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VANUATU

FEASIBILITY STUDY INTO THE BIOLOGICAL CONTROL OF THE ROSE BEETLE *ADORETUS VERSUTUS* HAROLD WITHIN SOUTH PACIFIC

par

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Biological Control of Taro beetles in the South Pacific

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Terms of Reference of Entomologist

As part of the SPC Taro Beetle project of the EDF funded Pacific Regional Agricultural Programme, the entomologist will carry out a feasibility study into the biological control of the rose beetle (*Adoretus versutus*) within the South Pacific for a period of 12 months. The entomologist will be stationed in Vanuatu. Research already started on the ecology and biology of this insect will be continued. In addition, the entomologist will carry out an assessment of the importance of the insect in the South Pacific and survey the area of origin for biological control agents. Specifically, the role of the entomologist are as follows :

1. The entomologist will be responsible to the Team Leader of the Biological Control of Taro Beetles Project.

2. With the Team Leader of the Biological Control Taro Beetle Project he will design a work programme and implementation schedule for the Biological Control of the Rose Beetle Project.

3. Through established SPC contracts, INRA and CIRAD, liaise with other international organisations specialising in biological control research to assess available biological control agents which may be usefully tested against the rose beetle. This will include biocontrol agents for *Papuana* spp., identified by the Taro beetle project team.

4. Establish links with the other countries (American Samoa, Cook islands, Fiji, New Caledonia, Tonga, Wallis and Futuna, Western Samoa and others) of the region in which *Adoretus* spp. occur and, with a consultant economist visit them to assess the economic importance of the pest. Arrangements will be made for appropriate assistance on the economic analysis.

5. In conjunction with 4., assess differences in damage levels between these countries in relation to natural mortality factors (for example the parasite *Micromeriella marginella* was introduced into Fiji in 1917 and populations and damage levels there should be compared with other countries).

6. Review available information on biological control agents which occur in the area of origin of *Adoretus versutus* or other *Adoretus* spp. Using this information plan and undertake visits to these areas in order to :
a) assess effectiveness of known natural control agents,
b) determine if other, unrecorded agents are present,
c) whether facilities and logistics in these areas are such that longer term studies are possible.

7. Assist entomologists from the team in Solomon Islands with studies on taro beetles in Vanuatu.

8. After six months prepare a technical progress report for the Team Leader of the Project.

9. Before leaving Vanuatu, draft a final report detailing the work accomplished and making recommendations of the feasibility of biological control of the rose beetle to Vanuatu and the measures necessary to select, collect, screen, introduce and monitor the performance of any biological control agents suggested.

A meeting will be held with the South Pacific Commission Plant Protection Service, the Department of Agriculture Liverstock and Horticulture, Vanuatu, the Co-Ordinator of Pacific Regional Agricultural Programme, the EEC and the consultant to discuss the draft final report.

PLAN

INTRODUCTION

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INTRODUCTION

Adoretus versutus (Coleoptera, Scarabaeidae, Rutelinae), known as "rose beetle" is a pest capable of outbreaks causing heavy defoliations on many crops, particularly in countries to which it has been accidently introduced.

This was the case in VANUATU, where rose beetle introduced in 1982 on Efate island caused a lot of damage in 1988 and 1989 on Espiritu Santo island. Cocoa seedlings were particularly susceptible to rose beetle attacks when growing near open grassy areas and tended to suffer more during the first two years after planting out. Also, in 1988, adult cocoa trees were affected and could be completely defoliated (photos 1 and 2). **WATERHOUSE et al. (1987)** report that in French Polynesia and VANUATU the rose beetle is listed among the ten worst pests.

In 1990, population levels decreased and now, in 1992, rose beetle populations have reached correct levels.However, cocoa seedlings remain very susceptible in the nursery, just after planting and for a few months afterwards.

Other countries in the South Pacific are affected by rose beetle, such as Fiji, Western Samoa, American Samoa, Tonga and the Cook islands, where not only cocoa trees are attacked but also ornamental plants and subsistence crops.

Our main concern is that a new outbreak of rose beetle might occur in a few years time in VANUATU and the other South Pacific countries where it is found. If the pest is progressing, the culture of the cocoa will be in danger in large parts of the South Pacific. In VANUATU, farmers currently earn about 120 million vatus a year from cocoa. If no method is found to control rose beetle damage on cocoa, production will fall and smallholder incomes, as well as national export earnings, will be affected.

In addition, farmers will stop planting cocoa in the worst affected areas. This would have serious consequences for the Government program of export diversification and for the operation of the cocoa development project.

Rose beetle can be considered a quarantine risk to other countries to which it may be transferred, particularly those with large cocoa industries such as the Solomon islands and Papua New Guinea.

Photo 1 : Defoliate cocoa tree by *Adoretus versutus* during 1988 outbreak Saraoutou Research Station

Photo 2 : Damages of *Adoretus versutus* on cocoa trees in 1988 - Saraoutou Research Station

To investigate rose beetle biology, some studies have been carried out by **PUREA (1971)** and **MOALA (1973)**. To control rose beetle in the South Pacific, several methods of cocoa tree protection have been considered by **MORIN (1989) and LEFEUVE (1990)** :

- Agronomic methods have been tested but the cost is high and these methods are too restricting,
- Chemical control has been used but has been shown to be ineffective because most of the rose beetle life cycle is spent in the soil and it is always new adults that cause the damage.

In view of the difficulty of controlling rose beetle with insecticides and/or cultural techniques, it was recommended that further attention be given to the possibility of biological control.

- Biological control : Micromeriella marginella modesta (Hym. Scoliidae) introduced in Western Samoa, Fiji and VANUATU does not seem to have produced any positive results. No predator or parasitoid has been observed on Adoretus versutus in VANUATU.

Concerning Adoretus versutus in VANUATU, **LEFEUVE (1990)** showed that rose beetle populations have declined since 1988, suggesting that a regulatory factor is presently operating.

Also, in order to understand the decline in rose beetle populations, a feasibility study of biological control is being considered here.

This study has for objectives :

* continue to study the biology and ecology of rose beetle following on from the study already initiated in VANUATU **(LEFEUVE, 1990)** on population fluctuations over one year in relation to weather conditions,
* establish links with American Samoa, Western Samoa, Tonga, Fiji, the Cook islands where Adoretus versutus occurs and to obtain possible biological control agents from the samples collected,
* collect field samples in VANUATU in order to identify biological control agents,
* check on the establishment of Micromeriella marginella modesta in VANUATU and FIJI,
* collect information on biological control agents occurring in the area of origin of Adoretus versutus,
* assess the economic importance of rose beetle in the South Pacific with a consultant economist.

CHAPTER I
COMPLEX ADORETUS VERSUTUS HAR. - HOST PLANTS

A- ADORETUS VERSUTUS

1. Classification

Adoretus versutus Harold is a Coleopteran - Scarabeidae Rutelinae (photo 3).

It was named Indian rose beetle but nowadays is often simply known as the rose beetle.

It was originally described as *Adoretus vestitus* by **BOHEMAN** (1858) but this name was already taken and in 1869 it was dropped in favour of *A. versutus* Har.

2. *Adoretus versutus* distribution

Adoretus versutus area of origin seems to have been India and Sri Lanka (WATERHOUSE et al., 1987), (map A).

It has been observed in Pakistan, Bangladesh, Java and on many islands in the South Pacific : the Cooks islands since about two years ago, Fiji, Western Samoa, American Samoa, Tonga, Wallis and Futuna.

It is also known in Madagascar, Mauritius and on nearby islands (WATERHOUSE et al., 1987).

It is absent from the Solomon islands and Papua New Guinea.

Adoretus versutus has been recorded in VANUATU where it was first detected in 1982 around Bauerfield airport in Port Vila (EFATE island).

We suppose *A. versutus* arrived accidently on Efate island by aircraft and has been introduced to the other islands in VANUATU (Espiritu Santo, Malekula, Ambae, Ambrym, Paama...).

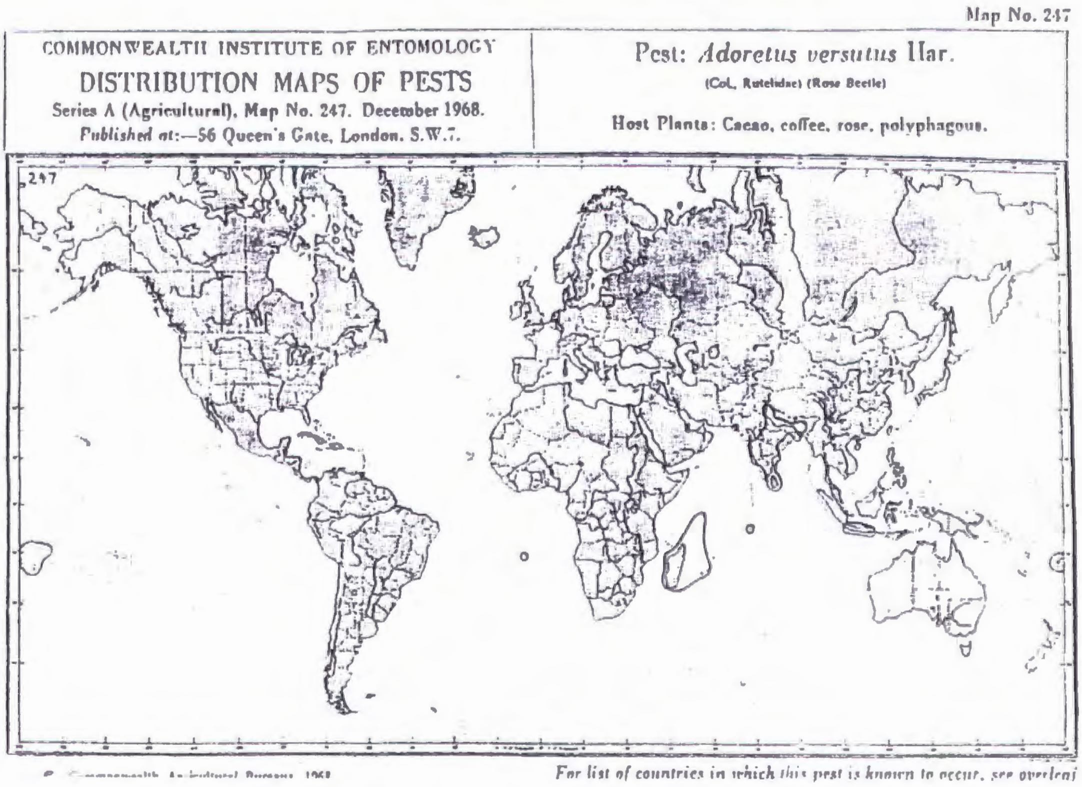
The rapid multiplication and dispersal on Efate is attributed to the fact that most of the fences are made up of closely-spaced, live *Hibiscus tiliaceus*.

In spite of the wide distribution of the pest in the world, it does not seem to be a pest everywhere and we are led to think that rose beetle is naturally controlled in some countries where it is not a pest.

It will probably be in these countries, India and Sri lanka, that a good biological agent will be found to introduce into VANUATU.

Photo 3 : Adoretus versutus Har.

Coleoptera Scarabaeidae Rutelinae



Map A : Adoretus versutus distribution

3. Life cycle of Adoretus versutus

3.1. Eggs

The eggs are laid individually in the soil 7-10 cm deep and hatch between 8 and 14 days later **(WATERHOUSE et al., 1987).** They are oval (photo 4) (1 x 1.5mm) when young and round when old (1.4 x 1.6mm) **(MORIN, unpublished).**

3.2. Larval stages

Larvae are typical of the family Scarabaeidae (photo 5).

They have a strongly sclerotised brown head capsule and can be confused with Cetoninae larvae, which crawl on their back and are the same size but which are stronger and very active.

A. versutus larvae are frail, white with fine hairs on the body and they almost always fold up in a half-circle.

The larvae are found in the ground, in which the whole cycle lasting a little over three months (about 120 days) takes place. The fact that Adoretus spends most of its life underground adds to the difficulty of studying it.

They may be found close to the surface when the soil is wet or they move deeper into the soil if it dries out.

They feed on roots and decaying vegetation and sometimes on branches.

There are three larval instars lasting usually 12 to 14, 12 to 14 and 28 to 33 days, respectively **(PUREA, 1971).** Larval shedding has been observed (photo 6).

3.3. Prenymph and nymph

The third instar becomes successively prepupa, characterised by the empty rectal pocket at the end of the abdomen, and pupa (photo 7).

After 10 days, the adults begin to emerge **(WATERHOUSE et al., 1987).**

3.4. Imago

Adult is 12.8 mm long by 6.8 mm wide (photo 3) **(com. at IRHO).**

It has a dark brown body covered with dense greyish-white down dotted with brown-red hairs surrounding small blackish-brown alveoles on the wing cases.

The strongly-developed fore and rear legs are used for burrowing.

The adults are nocturnal and feed mainly in the early hours of the night. After, they hide 5-10 cm deep in the ground and disappear completely during the daylight hours (photo 8).

This habit has resulted in the relatively late detection of the insect.

If disturbed during feeding, the beetles fall to the ground.

The generations are continuous.

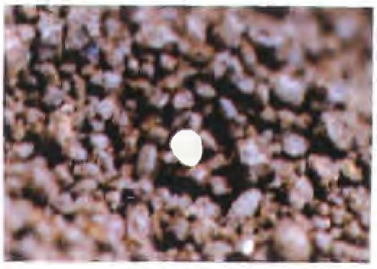


Photo 4 : Egg

Photo 7 : Nymph

Photo 5 : L3 larvae

Photo 8 : Adult burying in the ground

Photo 6 : Larvae shedding

Photo 9 : Male Adoretus versutus

4. Reproduction

Copulation occurs on the food plants at night, and lasts from 1.5 to 3 hours (**WATERHOUSE et al., 1987**).

There is some evidence that a pheromone of virgin females attracts males.

Attractivity between 9.30 p.m. and 11.00 p.m.. **GHOURI and SALIK (1960)** stated that in Pakistan, rose beetles retire underground at about midnight, but in Western Samoa, **PUREA (1971)** observed flight from the food plants chiefly between 5.45 a.m. and 6.30 a.m.(**WATERHOUSE et al., 1987**). Presumably the time of cessation of activity would be affected by the time at which satiation occurred.

Fecundity of the females is not known but comparison with related beetles of similar size suggests the possibility that each female may produce about 40 eggs (**CARNE,1957**).

4.1. Sexual dimorphism

The male differs in the last sternite which is not large (photo 9) as it is in the female.

4.2. Cytological data

The value found of 2n=22 is in agreement with an earlier report (**KACKER, 1970**). All autosomes, except the last acrocentric pair, are metacentric pairs. The sex chromosomes X and Y are smaller than the autosomes. The number of autosomal bivalents during metaphase I was reported to be 11 in addition to heteromorphic XY, by **BEHERA, DASH and MOHANTA (1975)**. Only 10 autosomal bivalents have been revealed in addition to the sex parachute. The chromosome number was further confirmed at metaphase II (**YADAV et al. , 1976**).

5. Antagonistic fauna

Little information on natural enemies of _Adoretus versutus_ and other _Adoretus_ species is available. About 15 species have been recorded but without mention of their effectiveness (**WATERHOUSE et al., 1987**).

The Hymenopteran Scoliidae _Micromeriella marginella modesta_ is the most often cited.

It has been introduced to Fiji but we do not know what has been the effect on _A. versutus_.

Two pathogenic fungi from Hawaii have been also tested without success (**LEVER, 1945**).

In Mauritius, another Scoliidae species has been introduced : _Campsomeris coelebs_ from Madagascar (**De CHARNOY,1917**) then later a diptera Tachinidae _Prosema siberita_ from Java (**JEPSON, 1930**). The effect of these two parasites is not known.

A Pyrgotid Parasite of Adoretus ranunculus, a serious pest of young nursery cocoa plants in the Philippines, has been recorded on beetles collected and kept in the laboratory under observation. A few adults of the Pyrgotidae had emerged from puparia inside the broken abdomen of dead beetles. The rate of parasitism was very low. However, the parasite was reared from samples collected. The flies are nocturnal in habit **(CABALLERO et al., 1987)**.

B- HOST PLANT : COCOA TREE

1. Classification

Theobroma cacao L. is of the family Sterculiacae.

2. Area of distribution in the Pacific islands visited

In the countries studied and visited, there are cocoa plantations in VANUATU (Espiritu Santo, Malekula, Malo, Ambae, Pentecost and Efate islands), in Fiji (Vanualevu, Vitilevu and Taveuni islands), Western Samoa, American Samoa, but not in Tonga or the Cook islands.

Also, cocoa industries are very important in the Solomon islands and Papua New Guinea.

3. Damage characteristics

Adoretus versutus can cause heavy damage in nurseries and young plantations.

Seedlings are very vulnerable to attack because they can be rapidly defoliated (photo 10). The pests attack the seedlings in nurseries after the age of three or four months and young cultivations after planting out.

They perforate the leaflets starting from the middle without destroying the ribs.

The foliar surfaces eaten are of small size but very numerous and give a skeletal aspect to the leaflet (photo 11). The attacks are stronger at the ends of the leaflets than at the base.

Besides this special and characteristic alimentary behaviour, the adults make depressions in the border of the areas eaten, which enable the damage of Adoretus to be more surely distinguished from that caused by other foliage pests.

The pests feed in the early hours of the night.

Although the attacks sometimes occur on plantings more than three years old, the damage caused to the host plants after this age is negligible.

The effect of adult feeding on mature cocoa trees is unimportant but plants up to eighteen months old may be severely damaged or even killed.

Damage is greatest between December and April when adult numbers are highest **(ENTWISTLE, 1972)**

Photo 10 : Defoliate cocoa seedling

after 3 months (July 1992)

on IRCC station

(VANUATU)

Photo 11 : Damages on cocoa leaf

Skelethal aspect

C- OTHER MAJOR HOST PLANTS

Rose beetle is a polyphagous insect.

In Vanuatu, a significant host is *Terminalia catalpa* (Natapoa) which can be completely defoliated (photo 12).

Other host plants include :
Coffee (*Coffea robusta*), Igname (*Dioscorea sp.*), Chou kanak (*Hibiscus manihot*), ornamental plants : roses, acacia, Hibiscus, Bougainvillea (*Bougainvillea spectabilis*), Nadau (*Pometia pinnata*), Nakavika (*Syzygium malaccensis*), Acalypha (*Acalypha wilkesiana*).

R. **WELLER** (pers. comm. 1985) reports considerable damage to unshaded coffee on Efate and to *Hibiscus tiliaceus* (Burao), a fibre plant, which is also used as a living fence in Vanuatu (photo 13).

Attacks on cocoa and roses appear to cause the greatest concern.

For the most part, other food plants recorded are ornamentals. They include roses, *Acacia*, *Barringtonia edulis* (photo 14), *Bauhinia*, *Bougainvillea spectabilis*, *Poinciana regia*, *Acalypha*, *Lagerstroemia indica*, *Alphitonia zizyphoides* and *Zinnia elegans* (**DUPONT**, 1917, **FRIEDERICKS**, 1914, **LEVER**, 1945, **SWAINE**, 1971, **VEITCH**, 1919)

The adults cause more damage to the host plants during certain periods of the year than during others.

D- CONTROL TRIALS

Chemical control is difficult because *A. versutus* only visits the host plants at night and new insects arrive each night.

MORIN has carried out insecticide trials.

Insecticide protection is not effective because of the continuous damage caused by new insects. However, very good results have been obtained by covering seedlings with three coconut leaves (**MORIN**, 1989). The presence of shade has an influence on the damage caused by rose beetle (**LEVER**,1945).

Several methods of cocoa tree protection against *A. versutus* have been considered by **LEFEUVE** (1990) :

* Agronomic methods : **LEFEUVE** showed that coconut palm fronds planted around the young cocoa seedlings offer very good protection until they are too tall to be covered. The cost of this method is high : 170 000 VT/year/ha and coconut fronds have to be renewed every three months and checked and readjusted once a month (**LEFEUVE**, 1990).

In Fiji, physical protection is given by cylinders of plastic gauze.

* Biological control : **LEFEUVE** has never noticed either a predator or a parasitism occurring on *A. versutus* but he showed that under quarantine, the larvae are obviously well-infested by the fungus *Metarhizium* (INRA stock : MA 238).

Photo 12 : Terminalia catapa (Natapoa)

in 1988 (VANUATU)

Photo 13 : Hibiscus tiliaceus (Burao)

in December 1991 on Pentecost island (VANUATU)

Photo 14 : *Barringtonia* edulis (Navel)

in 1992 (South Santo, VANUATU)

* Chemical control : Results from **LEFEUVE** trials showed that except for Lindane (7 ml of a.i./l) and cronophos applied by brushing, chemicals are not offering complete protection to the young cocoa seedlings.

However, such methods are labour intensive, expensive and may have the disadvantage of reducing photosynthesis and hence growth.

The problem is that a considerable part of the rose beetle life-cycle occurs underground.

CHAPTER II
BIOECOLOGICAL STUDIES
IN VANUATU

Biological studies were carried out from November 1991 to July 1992.

A- LABORATORY STUDIES

Laboratory studies were conducted at Valeteruru Experimental Research Station at Espiritu Santo in VANUATU.

1. Culture

1.1. Culture techniques

Culture techniques are based on the **LEFEUVE** method of breeding in the soil (1990).

Eggs, larvae, nymphs and adults collected in the soil on **SITE 1 (Valeteruru station)** and **SITE 2 (Saraoutou station)** are being bred in the laboratory.

Each stage is individually placed in boxes : either boxes (Φ50mm-h=300mm) or boxes (203x77x25mm) divided into compartments (40x40mm) (photo 15).

Eggs and nymphs were deposited in soil only. Larvae have been bred with soil and a piece of carrot as food, renewed every week (photo 16).

Adults were placed in square boxes (175x120x70mm) with soil for burrowing and where females laid eggs in the daytime, and with cocoa leaves as a source of food during the night.

1.2. Setting-up and maintenance of the culture

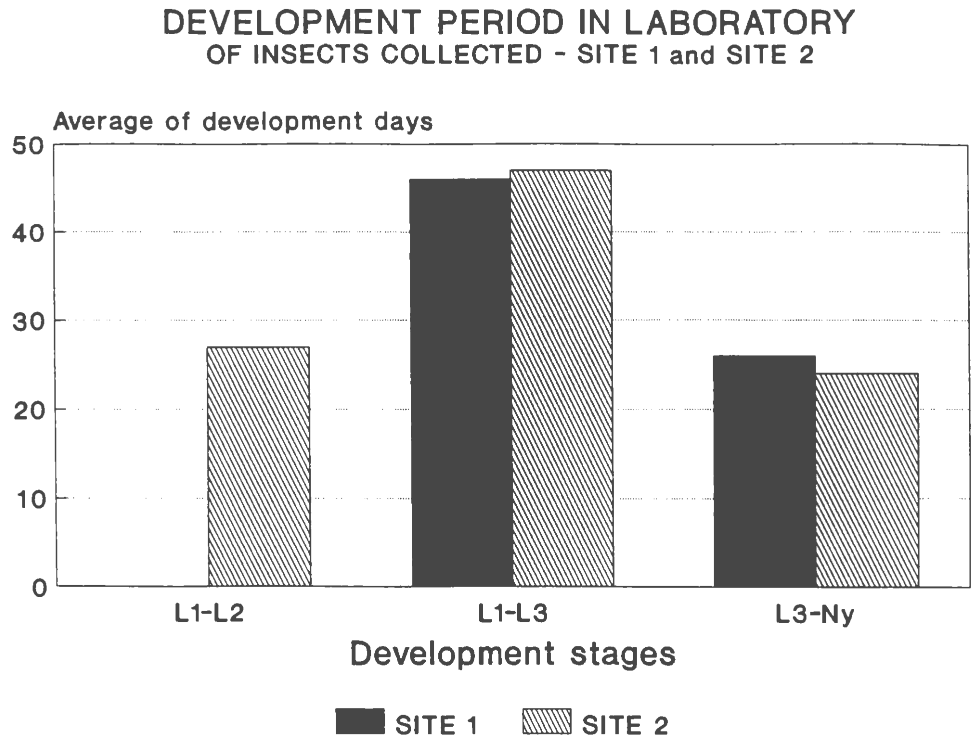
From adults collected in the soil, by beating or light traps on **SITE 1 (Valeteruru station)** and **SITE 2 (Saraoutou station)** or adults obtained from larvae and nymphs, eggs have been obtained in the laboratory, collected and counted. Development times have been noted.

Insects collected and those obtained from breeding at the laboratory can be used for biological control tests.

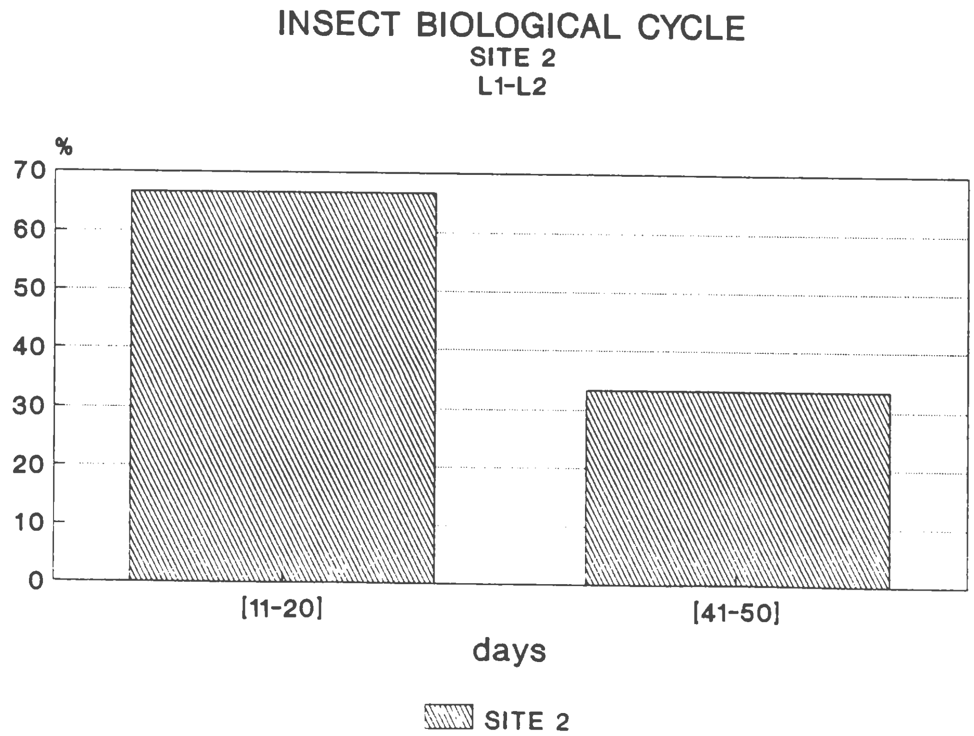
A few adults collected during the night were put in a cage outside (790x510x890mm) with three young cocoa trees as a source of food, in order to obtain eggs, larvae, nymphs and again adults to obtain a continuous culture. Regularly, to replace dead insects and to act against consanguinity, new adults were added

Photo 15 : Culture of Adoretus versutus larvae
in laboratory

Photo 16 : Piece of carrot as source of food
for Adoretus versutus larvae
in laboratory

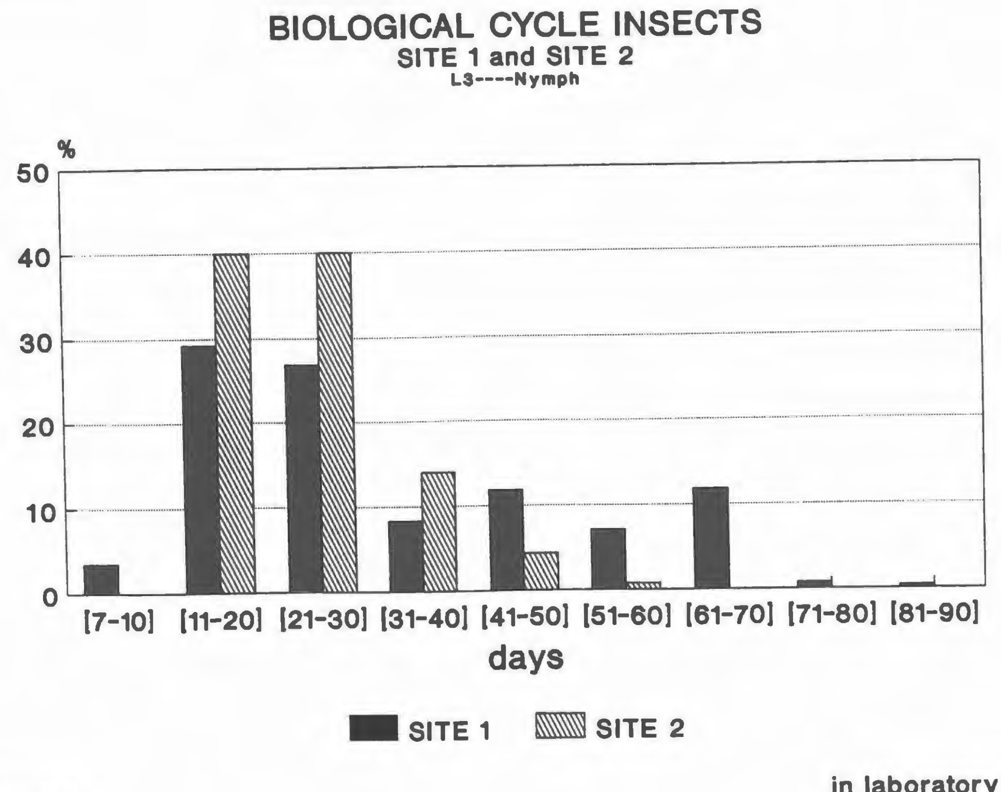


Graph 1

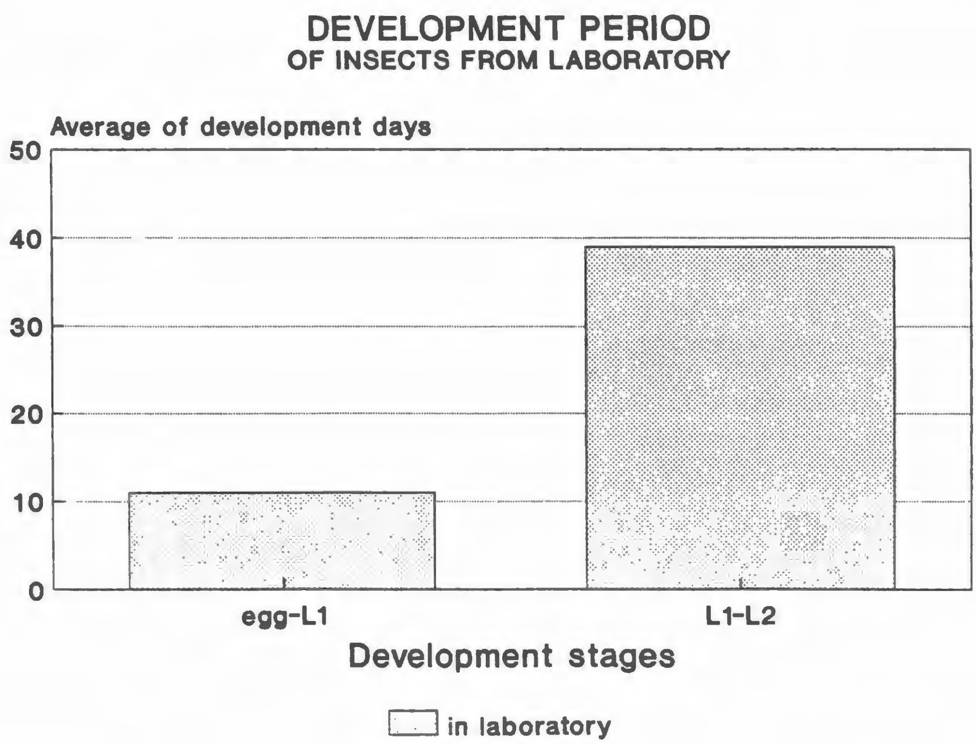


Graph 2

in laboratory



Graph 3



Graph 4

to the cage. The cocoa trees were changed when too much damage was observed.

1.3. Results

* From insects collected in the soil, we observed that the development period, under laboratory specific conditions (25°to 31°C and relative humidity, 55 to 85%) was the same for **SITE 1** and **SITE 2** (Graph 1).

L1-L2 : about 27 ± 15 days.
L1-L3 : 47 ± 8 days (L2-L3 . 20 days)
L3-Ny : 25 ± 15 days

The Biological cycle has been noted (Graph 2 and 3) :

L1 to L2 : 67% between 11-20 days
34 % between 41-50 days.

This result shows that there are certainly two kinds of white grubs or indeed possibly two different species, and so a mixed population.

L3 to nymph : 40% between 11-20 days
40% between 21-30 days

* From adults collected by beating, few new individuals have be obtained in laboratory.
. Most of the eggs (57%) hatched between 0 and 10 days, 35% hatched in 11-20 days, 8% in 21-30 days.
. Only few young larvae have been obtained. 50% had development times between 20-30 days, 50% between 50-60 days.

* From the culture cage outside, the first insects were introduced in November 1991. A control was made during the first two weeks of May 1992. Two L1, five L2, twelve L3, two prepupae were obtained.

Most of L3 changed into nymphs after about 21 to 38 days.

Graph 4 confirms **LEFEUVE data (1990)**:

laying-hatching : 11 ± 5 days
L1 to L2 : 39 ± 19 days

2. Behavioural studies

The tests were conducted either in an olfactometer (by preference), or in boxes (175x120x70mm).

We know that rose beetle has a nocturnal feeding activity. In the laboratory, adults bred in boxes have been observed in the evening under strong light for few hours. We observed that the adults do not stop eating. We concluded that rose beetle feeding is controlled by an internal clock.

2.1. Attractivity tests

2.1.1. By virgin females in a cage in front of released males.

2.1.1.1. Materials and methods

Virgin females were selected from newly-emerged adults. These females were isolated with soil and cocoa leaves as a source of food until the experimental test one day later.

Fifteen virgin females were locked in a latticed cage in an olfactometer and fifty males were released. Around the cage, four sheets of paper with glue were placed to collect the males attracted by the virgin females.

This test was repeated three times.

2.1.1.2. Results

No interesting results were obtained.

2.1.2. By foliage

These tests are described in section 2.3.

2.2. Feeding evaluation

2.2.1. For one rose beetle after 24h, 48h and 72h.

2.2.1.1. Materials and methods

One male and one female were put individually inside a round box (Φ185-h=200mm) with a cocoa leaf, to evaluate feeding after 24h, 48h and 72h from the same leaf. This test was repeated 12 times. The source of food was always Amenolado cocoa trees from Valeteruru station (SITE 1).

Feeding Area (in mm^2) was estimated from the cocoa leaf using millimeter paper.

2.2.1.2. Results

Feeding areas measured for one rose beetle after 24h and for the same rose beetle after 48h and 72h showed that for a given male insect, feeding area decreased between 24-48h (191 mm^2 ± 158 mm^2 - 140mm^2 ± 96 mm^2) and 48-72h (140mm^2 ± 96 mm^2 - 126mm^2 ±162 mm^2). This can be explained by the foliage becoming less fresh after 48h and 72h.

However, the results were not the same for the females. Feeding area for the females was the same as that for the males during the first 24h (195mm^2 ± 184 mm^2) but increased between 24-48h (267mm^2 ± 174 mm^2) and remained virtually constant between 48-72h (236mm^2 ± 184 mm^2) when the feeding area of the males was reduced.

Graph 5 shows cumulated feeding after 24h, 48h and 72h. We observed that the females were eating more than the males, except during the first 24h (190mm^2 ± 158 mm^2).

2.2.1.3. Conclusion

Males and females were able to eat from the same cocoa leaf after 24h, 48h and 72h. Males ate less as time passed whereas the females' feeding area increased.

2.2.2. For different cocoa tree clones

2.2.2.1. Materials and methods

8 different cocoa tree clones were chosen at random from the clone park on **SITE 1 (Valeteruru station)** : 19 sial 93, 100 Tag 3, 40 Tag 11, 119 IC 100, 42 IC 560, 21 Tag 4, 82 Tag 6, 61 IC 595.

About two leaves were offered to rose beetles (5 males, 5 females) during 72h and feeding areas (mm^2) were measured using millimeter paper. Only one test was performed.

2.2.2.2. Results

Graph 6 shows that for 6 clones the feeding area for males is inferior to that for females. For 2 clones we observed the opposite (82 Tag 6 and 61 IC 595).

Feeding area was between 2400 mm^2 and 3900 mm^2 for the males ; 2400 mm^2 to 6800 mm^2 for the females.

2.2.2.3. Conclusion

This test has not been repeated. Therefore, it is difficult to conclude if one particular clone was preferred to another. With only one test performed, we can only conclude that there is no significant difference between the 8 clones tested and that the feeding area of females is greater than that of the males in most cases.

2.2.3. For different rose beetle host plants

2.2.3.1. Materials and methods

Feeding areas were recorded on 5 different rose beetle host plants, for males and females separately, with 4 repeats.

