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CONTROLLING *SUFETULA* SPP.: A COCONUT INSECT PEST ON PEAT SOILS

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SUMMARY

We demonstrated experimentally that *Sufetula*, a root-mining insect, has a depressive effect on coconut yields on peat soils. The impact of the pest resulted in a shortfall in earnings that warranted taking control measures. We considered control methods suitable for rehabilitating infested mature coconut plantings and for preserving young coconut plantings. Currently, cultural control is the only effective method. It involves eliminating all identified shelters for the adult insect, i.e. fern cover and heaps of coconut waste (dry fronds and husks). The aim is to achieve totally bare soil, with moss cover that does not attract the pest, or planted with an unattractive intercrop such as pineapple.

INTRODUCTION

In an earlier paper (Bonneau *et al.*, 2004), we reported the discovery of a factor limiting yields in a coconut plantation on a peat soil, namely the root-mining insect *Sufetula* spp. Since then, the depressive effect of the pest has been assessed, and control methods have been proposed to limit its impact.

This paper reports quantitative evaluation of the pest's depressive effect and proposes possible control methods that can be used on an estate. For the time being, the only accessible and usable method is cultural control by creating conditions that are not conducive to pest infestation on the soil surface in the vicinity of coconut palms.

MATERIALS AND METHODS

These were the same as those described previously (Bonneau *et al.*, 2004). The study was carried out on a coconut estate (18 000 ha) belonging to Riau Sakti United Plantations (RSUP) and planted on deep peat on the east coast of the island of Sumatra (Indonesia, Riau province). Field trials were used to test *in situ* the effects of treatments applied to the coconut palms.

We are continuing here with a trial already described in Bonneau *et al.* (2004) (Trial 3) and we also refer to two other experiments, Trial 4 and Trial 5, which did not feature in the earlier article. Different variables were observed: fruit setting, yield as

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number of nuts per tree, vegetative growth of aerial parts, and roots. For the roots, one of the observed variables was the number of healthy root segments of specified length. The length of a healthy root segment represents the interval between two successive pest attacks. It is inversely proportional to the pest pressure: the larger the number of long healthy root segments in the total observed length of one root, the lower is the pest pressure. Conversely, the larger the number of short healthy root segments, the greater is the pest pressure.

MEASUREMENT OF PEST'S DEPRESSIVE EFFECT

Trial 3

Trial 3 (Bonneau *et al.*, 2004) was continued under the same conditions, i.e. by comparing two cultural practices:

- Interrow covered by ferns, weeded planting row and a weeded circle with a radius of 2 m around the coconut palms. This treatment was intended to provide suitable conditions for the pest, hence maximum pressure on coconut palm roots.
- Totally bare soil over the entire surface: chemically eliminated ferns were gradually replaced by a carpet of moss (unattractive to the pest) and coconut waste (dry fronds, dry spikelets and husks) was piled up and regularly burnt. The aim of this treatment was to eliminate shelters for adult pests and thereby induce minimum pressure on coconut palm roots.

Each of the two main treatments (called 'ferns' and 'bare soil' in the following text) was subdivided until 2000 into three subdivisions with different types of silicate fertilizers, for which an absence of any effect was demonstrated. We therefore subsequently concentrated exclusively on the main treatments.

Each unit plot contained 36 coconut palms (six rows of six) of which 16 were useful palms (four rows of four). There were four replicates, i.e. 24 unit plots. The trial was planted in May 1997, after clearing primary forest at the beginning of 1992, followed by five years of fallow (alternating regrowth and annual crops).

Figures 1 and 2 show the depressive effect of the fern treatment compared to the bare soil treatment. Figure 1 shows that fruit-setting was better in the fern treatment up to the fourth year after planting, then it levelled off in the fifth year, and became sustainably better in the bare soil treatment from the sixth year onwards. There was a yield difference of around one nut per bunch, each month, in favour of the bare soil treatment. This difference was more or less stable from the sixth to the ninth year after planting.

The trend was also found in ripe nut production (Figure 2): it was found that the coconut palms in the bare soil treatment systematically produced more nuts than the palms in the ferns treatment from the sixth year onwards, with the difference remaining more or less stable over time.

