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A summary of the COPR/OCLALAV* Research and Development Project on Sahelian grasshoppers in the Middle Niger Valley, August 1976 - December 1978

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Foreword

This paper summarises the work and findings of a collaborative project on grasshopper research and control in the Sahel, conducted by the British Centre for Overseas Pest Research (COPR) and the Organisation Commune de Lutte Antiacridienne et de Lutte Antiaviare (OCLALAV) of Senegal, during the period 1976 to 1978. It also gives an appraisal of the grasshopper problems of the Sahel based on the author's wider experiences in the region and elsewhere, and on unpublished and published work including the records and reports of OCLALAV over the past two decades which reside in the archives of the Food and Agriculture Organization of the United Nations in Rome.

This appraisal is particularly timely in view of the recent grasshopper epidemics in the Sahel which attained such magnitude as to require the rapid and extensive intervention of the whole international community to provide resources and expertise to combat them. With the threat of similar outbreaks continuing for some years to come, the data in this paper, and in its earlier French language version published in 1979, may be of particular value to all concerned in emergency control measures and longer term research and development designed to devise more effective grasshopper control strategies for the future.

In publishing this paper COPR and its successor the Overseas Development Natural Resources Institute (ODNRI) wishes to record its gratitude to the author and to all the individuals and organisations who contributed to the successful execution of the project, through scientific and technical expertise, financial and logistical support, provision of equipment, operational bases, accommodation and other essential facilities. The work accomplished, which involved extensive field work often under difficult and trying conditions, could not have been accomplished without the fullest cooperation and enthusiasm of all concerned.

Prof. Tecwyn Jones OBE
Deputy Director
ODNRI

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As leader of the project, the author, on behalf of himself and the members of his team, is greatly indebted to all persons and institutions who assisted in the implementation of the project by providing information, advice and facilities.

ACRONYMS

AGRHYMET	Development Centre for Agrometeorology and Applied Hydro-Meteorology
CIDA	Canadian International Development Agency
CILSS	Comité Inter-Etats pour la Lutte contre la Sécheresse dans le Sahel
COPR	Centre for Overseas Pest Research
(now ODNRI)	(Overseas Development Natural Resources Institute)
FAO	Food and Agriculture Organization of the United Nations
GALA	Groupe Aérien de Lutte Antiacridienne (of OCLALAV)
GERDAT/PRIFAS	Groupement d'Etudes et de Recherches pour le Développement de l'Agronomie Tropicale/Le Programme de Recherches Interdisciplinaire Francais sur les Acridiens du Sahel
IRLCOCSA	International Red Locust Control Organization for Central and Southern Africa
ODA	Overseas Development Administration
OCLALAV	Organisation Commune de Lutte Antiacridienne et de Lutte Antiaviare
OICMA	Organisation Internationale contre le Criquet Migrateur Africain
OSRO	Office for the Sahelian (now Special) Relief Operations
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

Summaries

SUMMARY

A brief account is given of the background, work and results of the COPR/OCLALAV Research and Development Project on Sahelian grasshoppers during the field operations of August 1976 to December 1978. Most of the report is devoted to the description and discussion of the economic importance of the Sahelian grasshoppers and to strategies and methods for their control. This is based on other published and unpublished data as well as on the results of the project. *Oedaleus senegalensis*, the Senegalese Grasshopper, economically the most important species, is examined separately in some detail; the other grasshopper species are discussed as complexes associated with particular agroecosystems in the Sahelian and Sudanian zones. *Zonocerus variegatus*, a species of particular importance in the forest zone, is also included.

It is concluded that grasshoppers are chronic and important pests. Practically all crops are subject to attack, but damage to cereal subsistence crops is the most serious. There are considerable numerical seasonal and annual changes which are due partly to the action of natural enemies, but particularly to the effects of weather. Mass outbreaks occur from time to time, when crop destruction can be severe, and locally total, but even in years of low incidence, some damage occurs. Since 1970, therefore, control of grasshoppers was required every year somewhere in the Sahel and the Sudan zones. During the same period the frequency and severity of grasshopper damage was higher in some areas than in others, being particularly high in the major drainage basins of Senegal, Niger, Chad (and the Nile), which are also principal crop-growing areas. The Yelimane-Nioro area in western Mali appears to be particularly vulnerable.

Preventive control strategies are examined in relation to the individual species and complexes of species. Adequate monitoring of grasshopper numbers, especially during certain critical periods, is fundamental to the success of preventive control operations. Generally, it is considered that because of the widespread nature of the grasshopper problem, the best means towards adequate monitoring and preventive control, is through the active participation of the farming community. The various control methods and techniques appropriate to Sahelian conditions are reviewed. It is concluded that while development of cultural and biological control methods is feasible and should be the aim of an integrated pest management strategy in the Sahel, in the forseeable future, the use of pesticides remains the only effective means of controlling major grasshopper outbreaks.

Grasshopper control has so far received considerable support from OCLALAV. It is concluded that this participation should be gradually phased out and the responsibility be fully assumed by national plant protection services. It is important that the control potential of the regional organisation should not be allowed to weaken through lack of support of its member states and the international community.

RESUME

Ce rapport est un compte-rendu sommaire des travaux entrepris par le Projet de Recherches et de Vulgarisation COPR/OCLALAV sur les Sauteriaux du Sahel pendant la période des opérations sur le terrain entre août 1976 et décembre 1978, ainsi que des principaux résultats obtenus. Le gros du rapport se consacre à une description de l'importance économique des sauteriaux du Sahel et à une discussion des stratégies et des méthodes de lutte. Afin d'élargir le champ des discussions, non seulement les résultats obtenus par le Projet mais aussi certaines autres données, publiées ou inédites sont inclues. *Oedaleus senegalensis*, en tant qu'espèce la plus importante, fait l'objet d'une étude particulière; les autres espèces acridiennes sont groupées sous forme de complexes associés à certains agro-écosystèmes des zones sahéliennes et soudanaises. On considère également *Zonocerus variegatus*, espèce particulièrement importante dans la zone forestière.

Le rapport aboutit à la conclusion que les sauteriaux sont des ravageurs chroniques d'une certaine importance. Presque toutes les cultures en souffrent des attaques, mais ce sont les cultures céréalières alimentaires qui en subissent les plus grands dégâts. Les

variations numériques saisonnières et annuelles des populations acridiennes sont considérables; elles sont dues en partie à l'activité d'ennemis naturels mais surtout aux influences météorologiques. De temps en temps une pullulation généralisée se produit, qui aboutit à une destruction importante, parfois totale, des récoltes; mais même aux saisons à incidence faible, il en résulte quelques dégâts. Ainsi depuis 1970, une lutte antiacridienne a été nécessaire chaque année quelque part dans les zones sahélienne et soudanaise. Pendant la même époque les dégâts provoqués par les sauteriaux ont été plus fréquents et plus sévères dans certaines aires que dans d'autres, surtout dans les principaux bassins hydrographiques du Sénégal, du Niger, du Tchad (et du Nil), lesquels sont aussi les régions agricoles les plus importantes. La région Yélimane-Nioro au Mali occidental parait particulièrement vulnerable aux ravages des sauteriaux.

Des stratégies préventives sont considérées par rapport aux espèces particulières ainsi qu'aux complexes d'espèces; il en ressort qu'une surveillance adéquate des nombres d'acridiens, surtout a certaines époques critiques, est essentielle à la réussite des mesures de lutte préventive. Etant donné l'étendue du problème, il parait qu'une stratégie de lutte préventive suffisamment généralisée pour être efficace demanderait la collaboration active des cultivateurs. Les différentes méthodes de lutte sont examinées ainsi que les techniques appropriées aux conditions sahéliennes. Certaines mesures de lutte culturale et biologique paraissent réalisables et leur développement devrait figurer dans le cadre d'une stratégie de lutte intégrée contre les fléaux du Sahel. Toutefois, dans l'immédiat, l'emploi de pesticides synthétiques reste le seul moyen de lutte efficace de grande échelle contre les attaques de sauteriaux.

La lutte contre les sauteriaux a recu jusqu'à présent un appui considérable de la part de l'OCLALAV, ce qui a contribué au déclin de son potentiel de lutte contre le criquet pèlerin. Il est donc nécessaire d'envisager le dégagement de l'OCLALAV pour permettre aux services nationaux de protection des végétaux et du développement rural, suffisamment renforcés, d'en assumer la charge totale. Il est donc important d'éviter que le potentiel de lutte des organismes régionaux ne s'affaiblisse, faute d'appui de la part des Etats membres et de la communauté internationale.

Chapter 1

Background to project

During late 1960s and early 1970s prolonged drought in the Sahelian zone of Africa resulted in severe food shortages, at times bordering on famine. The Office of the Sahelian Relief Operations (OSRO) was set up under the aegis of the Food and Agriculture Organization of the United Nations (FAO) to provide emergency assistance.

Conditions improved in 1974 when rain fell at almost its yearly average over much of the Sahel. Planting was good, but a good harvest was not obtained because of a widespread outbreak of pests, chiefly grasshoppers, which devastated crops. Senegal alone estimated a national shortfall of over 30% in expected millet production and losses were possibly even higher in parts of Mali, Burkina Faso, Niger, Chad and Nigeria.

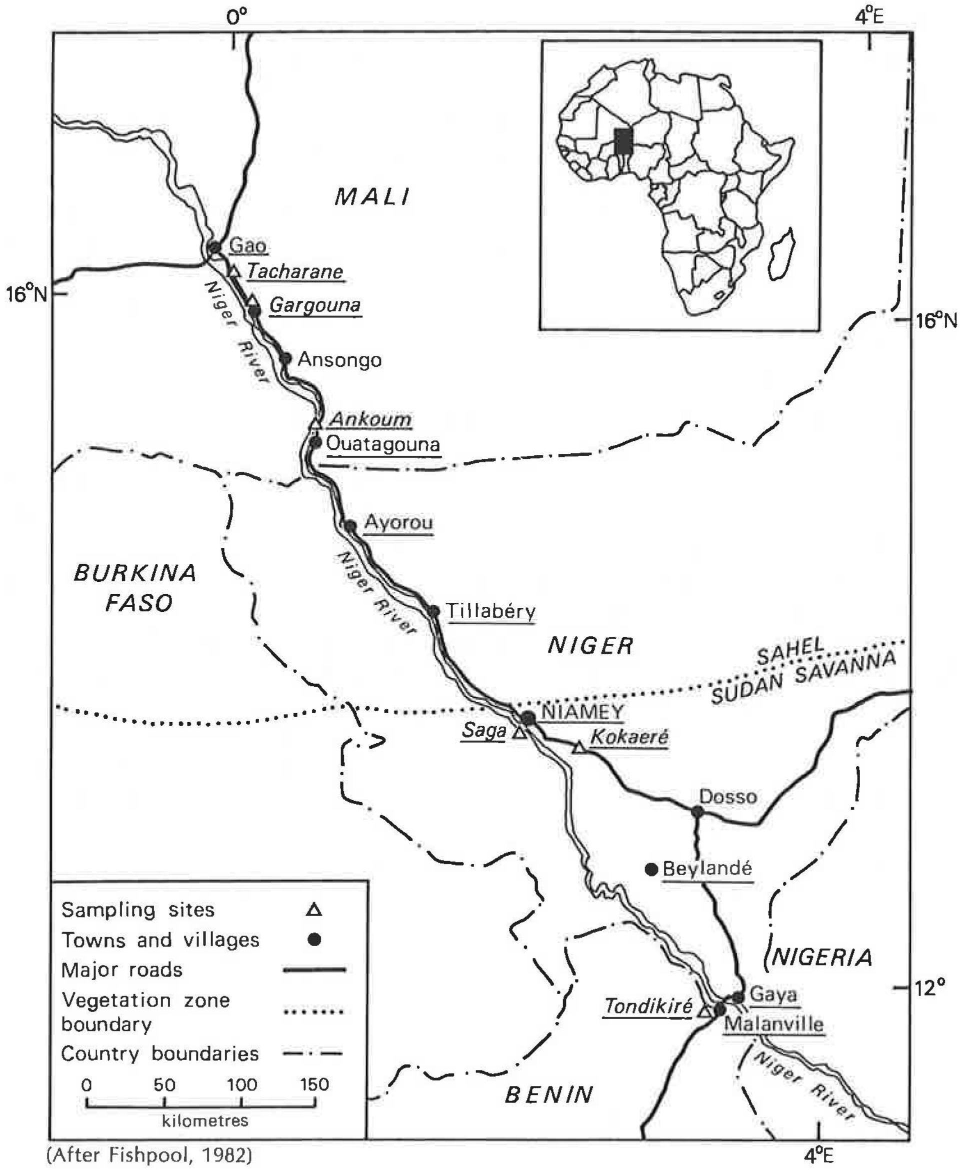
At the end of 1974 a special meeting was convened by the US Agency for International Development (USAID) in Washington DC, United States, between several potential donor and recipient country representatives, to consider emergency and medium and long-term assistance for the protection of food crops in the Sahel against the ravages of insect pests. It was recommended that all help for the emergency pest control operations for 1975 be channelled through OSRO. In February 1975, OSRO convened a meeting at Dakar, Senegal. This was attended by representatives from the national and regional plant protection services in the Sahelian zone who had submitted to OSRO requests and requirements for assistance with emergency pest control operations for safeguarding subsistence crops during the 1975 campaign.

By the end of March 1975 OSRO, with donor aid, was able to meet 40% of these requests, to the sum of US$ 4,000,000. By the end of the campaign over US$ 5,000,000 of aid was provided by OSRO, exclusive of bilateral aid. The aid provided insecticides and control equipment, vehicles, operational funds training and a coordinating service. The latter was supervised by staff from the Centre for Overseas Pest Research (COPR), who in close collaboration with the national plant protection services of Sahelian states and the two regional locust control organisations, Organisation Commune de Lutte Antiacridienne et de Lutte Antiaviare (OCLALAV) and Organisation Internationale de Lutte contre le Criquet Migrateur Africain (OICMA), helped to organise and carry out control operations against crop pests such as grasshoppers, stemborers, aphids and beetles. Insecticides, control equipment, vehicles and an additional quantity of transport and equipment were distributed in good time by OSRO throughout the Sahelian zone despite the difficulties of communication and transport during the rains. Although pest attacks were heavier than forecasted, the worst of the damage was averted by controlling a total area of over 1,000,000 ha, about half of it controlled by ground teams and farmers and the other half by aerial spraying. This was the first time that control of subsistence crops had ever been undertaken on such a scale in the Sahel and it did much to relieve the famine conditions. In turn, the success of the operations owed much to the coordinating service whose activities included the initial planning of operations and activities of the various control units; special surveys by ground and air, including helicopters, to locate, assess and delimit the infestations; timely warning of serious developments requiring emergency intervention; the planning of day-to-day strategy of central operations and development forces; training of technical personnel of plant protection services and farmers in the handling, preparation, application and storage of insecticides and the use of various types of control equipment; monitoring of the crop pest situation and reporting on the situation to OSRO and the various organisations concerned.

To keep track of the pest situation in time and space, a series of monitoring stations was established along a transect crossing the Sahelian zone from its northern extremity at Gao, with a rainfall of about 200-250 mm, and following the course of the River Niger across the Sahel southwards to the Niger/Benin border at Gaya-Malanville, where rainfall is about 750 mm. The stations were sited along the Gao-Gaya road for ease of communication and ready access to the river valley with its wide range of ecological conditions, crops and crop pests (Figure 1). Each station was manned by a technical officer from a national or regional plant protection service who was responsible for periodical field surveys of crop pests at chosen sites near his station and for conducting light trap and weather observations.

Figure 1

The chain of sampling sites and principal monitoring stations (underlined)



(After Fishpool, 1982)

These early results were of considerable interest as they indicated the economic importance of the various insect pests. Grasshoppers were found to be the most important group of crop pests, being responsible for considerable damage to practically every type of crop, especially cereals such as millets, maize and sorghum. Although the number of species was greater in the south, damage was higher in the northern part of the Sahel, because the fewer species there tended to multiply to higher numbers, often reaching swarming proportions. Many species are highly mobile and fly by day, or more often by night, singly or in concentrations, over distances of tens or even hundreds of kilometres. Evidence from light trap and field observations suggested that such movements have a seasonal pattern associated with the Inter-Tropical Convergence Zone (ITCZ) which also brings the monsoon rain to the Sahel.

Chapter 2

The COPR/OCLALAV Project

The success of the 1975 campaign encouraged donors to continue their support for crop protection operations in the Sahel, albeit on a more modest scale, and also to assess the needs for a long-term crop protection development programme. During 1976-1977 a number of design teams examined the requirements and submitted proposals for a major long-term pan-Sahelian integrated pest control project aimed at protection of subsistence crops.

While participating in these activities, the UK Government through the Overseas Development Administration (ODA) and COPR, also examined the possibility of more immediate, medium-term bilateral aid for strengthening crop protection in the Sahel. This approach led to the creation of a joint COPR/OCLALAV project with the aim of improving preventive control methods and strategies against grasshoppers, the principal subsistence crop pests in the Sahel.

The project was a natural sequel to many years of cooperation between the two organisations on the survey and control of the Desert Locust (*Schistocerca gregaria* Forsk.). The choice of OCLALAV as counterpart, rather than individual Sahelian countries, enabled the more general regional approach which the problem demanded. The agreement between the two organisations stipulated as its major objectives: to set up an information and monitoring service for the major grasshopper pest species as the first step towards a rational strategy of preventative control; and to improve control techniques by fields studies and experiments, and by training and extension exercises for the plant protection officer and farmer. The project was primarily concerned with the regional aspects of grasshopper pest survey and control but the joint effort of the two organisations envisaged close liaison and cooperation with the national plant protection services of all the countries of the region.

The investigation aimed to follow the lines of the monitoring service established during the OSRO 1975 campaign, based on a series of survey and observation points along a main, generally north-south, transect of the Sahelian zone, positioned at intervals on the eastern bank of the Niger river from Gao (Mali) through Tillabery (Niger) to Gaya (Niger) and Malanville (Benin) (Figure 1). Monitoring was to be carried out by trained observers by means of systematic sampling and light-trap catches at selected sites.

The programme was to include:

- faunal studies of grasshoppers and their systematics
- geographical distribution of different species
- ecology of the natural habitats of grasshoppers and their relation to crops
- biology of the main species including the life cycles and seasonal breeding patterns
- dynamics of populations including seasonal changes in distribution in relation to weather, and their habitats
- development of appropriate and effective survey and control strategies and techniques, the emphasis being on preventive control

- provision of training by participation of agricultural officers in the work of the project, and
- participation of senior project personnel in relevant training courses and seminars (organised by OCLALAV, OICMA, United Nations Develoment Programme (UNDP), FAO, Commission Inter-Etats pour la Lutte contre la Sécheresse au Sahel (CILSS) and the National Plant Protection Services).

These proposals were discussed and agreed by both parties and in due course additional financial support for the programme was provided by ODA.

The details of the inputs, responsibilities and administrative arrangements were given in a Memorandum of Understanding exchanged by the two organisations. The terms of refernce, and the various arrangements and the Memoranda of Understanding stipulated in the Agreement were followed with few departures and modifications until the closure of the project at the end of December 1978. In fact, the obligations and the contributions of the signatories in terms of personnel, equipment and funds exceeded the original undertakings and in addition there were some contributions from outside sources, such as the Canadian International Development Agency (CIDA).

The project got under way in early August 1976 in Niamey, the principal project base. A number of operational bases, similar to the monitoring service of the 1975 OSRO campaign, were established at intervals along the Gao-Gaya transect line across the Sahel (Figure 1, Table 1). The principal one was at Gao, the headquarters of the OCLALAV Mali Unit (Groupement).

Table 1

Bases and sub-bases (B), monitoring stations (M), sampling sites (S), light traps (L) and study sites (E) operated during the project

		Type	1976	1977	1978	Remarks
Mali						
Tabrichat	1744N 012E	S		....	....	Sondage only
Tin Aouker	1648N 008E	E			—	Radar study site
Gangaber	1622N 005E	S	...	...	....	Sondage only
Gao	1616N 003W	BL	—	—	—	Main sub-base, L only
Tacharane	1610N 004E	SF	..	...	.....	Sondage, F
Gargouna	1556N 013E	MLS	—	—	—	Monitoring, F
Daoga	1553N 014E	E			—	Radar study site
Tabango	1546N 022E	L	—	—		L only
Herba	1531N 033E	MLS			—	Monitoring
Firthindi	1524N 045E	S		..	....	Sondage only
Ankoum	1515N 043E	MF	—	—	—	Monitored jointly
Watagouna	1511N 043E	ML	—	—	—	
Niger						
Ayorou	1444N 055E	ML		—	—	
Famale	1433N 105E	L		—		Light trap only
Tillabery	1413N 127E	SML	—	—	—	M from 1978
Bani Bangou	1503N 224E	E		—		
Tondi Kiwindi	1428N 202E	ML			—	
Niamey	1331N 207E	BLM	—	—	—	Main base L, M from 1978
Saga	1327N 207E	SF	..	...	....	Sondage, F
Say	1307N 221E	L		—		
Guesselbody	1326N 222E	SF	...	....	......	=Kokaere, sondage, F
Beylande	1245N 252E	ML	—	—	—	
Gaya	1153N 327E	BLM	—	—	—	Sub-base, monitoring
Benin						
Malanville	1152N 324E	BLM	—	—	—	Sub-base, L (1977)
Tondikiré	1152N 320E	MF	—	—	—	Monitored from Malanville
Degué Degué	1153N 318E	M		—	—	
Bodjekali	1151N 322E	M		—	—	
Burkina Faso						
Gorom Gorom	1426N 014W	ML	.	—		
Dori	1403N 002W	L	.	—		

—— regularly, ... occasionally (sondage)
(F) Sites of ecological studies

Chapter 3

Summary of events and work carried out during the project

1976 WORK PROGRAMME

Only a limited number of monitoring stations were put into operation in 1976 (Table 1). The emphasis of the work was on monitoring grasshoppers by general surveys and, more intensively, by regular light-trap catches and field assessments at selected sites, manned full or part-time. Only a skeleton cover was possible with the resources and the personnel available.

Trainees from plant protection services were given an introductory course and a period of apprenticeship and then allocated a station. Under the part-time supervision of a research or technical officer, they assumed responsibility for the routine observations, light trapping, field assessments and sampling of grasshopper populations at the study sites. These sampling sites were chosen for preference within walking distance of the bases, but particularly to provide a representative sample of the widest range of the ecological conditions characteristic of the area. In addition, a number of sampling sites (stations de sondage) were chosen in the intervals between bases and visited less frequently by itinerant technical officers.

The routine consisted of conducting field counts and sampling of grasshoppers and recording them according to species, sex, stage of development and numbers at each site, on specially designed forms. The forms, some of which were originally designed in the days of the OSRO campaign in 1975, were gradually modified in the light of experience (the final version, as used in 1978, is given in Appendix 1).

The visits to the stations were normally made on alternate days. Light-trap observatioins were made nightly (conditions permitting) for 2 h after dusk. Here again the details of each species captured were recorded.

The 1976 field operations were late in starting and only the end of the monsoon breeding season could be monitored more or less adequately. Grasshopper populations were considerably lower than in 1975, partly as a result of the campaign waged that year, but also because of natural causes, as a general decline was also noted in areas where no control measures were carried out. This situation adversely affected control experiments since within the study area, only in one locality, near Ansongo, did the grasshopper populations develop sufficiently to attack crops and warrant control. Here, a mixed population of *Oedaleus senegalensis* (Krauss), *Cryptocatantops haemorrhoidalis* Krauss, *Diabolocatantops axillaris* (Thunberg), *Acrotylus* spp., *Pyrgomorpha conica* (Oliver) and a few other less important species, invaded several hectares of ripening millet and sorghum in early October, causing some damage. With the participation of the local plant protection unit, the necessary quantity of HCH dust was provided together with a demonstration of hand-dusting and the infestation was then effectively treated by the farmers themselves. The response from the farming community was enthusiastic and augured well for the success of this simple, safe and inexpensive, yet reasonably efficient, method of control.

Despite the low density of the populations, useful faunistic, biological and ecological observations were made during the season. Not only were all the species recorded in 1975 found again but there were several new additions to the list. One of them, *Spathosternum beninense* Popov 1980, was later described as new.

As a corollary to the observations in the Gao-Gaya sector, surveys were extended deep into the desert area in the north and into the Guinea savanna to the south. This gave the delimitation of the geographical distribution of the different species and the recognition of those that are truly Sahelian. Much was also learnt about their life cycles, ecology, seasonal distribution and movements. During 1976 the southward retreat of the ITCZ was comparatively late and the *O. senegalensis* populations oviposited and died out before reaching the more southerly latitudes. Scarcely any were seen south of Niamey to Gaya where they were common at the beginning of the monsoon.

