Département amélioration des méthodes pour l'innovation scientifique Cirad-amis

Exceptional outbreaks of the oriental migratory locust in Indonesia : towards an integrated pest management strategy.

Report and recommendations based on a survey conducted in southern Sumatra, 19th June - 2nd July 1998

Michel LECOQ

Programme Protection des cultures
Prifas - Acridologie opérationnelle

CIRAD-AMIS N° 25/98
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Lecoq M., 1998. *Exceptional outbreaks of the oriental migratory locust in Indonesia: towards an integrated pest management strategy. Report and recommendations based on a survey carried out in southern Sumatra, 19th June - 2nd July 1998.* CIRAD, Montpellier, France. 47 p.

Acknowledgements

The author would like to thank everyone who helped make this survey a success, especially the different authorities from the Ministry of Agriculture who were contacted in Jakarta and Bandar Lampung on Sumatra. He is very grateful to Mr. Sukirno for his kindness and constant assistance during this appraisal mission.

Summary

Serious outbreaks of oriental migratory locusts, *Locusta migratoria manilensis* (Meyen 1835), have been reported on different islands of the Indonesian archipelago since early 1998, especially in southern Sumatra. In the long term, the intensive deforestation that has been under way over the last 20 years is certainly partially responsible for these outbreaks. The drought that prevailed in the region in 1997 also seems to be a major recent factor that prompted these outbreaks. Recommendations are put forward to improve the efficiency of control treatments and set the stage for collecting essential baseline information required to develop a long-term preventive locust control strategy based on integrated pest management principles.

Résumé

De fortes attaques du Criquet migrateur asiatique, *Locusta migratoria manilensis* (Meyen 1835), ont été signalées en différentes îles de l'archipel indonésien depuis le début de l'année 1998 et tout particulièrement dans le sud de Sumatra. Sur le long terme, ces pullulations sont certainement la conséquence du déboisement intensif survenu depuis une vingtaine d'année. Sur le court terme, il semble bien que la forte sécheresse ayant sévi dans l'ensemble de la région en 1997 soit en grande partie responsable. Des recommandations sont formulées pour améliorer l'efficacité des mesures de contrôle, ainsi que pour permettre d'acquérir les informations de base indispensables à la mise au point d'une stratégie de lutte préventive basée sur les principes de la lutte intégrée.

Key words

Indonesia, Migratory locust, outbreak, pest control, integrated pest management

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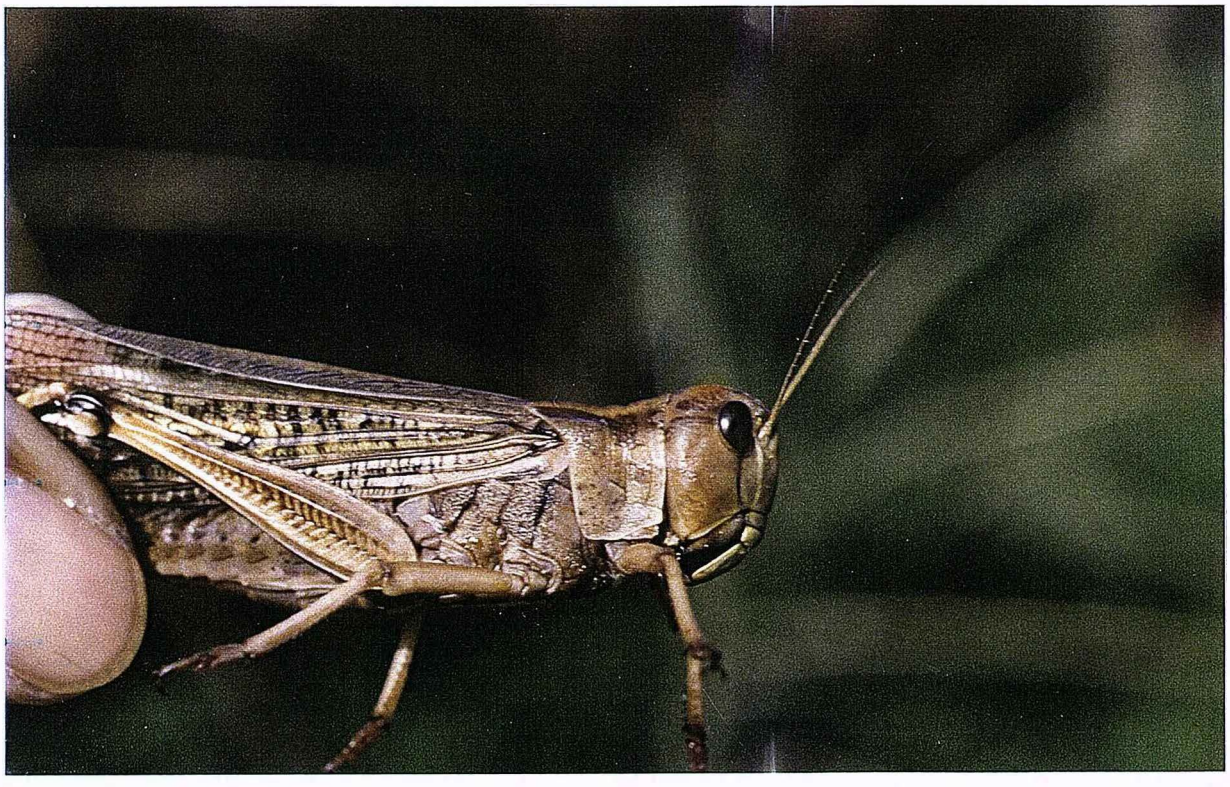
Oriental migratory locust, *Locusta migratoria manilensis*

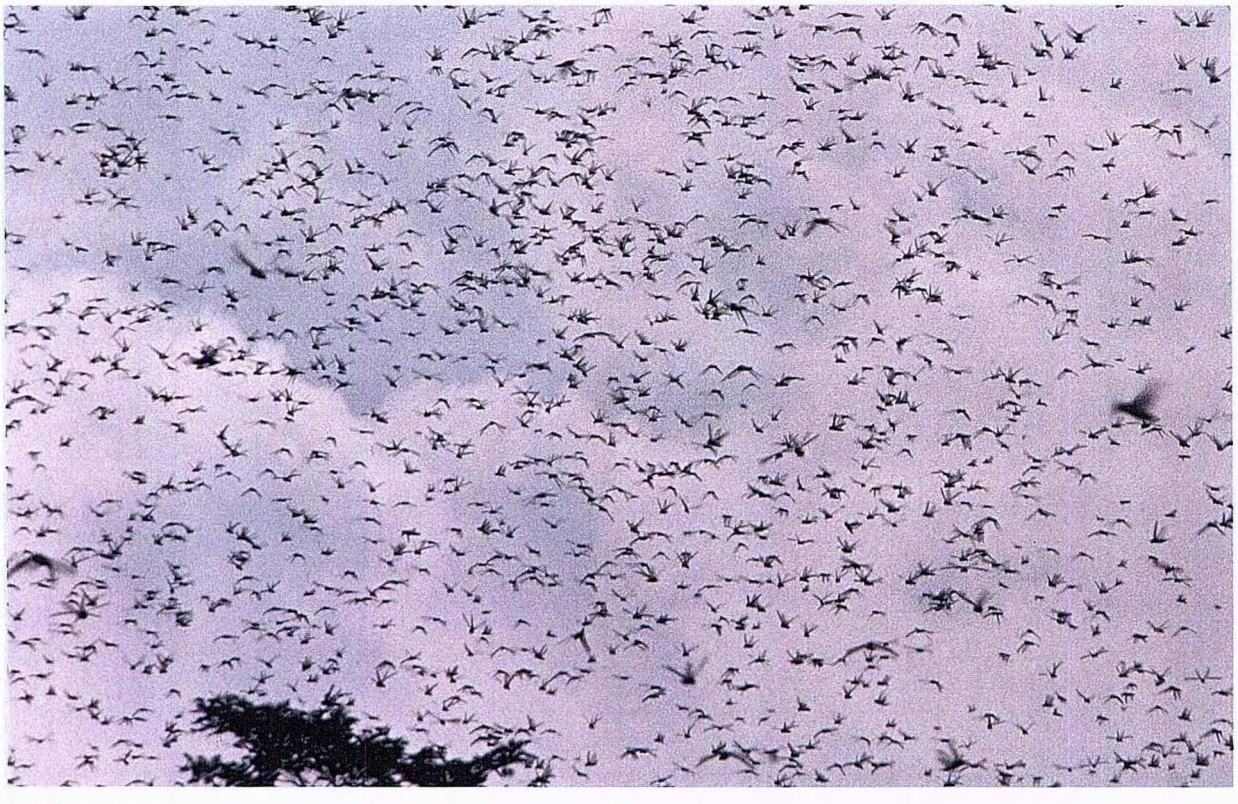
Young gregarious adult



Gregarious adult

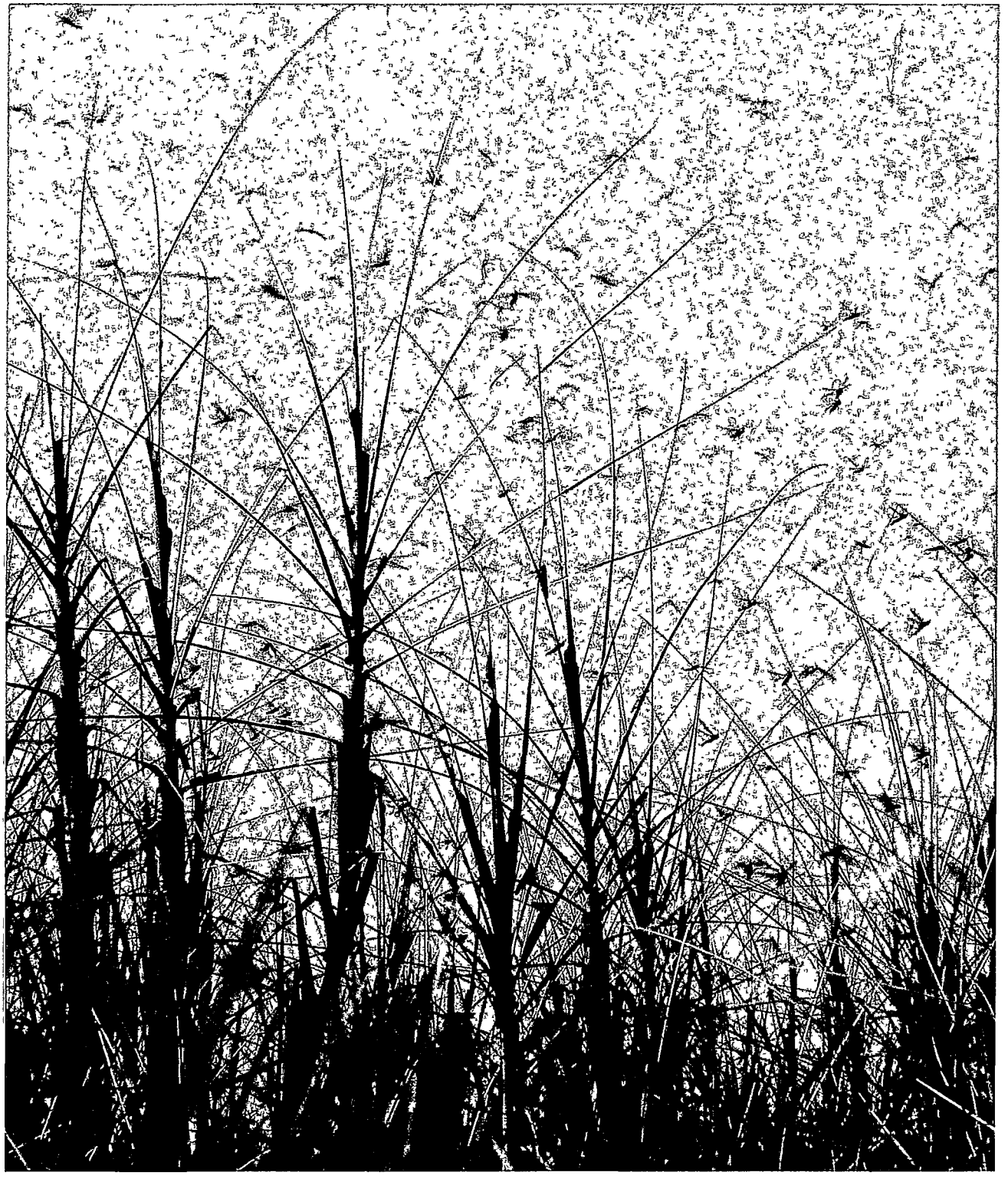
Oriental migratory locust, *Locusta migratoria manilensis*