This result occurred with all other things being equal and non-limiting since planting. The same planting material (a mixture of MAWA and Khina 2 hybrids in the same proportions in the two treatments) was the same, and it was planted on

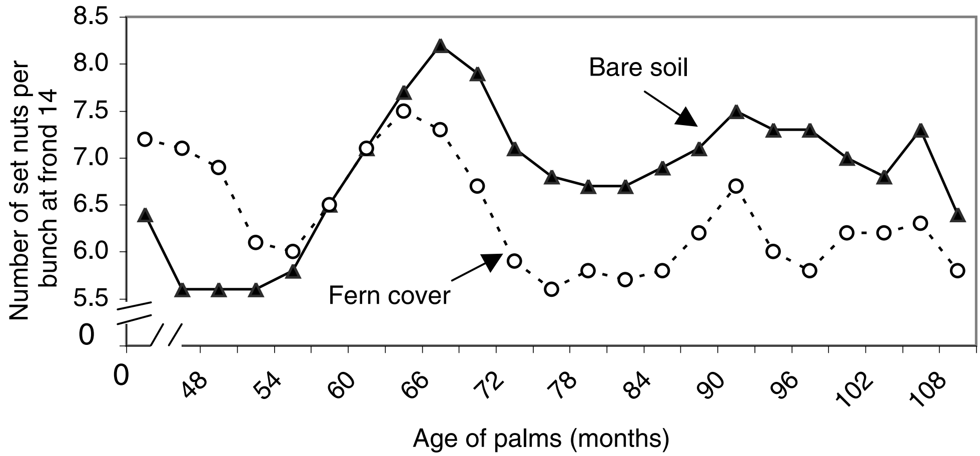

Figure 1. Trial 3. Effect of soil cover type on coconut fruit-setting. Each point is the weighted mean of the six preceding monthly values.

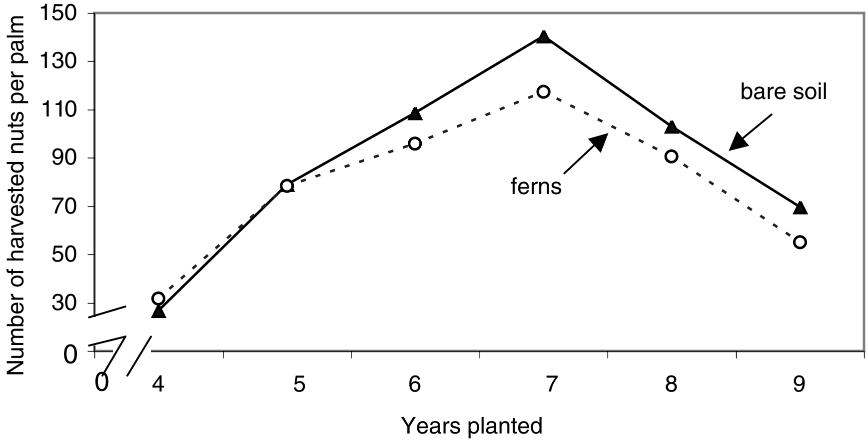

Figure 2. Trial 3. Effect of soil cover type on coconut yield.

the same soil (deep peat), with the same land preparation (compaction of the entire surface), with a water table controlled at the same level (–30 to –40 cm) and identical fertilization (we checked the nutritional status of the coconut palms by annual leaf analyses, and it remained satisfactory and identical for both treatments).

The difference in fruit-setting and production between the two treatments could therefore only come from the treatments themselves, i.e. the type of soil cover. Worth noting are the good yields for young hybrids in the bare soil treatment (140 nuts palm^{-1} year^{-1} in the seventh year after planting). This clearly showed that there were no limiting factors other than the one studied under the experimental conditions applied.

Table 1. RSUP. Trial 3. Correlation between pest pressure on roots and coconut yield.