Observations were continued during the dry season on species which survive as adults and constitute about half of the total grasshopper fauna of the Sahel. With the decreasing temperatures from the beginning of the dry season, especially at night when they frequently fell below 20°C (the postulated threshold), there was a corresponding reduction of activity, but while some species like *Aiolopus simulatrix* (Walker) and *C. haemorrhoidalis* vanished almost completely, presumably being hidden most of the time in sand, in cracks in the soil and in tufts of vegetation, others remained remarkably active. For instance, in Gao throughout the dry season there was no weekly period without some specimens being caught in light traps, although only in small numbers.

1977 WORK PROGRAMME

The programme established in 1976 was followed with some amendments and additions and this was the first year when continuous observations were possible throughout the monsoon season from April to October. Monitoring by light trapping at the stations was usually combined with field counts and sampling carried out in the vicinity. The number of stations was increased to twelve (Table 1).

With four exceptions, the stations were functional throughout the season, but the traps were variable in design and possibly in the efficiency of their operators. At the Niamey base two light traps were run from the mains, using bulbs suspended over water-baths filled with diluted detergent which killed any insects that fell into the baths after they had been attracted and disorientated by the lights. At all the other stations, however, the night's sampling was done manually around the light source for 2 h after dusk. Standard 150 watt tungsten filament/mercury vapour bulbs were used at all the stations, except Say and Famale, where pressure lamps were used. The most effective sampling programmes were acomplished at Beylandé and Gao in the Gaya and Malanville regions, the stations with resident experienced personnel. At Niamey good coverage of *O. senegalensis* populations was obtained. Particularly difficult logistic problems were experienced in maintaining the stations in Burkina Faso and these remained without supervision for much of the time because of difficulties in communication.

Grasshoppers caused little damage to crops until mid-August when there were some outbreaks of *O. senegalensis* attacking millet (*Pennisetum* sp.). This was followed by an upsurge in activity of this species, culminating in an exceedingly severe infestation during which much of the millet crop in southeastern Niger was devastated (see Cheke, Fishpool and Forrest, 1980). Work concentrated on studies of this species' ecology and behaviour and most of these were carried out in Bani-Bangou, northeast of Niamey, the areas severely affected in southeastern Niger and southeast of Gao in Mali.

At the end of the season intensive studies on egg laying were carried out in a millet field near Niamey and much valuable information on egg predators, parasites and the spatial distribution of egg pods was obtained (Cheke, Fishpool and Ritchie, 1980).

1978 WORK PROGRAMME

This was the last year of field operations. From 21 December 1977 to 5 January 1978 a survey of the grasshopper fauna was made from Niamey, south through the Benin-Togo gap to the coast between Cotonou and Lomé. The round-trip itinerary followed was similiar to that in 1976–77 and much of the sampling was at the same sites. This completed the earlier studies, the results of which are published in Popov (1980a) and Fishpool and Popov (1984).

From January to March, a survey of oviposition sites of *O. senegalensis* was carried out along the transects Niamey-Menaka, Menaka-Ansongo, Gao-Niamey and Niamey-Dokimana. This provided considerable information on the distribution of laying at the end of the 1977 monsoon, when mass multiplication and displacements occurred. Some observations were also made on egg development and survival. The results of this study are published in Popov (1980b) together with the results of an analogous survey carried out at the end of the 1978 monsoon season. Radar observations were carried out from 19 September to 23 October. The main base was at the camp near Daoga, a small village south of Gargouna (Figure 1), where the principal radar studies were made. A second base, where a second radar unit was deployed for part of the time, was established at Tin Aouker, about 75 km north of Gao in Tilemsi valley. Successful observations were made on the nocturnal migratory flight of grasshoppers at the two sites and these were correlated by parallel studies with light traps and field counts (Figures 2 and 3). The observations provided direct evidence of the long-range nature of some of the flights of some Sahelian grasshopper species including *O. senegalensis*. These results were published in Riley and Reynolds (1983).

During the dry season and until early March, light-trap observations were conducted only at Gao, Watagouna and Niamey; during May and

Figure 2

A camping site during a survey of the Tilemsi Valley in Mali (September 1978)

The light trap is a tungsten filament mercury vapour 150 W bulb operated by a portable Honda 300E generator. Generally the trap was lit 2 h after sunset. During major displacements, particularly those of *Oedaleus senegalensis*, thousands of insects are attracted to the light trap.

Figure 3

Sorting and identification of light-trap captures, noting the species, the numbers of each sex and their development

June, at the beginning of the monsoon, all the stations were manned. Observations were by combined light-trap captures and field counts and sampling. The main emphasis was on *O. senegalensis*, the species of principal economic importance, but observations were also carried out on the distribution, biology and ecology of other species of grasshoppers (Figures 4 and 5) (see Fishpool, 1982).

All field operations were concluded by the end of November.

Figure 4

Concentrations of *Oedaleus senegalensis* at the end of the 1978 monsoon; it is during this period that adult concentrations become engaged in major displacements following the southward retreat of the Inter-Tropical Front

Figure 5

During displacements grasshopper invade standing crops and inflict serious damage

Oedaleus senegalensis attacking millet

Diabolocatantops axillaris attacking sorghum

Chapter 4

Results and conclusions

THE SENEGALESE GRASSHOPPER - *OEDALEUS SENEGALENSIS*

In view of the outstanding economic importance of this species in the Sahel, which far exceeds that of other grasshoppers, special attention was given to its study. The summarised information given below is based principally on the project data amplified where necessary by information from other sources.

Distribution

Oedaleus senegalensis (Figure 6) affects all the Sahelian countries including the Cape Verde Islands but also extends beyond them to parts of North Africa and southwest Asia (Batten, 1969), however, this account refers only to the Sahelian countries.

The distribution area of *O. senegalensis* is shown in Figure 7. This area comprises the dry tropical belt south of the Sahara, delimited approximately by 200 and 1000 mm mean annual isohyets. In western Africa the distribution area is relatively narrow but in eastern Africa it widens southwards to central Tanzania. The species is not found in the Sahara and is rarely found north of it.

Habitat

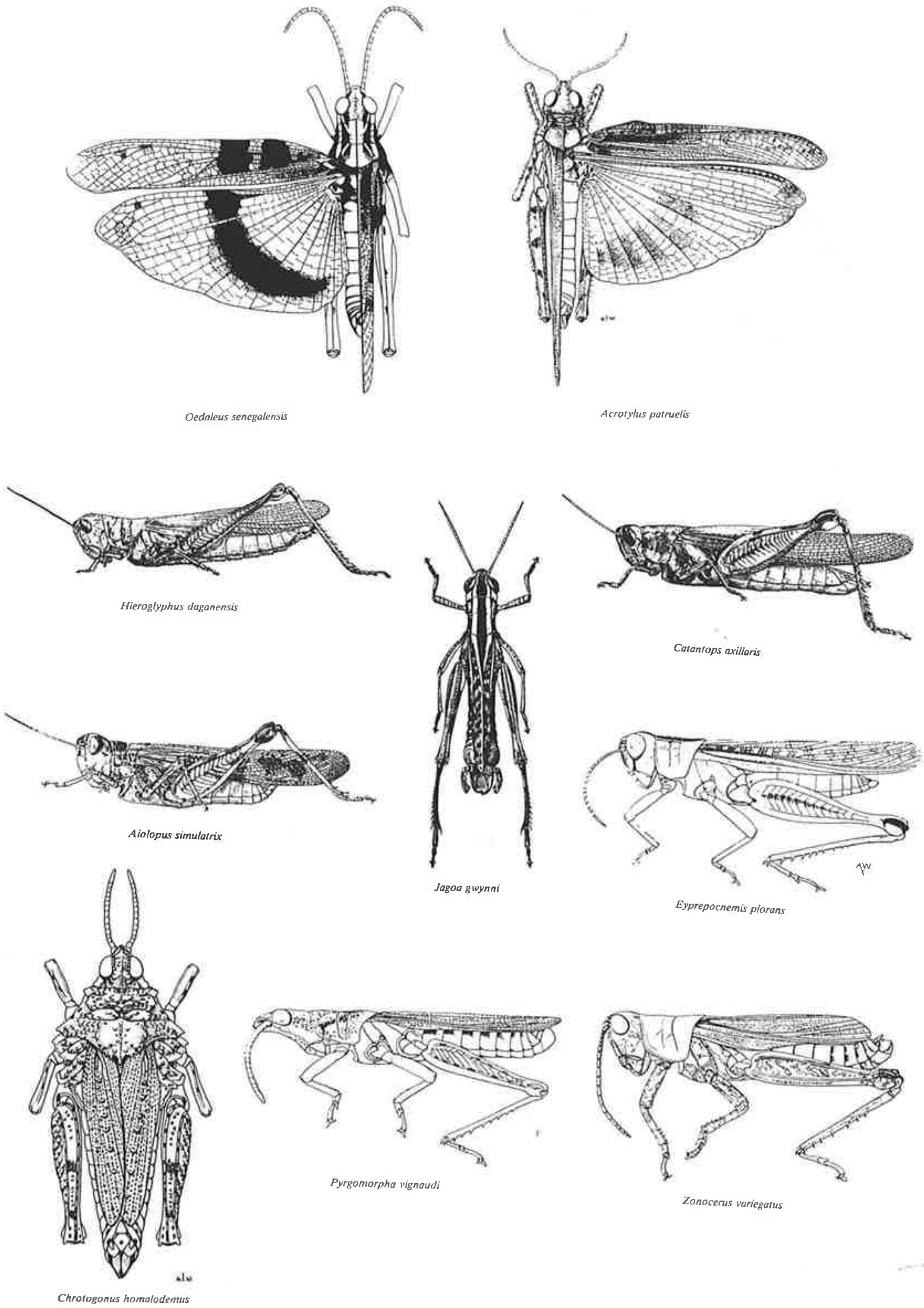
In West Africa *O. senegalensis* occurs principally in open or lightly wooded dry savanna, steppe or ephemeral prairies that develop on sandy soils and have a perennial and/or annual grass cover. The tussock grass *Aristida sieberiana* is characteristic of the perennial and *Cenchrus biflorus* of the annual communities. The annual communities, termed ephemeral prairies by Rossetti (1965), include in addition to *Cenchrus*, numerous other grasses and herbs. The prairies cover vast areas of the Sahel and develop principally on land with regular, or more often sporadic, cultivation of bulrush millet (*Pennisetum americanum*). Millet is a favourite food/shelter plant (Figure 8) and *O. senegalensis* is one of the few grasshopper species which readily accepts these cultivations as its natural habitat. It is possible that the increased importance of this pest in recent years is a result of the expansion of agriculture in the Sahel, see also Batten (1969) and Cheke, Fishpool and Forrest (1980). The grasshopper is predominantly graminivorous but not markedly selective and feeds readily on whatever grass species is available (Boys, 1978).

Phase and pre-reproductive behaviour

The species manifests notable phase attributes but at a lower level of gregariousness than in true locusts. At higher densities, nymphs (hoppers) may aggregate in groups when roosting or basking and may occasionally form marching bands. The bands tend to be small; the largest observed by G. B. Popov was composed of third to fifth-instar hoppers, with a front of

Figure 6

Some common Sahelian locust and grasshopper species



(After Dirsh, 1965 and COPR, 1982.)

Figure 6 continued

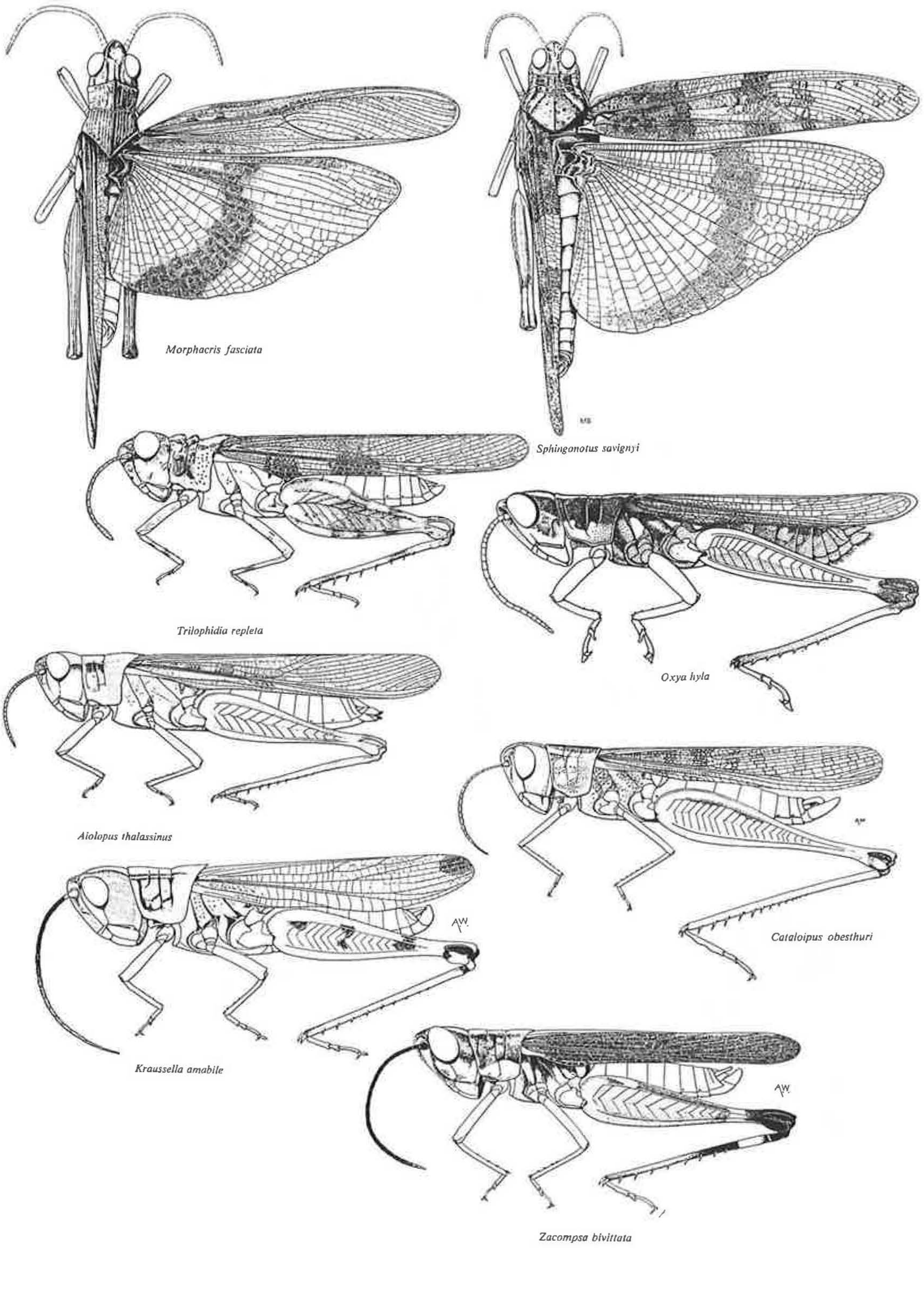
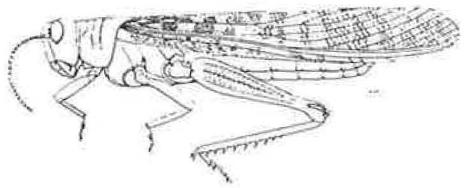
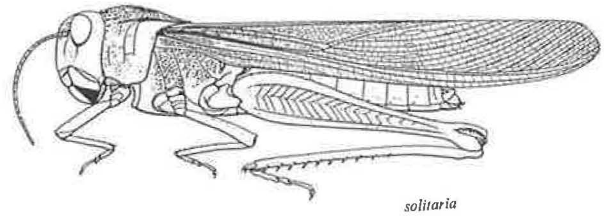


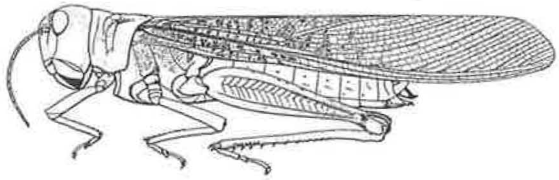
Figure 6 continued



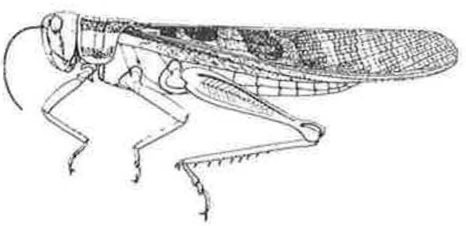
Schistocerca gregaria



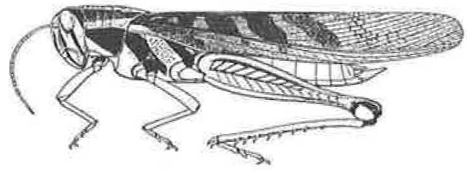
solitaria



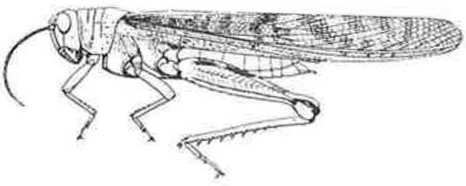
Locusta migratoria



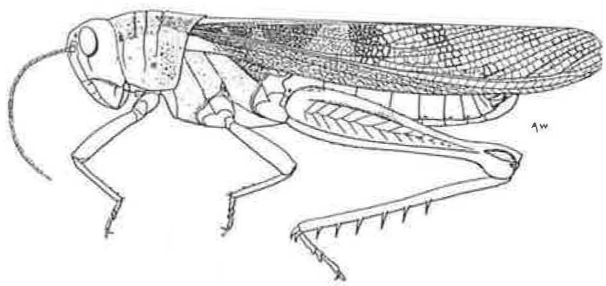
Nomadacris septemfasciata



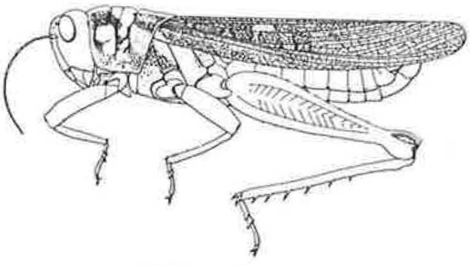
Ornithacris cyanea



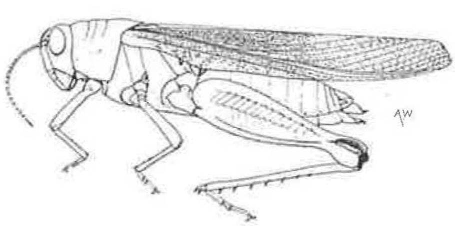
Anacridium melanorhodon



Acanthacris ruficornis



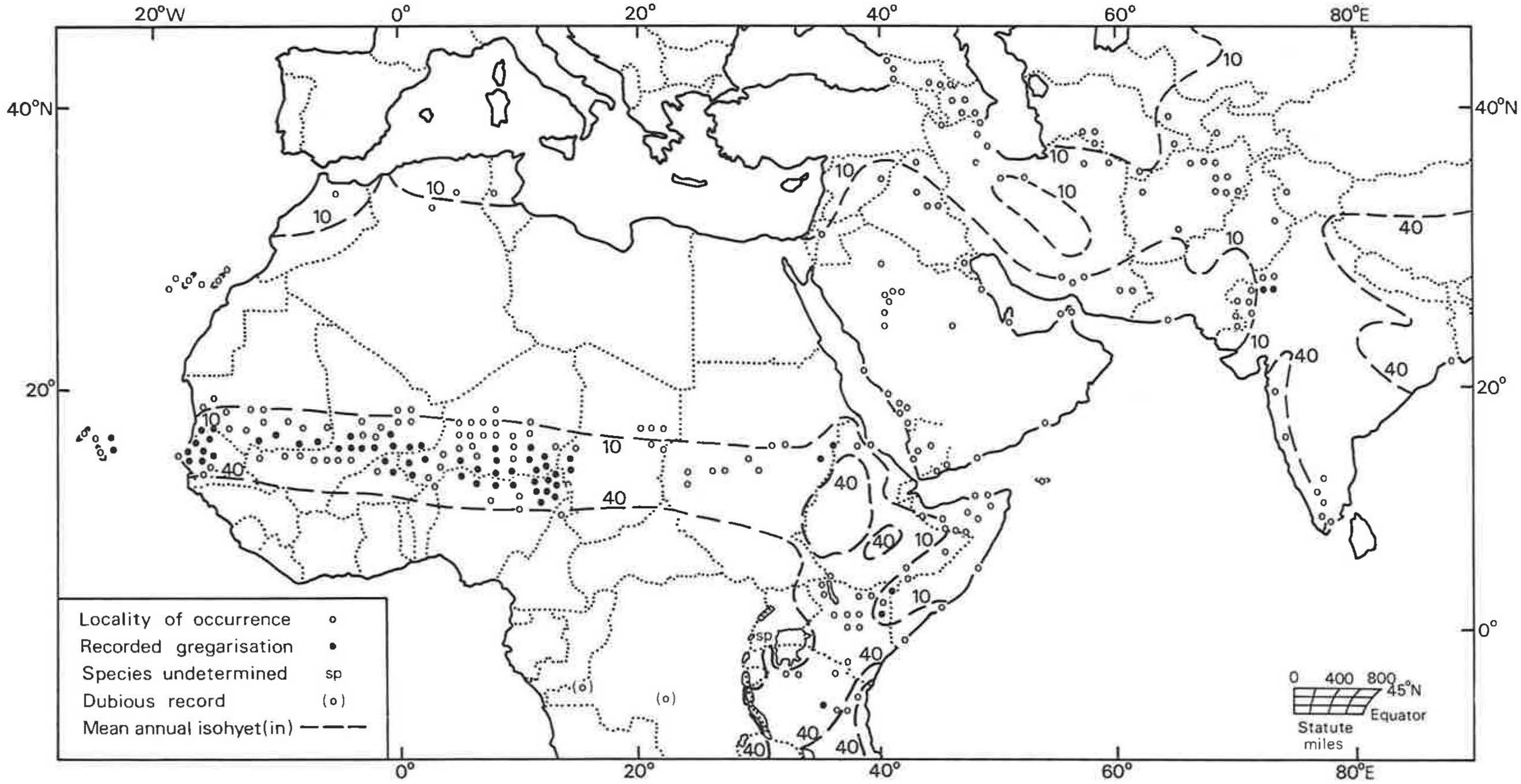
Kraussaria angulifera



Acridoderes strenuus

Figure 7

Distribution area of *Oedaleus senegalensis*



(After Batten, 1969, with additional information from later sources.)

Figure 8

A typical example of the habitat of *Oedaleus senegalensis* in the Sahelian zone; a sandy terrain extensively planted with *Pennisetum* millet (dry remains in the foreground), while the fallows have perennial and annual grasses and forbs, notably *Aristida sieberiana, Cenchrus biflorus* and *Eragrostis* sp., often with scattered trees and shrubs such as *Combretum* spp., *Acacia* spp. and *Guiera senegalensis*

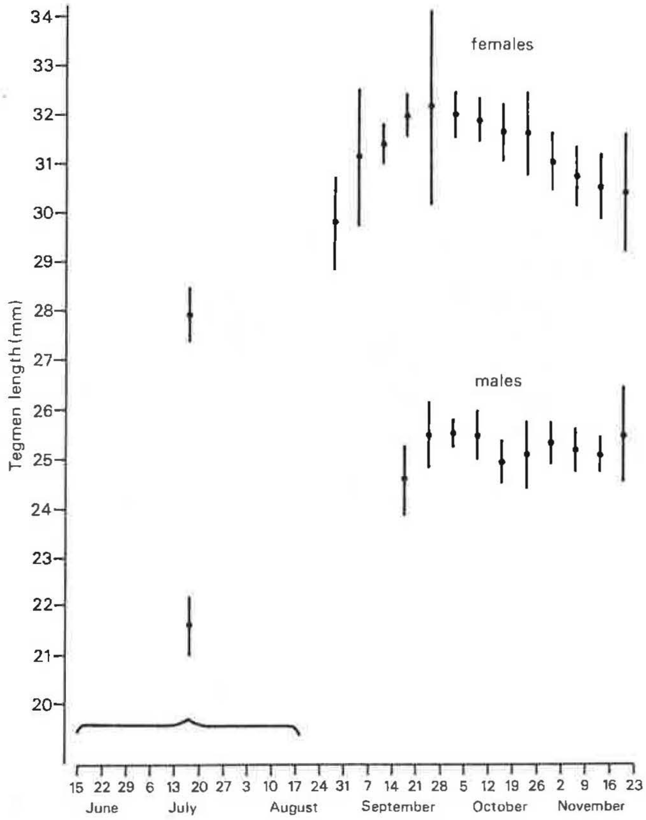
50 m and which extended for 200 m. (Much larger bands, extending for several kilometres have been recorded during the 1984-1985 upsurge (N. D. Jago, personal communication).) The density of the marching hoppers was low, about of 2–5 m^2, but there was a marked unidirectional orientation and a distinct front to the band. Such gregarious behaviour is generally asociated with colour changes in the majority of hoppers, from a mottled paler greenish, stramineous or brownish in the solitarious to a contrasting pattern of fawn and dark blackish-brown in the gregarious individuals. Gregarised adults form loose swarms which may fly by day (Popov, 1976) but more frequently fly by night, like the low density solitarious individuals (Riley and Reynolds, 1983). A downwind orientation is usual at both times but while the day-flying grasshoppers tend to adopt a rolling flight close to the ground (G. B. Popov, personal observation), at night they commonly rise to 200–400 m and even 600–700 m above the ground and may travel distances of over 100 km and perhaps as much as 450–500 km on a particular night's flight (Riley and Reynolds, 1983).