Host plants :

- Terminalia catappa (Natapoa)
- Coffea robusta (Coffee)
- Theobroma cacao (Cocoa)
- Acalipha wilkesiana (Acalipha)
- Hibiscus tiliaceus (Burao)

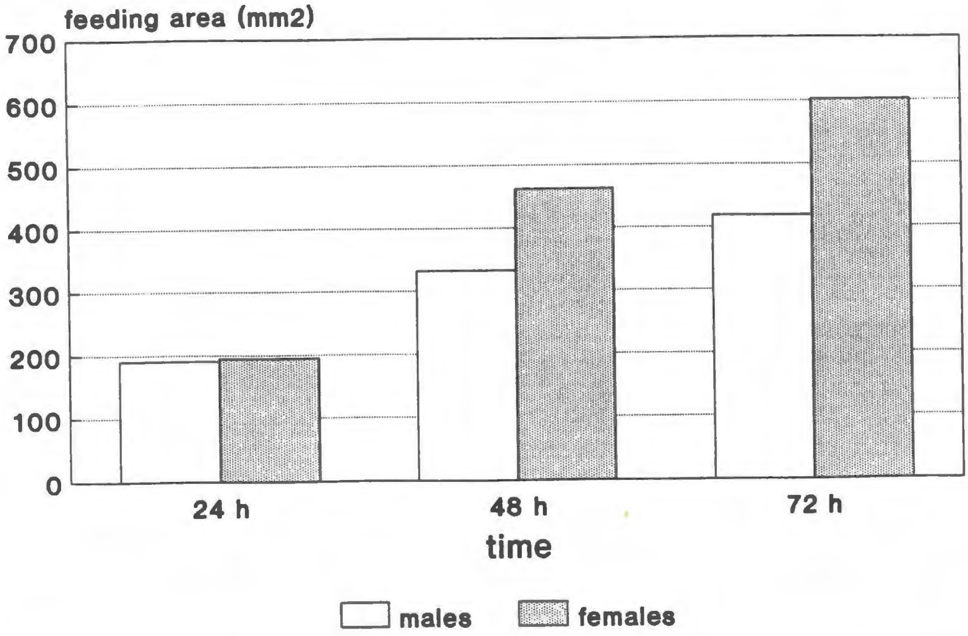
A single male was placed in each of 5 boxes (175x120x70mm) containing leaves from one (different) host plant. The same was done for 5 females.

Feeding area was observed after 24h, 48h and 72h. It was measured using millimeter paper (in mm^2).

2.2.3.2. Results

Graph 7 shows that feeding area is greater for a given female than for a given male after 24h, after 48h and after 72h.

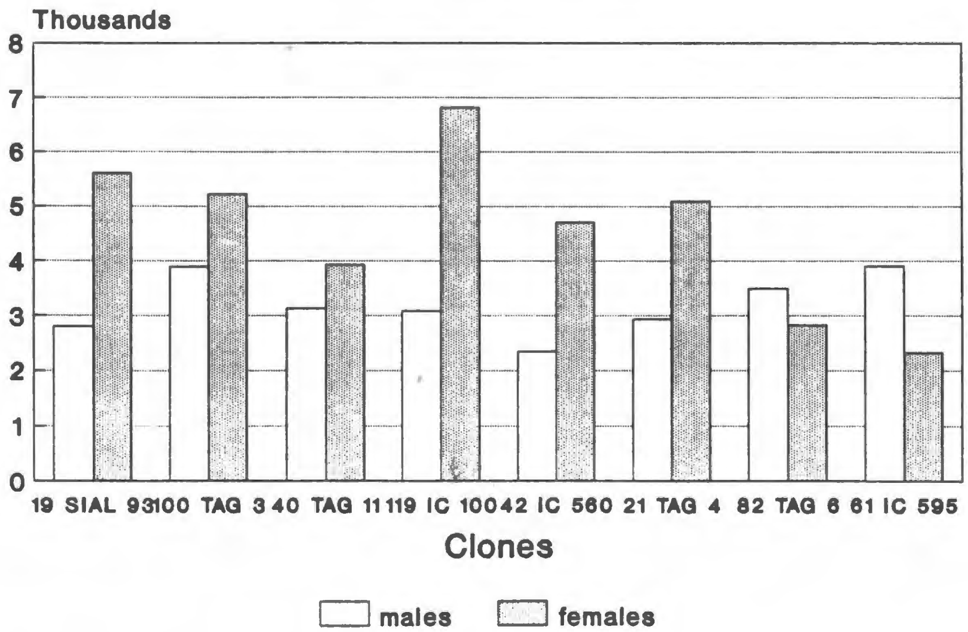
AVERAGE CUMULATED FEEDING FOR 1 R.BEETLE
IN 24h, 48h, 72h



12 repeats

Graph 5

DIFFERENT CLONE APPETENCES
FEEDING in 72 hours



Graph 6

Results show that during the first 24h, cocoa leaves ($231\ mm^2 \pm 131\ mm^2$ for male ; $277\ mm^2 \pm 29\ mm^2$ for female) were preferred to Natapoa ($125\ mm^2 \pm 45\ mm^2$ for male ; $252\ mm^2 \pm 111\ mm^2$ for female) and Burao ($119\ mm^2 \pm 28\ mm^2$ for male ; $252\ mm^2 \pm 150\ mm^2$ for female). Acalipha ($43\ mm^2 \pm 22\ mm^2$ for male ; $71\ mm^2 \pm 32\ mm^2$ for female) and Coffee ($22\ mm^2 \pm 9\ mm^2$ for male ; $30\ mm^2 \pm 25\ mm^2$ for female) were very clearly less eaten.

After 48h and 72h, eating continued to increase for each of the 5 host plants. We observed the same results as those found after 24h : cocoa was preferred to Natapoa and Burao. Coffee and Acalipha were not in comparison very appetising to rose beetle.

2.2.3.3. Conclusion

Cocoa, Natapoa and Burao are very susceptible to rose beetle attacks.

2.3. Feeding choice tests

2.3.1. For different physiological stages of cocoa leaves.

This test was performed to discover which physiological stage of the cocoa foliage is preferred by the rose beetle.

2.3.1.1. Materials and methods

Tests were performed in an olfactometer. Cocoa leaves at 5 different physiological stages could be chosen by adult rose beetles : Yellow leaves, dark green leaves, clear green leaves, grey-green young leaves and red new leaves (photo 17).

To allow for possible variations in choice according to sex, we tested alternately with either males or females only.

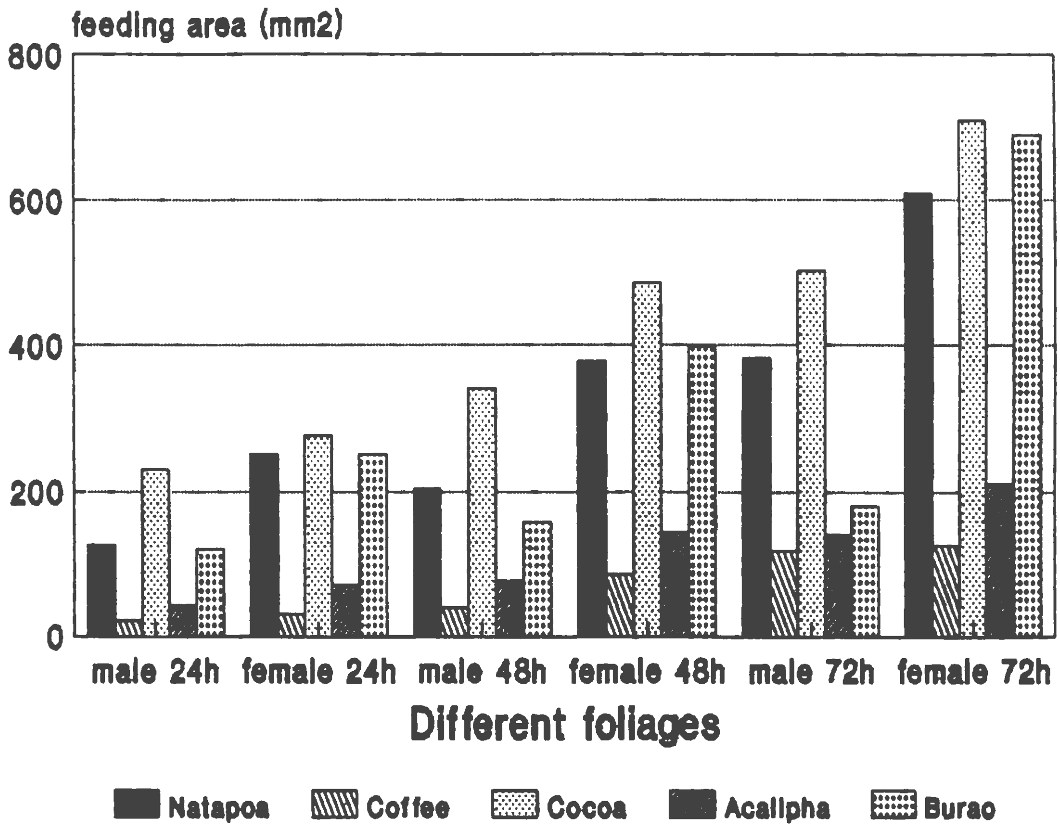
The test was repeated three times for males, three times for females with, for each test, about 50 adults.

The tests were performed at night during rose beetle feeding activity. After one or two nights, feeding area results (mm^2) were noted for rose beetle feeding according to the physiological stage of the cocoa leaves.

2.3.1.2. Results

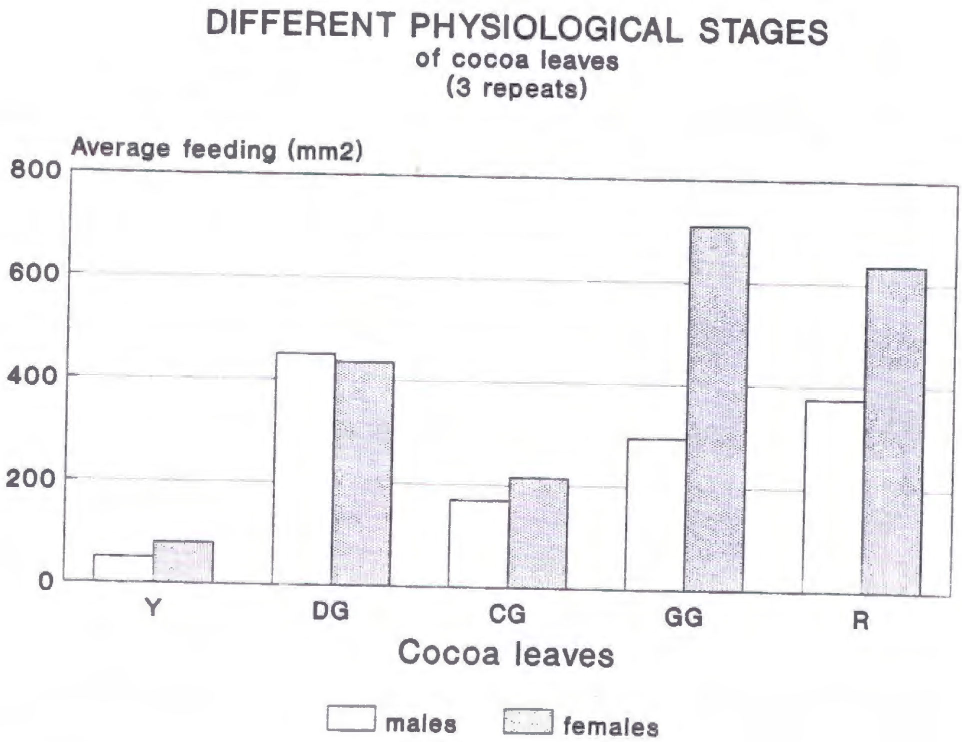
Graph 7 bis shows the results of the tests. We observed that the dark hard green leaves are eaten by males and females equally and are consumed mainly because more functional. These were the leaves preferred by the males. The young grey green leaves are preferred by the females followed by red young leaves and dark green leaves. The clear green and yellow leaves were the least attractive.

AVERAGE FEEDING in 24h, 48h, 72h
FOR ONE ROSE BEETLE (4 repeats)



Graph 7

Photo 17 : Foliage choice test in olfactometer laboratory



Graph 7bis

2.3.1.3. Conclusion

We observed that rose beetle is able to eat all kinds of foliage but preferred young foliage. This might be explained by the compounds contained in the young leaves. This could be tested by chromatographic studies on chemical composition at the different leaf stages. We observed that rose beetles were not very attracted to old leaves (yellow) whereas it appears than on coffee trees, only yellow leaves are attacked. **LEFEUVE (1990)** suggested that this might be due either to a visual stimulus (this has not be tested) or to the nitrogen content of the plant (the yellow leaves being deficient in nitrogen). We concluded that the content of the leaf must be very important to rose beetle feeding.

2.3.2. For different rose beetle host plants

2.3.2.1. Materials and methods

Seven different rose beetle host plants were tested in an olfactometer.

- Coffea robusta (Coffee),
- Theobroma cacao (Cocoa),
- Terminalia catappa (Natapoa),
- Hibiscus tiliaceus (Burao),
- Pometia pinnata (Nandao),
- Dioscorea sp. (Igname),
- Acalipha wilkesiana (Acalipha).

As in the test described in 2.3.1.1., females were tested separately from the males.

About 50 males or females are used for each test and the test was repeated three times.

2.3.2.2. Results

Results are presented on graph 8.

The males showed a clear preference for cocoa leaves (dark green leaves)(1342 mm^2) before Nandao leaves (630 mm^2). For the other foliage offered, males and females were attracted indifferently to coffee, natapoa, burao, igname and acalipha (<200 mm^2).

2.3.3. Conclusion

Cocoa is the most important host plant for rose beetle attacks. When rose beetle has cocoa trees available, it is the first plant attacked.

In the field, Hibiscus tiliaceus was much attacked in some sites around pasture but when no cocoa trees were nearby.

2.4. Orientation tests

2.4.1. Materials and methods

Three different tests were performed to investigate rose beetle feeding after :

- eye ablation,
- antenna ablation,
- combined eye and antenna ablation.

A control group was also tested.

The experiment was performed for each test on 3 males, 3 females and 3 males and 3 females together.

The test has not be repeated.

The eyes were painted with nail varnish and the antennae were cut under a binocular lens.

2.4.2. Results

We observed that after the eyes were varnished rose beetles were immediately highly disturbed by the nail varnish and tried to remove it with their legs. Therefore, the operator had to restrain their legs until it dried. This may indicate that vision is very important to the insect.

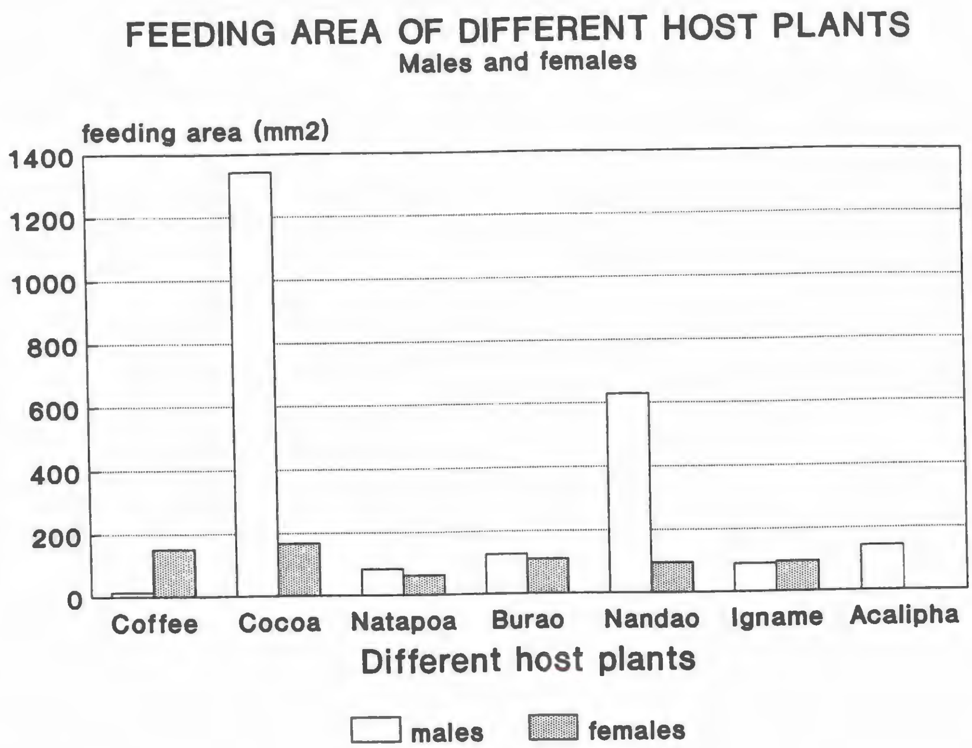
Graph 9 shows that, when compared with the control, the males and the females separately, and the males and females together are not affected by antenna ablation for feeding (3-4,5% of the leaves eaten - control 1,9 - 3,8%).

Concerning eye ablation, when compared with the control, males seemed unaffected (2,4% - control 1,9%) whereas the feeding of the females did seem to be affected (0,9% - control 3,8%) also the result obtained with males and females together (2% - control 3,8%).

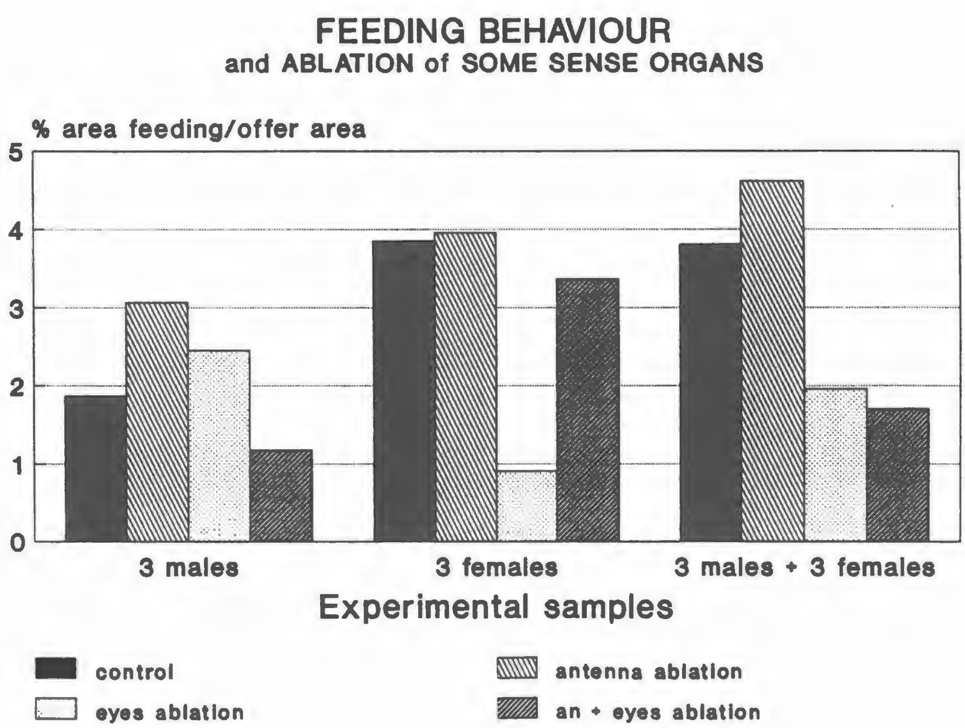
For eye and antenna ablation together, females alone seemed not to be very affected for feeding, whereas the males did seem to be slightly affected.

2.4.3. Conclusion

It appeared that the feeding of females is affected by eye ablation and also that visual stimulus seems to be important in the choice of plant and feeding. Antenna ablation did not seem to affect rose beetles to any great extent.



Graph 8



Graph 9

B- Field studies

Climatic data (SITE 1 : Valeteruru station)

* Pluviometric data

Graph 10 shows rainfall from November 1991 to July 1992, the period of all the observations.

Most rainfall occurred in February 1992 (580mm) then April 1992 (360mm), January 1992 (305mm) and November 1991 (290mm) because of the rainy season.

In December 1991 rainfall was abnormally low (70mm).

From May to July rainfall seemed to correspond to the dry season, but even in July 1992 rainfall reached about 130mm.

* Temperature data

Maximum and minimum temperatures were recorded from November 1991 to July 1992 (Graph 11).

Maximum temperatures were reached in February and March 1992 during the hot and humid season.

Schematically, maximum temperatures were always above 26°C and below 32°C.

Minimum temperatures were recorded in July and June 1992 during the cold season.

Schematically, minimum temperatures were always above 20°C and below 31°C.

We noted a particular temperature stability.

1. Field sampling for population dynamics

The objective was to use techniques developed in the first study **(LEFEUVE, 1990)** to be carried out on the biology and ecology of the rose beetle, including studies of population fluctuations over one year, from November 1991 to July 1992, in relation to weather conditions and other factors.

1.1. Larvae

1.1.1. Materials and methods

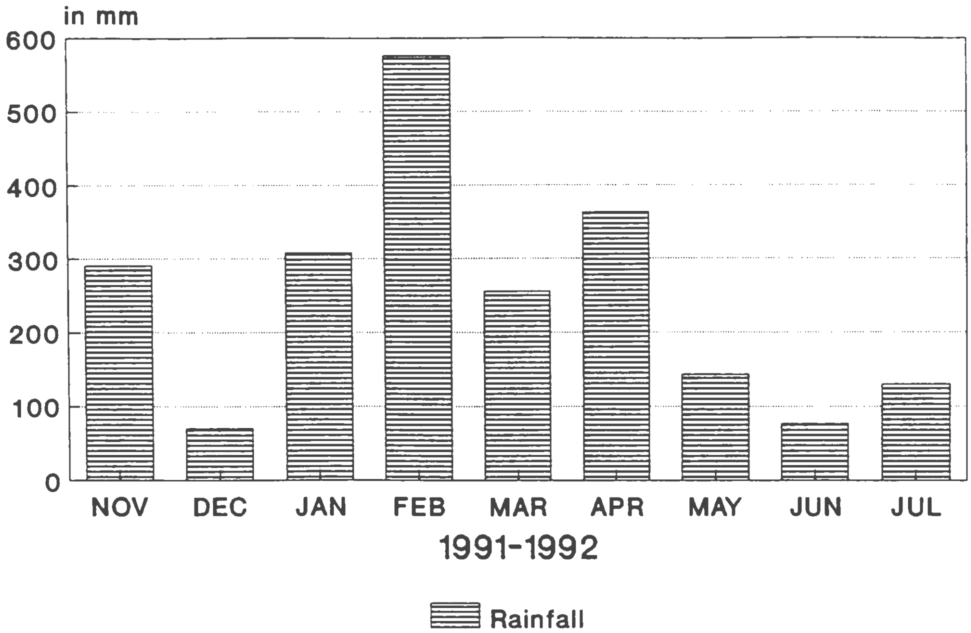
1.1.1.1. Presampling/deciding number of sites and samples.

10 biotopes for rose beetle collection were chosen on **SITE 1-Valeteruru station** (6 biotopes, map B, Annex 1) and **SITE 2-Saraoutou station** (4 biotopes, map C, Annex 1).

* **SITE 1 :**

- Biotope I : Field in front of the research station, grass only. Area of 1 ha.
- Biotope II : Around adult cocoa trees (4 years old). Area of 1.5 ha.

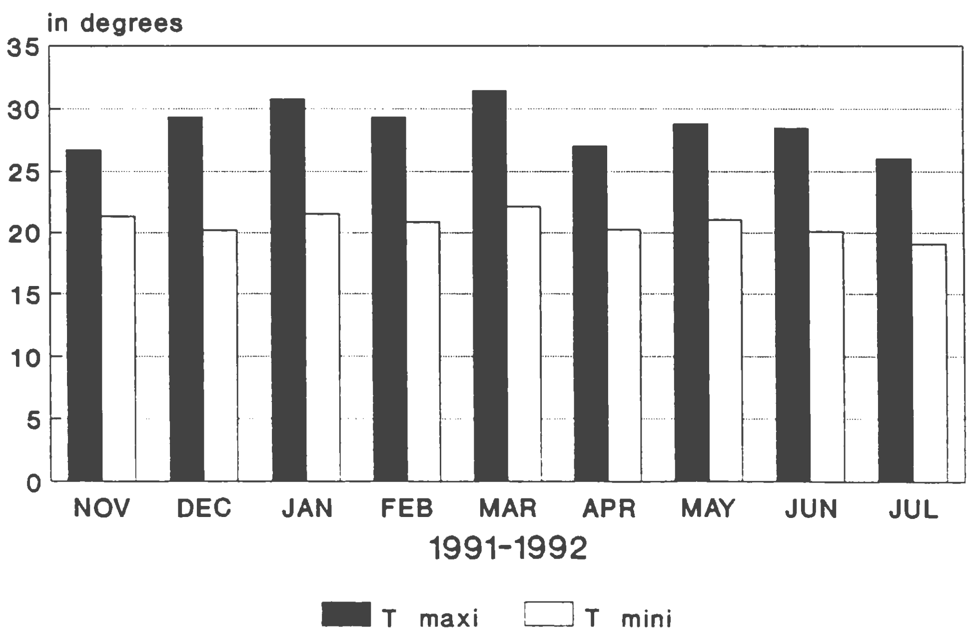
RAINFALL
November 1991 to July 1992



Graph 10

Valeteruru station observations

MAXI and MINI TEMPERATURES
November 1991 to July 1992



Graph 11

Valeteruru station observations

- **Biotope III** : Around intercropping plot (young cocoa seedlings, 1.5 years old, coconuts, papaya trees...). Area of 1,35 ha.
- **Biotope IV** : Around adult cocoa hybrids. Area of 6 ha.
- **Biotope V** : pasture with grass. Area of 3 ha.-
- **Biotope VI** : Around adult cocoa hybrids. Area of 1,5 ha.

*** SITE 2 :**

Plot P.42 (Area of 8 ha)

- **Biotope VII** : Around west of the adult cocoa plot (8 years old),
- **Biotope VIII** : Around adult cocoa plot under coconut, to the north,
- **Biotope IX** : to the south of the plot P.42, in the center of intercropping plot,
- **Biotope X** : under coconut, to the north of the plot, alongside coffee tree plantations much attacked by rose beetle.

These two sites were chosen since much-attacked crops (cocoa trees, coffee trees) were growing there.

Collections were usually made around crop plots because **MORIN** (pers. com.) during 1988 observed that 67% of the insects are found on the border lines.

1.1.1.2. Monthly sampling

Larvae were observed by digging around in the ground over 25x25 cm to a depth of about 10 cm. Eggs, larvae, prepupae, pupae and adults were all observed.

The ten different localities described in 1.1.1.1 were observed every month from November 1991 to July 1992 in order to evaluate population fluctuations .

50 quadrants (25x25x10cm) were studied each month at each of the ten sites to record numbers of each stage. The size of the quadrant was chosen to be compatible with the biology of the species and the sampling conditions.

LEFEUVE (1990) observed no individuals in bare soils which would confirm that the larvae feed on grass roots.

Three collectors used boxes with 10 separate compartments. Each compartment corresponded to collection from a square 25x25x10 cm.

During collection, each stage was boxed immediately to be sheltered from the sun and heat. After 50 samples (50 squares) in a biotope had been collected, they were counted in the laboratory. Data were registered on a computer each month for each biotope. Each stage was bred in separate boxes with soil and a piece of carrot as described under Culture technique (A- 1).

About one week after collection, mortality rates were checked and dead individuals removed. Mortalities were due to wounds, sun and mainly manipulation of the different stages.

From this procedure, we knew exactly the number of insects collected and the number of insects bred in the laboratory for a comparative study of development and possible diseases.

The number of insects of each stage collected/M^2 was calculated for each biotope and for each month from November 1991 to July 1992.

1.1.2. Results

All the stages were found between November 1991 and July 1992.

In the 10 biotopes from November 1991 to July 1992 we observed that the number /M^2 is :

- greatest for the L1 instar from November 1991 to January 1992 (about 30 L1/M^2),
- greatest for the L2 instar from February to April 1992 (about 31 L2/M^2),
- greatest for the L3 instar in June and July 1992 (about 17 L3/M^2), and particular in biotope VIII under coconut (83 L3/M^2). This shows that this biotope is more favourable to Adoretus versutus breeding, until the adult stage.

The results are presented separately for each biotope (Graph 12 to 21).

They can be compared with the results of **LEFEUVE (1990)** (Graph 22).

For the same period in November and December 1989 and 1992, **LEFEUVE** found in 9 sites (A to I) about 5,7 L1/M^2, 5,7 L2/M^2, 5,5 L3/M^2. For one particular biotope (E) (biotope VIII in 1991-92), **LEFEUVE** observed numbers similar to our results for November and December : 27 L1/M^2, 20 L2/M^2, 16 L3/M^2 (Graphs 12 to 21).

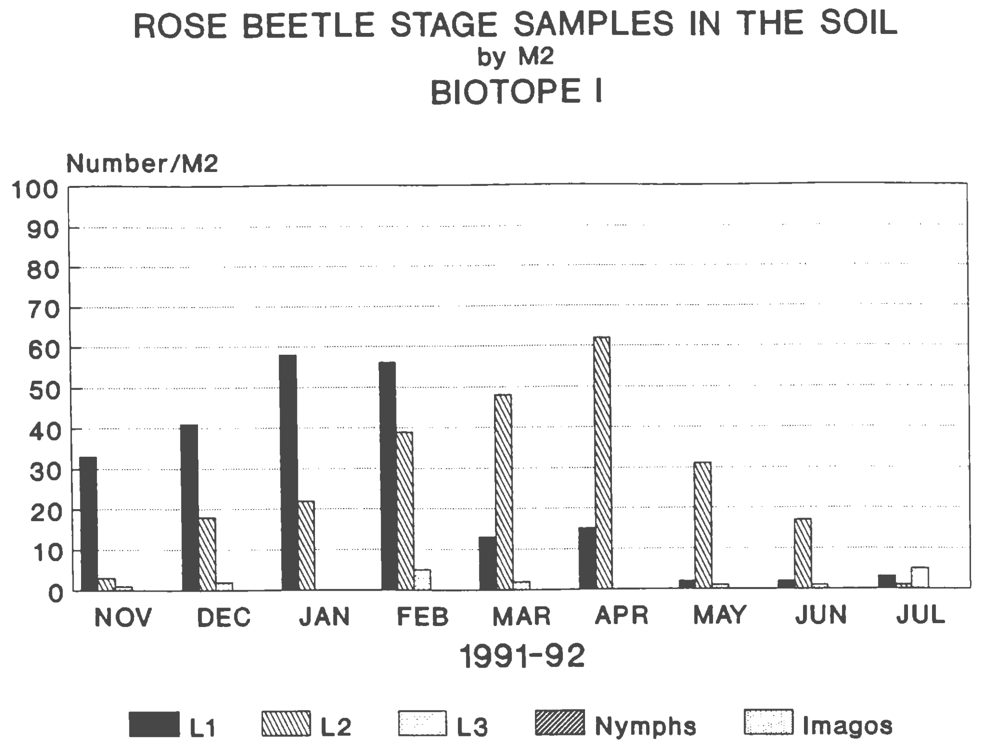
Nymph numbers were greater in 1989 (0,44/M^2) than in 1992 (0,15/M^2) ; Adult numbers seemed greater in 1992, 1,4 IP/M^2 against 0,88 IP/M^2 in 1989.

Concerning mortality rates after one week due to manipulation , we observed that mortality is very high on **SITE 1** and **SITE 2**, particularly between January and March 1992 (between 50% and 90% on **SITE 1** ; between 35% and 81% on **SITE 2**).

This can be explained by the fact that it was the hot season and during the first collections the larvae needed to be boxed very quickly in good conditions, with the minimum of manipulation - conditions difficult to respect in practice. I n November and December 1991, mortality after collection never went above 42% and during the period from May to July 1992, mortality stayed under 40%.

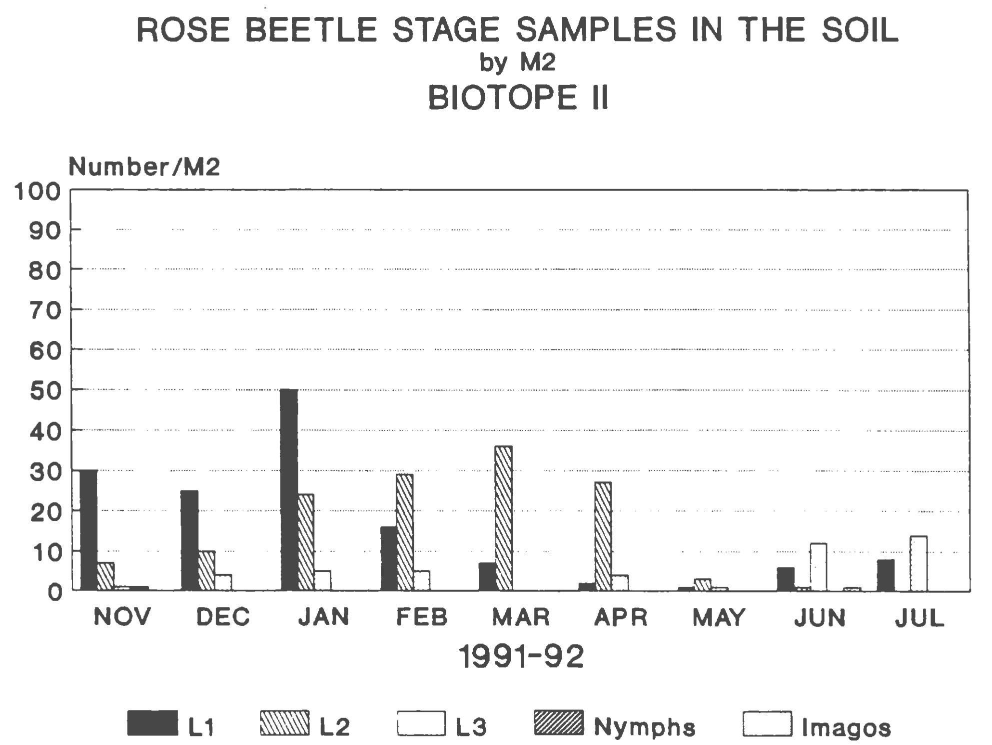
1.1.3. Conclusion

Graphs 12 to 21 show that all rose beetle stages were present from November to July in different proportions. L1 were collected in greater numbers at the end of the year (November and December), L2 during the rainy season (February to May) and L3 after the rainy season (June and July).



