: Mireille Jolet explains that the number of organic farmers has gone up from 50 to 150 over the last three to four years.

*What benefits of the GAMOUR project does Mireille Jolet point out? Correct answers:*

1. GAMOUR makes it possible to grow cucurbit crops out in the field, thus enabling diversification.
2. In spite of the fact that you need to surround the crops with maize and irrigate, then take care of the bait, you save money because the quantities produced are higher.

6. Some emblematic conventional farmers have made the move and come on-board the GAMOUR project, setting an example for other farmers.

What benefits of the GAMOUR project does conventional farmer Sergio Victoire mention? Correct answers:

3. Spending on crop protection products is significantly cut.

5. The labour required to treat crops was slashed from two and a half days a week to ten minutes a week.

H. RESULTS AND ECONOMIC DATA

**Initial diagnosis: diversity of farms**

The data shown below (results and economic data taken from the proceedings of the final symposium (restitution, outcome and perspectives) on the GAMOUR project (Saint-Pierre, 21–24 November 2011).

At the project's three pilot sites (Petite-Ile, Salazie and Entre-Deux) twenty-eight farms were surveyed to: describe the farming structures, analyse the strategies applied to control vegetable flies, and describe the relationships between farmers and agricultural support organisations. Farms were classified in four groups, demonstrating the diversity of the vegetable-growing sector on Reunion Island: large independent vegetable farms, large farms belonging to producers' organisations (POs), small farms, and small farms at the end of their cycle. The decision to grow cucurbits may be deemed opportunistic: apart from perennial chayote vines, the provisional cropping calendar and spatial distribution of plots are extremely erratic. There are three fly control strategies: the conventional method where insecticides are used systematically or as needed, a reduction or the abandoning of farmed surface areas, or adapting by shifting the growing period. Another point specific to vegetable farms is their degree of integration in the farming community. This ranges from no relationship at all with farming organisations, to complete integration in
support schemes for farmers, expressed by the application for official labels and membership of cooperatives. Another structural difficulty in this sector is the traditionally low level of interaction between the organisations offering technical support for farmers. One third of vegetable farms are isolated and do not receive any technical advice on a regular basis. The remaining two thirds receive visits at varying intervals from appointed technicians from different technical and scientific organisations on the Island (Chamber of Agriculture, FDGDON, ARMEFLHOR, CIRAD and POs), whose advice they appreciate. However, it should be noted that although there are often some very sound relationships between the organisations (GAMOUR is an example of this), the information gathered by the various bodies is rarely capitalised on.

**Fly monitoring system and results**

When the GAMOUR project was applied on farms (September 2009-July 2011), a network of entomological surveillance was introduced at the three pilot sites. A ‘cue-lure’ trapping network shows that populations of Dacus demmerezi (Bezzi) and Bactrocera cucurbitae (Coquillett) are kept low all year round at Salazie (700 m altitude). The Entre-Deux (600 m) and Petite-Ile (800-1200 m) zones experience summer outbreaks of B. cucurbitae or D. demmerezi, indicating seasonal fluctuations in fly pressure. These results were discussed with the farmers, who tended to overestimate fly pressure.

**Farm monitoring system**

The selected farms were subject to technical and economic monitoring. Data was centralised online via a computer application and the project website (http://gamour.cirad.fr/site/), and indicators were established in management charts and on graphs. Monitoring involved: assessing the quality of the GAMOUR practices applied by the farmer, recording production data (number of crates sold) and measuring losses per farmer, recording the crop stage of cucurbit production, and logging the number of curative treatments applied to cucurbits and any comments from the farmer. The main economic difference concerned the almost total lack of curative insecticide treatment on crops protected using the GAMOUR method: 0.1 treatments/cycle versus 4.2 for conventional control methods, with no negative impact on output. Although more time is spent on prevention, applying bait, traps and planting borders
that then need to be maintained, the drastic reduction in insecticide treatments helps save labour time (up to 80% less labour time for a maximum of 6 hours/week/ha of cucurbits in conventional farming) and slashes overall costs (up to 66% lower costs, estimated at a maximum of €88/ha/week for plant protection products and labour time in conventional farming). An analysis of yields is based on the monitoring of 7.6 ha of chayote vines, and 19 courgette cycles, compared to seven ‘control’ cycles. There is a trend towards higher yields and/or fewer losses, but there is no statistical significance. These results may be explained by two factors: variability in the data collected and possible overestimation of the effect of fruit flies on chayote by the farmers.