Day and night observations and sampling coupled with dissection and counts of endocrine rings in tibiae, as a means of assessing age, show that for the first 2 days following the final moult adults fly very little, if at all. They begin to appear in light trap catches from day 3 and then in numbers from day 6 (Cheke, Fishpool and Forrest, 1980; Jago, 1983). Flight activity is then at its height until vitellogenesis and for some time after that, but with advancing ovarian development flight declines and gravid females are practically never found in light traps (Fishpool, 1982; Jago, 1983; G. B. Popov, personal observation). The presence in light-trap catches of females showing evidence of previous laying, however, indicates that flying is once again resumed between ovipositions. This seems to be a more plausible interpretation of light-trap records than that of Jago (1983) who postulated that light traps are 'selective' and that gravid females are, in some unexplained manner, 'not attracted' to light. Decline of flight activity at the time of reproduction, notably shortly before oviposition, may well be a general phenomenon in the Acridoidea; it is certainly true even of such active fliers as *Schistocerca gregaria* in its gregarious phase (Popov, 1958).

Investigations on morphometric phase changes in *O. senegalensis* by Ritchie (1981) were inconclusive. Recent field studies in Nigeria (O. S. Bindra, unpublished), however, show that contemporaneous populations from the same area and presumed common parentage may differ morphometrically similar to the phase changes in locusts. Alternatively, Cheke,

Figure 9

Variation in tegmen length of male and female *Oedaleus senegalensis* during the 1977 season; samples all taken at Niamey, vertical lines are 95% confidence limits



From Cheke, Fishpool and Forrest (1980)

Fishpool and Forrest (1980) found that there was a parallel increase in the tegminal lengths of both sexes of *O. senegalensis* in day and night samples taken at Niamey from July to September (Figure 9). Adult females caught in October and November showed a decrease but the males' tegmen lengths remained at the peak level. There were similar trends for the measurements of samples taken elsewhere during 1977. Furthermore, the femur lengths varied with the tegmen lengths, the ratio between the two did not alter markedly, although extreme values of 1.4 and 1.9 were recorded. No significant differences were found between samples taken by day and those attracted to lights at night at the same localities and dates. It is evident that critical studies under controlled conditions are needed to elucidate the morphometric phase changes in *O. senegalensis*.

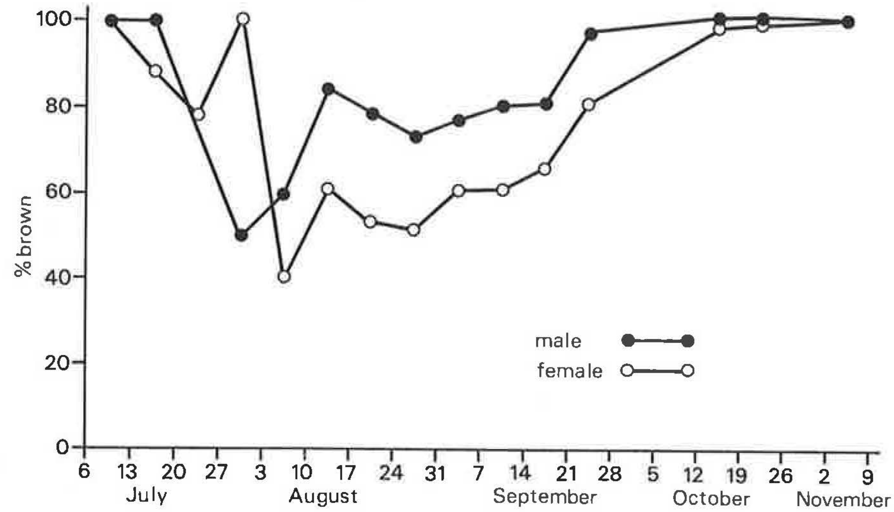
Cheke, Fishpool and Forrest (1980) also recorded seasonal changes in the proportion of adults with some green pigmentation in relation to fully brown ones. These changes are considered to be due to seasonal changes in the vegetation rather than to any phase effects. Thus, during the 1977 season at both Niamey and Watagouna, the brown forms predominated at the start of the season; later than substantial numbers of green forms appeared but then became progressively rarer as the season developed (Table 2 and Figure 10).

Reproduction

The onset of reproductive behaviour is described by Cheke, Fishpool and Forrest (1980), who record that copulation was usually preceded by display involving the flicking of hind legs kept in a closed position. Flicking was more pronounced in males and at the time of pairing, though it also occasionally occurred at other times. Following display the male mounted

Figure 10

The percentage of brown morphs in samples of *Oedaleus senegalensis* taken at Watagouma during 1977



From Cheke, Fishpool and Forrest (1980)

Table 2

Numbers and colour of *Oedaleus senegalensis* caught at Niamey in 1977

	No. green		No. brown		Total		% brown	
Date	Male	Female	Male	Female	Male	Female	Male	Female
1-7 June	0	0	1	0	1	0	100	-
8-14 June	0	0	2	0	2	0	100	-
15-21 June	0	0	1	1	1	1	100	100
22-28 June	1	3	3	2	3	5	75	40
29-5 July	0	0	0	2	0	2	-	100
6-13 July	0	0	2	0	2	0	100	-
14-21 July	0	2	2	4	2	6	100	66.6
22-28 July	0	0	2	2	2	2	100	100
29-4 August	0	0	0	0	0	0	-	-
5-11 August	1	0	1	0	2	0	50	-
12-18 August	0	0	0	0	0	0	-	-
19-25 August	0	0	0	0	0	0	-	-
26-1 September	0	0	0	0	0	0	-	-
2-7 September	0	0	0	0	0	0	-	-
8-14 September	2	12	30	23	32	35	93.7	55.7
15-21 September	0	14	19	30	19	44	100	68.2
22-27 September	0	2	14	3	14	5	100	66.6
28-4 October	54	108	4413	2198	4467	2306	98.8	95.3
5-11 October	97	105	7922	5819	8019	5924	98.8	98.2
12-17 October	22	139	14,282	10,752	14,304	10,891	99.8	98.7
18-24 October	0	0	21	22	21	22	100	100
25-31 October	0	0	9	5	9	5	100	100
1-7 November	0	0	3	2	3	2	100	100

the female and copulation could then be maintained with the male positioned on top of the female, or with the sexes pointing in opposite directions (Bhatia and Ahluwalia, 1967; W.W. Page, unpublished).

Oviposition by individual females has been observed in the daytime on a number of occasions and it appears that much of the laying occurs at night (Popov, 1980b).In Sahelian habitats oviposition is predominantly associated with open or bare, usually well-drained, patches of sandy or sandy/silty soil. Egg laying also frequently occurs in millet fields and the associated fallows in various stages of regeneration.

Egg pods are usually deposited at the base of tufts of vegetation or in open ground. Their distribution is patchy and frequently grouped. The density of egg pods in groups during years of mass multiplication can reach

12-15 m^2 (Popov, 1980b). Grouping can be due partly to the heterogeneity of ecological conditions, such as micro-relief, soil, pattern of vegetation, but at times can be attributed to the inter-attraction between females at the time of laying (Popov, 1980b). Such grouping of egg pods further concentrates hoppers following emergence and may lead to gregarisation and formation of bands.

Hopper and adult concentrations can also result from the differential drying out of the vegetation and amongst adults in particular, during displacement, when feeding or sheltering in localised areas of green vegetation or crops. Grass fires are also an important factor in concentrating adults. Further concentration of adults on migration occur in areas of convergent air flow (Riley and Reynolds, 1983; see also page 42).

Life cycle

Practically all the records and studies of the life cycle of *O. senegalensis* come from the dry tropical part of its distribution area. This has a monsoonal rainfall regime characterised by a long dry season of about seven months when practically no rain falls. During the remaining five months, the monsoon rains are unpredictable in their timing, amount and distribution. The species has adapted to the vagaries of such a climate by its strategy of dry season survival in the egg stage in a state of obligate diapause or facultative quiescence.

EGG DEVELOPMENT

The principal sources of information are from India (Venkatesh, Ahluwalia and Harjai, 1972), Cape Verde Islands (Saraiva, 1962) and the Sahelian countries (studies by the Groupement d'Etudes et de Recherches pour le Développement de l'Agronomie Tropicale/Le Programme de Recherches Interdisciplinaire Francais sur les Acridiens du Sahel (GERDAT/PRIFAS) team: Launois (1978) and Lecoq (1978) and the COPR/OCLALAV project: Cheke, Fishpool and Forrest (1980); Fishpool (1982); Fishpool and Cheke (1983) and Popov (1980b)). All these studies agree that egg development in *O. senegalensis* is complex and that the eggs are very resistant to dry conditions.

In the Sahel, eggs laid during the earlier part of the monsoon until about mid-August develop directly without interruption; eclosion under ambient conditions in Niamey occurred 12-15 days after laying. If available, laying takes place preferentially in moist soil which ensures direct egg development. When laid in dry soil, however, eggs undergo a state of initial development but then become quiescent. Development is resumed if the eggs are moistened and hatching occurs in 9-10 days or less.

A changeover from non-diapausing to diapausing eggs occurs during late August and September and thereafter the eggs do not develop even in moist sand. This is evidently a result of a physiological change that occurs in the female grasshopper and is probably controlled photo-periodically. It appears to be independent of soil moisture, since it is not accompanied by a change in oviposition behaviour and laying continues to take place in wet, rather than dry sand.

Both diapausing and quiescent eggs are highly resistant to desiccation. While most of the eggs at the beginning of the dry season are in diapause, in the event of an early end to the rains, some of the eggs laid before the onset of diapause would have remained unhatched in a state of quiescence. Only quiescent eggs are likely to respond to the dry season rains and, given the poor chances of nymphal survival during the cold dry season, selective pressure would favour diapause, assuming that diapause and quiescence have an equal survival potential.

What terminates diapause is unknown, but diapausing eggs from the previous year, watered artificially from January to March, hatched at the end of March (McAleer, 1977). Under natural conditions, early monsoon rains on 8–9 March 1978 in southwest Niger led to a generalised hatching after 8–13 days in areas which received over 25 mm rain. In areas of lighter rain only partial hatching occurred and many eggs remained quiescent. The remaining unhatched eggs completed their development and hatched after the subsequent rains.

From these observations the following scheme of egg development in *O. senegalensis* can be postulated for the Sahelian zone. Given a good start and an adequate follow-up to the monsoon rains (such as in 1978) when the amount of water in the soil is not a limiting factor, most of the overwintering eggs will hatch at the beginning of the monsoon, with a hatching peak 8–13 days after the first major fall of rain. The amount of early rains on parched soil at the end of the dry season is important. The threshold is not known but it appears that a fall of less than 25 mm will result in only partial hatching and some of the eggs will remain quiescent or undergo only partial development and hatch with later rains. It is likely that the threshold varies somewhat with temperature and soil conditions but its existence ensures emergence of hoppers in conditions of adequate food supply. Given adequate early rains, however, there is no evidence from field observations that, irrespective of soil moisture, a substantial proportion of eggs will undergo a protracted hatching sequence lasting through to the end of the monsoon or until the following season(s).

It is known, however, from literature (Saraiva, 1962; Venkatesh, Ahluwalia and Harjai, 1972; Cheke, Fishpool and Forrest, 1980; Popov, 1980b) that eggs can remain viable for one year or longer (5 years according to Saraiva). Under laboratory conditions some egg pods can have complex extended hatching sequences, with emergence occurring sporadically over a period of 44.5 months from the first wetting (Cheke, Fishpool and Forrest, 1980; Fishpool and Cheke, 1983).

Such a mechanism can have a potentially important role in the species' survival, by minimising the effect of catastrophies like out of season rain or prolonged drought. Theoretically it could also contribute to the genesis of outbreaks, notably through an accumulation of quiescent and diapausing eggs during dry periods and their simultaneous eclosion with the advent of abundant widespread rainfall.

HOPPER DEVELOPMENT

In the Sahel hopper development is completed in 17–20 days and the interval from hatching until the first laying is about 35 days. Depending on the duration of the monsoon, one, two or three generations are produced. In the event of an early and prolonged monsoon (as in 1978) a fourth generation is possible but is probably exceptional (Fishpool, 1982).

Natural mortality

The best known causes of natural mortality are those that occur during egg development (Greathead, 1963; Cheke, Fishpool and Ritchie, 1980; Popov 1980b). Eggs are attacked by larvae of the bombyliid flies *Xeramoeba oophaga* (Zakhvatkin) and *Systoechus* spp. (Figure 11) and various Coleoptera, *Mylabris* sp., a histerid, *Contipus digitatus* Mars but chiefly by tenebrionid larvae. Several of the latter bred to the adult stage, proved to belong to *Pimelia senegalensis* Ol. (Figure 12), a common and locally abundant polyphagous scavenger, but probably some other tenebrionid species were also involved.

A high level of mortality was found in eggs sampled from November 1977 to March 1978 (Popov, 1980b). Of the 1340 egg pods sampled only

Figure 11

An egg pod of *Oedaleus senegalensis* attacked by the larva of a bombyliid fly, probably *Systoechus* sp.

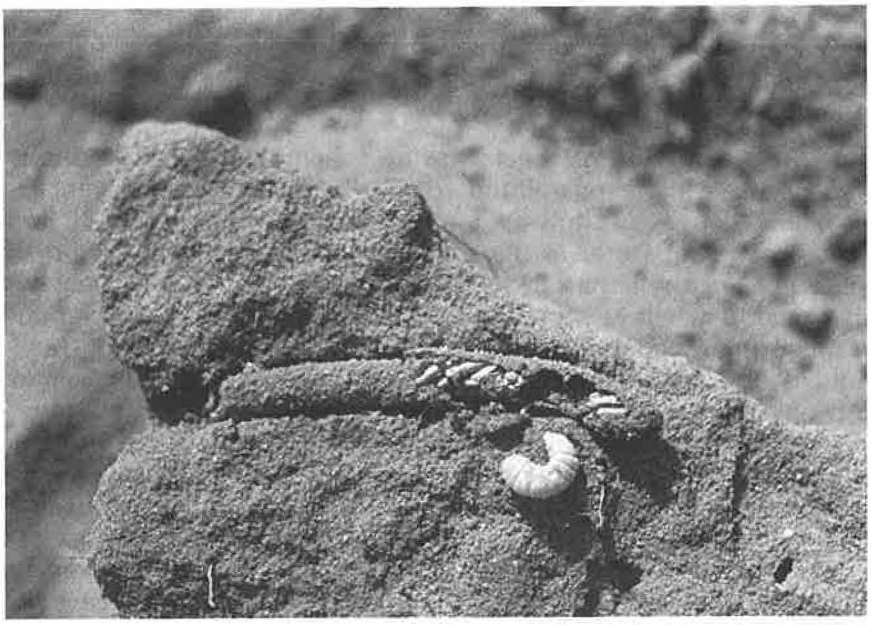
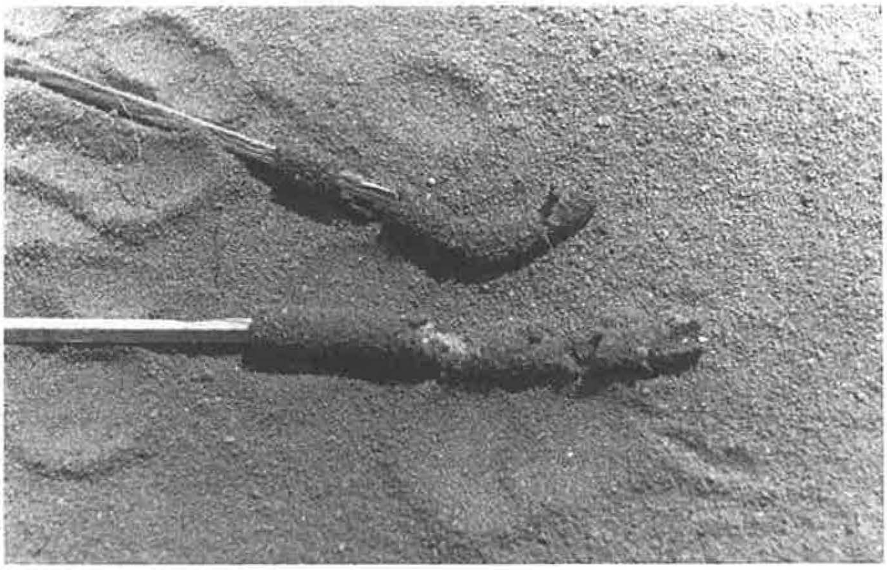


Figure 12

Egg pods of *Oedalus senegalensis* completely destroyed, probably by tenebrionid larvae, such as *Pimelia senegalensis*



42% were intact, the remaining 58% were destroyed by natural enemies. The destruction of pods in all cases was effectively total, since even partial destruction led to exposure and eventually to desiccation and decay of the remaining eggs (Table 3). Mortality due to other causes, such as sterility or climatic factors (flooding and desiccation), was low.

Both nymphs and adults are attacked by various arthropods such as scorpions and solifugids and predaceous insects like asilid flies, sphecid wasps, ants, mantids and ant lions, and also by many species of lizards, snakes and birds. Cheke, Fishpool and Forrest (1980) list 15 species of birds recorded in Niger, including bee-eaters, cattle egrets, storks, rollers, small hawks and kites. These records, however, do not provide estimates of the extent of mortality.

Table 3

Record of egg pods sampled during November 1977 - March 1978 in Gao, Niamey and Tamou areas

Sector	Area sampled (m^2)	Density /10 m^2	Egg pod records						Number of samples		
			Total	Intact	S	X	M	T	Total	+	−
Niamey - Quallam 98 km	228	16.4	373 (100)	178 (48)	64 (17)		12 (3)	119 (32)	12	9	3
Quallam - Mali border 100 km	227	1.7	39 (100)	14 (36)	6 (15)			19 (49)	14	7	7
Mali border - Menaka 97 km	107	0.5	5 (100)	2 (40)				3 (60)	14	3	11
Menaka - Ansongo 216 km	40	0	0						7	0	7
Gao - border 225 km	231	1.8	42 (100)	24 (57)		6 (15)		12 (28)	19	6	13
Border - Tillabery 122 km	130	16.3	212 (100)	101 (48)	5 (2)	42 (20)	7 (3)	57 (27)	10	5	5
Tillabery - Niamey 110 km	60	6.5	39 (100)	9 (23)	6 (15)	3 (7)		21 (55)	8	2	6
Niamey - Tamou 100 km	279	9.1	253 (100)	114 (45)	9 (3.5)		9 (3.5)	121 (48)	11	9	2
Guesselbodi	198	19.0	377 (100)	119 (30)	60 (15)		12 (3)	186 (47)	9	8	1
Total	1500	8.9	1340 (100)	561 (42)	150 (11)	51 (4)	40 (3)	538 (40)	104		

from Popov (1980b)

\+ Sample with egg pods — Sample without egg pods
S = *Systoechus*, X = *Xeramoeba*, M = *Mylabris*, T = Tenebrionidae

Figure 13

Migrating adults suffering from severe dehydration are strongly attracted to water where large numbers drown, or become trapped in the mud and perish

Fledgling adults often become impaled and entangled in the spiky seeds of kram-kram (*Cenchrus biflorus*) and many perish, while others have their flight ability impaired. The end-of-season adults on migration apparently suffer from severe dehydration as they show an almost suicidal attraction to water and wet areas of mud along rivers, wadis and seasonal marshes encountered on their course. Here they aggregate in vast numbers and many are drowned or bogged down in mud and perish (Figure 13). Other adults may, on migration, be carried out to sea and drowned in large numbers as happened, for instance, off the coast of Mauritania in October 1982.

Such losses have not been quantified and their effect on the population dynamics of *O. senegalensis* is unknown. Probably their impact is less than that due to the synoptic and climatic effects of the weather, notably wind and rainfall, for it is essentially these elements that determine the displacement and distribution of grasshopper populations and the success or failure of their survival, breeding and multiplication.

Seasonal breeding and migrations

On the basis of information from various sources, Launois (1978) elaborated a model to express the population dynamics of *O. senegalensis* in western Africa.

Similarly to the Migratory Locust in Madagascar (Launois, 1974), populations of *O. senegalensis* are considered to seek optimal humidity and temperature conditions and this involves them in spatio-temporal displacements across their distribution area. Thus, for the central part of Niger (where part of the GERDAT/PRIFAS team's studies were conducted) the spatio-temporal evolution of the populations in an average year will follow the trend presented schematically in Figure 14.

The model divides the total distribution zone of the species across the Sahel into three belts or areas:

an area of initial multiplication, AMI, in the south;
a transitory area of multiplication, ATM, in the centre, and
a northern area of multiplication, ASM, (Figure 15).

The model further postulates three annual generations, G1, G2 and G3. The parents of the first rains generation G1 are the adults of G3, the last rains generation of the preceding season. These migrated from their source (ASM) in the northern part of the distribution area, some 500 km southwards in the wake of the retreating Inter-Tropical Convergence Zone (ITCZ), depositing their eggs en route but principally in the southern area (AMI).

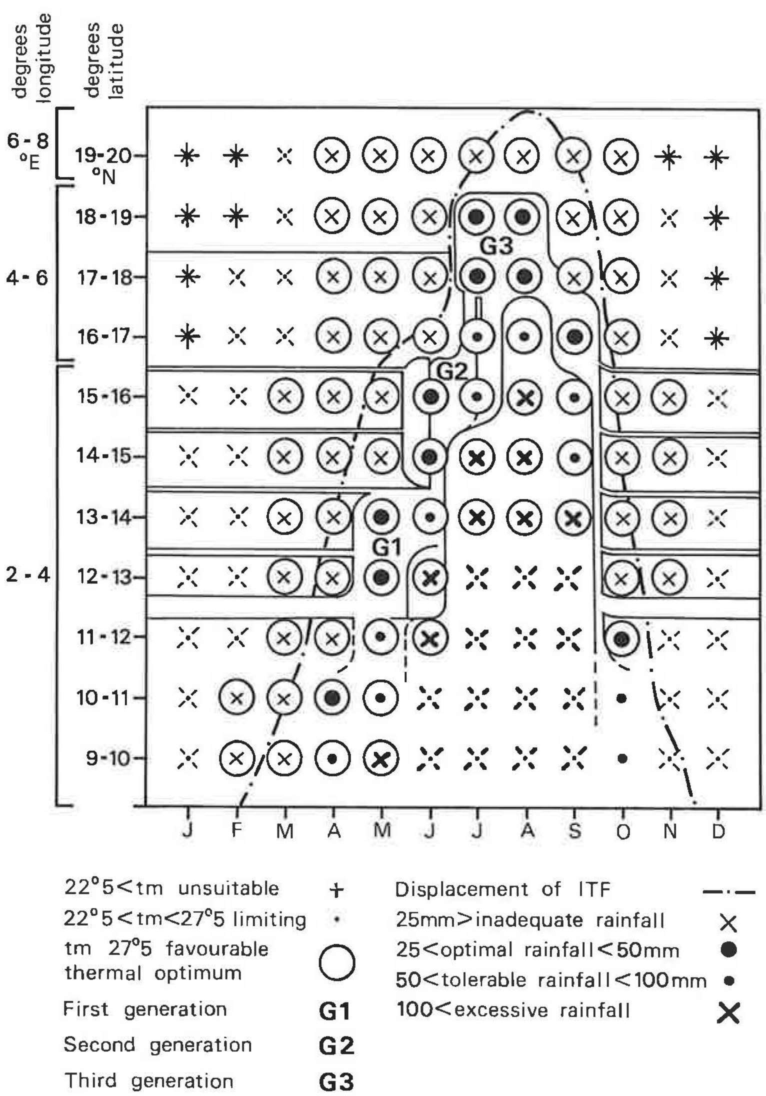
These eggs survive the dry season largely in a state of obligatory diapause lasting 5-6 months and hatch with the first rains. The resulting adults of G1 leave the AMI zone, which becomes progressively humid, and emigrate, following the advancing ITCZ to reach the intermediate ATM zone at roughly the time of the first rains. There they breed to produce the G2 generation which becomes mixed with the local G1. The resulting adult progeny of both then advances further north into ASM where the third generation, G3, is formed. The adults of G3 appear towards the end of the rains when ASM begins to dry out and they soon begin to leave it, moving southwards in the wake of the retreating ITCZ.

Laying occurs en route, with little in ASM, somewhat more in ATM but most in AMI. By now most of the eggs are in diapause in readiness for the advancing dry season.