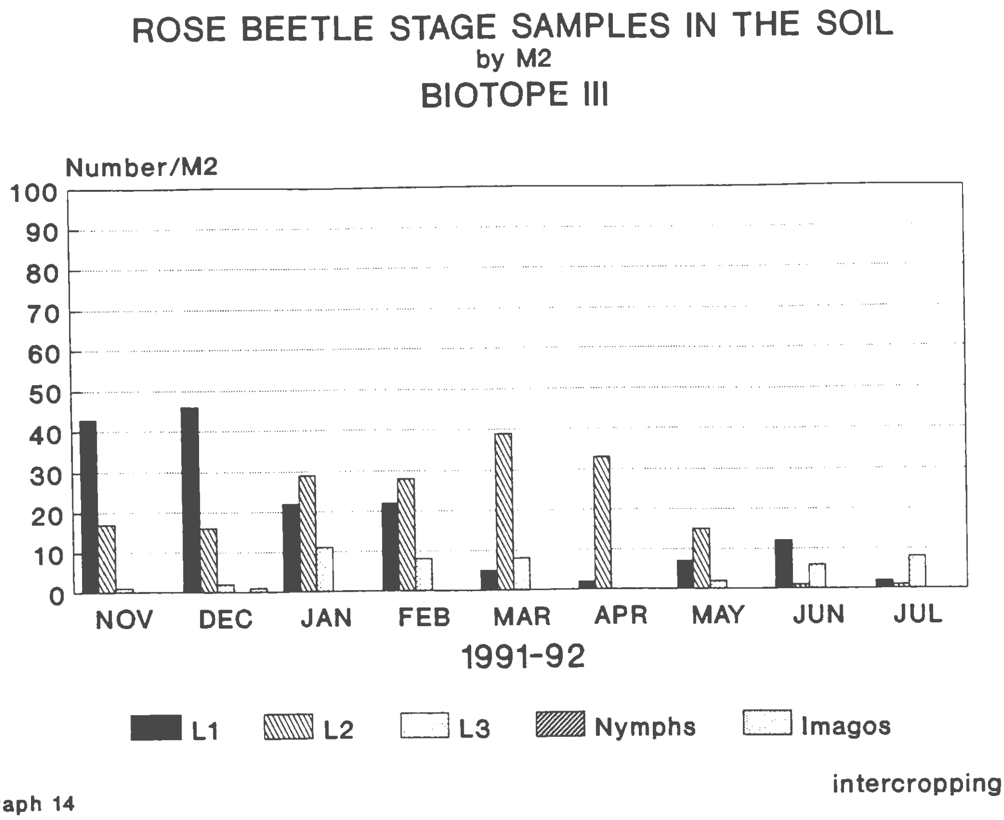
Graph 12

pasture

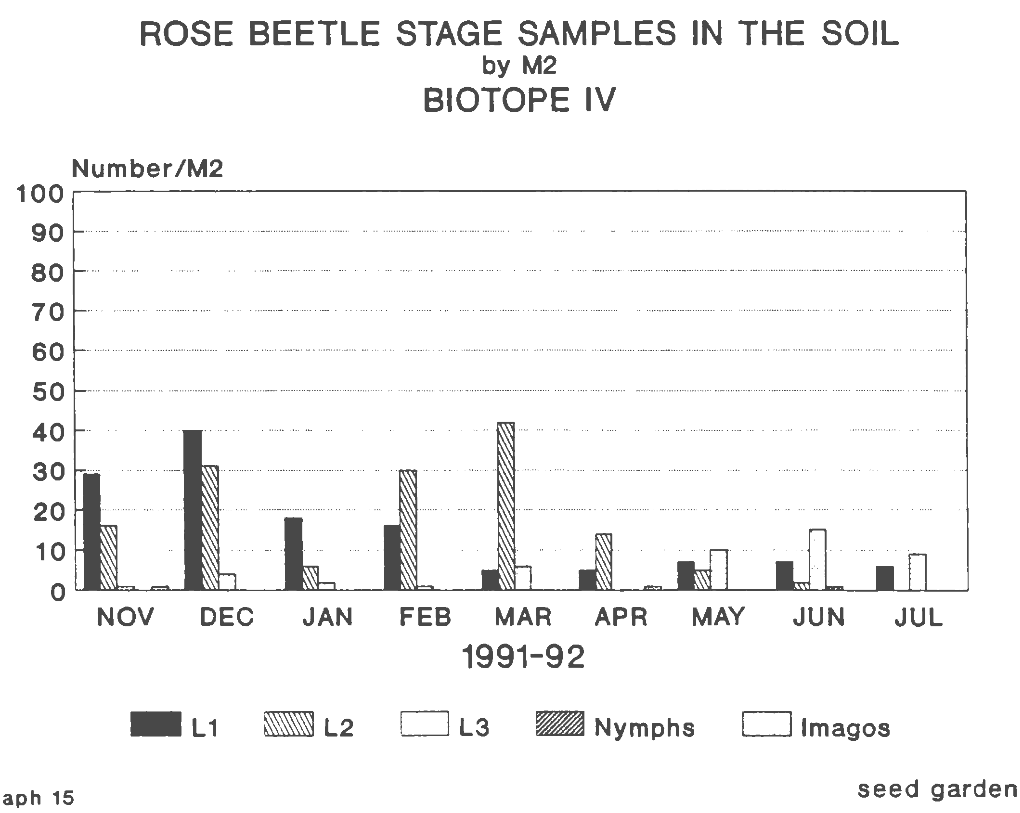


Graph 13

damaged cocoa

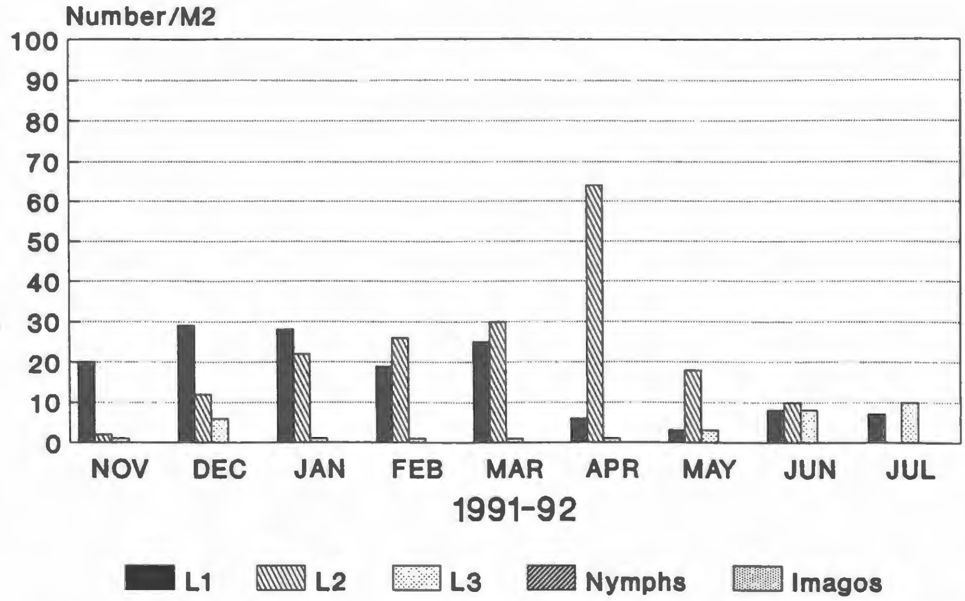


Graph 14



Graph 15

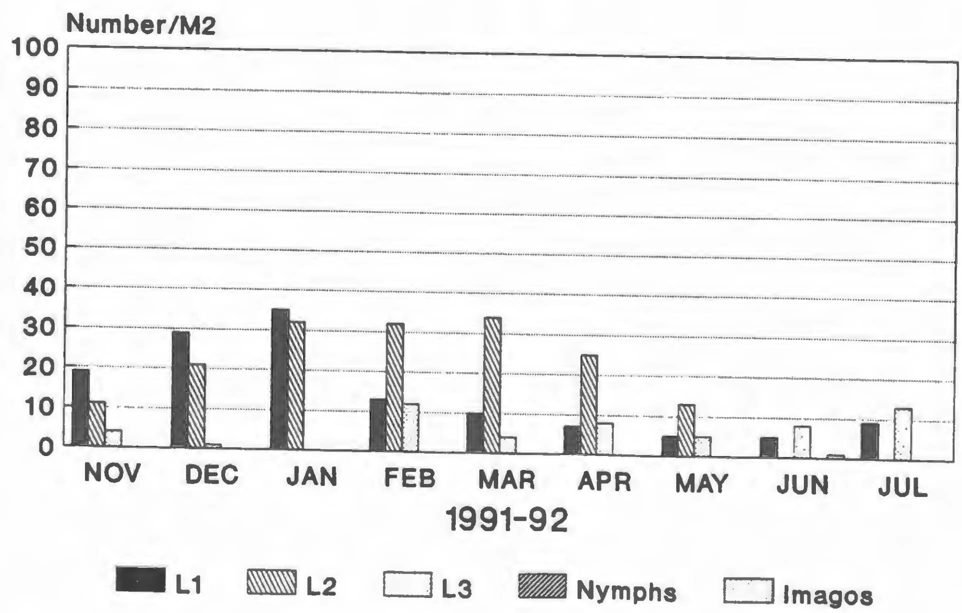
ROSE BEETLE STAGE SAMPLES IN THE SOIL
by M2
BIOTOPE V



Graph 16

provisional pasture

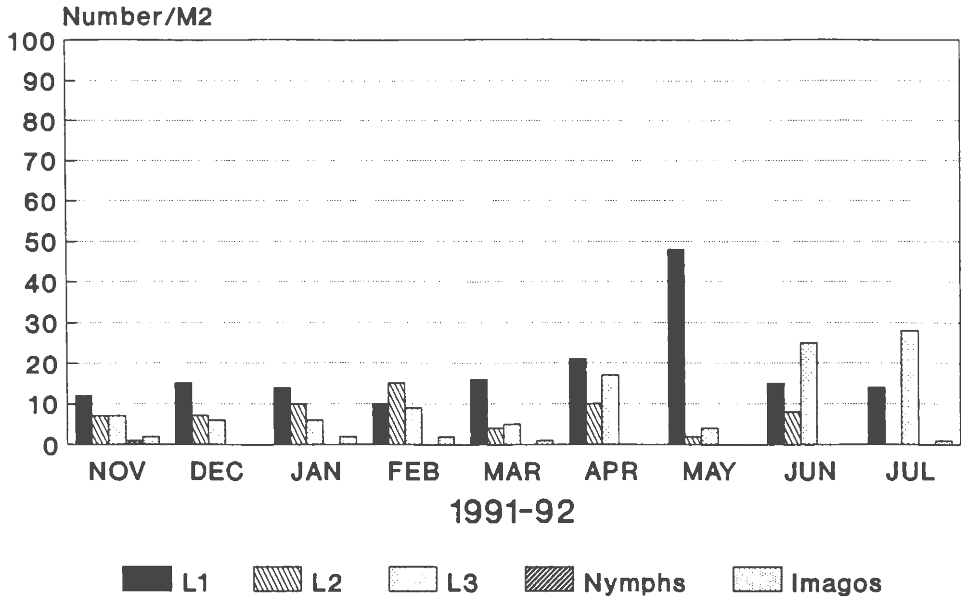
ROSE BEETLE STAGE SAMPLES IN THE SOIL
by M2
BIOTOPE VI



Graph 17

hybrid cocoa trees

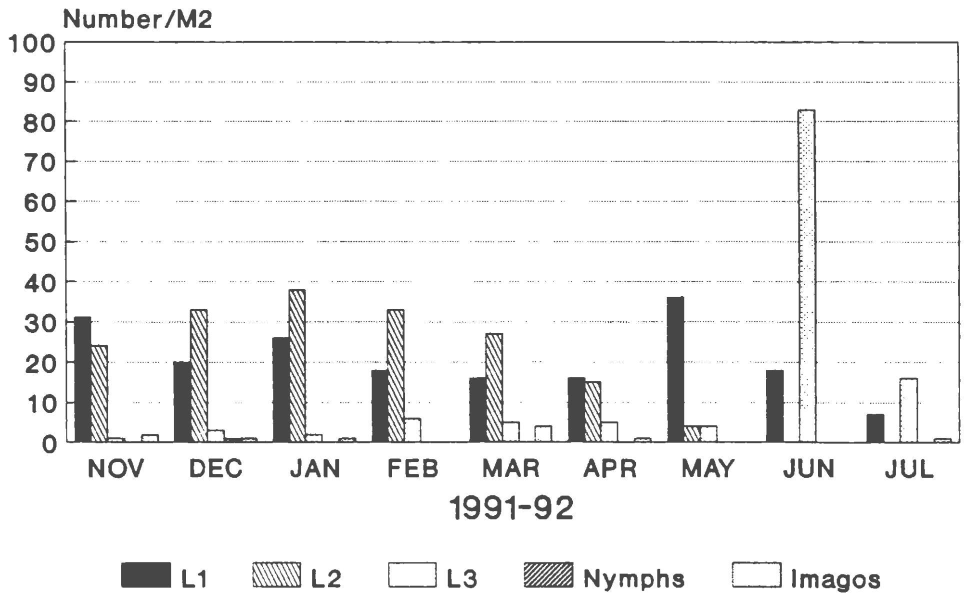
ROSE BEETLE STAGE SAMPLES IN THE SOIL
by M2
BIOTOPE VII



Graph 18

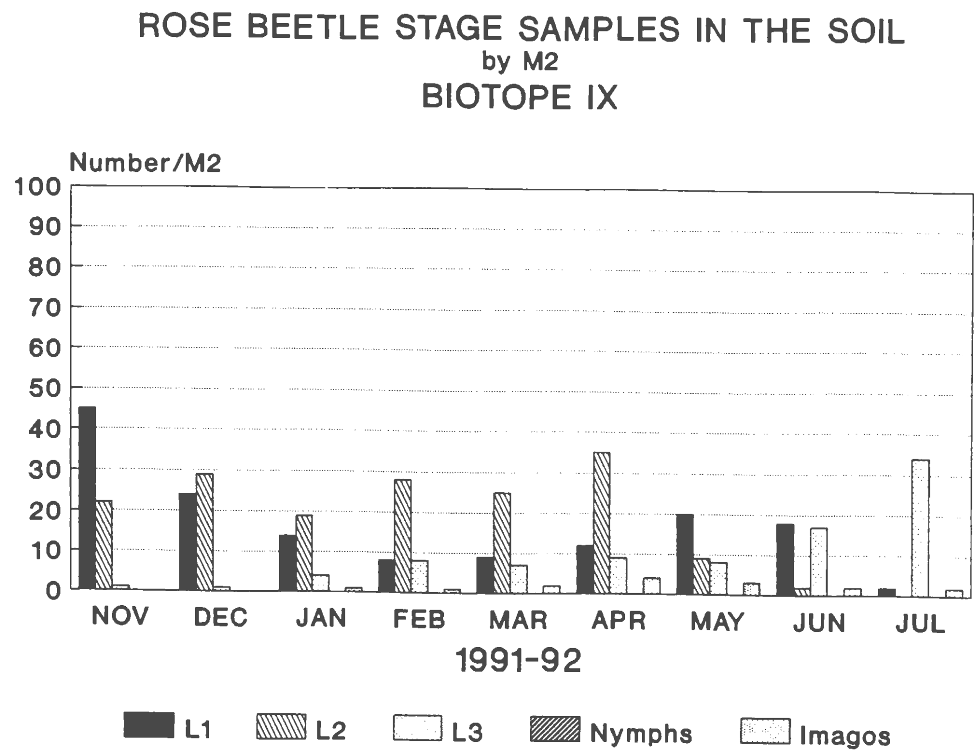
hedge cocoa plot

ROSE BEETLE STAGE SAMPLES IN THE SOIL
by M2
BIOTOPE VIII



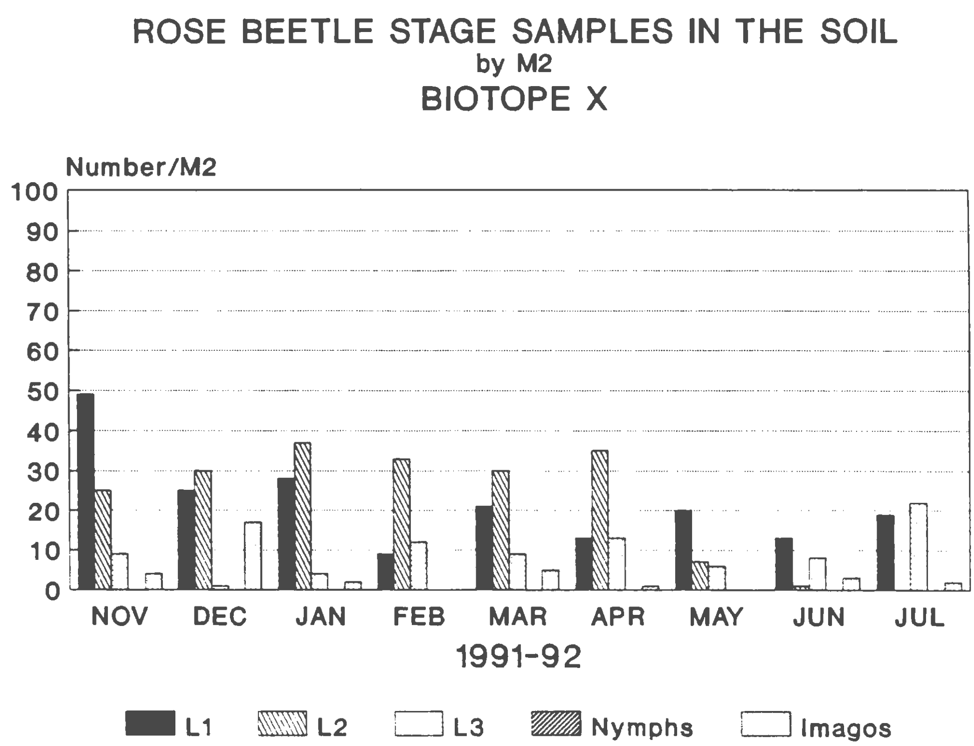
Graph 19

coconut shade



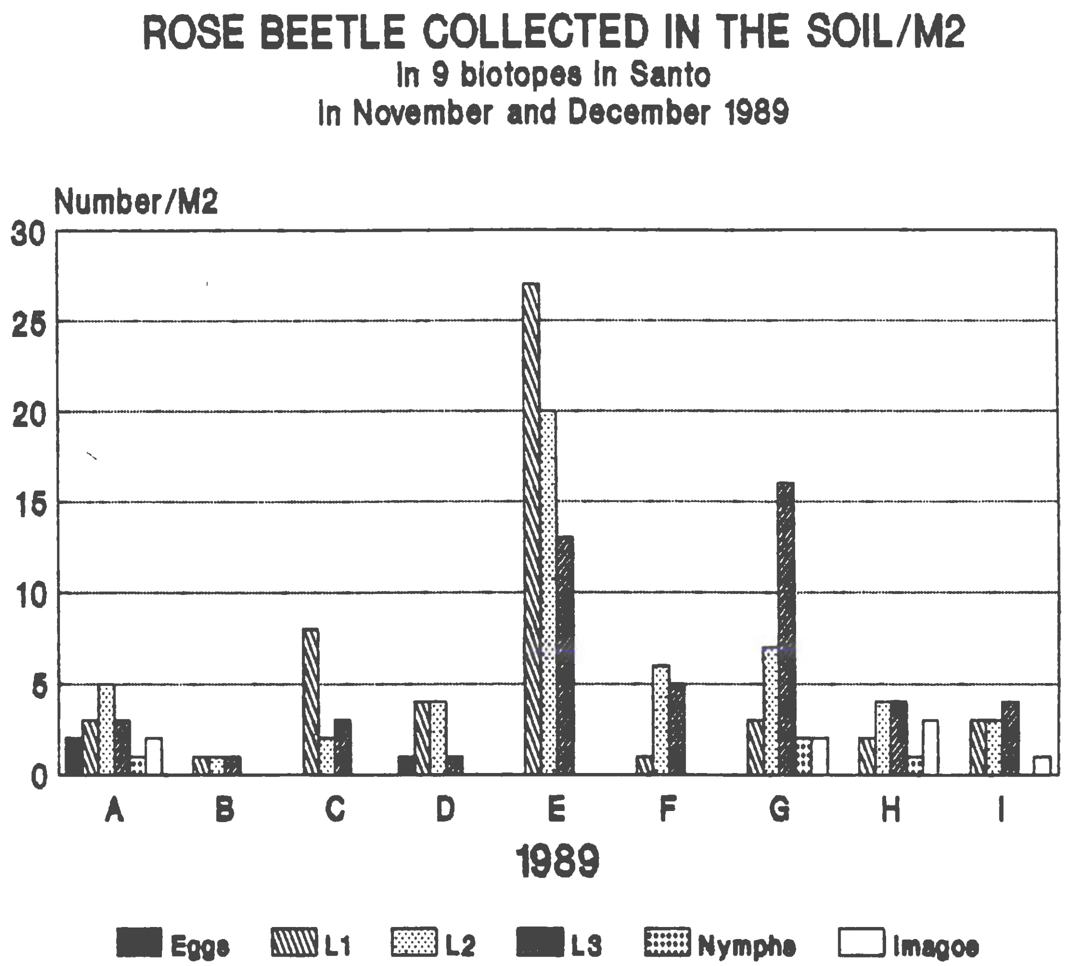
Graph 20

intercropping crops



Graph 21

damaged coffee



Graph 22

(according to LEFEUVE, 1990)

1.2. Adults

1.2.1. Beating technique

1.2.1.1. Materials and methods

1.2.1.1.1. Site selection

Two localities were selected to collect rose beetle adults by beating.

* **SITE 1** (Valeteruru station) : cocoa trees 4 years old. Area of 1,5 ha.
* **SITE 2** (Saraoutou station) : cocoa trees 8 years old. Area of 8 ha.

1.2.1.1.2. Sampling every two weeks

MORIN (1989) tested light traps, hour by hour from the beginning of the night until 12.30 p.m. and concluded that 50% insects were captured during the two first hours.

In addition, adult populations were studied at the beginning of the night by shaking branches over a collector into which the insects falled. This operation was repeated 200 times to make up a general sample.

One sample was taken every two weeks on **SITE 1** plot and **SITE 2** plot, including 7 samples of 25 beats along the borders and 1 sample of 25 beats in the center of the plot since populations are greater around the plot than in the middle : 67 % having been found on cocoa trees at the borders **(MORIN, 1988)**. This was confirmed by observations of more serious damage around the borders.

1.2.1.2. Results

Graph 23 shows results of beating from November 1991 to July 1992.

The results show that adults are present all the year round as suggested by **VEITCH (1919)** and **FRIEDERICHS (1914)** because larvae are always to be found in the soil and adults can be sighted at any time.

In this study, we were able to collect adults continuously from November 1991 to July 1992, the entire period of the investigations in VANUATU.

We observed than the highest population levels were in April and May (80 to 175 adults for 200 beats on **SITE 1** ; 160 to 230 adults for 200 beats on **SITE 2**) after the hot,rainy season.

Also, we observed that the levels of adults collected at the beginning of the night were, for every collection, greater on **SITE 2** plot (230 adults at the end of April 1992) than on **SITE 1** plot (175 adults at the end of april). This can be explained by the fact that **SITE 1** on Valeteruru station had been better maintained than **SITE 2** and because **SITE 2** was surrounded by large areas of pasture.

The number of insects collected was lower between November 1991 and March 1992 and in July 1992.

Female and male numbers showed that the number of males is always greater than that of females on **SITE 1** and **SITE 2**. For example, in May 1992, on **SITE 2**, about 140 males were collected against 95 females. On **SITE 1**, the same week, 90 males were collected against 58 females.

This might be explained if the males arrived first on the host plant and if a pheromone emitted by the male was able to attract the females. The higher number of males compared with females was possibly because not all the females had arrived on the foliage.

When we compared the sex ratio (number of males/ number of females) on **SITE 1** and **SITE 2**, we observed that the sex ratio is always superior to 1. Also, the sex ratio is often higher on **SITE 1** than on **SITE 2** (about 3 on SITE 1 against 1,4 on SITE 2 at the end of November (Graph 24).

No interpretation could be made regarding collection in full moonlight, although **PROVOST (1959)** reported that capture rates are lower in full moonlight because of the increased light.

Comparison of population levels on Espiritu Santo island in 1988 and 1990.

*** 1988 :**

In 1988, population levels were very high in April/May with almost 2000 insects/200 beats, then fell to under 400 at the end of the year (Graph 25) **(MORIN, 1989)**.

We noted insecticide treatment (Graph 25) and observed that population levels fell for a short time after.

Populations were twice as high on the borders as in the middle of the plot and, in practice, this lead to damage that was always more serious along the borders. Of 214 *A. versutus* collected in 1988, 67% were on border cocoa trees **(MORIN, 1988)**.

*** 1990 :**

We have data for only one month, January 1990 (Graph 26).

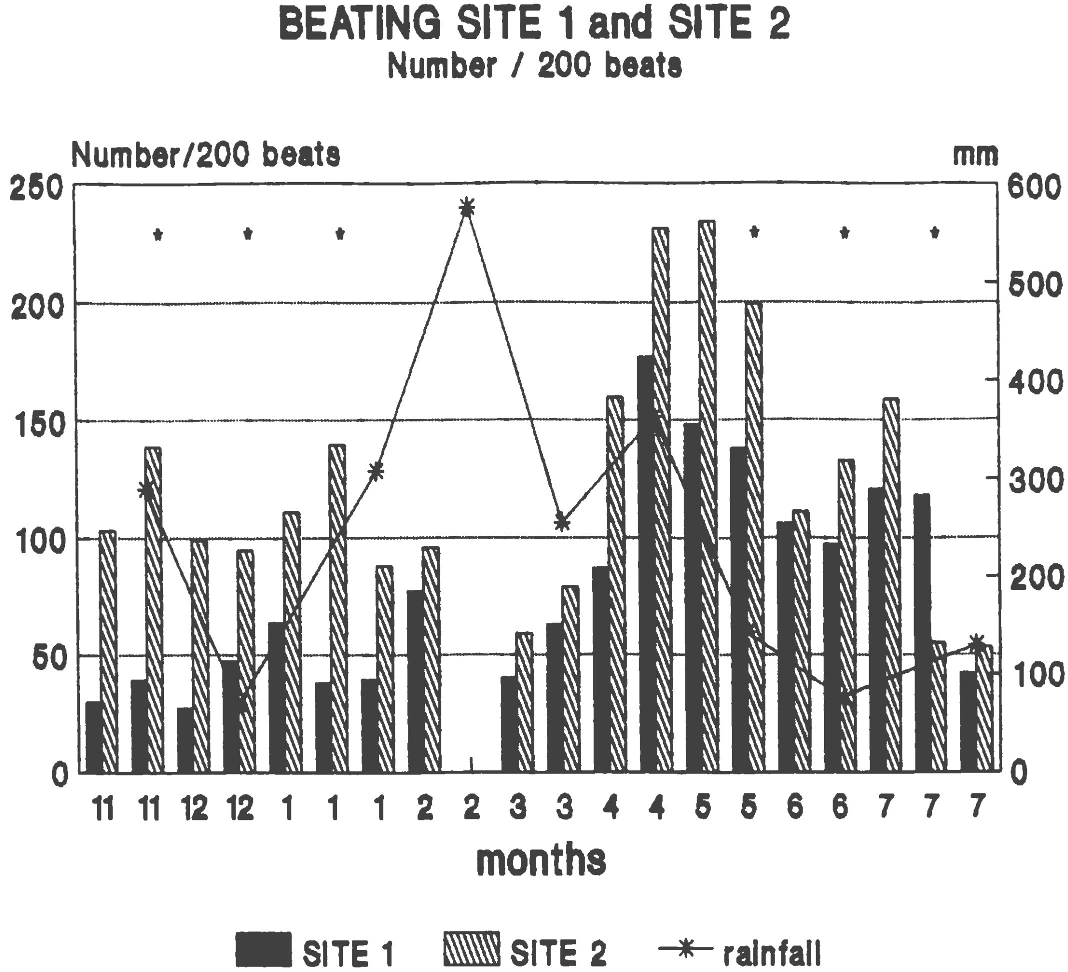
If we compare rose beetle adult population levels from the same period in 1988-89, 1990 and 1992 (Graphs 25, 26 and 23), we note at the beginning of February 700 insects (1988), 400 (1989), 160 (1990) and 90 (1992).

These results showed a decrease in rose beetle population levels on Saraoutou station **(SITE 2)** after the outbreak in 1988.

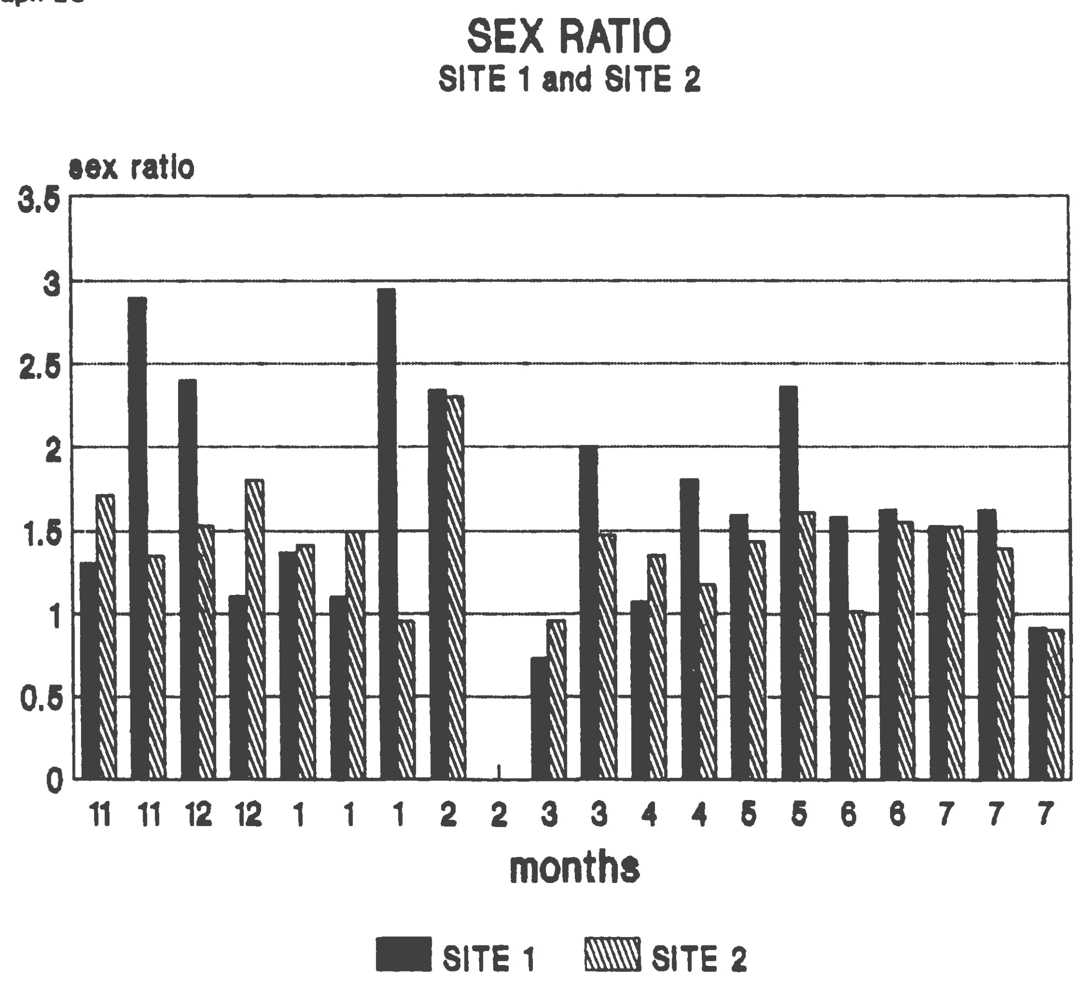
1.2.1.3. Conclusion

As in 1988, in 1992 the highest level of rose beetle population was in April and May. The rainfall after the dry season initiates the emergence of the adults.

This result correlates with the number of L3 stage in April 1992.



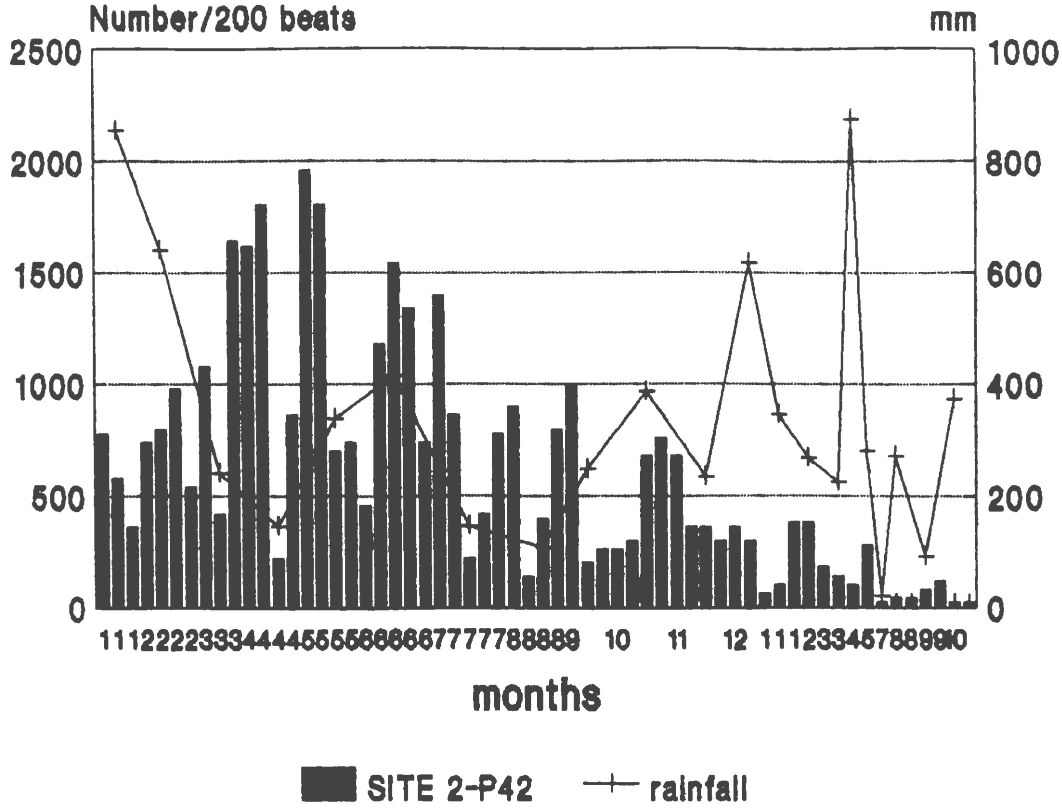
Graph 23



Graph 24

BEATING SITE 2-P42 1988-89

Number/200 beats
Insecticide traitement

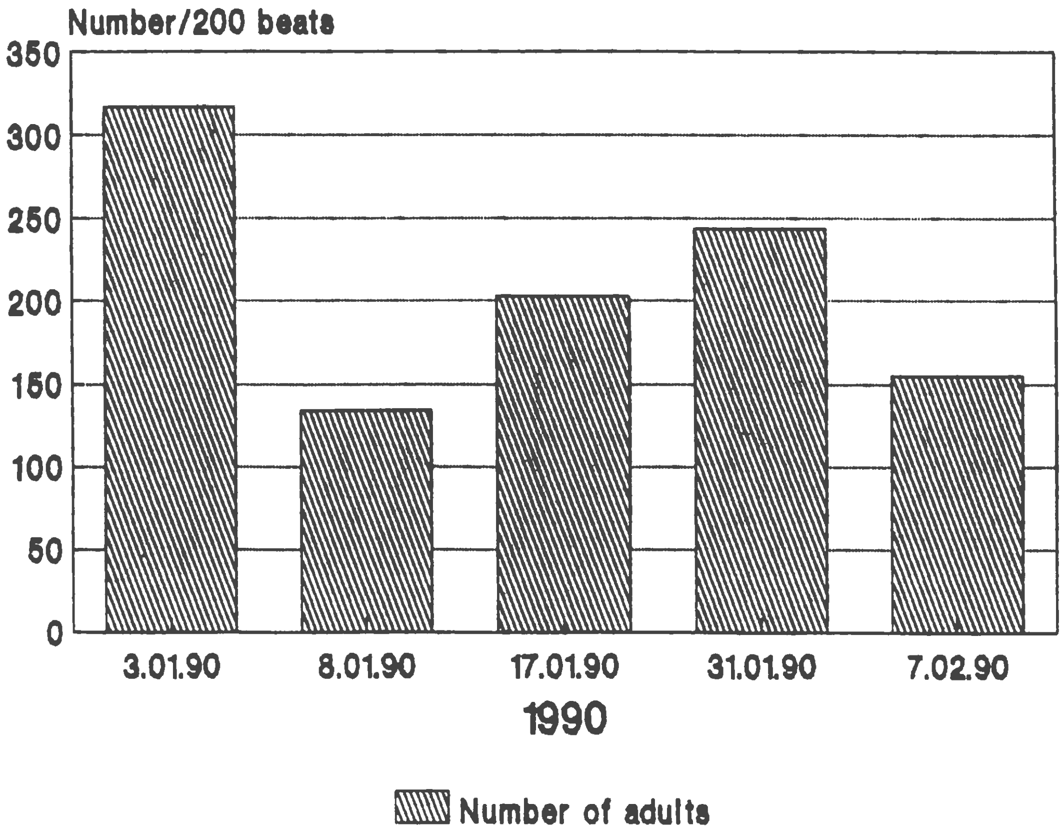


Graph 25

(according to MORIN, 1988)

BEATING SITE 2

of Jan. and Feb.1990



Graph 26

(according to LEFEUVE, 1990)

The important result is that in 1988 there were 9 times more rose beetle than in 1992.

With the beating results from 1988 to 1992, we can conclude A. versutus had considerably decreased but this has to be further investigated because it may represent only a latent phase before a new outbreak in a few years.

1.2.2. Light trap

Some beetles are highly attracted to light and others shun direct light. Also, rainfall has great influence on the emergence of Rutelins and Melolonthis **(VEERESH, 1974,1977 ; RAO, 1966, TAYLOR, 1966, GRUNER, 1973).**

To understand the activity of rose beetle during different months of the year, a light trap study was made.

1.2.2.1. Light trap technique - Materials and methods

Since the insect reveals a certain degree of phototropism, a light trap was tested.

A mercury vapour light (125 watt - 220 Volt) was used, giving a white light of 6200 lum.

The light trap was operated from the beginning of the night until, respectively, 11.30 p.m. on **SITE 1** and 12.30 p.m. on **SITE 2**.

Rose beetle appeared just at sunset, emerging from dried pasture litter and returned to the pasture and soil before 12.00 p.m.

Light trap captures of rose beetle were set up at 3 localities at first (**SITE 1a** adult cocoa plot, **SITE 2** and **SITE 1b** near laboratory) but **SITE 1a** light trap was not available at all times.

The results will be given mainly for **SITE 2** light trap.