Adult (certainly transient)



Flying swarm

Oriental migratory locust, *Locusta migratoria manilensis*



Damage to sugarcane plants

Introduction

Serious outbreaks of oriental migratory locusts, *Locusta migratoria manilensis* (Meyen 1835)[1], have been reported in southern Sumatra since late 1997. These outbreaks have been steadily increasing in size since the beginning of 1998. The present locust outbreaks are much larger than the small local upsurges recorded in the past, and they were probably triggered by the serious drought that affected these regions in 1997.

The Indonesian Ministry of Agriculture asked CIRAD to carry out an appraisal mission to collect information on this problem, determine what caused it, and put forward recommendations on ways to improve locust control over the short- and long-terms.

1. General aspects of the appraisal mission

This mission, carried out from 19 June to 2 July under excellent conditions, was funded by the Cultural Service of the French Embassy in Indonesia. The Indonesian authorities gave the expert access to all available information on the situation, organized a field survey in the main locust outbreak areas in southern Sumatra, and set up meetings with different concerned private and public organizations and directors.

The two main types of biotopes in southern Sumatra were quickly visited, i.e. food-crop and plantation estate areas (Figures 1 and 2). More forested areas and flood plains were also surveyed to identify biotopes that oriental migratory locusts could potentially colonize.

1 Farrow & Colless (1980) (from numerical taxonomy analysis) consider that migratory locusts from the tropics and southern hemisphere represent a single polymorphic, non-diapause subspecies, *L. m. migratorioides* (Reiche & Fairmaire).

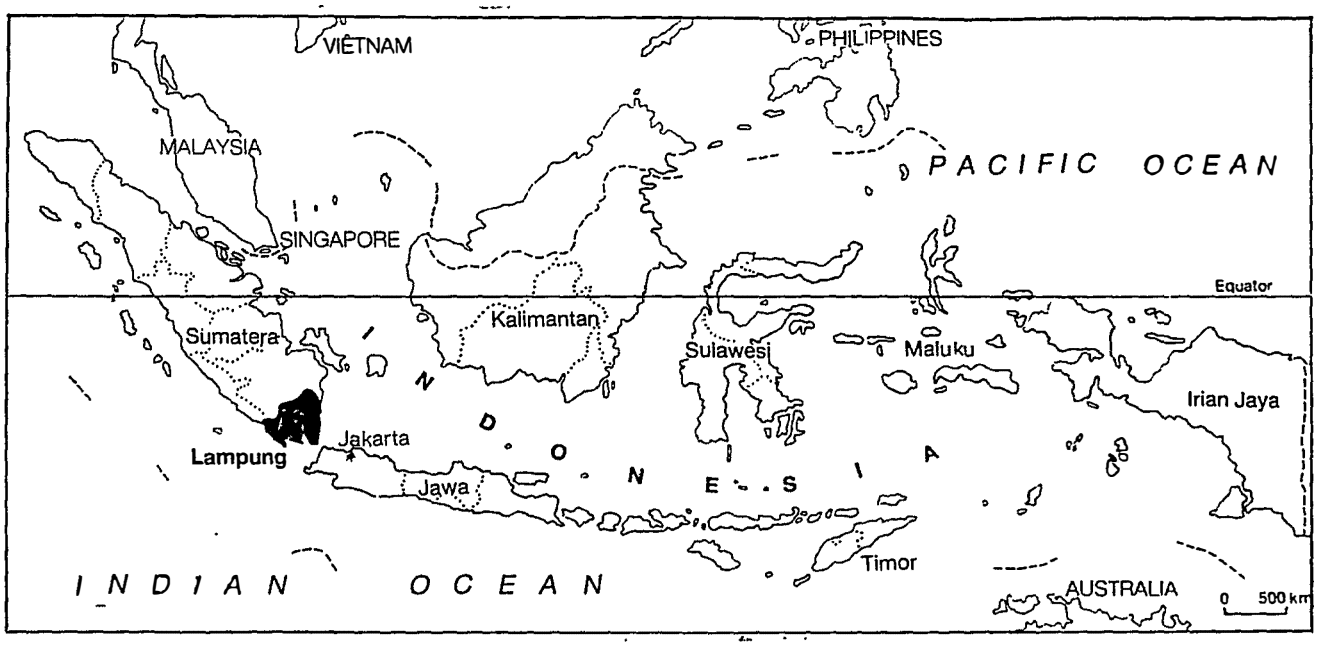


Figure 1. Localisation map.

Figure 2. Schedule of surveys and visits in southern Sumatra (Lampung Province).

1.1. Consultancy mission schedule

Date	Activities
Friday (June 19)	Flight Montpellier - Paris
Saturday (June 20)	Flight Paris - Jakarta
Sunday (June 21)	Jakarta, meet with CIRAD representative G. de Taffin Contact (by phone only) with Mr. Desmier de Chenon, CIRAD entomologist
Monday (June 22)	Jakarta, bibliographical review of the locust situation
Tuesday (June 23)	Flight from Halim Perdanakusuma Airport Meet with Head of Province Agric. Service, Lampung (Mr. Subagyono) Visit Central Lampung locust outbreak area (food-crop area, plantation estate area, other area), Pest Laboratory, Regency Agric. Service Overnight in Bandar Lampung
Wednesday (June 24)	Trip to North Lampung regency (locust outbreak area) Visit locust outbreak area (food crop area, estate plant area, others area), Pest Laboratory, Regency Agric. Service, Estate Plant Companies Overnight in sugarcane plantation near Kotabumi (North Lampung)
Thursday (June 25)	Visit locust outbreak area in North Lampung (continued) Return to Bandar Lampung Overnight in Bandar Lampung
Friday (June 26)	Meet with Head Province Agric. Service, Lampung Return to Jakarta
Saturday (June 27)	Analysis of collected data and documents
Sunday (June 28)	Drawing up survey mission report
Monday (June 29)	Meet with Director General of Food Crop Protection Visit to Bogor Agricultural University (Dept. Plant Pests and Diseases) Visit to National Coordination Agency for Land Surveys and Mapping
Tuesday (June 30)	Meet with Director General of Food Crops and Horticulture Meet with Vice Director General of Forestry and Estate Crops Visit to National Coordination Agency for Land Surveys and Mapping
Wenesday (July 1)	Meet with French Embassy, ORSTOM staff and CIRAD representative Flight Jakarta - Paris
Thursday (July 2)	Flight Paris – Montpellier

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2. The locust situation in Sumatra

2.1. Size of the locust outbreaks

2.1.1. Patterns in 1997-98

The oriental migratory locust outbreaks observed in Indonesia in 1998 seem to have affected many parts of the archipelago: Sumatra, Java, Kalimantan (Borneo), Sumba, Timor, Sulawesi (Celebes), and Flores (Figure 4). By far the most serious outbreaks were recorded in southern Sumatra, in Lampung province. The present survey focused on the latter area.

In southern Sumatra, the provinces of Lampung, Sumsel and Bengkulu, in the southem part of the island, have been affected. Some outbreaks were noted in October 1997. The first serious outbreaks, however, did not occur until January 1998 (Figure 3 and Table I). Since then, the area invaded by locusts has been steadily increasing, to the extent that just in the month of May 7555 ha were affected (2332 ha of rice and 5223 ha of maize).

In late March 1998, for the whole rainy cropping season (October-March 1997-98), 7678 ha were infested in southern Sumatra (4991 ha of rice and 2687 of maize).

At the onset of the dry cropping season in 1998 (April-September), from early April to late June, 14434 ha had already been affected in southern Sumatra (6029 of rice and 8405 of maize) (this excludes the second half of June in Lampung province as no data were available yet for this period).

Overall, from October 1997 to late June 1998, 22092 ha of rice and maize crops were invaded by locusts in southern Sumatra.

The figures for all of Indonesia are 24121 ha (12464 of rice and 11657 of maize).

In Sumatra, various information collected during the survey indicated that in May, when the greatest outbreaks were observed, some hopper bands were larger than 200 x 500 m, with densities of hundreds of hoppers/m^2. Continuous bands were seen along the edges of some roads, for distances of up to 3 km. Some locust swarms, probably several hectares in size, were observed wandering around the region. The clear gregarious behaviour of locusts noted during the survey in June, indicates that outbreaks have been continuous for many generations. About three generations are required to develop a typical gregarious phase. Locust densities undoubtedly began increasing at the onset of the 1997-98 rainy season, thus prompting quick phase transformation, a series of three generations (G1 to G3) and an increase in gregariousness between November 1997 and May 1998.

The extent of crop damage varied in the outbreak areas. Throughout Indonesia, crop losses were estimated as ranging from 50 to 100% of the harvest for 6451 ha, from 25 to 50% for 6732 ha, and less than 25% for 10938 ha (Table II).

In late June, during our survey, the situation was still very active, even though there was a clear decline in locust populations. High densities of gregarious 4th instar adults (G4) were appearing. Many swarms and hopper bands are still present and could endanger dry season crops.

Note that the data presented above are only partially representative of the widespread locust problem in southern Sumatra in 1998, i.e. they only concern the food-crop area. No accurate data were available during the survey for the estate plantations, i.e. "estate crops" (especially sugarcane), where locust outbreaks and damage seem to have been even more extensive. These areas are very suitable for oriental migratory locusts, and they are certainly source areas (at least part of them) of the outbreaks currently under way in Sumatra. Head staff at one plantation told us that during the 1997-98 season they used 2000 l of pesticides (commercial product), but this quantity was insufficient to control the locusts and they could not apply more because of a lack of funding. They lost an estimated 15% of the total sugarcane production.