As Launois (1978) points out, there are considerable variations from year to year but the model allows for these. The principal factor, or complex of inter-dependent factors, is created by the variation in the dynamics of the atmospheric circulation which determines the chronology, duration, speed, pattern and depth of the advances and retreats of the ITCZ and the

Figure 14

Schematic representation of spatio-temporal evolution of *Oedaleus senegalensis* populations in Central Niger in relation to the environment in an average year



amount and distribution of the concomitant rainfall. Superimposed upon this are the variations in the grasshopper populations; their phenology, numbers and distribution which determine the nature and level of the responses by grasshoppers to particular conditions and opportunities for breeding and displacement. Given this complex relationship and the vagaries of the Sahelian weather conditions, the situation varies from year to year to the extent that no two years are exactly the same.

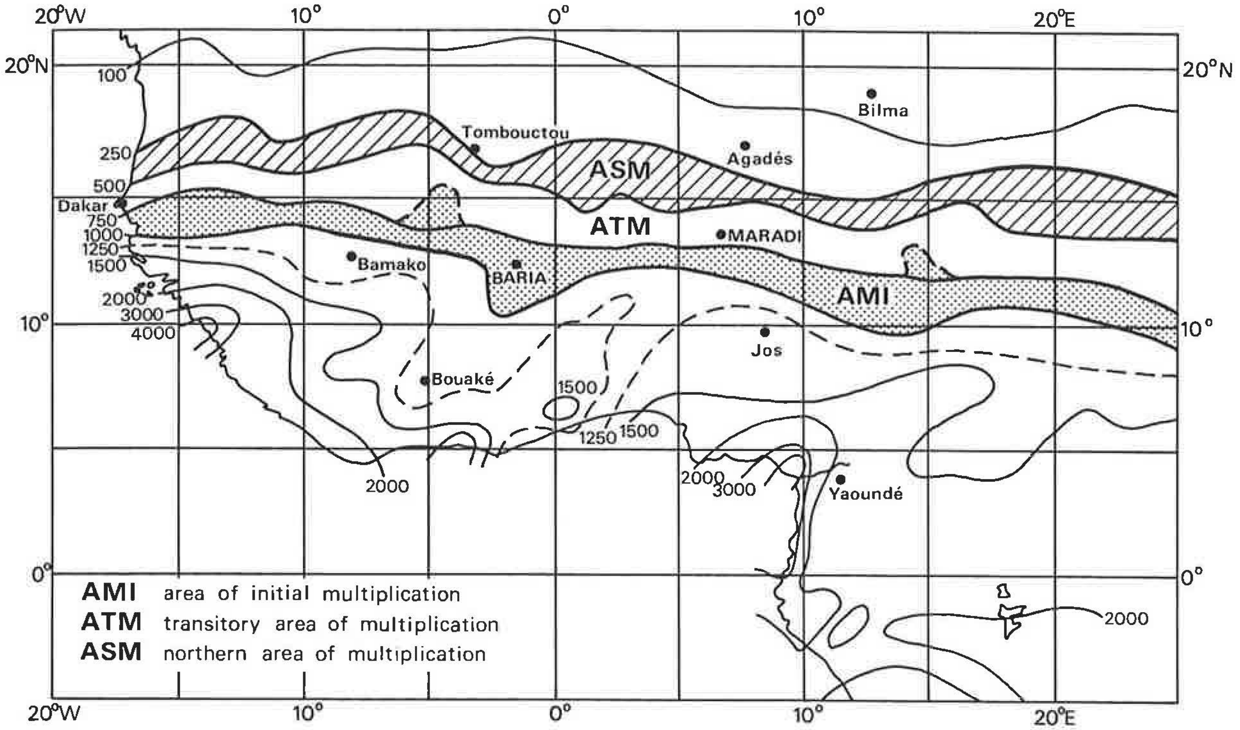
Nevertheless, in general terms the model fits reasonably well what is known and what has been observed of the population dynamics of *O. senegalensis*. The southward migration of the end-of-monsoon adult populations following the retreat of ITCZ has been recorded and documented on several occasions. The outstanding examples are:

October 1974, when Popov (1976) followed the gradual advance of adult concentrations and swarms from Kamadougou on the Niger/Nigeria border through northeast Nigeria to Maiduguri and Bama over a distance of some 300 km;

1977, the observations cited in Cheke, Fishpool and Forrest (1980) and unpublished reports, provided evidence of a large-scale southward movement of swarms and concentrations of *O. senegalensis* at the

Figure 15

Limits of breeding areas of *Oedaleus senegalensis* in western Africa



end of the monsoon across southern Niger, many reaching Nigeria; observations of Lecoq (1978) in Saria, Burkina Faso; the 1978 observations by the COPR radar unit which recorded a downwind orientated long-range flight of a concentration of grasshoppers (predominantly *O. senegalensis*) over a distance of 100 km (Riley and Reynolds, 1983).

Alternatively, evidence for the advance migration of populations from south to north at the beginning of the monsoon season is less conclusive. There are some cogent reasons why this is so: populations at the beginning of the reproductive cycle are generally smaller and less obvious than at the end of it; early rains are sporadic and patchy leading to correspondingly sporadic and prolonged emergence and fledging of the G1 populations, consequently their northward advance is similarly staggered and thus less obvious.

Nevertheless, there are examples of early season advance migrations, the most impressive of which is that of 1975. The 1974 populations were large and dense, their 1975 G1 progeny was also large and in places, notably in southern Gourma, had aggregated into dense concentrations and swarmlets. In June these were observed moving northeastwards with the prevailing monsoon winds. In one area, in the vicinity of Hombori, they advanced some 50 km into an area which had only just had its first rain and hence the adults must have moved over at least that distance (G. B. Popov and S. Coulibaly, personal observations).

The seasonal migrations in association with the ITCZ are in no doubt; whether monitoring of this mobile pest and its unstable environment is done with the help of the model or without it, close surveillance is an essential prerequisite to the success of any preventive control strategy.

In addition to rainfall, temperature and ecological conditions which determine the success and the rate of survival and multiplication, the synoptic weather situation, notably wind systems, that govern the displacement of adult populations needs to be monitored. The importance of wind systems is best illustrated during the retreat of the ITCZ which is probably the most critical period in the population dynamics of *O. senegalensis*.

The following factors are particularly relevant:

- the fact that egg diapause is determined by the female grasshopper and is photoperiodically controlled;
- all eggs laid from about mid-August are in diapause and, in the event of adequate rainfall, final fledging is likely to be complete by late September;
- in such a situation the peak of the final end-of-monsoon laying will take place approximately from the last week of September until the end of October, and thereafter the adult populations will decline rapidly at the end of their life cycle;
- given the fact that the major flight is by teneral adults from about days 4-5, after fledging (p.19), the peak flight period and migration will fall principally during the earlier part of adult life, i.e. on average from about mid-September through October. Theoretically, however, an occurrence of late rains, preceded by dry periods could lead to an accumulation of quiescent eggs, protracted hopper emergence and development and prolonged fledging. Allowing for such variations in chronology of end of season fledging, the displacement of adults and of the distribution of laying is otherwise determined by the timing and the speed of the retreat of the ITCZ.

A successful monsoon breeding and build-up of grasshopper populations, an early retreat of the ITCZ, for instance such as that in 1983 (Figure 16), will enable a 'normal' generalised southward spread of flying adults from ASM, throughout ATM to AMI as postulated in the model. There would be a little end-of-monsoon oviposition in ASM, somewhat more in ATM and the bulk of it in AMI (as in Figure 17). The sampling area for the survey of oviposition is shown in Figure 18. Examples of this situation were 1974, 1977 and 1982. The 1977 light-trap records at the project stations demonstrate the chronological sequence of southward progression of the adult population in the wake of the retreating ITCZ (Figure 19).

On the other hand, a late retreat, coupled with prolonged stagnation of the ITCZ in the latitudes of ATM, as for instance in 1976, is likely to lead to an accumulation of the G3 adults. The majority will lay and die with few surviving to reach AMI by the time the ITCZ resumes its southward retreat. While such an occurrence would at the time protect the crops in AMI against the G3 adults and their G1 descendants, it could lead to dangerous developments in ATM. Both G1 and G2 will be produced in ATM with the likelihood of a concentration and gregarisation of the progeny, thus later aggravating the situation in ASM and eventually in AMI during G3. The 1976-77 seasons' sequence is an outstanding example.

Prolonged stagnation and oscillations of the ITCZ in northern latitudes in ASM as in 1978 may result in scattering, mortality of adults and laying under adverse environmental conditions in ASM, ultimately leading to a decline in grasshopper numbers.

Economic importance

There are few accurate assessments of damage by *O. senegalensis* but in sub-Saharan countries, where pre-harvest losses through birds, rodents, insects and plant disease are estimated at some 30%*, this species is generally regarded as the most serious pest of millet, the principal subsistence crop. Damage to crops is usually most serious in the seedling stage, often necessitating multiple resowing (Popov, 1976; Risbec and Mallamaire, 1949; McAleer, 1977; OCLALAV, 1973-1983). A second serious period of damage occurs when the cereals are in the milky stage of grain formation,

*1983 report of the FAO Committee on World Food Security.

Figure 16

Retreat of the ITCZ at the end of the 1983 monsoon

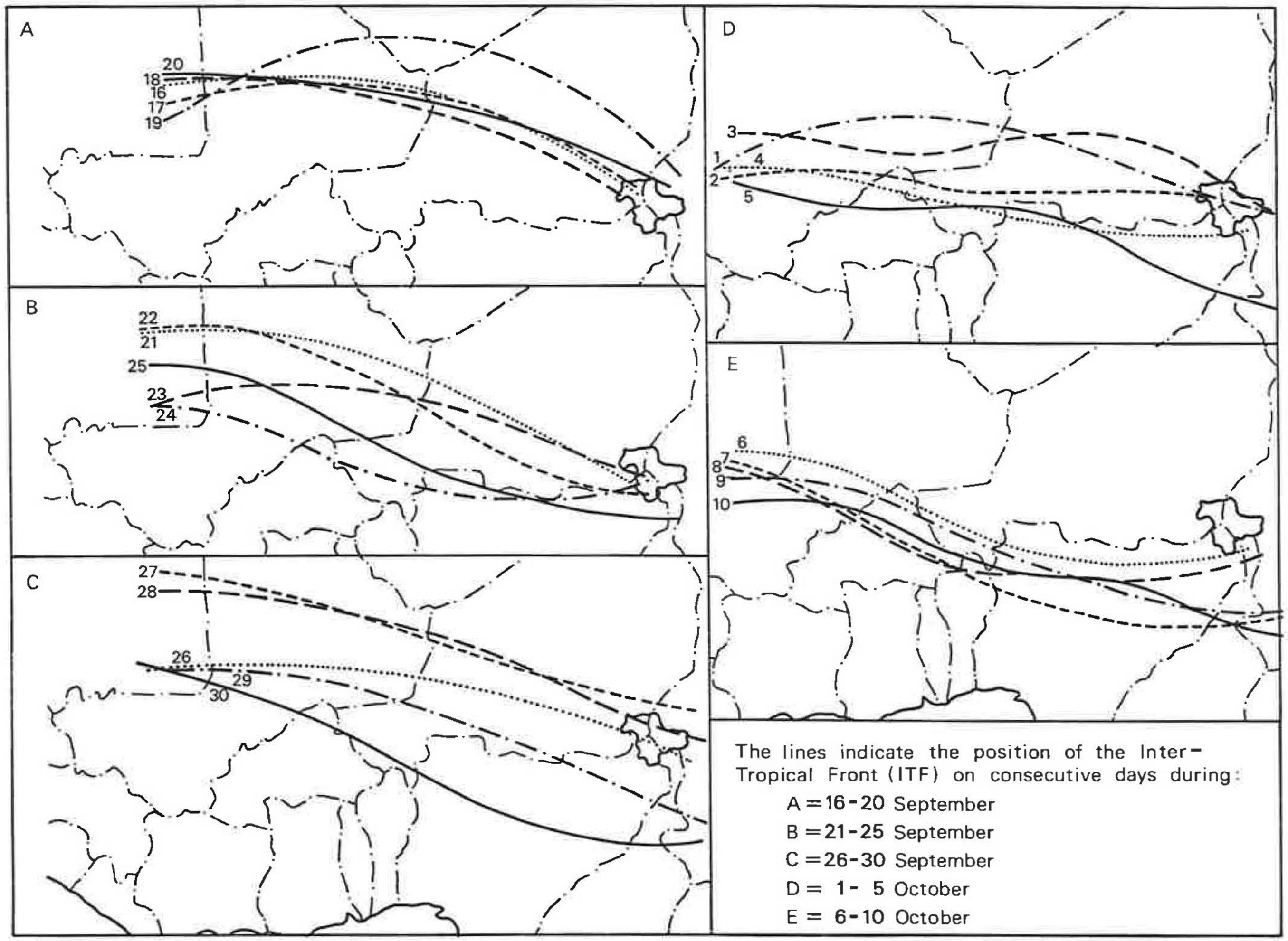
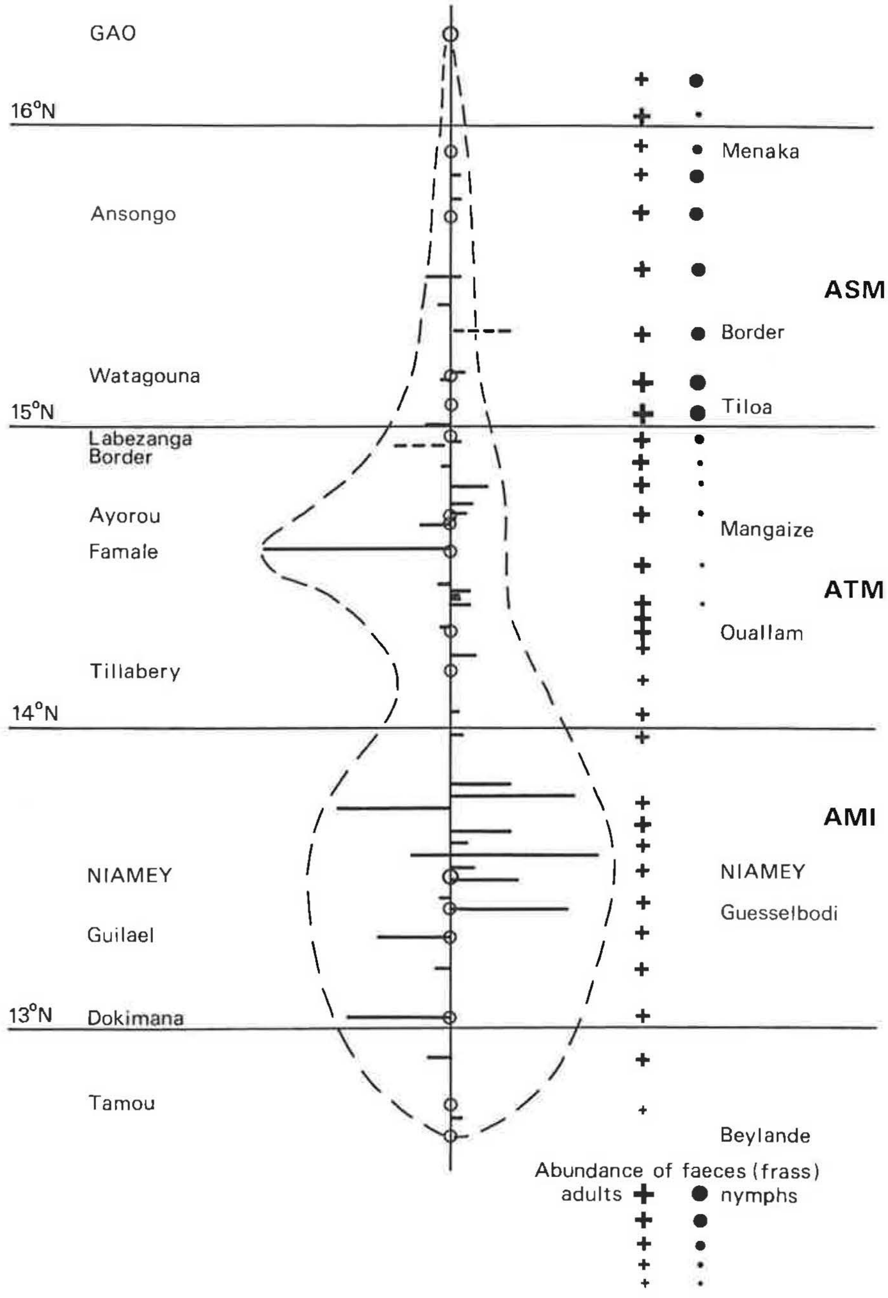


Figure 17

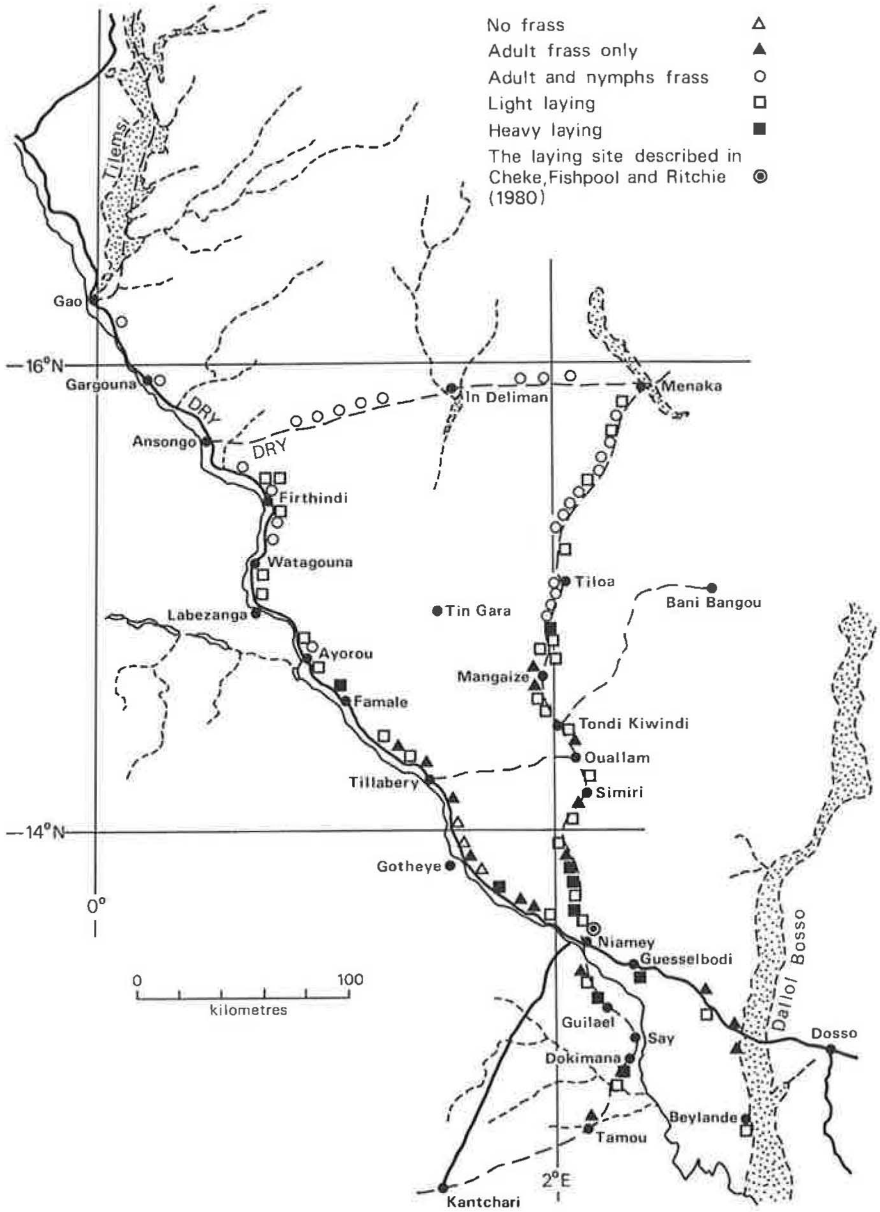
Graph of the geographical distribution of laying along the main axes: Niamey-Menaka, Gao-Niamey and Niamey-Tamou: including records for Beylande and Guesselbodi and also for Niamey*



*From Cheke, Fishpool and Ritchie (1980)
The horizontal bars correspond to the average laying density recorded for each sampling site. The abundance of the adult and nymphal frass, as recorded on the five-point abundance scale, is also given. Note that the nymphal frass occurs in measurable quantities only north of Ouallam. (The position of samples and sampling axes is shown in Figure 18.) After Popov (1980b)

Figure 18

Study area showing the sampling axes and sites used in the survey of terminal oviposition by *Oedaleus senegalensis* at the end of the 1977 monsoon in the Middle Niger Valley



From Popov (1980)

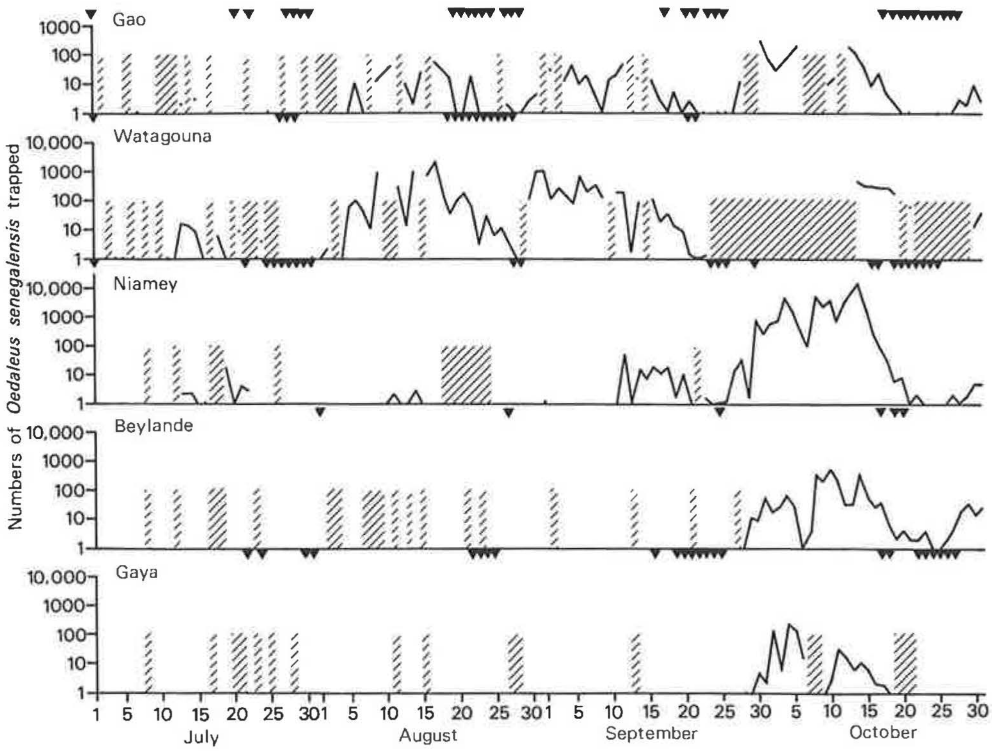
when the grasshoppers, particularly the females, feed preferentially on the ripening grains (Boys, 1978).

During major outbreaks, total crop losses may occur over limited areas and add up to a serious overall production deficit over large areas. In 1974, Senegal assessed its shortfall in millet production at 30%, nearly all of it attributed to grasshopper attack (official reports). In Mali, one report of damage to rice and millet (among other crops) assessed losses at 3,000,000 CFA francs (US$10,000) over an area of 9000 ha (COPR, 1982). Crop damage in northern Nigeria in 1977 due to attack by *O. senegalensis* was estimated at N3,000,000 (US$3,000,000) (O. S. Bindra, personal communication).

Apart form millet, other cereal crops such as maize, sorghum, rice and wheat may also suffer serious attack. There are also reports of damage to

Figure 19

The numbers of *Oedaleus senegalensis* taken at light during July-October 1977



The hatched areas denote dates when no trapping took place as a consequence of inclement weather, petrol shortages etc; the symbols refer to nights when moonlight was recorded at the station (Cheke, Fishpool and Forrest, 1980).

groundnuts, cowpea and lucerne, but this appears to be light. There are also many cases of damage to pastures but the extent and the impact of the losses are not known (COPR, 1982).

The level and distribution of infestations and the concomitant damage vary from year to year (p.49). The most serious and widespread outbreak on record is that of 1974, when all the Sahelian countries, including the Sudan, were affected. The infestations were also heavy and widespread in 1975, but following the OSRO campaign in that year, the grasshopper populations were much reduced in 1976. During 1977, there was a heavy outbreak in Niger, where some observations were made by Cheke, Fishpool and Forrest (1980) on the nature and extent of the damage. It was found that the most serious damage was to millet in the milky stage, although it was almost as heavy in the pre- and post-milky stage (Table 4). There was also considerable damage to sorghum.