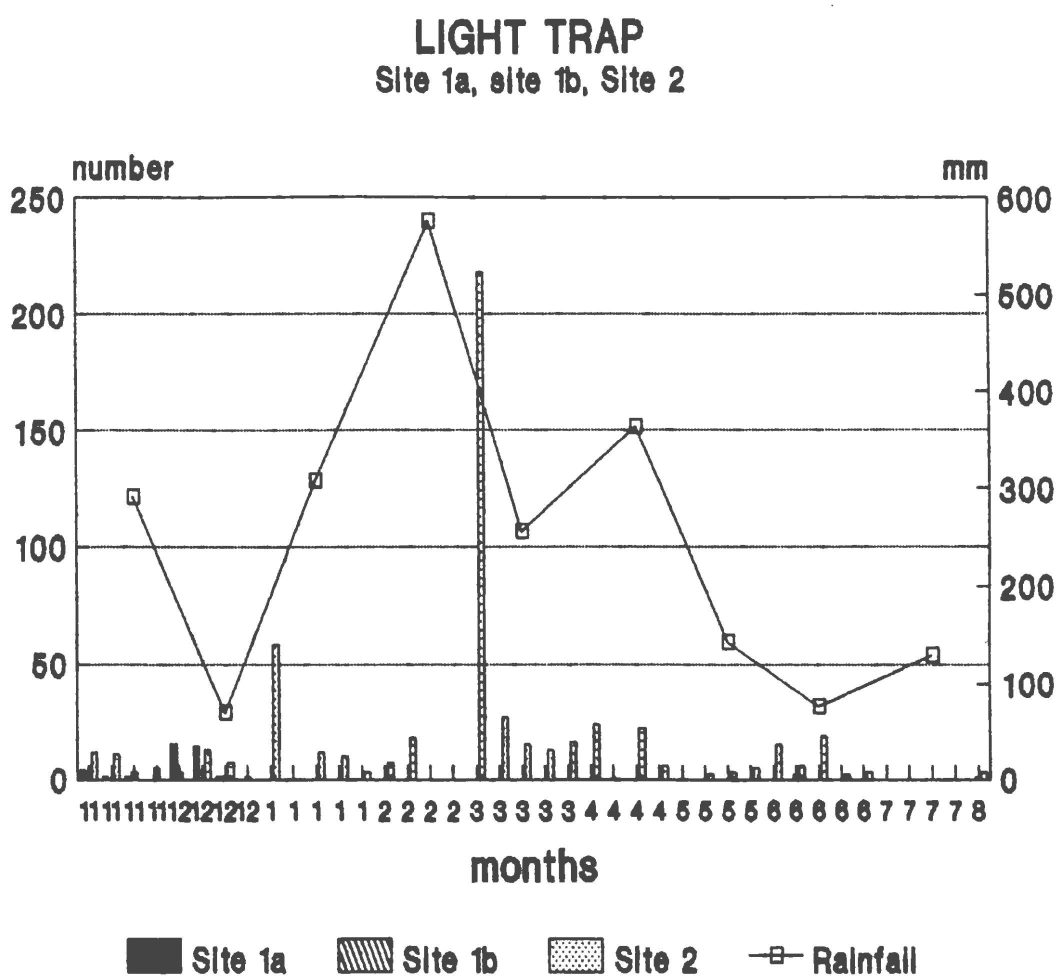
1.2.2.2. Collection results

A. versutus with nocturnal activity is attracted by lights of the house.

Large numbers of beetles were found during the period March (289), April (52) and May but rose beetle captures were low (Graph 27). Adult catches are correlated with rainfall.

VEERESH and RAJANNA (1979) collected Rutelinae by light trap during different months in the year 1978 at Hebbal (Bangalore). They observed the greatest number in April and May as we did. Among Rutelinae collected, there were Adoretus versutus, Anomala ruficapilla, A. bengalensis, A. varicolor and A. dorsalis.

We found the light trap very attractive for other small Scarabaeinae which are very useful in VANUATU because they are capable of dispersing and burying the dung of ruminants imported by man : Onthophagus gazella, Euoniticellus intermedius and Liatongus militaris (GUTIERREZ et al., 1988).


LIGHT TRAP
Site 1a, site 1b, Site 2
number
mm
250
200
150
100
50
0
600
500
400
300
200
100
0
11 11 11 11 11 12 12 12 12 1 1 1 1 1 2 2 2 2 3 3 3 3 3 4 4 4 4 5 5 5 5 6 6 6 6 6 7 7 7 8
months
Site 1a
Site 1b
Site 2
Rainfall

Graph 27

Comparison of data of 1988 (MORIN) and 1989 (LEFEUVE) :

* 1988 :

MORIN (1989) observed rose beetle collection for seven nights between January and March 1988 in two different localities. Analysis was made hour by hour from sunset until the electricity generator was shut down. No information on rose beetle activity is available for just before the beginning of the day (Graph 28). 50% of the insects (about 250) were caught during the two first hours.

* 1989 :

LEFEUVE (1990) observed that the results were very disappointing for the number of insects collected because they were very low, never exceeding 20 from November until December (Graph 29). **LEFEUVE** concluded that this technique does not give satisfactory results.

1.2.2.3. Conclusion

The light trap enabled Adoretus versutus to be captured but collection sizes were much smaller than with the previous method described (1.2.1.). Even if population levels were greater in 1988, **MORIN (1989)** made the same conclusion.

Results obtained by **LEFEUVE (1990)** during November and December 1989 were similar to those obtained in the present study for the same period in 1991.

Use of a light trap is interesting only for activity studies in the night and for insect percentages at a particular site. Beating is the best technique to directly monitor population levels and damage on cocoa trees.

Light trap and beating data enable the activity of the insects during the seasons in relation to ecosystem factors to be assessed.

2. Pheromones

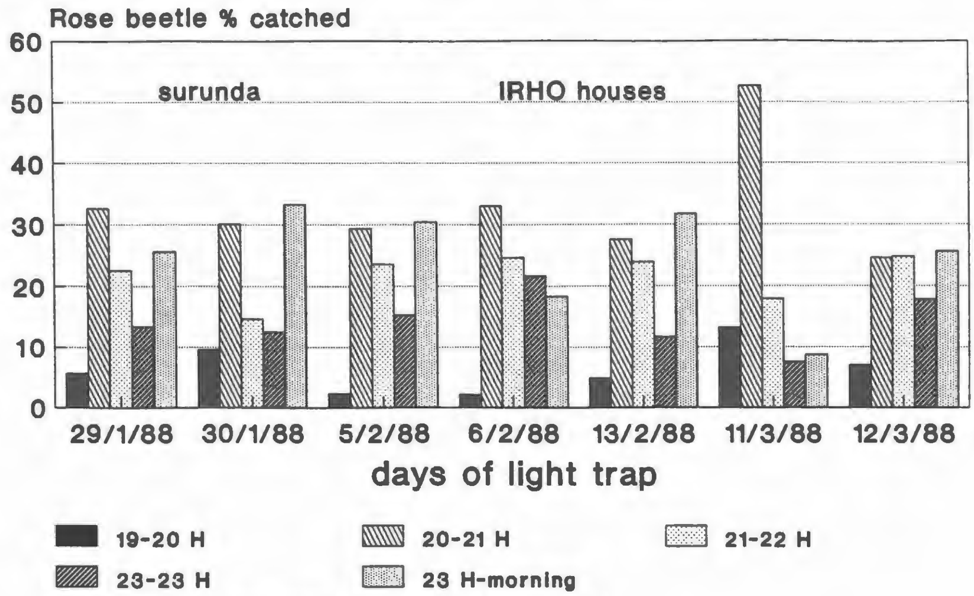
2.1. Materials and methods

Attractive traps could be tested : Adoretus sp. is sensitive to nerolidol and to geraniol **(DONALDSON et al., 1986)**.

The chemical traps were located in 3 places on **SITE 1.**

The experimental chemical (eugenol) was placed on filter paper in a round box in the middle of the trap. The chemical was renewed twice each week for 3 weeks and the trapped insects were collected every day or every three days.

LIGHT TRAP
ROSE BEETLE % LINKS TO NIGHT PERIOD
night at 19h30

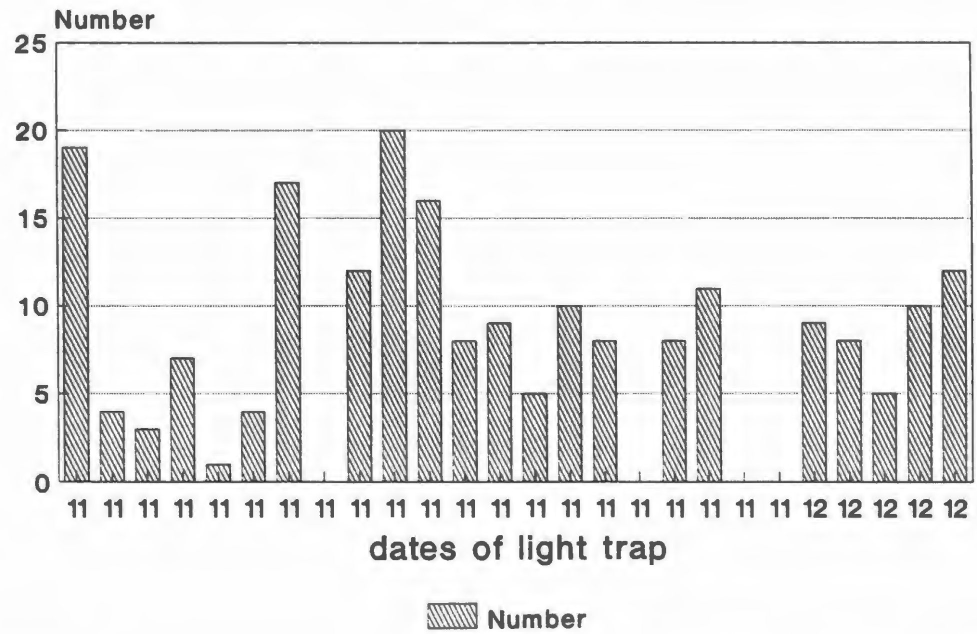


P1 mercure vapor (6200 lumens)
P2 12V tube (UV)

Graph 28

(according to MORIN, 1988)

LIGHT TRAP
Nov. and Dec. 1989



Graph 29

(according to LEFEUVE, 1990)

2.2. Results

Eugenol did not appear to be very attractive for rose beetle during the experiment.

No interesting results were obtained.

However, we noted that a particular odour emits from rose beetle adults collected directly from the host plant and stored in plastic boxes.

2.3. Arrangements for overseas studies

Contact has been made in France with the chemical mediators INRA laboratory (Mrs B. FREROT) to obtain some ideas (Annex 4).

Adults were sent to France with a traveller (Mr CALVEZ) but, unfortunately, the insects arrived dead.

CHAPTER III
BIOLOGICAL CONTROL STUDIES

Among biological control agents, pathogens have special capabilities. Being relatively immobile, they tend to rely on the infected host for transmission from one host population to another, and can thus overcome the limitations imposed on the more independent parasites and predators by scattered host distribution or cryptic habits. In the same way the possession of resistant stages enables pathogens to span seasonal interruptions in host activity and abundance (DALE, 1977).

A- SCREENING OF BIOLOGICAL CONTROL AGENTS

1. Bibliographic data

1.1. Insects

Nematodes actively infest insects which they kill in 24-48 hours if ambient conditions are favorable (10°C < temperature < 28°C).

Steinernematidae are non-specific and show a wide spectrum of activity. There are four larval stages but only the free L3 stage is infectious for insects because of their high resistance in the soil in unfavourable conditions.

The L3 nematode penetration is by the anal or buccal orifices **(WEISER, 1964, POINAR, 1975, 1979)**. Once inside the insects, the nematodes migrate to the faeces and hemocoele where bacteria (Xenorhabdus nematophilus) are liberated. The insect dies quickly and the nematodes continue their development. When new L3 are produced they can leave the host insect to infest new host insects.

Generally, "green muscardine" due to Metarhizium anisopliae developed on larvae and adults **(ROBERT, 1989)**. It is possible to observe spores of the fungus under the microscope in a water droplet . Document 1 (Annex 2) summarises the different phases of the life-cycle of a muscardine in an insect host **(ROBERT)**.

1.2. Coleoptera

Fungi imperfecti from a natural population of Otiorrhynchus sulcatus (Metarhizium flavoviride, M. anisopliae, Paecilomyces fumuso-roseus, Beauveria bassiana, B. brongniartii), Nematodes Rhabditida, Bacillus cereus have been isolated **(MARCHAL, 1977)**

Field prospections showed that the fungus Beauveria bassiana Vuillemin was the predominant enemy of Sitonia discoideus Gyllenhal (Col. Curculionidae) larvae and pupae in the Mediterranean region **(AESCHLIMANN et al., 1985).**

1.3. Scarabaeidae

Neoaplectana carpocapsae (= Steinerneama feltiae) and Heterorhabditis sp. have been used successfully for control of several turfgrass scarabs including Japanese beetle, Popillia japonica, European chafer, Rhizotrogus majalis, and northern masked chafer, Cyclocephala borealis **(KLEIN, 1987, VILLANI and WRIGHT, 1987, SHETLAR et al., 1988)**

Heterorhabditis megidis sp. (Heterorhabditidae : Rhabditidae) parasitized third stage Japanese beetle larvae, Popillia japonica (Coleoptera Scarabaeidae) collected in Ohio **(POINAR et al., 1987).**

Five entomophagous nematodes were evaluated in the laboratory against the white grub Lygyrus subtropicus, a serious pest of sugarcane in Florida. L. subtropicus appears to be an excellent host for Steinernema glaseri **(OMELIO SOSA et al., 1985).**

S. entomophila has been found highly pathogenic for, and specific to, grass grub, Costelytra zealandica (Col. Scarab.)**(GLARE et Al., 1990).**

In Cetonia aurata L. (Coleoptera Scarabaeidae) breeding, a disease caused by Adelina sp. (Protozoa-Coccidia) was recorded by **ROBERT (1989).**

1.4. Melolonthinae

We note that a biological control program of Hoplochelus marginalis, introduced from Madagascar to La Reunion island in 1972, has been developed including :

- entomophagous insects such as Campsomeris spp. and Tiphia parallela (Hym. Scoliidae),
- entomopathogenic microorganisms such as viruses, bacteria, fungi, protozoans and rickettsia. Finally, the strain Metarhizium anisopliae 78 and a new strain of Beauveria brongniartii have been selected for their efficacity, the latter showing good capacity to control the pest agronomically **(VERCAMBRE et al., 1990).**

1.5. Rutelinae

Studies on Adoretus hirsutus in China **(CHANG et al., 1980)** showed that larvae were susceptible to attack by Bacillus popilliae, which has been used successfully against the Japanese beetle Popillia japonica in the United States. Limited trials made in Western Samoa indicated that Adoretus versutus could be killed by exposure to the baculovirus Oryctes and the fungus Metarhizium anisopliae **(PUREA,1971).**

Document 2 (Annex 2) shows some examples of introductions for the biological control of Adoretus versutus **(WATERHOUSE and NORRIS, 1987)** and a review of natural biological control of Adoretus spp., information collected from a request made in 1989.

A catalogue of the parasites and predators of insect pests has been established by THOMPSON (1943).

2. Results from laboratory tests using nematodes from INRA.

Two nematode strains have been imported from France:
- Steinernema carpocapsae (PB, K27),
- Heterorhabditis bacteriophora : H88

These nematodes are usually used in biological control as entomopathogens.

To try to breed nematodes in the laboratory, it was hoped to import Galleria mellonella as host insect. This proved impossible because this insect is a serious pest of beehives and Vanuatu has banned its import. Instead, local moths were bred on wax, for use as host insect in nematode tests.

2.1. Infestation technique and results

Eight repeats were made of tests to infest moth larvae and Adoretus versutus larvae.

In each of three petri dishes (Φ 90mm;h=13mm) 10 Adoretus larvae , and in three other petri dishes 10 moth larvae, were placed on filter paper impregnated with 1,5 ml of nematode solution.

The nematode-moth and nematode-Adoretus complexes were incubated at room temperature (28°C). We observed that most Adoretus larvae died between 24 hours and 48 hours but that a few days were necessary to obtain dead moth larvae, which may transform into adults during this time.

2.2. Nematode collection and results

Document 3 and photo 18 show the procedure.

Dead Adoretus or moth larvae are put on filter paper into a large petri dish (Φ 145mm;h=23mm) containing some water.

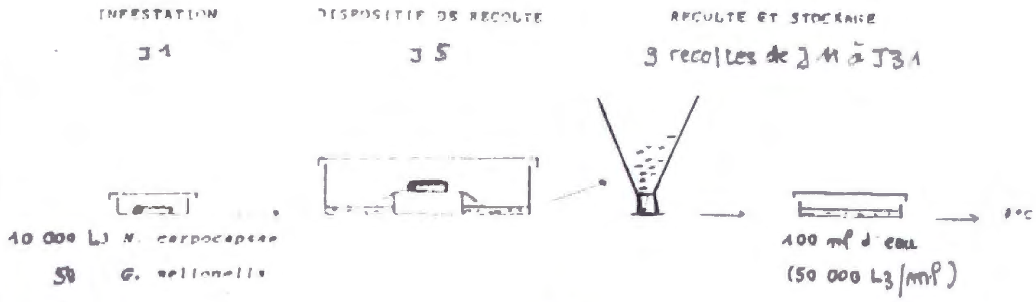
L3 leaves the cadaver and migrates to the wet paper, and thus into the water where they can be kept. The nematodes can be collected for one month.Using this nematode solution, Adoretus larvae can be infested.

2.3. Nematodes isolated from the soil

From soil samples, nematodes can be isolated and identified. Few nematodes were isolated but were identified as soil free nematodes belonging to the order Thylenchida that are of no interest in biological control.

2.4. Results

Only Steinernema carpocapsae was properly tested because it was impossible to store Heterorhabditis entomophaga at the required 9-14°C in the laboratory (electricity generator was shut down during the night).



Document 3 : Scheme of production of nematode with moth

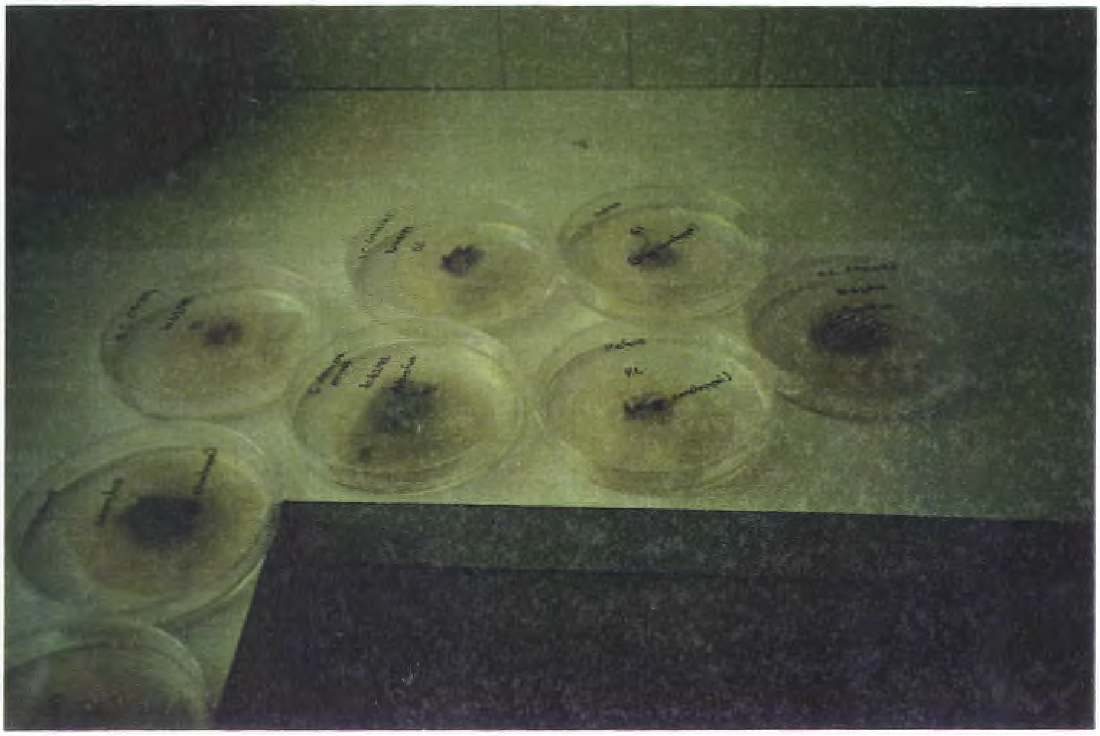


Photo 18 : Collect technique

S. carpocapsae gave good results but not enough tests were performed because it was difficult to store nematodes under laboratory conditions. It will be necessary to carry out further studies.

3. Fungi at INRA

In the laboratory, Serratia entomophila strains and Adelina strains (coccidia) could not be developed on Adoretus.

Serratia marcescens is a bacterium. Symptoms of the disease are typical. An insect killed by this disease has the body and hemolymph a pink colour.

4. Diseases from Taro beetle

Taro beetle (Papuana uninodis) is one of the most important insect pests in the Solomon islands.

B.THISTLETON and W. THEUNIS carried out research on Taro beetle diseases.

Six strains of the rhinoceros beetle baculovirus Baculovirus oryctes and six strains of Metarhizium anisopliae were isolated.

Other contacts were developed with workers overseas and arrangements made to obtain cultures of various pathogens (Metarhizium anisopliae, M. flavorivide, Beauveria bassiana, B. brongniartii, Paecilomyces lilacinus, Bacillus thuringiensis) of scarabs for testing in the Solomon islands (Annex 3).

No diseases were isolated from field-collected larvae. Twelve dead insects (larvae and pupae) from the laboratory were found to be infected with fungi. In eight of these, the fungus was identified as Metarhizium anisopliae.

Metarhizium anisopliae and bacillus thuringiensis were successfully cultured on nutrient agar.

Concerning disease tests, preliminary results gave positive results for infection by Metarhizium anisopliae, but not as yet for baculovirus oryctes or Bacillus thuringiensis.

The idea was to transfer diseases from the Solomon islands to Vanuatu but delays have occurred in the Solomon islands.

B- FIELD STUDIES

1. Disease sampling in VANUATU

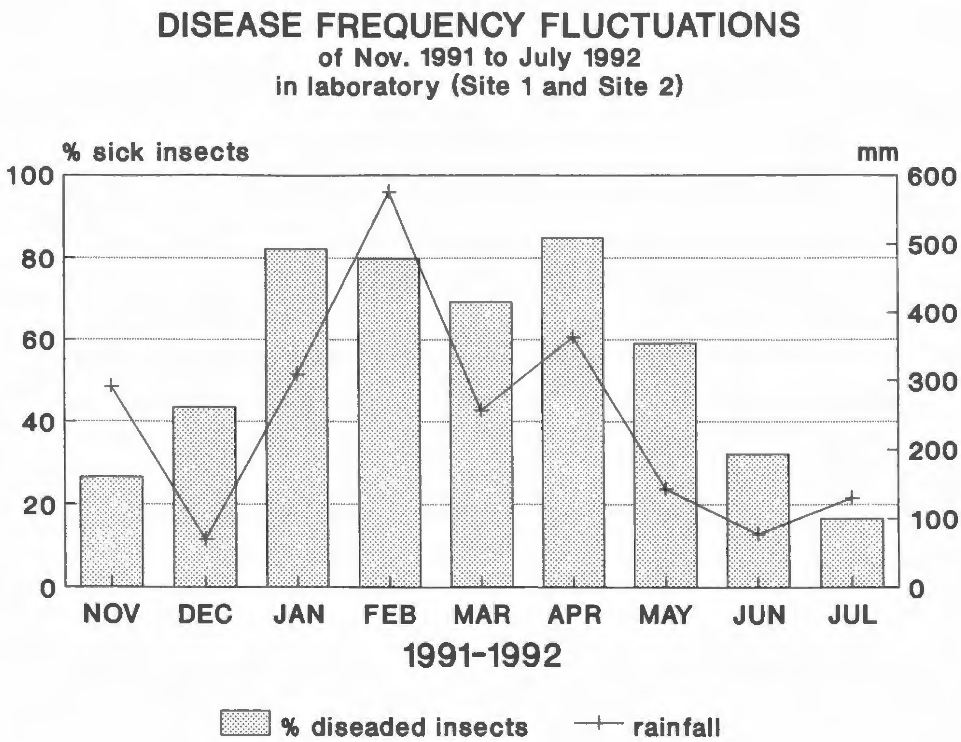
1.1. Larvae

1.1.1. From monthly samples

Each stage collected from 10 biotopes, on **Valeteruru station (SITE 1)** and **Saraoutou station (SITE 2)**, was bred in the laboratory to investigate disease development. Most of the diseases recorded were observed on larvae (L1, L2 and L3).

Photo 19 : Green muscardine on rose beetle larvae
(Vanuatu 1992)

Photo 20 : Dead rose beetle larvae for haemolymph exam
(Vanuatu 1992)


DISEASE FREQUENCY FLUCTUATIONS
of Nov. 1991 to July 1992
in laboratory (Site 1 and Site 2)
% sick insects
mm
100
80
60
40
20
0
600
500
400
300
200
100
0
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
1991-1992
% diseaded insects
rainfall

Graph 30

Techniques used for disease observation were :

- For fungus observation : From dead larvae, a green or a white muscardine can be observed under a binocular lens, (photo 19). For examination under the microscope, a sample of the green or white mycelium was deposited on a piece of cellotape and mounted thus on a slide. If the microscopic preparation was fine enough, spores could be observed and identified.

- For the detection of other diseases, histochemical techniques were used :

Hemolymph collected from the dead larvae (photo 20) was placed on a slide. When the hemolymph had dried, Methyl eosin blue (May Grunwald) was applied to colour the pathogens.

1.1.1.1. Disease frequency for different biotopes

Disease was observed in from 43 to 62% of larvae collected in the field from the 10 different biotopes and those bred in the laboratory.

The results showed no great difference between the percentage of diseased insects on **SITE 1** (46-63%) and **SITE 2** (43-53%), but the four sites on **SITE 2** seemed to show lower levels of disease.

1.1.1.2. Disease frequency from November 1991 to July 1992

Graph 30 shows that a greater number of insects with disease were noted between January and April (69-84%) during the rainy season, whereas usually levels do not go above 43 %. The wet season could favour disease development (fungi for example.)

1.1.1.3. Diseases recorded between November 1991 and July 1992

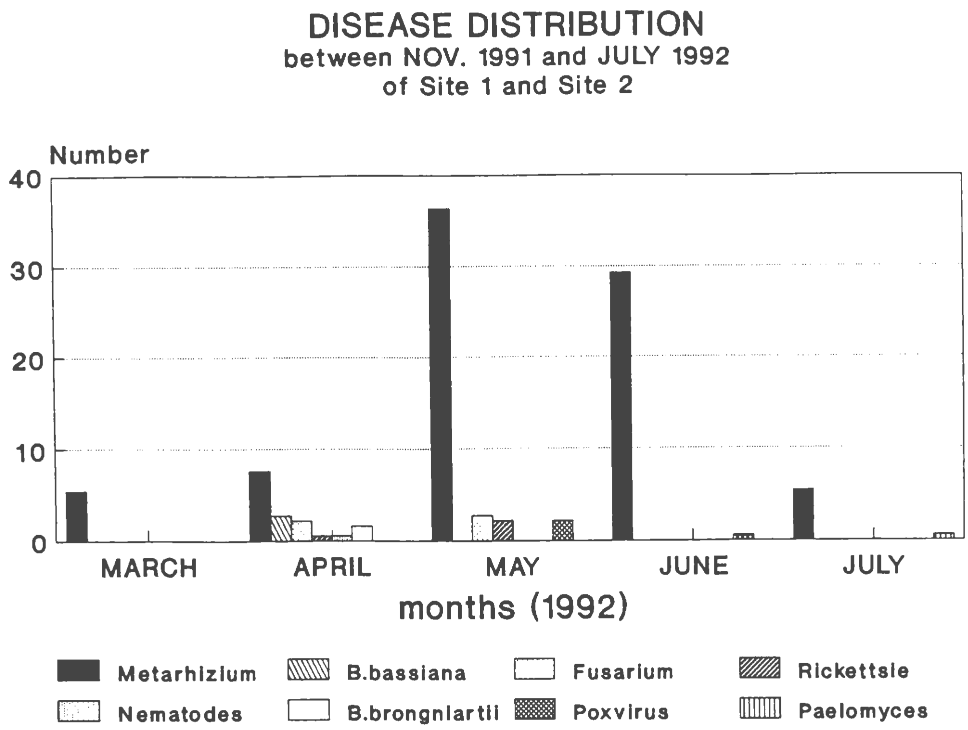
Pathogenic agents encountered on **Site 1** and **SITE 2** are : metarhizium, Beauveria bassiana, B. brongniartii, Fusarium, Rickettsia, Poxvirus, Paelomyces and Nematodes.

Graph 31 : Most of Metarhizium observations were reported in May and June 1992. Most of the diseases noted were recorded in April 1992.

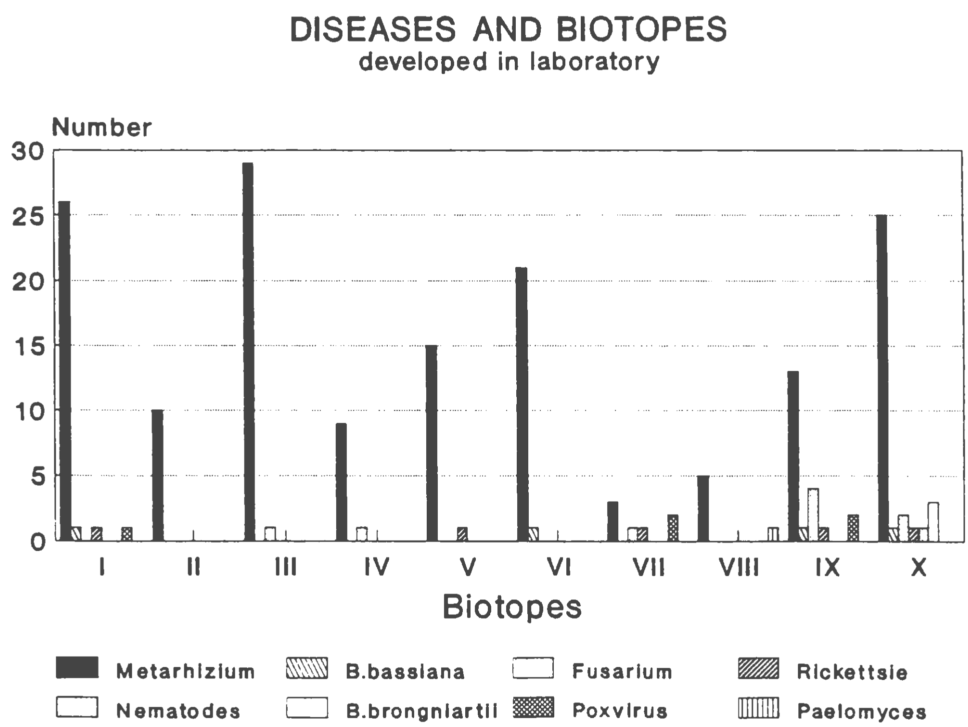
1.1.1.4. Diseases and sites observed

Graph 32 shows that Metarhizium was observed from larvae collected in each of the 10 biotopes on **SITE 1** and **SITE 2**.

This result shows that Metarhizium is present everywhere and can be developed on rose beetle larvae.



Graph 31



Graph 32

1.1.1.5. Average period of disease development in the laboratory

The average period for disease development was found to be from 1 to 7 weeks. For Fusarium, Rickettsia, Poxvirus, about 6 weeks were necessary to observe the disease from dead larvae. For Metarhizium, dead larvae were analysed after 5 weeks. For the other diseases, only a few diseased specimens were analysed.

1.1.1.6. Disease development times

Graph 33 : Most of the diseases were observed, usually between 1 and five weeks after collection in the field (Fusarium, Metarhizium, Paelomyces, Rickettsia, poxvirus...)

1.1.2. From other collections

From December 1991 to June 1992, beetle larvae from VANUATU and soil samples were sent to FRANCE for identification and investigation of parasites and pathogens in the INRA laboratory (Annex 4).

1.1.2.1. Pathogens isolated from larvae (Document 4 and Graph 34)

* **Sample 1** : Specimens identified as Adoretus. 49 larvae and 9 prepupae were put under observation and in 7% Metarhizium was observed.

* **Sample 2** : 71 larvae and 1 nymph of Adoretus and 15 Cetoninae larvae were identified and put under observation.

Metarhizium was observed on 18% of Adoretus specimens and Serratia marcescens on 1.4%.

* **Sample 3** : 51 Adoretus larvae and 1 nymph on which 2 cases of Metarhizium (4%) and 2 Serratia marcescens (4%) were observed.

* **Sample 4** : 6 Cetoninae larvae and 8 Melolonthinae larvae with one case of Metarhizium (12%) on Adoretus.

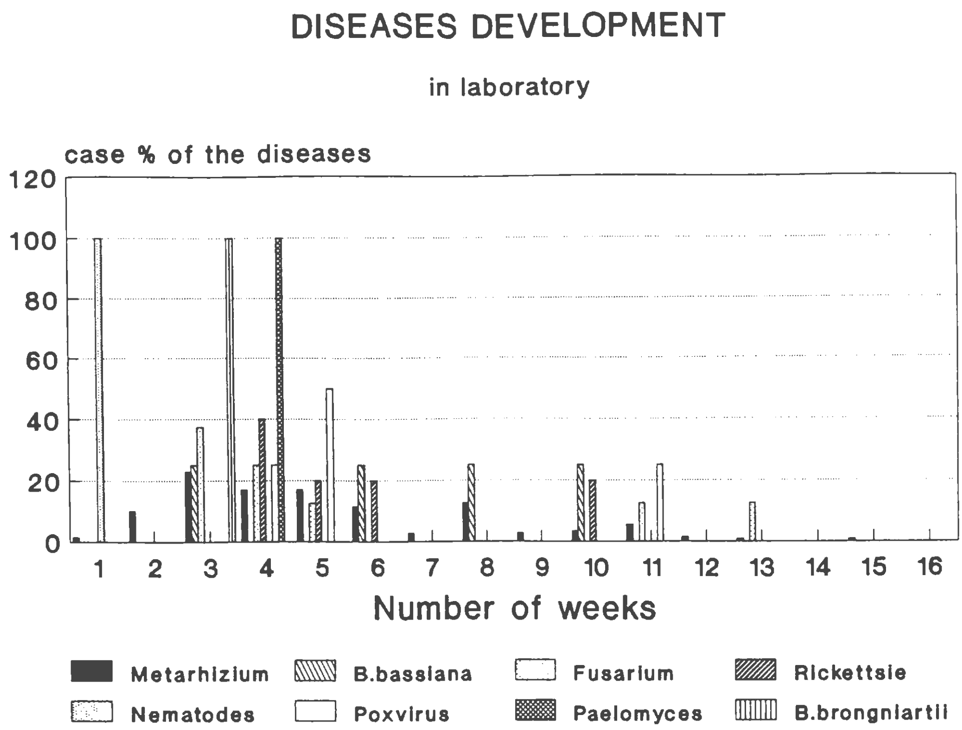
* **Sample 5** : 164 Adoretus larvae with 9 cases of Metarhizium observed (9%).

* **Sample 6** : 202 Adoretus larvae with 24 cases of Metarhizium observed (12%) and 1 case of Bacillus sphaericus (0.5%) and 1 case of Bacillus cereus (0.5%).

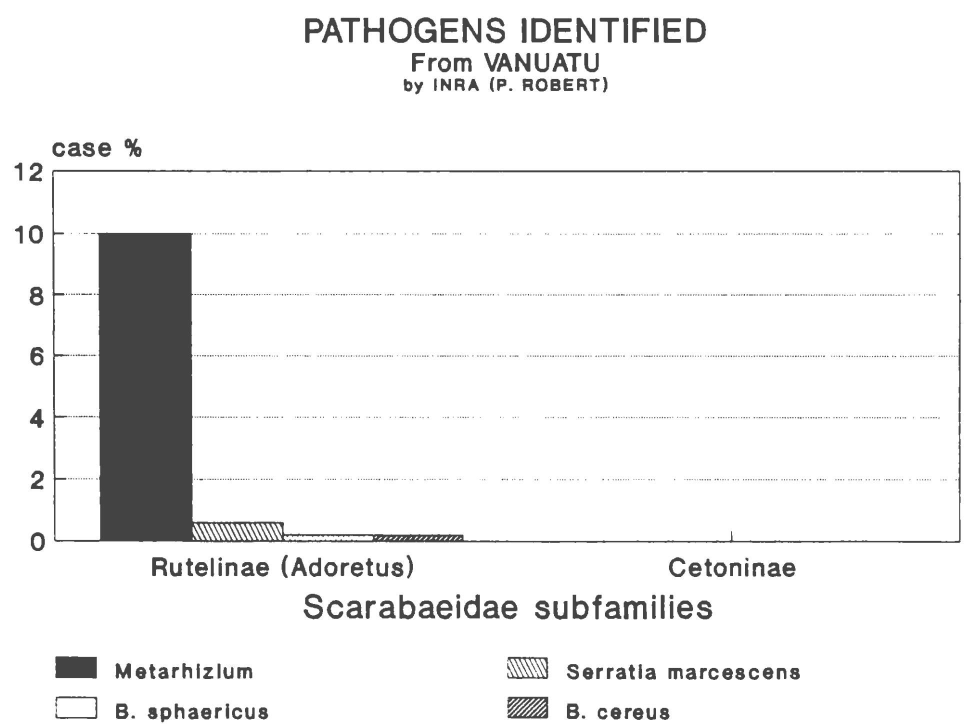
All these results are compiled in Document 4 and Graph 34.

The assigment to subfamily Rutelinae and genus Adoretus (**BARAUD et al., RICHTER 1966**), has been confirmed after the positive identification by CIRAD, Montpellier (taxonomic and faunistic laboratory) of larvae, and adults emerged from larvae, collected and put in quarantine.

However, quarantine has only been realised for Sample 1 and the results will be completed in the next few months.



Graph 33



Graph 34

RESULTS OF FIELD SAMPLES ANALYSED BY INRA
Document 4

N°	date reception	Subfamily Genus	Number of insects in quarantine	Pathologic observations	For determination
1	23-12-91	Adoretus	49 L + 9 PN	4 Metarhizium	
2	19-2-92	Adoretus	71 L + 1 N	13 Metarhizium 1 Serratia marcescens	
		Cetoninae	15 L	-	2 I.P.
3	4-3-92	Adoretus	51 L + 1 N	2 Metarhizium 2 Serratia marcescens	
4	30-3-92	Adoretus	8 L	1 Metarhizium	
		Cetoninae	6 L	-	
5	17-4-92	Adoretus	164 L	9 Metarhizium	16 I.P.
6	8-6-92	Adoretus	202 L	24 Metarhizium 1 Bacillus cereus 1 B. sphaericus	

RESULTS OF FIELD SAMPLES IN SOUTH PACIFIC AND
ORIGIN AREA ANALYSED BY INRA
Document 5

Country	date reception	Subfamily Genus	Number of insects in quarantine	Pathologic observations	For determination
Fiji :	12-3-92				
-Vitilevu		Adoretus	21 L	2 Bacillus cereus	
-Vanualevu		Adoretus	38 L	29 Poxvirus 1 Metarhizium	
Sri Lanka	14-5-92	Melolonthinae	18 L	R.A.S.	
Cooks islds	23-6-92 26-6-92	Adoretus	34 L	R.A.S.	
West.Samoa	2-7-92	Adoretus	40 L + 2 N	1 Metarhizium 1 Bacillus sphaericus	1 I.P.
Tonga	3-7-92	Adoretus	52 L	R.A.S.	
Fiji	10-7-92	Adoretus	37 L	R.A.S.	