Table 1. Area affected by oriental migratory locust outbreaks in food-crop areas of Indonesia in 1997/98.

(data source: Dir. General for Food Crops and Horticulture, Jakarta)

	O	N	D	J	F	M	A	M	J	Total
TOTAL	10	74	27	310	4018	4004	5604	8254	1820	24121
Rice	5	65	17	188	2535	2557	3019	3003	1075	12464
Maize	5	9	10	122	1483	1447	2585	5251	745	11657

NB. these totals exclude data for Lampung Province for the last half of June.

Table 2. Extent of food-crop losses due to oriental migratory locust attacks in 1997/98 (areas invaded and associated crop losses from October 1997 to April 1998)

(data source: Dir. General for Food Crops and Horticulture, Jakarta)

	Percentage crop losses				
	25 %	25-50 %	50-85 %	85-100 %	Total
TOTAL	10938	6732	3519	293	24121
Rice	7421	3161	1255	627	12464
Maize	3517	3571	2264	2305	11657

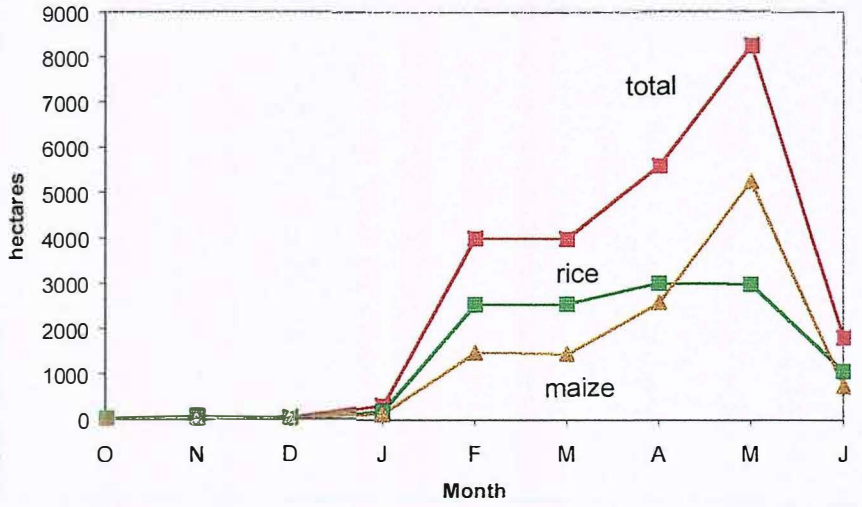

Figure 3. Variations in areas invaded by oriental migratory locusts in Indonesia in 1997/98.

(data source: Dir. General for Food Crops and Horticulture, Jakarta)

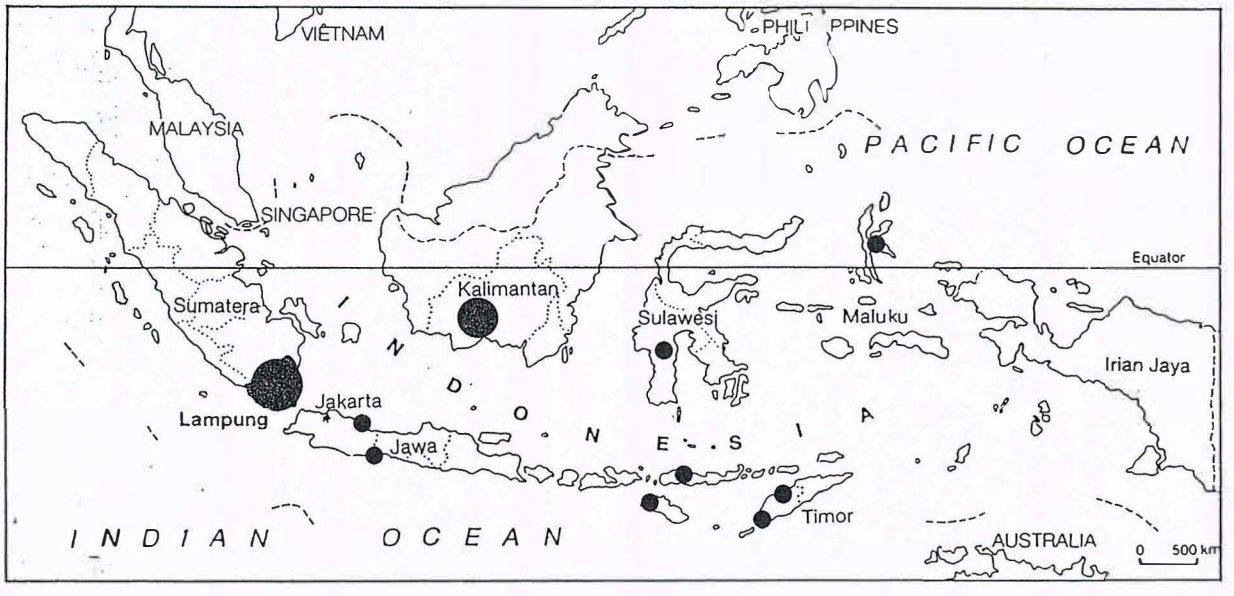

Figure 4. Oriental migratory locust outbreak areas in Indonesia in 1998.

(data source: Dir. General for Food Crops and Horticulture, Jakarta)

2.1.2. A few survey observations (late June 1998)

There was not enough time during this short appraisal mission to carry out in-depth observations. Nevertheless, a few examples of locust outbreaks noted during the surveys are tentatively reported here to illustrate the seriousness of the locust situation, despite the fact that a reduction in the locust population was already under way. The supplementary photographs presented at the beginning of this report illustrate the locust situations that prevailed.

24 June. Metro region (central Lampung). Hopper band in an irrigated rice-growing area that had been dried out for 3 weeks. They are first and second instar hoppers. Hopper densities were as high as hundreds of hoppers/m^2, but usually dozens of hoppers/m^2. The invaded area was about 1 ha (not accurately measured). A few old *transiens* adults were also noted at low densities (<1000/ha). The soil is heavy and clayey. Many oviposition holes made by female locusts were observed (sometimes 10-30 holes/m). They corresponded to unsuccessful attempts to lay eggs, indicating that the environment was unsuitable for breeding.

25 June. Kotabumi region (northern Lampung). Perkebunan Nusantara VII Plantation. Remainder of a swarm on the edge of a sugarcane field. Adult densities were low, i.e. probably not more than 1/m . These locusts were gregarious. They were survivors of a swarm that was observed the previous month. There was still very obvious locust-induced sugarcane damage. Most basal leaves were withered, with only the rachis remaining. This sugarcane had still managed to recover and new leaves had appeared.

26 June. Kotabumi region (northern Lampung). Perkebunan Nusantara VII Plantation. Two swarms were observed in sugarcane fields on this plantation which seemed to be seriously infested (hopper bands - not observed - were also reported to us). In both cases, the size of the swarm, which was difficult to assess, seemed to be quite large and spread over at least 1-2 ha. The survey observations were carried out from 8:30 to 9:30 a.m. when the swarms were still not very mobile, and only flying around their roosting site. A few other scattered flights were noted. These flights were quite low, never more than 5 m. Locust densities were high, and the flying swarm had a milky appearance on the horizon, when seen from a distance. The population was made up of typical gregarious locusts. There was a mixture of young and old locusts (the latter being easily identified by their yellowish colour, especially the males). Like the area observed the previous day, there was considerable crop damage, and new leaves had reappeared, while the old ones were withered or had been completely eaten.

26 June. Kotabumi region (northern Lampung). Around the Perkebunan Nusantara VII Plantation sugarcane factory. Moulting hopper band/young swarm. This gregarious formation was a mixture of fifth instar hoppers and young fledglings that had just moulted. There were quite high densities of hoppers (gregarious colouring, i.e. orange base, black, with small white spots), sometimes more than 100/m. The hoppers were

in a wasteland area of a few thousand square metres. The fledglings were flying around in loose formations, with movements in various directions. One of these formations landed in a rice-growing area about 100 m from the hopper band. Many farmers and children were trying to chase away the locusts with flags, branches, etc. One farmer was trying to treat the rice crop with a small manual knapsack sprayer. A few old parental adult locusts were also noted, and the female locusts continued laying eggs.

All of these swarm locusts were gregarious, indicating a long-standing past under conditions favourable for gregarization.

2.2. History of locust outbreaks in Indonesia

Oriental migratory locust outbreaks are not just a recent phenomenon in Indonesia, despite the fact that the most serious outbreaks to date have been in other regions.

The distribution range of this subspecies is generally limited to Malaysia, Indonesia, Thailand, Kampuchea, Vietnam, the Philippines and Taiwan. The main outbreak area has historically almost always been the Philippines. The main gregarization areas are in the southern part of Mindanao Island, in Cotobato region. Outbreaks occurred very frequently until the 1960s (especially 1895-96, 1902-05, 1909-10, 1914-15, 1919-29, 1932-39, 1941-49, 1958-60), but they have declined since then due to human activities. Quite serious past outbreaks have also occurred in the Sabah region of northern Borneo (1918-20, 1926-27, 1930-31). In addition, a few outbreaks (certainly of local origin) have been noted in southwestern Malaysia. Finally, swarms probably coming from the Philippines infested Taiwan in 1923-24 (COPR, 1982; Roffey, 1972; Uvarov, 1936).

Local and bibliographical information collected on Indonesia indicates that oriental migratory locust outbreaks are a long-standing phenomenon in this region. Local outbreaks have been recorded in the past, but they seem to have been quite rare.

As early as 1877, *Locusta* outbreaks were reported on Halmahera Island, in the northern part of the Moluccas Islands. These swarms likely originated from the Philippines. Similar swarm infestations were also noted in the northern part of Celebes Island in 1923 and 1932.

The main local outbreaks in Indonesia seem to have mainly affected Borneo:
- Central Kalimantan in 1952, 1959, 1972, 1976, 1980, 1988, 1990/91 and 1991/92, September 1993 (1013 ha, including 937 of rice and 76 of maize);
- West Kalimantan in 1968, 1988, 1993 (3965 ha, including 3962 of rice and 3 ha of maize).

Oriental migratory locust outbreaks were also reported from 1973 to 1976 in Sumba Island.

Finally, in Sumatra, locust outbreaks have been concentrated in the southern part of the island. Indeed, small upsurges were treated in the past on some sugarcane plantations that were set up in the early 1980s. There were no reported outbreaks in food-crop areas until the 1990s. Some outbreaks affected Lampung province in 1992 (352 ha of rice, i.e. 35 ha with 100% damage, and 146 ha of maize, i.e. 92 ha with 100% damage). Outbreaks were reported in the same area in 1995 and 1996 (210 ha of rice, including 30 ha with 100% damage and 207 ha of maize). In 1998, the outbreaks were concentrated in the same region, and by far the most serious to date (Figures 5 and 6).

There has therefore been a history of small *Locusta migratoria manilensis* outbreaks in Indonesia. However, past outbreaks were quite limited local phenomena, mainly affecting Kalimantan province in Borneo. Clearly, the current outbreaks are not proportionally comparable to those recorded in the past. They are also mainly concentrated in southern Sumatra, where the phenomenon is relatively recent (but not new) and seems to have been gradually worsening over the years.