Attacks by *O. senegalensis* were serious throughout the Tahoua - Diffa area, and also in the adjacent parts of Nigeria (O. S. Bindra, unpublished data) (Figure 20). In many areas, particularly around Tanout crops were devastated.

The most serious damage by grasshoppers in the Niger valley during the 1977 season was in the Watagouna-Ansongo sector. Although grasshoppers were present there since June, serious attacks did not develop until September-October. OCLALAV treated 6950 ha along the river bank in the Ansongo area, where *O. senegalensis* were attacking millet, sorghum and rice, causing 20-40% loss of crops.

In Mali and Mauritania, grasshopper attacks were more severe in 1978. Niger had serious infestations again in 1980 when the aircraft of the

Table 4

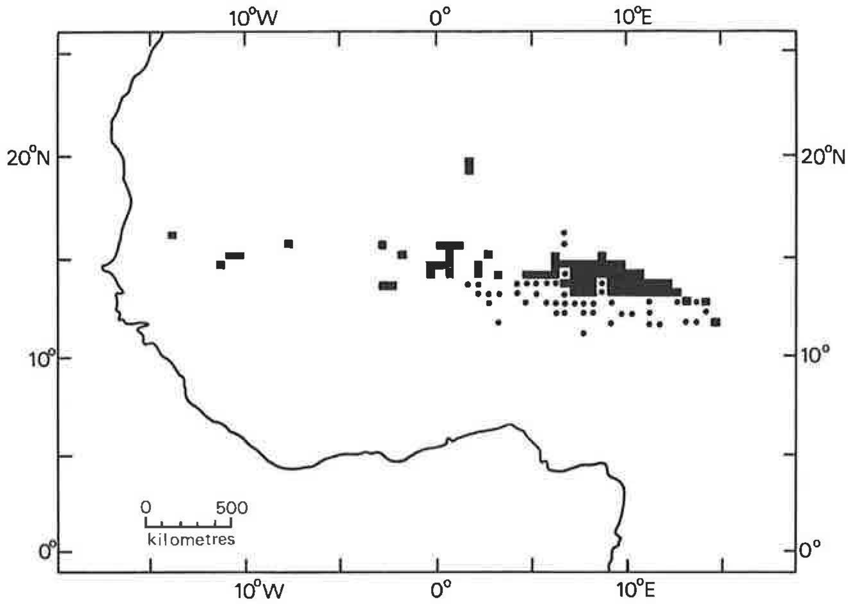
Estimates of damage to seed heads of millet

Ages of seed head	Mean percentage of surface area eaten								
	Issawan 3 October			Bakin Birji 5 October			Tagalal 8 October		
	x	SD	*n*	x	SD	*n*	x	SD	*n*
Pre-milky stage	10.5	17.6	13	73.3	31.4	9	37.8	29.5	25
Milky stage	18.4	32.5	17	81.1	25.6	19	49.3	36.0	27
Post-milky stage	16.7	21.3	20	79.7	22.1	19	35.7	33.8	12

From Cheke, Fishpool and Forrest (1980)

Figure 20

The known distribution of *Oedaleus senegalensis* during 1977



The squares denote one quarter degree squares within which the grasshopper was recorded causing damage, and the dots denote one quarter degree squares within which the species was abundant but where confirmed records of damage are wanting (Cheke, Fishpool and Forrest, 1980).

plant protection service treated some 400,000 ha. More recently, the 1982 outbreak in Mauritania was among the worst on record; serious damage was caused to crops and pastures by swarms of grasshoppers, predominantly *O. senegalensis*. Some of the swarms were swept out to sea by strong winds and drowned (OCLALAV, 1973-1983).

In general, since 1970, control of grasshoppers including *O. senegalensis* has been carried out in most Sahelian countries practically every year. Control operations by OCLALAV alone (Table 5) add up to many hundreds of thousands hectares.

In view of the mobility of its populations (pp.26-29) the problem of *O. senegalensis* has a marked subregional character. On many occasions, such as 1974, 1975, 1978, 1980, 1982, infestations from source areas in one country later spread to a neighbouring one. For instance, the late season adult populations from source areas in western Mauritania frequently invade crops in Senegal and even reach the Gambia, while others from source areas in eastern Mauritania may invade Mali and Burkina Faso. Source areas in eastern Mali could affect those in western Niger and Benin and further east seasonal exchange of populations is known to occur between Niger and Nigeria. For this reason, to be truly effective preventive control strategies must be coordinated on a regional, or at least subregional basis.

Table 5

Control operations carried out by OCLALAV against Desert Locust and grasshopper infestations in the Sahel

Campaigns (year)	Treated area (hectare)			Insecticide used (litres)
	Desert Locust	Grasshopper	Total	
1966	-	-	-	-
1967	30,400	-	30,400	62,300
1968	59,800	-	59,800	46,700
1969	27,700	-	27,700	15,700
1970	150,200	10,500	160,700	99,500
1971	1100	1300	2100	1400
1972	-	-	-	-
1973	-	-	-	-
1974	27,700	194,100	222,100	156,400
1975	16,400	328,000	344,400	309,400
1976	121,200	34,100	155,300	78,600
1977	-	57,400	57,400	58,400
1978	12,500	232,400	244,900	123,800
1979	-	51,100	51,100	25,800
1980	98,400	75,600	174,000	52,600
1981	4600	58,600	65,200	20,000

OTHER SAHELIAN LOCUSTS AND GRASSHOPPERS

Apart from the Senegalese Grasshopper there are four species of locusts and about thirty species of grasshoppers that attack crops in the Sahel. Some extend into adjacent bioclimatic zones, either individually or as complexes of species. The more outstanding species are shown in Figure 21, together with an indication of their economic importance, according to the criteria established in *The Locust And Grasshopper Agricultural Manual* (COPR, 1982) and their agroecological associations and groupings.

A brief appraisal of the biology, ecology and economic importance of these species is made below. For further details on the grasshopper fauna of savannas of Mali, Niger, Benin and Togo see *The Locust and Grasshopper Agricultural Manual* (COPR, 1982) and Fishpool and Popov (1984). The Desert Locust (*Schistocerca gregaria*) and the African Migratory Locust (*Locusta migratoria migratorioides*) (Reiche & Fairmaire) (Figure 6) are well known and outside the scope of this study.

Locust species (Group I, Figure 21)

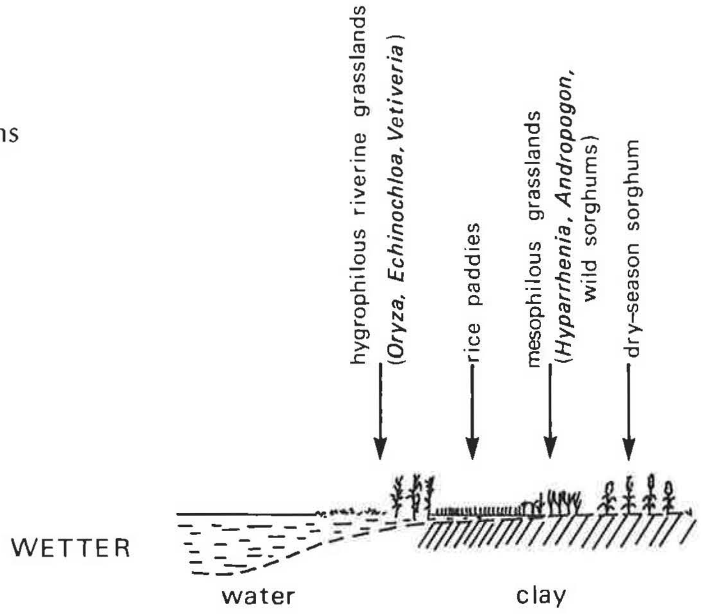
RED LOCUST *NOMADACRIS SEPTEMFASCIATA* SERVILLE (FIGURE 6)

This locust is a major pest in Central and South Africa where the International Red Locust Control Organization for Central and Southern Africa (IRLCOCSA) is responsible for maintaining continuous surveillance and preventive control in the various outbreak areas in Tanzania, Zambia, Malawi and Mozambique.

In western Africa, however, it is a grasshopper of localised, sporadic and rather infrequent importance. Its major populations occur in the central Niger delta and the Chad basin, where they largely coincide with the more humid parts of the outbreak areas of *Locusta*. In 1957 an outbreak in the Niger delta led to formation of bands and swarms sufficiently alarming to

Figure 21

Distribution of the principal locust and grasshopper species in the agroecosystems in the Sahel



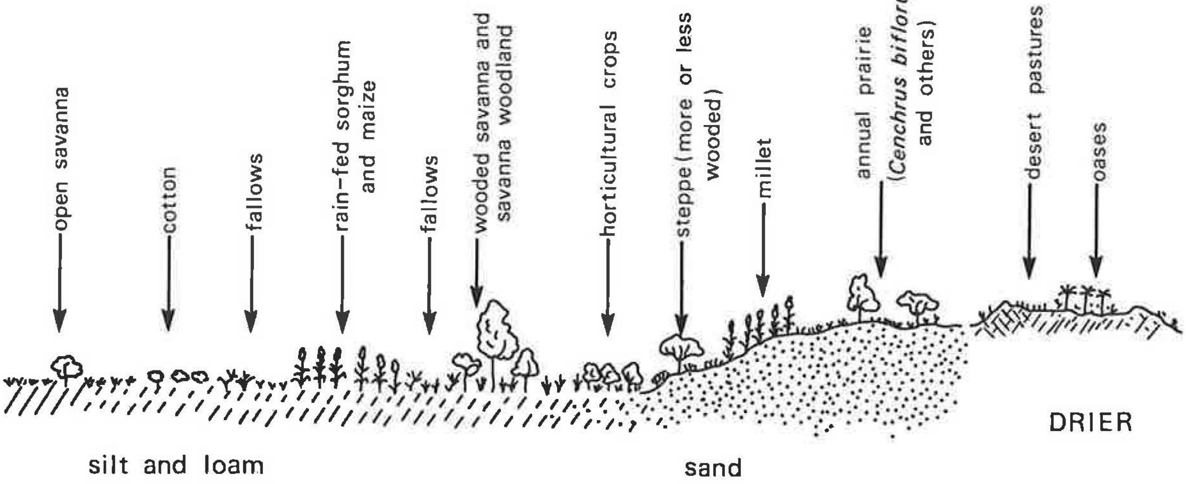
Locust species						
Nomadacris septemfasciata A(E) (Red Locust, Criquet nomade)	I	1	xx		xxx	xx
Locusta migratoria migratorioides A (African Migratory Locust, Criquet migrateur africain	I	2	xx	x	xxx	xx
Anacridium m. melanorhodon C (Tree Locust, Criquet arboricole	I	3				
Schistocerca gregaria A (Desert Locust, Criquet pèlerin)	I	4				
Grasshopper species						
Hieroglyphus daganensis E	II	1	xxx	xx		x
Orthochtha venosa	II	2	xxx	x		
Paracinema tricolor G	II	3	xx	x		
Eyprepocnemis plorans C	II	4	xxx	x		
Aiolopus simulatrix B(D)	III				xxx	xxx
Cataloipus fuscocoeruleipes E	IV	1	xx			x
Cataloipus cymbiferus E	IV	2	x			x
Jagoa gwynni E	IV	3	xx			
Ornithacris turbida G	IV	4				
Pnorisa carinata G(H)	IV	5				x
Duronia chloronota G	IV	6				x
Kraussaria angulifera C	IV	7				x
Oedaleus nigeriensis G	IV	8				
Kraussella amabile H(G)	IV	9				
Zacompsa bivittata K(G)	IV	10				
**Catantops stramineus* E(G)	V	1				
Acridoderes strenuus E(G)	V	2				
Heteracris annulosa G	V	3				
Oedaleus senegalensis C	VI	1				
Diabolocatantops axillaris D	VI	2				
Cryptocatantops haemorrhoidalis (E)H	VI	3				
Sphingonotus savignyi G	VI	4				
Acrotylus longipes E	VI	5				
Aiolopus thalassinus F	VII	1		x		
Morphacris fasciata G	VII	2		x		
Trilophidia conturbata (G)K	VII	3		x		
Acrotylus patruelis F	VII	4		x		
Zonocerus variegatus C	VIII	1	x	x		
Chrotogonus senegalensis G	VIII	2	x			
Pyrgomorpha conica	VIII					
Pyrgomorpha cognata E	VIII	3	x			
Pyrgomorpha bispinosa	VIII					
Oedaleus johnstoni (E)	IX	1				

*See Jago (1984).

The overall assessment of the importance of a species is indicated by the ratings given in *The Locust and Grasshopper Agricultural Manual* (COPR, 1982) as follows:

A	Major pest of many crops	F	A regular minor pest
B	Major pest of few crops	G	An occasional minor pest
C	Pest regularly of substantial importance	H	Of very minor importance at times
D	Pest occasionally of substantial importance	K	Few records of minor damage; negligible economic significance
E	Pest occasionally of localised importance	A–E	would usually justify control measures whereas F–K would not

The economic importance of a species may vary greatly in different parts of its range; when the rating for the Sahel is markedly different, the alternative assessment is given in brackets.



xxx			xx			x								
xx			xxx		xx						xx			
						xxx			xx	xx	x			
	xx	xx	xx						xx	x	xxx	xxx	xxx	xxx
		x	x	xx										
			x	x										
		x	x		x									x
		x	xx	xx							x		xx	
xx	x	xx	x	x										
xx	x	xx	x	x										
xx	x	x	x	x										
xx	x		x	x						x	x	x		
xx			x	x										
x			x	x	x									
xx	xx	xx	xx	xx	xx	x			xx	x	xx			
x		x	xx	x	x				x		xx	x		
xx		x	x			x					x			
x			x			x					x			
			x	x	xx	x	xx		xx	x	x			
			x	x	xx	x	xx		xx	x	x			
							xx		xx		x			x
		x	xx	x	x						xxx	xxx	x	
		x	xx	x	x				x		xx	x	x	
		x	xx		xx				x	x	xx	x		
											x	x	xx	x
											x	x	x	x
			x		x			xx			x			
			x					xx			x			
			x		x			xx			x			
			x					xx			x			x
		x			x			xxx			x			
		x			x			x			x		x	x
		x			xx			x x			x		x	x
											(x)	x	xxx	

warrant large-scale spraying operations by the Groupe Aerien de Lutte Antiacridienne (GALA) the air unit of OCLA (now OCLALAV). Since then no notable populations have been observed in that area.

The Red Locust occasionally multiplies and forms aggregations in the Chad basin in its natural habitat of tall grasslands. It may then spread and damage sorghum and maize crops. In 1979, its multiplication coincided with an outbreak of *Locusta*, when for a time the two species formed extensive mixed populations in the Waza-Gulumba area. Some of these were controlled, but while some of the *Locusta* adults eventually formed swarms and emigrated, all the *Nomadacris* adults dispersed (Popov, 1980c).

As this species shares the habitats of *Locusta*, and the latter are under regular surveillance by OICMA, it is unlikely that any major upsurge of *Nomadacris* in the Sahel could remain undetected and uncontrolled.

TREE LOCUST - *ANACRIDIUM MELANORHODON MELANORHODON* WALKER (FIGURE 6)

This locust is particularly important in the Sudan, where it is a serious pest of fruit trees and occasionally, cotton and bulrush millet, but is mainly a pest of *Acacia senegal*, the producer of gum arabic, an important industrial crop. Major control operations are carried out annually, usually against swarms which persist through the dry season. Control is difficult because of the arboreal habits of the locust.

The pest is also of some importance in the Ouadaï district of eastern Chad, but less so farther west through the Sahel, where gum arabic is not as important and where the trees, chiefly *Acacia* spp. and *Balanites aegyptiaca*, which form its principal habitat, are still so plentiful that damage to them passes unnoticed.

There are some signs, however, that with the expansion of agriculture in recent years and the concomitant deforestation, the economic importance of the Tree Locust has increased. This is the case in the northern parts of Nigeria, and in Mali and Senegal, where some control against it has been undertaken from time to time by national plant protection services and OCLALAV (Appendix 3).

A. *melanorhodon* was relatively infrequent in the project study area and provided little opportunity for observation. The largest populations were recorded as small swarms in Menaka, Delimane and Gargouna areas during January and February 1978. General information on this species can be found in Popov and Ratcliffe (1968), COPR (1982) and Fishpool and Popov (1984).

The outstanding feature of the Tree Locust as its name implies, is its marked arboreal habit. The hoppers may form aggregations in trees, but seldom leave their roosts; this happens when pressure of numbers leads to defoliation and forces them to seek sustenance elsewhere. The hoppers then venture into the open and may march long distances as loose bands and invade such crops as cotton and millet.

The adults, however, are markedly gregarious and form dense swarms, which persist through the dry season. The swarms fly from one group of trees to another, usually by night (hence the Arabic name, sari al leil, the night wanderer). This is the time when the worst damage to gum arabic, fruit trees and various crops usually occurs. While defoliation may not kill gum trees, it seriously lowers their yield.

Control of Tree Locusts faces some practical difficulties:

- no effective monitoring or preventive control system exists;
- control relies on the destruction of swarms during the dry season; this is physically difficult from the ground because locating and

tracking swarms through thick bush and then spraying them on tall trees is not easy, while aerial control directed against relatively small and inconspicuous targets is best done by helicopters, which is costly.

There is room for improvement; perhaps some of the equipment and methods currently being developed for controlling Quelea could prove useful.

Grasshopper species (Groups II-IX - Figure 21)

It is most convenient to examine the grasshoppers as species groups, or complexes in relation to their agroecosystems. The members of a given complex tend to have similar ecological characteristics, comparable feeding habits and often (although not necessarily always) similar responses to environmental changes. Therefore, the numerical changes in their populations tend to follow similar trends.

To avoid repetition, each complex is discussed only briefly, highlighting the special characteristics of the complex and of its component species, particularly those of importance as pests. Suggestion for control methods and strategies are discussed separately at the end.

COMPLEX II

This complex of species (Figure 21) is primarily associated with hydromorphic clays subject to seasonal flooding, generally located in the major drainage basins of the Senegal, Niger and Chad. Characteristic vegetation comprises hygrophilous communities of grasses including the genera, *Oryza, Echinochloa, Vetiveria* and often forbs belonging principally to the Leguminosae, Malvaceae and Convolvulaceae. The principal crop is rice. The main grasshopper species are *Hieroglyphus daganensis* Krauss (Figure 6), *Orthochtha venosa* (Ramme) and the secondary ones, *Paracinema tricolor* (Thunberg), *Eyprepocnemis plorans* (Charpentier) (Figure 6), *Phyllocercus bicoloripes* Uvarov and *Oxya hyla* Serville (Figure 6). All are strict graminivores.

In the Sahel, damage to rice by grasshoppers appears to be relatively infrequent and localised. In the project area it was recorded in September 1975 near Ayorou, where *H. daganensis* was responsible for light peripheral damage in a few paddies. More serious and widespread attacks occurred in 1974 and 1975 and more recently in 1983, in the Borgou province of northern Benin as part of a generalised outbreak of grasshoppers in the Niger river valley during the monsoon. Damage, which was chiefly to foliage, was by *H. daganensis, O. venosa* and another *Orthochtha* species. Other grasshopper species were unimportant.

Serious attacks to rice are also recorded in parts of the Chad basin, and seem to have an almost chronic aspect in the Maga-Pouss area of northern Cameroon. Practically all the reports emanate from the Yagoua Development Scheme, and it is possible that the problem could be more widespread, with attacks on traditional paddies outside the scheme remaining largely unreported. The ecologically similar, adjacent parts of Chad could also be involved.

The source areas are the vast floodplains of the Logone and probably the analogous ones along the Chari. These support grasslands of *Echinochloa, Oryza, Vetiveria* and other hygrophilous plants, which are the habitats of these grasshopper species. Occasionally, during mass multiplication, the grasshoppers exhaust the capacity of their natural habitats, and overflow into adjacent paddies.

The two principal species, *H. daganensis* and *O. venosa* although members of different subfamilies of Acrididae, Hemiacridinae and Acridinae respectively, show some remarkable similarities in biology and behaviour, and frequently form mixed populations. Both are good swimmers, especially in the nymphal stage; they invade the paddies by swimming at the time when both the paddies and grasslands are flooded. Both species avoid pursuit by diving and then swimming under water, or by dodging behind grass stems and rapidly sliding downwards and backwards in a manner common to many graminicoles. Then, in their peculiar way, they continue to slide down, well below the surface of water, to remain submerged, if necessary for many minutes, until the danger has passed.

Both species form aggregations (often mixed) when hoppers tend to develop black pigmentation of a rather similar pattern on the face and the underside. Both species show alary polymorphism albeit of a different nature. *H. daganensis* is dimorphic and can be brachypterous and flightless or macropterous and capable of sustained flight. *O. venosa* is generally fully winged, although not a particularly strong flier. It occasionally produces individuals with extra long wings of the kind recorded by Descamps (1968) for *Jagoa gwynni* (Uvarov). There is some indication that macropterism is density dependent as the long-winged forms tend to be more numerous in years of mass outbreaks, but more critical observations are needed.

Both species have a general Sahelian distribution, but of the two, *H. daganensis* is more common and has a wider ecological tolerance. Breeding populations of this species have been recorded as far north as Aguelhoc in the northern Tilemsi valley and it also occurs in numbers in ecosystem IV where it forms mixed populations with *Cataloipus, Jagoa* and others and causes damage to maize and sorghum. The other pest species of rice included in this group are *E. plorans* in Egypt and *O. hyla* in Southeast Asia. While they and *Paracinema tricolor*, are common in this ecosystem in the Sahel, their importance as pests is generally small. *Phyllocercus bicoloripes* however, which as a rule is an uncommon species, was in 1975 an important component of the species complex damaging rice in the Pouss area.

COMPLEX III

This complex is associated with clay plains subject to seasonal inundation by rain or flood. Generally such plains support perennial and/or annual tall and short grass communities and, in some areas, woodlands. The typical crops are rain fed and include sorghums (Guinea corn), maize, cowpea, cotton and locally, sugarcane.

This ecosystem is principally found in the major flood basins of the Senegal, Niger, Chad and Nile. It forms a transition between complexes II and IV and generally speaking most of the grasshopper species in these also occur in complex III. It could thus be regarded as part of either or both, but is considered here separately *sensu stricto* as characteristic of *Aiolopus simulatrix* (Figure 6), the Sudan Plague Locust or Qaburah, a major pest of sorghum in the Sudan, which is placed in category (B) in *The Locust and Grasshopper Agriculture Manual* and thus ranks as second only to the major locust species in importance (COPR, 1982).

A. simulatrix occurs throughout the Sahelian belt eastwards to the Sudan and Egypt and to southwest Asia, where it extends north to Turkestan and east to Bangladesh (Hollis, 1968). Across this wide range, the species shows considerable ecological and biological plasticity; it occurs in a wide range of habitats and may survive the dry season in the adult or the egg stage. In the Sudan and Sahel, however, these characteristics are expressed more narrowly. It is closely associated with black hydromorphic clay soils and survives the dry season as an adult hidden deeply in the cracks in the soil; this characteristic behaviour is the origin of its Arabic name, Qaburah, the burrower.

In view of the importance of this species, particularly in the Sudan, the salient aspects of its behaviour, life cycle and seasonal displacements are briefly given below. Most of the information is from Joyce (1952a, 1952b), S. R. Spencer (unpublished data), Schaefer (1976), COPR (1982) and G. B. Popov (personal observations).

Overwintering of adult A. simulatrix

At low temperatures, the overwintering adults are inactive and remain hidden in cracks for many days. With rising temperatures and humidity heralding the approach of the monsoon, they begin to emerge in increasing numbers. There is a marked diurnal pattern of behaviour in association with changes of temperature: a period of emergence often coupled with feeding occurs mid-morning, followed by sheltering in cracks during the heat of the day, and this is in turn followed by re-emergence as temperatures decline in the afternoon (G. B. Popov, personal observations).

Activity increases further with the approaching rains. There are flights, often by night, into areas of rainfall, leading to concentrations on patches of the first vegetation and early crops, with concomitant, sometimes serious, damage (S. R. Spencer, unpublished data).

Seasonal breeding and displacements of A. simulatrix

Breeding begins soon after the start of the rains. The first generation is usually produced in the area of overwintering from late May–June and numbers may rise locally by migration from other areas. Egg incubation lasts about 18 to 28 days. There are five hopper instars and the duration of hopper life varies from 35 to 51 days (COPR, 1982). The adults of the new generation soon decline in numbers and it is thought that many (or most) migrate northwards following the advance of the ITCZ to produce a second generation in the northern areas (Joyce, 1952a, 1952b; S. R. Spencer, unpublished data). The adults of the second generation then return southwards with the retreating ITCZ, to more or less the original area of their parents in the south.

When the returning populations are large, which is frequently the case, serious crop damage can result, especially if the sorghum is in the milky grain stage at the time.