BACILLUS THURINGIENSIS AND B.SPHAERICUS STRAINS
Document 6

Origin	Nb samples	Analysis	Nb of Bt	Nb of B.sphaericus
VANUATU	66	30	9	5
FIJI	24	8	0	2
SRI LANKA	57	8	2	0
COOK ISLDS	11	5	2	0
TONGA	8	5	0	0
FIJI	7	5	0	0
WEST.SAMOA	10	5	0	0
	----------	----------	----------	-------------
	183	66	13	7

1.1.2.2. Pathogens isolated from soil samples.

1.1.2.2.1. Bibliographic data

Two Bacillus thuringiensis strains (LM 63 and LM 79) showed a toxic activity against the Coleopteran chrysomelid larvae : Leptinotarsa decemlineata, Phaedon cochleariae, Melasoma populi and Melasoma tremulae (CHAUFAUX et al., 1990).

Bacillus cereus, B. popilliae and Serratia marcescens were isolated from pest June beetles, Phyllophaga spp. in Southern Quebec (POPRAWSKI et al., 1990)

1.1.2.2.2. Results

From 66 soil samples sent to FRANCE, 30 were analysed and the following pathogens were observed (Document 6) :

- 9 Bacillus thuringiensis (30%)
- 5 Bacillus sphaericus (17%).

We noted a large percentage of Bacillus thuringiensis in VANUATU soil. This could be very important.

Electrophoretic characterization has been realized on 9 Bacillus thuringiensis strains isolated from soil samples : 5 strains showed two bands : 40 and 25 Kdaltons,

2 strains showed two bands : 132 and 40 Kdaltons,

2 strains showed two bands : 40 and 45 Kdaltons.

Seven strains were considered atypical strains (40 and 25 kdaltons ; 40 and 45 Kdaltons) because they do not resemble known larval pathogen strains of insects such as Diptera, Coleoptera or Lepidoptera. However, 2 other strains showed bands at 132 Kdaltons. This resembles a Lepidoptera pathogen strain.

These strains will be tested for pathogenic activity on insects available at the INRA laboratory (La Miniere).

From 10 soil samples sent to CIRAD, Montpellier, 19 Bacillus thuriniensis strains have been isolated.

1.2. Adults

Adults collected from beating, light traps or other collections were observed in the laboratory in Santo.

Aspergillus was observed on dead adults in the laboratory.

1.3. Conclusions

It is important to note that the white grubs belonged to three subfamilies of Scarabaeidae family : Cetoninae, Rutelinae and Melolonthinae.

Metarhizium anisopliae was often observed on rose beetle specimens in VANUATU (photo 21 and Graph 34).

This suggests that the fungus will be a good regulatory agent of Adoretus versutus populations in VANUATU.

We found many cases of Bacillus sphaericus and B. cereus and a few examples of Serratia marcescens in dead larvae and soil samples.

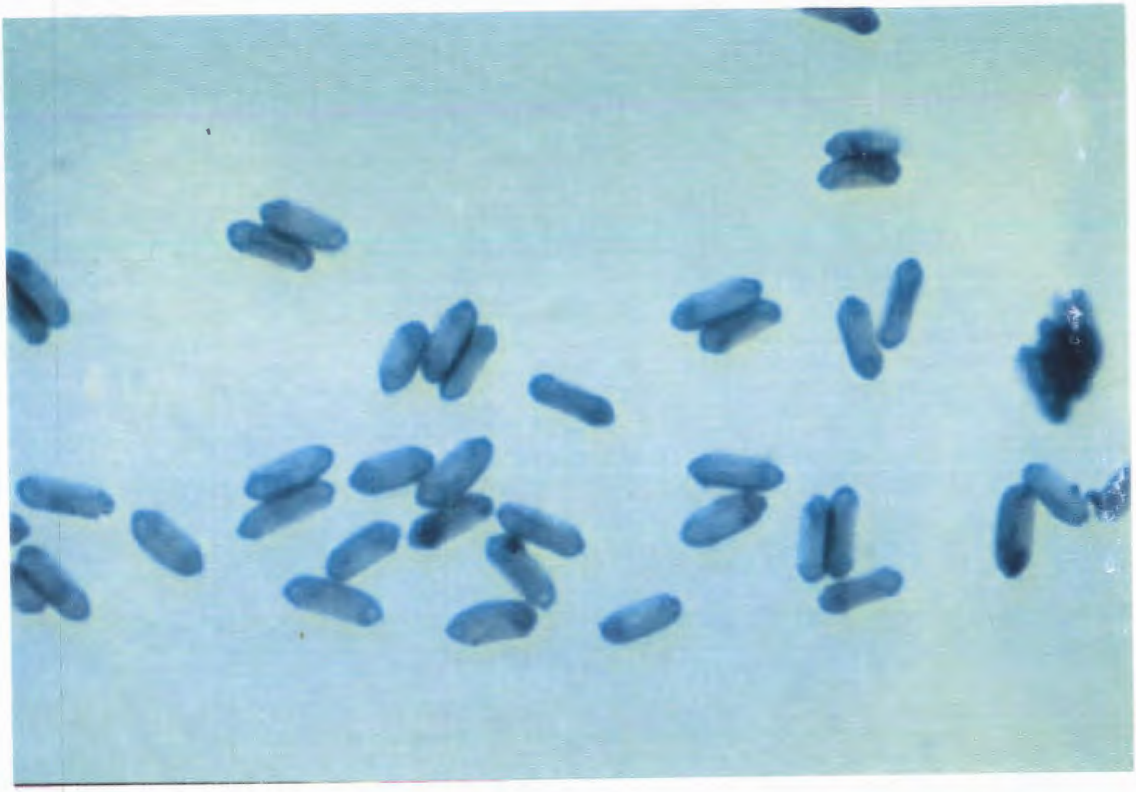


Photo 21 : *Metarhizium anisopliae* isolated from *Adoretus versutus (Vanuatu)*

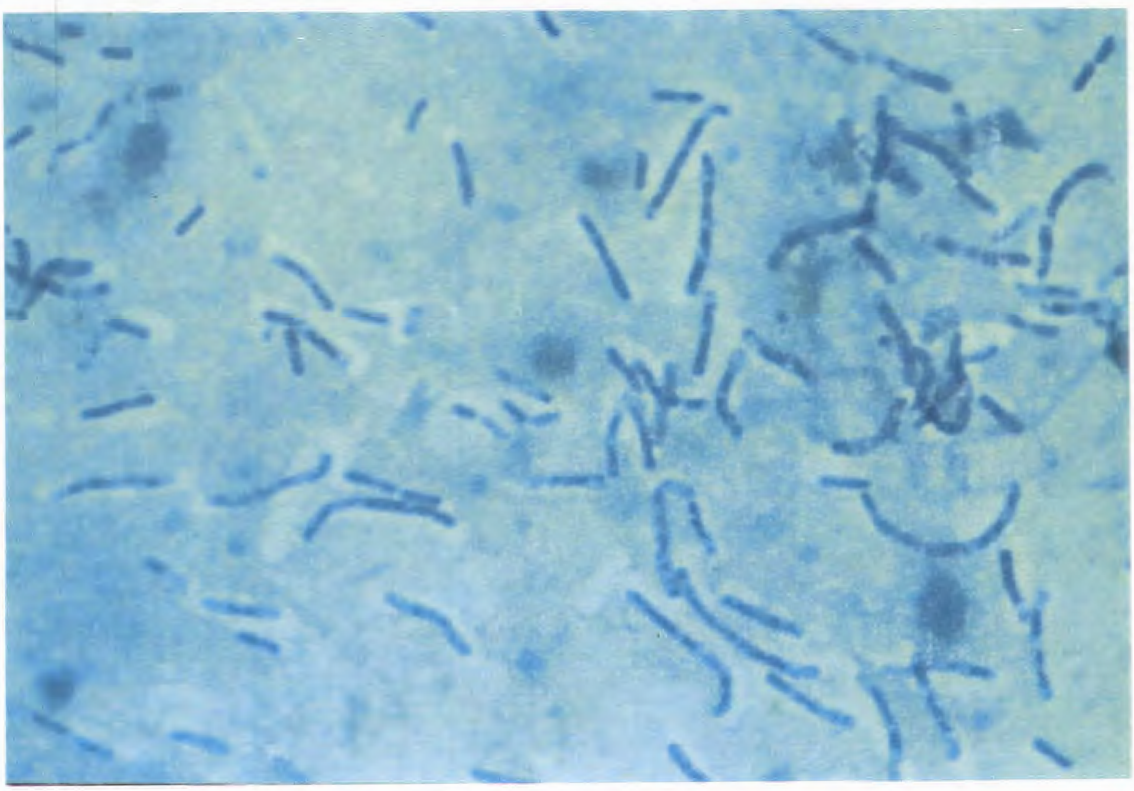


Photo 22 : *Bacillus thuringiensis* isolated from soil samples (Vanuatu)

Bacillus thuringiensis was found in soil samples (30% of the analysed samples) (photo 22).

From 7384 rose beetle individuals bred in the laboratory from November 1991 to July 1992, 3856 died, about 52% - similar to the figure found in the control of mortality after collection on **SITE 1** and **SITE 2**.

Among dead insects, 184 cases of disease were identified (2,5%).

2. Check on the establishment of Micromeriella marginella modesta in VANUATU.

115 field-collected mated females of C. marginella modesta (Smith)(Document 7) were sent by Hawaii Department of Agriculture to Bob Weller on 14th february 1984.

2.1. Collection of samples from EFATE

A visit was organized in March 1992 with the help of B. TARILONGI (Annexes 4 and 5).

The collection on Efate is the collection noted **sample 4** in 1.1.2. and in which only Cetoninae and Melolonthinae were found.

4 localities were prospected :

- Charly ROGERS plantation in Montmartre (photo 23),
- North Efate,
- Mélé,
- Tagabe

Only 1 case of Metarhizium was observed.
No parasite was isolated.

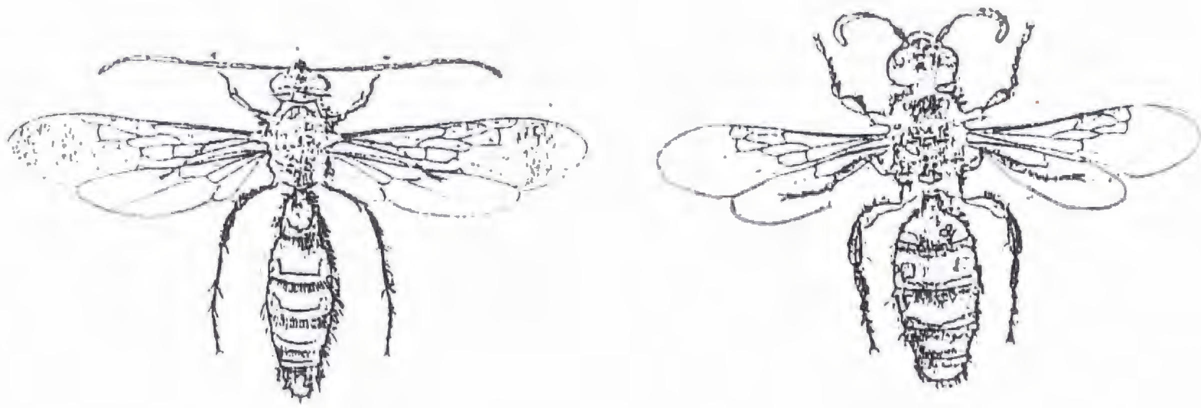
2.2. Comparison of populations with Espiritu Santo

On Efate island, damage seemed to have stabilized at much lower levels in the last few years. The reason for this is not known at present but should be investigated.

3. Collection of biological control agents from other countries.

3.1. Visit to Fiji to locate Micromeriella marginella.

There is no evidence that the scoliid wasp from Hawaii has reduced the pest status of A. versutus in Fiji. It was, in any case introduced primarily for the control of other beetle pests in sugarcane (Rhopaea sp.) (LEVER, 1945). A partial success for this scoliid from the Philippines against A. sinicus Burm. in Hawaii is claimed by De BACH (1964). It is not known whether the two parasitic fungi from Hawaii, Sterigmatomycosis feruginosis, botrytis sp. and Beauveria sp. (JEPSON, in LEVER, 1945) have become established in Fiji.



Document 7 : *Micromeriella marginella modesta*
(= Scolia manilae) (X 5)

Photo 23 : Cocoa plantation and pasture on Efate island
(Vanuatu - March 1992)

M. marginella modesta (=Scolia manilae Ashm.)(Philippine origin) was introduced from Hawaii in 1917.

Over 800 adults (600 mated females, 200 males) were released in an infested area (Sigatoka district). It was not at first thought to be established because no trace of the parasite could be found during the ensuing twelve months but was finally recovered five years later, 60 miles away from the point of release (Dreketi near Lautoka mill). It was believed to assist in controlling the above 2 species of beetles and also R. subnitida (VEITCH, 1919 and 1924 ; O'CONNOR, 1950).

3.2. Collection and comparison of populations with VANUATU.

Visits were organized with the help of Sada LAL, and Mr MISIKINI in Vanualevu at the beginning of March 1992 (Annexes 4 and 5).

21 Adoretus larvae on Vitilevu island and 38 on Vanualevu island (map D, Annex 1) were collected and sent to FRANCE.

- Site A : 35 km north east of Suva (Vitilevu): Naduruloulou Research Station, Ministry of Primary Industries ; 20 squares 25x25x10cm were sampled (photo 24).
- Site B : Vanualevu (Labassa) ; 31+15 squares 25x25x10cm were sampled.

No parasites were isolated but another very interesting result has been mentioned. The results are compiled in following section (3.3.1.). No comparison with VANUATU could be made.

3.3. Visits to South Pacific islands

3.3.1. Fiji (map E, Annex 1)

3.3.1.1. Materials and methods

* A first collection was organized on Vitilevu and Vanualevu islands (main islands of Fiji) to investigate the parasite introduced in 1917, Micromeriella marginella modesta.

* A second collection was organized to investigate pathogens and parasites on Vitilevu and Taveuni islands (map D, Annex 1).

The Fiji visits were organized by Sada LAL and Parnish PRASAD (Annexes 4 and 5).

Three localities were visited to the north of Suva (80 km) on the east coast :

. WAIMARO Farm : 7 larvae collected,
. VUNIVESSI : no samples found,
. DOBUILEVU Research station : 31 beetle larvae were collected in wet soil between stones.

They were stored in a box with compartments with soil and a piece of carrot as source of food.

Soil samples were collected.

Photo 24 : Sampling on Vitilevu island (Fiji)
in March 1992

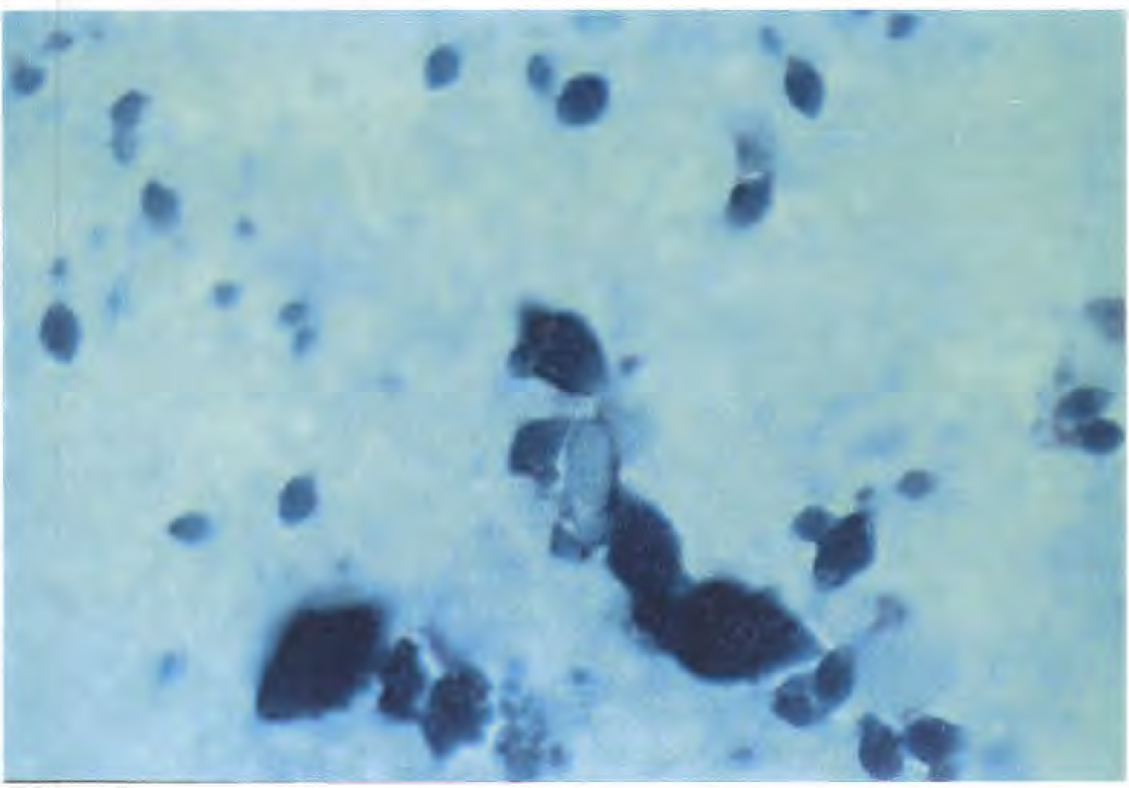


Photo 25 : *Entomopoxvirus* isolated from *Melolonthinae* larvae collected on Vanualevu (Fiji)

3.3.1.2. Results (Document 5)

* From the first collection, 21 beetle larvae from Vitilevu, 38 beetle larvae from Vanualevu are under observation. Results from INRA showed 2 Bacillus cereus from the Vitilevu collection, 1 Metarhizium and 29 Poxvirus (photo 25)(76%) from the Vanualevu collection, on specimens identified as Melolonthinae (Graph 35).

From 24 soil samples, 8 were analysed and 2 Bacillus sphaericus were observed (25%) (Document 6).

* From the second collection, beetle larvae samples were identified as Rutelinae, Adoretus specimens. 37 larvae are under observation and nothing has been noted for the moment (Document 5).

From 7 soil samples, 5 were analysed and nothing was isolated (Document 6).

In conclusion, Entomopoxvirus was discovered on Rutelinae, Adoretus larvae on Vanualevu island in Fiji. It is the first time that this poxvirus has been discovered in the world and it is of interest because it is present only on Vanualevu island.

Similar cytoplasmic inclusions have been isolated on Melolontha melolontha L. (HURPIN et al., 1963).

On REUNION island, an entomopoxvirus has been found on one Adoretus sp.. In the site where it was studied, more than 10% of larvae and adults were infected and subsequently died. Bacillus popilliae has also been found (MOREL, pers. com.).

3.3.2. Tonga (map E, Annex 1)

3.3.2.1. Materials and methods

Links have been made with Mr KAMI and Mr LUU (Annexes 4 and 5).

Collection was realised in June 1992 on the main island TONGATAPU (see map F, Annex 1) in vegetable fields (cabbages, radish, beans,...). On 15 squares (25x25x10cm) 70 beetle larvae were found and sent to FRANCE in soil with a piece of carrot : 52 L3, 18 L1L2,

Soil samples have also been sent.

3.3.2.2. Results

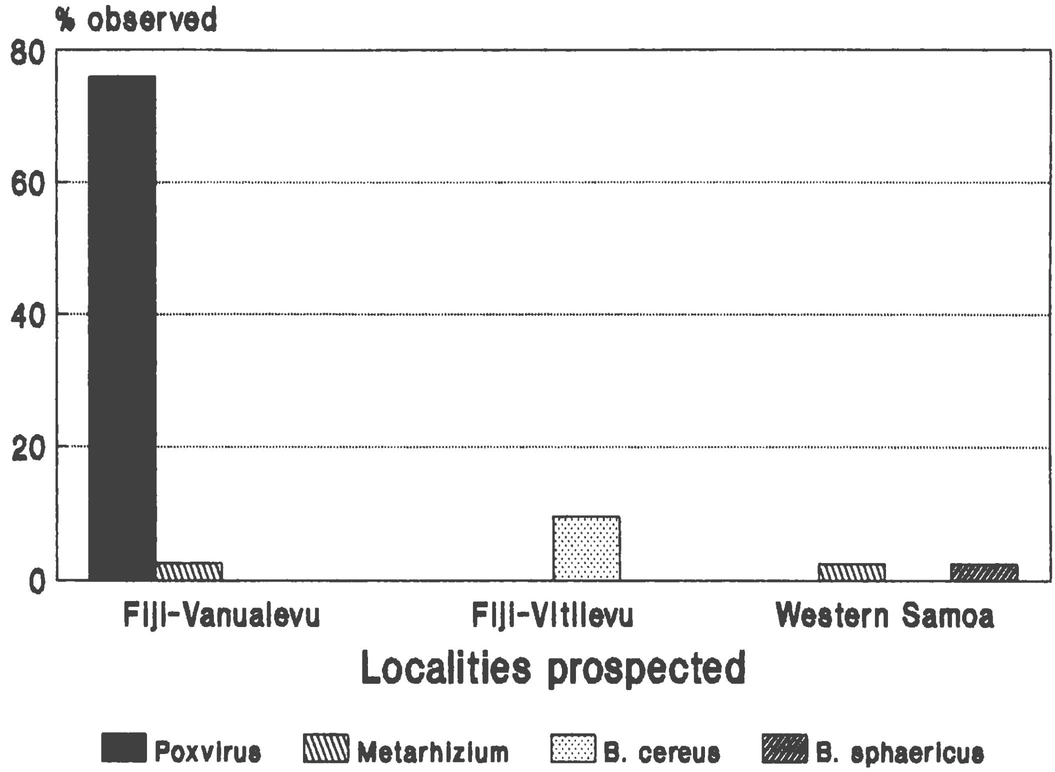
Insects collected were all identified as Rutelinae subfamily and Adoretus genus. 52 larvae are under observation in the laboratory and nothing has been observed for the moment (Document 5).

From 8 soil samples, 5 were analysed but nothing was observed (Document 6).

3.3.3. Western Samoa (map E, Annex 1)

The rose beetle are probably introduced to Samoa from overseas and were first recorded in Samoa by the German Scientist

FIRST RESULTS FROM FIJI and WESTERN SAMOA ABOUT PATHOGENS ON ADORETUS
by INRA (P. ROBERT)



Graph 35

Dr K. FRIEDRICHS in 1914.

Nothing is known of natural biological control agents of this beetle in Western Samoa other than one report of an unidentified "orange" disease **(PUREA, 1971)**.

All attempts failed to confirm the existence of an "orange" disease in larvae of A. versutus as being either a pathogenic disease or a physiological disorder **(MOALA, 1973)**.

Micromeriella marginella, was listed by **DUMBLETON (1957)** as being introduced from Hawaii (origin Philippines) in 1955. No recovery records exist (SPC Biological Control, 7 August 1979).

In 1967, the most successful control agent, the virus Baculovirus Oryctes (syn. Rhabdionvirus oryctes HUGER) was introduced into the Rhinoceros beetle population of Western Samoa. Following verification showed that baculovirus was responsible for the decline in beetle population **(MADDISON, 1979)**.

The results obtained from inoculation of rose beetle larvae with Baculovirus suggested that the virus could affect the larval stage. Microscopic slides showed some pathological symptoms such as inclusion of polyhedral bodies.
However, in some cases protozoan parasites were suspected and positive confirmation of virus infection was not obtained **(MOALA, 1973)**.

It has been reported that Baculovirus also affects Scapanes australis in New Guinea (BEDFORD, 1972) and Oryctes monoceros in the Seychelles.

3.3.3.1. Materials and methods

The visit was organized by Dr SEMISI and O. AUKUSO, in June 1992 (Annexes 4 and 5).

Collection was made on UPOLU island (map G, Annex 1). Beetle eggs were observed. 10 L2, 20 L2 and 30 L3 were collected.

They were stored in a box with compartments with soil and a piece of carrot as source of food.

3.3.3.2. Results

Samples were identified as Rutelinae, Adoretus. 40 larvae and 2 nymphs are under observation in the laboratory. The following cases of disease have been detected at present : 1 Metarhizium anisopliae (2,38%) and 1 Bacillus sphaericus (2,38%) (Document 5 and Graph 35).

From 10 soil samples, 5 were analysed but nothing was observed (Document 6).

3.3.4. American Samoa (map E, Annex 1)

The visit was organized by Dr VARGO and Mr FAAUMU, in June 1992 (Annexes 4 and 5).

No beetle collection in the sites visited (map H, Annex 1) was made but an important literature review was undertaken in the library.

Damage was observed on 18 Taro varieties and grapefruit leaves (photo 26). A list of trees with leaves showing consistent rose beetle damage from June to December 1991 has been compiled (**SWORTS, pers. com.**).
Determination of the nightly feeding cycle was carried out (**SWORTS, VARGO,** unpublished)

3.3.5. Cook islands (map E, Annex 1)

3.3.5.1. Available data

Entomophagous insects have been introduced to the Cook islands (**WALKER** et al., **1979**). No parasite to control Coleoptera has been recorded.

Adoretus versutus was introduced in 1988 in imported plants arriving in aircraft from Samoa. The first damage was observed on Acalipha and Hibiscus.

Cocoa trees are not found in the Cook islands, except a few trees on the Research station.

Damage was observed in the field and a visual estimation made : Avocado , orange, citrus, apple (2%), lychees (60-80%), beans (young : 70% ; adults : 30%), sweet potatoes (5%), papaya, Hibiscus tiliaceus (60%), terminalia catappa (80-90%), cashew (15%), white guava (5%), Barringtonia edulis (90%), bananas (7%), pomelos (4-5%), ginger plant (20%). The percentage is a visual estimation of the foliage area attacked with regard to total foliage area.

3.3.5.2. Materials and methods

Links were established with Mr PAREI JOSEPH to investigate rose beetle damage and to collect some samples (Annexes 4 and 5). Damage observations are described in chapter IV.

60 beetle larvae were sent back (20 by mail, 40 using D.H.L. express).

They were stored in a box with compartments with soil and a piece of carrot as source of food.

20 samples were collected on the Research Station of Totokoitu (50ha) on Rarontonga island (map I, Annex 1) (67,1 km^2), under coconuts and with young papaya seedlings. 20 were taken from a garden (grass) with adjacent damage to fruit trees (lychees...).

Soil samples were also sent.

A field visit was organized to investigate beetle damage to lychee (photo 27), Barringtonia edulis and beans.

3.3.5.3. Results from FRANCE

All the specimens have been identified as Rutelinae.

34 Adoretus larvae were put under observation in the

Photo 26 : Grape fruit damages in American Samoa

Photo 27 : Lytchee damages in Rarotonga (Cook islands) laboratory and for the moment nothing has been observed (Document 5).

From 11 soil samples, 5 were analysed and 2 cases of Bacillus thuringiensis were isolated (40%) (Document 6).

Electrophoretic characterization of these 2 strains was performed and four bands obtained : 140, 68, 50 and 35 Kdaltons. These strains are considered atypical strains. However, a 140 Kdaltons band resembles a larval pathogen strain of Lepidoptera. These two strains will be tested on insects of INRA laboratory.

3.4. Arrangement of contacts for further collections in the South Pacific islands visited.

All the South Pacific islands visited are available for collection and sending back of beetle larvae.

3.5. Tests of agents from laboratory studies

7 Bacillus sphaericus strains have been isolated : Five from Vanuatu and two from Fiji. These strains were sent to **INSTITUT PASTEUR** (Annex 4) to check effectiveness against mosquitoes. One strain of B.sphaericus is effective against mosquitoes and is actually commercialized (**ROBERT, pers. com., 1992**).

Every strain isolated, Metarhizium, Bacillus thuringiensis, Bacillus sphaericus has been kept. These strains can be used by the I.R.C.C. for a collaboration program.

4. Conclusion

Concerning the identification of specimens collected in Vanuatu, Fiji, Western Samoa, Tonga and the Cook Islands, we now know that the adults that emerged from these larvae looked like Rutelinae adults (claws of the posterior legs are different : one is stronger than the other) **(DELVARE et al., 1989)** and are Adoretus spp (DELPLANQUE, pers. com., 1992). Characteristics to distinguish Melolonthinae and Rutelinae larvae have been found at the taxonomic and faunistic laboratory at CIRAD, Montpellier and lead to positive identification of the collected specimens as Rutelinae larvae (RICHTER, 1966) and as Adoretus genus by observation of the male genitalia.

C- STUDIES IN THE AREA OF ORIGIN

1. Literature
   Review available information on biological agents

The rose beetle is not regarded as an important pest in its area of origin (WATERHOUSE et al., 1987). This suggests that it may be attacked there by effective natural enemies .

The absence of records suggests that the rose beetle may be attacked in the subcontinent by natural enemies that have not so far been reported.

In India, Beauveria brongniartii was isolated on Adoretus versutus (JAYARAMAIAH et al., 1983) (Annex 2, document 2).

Adoretus lasiopygus causes serious damage in Southern India by devouring the leaves of grape-vine, mango etc...A. versutus and several other species are reported to defoliate cultivated roses, cannas etc...(ARROW, 1917).

As many as 17 different species of Adoretus are known to occur on economic crops in India. They feed on the foliage of their host plants, almost all of which are perennial. However, none so far have been found to attack Phaseolus aureus Roxb. and this is, therefore, the first record of a host plant for Adoretus sp. in India.

Exception is an attack in India in 1975 on sorghum (PUTTURAM et al., 1976).

2. Visit to area of origin

2.1. Sri Lanka

Links were established with scientists to organize visits to Sri Lanka, from 4 to 11 May 1992, to collect rose beetle larvae or other Scarabaeidae specimens in order to identify some parasites or pathogens (Annexes 4 and 5).

Other contacts have been made by mail (Annex 4).

2.1.1. Review

Adoretus suturalis has been recorded in Sri Lanka. Related species found are Anomala dorsalis and Holotrichia. No natural enemies have been recorded (Dr MAHINDAPALA, pers. com.).

Promecotheca cumingi (Col. Hispidae) was accidentally introduced in 1970 to Sri Lanka. Adults and larvae attack coconut leaves. To control this pest, three small parasitic wasps were used which attacked the eggs, larvae and pupae of the pest : Dimmockia javanica, was the most numerous parasite. As a result of this, the pest was controlled by the end of 1972.

2.1.2. Field visits

2.1.2.1. Localities visited and samples collected

* WALPITA Estate (35 km from Lunuwila, map J, Annex 1) ; Intercropping trials conducted, Division of Agronomy, Coconut Research Board, Western Province.

Collection : 4 adult beetles, 7 L1, 3 eggs and 3 soil samples.

* KANDY (120 km from C.R.I.) (map J, Annex 1) :

- Meeting with Extension Officer at Peradeniya, Regional Director, Department of Export Agriculture to identify the localities to visit around Kandy and Matale (map A).
- Meeting with Dr KUDAGAMAGE (Annex 4).

Collections were examined for Adoretus versutus, which was recorded in 1929 on Canna and other flower crops, Galle gymkhana Club. (South). Microtrichia euryotoma Burm. was also recorded, but no information on natural enemies was given.

- ANGANTENNA Estate : mixed-plantations : cocoa, coffee, pepper, coconut and bananas (50 ha).

- Mid-country Livestock Development Centre MAHABERIYYATENNE Farm, Digana, NLDB (2 acres).

Collection : 3 adult beetles, 2 eggs, 11 L1, 2 L2 and 2 soil samples.

* MATALE (map J, Annex 1) :

- Meeting with Dr GUNASEKENA Deputy at the Research Station at the Department of Export Agriculture in Matale.

- HAPUGASPITIYA (Owella). Cocoa factory. State Plantation Corporation (200 ha, altitude : 1100 ft). Cocoa plantations underneath rubber and pepper plantations.

No collection was made.

- MANDALA. State plantation Nalanda (Dambulla road)

Collection : 2 adult beetles, 2 Odontomecus similis, 10 L1 and 2 soil samples.

All the specimens collected were sent to FRANCE to P. ROBERT (Annex 4). Some problems were encountered trying to export live insects from Sri Lanka.

Damage was observed but we do not know if it was due to A.versutus (photo 28).

2.1.2.2 Results from FRANCE

18 larvae collected in Sri Lanka have been identified as Scarabaeidae Melolonthinae by P. ROBERT.

No interesting result has been obtained at present (Document 5).

However, from 57 soil samples, 8 have been analysed and 2 of them (25%) showed Bacillus thuringiensis (Document 6).One of these two strains shows bands at 105, 98 and 40 Kdaltons and the other shows bands at 35 and 38 Kdaltons. These strains, considered atypical, will be tested on insects available at the INRA laboratory to investigate pathogenicity.

All these results are partial.

2.2. India

Links were established with Dr NAIR and visits organized (Annexes 4 and 5). Other contacts were made (Annex 4) but for some of them no reply has been received.

2.2.1. Review

A Baculovirus disease was found on Oryctes rhinoceros beetles in Kerala (MOHAN et al., 1983). The symptoms conformed to those reported from South East Asia and the South Pacific Islands.

Photo 28 : Damages on cocoa tree
in Kandy (Sri Lanka)

Photo 29 : Damages on cocoas seedlings
in Allepey (India)

In Karnataka, three species of muscardine fungi were isolated on white grubs (JAYARAMAIAH et al., 1983). Beauveria brongniartii was isolated on Adoretus versutus at Coorg. The three fungi species were found on Holotrichia serrata at Bangalore and on Anomala bengalensis at Gulberga.

2.2.2. Field visits

* District Agricultural Farm (about 12 km from Kayangulam CPCRI) (map K, Annex 1), Mavelikara, Kallimel, Alappuzha district, Kerala State.

Damage was observed on cocoa trees but was supposedly due to Popillia complanata.

* R. Block (Mr ABRAHAM) from ALLEPPEY, 10 km. Alleppey to Kottayam by waterway. Intercropping between canals (bananas, coconuts, papaya...). Nursery was visited.

Young cocoa seedlings were much attacked (photo 29) but we doubt that it is rose beetle damage (photos 30 and 31).

Many larvae were collected in this locality. Between canals, grass is growing and it was here we collected samples. Few L1 (4,7%) were collected but many L2 (67%) and L3 (29%) were found.

On 14 sample squares (25x25x10) :
- 0 specimen in 8 squares (57,14%),
- 1 specimen in 3 squares (21,42%),
- 3 specimens in 1 square (7,1%),
- 6 specimens in 1 square (7,1%),
- 9 specimens in 1 square (7,1%).

Export of live insects from India was impossible. In addition, no specimen has been observed in FRANCE.

3. Conclusion

Prospections should be organized to discover useful species. However, it is very difficult to find Adoretus versutus in the area of origin, and therefore small chance of identifying pathogenic agents.

The problem of rose beetle control is that the immature stages spend most of the time underground and the adults do so for a considerable part of their life.

D- INFORMATION FROM OTHER COUNTRIES

1. From Malaysia, Singapore :

* Contact has been made with Mrs CHOO-TOH GET TEN (Annex 4).

According to **KARLSHOVEN**'s "Pests of crops in Indonesia"**(1981)** natural enemies of Adoretus compressus larvae have been observed : Maggots of predatory flies (the asilid Ommatius and the acrocerid Philodicus) ; a histerid larva ; a parasitic tachinid (prosena) ; and a dagger wasp (the scoliid Tiphia). The adult stage is parasitised by the pyrgotid fly Campylocera sp.. Pathogenic fungi and bacteria are also found.

Photo 30 : Damages on cocoa tree
in India

Photo 31 : Damages on cocoa tree in India

2. From Vietnam :

Contact has been made with Dr NGUYEN VAN CAM (Annex 4). Four species of Adoretus are found in Vietnam : Adoretus convexus, A. nitidus, A. sinicus, A.tenuimaculatus.

3. Information on Adoretus spp. from other countries were obtained following a request made in 1989 (Document 2 Annex 2 and Annex 4).

Adoretus spp. were recorded in :

* Japan : A. tenuimaculatus (TETSUO SAITO, pers.com., 1989 and JOJIRO NISHIGAKI, pers.com., 1989), A. falcungulatus, A. formosanus.