Variable (on eight observed roots per coconut palm)	Observation date	Treatments		*s.e.*
		Bare soil	Ferns	
Number of short healthy segments (0.1 to 0.5 m) of primary root between two attacks†	November 2004	13.6	33.1	3.6
	February 2005	20.8	36.4	2.4
	April 2006	12.0	22.8	6.8
Number of very long healthy segments (>5 m) of primary root between two attacks‡	November 2004	1.1	0.2	0.8
	February 2005	0.7	0.0	0.3
	April 2006	1.8	0.1	0.5
Mean length of lateral primary root (m)	November 2004	5.20	4.56	0.39
	February 2005	5.57	4.33	0.26
	April 2006	5.79	4.08	0.43
Average distance from first attack to stem (m)	November 2004	2.42	1.64	0.48
	February 2005	2.79	1.69	0.27
	April 2006	2.70	1.09	0.46
Mean intensity of DBL symptom on aerial parts§	November 2004	0.13	0.22	0.03
	April 2006	0.42	0.40	0.12
Production (number of nuts palm^{-1} y^{-1})	July 2004 to June 2005	103.1	90.5	3.6
	July 2005 to June 2006	69.7	55.0	2.1

†The lower the number of short healthy root segments, the lower is the pest pressure on roots.
‡The higher the number of long healthy root segments, the lower is the pest pressure on roots.
§Four intensity levels from 0 to 3.

We have demonstrated once again that the depressive effect of fern cover works via strong pest pressure on coconut palm roots. A correlation existed between the type of soil cover, the frequency of pest attacks on coconut roots, the existence of the dry bunches and leaves and defective fruit-setting (DBL) symptom (as described by Bonneau *et al.*, 2004) in the aerial organs of the coconut palms (although the difference between treatments is less striking for this variable), and depressed yields (Table 1). It was thus by encouraging the presence of *Sufetula* spp. around coconut palms that fern cover proved harmful.

In Trial 3, we were able to measure precisely the depression caused by the pest. It amounted to 21% in the ninth year (annual maximum) and 15 % on average over four years (six to nine years after planting). This was less than the –30 to –50 % depression we had estimated previously (Bonneau *et al.*, 2004), but it should be noted that:

– There is every chance that the depression will worsen over time.
– The bare soil treatment was not equal to zero incidence of *Sufetula*. Indeed, given the proximity between bare soil zones and fern zones, with small experimental plots, there was bound to be migrations and exchanges. Let us speak more of a low to moderate pest pressure in a bare soil, as opposed to strong pressure in a fern-covered soil.

Trial 4

Another experiment (Trial 4) consisted of replanting young coconut hybrids immediately after felling old coconut palms severely infested by *Sufetula* spp. The

Table 2. RSUP. Comparative growth of young coconut palms in three trials, according to different preceding crops. N.B. We have selected in each trial the treatments it is most possible to compare (planting material, fertilization).

Variable	Age of coconut palms (months after planting)	Trial 3 Fern cover after fallow	Trial 4 Treatment without mulch after old coconut palms	Trial 5 Fertilized treatment, surrounded by pineapple after pineapple
Collar girth (m)	24	1.30	1.05	0.97
	36	1.52	1.31	1.48
	42	1.55	1.31	1.60
Number of green fronds per palm	24	16.7	14.2	13.1
	36	24.0	19.4	22.5
	42	26.6	24.2	25.9
Distance from first attack to stem (m)	Observed at different times	0.88 to 1.94	0.64 to 0.79	1.59 to 2.06
Mean length of lateral primary root (m)	61 for Trial 3	3.14		
	43 for Trial 4		2.50	
	49 for Trial 5			4.08

trial was planted in November 1998, just after felling the old coconut palms. Three main treatments were tested: control without mulch; mulch made from cocopeat (mixed with residual fibres); and a mulch of chopped coconut husks. Each of the main treatments was subdivided: with or without controlling fern regrowth in the interrow, for which an absence of any effect was demonstrated (meaning that elimination of fern cover in the interrow, without eliminating other potential shelters for *Sufetula* adults, did not reduce the incidence of the pest). We therefore subsequently concentrated exclusively on the main treatments.

The trial comprised four replicates, i.e. 24 unit plots, each unit plot containing 25 coconut palms (five rows of five) of which nine were useful palms (three rows of three).

The water table was controlled at an identical depth inside the trial (–20 to –40 cm) and mineral fertilization was applied in a uniform manner. To limit attacks on the young palms, *Oryctes* pest control was carried out in the first two years, by applying insecticide granules in the frond axils of the young palms, and by collecting larvae from old felled decomposing coconut stems.