Although this hypothesis of seasonal migration of *A. simulatrix* in the Sudan has not been adequately tested by critical monitoring, there is some evidence in its support, deduced from:

the decline of the adults of the first generation in southern (overwintering) areas (for instance in Gedaref district) following fledging, suggestive of a general departure; this decline coincides with the northward advance of the ITCZ;

the marked increase in adult numbers at the end of the monsoon usually during October; this increase coincides with the southward retreat of the ITCZ;

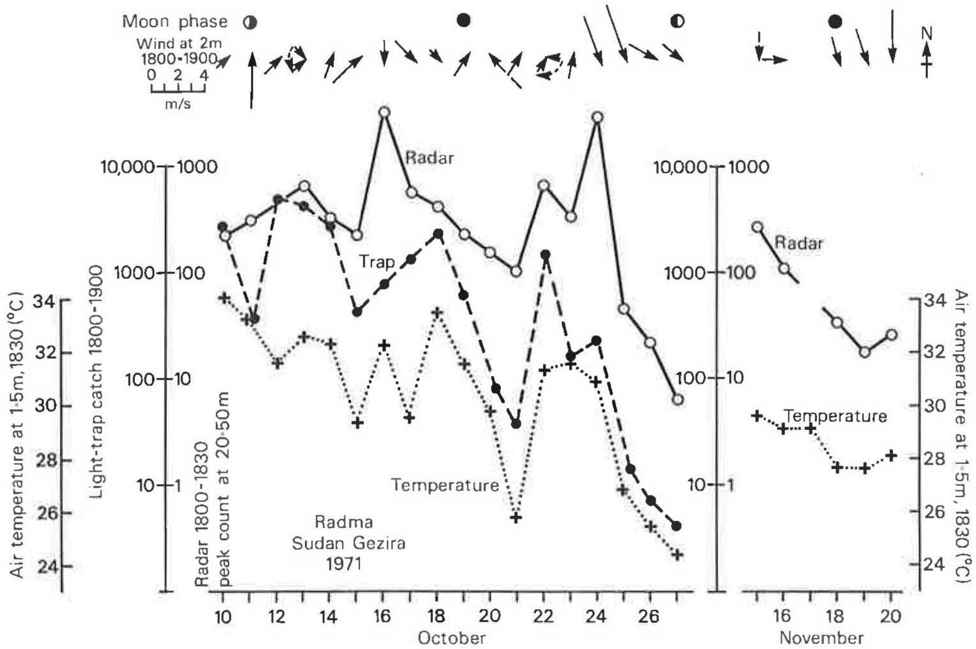
the occurrence of major movements of *A. simulatrix* at intermediate points at the 'right' time and moving in the 'right' direction; the most complete such evidence comes from radar observations by Schaefer (1976) in the Sudan Gezira during October 1971;

insects and birds flew on every night of the observations (Figure 22); it was found, on the basis of their radar echo signatures, that grasshoppers constituted the bulk of the flying insects and amongst them *A. simulatrix* was by far the most numerous (it was present in very large numbers in the area at the time);

the grasshoppers were observed taking off silhouetted against the twilight sky, at which point radar made its first contact at low elevations; the radar then indicated that peak take-off usually occurred about 15 min later than visual observations were possible;

Figure 22

Radar and light-trap records of *Aiolopus simulatrix* in the Sudan Gezira



After Schaefer (1976)

the average height of flight in *A. simulatrix* following take-off soon rose to 500 m; the ceiling being about 1500 m in September, falling at lower temperatures to 900 m in November;

the biomass of the flying grasshoppers was in the order of 1500 g/ha, with the volume densities in the range of 1/1000–1/1,000,000 m^3, equivalent to about 5–1000/ha;

the orientation of grasshoppers was consistently to the south south-west (towards the winter quarters, Schaefer (1976)); on most nights this orientation agreed with the direction of prevailing winds, but even when winds differed, the same orientation of grasshoppers was maintained in all but strongly opposed winds;

at a ground speed of 8 m/s the grasshoppers were estimated to cover about 40–150 km/night;

radar evidence on day-to-day variations in the density of airborne grasshoppers (Figure 22) showed two mass movements, together involving the majority of the insects, on evenings following a change of wind from southerly to northerly. There were two further, lesser peaks also near the surface position of the Inter-Tropical Front (ITF). Although the light-trap catches did not reflect either of the two major peaks shown by the radar, the maximum catches agreed well with the lesser radar peaks; (This difference, attributed by Schaefer (1976) to the effect of moonlight and high wind, could perhaps also be explained by the possibility that in the northerly airstreams a proportionately greater number of grasshoppers gained greater height beyond the effective range of the light traps.)

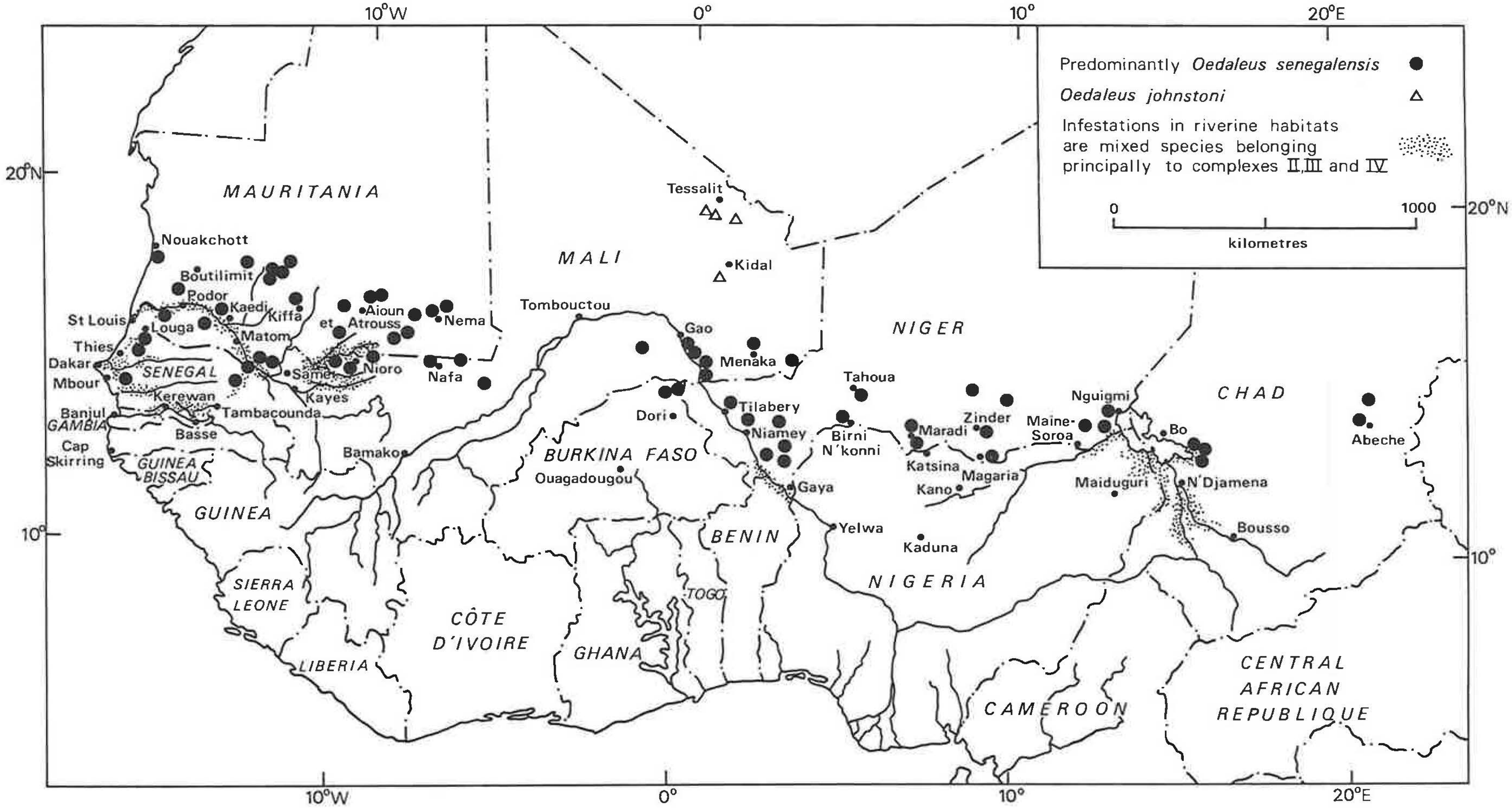
the concentration of insects was well marked in the areas of convergent air flow within the ITF and was even more pronounced in storm cold fronts.

Economic importance of A simulatrix *in the Sahel*

In the Sahel, as in the Sudan, the major populations of *A. simulatrix* are associated with hydromorphic clay soils within the principal drainage basins (p. 40), but its economic importance in the Sahel is comparatively less.

Figure 23

Principal localities where grasshopper control was conducted by OCLALAV during 1972–1980



Its importance appears to be greatest along the Senegal river valley and its tributaries in southwest Mali (Figure 23). It is one of the principal pests which attack the crops, chiefly sorghum, that are planted on receding floods at the end of the monsoon/beginning of the dry season. Serious attacks have occurred occasionally in Senegal and on the opposite side in Mauritania; 1974–1975 and 1975–1976 were particularly serious years when OCLALAV carried out extensive control operations (Appendix 3).

Attacks of a similar nature on dry season sorghum, 'masakowa', grown on black clay, 'firki' soils have been recorded in the Chad basin in Nigeria and Cameroon, notably in 1974. In Cameroon, serious damage also occurred in the Mora area at the beginning of the rains in June (Popov, 1976).

In the Niger valley damage by *A. simulatrix* to dry season sorghum was noted on a local scale in Ansongo area in 1974–1975 and the species has also been recorded by the project in light traps, often in large numbers at all the stations, particularly in the northern ones. *A. simulatrix* extends northwards to Adrar des Iforhas and is often numerous along the Tilemsi valley and some of its tributaries in areas of cracking clays. It attacks the annual pastures that develop in these valleys during the rains, often in mixed populations with *Oedaleus johnstoni* Uvarov, *Sphingonotus savignyi* Saussure, *Acrotylus longipes* (Charpentier) and other species. The damage at times, for instance in June 1975 and August 1978 (Appendix 3), was so severe it required control operations. Riley and Reynolds (1983) also recorded the occurrence of *A. simulatrix* in the Tilemsi valley and the fact that it was an important component of grasshopper populations recorded both by radar and by light trapping during their observations in October 1978.

Discussion

The importance of *A. simulatrix* in the Sudan contrasts with its more modest status in the Sahel and this necessitates an explanation, even if only a speculative one.

The close dependence of this species on cracking clay soils is important for the survival of its overwintering adult populations, and it might be expected that in the absence of appropriate sites, its survival would be jeopardised.

The seasonal migrations in the Sudan with the advance and the retreat of the ITCZ up and down the rainfall gradient coincide with the main north-south axis of the Nile valley. That this is probably important, is borne out by the persistent maintenance of this orientation by flying adults within the limits of their capabilities, even in conditions of unfavourable winds (p. 42). The grasshopper populations effectively remain at all times in contact with their natural clay habitat which covers great expanses of the Nile valley. This mechanism ensures minimum loss, maximum survival and multiplication, and favours the build-up and maintenance of high population levels.

Although in the Sahel the cracking clay habitats are well represented in the major basins of the Chad, Niger and Senegal, they are more limited in extent and do not have the appropriate north-south orientation of the Nile valley. Consequently, while multiplication (and the associated crop attacks) occur from time to time, they are offset by losses when grasshoppers on migration fail to encounter suitable shelter and breeding habitats. Consequently the populations do not reach the magnitude of those in the Nile valley.

COMPLEX IV

This complex comprises species that are characteristic of the southern Sahel and the Sudan savanna proper. The grasshopper fauna of the savannas is large (Fishpool and Popov, 1984), but many species are stenophagous, have a narrow ecological spectrum and do not readily move from their natural grassland habitats into crops to become pests. Others, however, while predominantly graminicolous and graminivorous, are not strictly so. They are also ecologically tolerant and do well under artificial conditions, particularly in fallows and wastelands adjoining the crops, which are often source areas where infestations develop and then spread to the crops.

It is a heterogeneous assemblage, ranging from the hygrotypic *Jagoa* (Figure 6), *Cataloipus* (Figure 6) and *Duronia*, more frequent in riverine communities, through the ubiquitous *Kraussaria* (Figure 6) and *Oedaleus nigeriensis* Uvarov to *Ornithacris turbida* (Walker), *Pnorisa carinata* Uvarov and *Kraussella amabile* (Krauss) (Figure 6) more characteristic of the savanna grasslands. Their life cycles are equally varied; while *Ornithacris, Jagoa, Cataloipus* and *Kraussaria* are univoltine, the others are bi- or multi-voltine. In this complex, only *Ornithacris* and *Duronia* are known to survive the dry season as adults, the others do so as eggs.

The complex constitutes a major threat to the principal subsistence crops in the Sahel and Sudan zones, covering and overlapping the full range from the irrigated crops in complex II and III, to the dry rain-fed complexes V and VI. The species in this complex may thus sometimes form mixed populations with such species as *Hieroglyphus daganensis* on the one hand and with *Oedaleus senegalensis* and *Diabolocatantops axillaris* on the other.

Cereal crops are particularly attacked, but other crops like cowpea, cotton and groundnut may also suffer serious damage at times.

Each species in the complex has its particular characteristics and can be locally dominant and economically more important in particular areas on particular occasions and be rare, or even absent, in others. For instance, *K. amabile* and *Zacompsa bivittata* (Uvarov) (Figure 6), which are generally regarded as having little importance and are given the low H and K rating in *The Locust and Grasshopper Agricultural Manual* (COPR, 1982), are important pests in the Cap Vert area of Senegal (Appendix 3 and M. Launois, personal communication).

Probably the most important single species in complex IV is *Kraussaria angulifera* (Krauss), a serious ambivorous pest throughout the Sahel from the Red Sea to the Atlantic. In 1972 the bulrush millet and cowpea crops in one district of Nigeria suffered losses estimated at US$300,000 and three other states were said to have suffered equally great losses (Oyidi, 1975). Heavy losses were also recorded in Potiskum in 1974 (Popov, 1976).

COMPLEX V

This is a small heterogeneous group of pests of relatively minor importance associated with thickets and scrub vegetation. Such scrub vegetation occurs in a variety of habitats throughout the Sahel but is particularly common on land abandoned after cultivation and is thus frequently close to crops.

The members of this complex are ambivorous herbicoles and arbusticoles; represented notably by species of *Catantops* and *Heteracris*. Like the members of complex IV, when numerous, they tend to overflow from the marginal source areas into crops and cause damage, particularly along the margins of fields. Almost any kind of crop is liable to damage, although this tends to be relatively light, but is frequently additional to that inflicted by species complexes IV and VI.

COMPLEX VI

This is a major complex of species affecting the drier, sandier parts of the Sahel. It includes the major pest *Oedaleus senegalensis* discussed separately on page 14.

The second most important species in this group is *Diabolocatantops axillaris* (Figure 6), an ambivorous herbi-arbusticole of wide ecological tolerance and a pest of a wide range of crops in the Sahel. This grasshopper, often with other members of the complex and also complexes IV and V, has been recorded causing damage to millet and sorghum in Niger (Cheke, Fishpool and Forrest, 1980) but also to cotton, vegetables and fruit trees (COPR, 1982).

In the Sahel, *D. axillaris* is univoltine, surviving the dry season as an adult. It is a strong flier and in the Sudan has been regularly recorded by radar flying at night at heights of up to 1200 m. On one occasion it was actually trapped together with *Aiolopus simulatrix* in an aircraft net at a height of 450 m (Schaefer, 1976). It is therefore possible that major seasonal displacements may also occur in this species. Swarms have occasionally been recorded in the flood plains of Lake Chad and the central Niger delta at Bambara Maundé feeding on *Hibiscus* spp. and other Malvaceae (G. B. Popov, personal observations). Such gregarious behaviour does not appear to be accompanied by any obvious morphological and colour changes.

The remaining species in the complex are of lesser importance, but may at times contribute to damage caused by other species. Occasionally some may be of local importance.

For instance, in recent years, *Sphingonotus savignyi* Saussure (Figure 6) has revealed itself as a serious pest of forestry plantations in the Cape Verde islands (J. F. Duranton, M. Launois, M. H. Launois-Luong and M. Lecoq, unpublished data).

COMPLEX VII

This complex is made up of a number of ambivorous, primarily terricolous species. These species are associated with irrigated crops, in orchards and gardens, generally situated alongside rivers and watercourses, and watered from canals, springs or wells. Although individually they are minor pests (categories F and G in *The Locust and Grasshopper Agricultural Manual* (COPR, 1982)), they can at times cause serious damage to seedlings of various vegetables, tobacco, flowers and other annual crops, including cereals.

The majority have no diapause and because of the artificially favourable conditions on irrigated land, they tend to breed continuously, presenting a constant pest problem for the cultivator.

COMPLEX VIII

The members of this complex all belong to the family Pyrgomorphidae, they are ambivorous and have a wide tolerance of ecological and climatic conditions.

Chrotogonus senegalensis Krauss is terricolous and a minor pest of primarily irrigated vegetable and garden crops. It could be also regarded as a member of complex VII and like them it can breed continuously to produce several generations annually, but has an even wider range of food plants. Damage to vegetables, coffee, citrus and oil palms has been recorded (COPR, 1982).

The three species, *Pyrgomorpha conica* (Olivier), *P. cognata* Krauss and *P. bispinosa* Walker, largely overlap in their distribution in west Africa and are extremely difficult to differentiate. They are, therefore, considered together. They are herbicolous and herbivorous and are minor ubiquitous pests of a wide range of non-graminaceous crops, chiefly vegetables.

The Variegated Grasshopper (le criquet puant), *Zonocerus variegatus* (Linnaeus), (Figure 6) has become increasingly important in recent years. It occurs in many parts of the forest zone in west and equatorial Africa, but always in clearings and in cultivated, deforested areas. It penetrates the savanna principally along the drainage systems.

In the west African forest zone there are two overlapping reproductions. A larger number of adults oviposit at the beginning of the rainy season. Egg development lasts 6–7 months and hatching occurs at the beginning of the dry season. There are usually six hopper instars and their development lasts about 100 days. A smaller number of adults oviposit at the end of the rainy season and their eggs hatch in the second half of the dry season, the duration of the development in both populations is similar (COPR, 1982).

Eggs are laid singly, but more frequently in clusters and egg fields, a thousand or so pairs aggregating during oviposition. Forty-one such sites examined in Nigeria averaged 618 egg pods each (Page and McCaffery, 1979). Such egg fields are often located along the edge of the fields in fallows, or along the margins of the roads. Hatching may be spread over two months as is the appearance of all subsequent life stages.

Following hatching, young nymphs remain together and often form dense, rather ostentatious, clusters. This behaviour is common in aposematic Pyrgomorphidae, probably because the repugnatorial effect is intensified in large numbers. This effect, which has earned 'le criquet puant' its name, is produced by the emission of an unpleasant smelling liquid from a gland on the back of the first abdominal segment. During the early instars the nymphs remain in the original habitat, often grouped, but the older nymphs and adults are less markedly gregarious and much more mobile and soon spread to adjacent vegetation and crops. It is at this time that they become harmful and the damage done is often severe, as the insects tend to feed selectively, preferring flowers and tender terminal shoots of such plants as citrus and coffee. Relatively few individuals can cause loss of yield and even long-term degradation and destruction of the plant.

There are many reports of damage by this pest, and *The Locust and Grasshopper Agricultural Manual* (COPR, 1982) lists over fifty cultivated plants attacked, particularly plantation crops such as banana, cassava, citrus, coffee and cotton.

The recent history of this pest in the Côte D'Ivoire is particularly noteworthy (Popov, 1979; Castel, 1980). Here *Z. variegatus* has long been known as a minor pest in gardens and crops, occasionally requiring small control operations (A. Mallamaire, personal communication). Its dramatic and disastrous expansion during 1975–1979 can be ascribed to two factors:

poor rains during 1974–1978, which had an adverse effect on the natural control agent, the fungus *Entomophthora grylli* and so favoured multiplication of *Zonocerus* (Page, 1978);

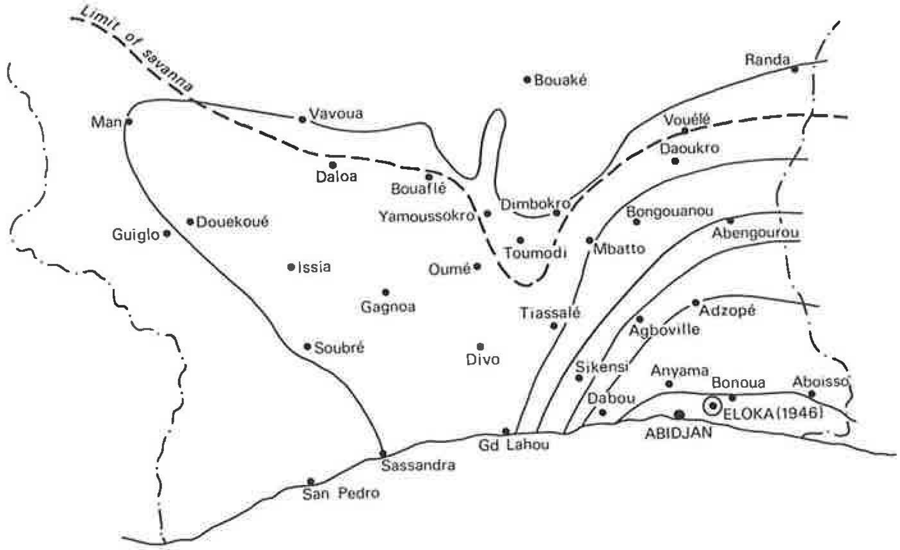
the rapid spread of the weeds *Solanum verbascifolium* and *Eupatorium odoratum* during the last decade, following large-scale deforestation for agricultural expansion, chiefly coffee plantations.

The altered agroecosystem greatly favoured *Zonocerus*, which found an excellent food/shelter host plant in *Eupatorium*, a plant introduced in 1946 into coffee plantations as a shelter plant and then, during the 1970s spread to become a principal weed problem. The forest clearings and fallows which became invaded by this weed soon became major habitats and source areas for *Zonocerus* infestations.

The dramatic spread of *Eupatorium* was rapidly followed by that of *Zonocerus*, which significantly progressed in an analogous manner from the southeastern corner near Abidjan, where *Eupatorium* was first introduced, north westwards to cover practically the whole of the forest zone by 1979 (Figure 24).

Figure 24

The spread of *Eupatorium odoratum* in the Côte D'Ivoire during 1950–1979



From Castel (1980)

It was only the combined effect of large-scale control operations and the eventual return of normal rainfall that brought a decline in the scale of the attack. The situation, however, remains potentially serious, since future spells of dry weather are likely to lead to recurrences of outbreaks.

COMPLEX IX

The agroecosystems affected by this complex are located in the so-called Sahelo-Saharan zone (Zolotarevsky and Murat, 1938), which forms a transition between the Sahel and the Sahara. Although drier than the Sahel, sufficient rain water is able to collect to produce pastures and allow cultivation by run-off and irrigation. The principal areas concerned are the Adrar and the Tagant systems in Mauritania, the Adrar des Iforhas in Mali and Aïr in Niger.

The importance of the acridid pests can be readily assessed in relation to the two principal ecotypes of this zone: the natural, or the desert pastures, which depend on run-off and drainage, and the cultivations, which also include the oasis type, relying on irrigation from wells fed from a water table.

The Desert Locust occurs here and the desert pastures in the southern borderlands of the Sahara constitute some of its principal recession breeding and outbreak areas. During outbreaks and plagues it is by far the most important pest species and has at times brought devastation to the Saharan oases and crops raised in the flood-fed graras of the Mauritanian Adrar.

The Desert Locust shares its habitat with a number of grasshopper species, some indigenous, but most widespread. Among the relatively few indigenous species of the Sahelo-Saharan zone probably the most important economically is *Oedaleus johnstoni* which, often in association with other species (Appendix 3), has on occasions (1975, 1976 1978, 1982) been responsible for serious damage to the annual pastures in the valleys of the Adrar des Iforhas, which are the livelihood of the Tuareg tribesmen. *O. johnstoni* is bulkier and less mobile than *O. senegalensis*, but is similar in that, on occasions, it aggregates in bands and swarms and may fly from one wadi to the next. Its major populations, however, have not been recorded south of the latitude of Gao.