These are the most serious outbreaks ever recorded in Indonesia, but the extent of this phenomenon should be kept in perspective. The infested area is around 24000 ha/year (possibly twice as much if the plantation areas are included). Hopper bands and swarms were also quite small (from a few to around 10 ha), i.e. very low for the oriental migratory locust, which can form much larger (several hundreds of hectares in size) and denser swarms. A striking example of this phenomenon is the widespread outbreak that has been under way in Madagascar since 1997.

The current locust situation in Indonesia, especially in Sumatra, is nevertheless a real problem that has been gradually increasing in importance over the last 10 years, and involves a locust species that could induce considerable crop damage. This situation warrants caution, and the causes of the phenomenon should be determined in order to develop a well-adapted control strategy.

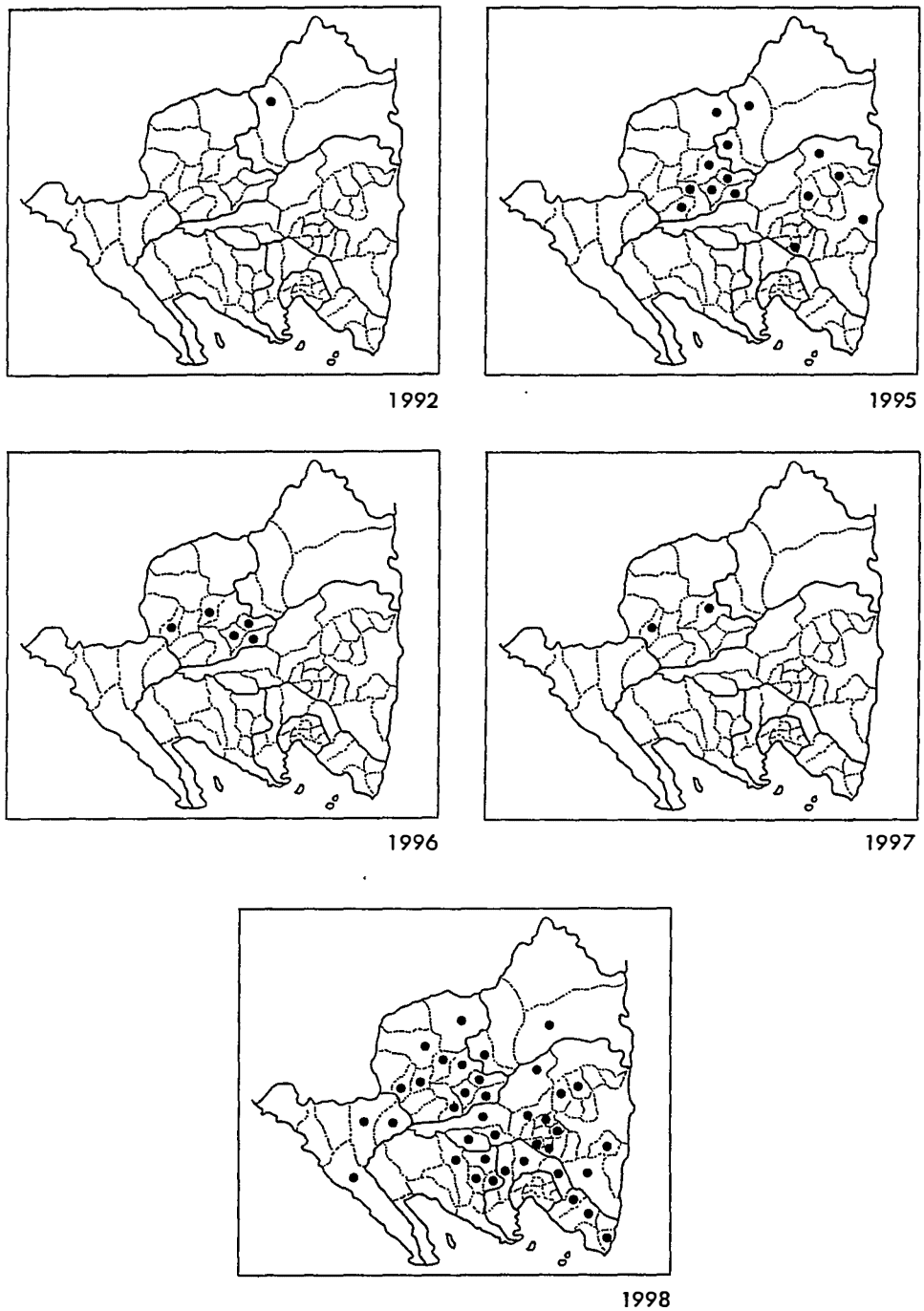

Figure 5. Outbreak areas in Lampung province from 1992 to 1998.

(Data source: Agriculture Service of Lampung province)

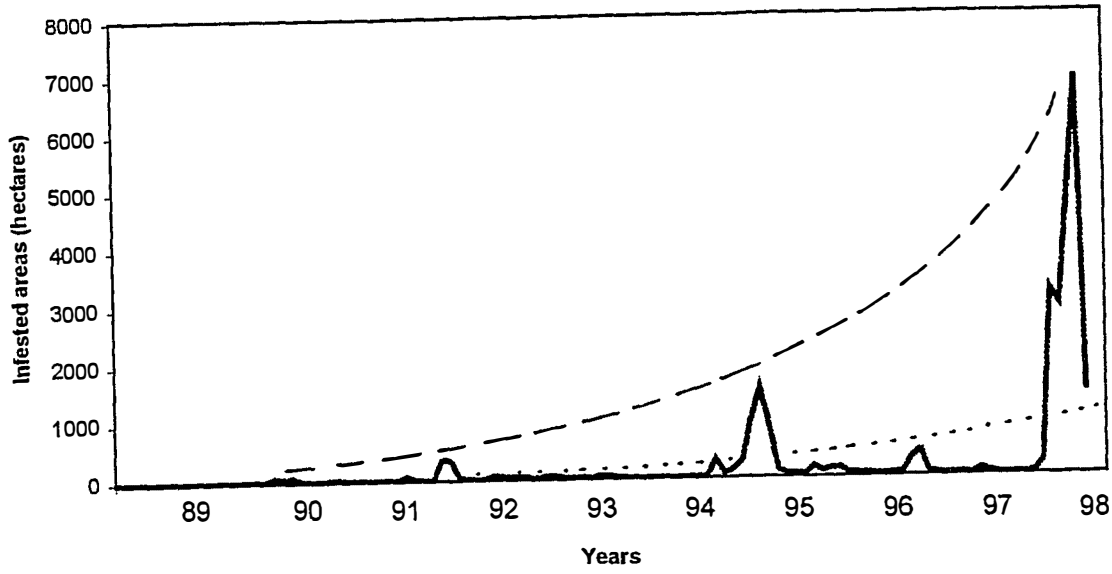

Figure 6. Variations in areas infested by locusts in Lampung province from 1989 to 1998.

(Data source: Dir. General for Food Crops and Horticulture, Jakarta)

Two trend curves are presented, showing that the situation has been steadily worsening over the last 10 years: the outbreaks are becoming more serious, and baseline levels of the locust populations between two outbreaks also seem to be higher.

2.3. Causes of the locust outbreaks

Deforestation

Agricultural development in initially wooded areas is certainly a prime cause of the oriental migratory locust problem in Indonesia.

As early as 1936, Uvarov predicted that the oriental migratory locust problem would worsen with deforestation and agricultural development, as favourable environments for this pest would be progressively created.

In 1987, Farrow also pointed out that continuous agricultural development in tropical and

subtropical regions of the Old World would certainly increase the risk of catastrophic damage due to migratory locusts. This has occurred in the Philippines, and more recently in Borneo, New Guinea and Queensland (Australia), where deforestation has also induced serious outbreaks of *Locusta* and other acridians (Roffey, 1972; Farrow, 1974).

In Sumatra, especially in the southern zone, deforestation has been especially intensive in recent decades. In many places, the natural forest has been replaced by large plantations: sugarcane, oil palm, natural rubber, cassava, etc. The plantations visited during this survey mission were set up between 1975 and 1980. The development of these plantations created new biotopes, some of which seem to be very suitable for migratory locusts, especially in sugarcane plantations on light soils.

Drought

Migratory locusts normally thrive in other tropical zones (Africa and Madagascar), i.e. drier regions where rainfall levels are generally less than 1000 mm/year. Southern Sumatra is usually much too humid for efficient locust breeding. Mean rainfall levels in this region are around 2000-3000 mm/year, but levels are sometimes even higher than 4000 mm (Table 3). Under normal conditions, populations of this locust are probably limited by the high humidity, which favour the development of many natural enemies. This would keep locust populations low and in the solitarious phase (with densities possibly lower during the rainy season when conditions are *a priori* less suitable).

Dry periods must be especially important under these excessively humid environmental conditions, i.e. as rainfall levels are more in line with the normal ecological needs of this insect. Moreover, drought must lead to a sharp drop in populations of the natural enemies, which are responsible for normal locust population control.

In other regions, especially in the Philippines, it is well known that outbreaks of oriental migratory locusts, *L. m. manilensis*, are correlated with drought periods (COPR, 1982). This link was noted as early as 1645. Locust outbreak years follow exceptionally dry years. The outbreaks occurring in southern Sumatra seem to confirm this trend. In the last 10 years, outbreak years followed unusually intense dry seasons: 1992 following the 1991 drought; 1995-96 following the 1994 drought; and 1998 following the 1997 drought (Table 3). Note that the exceptionally severe 1997 drought was followed by very serious locust outbreaks.

It could thus be legitimately assumed that outbreaks occurring in potentially favourable biotopes created through deforestation are the result of a temporary ecological imbalance triggered by the exceptional drought of 1997. This set the stage for a locust population explosion. During the 1997-98 rainy season, as the factors that normally control locust populations were absent, population levels were able to steadily increase within a few generations (probably 3-4). The gregarization threshold (about 2000 adults/ha) was readily surpassed. This prompted the phase transformation process, thus

producing gregarious locusts to form hopper bands and adult swarms. Locust populations logically peaked at the end of the rainy season after several generations of increasing gregariousness (Figures 7 and 8).

Since 1982, there have been many long dry seasons (associated with the El Niño phenomenon): 5 years between 1982 and 1987, 4 years between 1987 and 1991, only 3 years between the droughts of 1994 and 1997. This series of increasingly closer drought periods might therefore have prompted a slow rise in locust populations, thus promoting an increasing number of outbreaks.

These long dry seasons could also have promoted high population concentrations in some areas that remained greener. They could also have lead to the onset of gregarization even before the beginning of the rainy season, similar to the situation in outbreak areas of this species in Africa. However, in the present situation, this phenomenon alone could not explain the outbreaks, but rather only boost the favourable impact of the ecological imbalance on the locusts.

Obviously, studies on oriental migratory locust population dynamics in Sumatra (in both the gregarious and solitarious phases) would be the only way to check the validity of the above hypotheses. The problem is that no field data is currently available to carry out such studies.

Table 3. Rainfall levels in Gunung Madu Plantation (central Lampung) from 1982 to 1998.