Over five years of observations, from 1999 to 2003 inclusive, we discovered two noteworthy facts:

- Firstly, a very strong *Sufetula* pest pressure was exerted on all the coconut palms, irrespective of the treatment. The root systems of the coconut palms were very quickly and very severely attacked, as shown in Table 2, which compares three situations with different previous plant covers. At comparable coconut palm ages, pest pressure was greatest in Trial 4 with a very clear depressive effect on young coconut growth, compared to situations where pest pressure was low.
- Next, there was a depressive effect of coconut husk mulch around the base of young coconut palms. It created a severe and lasting nitrogen deficiency (data not shown) and it also encouraged pest presence in the immediate vicinity of the young palms.

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It can be seen from Table 3 that in the coconut husks treatment, all the coconut growth indicators were less good than in the other two treatments (control and cocopeat), whereas the indicators for pest pressure on coconut palm roots revealed significantly greater pressure. In particular, note the average distance from the stem of the first attack. It was only 19 cm in the coconut husks treatment, indicating that young roots emerging from the seednuts just after planting were almost immediately attacked.

Trial 4 therefore led us to conclude that:

- The presence of a strong *Sufetula* spp. pest population in the vicinity of young coconut palms substantially depressed growth through continual pressure on the roots.
- Whilst being highly recommended on mineral soils (Liyanage *et al.*, 1993; Ouvrier *et al.*, 1985; Salam *et al.*, 2004), recycling coconut husks at the foot of coconut palms proves to be doubly negative on peat as it causes a lasting nitrogen deficiency and worsens attacks by the pest, whose adults find a suitable environment in husk mulch.

Trial 5

Another experiment (Trial 5) consisted of studying the effect on different types of fertilizers on the growth of young coconut hybrids in an environment which was as free of *Sufetula* spp. as possible.

In order to achieve this, coconut palms were planted in the middle of a pineapple field. Some previous observations had shown that coconut palms were attacked less by the pest when intercropped with pineapple, and still less when also surrounded by a pure stand of pineapple acting as a barrier separating the coconuts from infested neighbouring coconut plots.

The palms in Trial 5 were planted in February 2002. They were separated from neighbouring mature plots by a strip of pineapple monoculture (at least 150 m wide), and the soil in the trial itself had previously been occupied for most of the time by cycles of pineapple intercrops. The coconut palms in Trial 5 were also intercropped with pineapple, a circle of 2 m radius around the coconut stems being left free.

In this trial, we do not comment on the effect of the fertilizer treatments, which are not the subject of this paper, but we concentrate on the effect of the environment on the growth of young coconuts in the best treatment (as a reference where mineral nutrition is optimal).

We note in Table 2 a very weak pest pressure on the root systems of the coconut palms in Trial 5, which contrasts with the severe pressure seen in Trial 4. Nonetheless, there were a few attacks, and a few *Sufetula* adults were regularly caught in the pineapple intercrops.

Conclusion

These three experiments confirmed that root damage shown by Bonneau *et al.* (2004) to be caused by the pest *Sufetula* spp. is of considerable importance in coconut

Table 3. RSUP. Trial 4. Effect of different types of mulch on the growth of young replanted coconut palms.

Variable	Age of coconut palms (months after planting)		Treatment 1: control without mulch	Treatment 2: chopped coconut husks	Treatment 3: cocopeat and fibre	*s.e.*
Collar girth (m)	24		1.05	0.90	1.11	0.04
	36		1.31	1.05	1.28	0.06
	48		1.31	0.98	1.29	0.06
Number of green fronds per palm	24		14.2	12.2	14.9	0.7
	36		19.4	14.2	21.5	1.2
	48		24.2	17.3	25.2	0.9
Sex-differentiated coconut palms (%)	48		82	58	91	7
Distance from first attack to stem (m)	40		0.64	0.19	0.47	0.10
Mean length of lateral primary root (m)	52		2.26	1.37	2.41	0.20
Number of short healthy segments of primary root between two attacks counted for four roots per coconut palm.	52	< 100 mm	15.4	43.0	28.6	7.6
		100–500 mm	20.0	37.8	28.1	3.7

plantations on deep peat soils. They can also affect other crops such as oil palm growing on the same peat medium (Achmad *et al.*, 2001). By exerting continual pressure on coconut roots, it causes a significant reduction in nut production. It is now strongly established that the DBL symptom is an expression of the continuous stress suffered by coconut palm roots. Everything occurs as though the palms need to devote much of their energy to scarring of the wounded roots and continual regeneration of new roots, to the detriment of the aerial organs. In other words, there are no longer enough carbohydrates to maintain fronds up to the end of the cycle or to fill bunches, since priority is given to regenerating the continually damaged root system.