Other desert species, some of which penetrate southwards to the Sahel, are minor pests individually, although in aggregate they can contribute to the damage. The principal ones belong to the terricolous genera *Sphingonotus* and *Acrotylus*, the graminicolous *Ochrilidia* and the herbicolous *Pyrgomorpha* and *Heteracris*. In addition to these, some typically Sahelian species reach the desert zone at the limit of their migrations, foremost amongst them *O. senegalensis* and *Aiolopus simulatrix*. Both of these can at times cause damage to crops and pastures. Among the locusts, *Locusta* has been recorded in the annual grassland habitats in Adrar des Iforhas, where it is reported to have contributed to the damage done by *O. johnstoni* and *A. simulatrix* (Appendix 3). In addition, *Anacridium melanorhodon* adults have been occasionally seen in Desert Locust habitats in Tamesna (G. B. Popov, personal observations). Even such hygrotypic Sahelo-Sudanian species as *Hieroglyphus daganensis* may sometimes be found breeding in localised humid sites in this zone, for instance in oued Eloudj in Adrar des Iforhas in 1976, but such occurrences are of no economic importance.

Grasshopper species of *Pyrgomorpha, Chrotogonus, Heteracris, Aiolopus, Acrotylus, Sphingonotus* occur in the Saharan oases where they are minor pests very similar to those of complex VII (p. 46). *Poekilocerus bufonius hieroglyphicus* (Klug), the large pyrgomorphid grasshopper usually associated with *Calotropis procera* or other asclepiads like *Pergularia tomentosa* can at times be very common. It has occasionally been seen in numbers on migration, but appears to be of no economic importance.

GENERAL CONSIDERATIONS

The economic importance of the principal and the best studied species, *Oedaleus senegalensis* was assessed on page 29. Such assessments are even more imprecise for the other species as they are less well known and usually occur in complexes so that it is difficult to attribute the extent of damage to the individual species and usually no attempt is made to do so. Even in the case of *O. senegalensis* the damage that was attributed to it had often had some contribution from other species sharing its habitat such as *Diabolocatantops axillaris, Cryptocatantops haemorrhoidalis, Acrotylus* spp., *Pyrgomorpha* spp. and others. In their turn, because of their mobility, populations of *O. senegalensis* often trespass into other ecosystems outside their own and contribute to the damage done by the other species.

The situation is thus a complex one but the following general considerations apply.

1. Between them, locusts and grasshoppers occur in practically all the major ecosystems of the Sahel and Sudan and may attack virtually every crop and cultivated plant except a few unpalatable species such as neem (*Azadirachta indica*) (Bhatia and Sikka, 1957).

2. Many grasshopper species have catholic tastes and attack a wide range of crops, but some, like *O. senegalensis, Aiolopus simulatrix* and *Hieroglyphus daganensis* are predominantly graminivorous and so are particularly serious pests of cereal subsistence crops.

3. The spatio-temporal incidence of attacks is subject to great variation, but according to available records there has been some grasshopper damage in the Sahelo-Sudanian zones every year since 1965. This was the case even during the Sahelian drought in the early 1970s.

4. There are occasionally serious large-scale outbreaks in the form of plagues, which lead to serious deficiencies in national cereal production and to complete devastation of crops and great hardship locally (p. 3).

5. The forecasting of such outbreaks has the same difficulties and limitations as forecasting the Sahelian weather and rainfall, which is the prime governing factor. The mechanics are not properly understood and need further study. Probably because of the biological and ecological differences,

particular events may produce different responses in different species in terms of the timing and scale of the outbreaks.

6. Some species are both resistant to drought and mobile and can effectively minimise the adverse effects of droughts, and do so probably more efficiently than many of their natural enemies. The effects of droughts could result in concentrations of their populations in areas where conditions are less extreme. Given their high reproductive potential, adequate rainfall following periods of drought, would enable rapid multiplication of grasshoppers ahead of their natural enemies and so lead to outbreaks. The years 1974–1975 following the Sahelian drought are a dramatic pan-Sahelian example although there have since been other examples of outbreaks on a more limited scale in 1977, 1978 and 1982.

The data suggest that within the framework of this general variability, there are specific areas within the Sahel that are subject to grasshopper attacks more frequently and heavily than others. The major source of available information on this are the OCLALAV reports that span a 9-year period from 1972–1980 (Appendix 3 and Figure 23). These records are subject to some reservations in that OCLALAV operations have generally been in response to emergency appeals by its member States and thus do not include operations by OICMA, the plant protection services of the member States themselves, various other government or private bodies and the farming community. The operations are inevitably weighted in favour of the more important agricultural areas, often at the expense of the less important and more remote ones.

Allowing for these reservations, the following areas appear to be particularly vulnerable to grasshopper attacks.

1. The whole of the millet-growing area which is subject to attacks of *Oedaleus senegalensis* (pp. 29–35, Figure 25).
Within it, damage has been most frequent in:

Chad: Massaguet - Massakori

Niger: Nguigmi - Diffa
Tanout - Gouré - Zinder - Magaria
Maradi - Tahoua - Birni
(extending to adjacent parts of northern Nigeria)

southwestern Niger and eastern Mali:
Ansongo - Watagouna
the Gourma (under reported), extending south to Gorom-Gorom - Dori area of

Burkina Faso

Mauritania: the southern Hodh extending to Nioro-Nara area of western Mali
southern Trarza/Tagant/Assaka area extending south into

Senegal: western Ferlo/Cap Vert, occasionally reaching

The Gambia.

2. The major river basins.
Grasshopper attacks have been particularly frequent and serious in:

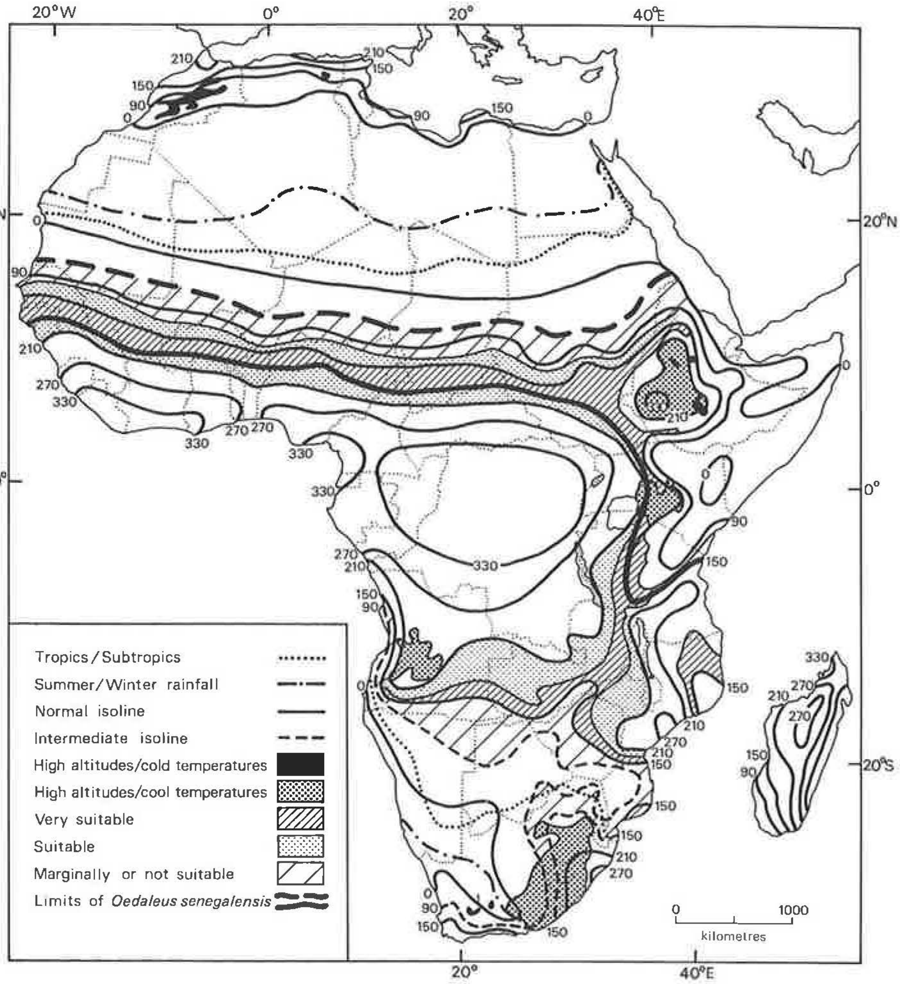
Chad basin: Chad: Kouloudia
North Cameroon Afara - Kousseri - Mora
Pouss-Maga areas
(also the outbreak areas of *Locusta* - under OICMA supervision)

Niger basin: eastern branch of the Niger valley, the Borgou province in Benin and the opposite side, Gaya department in Niger.

Central Niger delta; principal outbreak area of *Locusta* is under OICMA supervision.

Figure 25

Limits of the distribution of *Oedaleus senegalensis* in relation to agroclimatic suitability assessment for rainfed production of millet (*Pennisetum americanum*)



From FAO (1978)

There is little information on this area but grasshopper outbreaks are known from Bambara Maundé.

Senegal basin:

Western Mali (northern tributaries Kolombiné, Wadou, Terekolé, Kirgou, Senegal)

the main valley on both sides in Mauritania and Senegal, particularly the stretch between Bakel and Podor.

The Sine-Saloum and The Gambia.

There are also a number of tributaries and separate valleys and basins, for instance, the Kamadougou on the Nigero-Nigerian border, the Dalols in Niger, the Karakoro and the Gorgols in Mauritania, where grasshoppers are of some importance, but there is little information on these.

For their size, the basins with their much greater water, soil and human resources, are economically the most important. They also have a wider spectrum of ecosystems, crops and crop pest problems including grasshoppers. Moreover, given the mobility of *O. senegalensis*, these areas are also frequently attacked in addition to the millet-growing areas outside them. The importance of the river basins is made abundantly clear from the reports of OCLALAV, which has given much time to their defence (Appendix 3).

Probably, the most important single area is that of Yelimane-Nioro in western Mali. Here the succession of river valleys, providing abundant water and excellent soils, enabling the production of a wide range of flood and rain-fed crops, from rice to maize, sorghum, millet and pulses, virtually all the year round. These same conditions also provide a broad spectrum of excellent habitats where a large and varied grasshopper (and other crop pest) faunas can survive and multiply (G. B. Popov, unpublished data; OSRO surveys). Indeed grasshopper attacks have been recorded here every year since OCLALAV records began.

To sum up, grasshoppers are a chronic pest problem throughout the Sahel. All crops may be attacked, although their vulnerability differs. Some areas have a higher frequency and level of infestation than others. The size of grasshopper populations is subject to large variations principally in response to weather conditions and spatio-temporal variation of rainfall. Their attacks on crops may vary from negligible to total devastation, but some damage occurs practically every year and grasshoppers cause a large proportion of the pre-harvest losses estimated at some 30% throughout the Sahel (p. 29). Given the now chronic shortfalls in food production in much of the Sahel the problem of pest management is one of great importance and urgency.

CONTROL METHODS AND STRATEGIES

The nature of the problem

In West Africa the principal difficulty of grasshopper control is the sheer size of the problem. The main pest species, *Oedaleus senegalensis* alone affects all the potential millet-growing areas, including the associated fallows and wastelands as well as the adjacent pastures, extending beyond them into the more arid zone to the north (Figure 25). Altogether, the affected areas comprise about 70% of the total terrain in the Sahelian and Sudanian zones situated between the 200 and 1000 mm isohyets. The other grasshopper species between them partly overlap with *O. senegalensis* and contribute to the damage it does, and partly affect the drier and the wetter ecosystems including the valuable irrigated crops in major river basins (Figures 26–29).

The nature of the problem is substantially different from that confronted by the locust control organisations, OCLALAV and OICMA, where the habitats and outbreak areas of the Desert and the African Migratory Locusts are much more circumscribed and can be effectively surveyed and controlled by a limited number of specialised and experienced mobile teams. To expect these organisations to ensure, in addition to their normal responsibilities, adequate monitoring and control of *O. senegalensis* and other grasshoppers throughout the vast areas subject to their attacks, is unrealistic. The most that these organisations can be expected to do, and have so far attempted to do, is to assist with spraying operations against particularly dangerous grasshopper infestations (Appendix 3). It is evident that even such limited aid can only be expected if met by adequate compensation and on condition that these extra activities do not in any way jeopardise the organisations' primary responsibility for controlling the locusts. Regrettably these conditions have not always been respected in the past and this extra involvement has effectively contributed to the present decline and loss of control potential of the organisations.

Another serious matter for concern is the fact that all the grasshopper control effort in the Sahel continues to be entirely defensive and is accompanied by an inevitable escalation in the use of insecticides, chiefly through large-scale aerial spraying operations. While it is true that for the foreseeable future chemical control must remain the mainstay of crop protection against insect pests, there is much need for more effective and less costly preventive control strategies. These should be aimed at containing pest outbreaks while minimising the use of insecticides by more

Figure 26

The agroecosystem along the Niger Valley northwest of Malanville, Benin; it is a mosaic of crops, follows, pastures and scrubland followed by savanna and is an excellent environment for many species of grasshoppers

Figure 27

The grasslands along the rivers are an excellent habitat for grasshoppers and also constitute the principal grazing for stock

Figure 28

When grasshoppers consume all the food plants in their habitat they are forced to search for food elsewhere: they have a selective feeding behaviour; while the grasses are stripped of their leaves and reduced to bare stalks, the forbs are scarcely touched

Figure 29

When the populations are large the grasshoppers invade adjacent crops, in this case rice

judicious and timely applications and, whenever possible, by the use of alternative methods of control. In the light of these considerations, some suggestions for the preventive control of grasshoppers are made below.

Preventive control strategies

LONG-TERM APPROACH

The basis for a rational preventive control strategy depends on effective monitoring by systematic survey and assessment of the pest populations, with the objective of forecasting, locating, delimiting and, in due course, destroying any potentially dangerous populations before any serious damage has occurred. In the case of *O. senegalensis*, given its mobility and the fact that economically important populations may develop sporadically practically anywhere within its vast distribution area (p.14), monitoring has considerable, although not insuperable problems.

Much is already known of the population dynamics of this pest and there is a model that describes them (Launois, 1978). Recently, through the combined action of GERDAT, CILSS and AGRHYMET (Development Centre for Agrometeorology and Applied Hydro-Meteorology), several sophisticated programmes based on the model have been prepared (Launois, 1983). On the basis of these it is possible to create a monitoring and forecasting service for *O. senegalensis* provided an adequate network of strategically situated field observation stations and a data processing centre, preferably attached to AGRHYMET, can be established as part of the service.

Unfortunately, the present embryonic state of the national plant protection services, and the difficulties of the regional control organisations in the Sahel are such that without adequate strengthening, they cannot be expected to provide adequate monitoring to meet the requirements of the model. Likewise, the present structure of AGRHYMET needs to be strengthened, both in equipment and manpower, to enable it to take on the additional data-processing service.

Such an investment may appear to be over-ambitious for monitoring *O. senegalensis* alone but it is less daunting if considered within the context of a long-term objective for creating subregional monitoring services for all migrant crop pests in the Sahel. *O. senegalensis* is probably the best initial choice for spearheading the approach, which could later be followed by addition of other species of grasshoppers, then noctuid moths and other important pests. Additional closely correlated studies will be required to fill in the gaps in our knowledge and ensure the best development and realisation of the programme.

Such a programme appears to be within the aims and objectives of the regional studies of the CILSS/USAID Sahelian Integrated Pest Control Project. Indeed proposals along similar and more ambitious lines for subregional research and development have been made under the various proposals for the project, but regrettably so far have not materialised.

Another promising line of development for facilitating the monitoring of *O. senegalensis* and other species of grasshoppers and crop pests could be through utilisation of remote sensing imagery. Such a method has already been applied with considerable success in Australia for monitoring the dynamics of the Australian Plague Locust *Chortoicetes terminifera* (Walker) (Symmons and McCulloch, 1980; Hunter, McCulloch and Wright, 1981; Hunter, 1981). It was found that certain physiological phenomena and the related behaviour, notably building-up of fat reserves, onset of migratory flight, maturation and oviposition, are associated with the development and phenology of certain food plants. These food plants are important constituents of the habitats of the locust and their phenology is readily discernible from satellite imagery. The imagery can thus be used for forecasting the dynamics of locust populations. Furthermore, since livestock management services are already monitoring and assessing the value of grazing in the pastures that also include the locust outbreak areas, their figures can be used directly for locust monitoring. There is reason to hope that such application could be possible in the Sahel for *O. senegalensis* and possibly some other crop pests, but this will obviously need prior research and development.

A parallel line of investigation as an adjunct to other methods of monitoring, but also valuable in its own right, is the systematic gathering and analysis of data. Information on such economically important aspects as spatio-temporal distribution of grasshoppers, the species involved, an assessment of their numbers, crops damaged, level and nature of attack are abysmally inadequate and in most cases estimates are little more than inspired guesswork. Yet such statistics are fundamental to the planning of rational control operations.

Much useful data may already exist in published works, but much more is to be found in the files of regional and national plant protection and agricultural services. Such data, extracted, analysed and mapped, could provide much useful information. Further information could be gathered by means of questionnaires sent to agricultural and plant protection officers to be answered from their own observations and by interrogating the farmers in their sector, who are generally knowledgeable about the major pests in their crops. Such questionnaires, regularly submitted fortnightly or monthly to an appropriate information centre, and their analysis, will gradually provide a useful and reliable body of data as a foundation for pest monitoring and forecasts. Special surveys and fact-finding investigations can be carried out by appropriate technical personnel for particular cases and areas.

SHORT-TERM APPROACH

Meanwhile a parallel and, in many respects, a related line of approach towards more effective control of grasshoppers and other crop pests is strengthening and training the national agricultural extension and plant protection services, coupled with measures to ensure closer cooperation and participation of the farming community. The basic concept is that the plant protection services through the network of plant protection and agricultural agents should ensure:

the general planning and coordination of survey and control operations;

the provision of the necessary supervision and guidance, together with a supply of insecticides and control equipment to the farmers, who for their part should ensure best possible surveillance and control of crops in the land under their responsibility and through their village heads provide information on the general pest situation to the agricultural officers attached to their area;

in addition, the plant protection service should possess control teams to intervene in areas outside the responsibility of the farmers;

in emergencies help should be available from reserve control units, perhaps maintained at district, provincial, or national centres, and eventually, from the regional locust control organisations;

the latter, with their greater experience and special resources, could provide further guidance and help by training, planning of operations and liaison on a sub-regional and regional scale.

It is evident that efficient planning and coordination of effort are needed all along the chain of command, but the fundamental links in the chain are the plant protection and the agricultural extension officers on whom depend the actual field operations. Every endeavour should be made to give them the best possible training and subsequently to ensure all necessary guidance and support.

The ease and readiness with which such a structure could be put into effect will vary between the Sahelian countries. Some, for example, The Gambia, have already gone some way in creating and deploying well-trained and well-equipped plant protection teams in strategic positions throughout the country. Enquiries have been made by the Gambian Plant Protection Service to gauge the awareness and response of the farmers and then educational programmes have been conducted for them. Here the farmers, with the help of Government guidance and subsidies, already take an active part in protecting their crops from pest attacks.

Some other countries, however, have been reluctant to decentralise their plant protection services; the work is limited and falls short of what is really needed. The more privileged farmers have come to expect their crops to be protected for them, while the less fortunate ones probably never get any help. Emergency situations coupled with crop damage are frequent, with inevitable pressure on OCLALAV and OICMA.

Procedure and methods

OEDALEUS SENEGALENSIS

The procedure and methods for controlling grasshoppers vary in different areas depending on local conditions and the phenology of the pests and the crops concerned. The best time for carrying out control operations against *O. senegalensis* is at the beginning of the rainy season, with the first hatchlings of the G1 generation as the main target. The reasons for this are:

- the majority of oviposition sites are associated with shifting millet cultivations and are located either inside the fields, or in neighbouring fallows and pastures;
- the close association of laying with crop areas heightens their vulnerability; the danger is particularly great when, as often happens, millet is planted with the early rains and the emergence of nymphs then coincides with the particularly vulnerable seedling stage;
- the hatchlings are highly mobile and capable of attacking seedlings within hours of emergence;
- generally the centre of gravity of G1 populations is in the southern part of the distribution area which has a high human population and good communications which facilitate monitoring and control;
- early control will generally contribute effectively to reducing attacks later in the season;
- the logistics of surveys and preparatory operations are generally easier during the dry season;
- control operations are more effective and easier to carry out earlier in the rainy season, when not hampered by wet sticky ground and dense vegetation (Figures 30 and 31).

The prerequisite to effective early monsoon control is the location of the principal oviposition sites at the end of the preceding monsoon. There are two complementary lines of approach, i.e., monitoring the end of season adult populations, and survey and location of oviposition sites.

Figure 30

The working conditions in the Niger Valley at the start of the monsoon rains are easier than late on in the season as the vegetation has not had time to develop fully and the ground has not yet become impassable to vehicles

Figure 31

At the height of the monsoon season ground teams have much difficulty in coping with sodden, muddy ground and dense vegetation; this is both an obstacle to the operators and an effective screen for the grasshoppers

Monitoring of the end of season adult populations

This is a desirable operation in its own right for these populations are at the peak of their numbers and mobility and thus present the greatest immediate danger to any standing crops. Soon after fledging of the end of monsoon generation (G3), usually from about mid-September, the adults begin to move south in the wake of the retreating ITCZ. Crops, particularly ripening millet in the milky grain stage, are subject to attacks, which can be catastrophic (pp.29-35).

In the absence of proper monitoring, especially of some of the major source areas of the G2 and G3 populations, such as the Gourma or parts of southeastern Mauritania or Chad, there is often little or no information on the size and the distribution of these populations. Therefore, every effort must be made to mobilise help from all possible quarters to ensure timely detection required for effective control. Agricultural officers should make an extra effort to survey their areas extensively and should alert the farmers to look out for, and report, the grasshoppers. Whenever possible, observations should be supplemented by the use of light traps. Light trap catches are influenced by such extrinsic factors as wind, rain, moonlight, as well as intrinsic ones such as the strength and the quality of the light source, its exposure, orientation, etc. Consequently, the use of light traps as a means of monitoring the dynamics of grasshopper populations has been subject to criticism (see notably Jago, 1983).

Nevertheless, while the exact assessment of light-trap catches is subject to difficulties and ambiguities, the usefulness of light traps as a crude measure of flight activity, should not be dismissed lightly. Thus, during the 1978 season, when the COPR/OCLALAV project stations were monitored closely, there was a close correlation between major increases in light-trap catches and the contemporaneous increases in the field populations at the same stations (Fishpool, 1982). Similarly, using the figures of Jago (1983) himself for the records at Daoga station in 1978 (Figure 32), there appears to be a closer correlation between the measure of flight activity as assessed by radar observations and light-trap catches, than with field counts at the site. An even closer correlation between radar counts and light-trap catches was recorded by Schaefer (1976) in the Sudan for *Aiolopus simulatrix* (p.42).

Light traps are not regarded as precise instruments but are a supplement to surveys and other forms of field monitoring, being particularly useful for detecting sudden major increases in grasshopper numbers. It is in this capacity that they are in general use in Australia (*The Australian Plague Locust Commission Manual*, 1979) and it is in this capacity that they are recommended for monitoring *O. senegalensis* in the Sahel.

Given an electric power source (mains or a generator) the light traps are cheap, simple and easy to operate. The model of the light trap recommended for general use was designed by R. A. Farrow of CSIRO (see Appendix 2).

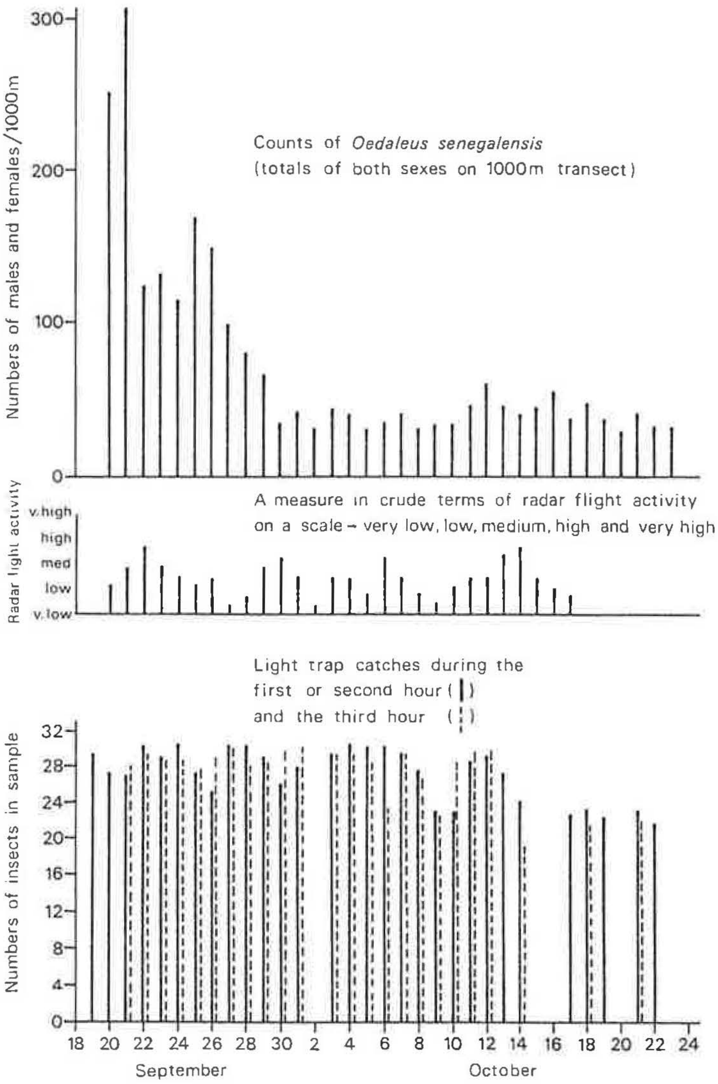
During their displacement the adults mature and begin to lay. The incidence of laying in particular needs to be recorded, especially when numbers and densities are high. Farmers should be instructed to mark the laying sites they observe on their land and to report them. It should be borne in mind that much of the laying may occur at night.