* Guam : Adoretus sinicus (MUNIAPPAN, pers.com., 1989)

* Tonga : Adoretus versutus

* Taiwan : Adoretus convexus, A. cribratus, A. formosanus, A. hirsutus, A. sinicus, A. tenuimaculatus (YAU-I CHU, pers.com., 1989)

* India : Adoretus tasiopygus, A. bengalensis, A. bicolor (VEERESH, pers.com., 1989), A. versutus (ARROW, 1917)

* Indonesia : Adoretus compressus, A. sundaicus, A.spp. (ARIFIN DJAMIN, pers.com., 1989), Chaetadoretus borneensis (SOEHARDJAN, pers.com., 1989)

* China : Adoretus formosanus, A. hirsutus, A. nigrifons, A.sinensis, A. tenuimaculatus, A. umbrosus, A. sinicus (GU BEN-KANG, pers.com., 1989). A. tonkinensis (CHENG BO-RU, pers. com., 1989), A. puberulus, A. compressus, A. runcinatus, A. bilobatus, A. hirticllis, A. striatus, A. sexdentatus (WU WEI-WEN, pers.com., 1989 and CHAI XI-min, pers.com., 1989);

* Bangladesh : Adoretus bicolor, A. bicundatus and A. lasiopygus (IBRAHIM ALI, pers.com., 1989)

CHAPTER IV
ASSESSMENT OF ECONOMIC IMPORTANCE

Rose beetle larvae breed in pasture because they feed on grass roots, and generally in uncovered localities or partial shade. Also, there is an important risk for crops around pasture or under old coconut plantations with little shade (LEFEUVE,1990).

In Malaysia, recent observations indicated attacked plants "lost" at least 50% of stem cross-sectional area ; they also suffered in stand uniformity and required over 30 % replacement (THONG et al., 1977) in Insects and Cocoa.

Cocoa established in forest clearings seems less attacked than that in areas of more generally cleared land, probably because of the greater breeding potential provided by areas of grass, weeds etc...

There are 2 aspects to the economic problems caused by insects. One concerns the loss of production that results from damage to crops, the other concerns the cost of attempts to prevent or control such production losses.

The parameter 'severity of damage' is a visual assessment of the percentage of the foliage of a plant eaten up by the pest. It was arbitrarily categorised into 5 degrees, as follows (CHOO-TOH, 1982) :

% of foliage eaten	severity of damage
< 10%	very slight
10-30%	slight
31-50%	moderate
51-70%	severe
> 70%	very severe

A- PHYSICAL DAMAGE IN VANUATU

1. Regular samples on Valeteruru station

1.1 71 selected cocoa seedlings

A census was carried out at night in order to assess the population of adults present on seedlings.

1.1.1. Materials and methods

One plot on Valeteruru station (area of 1.35 ha) was observed for 71 selected cocoa seedlings (photo 32 and Document 8).

Ecosystems around are :

- north : bush
- south : field
- west : hybrid cocoa plot
- east : Heliconia hedge before adult cocoa trees

These different ecosystems are separated by grassways.

The cocoa trees are located under coconut and between papaya trees (intercropping plot).

At the beginning of the study, in November 1991, the cocoa trees were 8 months old.

Every week, at the beginning of the night, rose beetles were collected from each of these 71 young cocoas, and stored in boxes. For each seedling, rose beetles were counted and sexed to establish the sex ratio for the plot.

This study was carried on from November 1991 to July 1992 to investigate population fluctuations over the year and distribution on the plot (borders and center).

Collection was made once at the beginning of the night and again 4 hours later to record numbers of males and females at time t=0 and t= + 4hours.

Every month, physical damage was evaluated on the 71 cocoa seedlings and expressed as a percentage.

1.1.2. Results

1.1.2.1. Weekly collection

The number collected was never more than 24 adults. Greatest numbers (between 30 and 50 insects collected) were observed in December 1991, February, March, April, May and the end of July 1992 (Graph 36).

This can be explained by the rainy season.

Usually, sex ratio is calculated as follows :

number of males / number of females.

The ideal sex ratio is 1.

Sex ratio was generally in favour of the males (S.R.>1) from November 1991 to July 1992. Some exceptions are observed particularly in March and April 1992 (S.R.<1).

This can be explained if the collection was performed after the beginning of the night because of rain.

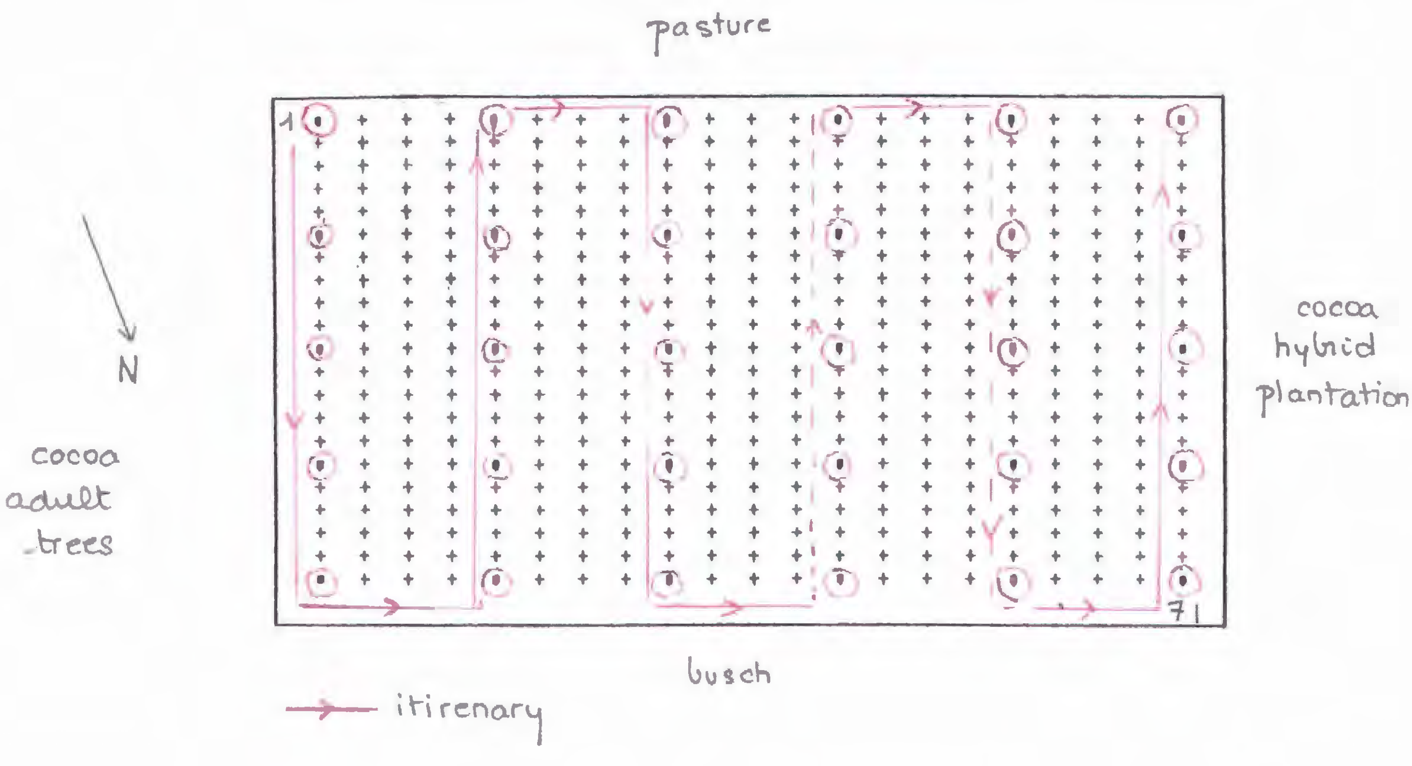
A large number of males were observed in the middle of November 1991 (S.R.=5) and during the first week of July (S.R.= 6.5).

1.1.2.2. Rose beetle distribution on the Valeteruru plot

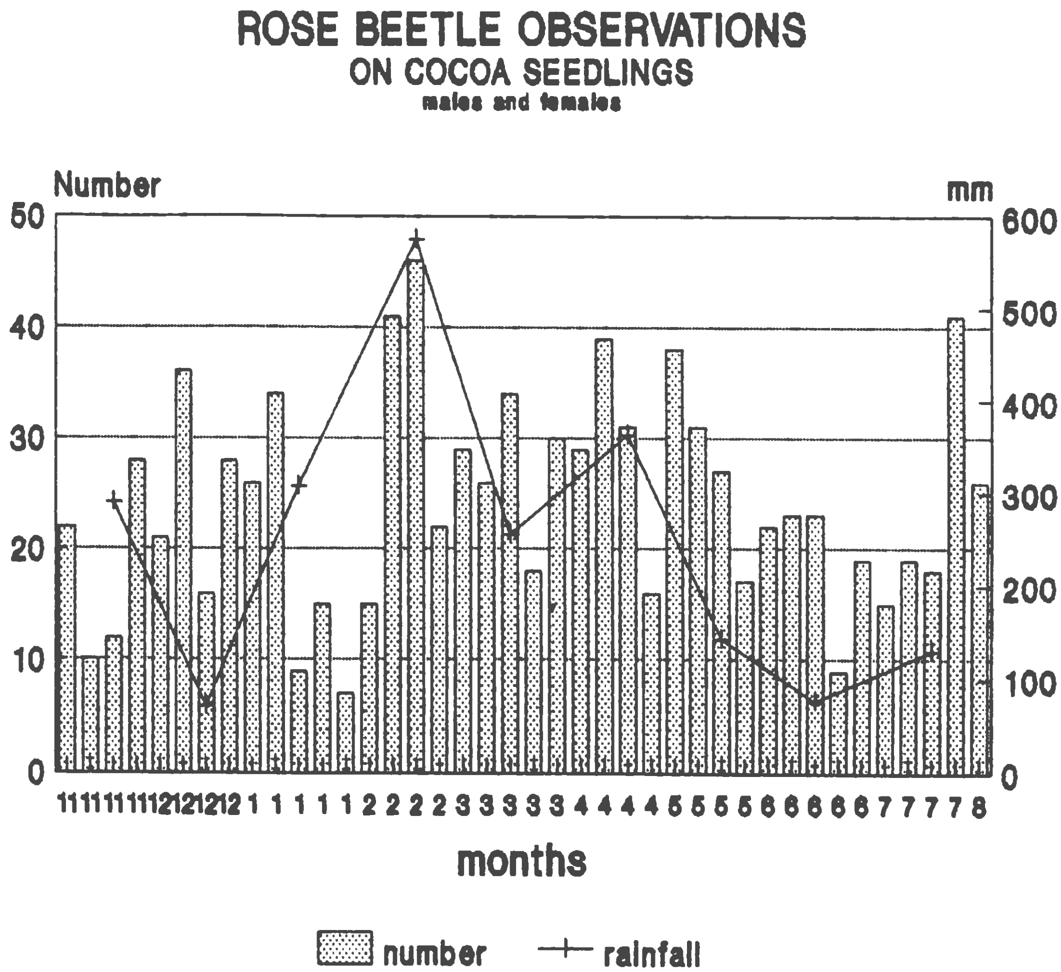
Rose beetle distribution was observed to compare numbers in the center and around the plot.

We know the ecosystem around the plot (see 1.1.1.).

Photo 32 : Young cocoas trees on IRCC intercropping plot (Vanuatu)



Document 8 : Experimental survey scheme


ROSE BEETLE OBSERVATIONS
ON COCOA SEEDLINGS
males and females
Number
mm
50
40
30
20
10
0
600
500
400
300
200
100
0
months
number
rainfall

Graph 36

Distribution can be influenced by the surrounding ecosystem.

From November 1991 to July 1992, results show generally a higher percentage of adults in the center of the plot than around the plot. This can be explained by the fact that cocoa seedlings do not form an impassable barrier around the plot.

Rose beetle distribution on 71 cocoa seedlings observed during 22 weeks shows, on 4 to 11 trees between 4 and 10 insects, six insects have been observed on 11 trees (Graph 37).

Results from November 1991 to March 1992 have been analysed by the Biometrics laboratory of IRCC/CIRAD in Montpellier (FRANCE). Not enough insects had been collected every week for meaningful analysis. Also, it is difficult to adjust distributions of theoretic laws and study spatial distributions for each week.

Graphs 38 and 39 are cartographic representations of the sum of 22 observation weeks (with cut in 2 classes). From these graphs, rose beetle seems to appear more often in the south and east. This can be explained by the adjacent grass field where rose beetle larvae can breed more easily in the soil.

Distribution of the sum can be fitted to a Poisson distribution but also to a negative binomial distribution. It seems to be a random distribution (Poisson) with a slight gradient which has an aggregative tendency. This can be explained by the plot environment.

1.1.2.3. Collection at the beginning of the night and 4 hours later.

Collection at the beginning of the night (6.30 p.m.) revealed more beetles (>15 adults) than four hours later (<5 adults).

This result confirms that rose beetles display greater feeding and mating activity just after the beginning of the night.

When we looked at sex, the number of males and females was the same at 6.30 p.m.(8) but 4 hours later, the number of males was less (1) than the number of females (3). This result seems to show that the females stay longer on the host plant than the males and need more feeding for ovogenesis or possibly that they arrive on the foliage later than the males.

According to **GHOURI and SALIK (1960)**, the beetles retire underground again about midnight, presumably having satisfied their appetite.

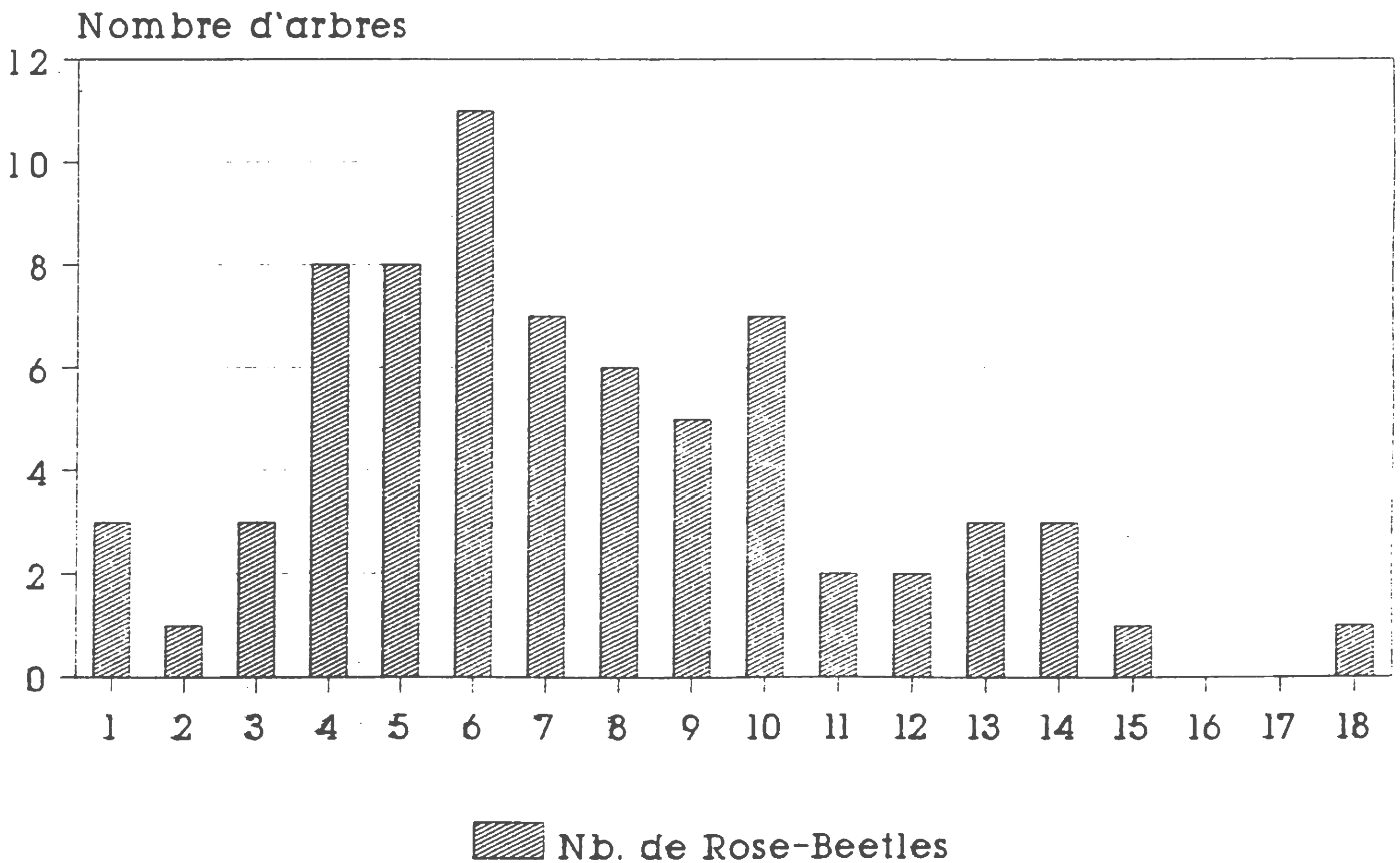
1.1.2.4. Physical damage

Physical damage estimation on the Valeteruru plot was difficult because new leaves appeared between November 1991 and July 1992.

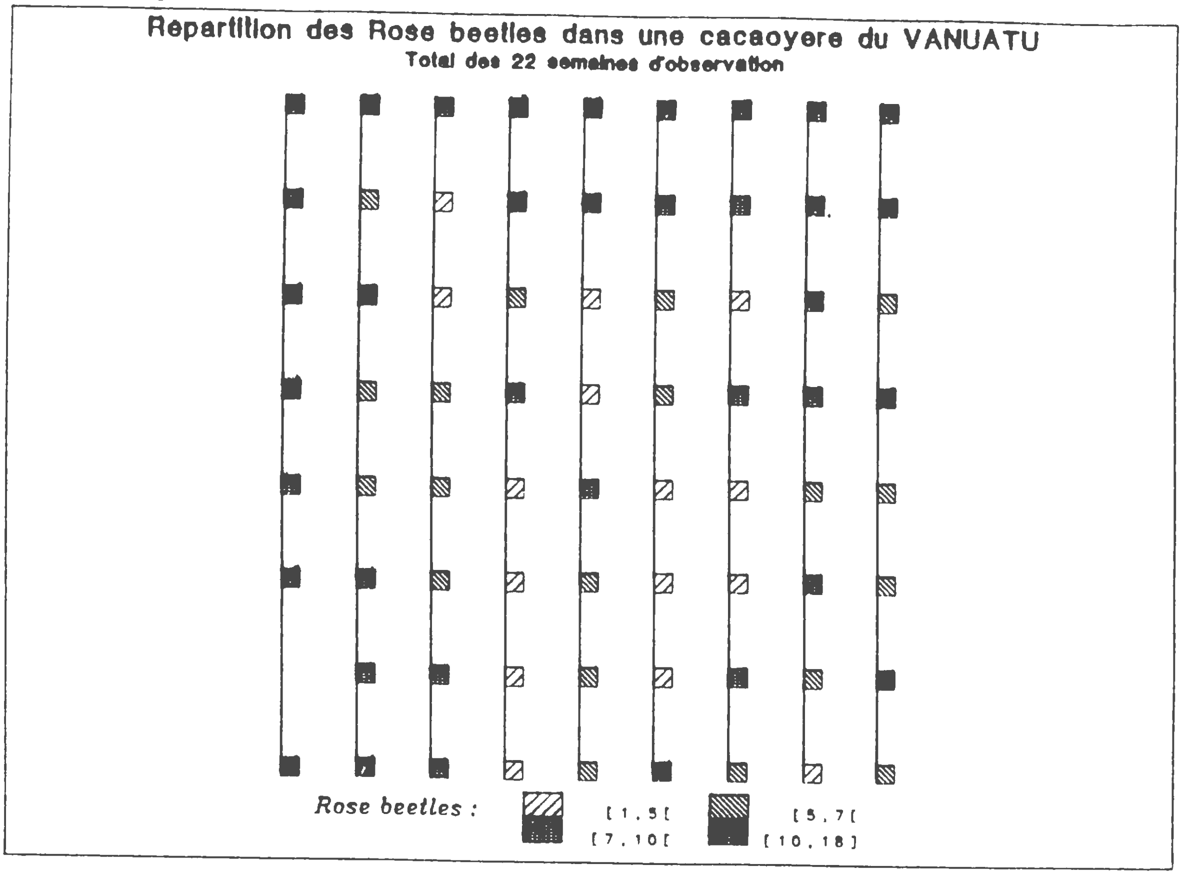
Graph 40 shows that attacks, for most of the 71 seedling cocoa trees, are generally between 0% and 40 % from November 1991 to August 1992. A few cocoa trees ($\leq$ 5) showed damage between 45 and 95 %.

For most of the trees, for example, damage was 5-10 % for the 10 months observed.

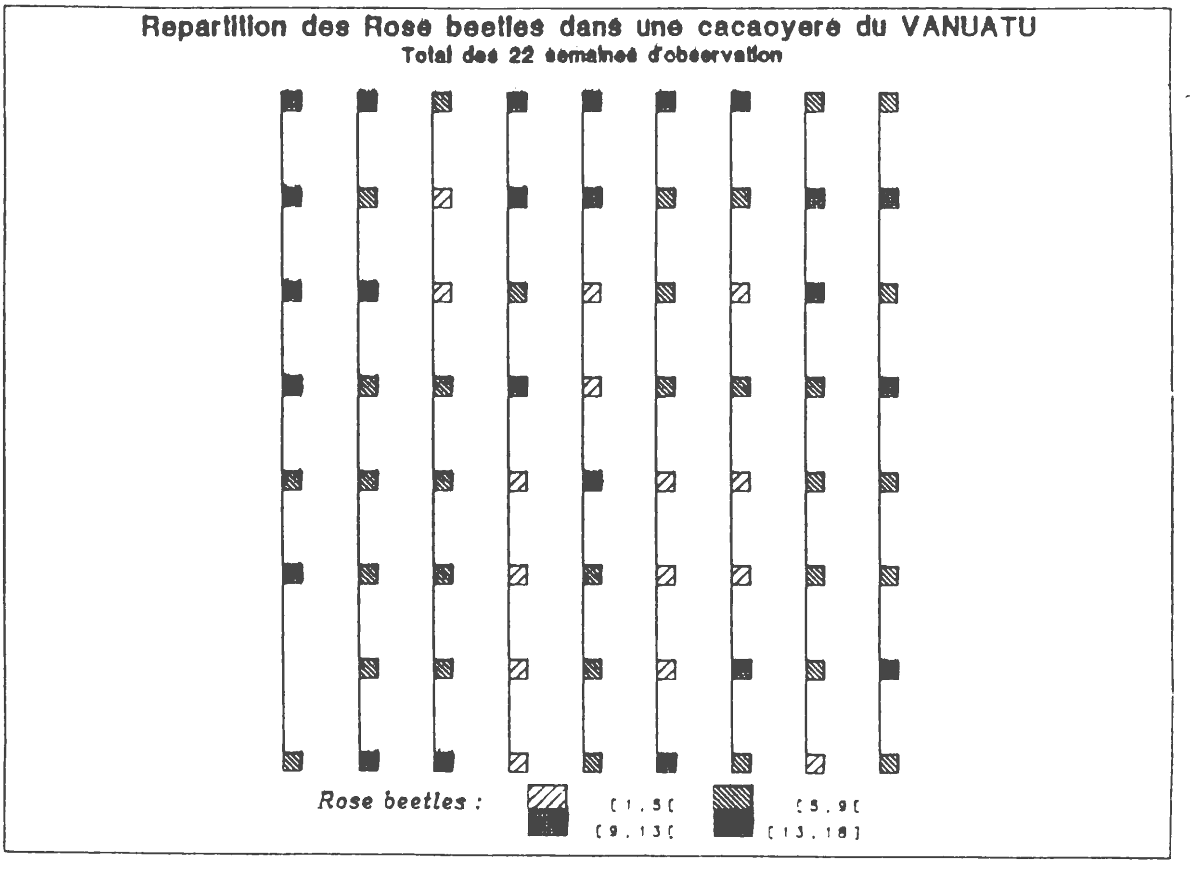
Répartition des Rose Beetles sur les 71 arbres observés
Somme sur les 22 semaines d'obervation



Graph. 37

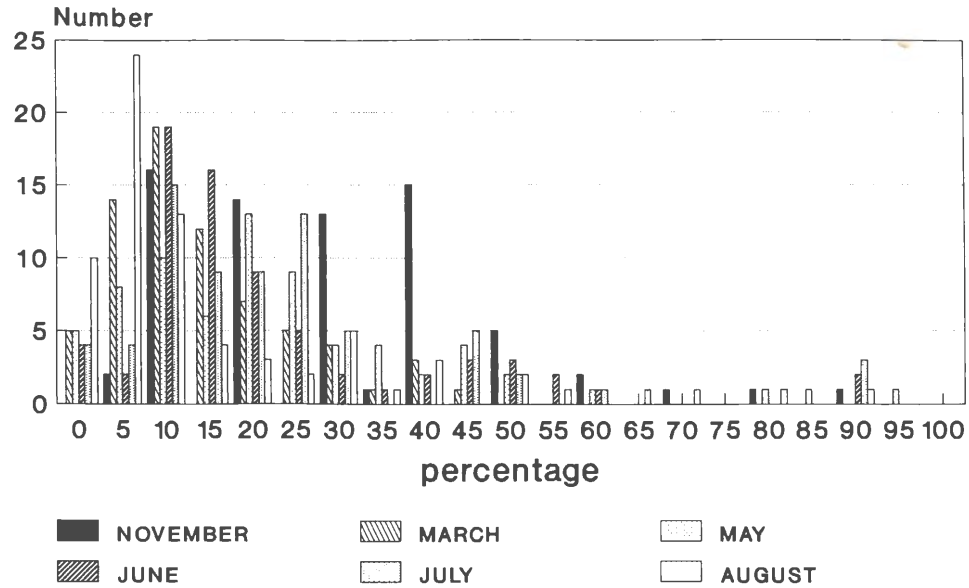


Graph 38



Graph 39

DAMAGE % OF 71 COCOA SEEDLINGS
NOV. 91 to AUGUST 92
Valeteruru station



Graph 40

Most damage was observed from November until March when the seedlings were 8-11 months old.

In June and July 1992, some of them (<5) seemed to be more attacked (90%, 60%, 45%).

At the end of the study, in July 1992, the cocoa trees were 1.4 years old and 4,2 % had died.

1.1.2.5. Conclusion

Interpretation remains difficult due to the small number of adult insects collected. The small numbers can be explained because rose beetle is a flying insect and we observed it only at time t. Thus the number of visiting insects may be relatively greater over the week. The time spent staying on or visiting the leaves for eating and mating is unknown.

1.2. Cocoa seedlings studied in three different localities over 7 months

1.2.1. Materials and methods

Three cocoa seedlings were sited in three different localities on Valeteruru station : garden, nursery, factory.

- the garden site was near the house with much pasture around,
- the nursery site was around cocoa and coffee seedlings under artificial shade with pasture in the neighbourhood,
- the factory site was in the neighbourhood of Amenolado cocoa trees and under shade with pasture around.

These three seedlings were changed every month from January to August 1992.

Every week, rose beetles were counted at the beginning of the night and damage measured.

Damage evaluation was performed comparing the available leaf area of the three cocoa trees at the beginning of the test, before exposure to rose beetle, and the area attacked by rose beetle every week.

1.2.2. Results

* Garden site : A great number of insects were found in February-March (5-6) contrary to the two other sites, the first, second, third and fourth weeks (3 to 6 adults). Similarly, most insects were observed in April-May (3-4) and May-June 1992 (2-6).

Damage was high in February-March (8-9%) and May-June (4-11,5%) when we observed the most rose beetles (Graph 41). Damage began the first week after installation and increased until the last week before the end of the month.

* Nursery site : Three seedlings were under shade near nursery cocoa trees. During February-March, rose beetle adults were found more during the second week (3) after the beginning of the test. In March-April most adults (4-5) were found the first and second weeks. The greater number of insects were found the third and fourth weeks in April-May (7).

Damage was observed in particular in February-March (13-20%) and March-April (7-16%) as early as the first week and increased until the fourth week. In May-June damage was also observed (4-10%) (Graph 42).

* Factory site : Rose beetle adults were only found the last week every month with most in April-May (7).

In July, one insect was found the second, the third and last weeks.

More damage was observed in June-July and July-August, contrary to the two previous sites. It was observed from the second week in June-July but can be noted as early as the first week (Graph 43).

1.2.3. Conclusion

* On the garden site, insects detected cocoa seedlings soon after installation but no insects visited this site in March-April. Most damage ranged from 7% to 11,5%.

* On the nursery site, most of the insects could be observed the third and fourth weeks. However, insects could be found here every week. This site was continuously visited by rose beetle throughout the experiment from January to August 1992. Most damage ranged from 13% to 20%.

* On the factory site, rose beetle seemed to detect young cocoa trees only three weeks after installation. Most damage ranged from 0,75% to 1,7%.

It was during April-May 1992 for the three sites, that the greatest number of insects were observed as the result of beating and collection on the intercropping plot (1.1.2.1.).

Cocoa seedlings can be detected and visited very quickly after installation, as observed on the nursery and garden sites but most rose beetle were generally observed the third and fourth week after cocoa seedling installation.

Damage data showed that the first damage could be observed very quickly, as early as the first week, and increased every week.

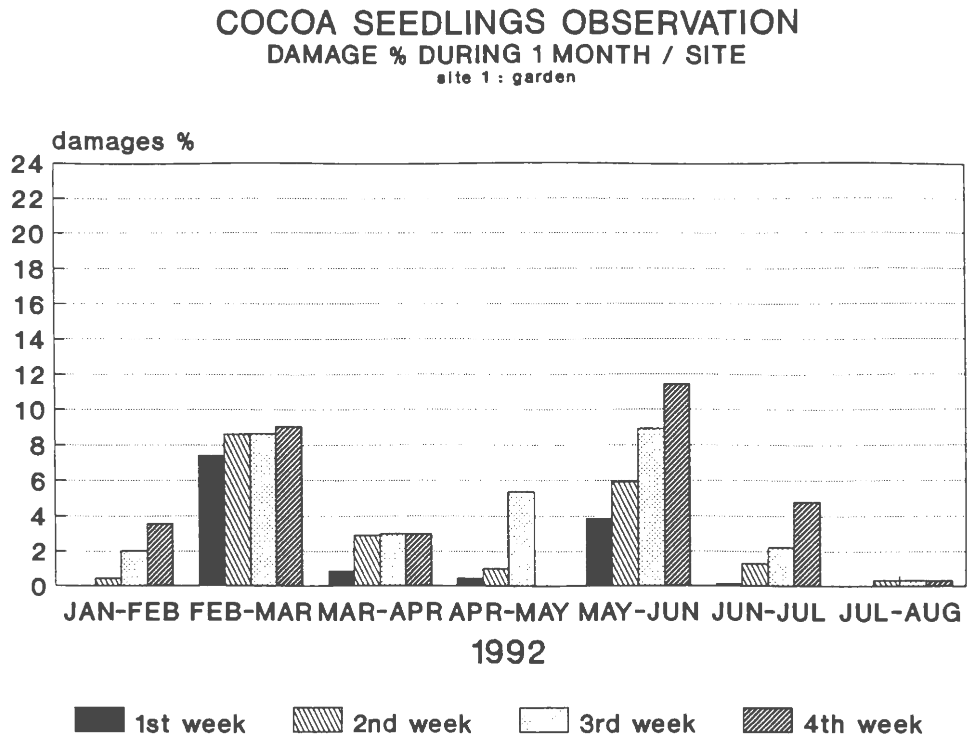
The degree of damage was greater on the nursery site (up to 20%) than on garden site (11,5%) and the factory site (1,8%). This can be explained by the host plants in the environment : many cocoa seedlings in the nursery with a large insect population in the surrounding pasture ; pasture around garden without important host plant for rose beetle ; shade and little-attacked adult cocoa trees in the proximity at the factory site.

1.3. P.R.V. estimation (Plantations Réunies du VANUATU, (United Plantations of Vanuatu))

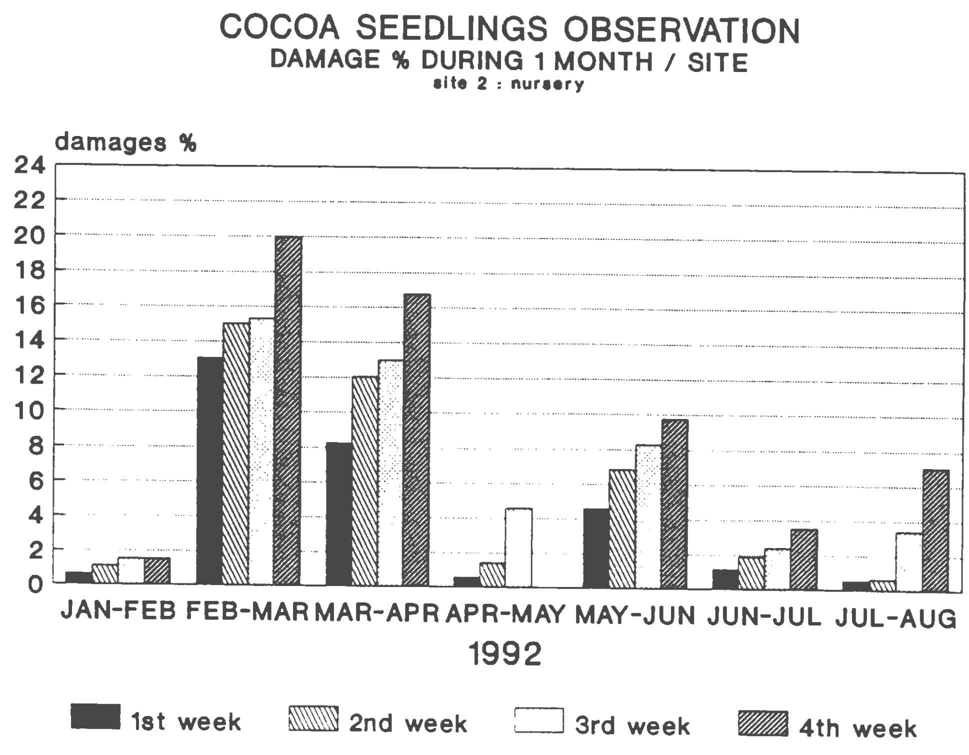
The P.R.V. manager asked about the risk of rose beetle damage to future plantings of cocoa under coconut palms (6 years old), (12 ha) on Espiritu Santo.

At the present time, cattle are kept under the coconut to eat the grass.

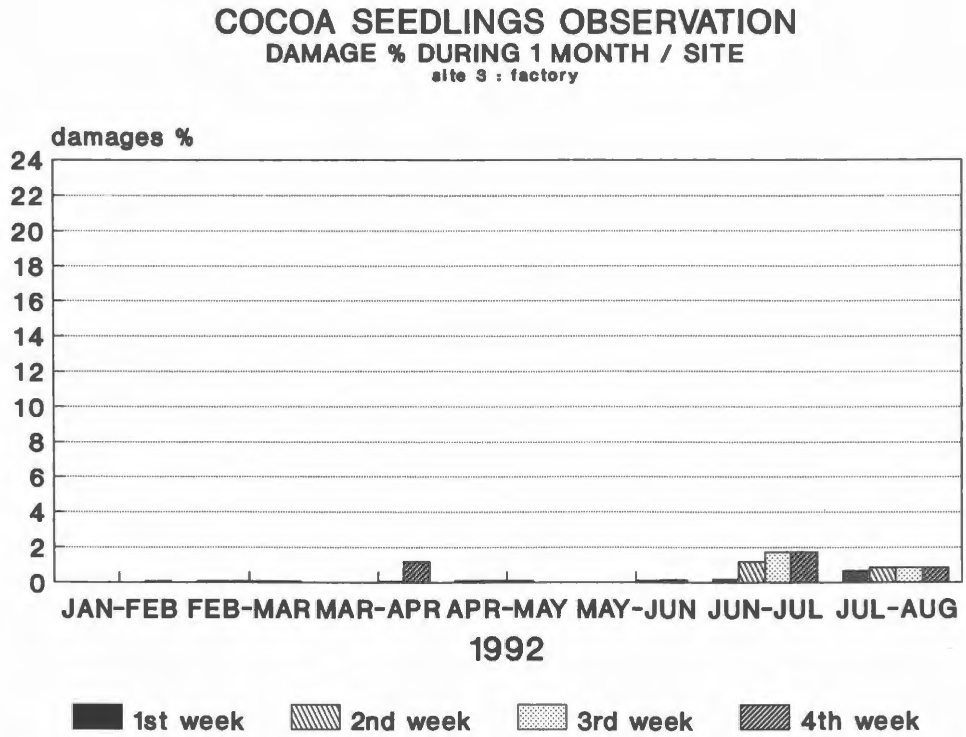
Pasture almost entirely surrounds the plot (to the west, south, east). In the north, there is a coffee plantation (1.5 years old).



Graph 41



Graph 42


COCOA SEEDLINGS OBSERVATION
DAMAGE % DURING 1 MONTH / SITE
site 3 : factory
damages %
24
22
20
18
16
14
12
10
8
6
4
2
0
JAN-FEB
FEB-MAR
MAR-APR
APR-MAY
MAY-JUN
JUN-JUL
JUL-AUG
1992
1st week
2nd week
3rd week
4th week

Graph 43

1.3.1. Materials and methods

* 246 cocoa seedlings were introduced to the P.R.V. plot (12 ha) under the P.R.V. scheme (Document 9) on 23 April 1992 for 33 days. Sixteen trees were introduced at each corner of the plot. Around, on the north side, 38 trees were introduced along the plot ; on the south side, 35 ; on the west side, 24 ; on the east side, 15 trees. A square of 72 young trees were concentrated in the center of the plot.
* 200 samples 25x25x10cm in the soil were taken from around and inside the plot to estimate larval population.
* Percentage damage on the plot for each of the 246 seedlings was estimated after t=12 days, t=19 days and t=33 days.
* Damage was noted as a function of plot orientation.