REHABILITATION OF MATURE COCONUT PLANTATIONS

Since the beneficial effect of bare soil was experimentally demonstrated, this cultural practice has been implemented throughout the estate. The trend is in fact towards bare soil, as it will never be possible to maintain perfectly bare soil on a permanent basis over such a large area (18 000 ha), given the labour costs involved.

We find that yields are tending to improve since the bare soil technique has been applied, all other things being equal (in particular, no fertilization at all since 2003, so that any yield improvement cannot be explained by better mineral nutrition).

Nonetheless, improvement is highly variable from one plot to another, depending on the history of the coconut palms. Firstly the degree of previous infestation by *Sufetula*, which has damaged the coconut palm root systems to a greater or lesser extent, which is itself linked to plot upkeep since planting. In addition past events, such as poor fertilization or severe termite attacks (Mariau *et al.*, 1992) when the palms were immature, may have permanently handicapped the coconut palms. *Sufetula* infestation has occurred in addition to any other limiting factors.

Rehabilitating plots by the bare soil method will therefore only be fully effective if *Sufetula* is the only factor limiting yields. In the best of cases, it takes at least two years after achieving total bare soil to see any improvement in yields. There have been some spectacular cases of rehabilitation, provided that bare soil is totally achieved and continuously maintained.

We have tried to evaluate the cost-effectiveness of the bare soil practice, starting from a soil occupied by a thick cover of ferns. Results are given in Table 4. We consider here all the costs specifically devoted to achieving totally bare soil, i.e. beyond the usual costs of maintenance (such as ring weeding and maintenance of drainage ditches).

Regarding the control of weeds, there is the cost of herbicide spraying: tools, chemicals and labour. This cost is decreasing with time, due to the elimination of ferns, which are progressively replaced by a carpet of moss, which is unattractive to *Sufetula* spp. Only occasional spot spraying of fern regrowth is required after moss is established.

The sole cost incurred when burning coconut residues is for the labour of a team of specialized workers. Coconut waste is piled up in small heaps at a distance of around 20 m from each other, a sanitation team sets fire, watches over the fires and only

Table 4. RSUP. Cost-effectiveness of bare soil practice. Prices are given in Indonesian rupiah (Rp) for 2005. Net profit per nut sold (selling price − production cost) = 96 Rp. Average coconut stand per hectare= 160. Starting from soil covered with ferns and coconut residues. Costs calculated per hectare. Sanitation (burning of coconut residues) consists of four rotations per year.

	Control of weeds (mainly ferns)					Sanitation (burning of coconut residues)		
Year	Herbicide (l)	Cost (10^3 Rp)	No. man-days	Cost (10^3 Rp)	Total cost	No. man-days	Cost (10^3 Rp)	Grand total Cost (10^3 Rp)
Y1	3.3	130	1.4	42	172	4	120	292
Y2	2.1	84	1.0	30	114	4	120	234
Y3	0.7	26	0.9	27	53	4	120	173
Y4	0.6	24	0.8	24	48	4	120	168
Y5	0.6	24	0.8	21	45	4	120	165

Average cost per hectare and per year over a 5-year period = **206**

Net benefit of a 1 nut tree^{-1} increase on 1 hectare: 160 × 96 = **15 360**

Required yield increase to compensate for the cost of implementation of bare soil practice: 206000/15360 = **13.4** nuts per tree

leaves the field when the last fire is totally extinguished. The present frequency of this operation is four times per year in the same block.

Given the present net profit per nut sold (calculated as: selling price minus production cost) and the present cost of labour and herbicides, we see in Table 4 that the minimum increase of yield to cover the cost of implementing total bare soil is: 13 nuts tree^{-1} y^{-1}. It is achievable if we refer to the results of Trial 3 and to the best examples of rehabilitation on the commercial plantation: in some cases (without statistical validation), an increase of about 20 nuts tree^{-1} y^{-1} has been observed.