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Average
January	363	393	194	282	348	283	731	269	214	362	221	347	467	369	312	268	227	325
February	409	315	329	268	491	513	341	511	301	217	209	421	259	281	337	217	351	334
March	493	346	471	473	321	127	387	294	296	298	330	268	410	413	383	238	284	340
April	319	184	216	254	318	230	214	118	116	311	229	135	310	349	177	242	141	227
May	109	192	257	92	88	207	159	136	154	166	96	182	22	121	109	109	281	147
June	118	81	103	159	206	95	54	88	65	24	65	180	38	125	70	9		96
July	23	57	162	185	71	42	91	89	94	10	162	168	4	145	51	27		91
August	1	44	99	162	64	40	199	148	99	0	135	41	0	51	166	13		72
September	6	0	251	189	345	10	81	60	108	9	134	82	27	147	188	0		113
October	46	159	239	228	123	44	247	69	71	65	126	91	36	199	63	3		124
November	118	287	341	255	429	202	347	304	109	266	212	184	80	209	199	42		242
December	409	469	344	302	280	379	360	354	356	246	364	345	335	246	309	197		353
TOTAL	2414	2527	3006	2849	3084	2172	3211	2440	1983	1974	2283	2444	1988	2655	2364	1365		2469,73

(shaded columns: years with a long dry season)

Data source: Gunung Madu Plantation.

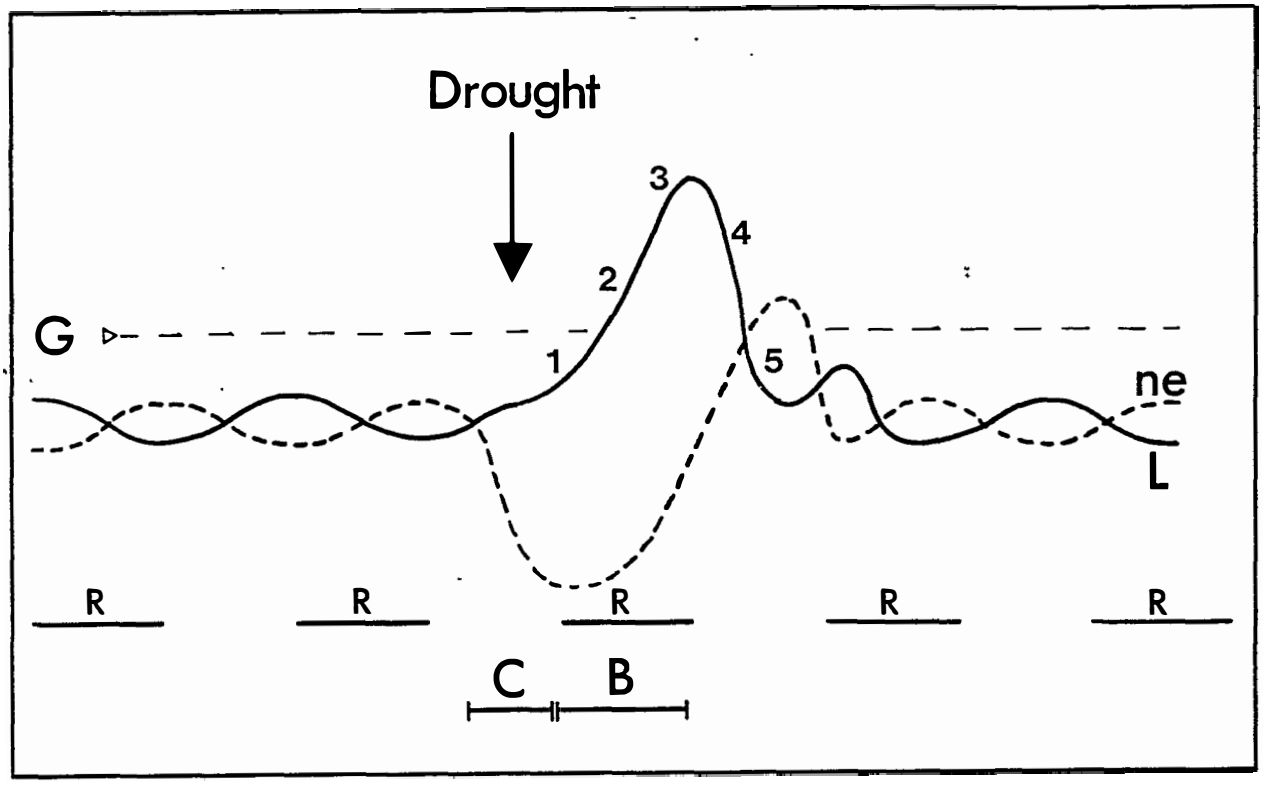

Figure 7. Hypothetical population dynamics of oriental migratory locusts in southern Sumatra and the effects of natural enemies on locust population control.

B. possibility of increasing populations through breeding; C. possibility of densation by limiting the inhabited area; G. gregarization threshold (2000 adults/ha); L. migratory locust population; ne. population of the natural enemy complex; R. rainy season; 1-5. successive generations of migratory locusts (3 in the rainy season, 2 in the dry season).

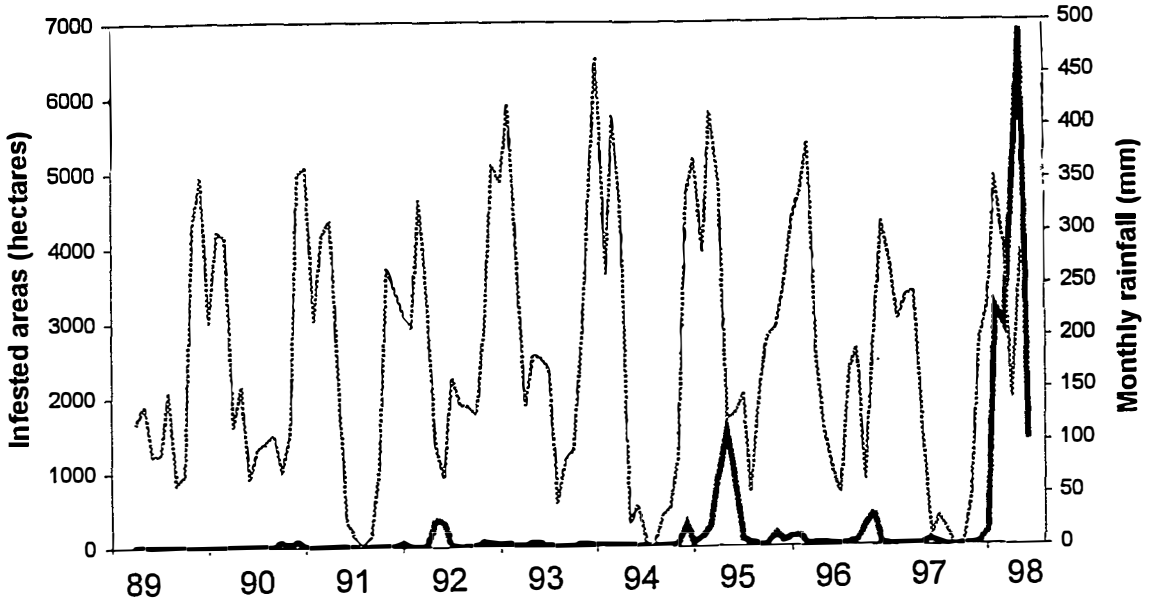

Figure 8. Comparisons of rainfall levels and areas infested by locusts in Lampung province from 1989 to 1998.

(Rainfall data source: P.T. Gunung Madu Plantation)

2.4. Outbreak source centres in southern Sumatra

Have the outbreaks occurred simultaneously at markedly different sites, or in one specific area (or several areas) that could be considered as outbreak source centres (i.e. areas from which swarms could emigrate to infest more widespread areas)? If the latter hypothesis applies, such zones could be localized in order to implement more preventive strategies for early control of locusts in their source areas at the onset of the rainy season.

A quick field survey revealed that in all cases the locusts came from elsewhere, i.e. in food-crop areas they came from sugarcane plantations, and in sugarcane plantations they came from forestry plantations, etc.

The most suitable areas for locust outbreaks were mainly observed in the area around the large estate plantations (mainly sugarcane plantations). It was pointed out to us that

other plantations, especially oil palm plantations, could also be suitable sites, but this would have to be checked (these plantations could become suitable if the tree cover is not too dense, if there is well developed grass cover, and if the soils are light enough). In food-crop areas, especially in rice fields, the soils are generally too heavy. The environment is too shady and the leaf-litter cover is unfavourable for locusts in forestry plantations. Obviously, there could be other suitable environments (e.g. wastelands), but in-depth ecological studies would be required to draw up an exhaustive inventory of locust biotopes and their potentials for oriental migratory locusts.

At the current state of knowledge, we consider that sugarcane plantations offer the best locust breeding potential. Indeed, outbreaks have been observed longest in sugarcane plantations, i.e. generally just a few years after the sugarcane crop was initially planted (the locust species involved was obviously not accurately identified at the time, and further surveys would be necessary; but research directors at both plantations told us that they had long carried out treatments to control small swarms identical to those currently being observed).

To date, not very widespread locust outbreaks have mainly occurred in plantations and were thus easily controlled. In contrast, the 1998 outbreaks seemed to produce many much denser swarms that, for the first time, have spread beyond the usual areas and infested food-crop areas.

Reconstruction of the situation over the last few months clearly highlighted one outbreak source centres located near the sugarcane plantations at the Central Lampung-North Lampung border (Figures 9 and 10).

If this outbreak source centre hypothesis is confirmed (which will require further surveys, a cartographic data analysis on the environment and a better understanding of locust population variations in the field), a regional preventive locust control strategy should be developed.