1.3.2. Results

1.3.2.1. Collection in the soil

Soil collection in April of larvae showed a large proportion of the third instar (2,96 L3 /M^2), 1,76 L1/M^2, 064 L2/M^2, 0,4 males/M^2 and 0,08 females/M^2. When we compared for the same period (April and May 1992) the number of the third instar/M^2 on the P.R.V. plot (2,96) with that in the 10 sampling sites on Valeteruru and Saraoutou stations (10,1), we were able to reassure and encourage the planters to plant young cocoas. However, this observation concerned only April and May.

1.3.2.2. Attack intensity

Intensity of attack in April and May 1992 after 12, 19, 33 days of installation is shown on Graph 44.

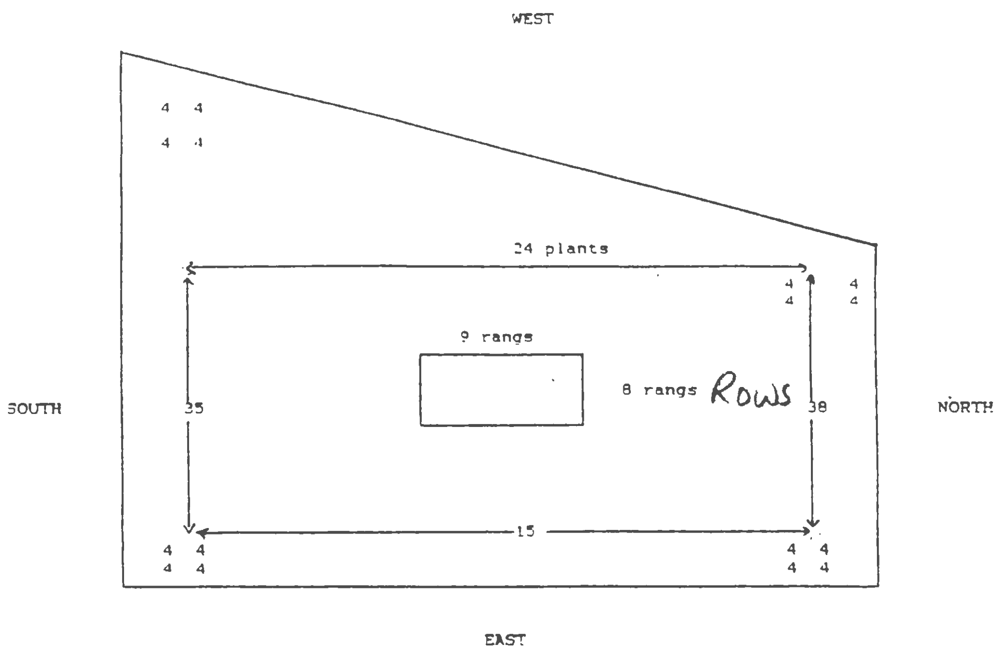
* After 12 days, most of the trees (60%) presented slight damage, 11% presented no damage, 11% more severe damage, 18% very severe damage and 0,81% were dead.
* After 19 days, 6,5% were not attacked, 64,2% presented slight damage, 4,9% severe damage, 22,8 % very severe damage and 1,63% were dead.
* After 33 days, the last observation, 5,3% were not attacked, 24,5% presented slight damage, 25% more severe damage, 39,2% very severe damage and 6,1% were dead.

In conclusion , we observed that during one month the number of young cocoas with no damage (O on Figure B) decreased whereas the number of damaged trees increased (+++ on Figure B). We noted the high percentage of trees much attacked (25% and 39,2%) after only 33 days of exposure.

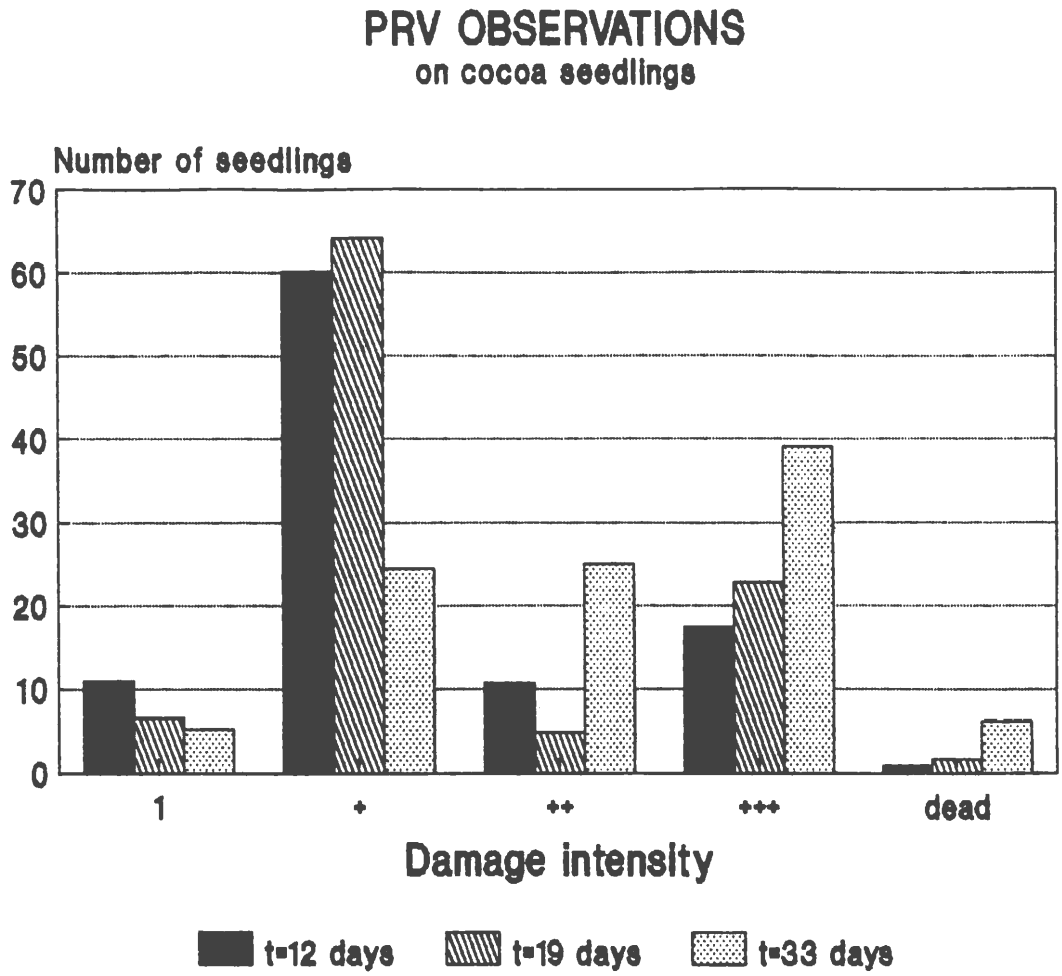
In consequence, young cocoa seedlings are very exposed to rose beetle attack in the P.R.V. plot even with a low larval population.

The level of the larval population would allow young cocoas to be planted without serious problems if the new leaves could support rose beetle damage. However, the pastures around the plot would be a good larval store and we observed important damage on <u>Hibiscus tiliaceus</u> hedges around the plot.

We will have to be very careful for the next few years.



Document 9 : P.R.V. plot and experimental scheme


PRV OBSERVATIONS
on cocoa seedlings
Number of seedlings
70
60
50
40
30
20
10
0
1
+
++
+++
dead
Damage intensity
t=12 days
t=19 days
t=33 days

Graph 44

Another estimation of rose beetle population will be necessary. Therefore, it seems that there is a danger in planting cocoa seedlings in this area.

1.3.2.3. Damage and orientation of the plot.

It is south-west orientation that is most exposed to attack, followed by the west and south-east. This could be explained by the surrounding pasture. The north side is also vulnerable (coffee plantation around) and this is confirmed by damage observed on the coffee trees.

1.4. Observation of an other important damage to cocoa trees.

It has been observed that A. versutus causes appreciable damage to adult cocoa tree branches (photo 33). Rose beetle bite-wounds on branches favour fungus development and foliage decay (photos 34 and 35). These observations were made at Valeteruru station and a fungus has been identified by CIRAD specialists as pholopsis, which is generally found near citrus and follows insect damage. These wounds are known to be caused by rose beetle because tests were done putting cocoa seedlings in a cage outside with soil and only rose beetle adults. During the test, we observed wounds on fresh branches.

2. Pentecost island (Annex 5)

Pentecost island (map L, Annex 1) was visited in December 1991. Six localities were visited from the south to north west coast of the island :

a- Rungzukzuk : L3 were collected.

b- Panas : beating gave no results concerning population levels.

c- Waterfalls : no insects collected.

d- Bwarnapné : Beating was performed but no adults were collected.

e- Lerutabataba (east Tayac) : cocoa trees 5 years old under coconuts. About 42% of the trees seemed to be attacked by rose beetle. All rose beetle stages were found.

f- Lolvatu.

Larvae were brought back to Valeteruru laboratory but no parasite or pathogen was observed.

3. Malekula island (Annex 5)

Malekula island (map L, Annex 1) was visited in July 1992 with **Mrs F. SKEA** (Annex 4) to investigate rose beetle damage.

About 6 sites were visited :

a- Matanvah village (Josua Vala):

. 10-20% damage was observed on cocoa seedlings,

. 0-1% damage was observed on adult trees.

Photo 33 : Defoliation on adult cocoa trees on Valeteruru Station (Vanuatu)

Photo 34 : Damages on branches

Photo 35 : Damages on branches

b- Sehbughas village (Edoar Varvaras): 0-1% damage was observed on adult trees.

c- Lerongrong village (Jojo Varvaras) : 0-5% rose beetle damage was observed on young trees, 0-1% on adult trees.

d- Touloué (west Malekula) showed 0-5% damage on young trees and no damage on adult trees.

c- Metenessell : On young cocoa trees (2-3 years old) rose beetle problems had been observed previously, but now damages were estimated to be only 0-1%.

d- Latava : Damage was about 0-5% on young and 0% on adult trees.

e- Sarmet (east Malekula, Freddy plantation) : Young cocoa trees four years old showed much damage. 200 seedlings were replaced of the 2000 planted, or 10%.

Damage on young seedlings seemed serious : 20-80% of the total foliage.

4. Santo island

Santo island (map L, Annex 1) was prospected where cocoa plantations are located, in February 1992 :

- Port Olry (OFT under coconuts) : No damage was observed because the plantation is situated in the bush and cocoa seedlings are protected.
- Looro plantation, Kolé. This is an old plantation under coconuts with pasture around. Mortality was not noted and no seedlings have been replaced but some signs of rose beetle were visible. Growth was retarded but there were no dead trees.

Rose beetle problems were observed particularly in the nursery, but usually not in the bush.

B- ECONOMIST VISIT / ECONOMIC DAMAGE IN OTHER COUNTRIES

A consultant economist (Mr PENNEY) visited South Pacific countries where rose beetle is and is not present. Conclusions of the visit will be in Mr PENNEY's report.

1. Western Samoa (Annex 5)

Rose beetle caused delayed growth and sometimes death to seedlings up to the age of 18 months. However, mature cocoa trees were seldom seriously damaged and any damage confined mainly to the outer leaves.

Damage was observed on cocoa trees (30-70%) (photo 36), Acalipha (20%), beans (90%), Fao (40%) and Pomuli (40-60%), yams (70%), the most important economic crops.

In cocoa areas, rose beetle damage was generalised and not confined to certain areas.

Rose beetle damage can be prevented by structural barriers such as coconut frond or bamboo fences placed around each plant, provided that these are at least as tall as the foliage. However, such fences are labour intensive.

Photo 36 : Damages on young cocoa trees in Western Samoa

There is a tradition of building a low wall of stones or sticks around seedlings to protect them from rose beetle, but the cocoa is liable to attack as soon as it grows above this barrier **(URQUHART, 1961)**.

Shade for cocoa plantations is recommended. If there is more than about 30-40% shade the beetles are less damaging, to the point of being insignificant.

A short prospection was carried out of an insecticide trial on 14-month-old cocoa seedlings for the control of rose beetle, from July to November 1984 **(ALOALII et al., 1985)**.

2. Tonga (Annex 5)

No cocoa trees are grown on Tonga.

Damage was observed on other important crops : radish (20%), grapevine (50%), ginger (80%), beans (30%), Fau (25-40%).

It seems that a Peace Corps Volunteer in the 70's worked with strains of Metarhizium anisopliae for control against the rose beetle. His success is unknown **(MORNEAU, pers. com.)** but the objective was to grow cultures of the fungus on growing agents like corn or oats and then apply these agents to the basal areas of plants where the larval stages and adults are usually found during the day.

3. Fiji (Annex 5)

VERNON (1976) describes serious, but local, damage to cocoa seedlings by adult feeding. **LEVER (1945)** quotes accounts of severe attack, sometimes fatal to cocoa seedlings.

FLETCHER (1916) reported attacks on grape, fig, pear and plum and **LEVER (1946)** added egg-plant, cowpea, ginger and vau (Hibiscus tilicaeus, a fibre plant). **VEITCH (1919)** recorded attack on guava and **VEITCH and GREENWOOD (1921)** stated that the adults fed sparingly on sugarcane foliage. **PUTTURAM et al. (1976)** reported attack on sorghum, the beetle feeding on the blossoms and milky grains.

The use of structural barriers in Samoa and Fiji has been successfully employed to preserve cocoa from damage during the first year after planting out but becomes impractical after that.

Damage was observed on Vanualevu (photo 37), Vitilevu and Taveuni islands. On Vitilievu island damage reached 90% on cocoa seedlings (photo 38) and it has been recorded that 10-15% of the young trees die.

On Taveuni island, serious damage was also observed (photo 39).

Photo 37 : Damages on cocoa trees on Vanualevu (Fiji)

Photo 38 : Damages on cocoa trees on Vitilevu (Fiji)

Photo 39 : damages on cocoa trees on Taveuni (Fiji)

4. Conclusion

Costs and potential success of control of weeds and insects in the South Pacific have been evaluated by **WATERHOUSE, MADDISON** and **GREATHEAD**, compiled by **MENZ**) at the Workshop Proceedings, Kingdom of Tonga, Ministry of Agriculture, Fisheries and Forests. Biological Control in the South Pacific. ACIAR/GTZ. 1985, 17-25 october.(p.).

Concerning Adoretus sp., the total estimated cost of the biocontrol program is S W Pacific ($000) : 300 ; Estimated chances of success : 0.20 ; Estimated % increase in yield in S W Pacific : 10.

CHAPTER V
CONCLUSIONS-RECOMMENDATIONS

In spite of the decrease of rose beetle (A. versutus) in VANUATU, the problem continues. Rose beetle still kills a great number of cocoa seedlings under coconuts with pasture around. Losses can reach 100% and planters are discouraged. Cocoa plantations can survive only in localities where they are protected by bush, for example.

It is a real problem in some South Pacific islands such as the Fiji islands.

In the Cook islands, rose beetle causes problems to several crops. In Tonga, it is present and damage prevents cocoa trials (pers. comm., KAMI). In Western Samoa, the impact of rose beetle has been studied very recently by Australian scientists but we do not yet have their report. In Fiji, it causes 15% mortality on young cocoas and important damage to cocoa seedlings under coconuts.

Rose beetle is a threat to further cocoa development, particularly under coconut when planters want to renew old coconut plantations and diversify crops. Tests carried out over 33 days showed 6% mortality of cocoa seedlings on the PRV plantation.

The major risk is rose beetle introduction to Pacific islands where it does not yet exist, such as the Solomon islands and Papua New Guinea. Any outbreak would be a major problem since large areas of cocoa trees are planted and the consequences would be very serious for these countries.

A new problem revealed by this study is the damage to branches on adult cocoa trees, which has never been observed before and which is responsible for foliage decay following fungal development at the top of adult trees.

Although insufficient, natural control has begun with a pathogen (Metarhizium ?) but no entomophagic insect (parasitoid) has yet been observed. It is possible that Metarhizium is responsible for the decline of rose beetle populations in Vanuatu but the control level is not as satisfactory as that of the area of origin.

Entomopoxvirus was isolated from Adoretus larvae collected in Fiji and here only on Vanalevu island. This is a very interesting study because this entomopoxvirus has never previously been described.

Visits to the areas of origin (India and Sri Lanka) were too short. No references were available on Adoretus spp. because it is not considered a pest. However, they have been promised. Contact must be made with JAYARAMAIAH and VEERESH (1983).

Some entomopathogens must be developed, such as the nematodes, Metarhizium, Beauveria.
This work has shown the potential of biological control but all the information is not available in this preliminary feasibility study.

RECOMMENDATIONS

A two-stage approach is suggested, the second phase only becoming operational if the first is successful.

Phase 1 : Firstly, we need more information on the numbers, types (parasitoids, predators or pathogens) and effectiveness of agents in the area of origin. This could be completed in 1 to 1,5 years ; Sri Lanka and/or India would be included in this survey. Facilities available are described in chapter IV.C-and costs are in the following document.

* A taxonomic study will really be necessary to differentiate the different Scarabaeidae species of the adults and larvae collected.
* Continue dynamic population studies (soil sampling and beating).
* Survey of breeding sites for parasites and pathogens on the larvae and adults collected.
* Continue to screen as wide a range of known control agents as possible.

Known entomopathogens and those identified by other laboratories, including Oryctes Baculovirus, must be tested.

Maintain mass culture.

Maintain contacts with American Samoa project.

Continue disease tests.

Evaluate the pathogenicity of the Metarhizium isolated from Adoretus versutus.

Physiological chemical studies on cocoa leaves from different cocoa clones by chromatographic techniques : presence or absence of compounds that might be attractive or repellant.

It is clear that the development of an effective control strategy for Adoretus will require long-term research.

Phase 2 : If one or more suitable agents are discovered in the first stage, then there would be a period of further testing (effectiveness and host specificity) of these agents in the country of origin (that means another year) followed by introduction into the Pacific, rearing, release and monitoring (control trials on cocoa seedlings). If it is decided to introduce a parasitoid or predator little equipment would be required ; more would be required to handle a pathogen.

Provisional budget is described in Document 10.

Document 10

PROVISIONAL BUDGET
ROSE BEETLE PROJECT Phase III
period 5 years

1 ecu = 7 FF

PHASE I : 18 months

*** SRI LANKA :** **ecus**

- Travel Sri Lanka - Fiji (20 days)	2 500
- Transport (0.16 ecus/km)	400
- Per diem (100 ecus/day x 20 days)	2 000
- Salary local staff (250 ecus/month x 18)	4 500
- Larvae collection in 3 sites (0.32 ecus/km)	2 800
- Minor equipment	2 000
- Dispatches via D.H.L. (1 per month)	1 600
- Overheads	1 650

*** FRANCE :**

- Overseas laboratories (identifications..)	10 000

*** FIJI :**

A - STAFF :

- Salary and charges : 1 entomologist (93 000 ecus/year x 1.5)	140 000
- Local staff : 3 employees (250 ecus/month x 18)	13 500
- Long distance travel (3 000 ecus/trip x 2)	6 000

B - EQUIPMENT :

- Major equipment	50 000
- Minor equipment	2 000

C - OPERATING COSTS :

- Internal travel (290 ecus/trip; 100 ecus/day)	5 000
- Regional travel (720 ecus/trip; 100 ecus/day)	12 000
- Running costs	5 000
- Local services	2 000
- Rent of house (800 ecus/month x 18)	15 000
- Charges to send samples, communications, correspondence	10 000
- Rent of laboratory space (800 ecus/month x 18)	15 000
- Overseas laboratories	2 000
- Purchase of books	4 000
- Workshop (7 people, 8 days; 100 ecus/day)	5 600
Travel (7)	5 000
Rent of room and Minor equipment	2 400
- Training (1 local scientist, 2 months)	
Travel	750
Salary	1 000
Per diem	1 000
- Technical assistance (3 review consultancies) (7 000 ecus each)	21 000
- Overheads	37 000
	382 700

Total Phase I : 382 700 ecus

PHASE II : 3.5 years (FIJI)

A - STAFF :

- Salary and charges (1 entomologist)
  (93 000 ecus/year x 3.5)........................325 500
- Local staff (3 employees)
  (250 ecus/month x 42)...........................31 500
- Long distance travel (3 000 ecus/trip x 4).......12 000

B - EQUIPMENT :

- Minor equipment..................................8 000

C - OPERATING COSTS :

- Internal travel (290 ecus/trip; 100 ecus/day)....10 000
- Regional travel (720 ecus/trip; 100 ecus/day)....12 000
- Running costs....................................12 000
- Local services....................................5 000
- Rent of house (800 ecus/month x 42)..............35 000
- Charges to send samples, communications,
  correspondence...................................14 000
- Rent of laboratory space (800 ecus/month x 42)...35 000
- Purchase of books.................................4 000
- Workshop (2).....................................26 000
- Training (2 scientists)...........................5 500
- Technical assistance (3 review consultancies)....21 000
- Overheads..79 125

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635 625

Total Phase II : 635 625 ecus

TOTAL Phase I + Phase II (5 years) = 1 018 325 ecus

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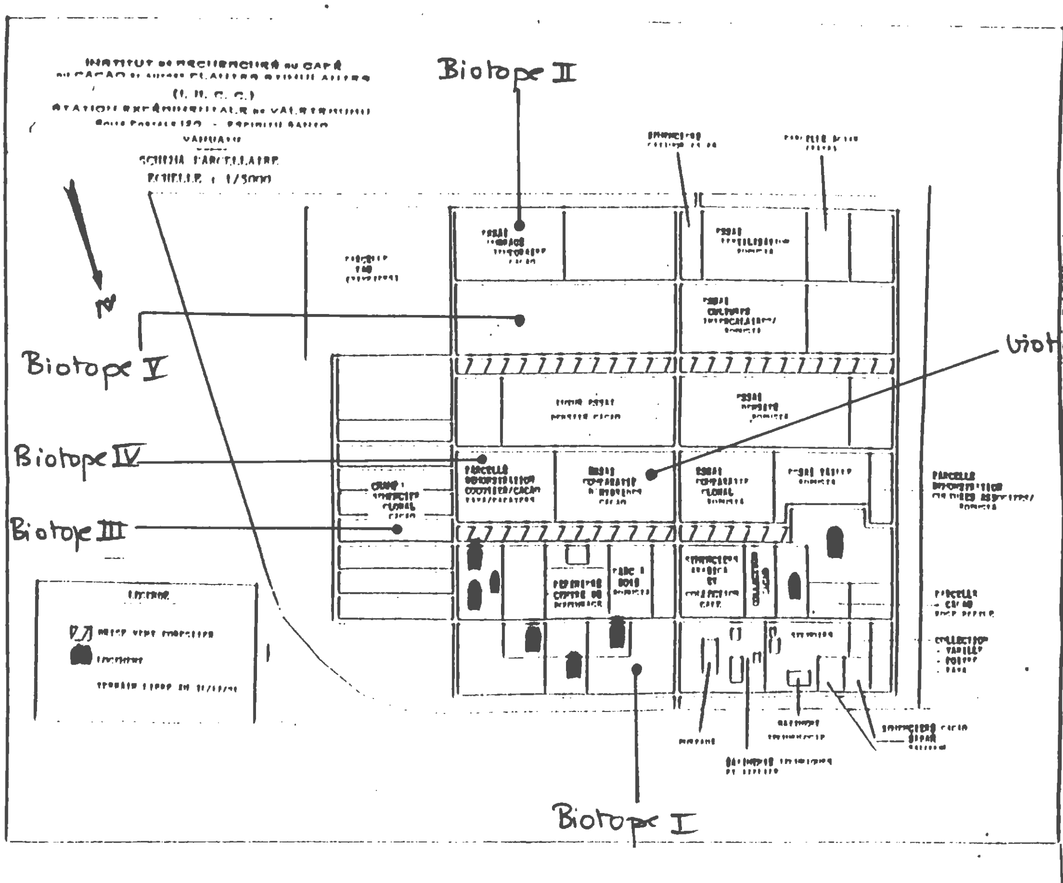
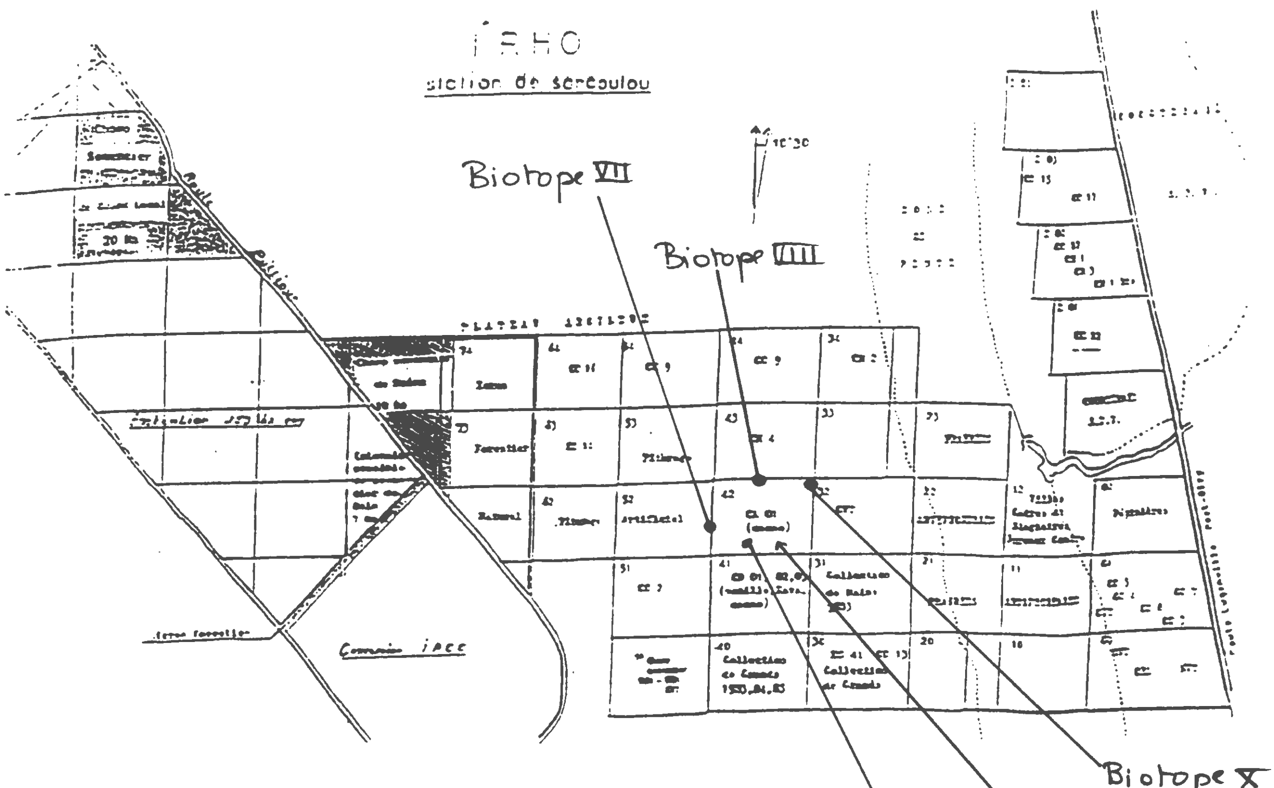
ANNEXES