With the bare soil practice, regular burning of windrowed coconut waste is a tricky operation. The waste needs to be burnt as frequently as possible so as not to leave shelter for *Sufetula* adults (once a month is ideal, although in practice an attempt is made to burn to every two to three months). However, given the abundant and well-distributed rainfall, some periods are unsuitable. On days of heavy rainfall and the following days, the windrow is too wet, preventing good combustion. On the other hand, when the weather is too dry, there is a risk that fires may burn out of control, burning the surface layer of peat at the same time as the coconut waste, and also burning the lower fronds of coconut palms near the fires. In practice, the best time for burning windrows is 3–10 days after the last heavy rainfall. Dry fronds and empty bunches burn much more easily than husks, which are a very hygroscopic. The different types of waste therefore have to be mixed carefully to ensure that everything burns as completely as possible. Moreover, in the future, we are considering removing husks from plots and incinerating them for ash recycling at the foot of coconut palms, given that coconut husk ash proves to be an excellent potassium fertilizer.

The smoke given off by coconut waste burning has a repellent effect on the entomofauna of herbaceous strata, including *Sufetula* adults. We have also seen that the smoke repels leaf-eating caterpillars in coconut crowns, which is a further advantage of this cultural practice. On the other hand, pollinating insects located in the upper storey of mature coconut crowns seem to be little affected on a lasting basis by the smoke. In particular, bees return to coconut inflorescences a few days after the waste burning operation. We also note that the pall of smoke emitted by organic waste burning remains partly blocked below the coconut palm canopy, with only a proportion escaping above the canopy.

Consequently, we have yet to find any major drawback with this practice of burning coconut waste in the interrows, provided the previously defined rules are respected. Taking in to account the zero-burning policy in place throughout ASEAN countries, a special authorization has been obtained from the regional department of environment to implement the practice of burning coconut residues, under strictly controlled conditions, as defined above.

However, the problem of long-term peat loss has to be considered. The organic matter returned to the soil by coconut waste is far exceeded by the quantities of organic matter recycled back to the soil in primary forests, so that we cannot guarantee that natural peat oxidation and shrinkage can be fully compensated. If, in addition, the peat is burnt, the medium can disappear even faster (Ochs *et al.*, 1992). So far, we have not noticed any visible combustion of the upper layer of peat after burning under strictly controlled conditions. Variables such as changes in peat depth and peat structure need to be observed closely over the long term.

IMMATURE COCONUT PLANTATIONS

Whether in replantings or new extensions, it is essential to prevent plots of young coconut palms from being infested by *Sufetula* right from land preparation and planting. Indeed, Trial 4 showed that it was inadvisable to plant young coconut palms in an environment where the pest was present, i.e. just after felling old coconut palms in an infested plot.

On the other hand, young coconut palms planted in an environment free of *Sufetula* display very satisfactory growth, when the other production factors (land preparation with compaction, stabilization of the water table at the optimum depth, appropriate fertilization) are provided. This technique, involving bare soil or intercrops plus barrier crops that do not attract the pest, thus makes it possible to reduce *Sufetula* pressure considerably to a non-limiting level, but does not completely eliminate the pest from the coconut palm environment.

Given that pineapple is the second cash crop at RSUP after coconut (Peng Fangren *et al.*, 1996), coconut-pineapple intercropping is perfectly suited to reducing *Sufetula* pest incidence in young plantings.

We now need to investigate how long it takes after replanting to reduce the *Sufetula* population to a level not harmful to young coconut palms, and which techniques might speed up the process (probably one or two cycles of pineapple as a break crop, which would make it possible to 'clean' the land more quickly). It also appears that the weaker the *Sufetula* population was in the mature coconut plantation, the less time it will take to obtain an environment suitable for replanting with young coconut.

OTHER CONTROL METHODS

We have seen that cultural control can be efficient and cost-effective by reducing *Sufetula* pest pressure to an economically acceptable level. However, it is unable alone to ensure satisfactory control of the pest and requires the constant mobilization of a substantial work force to maintain bare soil in a monoculture.

Chemical control is out of the question since, according to results obtained on an experimental scale of a few dozen coconut palms, the quantity of insecticide required for permanent control would be economically prohibitive over such an area. It would also entail environmental risks for the plantation, for the health of workers and neighbouring villagers, and would limit product marketing possibilities.

We are therefore now devoting all our efforts to biological control. No disease, parasite or indigenous predator of *Sufetula* has yet been identified. Attempts to introduce entomopathogenic nematodes to destroy larvae in the ground have been unsuccessful. We are investigating trapping by sexual pheromones, which are used for certain harmful lepidopterans (Campion *et al.*, 1981).

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