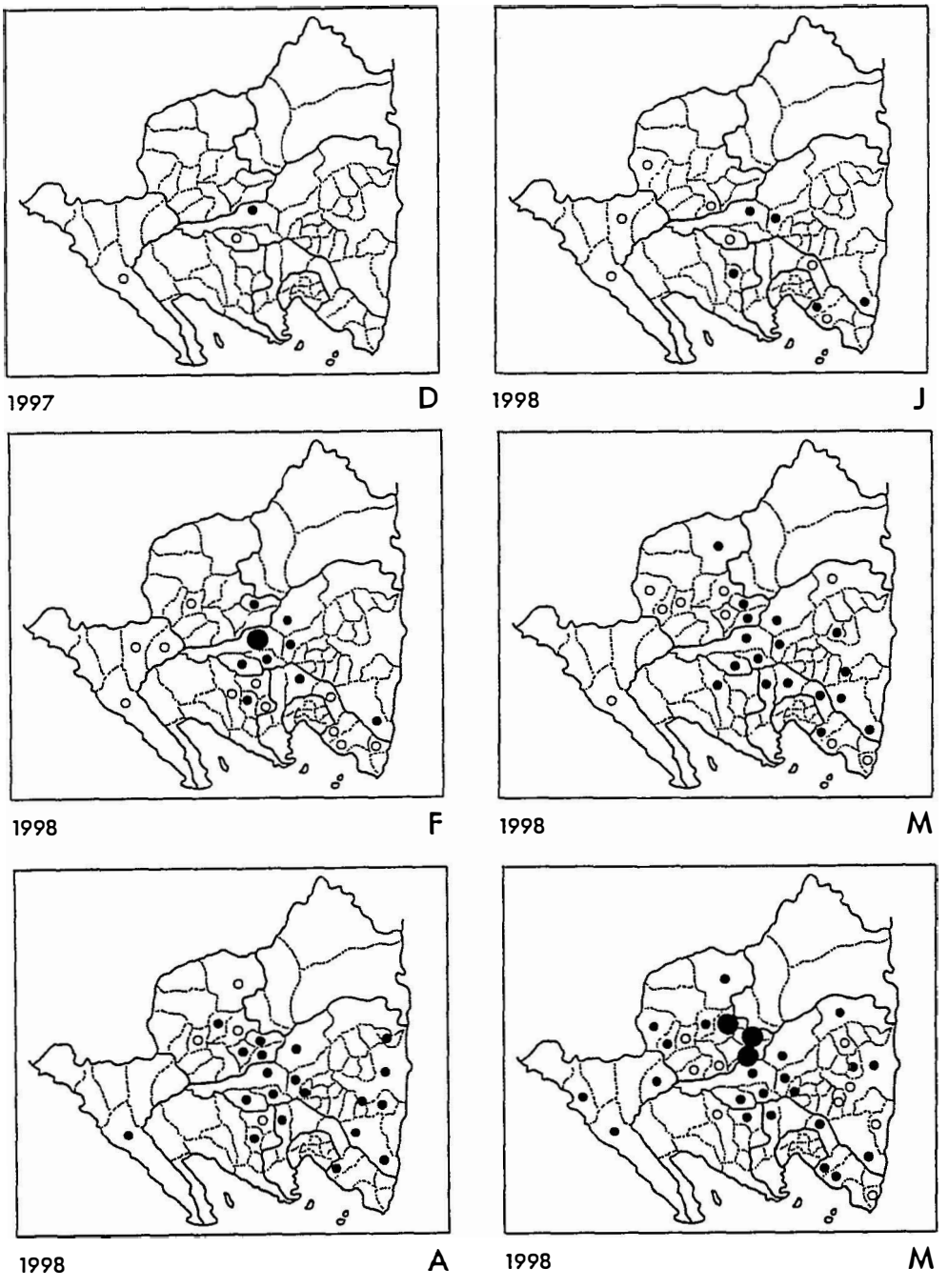

Figure 9. Development of migratory locust outbreaks in Lampung province during the 1997-98 rainy season.

Open dot : < 10 hectares; small solid dot : 10-500 hectares; large solid dot : > 500 hectares

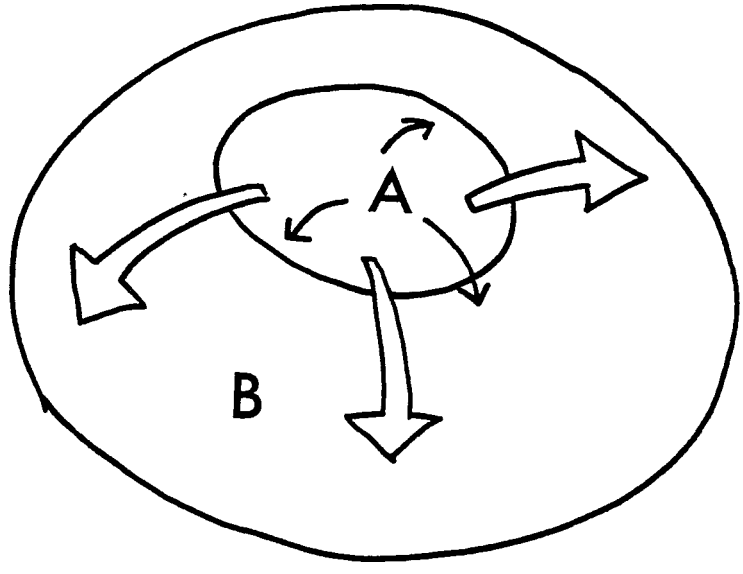

Figure 10. Hypothesis on swarm dissemination from one or several outbreak source centres in southern Sumatra.

A. outbreak source centre; B. primary swarm dissemination and secondary breeding zone.

2.5. How the locust situation will probably evolve

2.5.1. Short-term evolution

Past outbreak patterns indicate that they are always limited to a single rainy season and that the locust population levels recede during the following dry season. This highlights the importance of natural control factors, which have to quickly recover during the rainy season so that the natural balance can be promptly re-established. In areas with low rainfall and natural control factors only have a minor role (Africa, Madagascar), the switch to the gregarious phase enables locusts to survive much better under unsuitable conditions (too dry in these areas) and perpetuates outbreaks the following year.

The current outbreaks will therefore likely decline progressively for natural reasons. Indeed, in June the situation had already regressed considerably relative to May 1998.

However, two new facts indicate that the situation should be carefully monitored, and locust surveys and control should not be abandoned :

- The 1997 drought was the most serious and longest recorded in recent years, especially since the extensive deforestation that began in the 1970s and the creation of suitable biotopes for oriental migratory locusts. This event could have prompted a marked reduction in natural control factors and maintained locust densities at high levels for a longer period of time (more substantial reductions in the populations of "natural enemies" during the dry season, longer recovery of these enemies during the rainy season).

- The locust outbreaks were exceptionally serious and more locusts were in the gregarious phase, thus possibly helping the locusts prepare for the poor conditions that were coming. As early as 1936, Uvarov noted that gregarious swarms are highly resistant and persistent.

It is therefore also possible that the locust populations decrease more slowly, that there is not a complete return to initial population levels, and that, despite the fact that the populations could become solitarious again, locust numbers could remain at higher than normal levels (while remaining under the gregarization threshold). This could then promote a more frequent return to outbreak situations.

The situation should thus be very carefully monitored in the coming weeks and months (even though the higher than normal rainfall levels in June suggest that natural control processes will quickly overcome the threatening situation).

Finally, although it is quite unlikely, the possibility that the swarms in Sumatra could migrate westward to Java should be kept in mind. Locust swarm distribution maps for early 1998 show that dispersal was slow, which means that the locusts were probably moving at quite slow speeds. In 1987, Farrow already noted that, during recent outbreaks in Australia, New Guinea and South Africa, swarms were only moving 1-2 km/day, flying at low altitude (20 m), and spending a considerable amount of time in cropfields. In Queensland, swarms of locusts moved no more than 20-30 km over the course of their lives. This is probably the situation that prevails in Sumatra. Farrow pointed out that this behaviour contrasted with that observed in Africa and the Philippines, where swarms can migrate hundreds of kilometers during their lives.

2.5.2. Long-term evolution

The problem will undoubtedly return and be even more serious. It can only worsen in the coming years, with the increase in the area cropped and the creation of new favourable biotopes. Each dry period should then increasingly facilitate the development of locust outbreaks. Moreover, there is a good chance that average basic population levels will progressively increase. The recent increase in the frequency of long dry seasons, if this soon proves to be a general trend, will worsen the situation even further.

3. Main recommendations

3.1. Short-term recommendations

1. **Improve coordination** and rapid dissemination of information between the "Food Crops and Horticulture" and "Forestry and Estate" directorates. The locust situations in areas covered by these two directorates are closely linked. These situations can only be understood and efficiently controlled by adopting a general strategy, with both areas taken into account.

2. **Continue locust control operations**, along with careful monitoring of the situation in the coming months.

3. Continue **promoting mechanical control techniques**, especially in food-crop areas (large nets, light traps, etc.).

4. **Closely monitor the locust situation in real time**. Quick collection and centralization (weekly) of field and cartographic information (accurately highlighting the regions infested, the surface area, phenological stages, etc.). This rapid information transfer should enable accurate assessment of the situation, and facilitate forecasting and improve control planning (i.e. an operational control centre).

5. **Determine the economic impact** of locust outbreaks with respect to different crops (rice, maize, sugarcane, etc.), in terms of crop-yield and market-value losses.

3.2. Medium-term recommendations

6. **Increase training levels** of crop protection service agents with respect to locust problems (species identifications, phenological stages and phases, locust biology and ecology, locust survey and forecasting methods, control strategies, control techniques, etc.).

7. **Acquire basic documentation** on locust problems.

8. Plan a **training trip to CIRAD** for a crop protection service agent.

9. **Publish extension documents** and public awareness documents to be disseminated to crop protection service technicians and farmers.

10. Whenever possible, use **well adapted insecticides and formulations** for locust control (e.g. Adonis UL or EC, and Sevin XLS: cf. Annex). Formulations now being used necessitate overdoses of active ingredients [e.g. fipronil in EC formulations at 50 g a.i./l is now commonly used at 15 g a.i./ha, whereas UL formulations as low as 2 g a.i./ha are

possible]. It is essential to know the exact quantity of insecticide used per treated hectare in order to be able to increase the treatment efficacy in an environment-friendly way.

11. Pool all information available for the 1997-98 period (along with all previous data) for the two directorates "Food Crops and Horticulture" and "Forestry and Estate". This will make it possible to assess the extent of the overall damage, and especially to carry out an overall analysis of the locust situation, i.e. more accurate and complete than the preliminary analysis carried out during this mission.

3.3. Long-term recommendations

12. **Collect field data that is essential** for understanding the locust problem in Indonesia, and more specifically in Sumatra:

- Identification of the most suitable biotopes and possible locations of the initial outbreak area (or areas), i.e. outbreak source centres from which swarms can disseminate. Ecological mapping of locust biotopes.
- Collection of baseline data on locust population dynamics in the natural environment, and studies on outbreak determining factors (importance of deforestation in the creation of new favourable biotopes; impact of natural enemies on locust population control; effects of drought periods; effects of introducing various crops and different cropping practices, etc.).
- Survey on past outbreaks.
- Obtaining better information on locust problems in other Indonesian regions, especially Kalimantan and Sulawesi.

This will involve setting up a flexible light research and development programme over the long term to investigate the locust problem in Indonesia.

13. Develop **preventive locust control strategies based on integrated pest management principles**:

- Reduce pesticide use by:
  - . More efficient reporting and regular surveys of locust populations in outbreak source centres. Setting up a simple counting system for surveying locust populations. Taking critical phase transformation thresholds into consideration to detect high-risk situations (e.g. 2000 adults/ha for the first gregarious locust events).
  - . Early treatment operations, in the outbreak source areas, if possible.
  - . More accurate information for farmers on local locust control methods and prevention measures.

- Better insecticide use, especially in plantation areas (insecticide choices and well adapted spraying techniques).

- Testing of non-chemical locust control techniques:

  . Mechanical control: this is a good environment-friendly solution for small outbreaks in food-crop areas.

  . Biopesticides: currently the only valid alternative to chemical control for widespread treatments; all locust experts agree that it would be very difficult to develop a traditional biological locust control technique (i.e. using natural enemies as *Scelio* sp.)[2].

  . Cropping practices that could be detrimental to locusts.

It should be noted that, as there is a very wide range of different ecological and cropping conditions, no single control method can be recommended. Instead, a set of methods could be applied, depending on the phenological state of the locusts, the type of environment and how it is being utilized (natural vegetation, food crops, estate plantations, etc.).