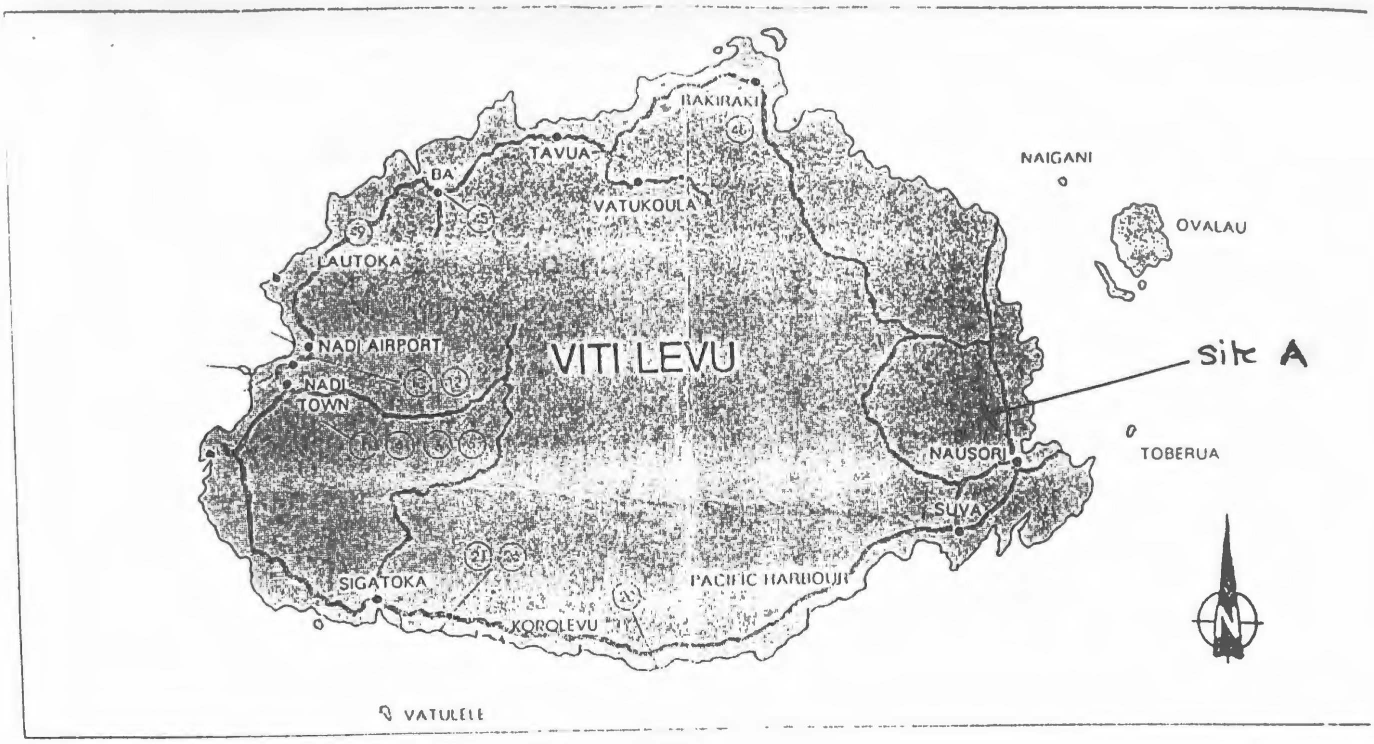
MAP B : I.R.C.C. Research Station

Site 1

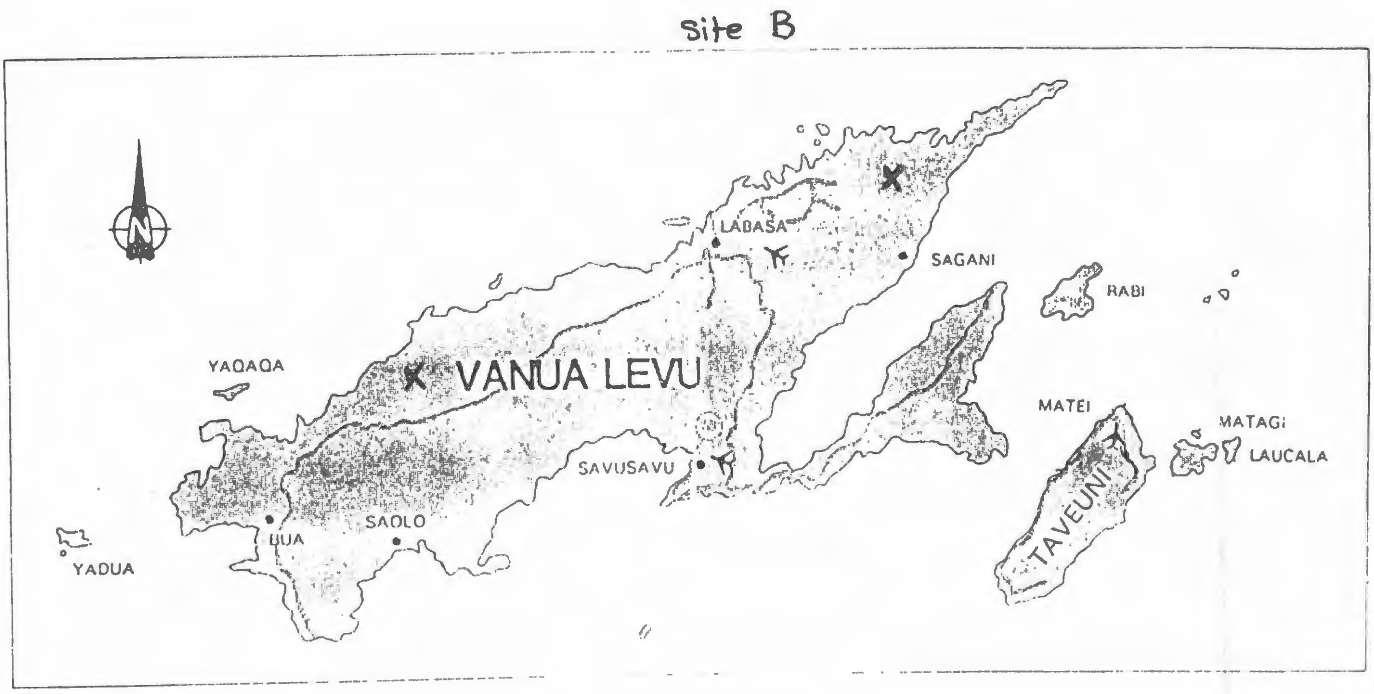


MAP C : I.R.H.O. Research Station

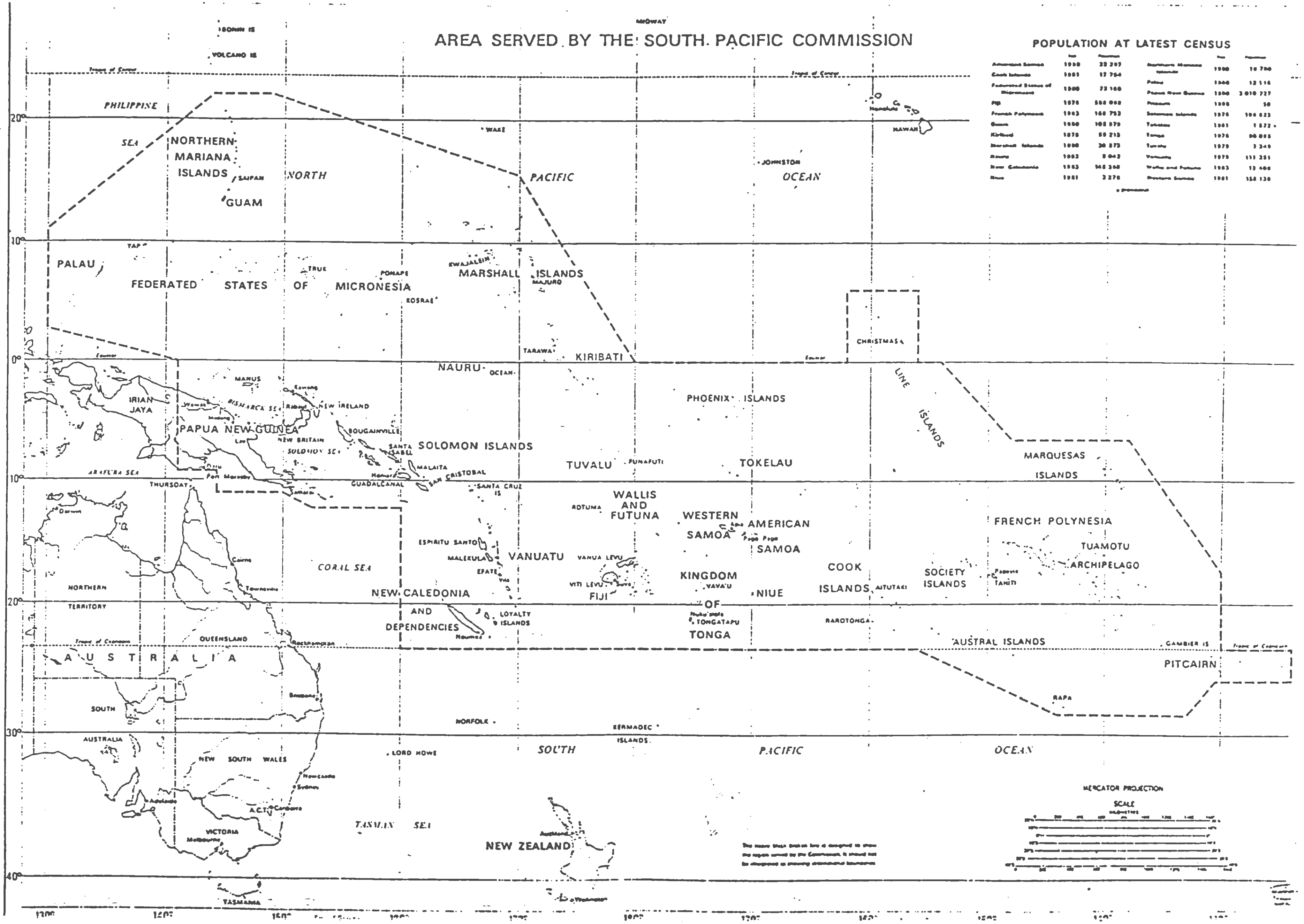
Site 2

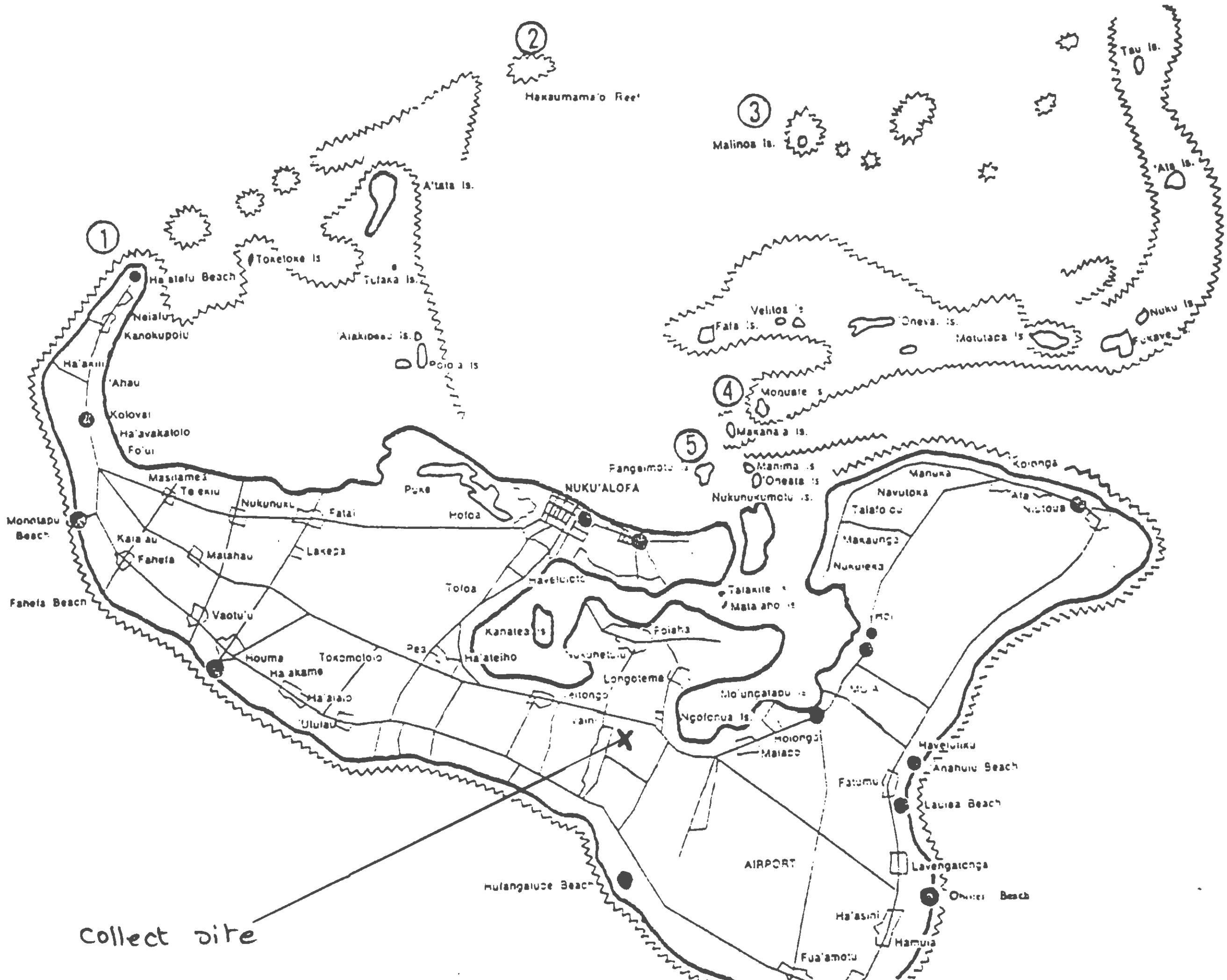


MAP D : FIDJI Islands

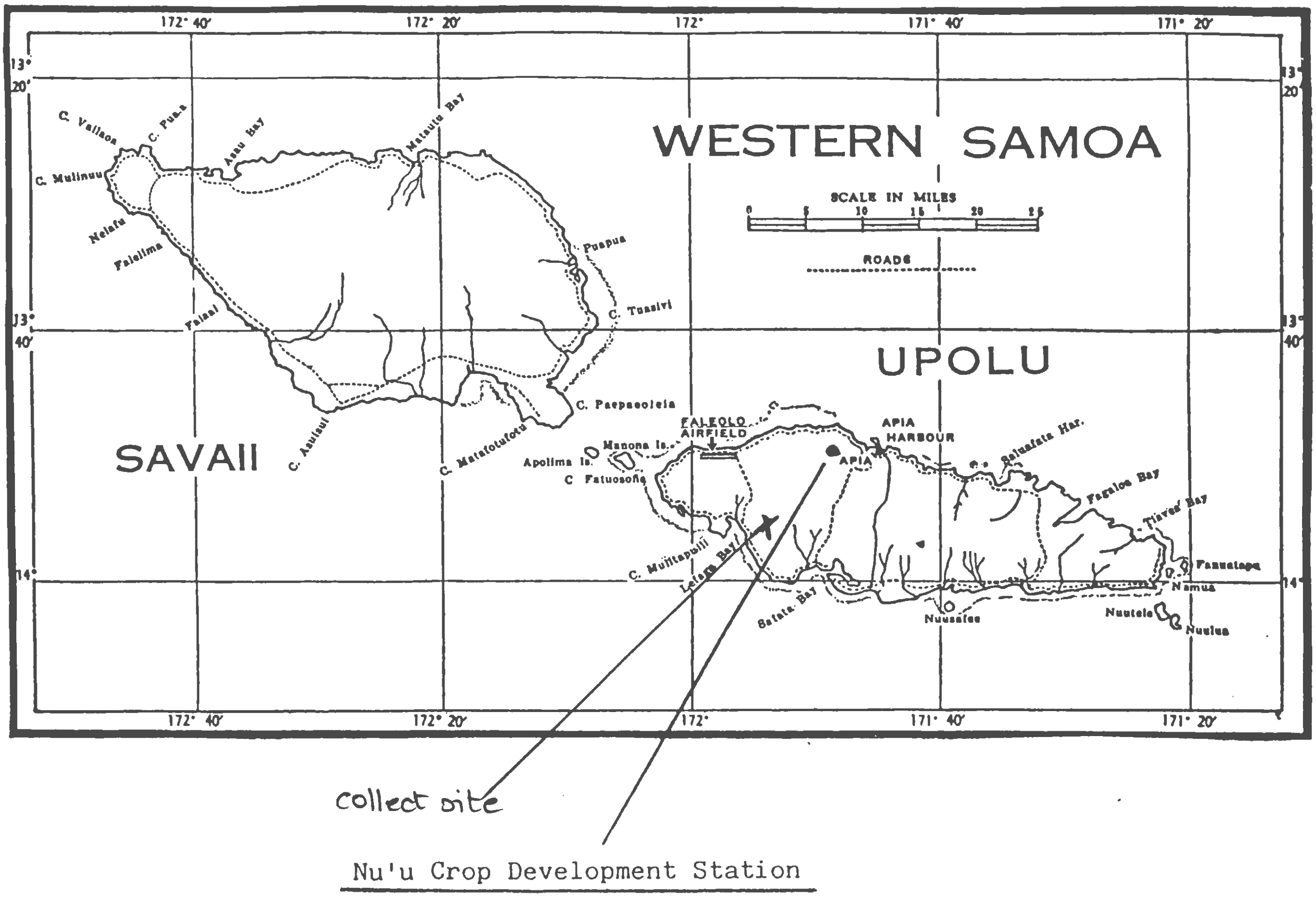


map E

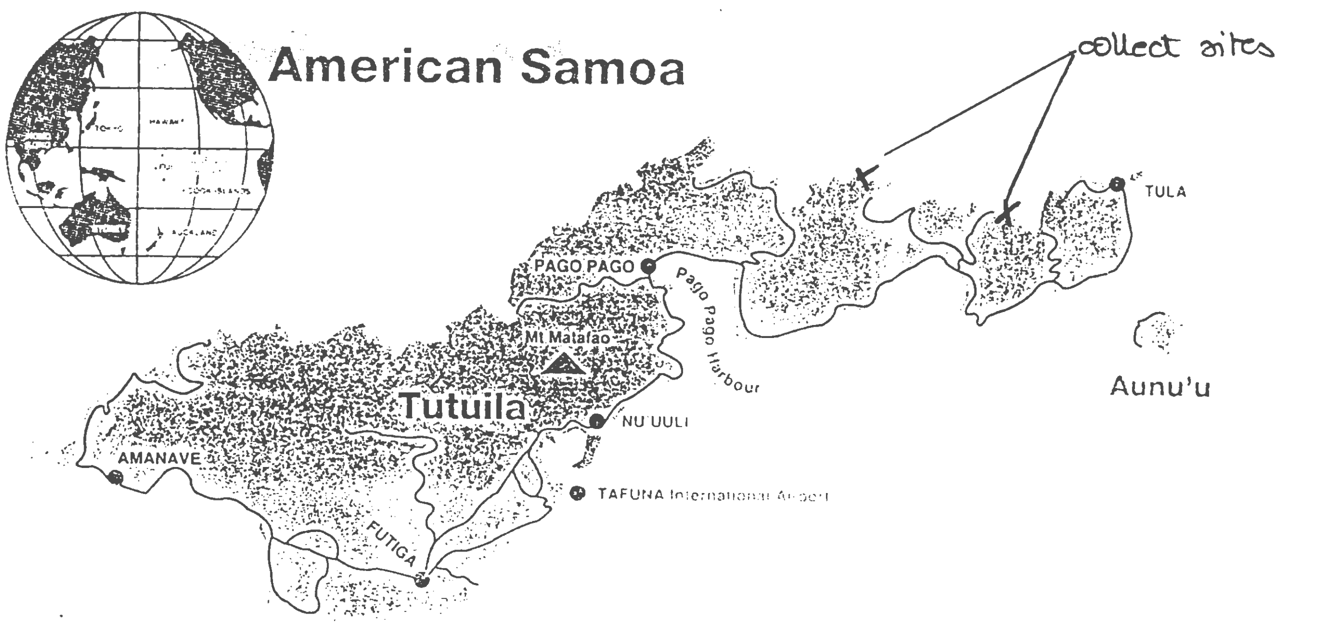

AREA SERVED BY THE SOUTH PACIFIC COMMISSION
POPULATION AT LATEST CENSUS
PHILIPPINE SEA
NORTHERN MARIANA ISLANDS
GUAM
NORTH PACIFIC OCEAN
JOHNSTON
HAWAII
PALAU
FEDERATED STATES OF MICRONESIA
MARSHALL ISLANDS
CHRISTMAS
NAURU
KIRIBATI
TARAWA
LINE ISLANDS
PHOENIX ISLANDS
IRIAN JAYA
PAPUA NEW GUINEA
BISMARCK SEA
NEW IRELAND
BOUGAINVILLE
NEW BRITAIN
SOLOMON SEA
SOLOMON ISLANDS
MALAITA
GUADALCANAL
SAN CRISTOBAL
SANTA CRUZ IS
TUVALU
FUNAFUTI
TOKELAU
MARQUESAS ISLANDS
ARAFURA SEA
THURSDAY
WALLIS AND FUTUNA
ROTUMA
WESTERN SAMOA
AMERICAN SAMOA
FRENCH POLYNESIA
TUAMOTU ARCHIPELAGO
ESPIRITU SANTO
MALEKULA
EFATE
VANUATU
VANUA LEVU
VITI LEVU
FIJI
KINGDOM OF TONGA
VAVA'U
TONGATAPU
NIUE
COOK ISLANDS
AITUTAKI
RAROTONGA
SOCIETY ISLANDS
TAHITI
CORAL SEA
NEW CALEDONIA AND DEPENDENCIES
LOYALTY ISLANDS
NORTHERN TERRITORY
QUEENSLAND
AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
TASMANIA
AUSTRAL ISLANDS
GAMBIER IS
PITCAIRN
RAPA
NORFOLK
KERMADEC ISLANDS
LORD HOWE
SOUTH PACIFIC OCEAN
TASMAN SEA
NEW ZEALAND
MERCATOR PROJECTION
SCALE



MAP F : TONGA islands

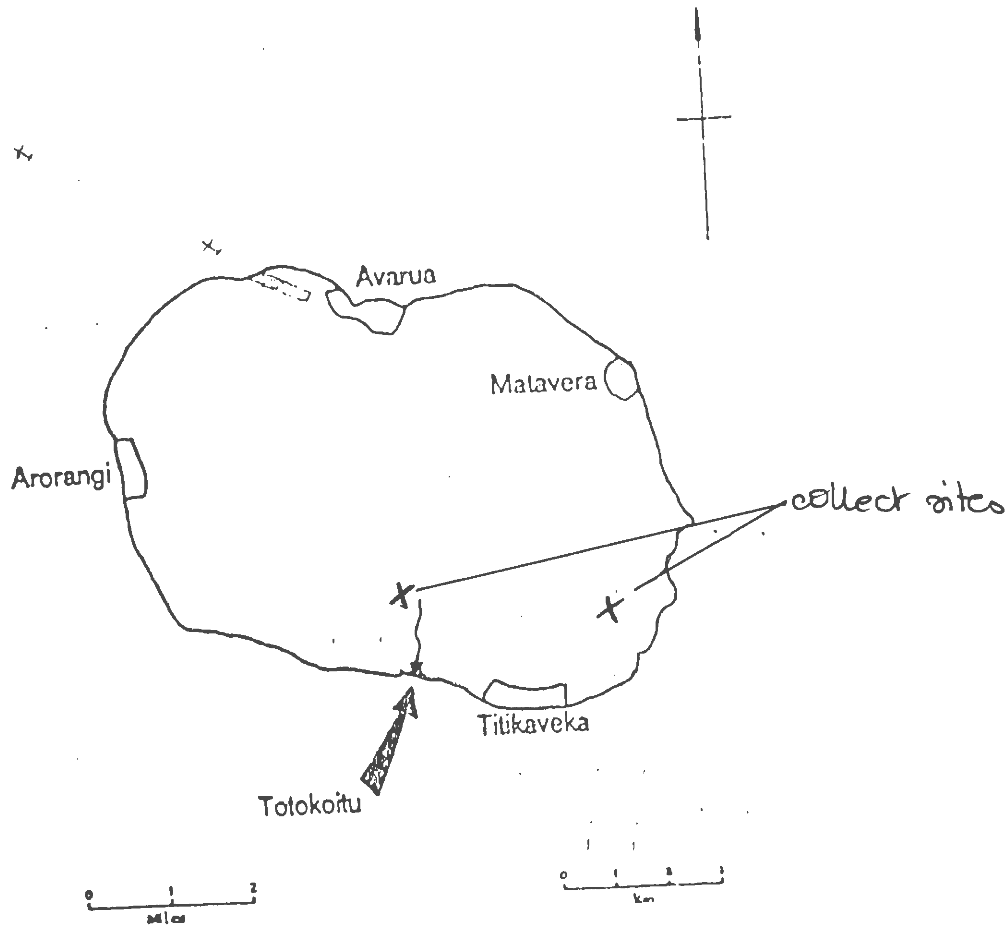


MAP G : WESTERN SAMOAS



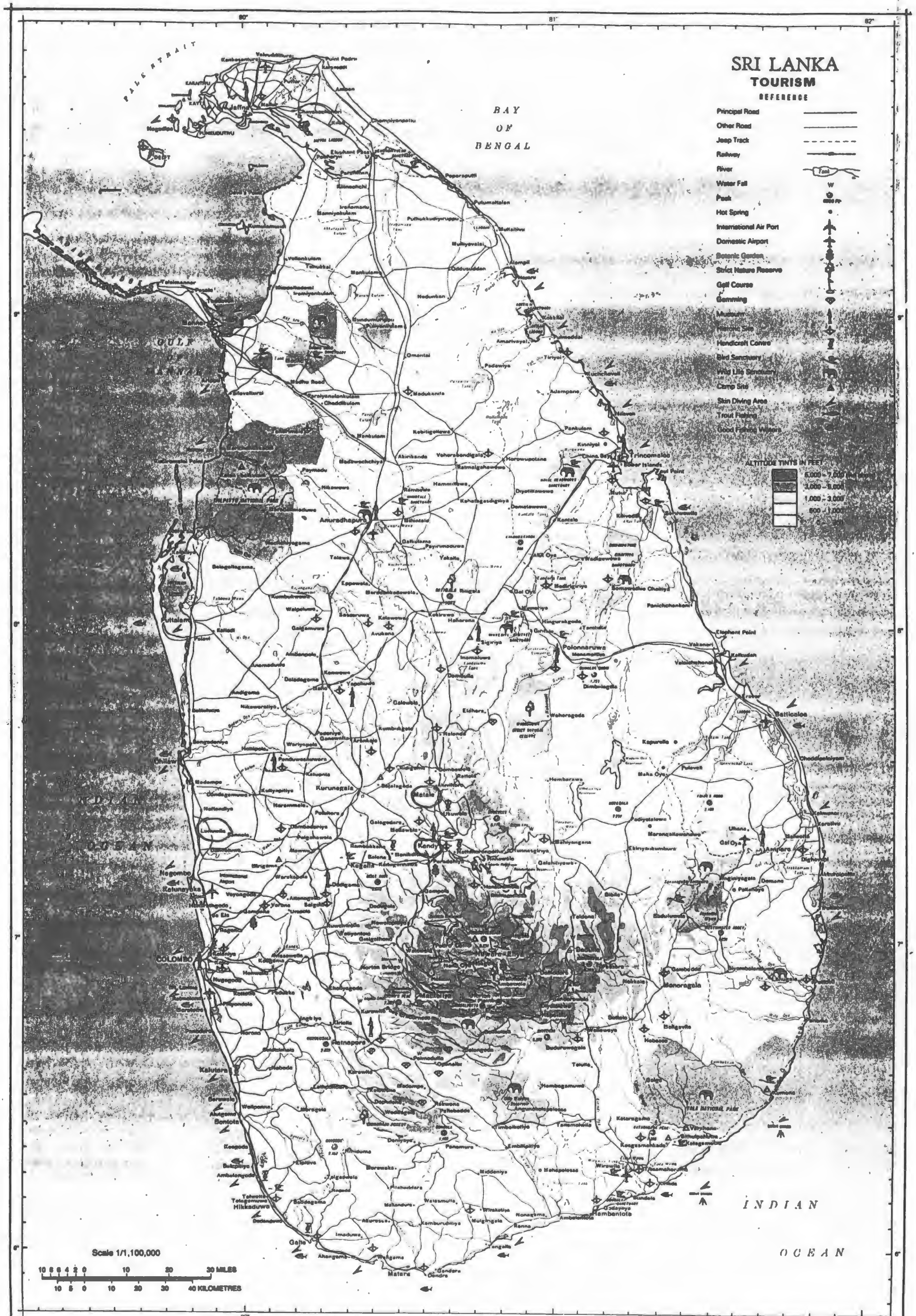
MAP H : AMERICAN SAMOAS

LOCALITY MAP OF RAROTONGA



MAP I : COOK Islands

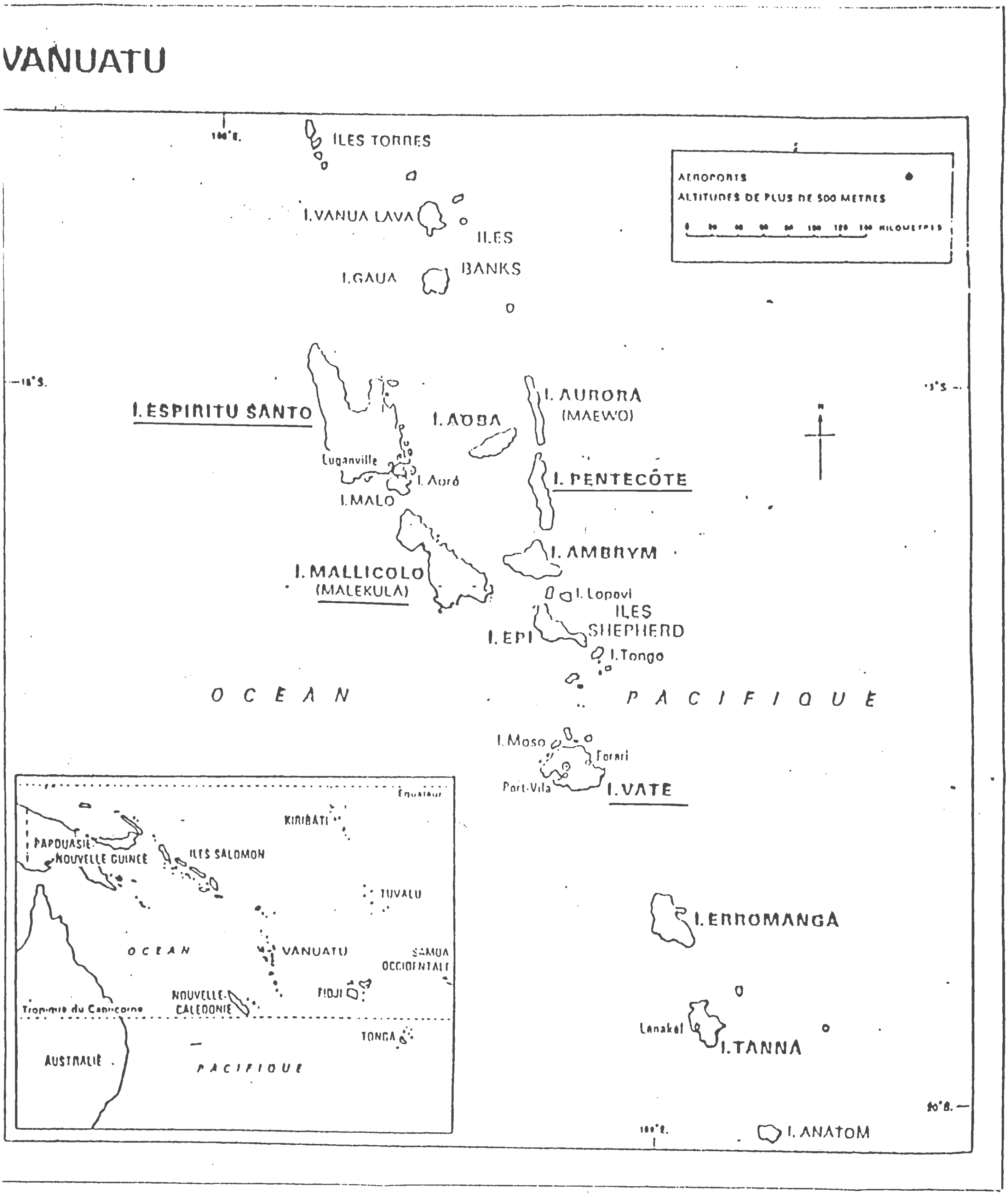
MAP J : SRI LANKA



MAP K : INDIA


SCALE - 1 cm = 30 km
KARNATAKA STATE
INDIA
KERALA STATE
Kasaragod
Cannanore
Wynad
Calicut
Malappuram
Palghat
Coimbatore
N
S
LAKSHADWEEP SEA
Trichur
Ernakulam
Idukki
TAMILNADU STATE
Kottayam
R-Block
Alleppey
Pathanamthitta
Mavelikara
Quilon
Shenkottai
Trivandrum
Kanyakumari

MAP L


VANUATU
ILES TORRES
AEROPORTS
ALTITUDES DE PLUS DE 500 METRES
KILOMETRES
I. VANUA LAVA
ILES
BANKS
I. GAUA
I. ESPIRITU SANTO
I. AOBA
I. AURORA
(MAEWO)
Luganville
I. Aoré
I. MALO
I. PENTECÔTE
I. AMBRYM
I. MALLICOLO
(MALEKULA)
I. Lopevi
ILES
SHEPHERD
I. EPI
I. Tongo
OCEAN
PACIFIQUE
I. Moso
Forari
Port-Vila
I. VATE
I. ERROMANGA
Lanakel
I. TANNA
I. ANATOM
Equateur
KIRIBATI
PAPOUASIE
NOUVELLE GUINEE
ILES SALOMON
TUVALU
OCEAN
VANUATU
SAMOA
OCCIDENTALE
NOUVELLE-
CALEDONIE
FIDJI
Tropique du Capricorne
TONGA
AUSTRALIE
PACIFIQUE

ANNEXE 2

Document 1

	Contamination	Infection	Invasion	Colonisation	Sporulation	Conservation
Etapes au niveau de la cuticule	Contact de l'insecte avec des spores	Germination de spores sur la cuticule de l'insecte			Apparition de mycélium puis de conidiospores qui porteront des spores colorées	Dissémination des spores autour du cadavre. Conservation dans le sol pdt plusieurs semaines
Etapes dans l'hôte		Traversée de la cuticule et pénétration dans la cavité générale	Multiplication d'éléments mycéliens (blastospores) Mort de l'hôte	Envahissement total de l'hôte par le mycélium		
Symptômes externes		Apparition de la plaquede mélanisation	Débutde pigmentation	Cadavre transformé en momie dure	Feutrage blanc qui prendraune teinte blanche, verte, rose-lilas selon la muscardine	

Phases successives du développement d'une muscardine chez un insecte

(ROBERT, 1989)

Document 2

INTRODUCTIONS FOR THE BIOLOGICAL CONTROL OF ADORETUS VERSUTUS
(in WATERHOUSE and NORRIS, 1987)
and
REVIEW OF NATURAL BIOLOGICAL CONTROL OF ADORETUS SPP. (1989)

SPECIES	COUNTRY	PATHOGEN PARASITE PREDATOR	REFERENCE	COMMENTS
A.versutus	Fiji	Micromeriella marginella	'VEITCH, 1924	Introduced not established
		Aspergillus glaucus	'JEPSON, in LEVER, 1945	?
		Botrytis sp.	'JEPSON, in LEVER, 1945	?
A.versutus	Mauritus	Campsomeriella coelebs	'De CHARNOY, 1917	?
		Prosena siberita	'JEPSON, 1939	?
A.versutus	West.Samoa	Micromeriella marginella	'DUMBLETON, 1957	-
			'ANON, 1979	-
A.versutus	SOLOMON IS	Micromeriella marginella	'IKIN, 1984	?
A.versutus	VANUATU	Micromeriella marginella	WELLER, pers.com., 1986	?
A.sinicus	HAWAII	Micromeriella marginella	'PEMBERTON, 1954, 1964	+
		Tiphia lucida	'PEMBERTON, 1954, 1964	-
		Tiphia segregata	'PEMBERTON, 1954, 1964	+
A.sinicus	GUAM	Campsomeris marginella	*MUNIAPPAN, pers.com, 1989	Native
		Tiphia segregata		
A.tenuimaculatus	JAPAN	Beauveria bassiana	*TETSUO SAITO, pers.com, 1989	Native
		B. brongniartii		
		Metarhizium anisopliae		
		Hamaxia incongrua	*JOJIRO NISHIGAKI, pers.com, 1989	
		Tenodera angustipennis		
		Vespa xanthoptera		
A. spp(6spp)	TAIWAN	Ochromeigenia ormioides	*YAU-I CHU, pers.com, 1989	Native
A. spp(13spp)	CHINA	Scolia clypeata	*WU WEI-WEN, pers.com, 1989	Native
		Tiphia popilliavora		
		T. phyllophaga		
		Campsomeris annulata		
		Beauveria bassiana	*CHAI XI-MIN, pers.com, 1989	
		Metarhizium anisopliae		
A. spp(2spp)	INDONESIA	Ommatius sp.	*ARIFIN DJAMIN, pers.com, 1989	Native
		Philodiens sp.		
		Campylocera sp.		
		Tiphia sp.	*SOEHARDJAN, pers.com, 1989	Native
		Prosena sp.		
		Campylocera sp.		
		Ommatius sp.		
		Philodicus		
		Histerid		
A.versutus	INDIA	Beauveria brongniartii	*JAYARAMAIAH, 1983	Native
A.bicolor		B. brongniartii	and VEERESH	
		B. bassiana		

+ in WATERHOUSE and NORRIS (1987)

* references in Annexe 4

ANNEX 3

Diseases from overseas laboratories

* International Mycological Institute (CAB), England,
* International Institute of Biological Control, England,
* Reading University, England,
* DSIR, Plant Protection Division, Aukland,New Zealand,
* Ministry of Agriculture and Fisheries, New Zealand
* CSIRO, Australia,
* Department of Primary Industry, Tasmania, Australia,
* International Rice Research Institute, Philippines,
* Plant Genetic Systems, Belgium,
* Bayer, Germany and Australia.

ANNEX 4

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  Centre de recherches de Versailles
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  78 026 VERSAILLES - FRANCE

* Monsieur C. LAUMOND
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  Entomologist
  NU'U Crop Development and
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  APIA

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  PO BOX 96
  RAROTONGA

* **Vanuatu** : Mr Ben TARILONGI
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  Mr C.P. RAMACHANDRAM
  C.P.C.R.I.
  Regional Station
  KAYANGULAM
  KRISHNAPURAM - 690 533 - Kerala

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  Indian Institute of Horticultural Research
  Hessaraghatta - Bangalore

* Dr D. MARIAMMA
  CPCRI
  Vittal - South Kanara

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  Bangalore 560024

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  Indian Council of Agricultural Research
  Krichi Bhavan - NEW DEHLI 110 001

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  University of Kelaniya

* Dr KUDAGAMAGE
  Head-Division Entomology
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  vn Biological Control Research Centre.

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OHYA, SHIZUOKA 422

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Department Pertanian - republik Indonesia
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* GU-BENKANG
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Professor of Entomology

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* Dr M. IBRAHIM ALI
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Entomology Division
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Contact with Agricultural Economist - VANUATU

* Mrs F. SKEA
  Agricultural Economist
  Department of Agriculture, Livestock and Horticulture
  Port Vila - VANUATU

ANNEXE 5

MISSIONS CALENDAR

Efate island :
19-11-92 : Meeting with Mr VOS (CEE Delegate) and Mr SMITH (Co-ordinator PRAP)

Pentecost island (VANUATU) :
4-12-91 : 12h30 Lonorore arrival
Nursery visit
Panas
Rungzukzuk
Lonorore
5-12-91 : Lonorore to Melssissi
Waterfalls
6-12-91 : Melssissi to Bwarnapné
Ena
7-12-91 : Ena to Bwatnapné to Loltong
Lolvatu - Nursery visit
Laoué
8-12-91 : Loltong
9-12-91 : Return to Santo island (VANUATU)

Solomon islands :
7-2-92 : Santo to Vila
8-2-92 : Vila to Honiara
10-2-92 to 13-2-92 : R.A.B. Meeting
12-2-92 : Field visit
14-2-92 : Return to Vila
19-2-92 : Return to Santo

Fiji :
22-2-92 : Santo to Vila
23-2-92 : Vila to Suva
24-2-92 to 28-2-92 : SPC Seventh Regional Technical Meeting on Plant Protection - Suva.
29-2-92 : Prospect on Vitilevu island (Naduruloulou Research Station) to locate *Micromeriella marginella.*
2-3-92 and 3-3-92 : prospect on Vanualevu island to locate *Micromeriella marginella*
4-3-92 : Library
Send parcels with larvae to INRA (FRANCE) by D.H.L.
5-3-92 : Return to Vila and Santo

Efate island (VANUATU) :

16-3-92 : Santo to Vila

16-3-92 to 20-3-92 : Prospect on Efate island to locate *Micromeriella marginella* : Tagabe, North Efate, Melé, Montmartre. Sent larvae parcel to INRA (FRANCE) by D.H.L..

20-3-92 : Return to Santo

Sri Lanka :

2-5-92 : Santo to Vila

3-5-92 : Vila to Bangkok (via Sydney)

4-5-92 : Bangkok to Colombo
Colombo to Lunuvila

5-5-92 : Prospect at the Agricultural Farm - Mavelikara.

6-5-92 : Prospect at Kandy

7-5-92 : Prospect at Matale

8-5-92 : Library and send parcels of larvae to FRANCE by D.H.L.

9-5-92 : Colombo

11-5-92 : Colombo to Trivandrum

India :

11-5-92 : Colombo to Trivandrum
Trivandrum to Kayangulam

12-5-92 : Library, meeting with Director
Visit Biocontrol Laboratory

13-5-92 : District Agricultural Farm
Microbial control of Rhinoceros beetle
Microbial control of Red palm weevil

14-5-92 : Prospect on Allepey - Nursery visit
Biological control of coconut leaf cating caterpillar

15-5-92 : Visit Research Station C.P.C.R.I. and library

16-5-92 : Trivandrum to Colombo

17-5-92 : Colombo-Bangkok-Sydney

18-5-92 : Sydney-Nouméa-Vila

19-5-92 : Vila to Santo

Efate :

3-6-92 : Santo to Vila
Meeting with economist consultant (Mr PENNEY), Mr VOS (CEE Delagate), Mr B. THISTLETON (Team Leader Taro Beetle Project)

4-6-92 : Return to Santo

South Pacific mission :

6-6-92 : Santo to Vila

8-6-92 : Vila to Nadi (Fiji)

11-6-92 : Nadi to Rarotonga (Cook islands)
Prospect in Cook islands

12-6-92 : Prospect in Cook islands and send larvae parcels to INRA (FRANCE) by D.H.L.
14-6-92 : Rarotonga to Pago Pago (American Samoa)
15-6-92 : Prospects
16-6-92 : Prospects and Library
17-6-92 : Prospects and Library
18-6-92 : American Samoa to Western Samoa
19-6-92 : Prospects and contacts
20-6-92 : Prospects
22-6-92 : Prospects and send larvae parcels to INRA (FRANCE) by D.H.L.
23-6-92 : Western Samoa to Tonga
24-6-92 : Field visits and prospects
25-6-92 : Send larvae parcels to INRA (FRANCE) by D.H.L.
26-6-92 : Library
29-6-92 : Tonga to Fiji
30-6-92 : Prospects on Vitilevu island
1-7-92 : Suva to Taveuni - Prospects on Taveuni islands
2-7-92 :Prospects on Taveuni islands - Taveuni to Suva
3-7-92 : Send larvae parcels to INRA (FRANCE) by D.H.L.
4-7-92 : Suva-Nadi (Fiji) ; Nadi-Vila ; Vila-Santo

Malekula island (VANUATU) :

8-7-92 : Santo to Malekula
Prospects with Agricultural economist
9-7-92 : Prospects with Agricultural economist
10-7-92 : Malekula to santo

Efate (VANUATU) :

16-7-92 : Santo-Vila
17-7-92 : Mr PENNEY draft report meeting
19-7-92 : Vila-Santo

21-8-92 : Santo- Vila
Meeting with Mr VOS (CEE Delegate)
23-8-92 : Vila-Santo

21-9-92 : Santo-Vila - Meeting with Computel (report preparation)
22-9-92 : Vila to santo

11-10-92 : Santo to Vila
12-10-92 : Draft report meeting
Vila to Santo

FEASIBILITY STUDY OF THE BIOLOGICAL CONTROL OF ADORETUS VERSUTUS HAR. (Coleoptera, Scarabaeidae, Rutelinae)

Adoretus versutus Har."rose beetle" is a pest whose adult stage causes important damage to ornamental plants, subsistence crops and particularly to cocoa seedlings in the South Pacific.

One example is the accidental introduction of A.versutus to VANUATU in 1982. During severe outbreaks in 1988, cocoa trees could be completely defoliated before the infestation settled down to a somewhat lower equilibrium level.

Agronomic and chemical control are not satisfactory options.

To explain the decline of rose beetle populations, it has been suggested that a natural biological control has taken place. In order to identify the parasitoid or pathogen responsible, biological and biological control studies have been realized from field collections in VANUATU.

Collection of field samples and information has been carried out in the areas of rose beetle origin (India and Sri Lanka) and prospections have been undertaken in the South Pacific islands (Fiji, Tonga, Western Samoa, American Samoa, Cook islands) to investigate natural biological control.

Biological studies in the laboratory showed that the female eats more than the male and that cocoa is preferred to other plants attacked by rose beetle. Field studies revealed that the pest is present throughout the year and field collections in the soil showed all stages present at any given time. Population fluctuations have been observed and population levels are higher after the rainy season. Results in 1991-1992 showed a decrease of A. versutus in VANUATU, compared with 1988 and 1990.

From field collections, a pathogen has been identified as Metarhizium anisopliae (21%), active particularly at the end of the rainy season in VANUATU. From other South Pacific islands, pathogens have been isolated from Melolonthinae larvae - poxvirus (76%) and Bacillus cereus (10%) in Fiji ; from Western Samoa, Metarhizium and B.sphaericus have been observed.

Soil sample analysis on VANUATU showed B. thuringiensis (30%) and B.sphaericus (17%).

Results from the other countries visited will be known within the next few months.

From collections in the area of origin, only Melolonthinae have been collected. Rose beetle not being a pest, it is difficult to find but it is in these countries that pathogen searches must be continued.

Economic assessment has been carried out by a consultant economist on damage to leaves but it is not possible to relate this to actual yield loss. However, cocoa seedlings have been observed damaged for ten months of the year and observations revealed about 4% dead trees. 33 days after planting, a field test showed that at the end of the rainy season 25% to 40% of cocoa seedlings were badly attacked.

Another important observation is that severe damage to branches caused by rose beetle has been shown to probably harbour bark canker.

All the results presented in this report remain incomplete since quarantine observations continue for most of the samples collected in the South Pacific islands.

Key words : *Adoretus versutus*, *Metarhizium anisopliae*, *Poxvirus*, Biological control, *Theobroma cacao*, area of origin, South Pacific islands