**Variability in the data collected**

The fact that few farmers are trained in agriculture, are not used to regular contact with a technician and are reticent at the idea of getting involved in producers’ organisations (less than 15% of the farmers involved are members of a producers’ organisation) explains the low level of traceability of output. Most of the data collected for the impact observatory are based on farmers’ declarations and are not always entirely reliable. Where it was possible to make comparisons, divergences became apparent (differences ranging from -60% to +150%) between the farmers’ declarations and the figures recorded by the producers’ organisations. In addition, from September 2009 to July 2011, 643 technical and economic data sheets were completed during weekly visits to GAMOUR farmers and centralised for the impacts observatory. Once the data was sorted, it was only possible to process 16% of those sheets to calculate the indicators referred to above.

Cucurbit crops are also affected by climatic and economic hazards. For example, the area around Petite-Ile suffered a long period of drought from August 2010 up to the end of the GAMOUR project, impairing crop development. The occurrence of other plant health issues, such as mildew, also affected certain yields, although their actual impact was deemed as minor. The production strategies developed therefore underwent constant adjustments, which were not necessarily compatible with a monitoring process aimed at defining and recording practices and production results. Less than six months after the project started, a quarter of the initial field mapping was no longer valid. Finally, cucurbits are mainly sold on the wholesale market where prices vary greatly and are not easy to predict. There have been examples of
successful growing campaigns giving satisfactory yields for farmers, but which were ultimately left unharvested due to low market prices.

**What about the effect of fruit flies on the chayote?**

The effect of vegetable flies on zucchini/courgettes has been recorded: the development of larvae in the fruit significantly impacts crops, but this is not the case for the chayote. When farmers saw chayote fruit that had fallen to the ground, they were quick to blame the fruit flies seen in the field. These observations led to the widespread application of insecticide on vines. However, a study conducted as part of the project measured the actual impact of flies on chayote crops. In the field, fruits measuring less than 6 cm long did not appear to be affected by females laying eggs and pitting the fruit. Two to four weeks after blemishes were made, the fruit did not show any particular difference compared to healthy fruit. These results were confirmed by laboratory emergence tests: only one of the 120 blemished fruits collected in 2008, and five of the 219 collected in 2009 saw adult flies emerge. *D.ciliatus* appears to be the only fly capable of emerging from chayote, regardless of whether the fruit was collected from the field or artificially infested in the laboratory. When the blemished fruit was dissected, a ‘defence reaction’ to the eggs and L1 larvae of *B.cucurbitae* and *D.demmerezi* was observed. Therefore, although adult flies nest in the vines, development of their larvae cannot be held responsible for the heavy losses recorded by farmers. This suggests that chemical protection against fruit flies in chayote crops is not appropriate, especially when the harmful secondary effects of chemical treatment are taken into account. The physiological stress on plants overladen with fruits in intensive chayote production systems could be what causes fruit to fall and is something that should be investigated further.

**How techniques are adopted and results perceived**

Ultimately, the number of chemical treatments applied by selected farms is easy to determine and provides enough information on each farmer’s situation and can therefore be used as a relevant indicator. It provides a good indication of the overall outcome of the GAMOUR project and its adoption by farmers. The mitigation of losses caused by vegetable flies is cited as a key benefit by
almost half of the farmers, although given the diverse range of data collected, no significant difference could be highlighted. The impact of vegetable flies may have been overestimated, mainly because the flies are visible. Reduced spending on insecticides and time savings are mentioned next. The adoption of GAMOUR practices by vegetable farmers has had an effect on the proportion of cucurbits being grown on several farms. Twenty percent of farmers have increased the number of cucurbit cycles (due to time savings or an increase in the profitability of these crops). A number of farmers who had considered giving up on cucurbit crops (by pulling up their chayote vines) have now continued production, and farmers who had pulled out of cucurbit production before the project have started new plants.