3.4. Summary of the recommendations

1. Improving coordination between "Food Crops and Horticulture" and "Forestry and Estate" directorates.
2. Continuing control operations and carefully monitoring the situation.
3. Continuing to promote mechanical control methods in food-crop areas.
4. Closely monitoring changes in the locust situation in real time.
5. Determining the economic impact of locust outbreaks.
6. Increasing agent training levels.
7. Acquiring basic documents on locust problems.
8. Planning a training trip to CIRAD for a crop protection service agent.
9. Publishing extension documents.
10. Using insecticides and formulations that are well adapted for locust control.
11. Pooling available information on past locust outbreaks.
12. Collecting field data essential for understanding locust events.
13. Developing preventive locust control strategies based on integrated pest management (IPM) principles.

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2 « ...classical biological control using either parasitoids or pathogens is unlikely to be successful against locusts. » R.A. Farrow, 1990. Methods for assessment of environmental impacts of alternative control agents. In « *Proceedings of The Workshop on Health and Environmental Impact of Alternative Control Agents for Desert Locust Control*», Oslo, January 14-17, 1990. p. 55-66.

Conclusions and prospects

The current oriental migratory locust situation in Sumatra represents a serious crop protection problem. The gregarization process is well under way. Many swarms have developed and these locusts are still breeding. Smaller oriental migratory locust outbreaks have also occurred on various islands in the Indonesian archipelago.

Nevertheless, this situation is not nearly as serious as that often prevailing in other parts of the world, where very large plagues can occur, e.g. currently in Madagascar. On about seven concerned islands, only Sumatra has had large-scale outbreaks and these should not spread beyond the southern tip of the island. These outbreaks will probably regress progressively during the dry season, as has already occurred in the past with smaller outbreaks. There are still, however, many unknown factors, and the situation should be very carefully monitored, as this phenomenon is more serious than it has ever been in Indonesia.

The locust problem in Sumatra is therefore not simply anecdotal. It is a real problem that seems to have steadily increased in proportion in recent years, and to have worsened as a result of the increasingly severe and frequent droughts.

In the short term, these outbreaks are linked with dry periods which have become increasingly frequent in recent years. In the long term, they are the result of the regular development of new favourable biotopes prompted by deforestation and cropping, especially sugarcane. This could thus become an ongoing problem that might even worsen.

In addition to the immediate measures that have to be taken to control the current situation, further studies should be carried out to pinpoint the factors that determine these locust outbreaks. A programme involving regular locust surveys and preventive control based on integrated pest management principles should be set up.

A light long-term research and development programme could also be set up. Recommendations were put forward on different topics that should be covered in this programme. It would be essential, for instance, to take all of the different affected areas into account, i.e. food crop and estate crop areas. The latter areas, especially the sugarcane plantations, would certainly be worth assisting in setting up such a programme, for logistical reasons and because these areas are of considerable economic importance.

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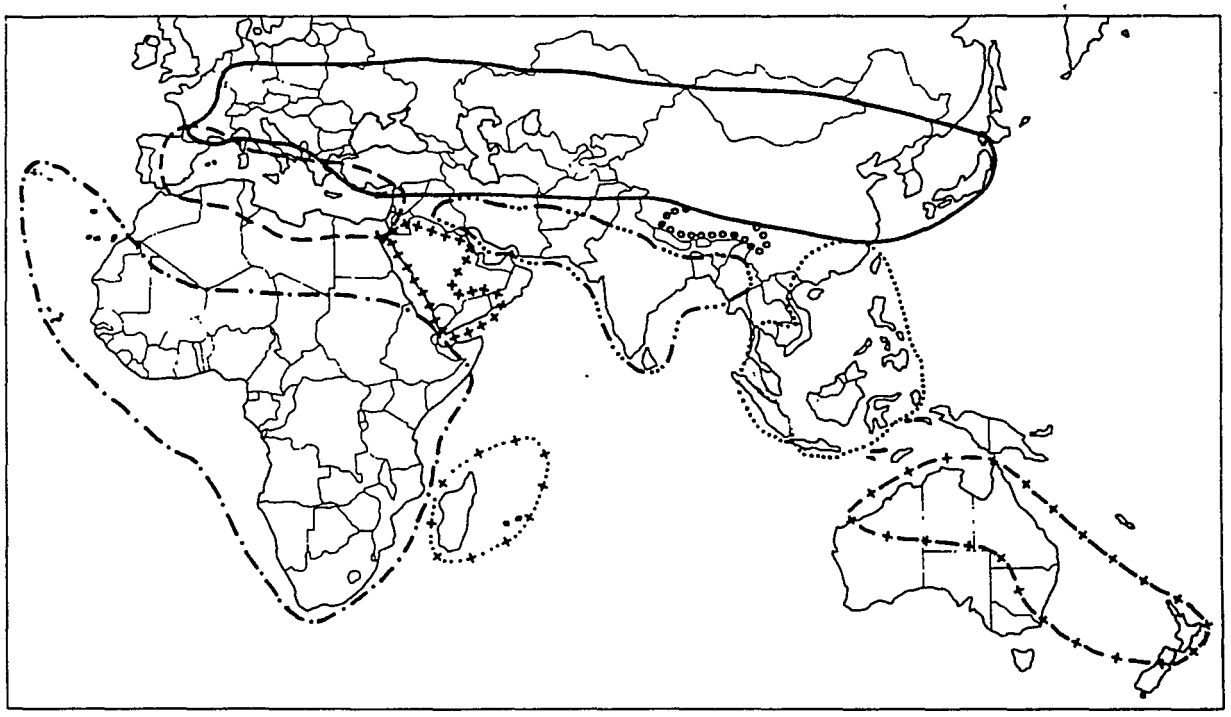
Annexes

Annex 1. Main features of the oriental migratory locust, *Locusta migratoria manilensis (modified from COPR, 1982)*

Locusta migratoria manilensis (Meyen, 1835) (*Acrydium manilensis* Meyen 1835), the Oriental Migratory Locust. This subspecies bears considerable resemblance to *L. m. migratorioides*. Like it, it is a non-diapause, tropical form. Moreover, based on numerical taxonomy analysis, Farrow & Colless (1980) consider that migratory locusts from the tropics and southern hemisphere represent a single polymorphic, non-diapause subspecies, *L. m. migratorioides* (Reiche & Fairmaire).

Distribution

Malaysia, Indonesia, Thailand, Kampuchea, Vietnam, Philippines, Taiwan.



Locusta migratoria migratoria and other northern subspecies
I. rossica, L. gallica (approx. only)
L. m. cinerascens
L. m. migratorioides
L. m. manilensis
L. m. burmana
L. m. capito
Indian subspecies
Arabian subspecies
Australian subspecies

Ecology and behaviour

It is widely distributed in low-lying grasslands in E and SE Asia. Plagues arise from outbreak areas where from time to time the population density rises, and transformation from the solitarious to the gregarious phase occurs. The most important of these are in

S. Cotabato province, Mindanao, Philippines, and in Sabah (Bomeo). The origins of the gregarious infestations in Malaya in 1912-19 and 1930 are uncertain. They were considered to have been the result of invasions by swarms from Bomeo, but there were no known plagues there and, as the later outbreak was in an inland area, it seems more likely that they were due to local breeding.

Outbreak areas in the Philippines and Bomeo occur in tropical grasslands which have developed following clearance of the forest. Here shifting cultivation practised for a few years before abandoning the land produces both food-shelter and oviposition habitats and conditions which promote transformation into the gregarious phase.

Life cycle

In the Philippines four to five annual generations occur (two in the dry season and two to three in the wet season). There is no diapause in the egg stage which lasts 10-24 days. From 2 to 12 egg pods per female (certainly no more than 3 in average in the field) are laid at intervals of 4-15 days, averaging 36 to 75 eggs per pod and producing 200 to 750 eggs altogether. Successive laying at the same site can result in egg pod densities as high as 4000 – 5000 / m^2. The whole life cycle in the tropics, from egg to first oviposition, takes between 58 and 140 days of which the five, or occasionally six, hopper instars occupy 26 – 61 days. Adult live up to 97 days.

Plague dynamics

In the Philippines records going back over 400 years provide evidence of an 11-year cycle in *Locusta* plagues. Drought conditions seem to be a fairly regular characteristic of « locust » years and it had been noted as early as 1645 that locust outbreaks followed periods of drought. Studies on the 1919-29, 1932-39 and 1941-49 plagues suggested that swarm formations occurred in the virtually uninhabitated grasslands of central Cotabato on Mindanao and led to the suggestion that increasing cultivation could possibly minimize, or entirely prevent, the development of migratory swarms. After the end of the last major plague in 1949 a short-lived plague developed in Cotabato in 1958. The initial increase in numbers and density occurred in grasslands around Sarangani Bay in S. Cotabato during an unusually protracted drought between October 1957 and March 1958. The adults subsequently moved northwards into central Cotabato and increased rapidly in numbers with the onset of the rains in April, gregarized, and produced numerous day-flying swarms during the latter part of 1958. Although there have been minor outbreaks in S. Cotabato since 1958, no plagues have developed there or elsewhere. Rapid agricultural development which has taken place in S. Cotabato since World War II seems to have been crucial in the declining importance of *Locusta* in the Philippines. Neglected lalang grasslands (*Imperata cylindrica* grasslands) are now being intensively cultivated or ranched and the farmers act as a ready-made scouting system which allows the timely application of chemical control measures.

Detail studies on the factors influencing the displacement of swarms have not been

undertaken but it has been noted that, with moderate wind, swarms can often make long sustained flights, and that they seldom migrate in strong or cloudy or rainy conditions. The northward spread of swarms through the archipelago appears to occurs mainly between March and October. Swarm movements between the islands of the Philippine archipelago have long been known, and serious outbreaks occurred in Taiwan when the island was invaded from Luzon. Evidence also suggests that the Celebes may have been invaded from the Philippines, a distance of some 400 km.

In Borneo upsurges appear to be of shorter duration than in the Philippines and the area reached by migratory swarms is virtually confined to Sabah where outbreaks occur in lalang grassland.

The incomplete data available suggest that flights of successive generations may move in different directions, possibly in relation to seasonal winds.

Economic importance

It has been regarded as one of the most important agricultural pests in the low-lying grasslands of S. E. and E. Asia and feeds on a wide range of crops but is primarily graminivorous. Damage has been reported in all countries in its area of distribution but there are few estimates of the value of crops destroyed. In the Philippines 10 million pesos worth of damage was caused in 1911-12, and direct loss of crops varying from 67,000 pesos to a peak of over 5 million pesos (in 1932) was recorded in every year between 1925 and 1934.

Useful plants attacked

Bamboo, banana, barley, beans, cassava, citrus, coconut, cotton, groundnut, Italian millet, lablab, lettuce, maize, melon, millet, pea, pigeon pea, pineapple, potato, radish, rice, sago palm, sisal, sorghum, soya, sugar cane, sweet potato, tobacco, wheat, willow. Also damage to rubber plants due to weight of individuals. Many species of grass are recorded as food.

Natural enemies

Eggs are attacked by the dipteran *Elassogaster sepsoides* (Walk.) which may destroy up to 34 % of egg pods in the Philippines. *Sarcophaga dux* Pand. And *S. kempi* S.-W. attack the later stages and 10.8 % of adults have been found affected. Eggs are also destroyed by mites, and many general predators including ants, bugs, hornets, mantids, wasps, various birds and mammals are also known to attack them.

The most important natural controlling factors are, however, heavy rain and floods, and eggs are totally destroyed if submerged for 6 days.

Annex 2. Main pesticides used in Indonesia to control oriental migratory locusts

BASSA 500 EC	Active ingredient BPMC (fenobukarb)	R*
BAYCARB 500 EC	"	R, L
HOPCIN 500 EC	"	R
KILTOP 500 EC	"	R
REGENT 50 SC (50 g/l)	Active ingredient fipronil	R
SEVIN 85 S	Active ingredient carbaryl (carbamate)	M, L
SEVIN 43 FW	"	M, L

Other available products are still being used. Some plantations use monocrotophos (GUSADRIN), despite the fact that this product is not recommended by the agricultural services. We also noted that the following products were being used:

NUVANTOP 500 EC	Active ingredient dichlorvos
REGENT 0.3G	Active ingredient fipronil

and perhaps permetrin.

* R, registered for rice; M, registered for maize; L, registered for *Locusta migratoria* (Source: *Pestisida untuk pertanian dan kehutanan.* 1997. Komisi pestisida, Departemen pertanian, Jakarta, Indonesia. 257p.

Annex 3. Main features of locust control pesticides

Details also given in the text

Active ingredients (recognized by FAO)	***Rate of action*** ***Locusta dose g a.i./ha***	***Toxicity WHO formulations for treatments with 1 l/ha*** **(highest concentration in g/l for this class)**	***Ecotoxicological impact (from FAO 1996) (L : low, M : medium, H : high)***			
			terrestrial invertebrates	birds	mammals	aquatic fauna
Organophosphates	rapid					
Fenitrothion (Sumithion)	225	III (<225)	M	**H**	M	M
Malathion	450	Unlikely	**H**	L	L	M
Chlorpyriphos (Dursban)	125	II (>50)	M	**H**	M	**H**
Pyrethroids	very rapid					
Deltamethrin (Décis)	12.5	III (<50)	**H**	L	L	**H**
Lambdacyhalotrin (Karaté)	20	II (>10)	**H**	L	L	**H**
Carbamate	average					
Bendiocarb (Ficam)	50	III (<50)	M	L	L	L
Phenyl-pyrazole	average (+persistent)					
Fipronil (Adonis)	1 - 2	III (<30)	M	L (M)	L	M – **H**
IGR (*hoppers only*)	delayed					
Diflubenzuron (Dimilin)	20 - 60	Unlikely	L	L	L	**H**
Teflubenzuron (Nomolt ?)	15 - 30	Unlikely	L	L	L	**H**
Triflumuron (Alcystin ?)	?	Unlikely	L	L	L	**H**

World Health Organization (WHO) toxicity classification for mammals: I (high risk); II (moderate risk), III (low risk)

Comments

1. Active ingredients

- This list was limited to active ingredients recognized by FAO, but there are other efficient products such as pyridaphention (OP)
- The brand names given are those commonly used in Africa

2. Dose

- The dosages are those recommended by FAO, and generally correspond to half the effective dose necessary for controlling desert locusts (except for pyrethroids for which a full dose is required).

- The recommended doses are valid for blanket treatments (i.e. regular), but can correspond to a dose/protected ha for irregular coverage treatment when highly active and more persistent products are used (fenitrothion, fipronil, IGR).

3. Rate of action

- very rapid: high mortality (knockdown effect), peaking within hours after treatment.
- rapid: peak mortality after 24 h.
- average: peak mortality in 48 h.
- delayed: mortality only observed during the following moult.
- persistence: very high mortality of insects arriving 8 days post-treatment

4. WHO toxicity

- Classification for acute toxicity through ingestion by humans, calculated on the basis of the LD50 for rat and the a.i. concentration of locust control formulations. This risk index does not take into account toxicity by skin contact or through inhalation, or the toxicity of some solvents and additives.

e.g.: lambdacyhalotrine is only slightly toxic by ingestion but a strong skin irritant.

- Latency time after ingestion of treated crops: this data is not readily available for locust control as the type of formulation has to be taken into account (oil-based, emulsion, granulated, etc.), along with the concentration and crops concerned.

e.g.: fipronil: 1 week for treatment doses against *Locusta* (Rhône Poulenc estimates).

5. Ecotoxicological risks

- Risk scale very roughly modified and supplemented on the basis of FAO data (1996). This is a risk index for a knockdown effect, without considering potential recolonization and indirect effects.

e.g.: high mortality of terrestrial insects (high risk) with pyrethroids, but there could be rapid

recolonization as these products have a very short residual effect. This is not completely true for fenitrothion. IGRs are also very specific to moulting invertebrates (various larval forms), but their high persistence can have a sustainable effect on locust population renewal. Sometimes the effects are only visible the following season.

e.g.: apart from fenitrothion, birds are not intoxicated by any of the insecticides noted here, but they can have a visible impact if the birds prey is destroyed during their breeding period.

Note that the absolute toxicity data are only valid if the pesticide treatment conditions are specified. It is much more important to assess the risk for a group of organisms in terms of toxicity, **but especially of exposure** when a pesticide is sprayed in a given environment, e.g. fipronil in water.

5.1 Terrestrial invertebrates

- This category mainly involves beneficial organisms (parasites and predators of pests).

- None of the insecticides noted here are safe for non-target insects. In terms of knockdown effect, contact pesticides have very spectacular effects (H risk), but they are not very persistent. There is very little difference with respect to the medium risk (M) group of pesticides. Fipronil, and even moreso IGRs, are slightly more specific, especially for phytophagous insects as they are stomach pesticides. They are also more persistent (see above).

5.2. Birds

- see above
- fipronil: there is very little risk of acute intoxication, except for gallinaceous birds, as the LD50 is very high. However, there is very little risk of exposure of gallinaceous birds to fipronil after locust control treatments due to the very low concentrations used. A repulsion phenomenon was demonstrated when fipronil was used in granulated form.

5.3. Mammals

- see above
- the usual safety precautions should be respected when handling all of these pesticides, except possibly IGRs which have no effects on the nervous system.

5.4. Aquatic fauna

- A very general toxicity index, as it encompasses fish, crustaceans, mollusks and insects, etc. Moreover, it often refers to the toxicity of the active ingredient but not of a more or less water-soluble formulation. The insecticide also acts in different chemical ways under different pH and salinity conditions, etc.

- It should nevertheless be pointed out that all of these pesticides have some toxic effects in water. Pyrethroids, in particular, should not be used (harmful for fish and invertebrates), as well as chlorpyriphos (especially for fish) and IGRs (especially for larval crustaceans).

- Concerning rice fields where routine treatments are carried out, these environments are

already so degraded that it would be hard to pinpoint the specific impact locust control treatments. On the other hand, important IPM extension projects are currently being implemented in some rice-growing areas, and care should be taken to not upset the results by conducting uncontrolled treatments targeting locusts.

- The situation concerning fipronil is complex. Note :

- that this product is very stable in acidic and neutral environments, and it is rapidly taken up in the soil layer and therefore does not reach the water table;

- that toxicity measurements for the active ingredient and some of its metabolites highlight a very broad LD50 range for fish and crustaceans, whereas there is very little impact on some other organisms such as marine shrimps; some of the metabolites have even higher toxicity (2-6-fold higher).

However:

- Based on theoretical calculations generally used to assess risks, it seems that **in fresh water** the risks of exposure (and thus of mortality) after treatment of water with oil-based formulations at low doses (2 g/l) are very low, even for the most susceptible organisms. However, this does not apply for higher concentrations (> 6 g/l), especially with emulsifiable formulations.

- There is even less risk of exposure to the most toxic metabolites as they only represent a minor proportion of the initial active ingredient. Moreover, they only appear under very special conditions. The most toxic metabolite (MB 46950) can be found in the soil in cases of anaerobic metabolism, where it can represent up to 47 % of the initial active ingredient. It can also be bioaccumulated in fish, but this phenomenon is reversible within 14 days.

- Marine crustaceans (coastal environment) represent a non-target group that is probably at high risk after waters are treated with locust control formulations.

5.5. Comments on carbaryl

Although it is already used for locust control purposes, carbaryl is not on the latest FAO list of recommended products for locust and grasshopper control drawn up by the Pesticide Referee Group (1996) as there is "not enough test data to determine effective doses". This product is often considered to be outdated because of the high doses that have to be applied.

For comparison, note that the 1983 FAO pesticide index reported two cases of successful use of this product, one against *Locusta migratoria manilensis* in the Philippines in 1959 (about 1000 g a.i./ha powdered product). In I983, FAO considered that carbaryl was "quick acting but not very efficient and slightly phytotoxic, and can be successful against relatively immobile insects". In USA, it is used against grasshoppers at 400-500 g a.i./ha in blanket treatments, but with XLS formulations (almost the same as SC). Lockwood even obtained 81% mortality with 238 g

a.i./ha carbaryl (Reduced agent and area insecticide treatments method = RAATs method[3]).

As is the case with many carbamates, carbaryl is known to be relatively safe for mammals. In France for instance, the latency time is 7 days on vegetables (+/- 1000 g a.i./ha). In USA, cattle can continue grazing in areas treated against grasshoppers (Lockwood, at 477 g a.i./ha). However, all recent pesticide indexes point out that is highly toxic to fish and bees and all beneficial insects.

Note also that there is an increased risk of exposure for aquatic fauna with all water-soluble EC formulations.

Sevin XLS is the most recommended formulation, but it should not be applied near water sources, and the dosages should be minimized (RAATS method of Lockwood).

5.6. Comments on Regent 50 SC

Regent 50 (fipronil active ingredient) is not a locust control formulation. The fipronil formulation for locust control is marketed under the brand name Adonis. With Regent 50 SC, there is a problem of bioavailability of the active ingredient for mobile insects such as locusts, which means that there is also a problem of effective doses. SC formulations are solid particle suspensions including the active ingredient, whereas in EC and UL formulations (i.e. the only formulations available with Adonis) the active ingredient is directly diluted and therefore more directly available via contact and especially ingestion (more readily metabolized by the insect). Consequently, Regent 50 SC has to be applied at very high doses, which means that high quantities of wasted product will long remain uselessly active on non-target organisms.

The most suitable formulation is therefore Adonis 50 EC (8 or 4 g a.i./l) or UL (4 or 2 g a.i./l), and the treatment dose should be as low as possible (2-4 g a.i./ha). In Madagascar, recent aerial treatments with an UL formulation revealed excellent efficacy at 2 g a.i./ha with 200 m track spacing. Treatments should not be carried out near coastal areas because of the risk of intoxicating marine fauna.

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3 J. Lockwood, S. Schell, R. Rockwell and N. Isu, 1996. *Field test of fipronil for control of rangeland grasshoppers in Wyoming (USA). Implications for Reduced agent/area treatments.* University of Wyoming, Laramie WY, USA.. 34 p.