A satisfaction survey was carried out among GAMOUR farmers: 80% of them said they were satisfied or indeed very satisfied. In addition, the local authority partners (municipalities) were very involved throughout the project. The project also had a motivational effect, with other farmers inspired by these pioneers. This is an interesting opportunity for future transfer of the technical package post-project. The general impression is that these practices are generally easy to take on-board, although proper explanations are required (or sufficient training) during the first growing cycle. Document-based communication (on paper), visits from a technician or field trips to farms applying GAMOUR techniques are all good solutions from the vegetable farmers’ point of view. A quality analysis emphasises two related variables that split the farmers into two groups and indicates that the better the perception of GAMOUR practices, the more the farmers are aware of their effectiveness. In other words, proper understanding of the GAMOUR strategy is related to the results obtained. Vegetable farmers taking a preventive approach (instead of the conventional curative strategy) to the vegetable fly problem implement practices more carefully and record a drop in fruit losses. The successful adoption of the GAMOUR strategy is reflected in the adjustments made by some farmers. Nonetheless, the techniques were not adopted across the board, even though all the selected farms benefited from very regular technical follow-up – something that is unusual in the Reunion Island vegetable-growing sector. The mixed results can be explained by the switch from a curative approach to a strategy aimed at controlling fly pressure. The extension of the GAMOUR technical innovations to other production areas will therefore require significant investment to coordinate actions helping farmers take on-
board the technical package. Finally, the diverse array of farms needs to be considered, especially since they do not all benefit from monitoring and advice from the technicians from the various agricultural organisations.

I. OUTLOOK

Training and transfer to farmers

When we see how the innovations in the GAMOUR project have been adopted, it is clear that any moves to extend these innovations need to include major investment in training and coordination to provide support for selected farms. This is particularly important when we bear in mind the considerable diversity of vegetable-growing farms and the significant differences in their access to the existing agricultural support facilities. The Chamber of Agriculture is in charge of agricultural development and coordinated the GAMOUR project between 2009 and 2011. Its goal is to disseminate and promote production techniques that reflect ambitions for sustainable, environmentally friendly agriculture. In this respect, GAMOUR is an exemplary agricultural system, fully in line with the objectives of the ‘Ecophyto Plan 2018’ launched by the French government in 2008 after the Grenelle national environment conference. Ecophyto is headed by the French Ministry for Agriculture, Food and Forestry and aims to cut pesticide use in half by 2018. Implementing GAMOUR techniques requires training and technical monitoring during at least one cucurbit growing cycle; this has been covered by the Chamber of Agriculture and its partners since 2012.

At the Chamber of Agriculture, one full-time equivalent (FTE) position is devoted to training and monitoring of farmers, and for the training of technicians from partner organisations or other structures such as GAB. Other organisations including FDGDON and AROP-FL (Reunion Island association of fruit and vegetable producers, which takes care of monitoring and training of partner organisation members) and GAB (for its members) are also involved. FARRE will fund 50% of the purchase of 30 augmentoria for its members and will take part in training and monitoring schemes. CIRAD oversees proper application of the GAMOUR protocol and will offer advice during the transfer phase. The DAAF will define fly trapping procedures (mass trapping or monitoring network). Armeflor will oversee applications for approval of fly
mass trapping systems. After training, farmers interested in benefiting from technical monitoring can sign an agreement covering one growing cycle. There is a minimum of five visits to check that the GAMOUR installations are in good condition and to advise the farmer throughout the cycle. The key stages in the monitoring process are: setting up the plots (sowing maize), sowing the fruit crop, setting up the para-pheromone traps as soon as the crops are in place, checking the state of the installations before fruit setting, and monitoring protection during the production period (installing the augmentoria, sanitation at the plot, use of Synéis-AppâtTM (spot treatment on the maize but not on the crops)).

Application of the GAMOUR method to organic farming

Organic farmers are virtually unarmed when it comes to dealing with cucurbit fruit flies. GAMOUR is therefore a valuable solution for them, as it is an alternative method that minimises use of synthetic pesticides. In fact, the various components in the GAMOUR technical package are all compatible with organic farming regulations, including Synéis Appât® and the insecticide-free para-pheromone traps devised for the project. The other components of the technical package (prevention, conservation biological control, agroecological practices, etc.) are part of the basics of organic farming. In addition to its role as a technical partner (training its members and distributing materials), GAB is also involved in awareness-raising initiatives for the general public and young people in particular. Demonstrations aimed at the public help disseminate these alternative methods.

Limitations of the GAMOUR method

Observations made by technicians in the field show that one of the main limitations of GAMOUR is that it is less effective when protected plots are located in the vicinity of farms using different protective methods. Extending the method to as many farms as possible is therefore key to its success. Widespread information campaigns, similar to those run on rodent control, and the distribution of augmentoria may be used as incentives. Finally, private gardens can also be infested with pests and could be included in the scheme if local authorities are willing to distribute small augmentoria in the same way as composters.
Other projects

The lessons learned from the GAMOUR project will be valuable for the Biophyto and Ecofrut projects, which also strive to innovate in the field of plant protection. Biophyto began in 2012 and focused on insecticide-free mango growing on Reunion Island (see http://www.agriculture-biodiversite-oi.org/Biophyto). Its results were presented in late 2014 and mainly concern the profiling of interactions between farming practices, plant cover, landscape structure and arthropod communities (pests, auxiliaries, etc.). Ecofrut also began in 2012 (http://reunion-mayotte.cirad.fr/actualites/ecofrut) and covers Reunion Island’s three main fruit crops (mango, pineapple and citrus).

Regional cooperation

With the PRMF (regional fruit fly applied research programme; Mauritius, Reunion Island, Seychelles, Madagascar and the Comoros), the introduction of an extensive surveillance network led to the detection of Bactrocera cucurbitae in the Seychelles in 1999 and swift eradication of Bactrocera dorsalis in Mauritius in 1996. From 2001 to 2008, the PRPV (regional vegetable protection programme) reproduced some of the initiatives introduced to control flies: provision of training on growing and control methods in Indian Ocean countries, and inventory campaigns to learn more about Tephritidae. The IRACC and e-PRPV programmes extended cooperation from 2010 onwards. These two programmes include a Tephritidae component focused on populating of an online database on pests in the region, while improving stakeholders’ operational capacities and reinforcing diagnostic facilities. They also inform and educate the various population groups on agroecology and support the development of smallholdings. The IRACC and e-PRPV programmes both focus on the monitoring and management of pest populations throughout the Indian Ocean and encourage the development of responsible farming and organic agriculture by setting up pilot projects, improving the quality of soil and the environment, and facilitating exchanges between farmers. They also aim to standardise control strategies in countries in the region. The experience acquired over the three-year GAMOUR project was highly beneficial to this standardisation process.
J. THE LAST WORD TO SERGIO AND MIREILLE

Sergio Victoire: “In my experience, on my farm, I can confirm that with all the methods we have applied, clean production is possible and we are able to bring healthy produce to the table.”

Mireille Jolet: “I know that they are working on Biophyto, a new scheme to do away with chemical products on mangos. It will be like an extension of the GAMOUR project and introduce other systems to take things further. It can only be beneficial to all organic farmers, but to conventional farmers too because they will be using it, and to children, the planet - for the future!”

H. REFERENCES AND LINKS


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