Survey and location of oviposition sites

In addition to the sites recorded at the time of egg laying, the presence of egg pods can be detected by subsequent surveys (Popov, 1980b). In general, the area to be surveyed is that where grasshoppers were known or suspected of having been numerous at the end of the monsoon, and where the ecological conditions are typical for the species (pp.20-23).

Figure 32

Records of *Oedaleus senegalensis* at the Daoga study site in the Niger valley during 18 September to 24 October 1978



Modified after Jago (1983)

Figure 33

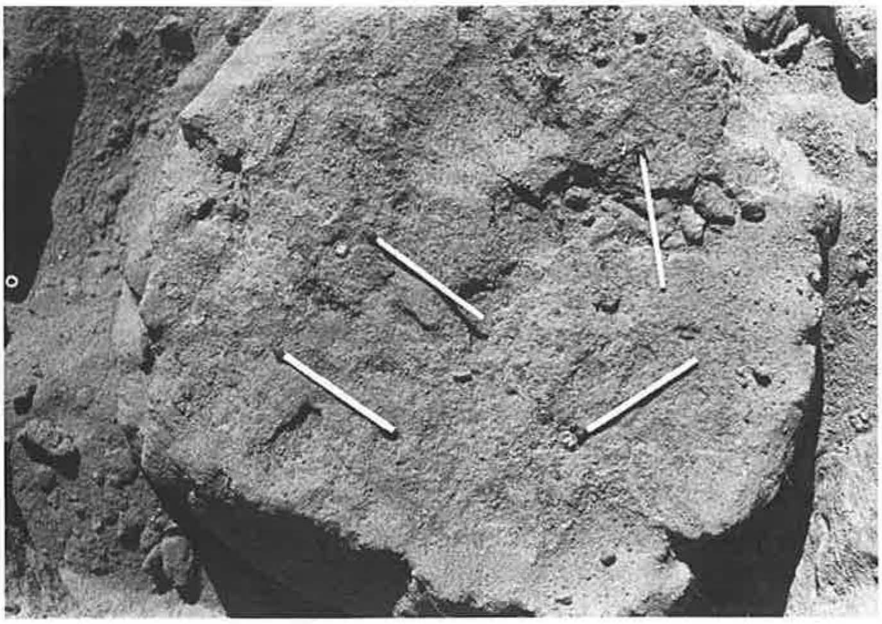
The presence of faeces (frass) at the site is a reliable indicator of the recent presence of grasshoppers, while the abundance and size of the frass pellets are a rough guide to their number and state of development

Figure 34

A thin layer, about 1-2 cm, of the soil surface is carefully scraped away to reveal the egg pods which are then marked with small sticks; the sampling is done along traverses or squares, measured in square metres

Figure 35

The egg pods, deposited more or less vertically in the soil, are revealed when the froth plug, the upper part of the egg pod filled with whitish frothy substance, is severed during scraping



In such areas, a succession of sites is examined along a transect, for instance, a track between two villages. The sites chosen are those where laying was observed or reported, and otherwise where faecal pellets (frass) is present in abundance (Figure 33). This does not guarantee the discovery of egg pods, since presence of frass is not proof of laying, but it will rapidly eliminate unlikely sites, those of low ecological value and those where the grasshoppers were absent or in numbers too low to be important.

The next stage consists of scraping and examining the soil to detect the presence of egg pods, their numbers, state of development, mortality and survival (Figures 34 and 35). This is the most laborious part of sampling and when populations are low and laying sparse even a large effort may find disappointingly small numbers of egg pods. Nevertheless this does not invalidate the method, or the value of the survey. The objective is to locate the major high-density concentrations of egg pods, which are economically important, so it follows that if laying is generally at a low density, its economic importance is small. It will, however, be prudent in planning control operations to sample extensively and thoroughly before reaching the final conclusion. The aggregate size of samples must be in the order of hundreds of square metres to be meaningful. The pattern and distribution of samples will be largely determined by the distribution of the end-of-season adults, and the grasshopper situation should be scrutinised closely as a preliminary to planning the survey of egg pod distribution. If the sampling has been sufficiently extensive and representative, the identified sites of denser laying will be a good guide to the location of the heavier early infestations at the beginning of monsoon rains. Once the principal laying areas have been located, the necessary planning and deployment of control forces can be conducted at leisure in anticipation of the rains.

The scale of hopper infestations will be influenced by the mortality and survival of the eggs, more than half of which could be destroyed by natural enemies during the period of incubation (pp.23-26). Even more important, however, is the effect of early rainfall. The eggs survive the dry season in facultative quiescence, or more usually of obligate diapause, but egg diapause is largely over by early March and a majority of eggs will develop and hatch following rains in excess of 25–30 mm. Since such falls of rain also encourage farmers to plant their millet this can result in an early and disastrous attack on the vulnerable seedlings.

These attacks are frequent because much oviposition occurs in potential millet-growing areas. The young nymphs are highly mobile. They can traverse large expanses of bare ground, or ground devoid of suitable food plants, more than 100 m from their hatching sites, within the first 48–72 h of their life (e.g. Dokimana, March 1978).

Such a situation calls for preventive control and provided egg-laying sites are located during the earlier surveys, effective control can be organised at an early stage. Given the relatively open nature of the terrain at the end of the dry season and the vulnerability of young nymphs, conditions for control are most favourable and hand dusting with appropriate chemicals such as propoxur (Figure 36) is the recommended method because:

the dusts are readily available in the Sahelian countries;

they are cheap, easily transported and can be distributed and stocked at village centres in areas affected by *O. senegalensis*;

they are relatively safe to man and domestic animals and there are thus no legal restrictions on their use;

they are not markedly phytotoxic and side effects like tainting do not arise at the early crop growing stage;

dusts are simple to use and can be broadcast by using dusting bags or thrown by hand (when preferably mixed in the proportion of one part dust, to 3-5 parts sand) and so can be applied by farmers themselves, after initial demonstration and instructions from plant protection/agricultural officers, and monitors;

dusts are persistent for several days and so can be applied several days before hatching, being particularly effective against emerging hatchlings.

Figure 36

Dusting with propoxur applied from dusting bags is an effective and inexpensive control method

Conversely other methods of control of egg fields, e.g. by mechanical labouring of land where oviposition has occurred, are not recommended. The eggs are remarkably resistant to desiccation and many will certainly survive the treatment. There is thus unlikely to be a substantial reduction in the number of hatchlings and the survivors will need practically the same amount of control. The reward of a few eggs killed is really an insufficient compensation for the labour and the additional hazard of accelerated erosion through unnecessary ploughing.

Action by the farmers needs to be strengthened by control operations carried out by plant protection service teams using knapsack dusters and sprayers and where appropriate, exhaust nozzle sprayers. This support is particularly necessary against infestations in areas away from crops, where the farmers will have less incentive for work. Here, application of persistent insecticides such as dieldrin, to create protective barriers for safeguarding crops might be conducted under strictly controlled conditions by trained operators to ensure elimination of all hazard to humans, grazing animals and crops.

Early monsoon infestations tend to be patchy and more suited to ground control operations. Exceptionally heavy widespread infestations such as those in 1974 and 1975, justify aerial spraying.

As a means of minimising crop losses some cultural control methods could be beneficial:

avoid planting close to sites where heavy laying is known to have taken place earlier;

or delay sowing in such sites until the annual vegetation has developed and provides alternative habitats, thus to some extent safeguarding the crops;

harvest as much as possible as soon as the grasshoppers pose a threat, particularly in those cases where the grasshoppers have not begun their attacks until the crops are on the point of maturity (Cheke, Fishpool and Forrest, 1980);

Saraiva (1962) advocated breaking up unproductive vegetation and piling it up into mounds to attract grasshoppers, where they could then be destroyed mechanically, or by fire or poisoning;

a different line of approach is the use of resistant crop varieties, for example, it is reported from India that the heads of a long-eared strain of millet were resistant to attack by *O. senegalensis* (Bhatia and Ahluwalia, 1967).

Control during mid- and late-monsoon breeding

A successful early-monsoon campaign will go some way towards protecting the crops and reducing grasshopper populations, but it is unlikely to eliminate them completely since a sizeable proportion, particularly of those away from the crops, is likely to remain uncontrolled. These escapes will fledge, migrate and breed and in due course become a hazard to crops.

The initial threat to the seedlings eases later in the season as the millet plants increase in size and can withstand considerable amounts of leaf damage. Also the pressure on the crops tends to diminish as the grasshoppers turn to alternate sources of food with the development of the annual vegetation.

A second, and occasionally serious, risk period is when the crops are in the milky grain stage of growth, particularly when this coincides with the period when a large part of the adult population is in the post-teneral, pre-vitellogenesis stage, when they feed preferentially on millet heads. This coincidence is most likely towards the end of the monsoon, when major displacements occur in the wake of the retreating monsoon (p.26). The heaviest damage recorded was during this period and crops should be protected by all available means. As always, close monitoring of the situation, identifying areas of greatest potential danger, as well as target areas for control operations, are an essential prelude to the success of the control operations. There is much room for the CILSS/FAO/USAID integrated control project for helping to develop the necessary monitoring and preventive control against this major Sahelian pest both at national and at regional levels.

Other species

The general principles of control methods and strategies discussed for *Oedaleus senegalensis* are also applicable to other species, but with appropriate modifications and adjustments to allow for their particular biological and ecological characteristics. As a rule each major species or complex species should be considered in its own right in planning operations and selecting the most suitable method. For best results this should be done with the advice and guidance of competent acridologists and integrated pest management specialists.

Baiting

Control by poisoned bait tends to be regarded as old fashioned, inefficient and costly on the grounds that the weight/quantity of the product that needs to be applied per unit area is tens if not hundreds of times that of the more economical and efficient ultra-low-volume spray formulations. Yet in some situations it can be more effective that other methods. One particular case is the control of overwintering populations of *Aiolopus simulatrix* adults when they begin to emerge in advance of the rains (p.41). The grasshoppers are shy, emergence is protracted and many individuals remain hidden, or seek refuge in cracks on the least disturbance. In the absence of green vegetation, however, they are strongly attracted to bait and good kills are achieved in due course. Baiting is also effective against grasshoppers in complex VII and partly VIII (Figure 21), particularly for protecting seedlings of off-season vegetables, and generally all seedlings early in the rainy season, before the natural vegetation has developed.

Mechanical control

This is another old-fashioned method and probably largely discontinued except perhaps locally by farmers, on their own initiative. Elsewhere in this report (p.61), a recommendation was made against ploughing for controlling egg fields of *O. senegalensis* as likely to be more wasteful in terms of labour, than useful in killing the eggs which are resistant to desiccation. This argument probably applies to most species with prolonged development, with the notable exception of *Zonocerus variegatus*. Much of the egg laying in this species occurs in dense groups or small egg fields of 1000 egg pods at a time. These are easily detected by the accumulation of insects at the time of laying. The eggs are apparently very sensitive to desiccation and their destruction through exposure could be attempted by cutting down the vegetation sheltering the egg field, or digging up the egg pods or both (Page 1978, Castel, 1980). Destruction of egg pods could also be an effective measure in controlling *Kraussaria angulifera*, which oviposits in dense clusters at the base of shrubs and trees.

Biological control

Acridids have a wide range of natural enemies (Greathead, 1963), and some of those that affect *O. senegalensis* and *Z. variegatus* are briefly mentioned on pp.23-26 and p.47, respectively. Next to the climatic factors these are probably the principal controlling agents of grasshopper numbers. Yet the outlook for the application of biological control methods under Sahelian conditions does not appear promising.

The common pathogenic fungus *Entomophthora gryllii* can be an important factor in reducing populations, notably of *Z. variegatus* in the forest zone (p.47). It is also present in the Sahel and outbreaks have been recorded locally on rare occasions, for instance, among the infestation of *Kraussaria angulifera* near Potiskum, northern Nigeria, in September 1974 (G. B. Popov, personal observation). The fungus, however, is very sensitive to climatic conditions (p.47) and therefore its effectiveness in grasshopper population control in the Sahel is unlikely to be great.

A recent development in the USA has indicated that *Nosema locustae*, a protozoan, has considerable potential for the economic control of grasshoppers in pasture lands (Henry, 1978). Its application in Argentina against range grasshoppers has been encouraging in reducing populations by up to 60% (R. A. Ronderos, personal communication), but recent trials against *O. senegalensis* in Senegal have been inconclusive (L. D. C. Fishpool, personal communication).

As regards insect enemies, given the uniform environmental conditions in the Sahel it is probable that the more active and effective species are widespread, their numbers in a natural balance and unlikely to be easily increased by manipulation. It is probable that if any species is rare or absent from parts of the Sahel, this is for a reason which is likely to be an effective barrier to their introduction. For instance the calliphorid fly *Stomorhina lunata* (Fabr.) is an important egg predator of *Schistocerca gregaria* east of the Nile but it is not known west of it (Greathead, 1962). Yet it is most unlikely that the Nile could be a barrier to this fly, which is an active flier. The reason for its absence is more likely to be a climatic one.

There seems to be rather more hope for successful introduction to Cape Verde Islands, which due to their distance from the mainland, may not have been colonised by all the Sahelian acridid predators and parasites that could survive there. If so, the introduction of such strict acridophagous species as *Systoechus* spp., *Xeramoeba oophaga* and possibly *Blaesoxipha* spp. could help in reducing grasshopper numbers.

Otherwise one way to further the effect of natural enemies is by minimising their losses, for instance, by judicious timing of spraying and dusting control operations against crop pests. Possibly in some cases, provision of food and/or shelter plants could be beneficial to natural enemies and help to increase their numbers.

Some conflict of interests is unfortunately inevitable. For instance, the meloid *Mylabris pallipes* is an important predator of grasshopper eggs, but also a pest of flowering bulrush millet. The control of *Mylabris* as a pest is likely to lead to increases in grasshopper numbers. Which is a better choice to control or not to control? The problem is not simple.

Ecological control

As Uvarov (1957) pointed out, locust and grasshopper problems are fundamentally ecological and many have been created or aggravated by man. There are numerous examples of outbreaks following agricultural development. Those of *Locusta* in the Gash valley of the Sudan, or the Hippo valley of Zimbabwe are classic examples. Another, more recent one, is the *Zonocerus* outbreak in the Côte D'Ivoire (p.47). More recent still is the example of Sarir in the Libyan Desert at the opposite extreme of the climatic range. Here, because of adequate funds, modern technology, available subsoil water and basically fertile desert soil, a major irrigation scheme came into existence. Initially, while only a single winter crop, barley, and wheat were grown, there were few problems; the introduction of a summer crop, forage sorghum, closed the gap and provided excellent survival and breeding conditions around the year for *Locusta migratoria* and several species of grasshoppers. These soon multiplied to catastrophic proportions, requiring major control operations (Duranton *et al.*, 1983). It is obvious that agricultural development will not be stopped because of grasshoppers, or other pests, but many of the later complications could probably be avoided, minimised or at least anticipated, by better planning and land management.

Generally such grasshopper outbreaks in virgin land developments soon decline to a lower level of pest activity (probably largely as a consequence of gradual colonisation by their natural enemies). The pest situation then shows periodical less-marked fluctuations, probably principally governed by climatic factors. Such an equilibrium can be further altered by environmental changes and agricultural practices. There are some outstanding examples: the outbreak area of *L. migratoria* in the Danube delta ceased to be one, once the marshes were drained and turned to agriculture. The last few decades have seen a general decline in the economic importance of the Moroccan Locust (*Dociostaurus maroccanus* (Thun.)) following agricultural development and an increase in areas subject to intensive grazing (Uvarov, 1977).

The changes following agricultural practices in the Sahel and elsewhere in western Africa could also be at times beneficial. For instance serious outbreaks of *Locusta* occurred in the Marte-Mintaur area in Borno state of Nigeria, in 1969 and 1970 (Popov, 1972), but not since the grasslands in that area were cultivated. On this basis it is probable that major agricultural developments in the Central Niger delta would change its status radically as a major outbreak area of *Locusta*. It is probably also true that eradication of the weed *Eupatorium odoratum* may largely eliminate the problem of *Zonocerus* in the Côte D'Ivoire. Pest problems alone, however, are insufficient to motivate such major schemes; one must await other and stronger incentives.

There are, however, some simple and inexpensive cultural practices that could be beneficial in protecting the crops and/or diminshing grasshopper infestations.

Management of source areas

Practically no grasshoppers inhabit intensively cultivated fields, but many breed in fallows, land abandoned after cultivation and natural plant communities, woodlands, grasslands, steppes and prairies (Figure 26). The problem of monitoring areas remote from crops has been considered in relation to *O. senegalensis* (p.61). The problem in the flood/irrigated areas is proportionately more restricted since these are more densely settled and intensely cultivated. It should, therefore, be easier to obtain a positive response from the farming community for the kind of action recommended for *O. senegalensis*.

Farmers should be taught to recognise and identify the source areas where the grasshoppers that affect their crops may originate. While the farmers might be understandably reluctant to monitor and control source areas remote from their crops, they are likely to be more cooperative when they are in the vicinity.

Management of the surrounds of cultivations

Much of the damage to crops is peripheral. It occurs wherever the fields are in contact with the fallows and waste-lands. The insects tend to accumulate along the margins, and from this shelter, forage and feed on the crops. The aggregate damage over a period of time can be serious. It can be reduced in several ways:

grouping of fields - one large field is proportionately less vulnerable than several small ones;

clearing of margins - grasshoppers are reluctant to venture into bare areas away from their shelter; when this is not possible, spraying of margins with persistent insecticides could create an effective barrier (to be done only by competent operators);

planting of less attractive crops next to the fallows;

monitoring the fallows and controlling grasshoppers when they reach danger levels, i.e. densities of tens or more per square metre and are beginning to cause appreciable damage to the vegetation of their habitat.

Weeding

In general, clean-weeded fields are less attractive to grasshoppers than unweeded ones. Judgement is necessary, however, for early in the growing season it might be advisable to delay weeding to protect seedlings (p.61). Unproductive wastelands choked with grazing resistant plants that are worthless as pasture are undesirable also because they are often a source of grasshopper infestations. This is an extra reason for their elimination, particularly when they are situated close to crops. This comment is especially relevant to such weed/grasshopper associations as *Eupatorium/ Zonocerus*. (p.47).

Use of repellants

The application of such repellants as a decoction of neem kernels (*Azadirachta indica*) in water, in special cases to particularly valuable crops, could help to protect them against grasshopper and locust attacks.

Introduction of resistant varieties

The comments made in relation to *O. senegalensis* (p.61) are in general relevant to all species.

Chemical control

The development of the above and other alternative methods of control must be the main objective towards integrated pest management in the Sahel and should help to reduce incidence of pests and dependence on pesticides. For the foreseeable future however the use of the latter is likely to remain the only effective way of controlling heavy infestations and major outbreaks. This line of protection should not be underrated; chemical control is a powerful tool that requires expert, judicious handling to minimise the undesirable hazards and side-effects inherent in its use. OCLALAV is one major source of such much needed expertise and control potential in the Sahel. Its record of control operations against grasshoppers carried out during the past decade (Appendix 3) bears ample testimony to this fact. While it is right that control of grasshopper pests should be gradually assumed by national plant protection services and the farming community, this transfer and development will require time.

Meanwhile it is imprudent to allow OCLALAV to lose its control potential through lack of support by its member states and the international community. Under the present drought conditions and food shortages in large parts of its territory, the Sahel can ill-afford crop losses due to pest depredations. A major outbreak such as that of 1974–1975 would be a disaster.

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Appendices

APPENDIX 1 RECORDING AND REPORTING FORMS

Meteorological observations

Station Observer Period

Date	Time	Temperature					Soil		Wind		Cloud		Remarks
	GMT	min	max	dry	wet	r.h.%	0	50 cm	direc.	force	amount	type	

Light-trap captures

Station Observer Period

Species	Time	Date																											
		1		2		1		2		1		2		1		2		1		2		1		2		1		2	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀

Oedaleus senegalensis counts at the stations

Station	Observer	Date and time

I. **State of vegetation**

Weather conditions	Temperature (°C)	dry / wet	Soil 0 / −5	Wind F / D	Cloud type	Soil humidity r.h.%

II. **Adults** (Sample number)

Method: 100 × 2 m	1	2	3	4	5
per bush –	1	2	3	4	5
	6	7	8	9	10

Average distance between bushes

Average distance between individual grasshoppers

III. **Nymphs** Average density per hectare

Method: in square metres	1	2	3	4	5
	6	7	8	9	10
	11	12	13	14	15
	16	17	18	19	20
	1	2	3	4	5
per bush	6	7	8	9	10
in 50 sweeps of the net	1	2	3	4	5

Age composition (minimum 50 nymphs) small medium large

IV. **Observations on behaviour**

Displacement
Gregariousness
Copulating
Egg laying
Various (e.g. action of predators, birds, etc.)

Report on damage by *Oedaleus senegalensis* and other species

Environment
Phenology and state of natural vegetation and crops

Part attacked (seedlings, leaves, flowers, heads, etc.)

Degree of damage (percentage estimated)

Extent of infestation (localised, patchy, generalised)

Other species

Stage of development of grasshoppers

Samples

Measures taken:

I. Reporting

II. Control

methods and equipment used
insecticide and quantity used
area treated
results

Comments

Characteristics of samples of adults of *Oedaleus senegalensis*

Station		Observer	

Method of capture	Date	Reference

No.	Sex	Age	Colour of body	WV	RM	FO	OD	RB	FB	Remarks

Key to abbreviations

No: serial number which should agree with that of preserved specimen.

Sex: male ♂ or female ♀.

Age designated as: JJ = very young; soft, freshly moulted insect; J = young immature with colourless hind wings to onset of maturation, wings colourless or light yellow; V = mature insects already laid or not, with or without resorption bodies; VV = old insects with yellow worn wings.

Colour of body: general coloration, greeny brown or green/brown.

WV = Wing wear (this increases with age and flight activity; note extent of wear using scale, 0, 1, 2, 3, 4.

RM = Presence of red mites on body and wings: 0; + a few, + + many.

FO = Froth on ovipositor ± particles of soil as a rule remaining after laying, note: 0, +, + +.

OD = Ovarian development: note according to size of ovarioles; 0 (no yolk), 1/4, 2/4, 3/4, 4/4.

RB = Resorption bodies, note: 0, +, + +.

FB = Fat body, note: 0, +, + +.

Observation: record and pressure any internal parasites (dipterous larvae, etc.) found during dissection of specimens.

Record of grasshopper species seen

Date	Station	Zone	Observer

Time (beginning of observations)	Temperature (°C)	dry / wet	Wind	direction / force

Species	Adults		Nymphs	
	presence	scale*	presence	scale

4 × 50 sweeps of net

Species:	Adults	Nymphs

*Scale of abundance	Number of individuals seen during 30 min
1	1
2	2-5
3	6-20
4	21-50
5	51-100
6	101-200
7	201-500
8	501-1000
9	1001-10,000
10	10,001 +

APPENDIX 2 SPECIFICATIONS OF THE LIGHT TRAP

This trap is in standard use by the Australian Plague Locust Commission. (The Australian Plague Locust Commission Manual, 1979). It consists of a tank with a light source erected or suspended above it.

The tank is circular with a diameter of approximately 300 cm and a height of approximately 50 cm. It is constructed of heavy gauge galvanised iron flanged both top and bottom with supporting struts for strength to support the weight of the water (approximately 1260 kg). The inside of the tank is painted with metal primer and coated with a highly reflective white polyurethane paint. A plug is provided to drain the water and overflow holes are drilled at a height of 25 cm to prevent the tank from overflowing during rain. The tank must be supported on a level base of prepared ground.

The light source is a 150 W tungsten filament/mercury vapour lamp with a high uv output; there are several proprietary makes available. They do not require a choke. The lamp is connected to the mains via a cable and time-switch. It is essential that electrical fittings are adequately insulated to prevent the tank becoming 'live'. The bulb is sealed with a hardened glass cover, such as a 5 litre Pyrex beaker to prevent damage by rain heavy-bodied insects and smearing by smaller insects which may also cause a breakdown in insulation.

The trap is placed in open ground away from trees and buildings. The inside surfaces of the tank above the water are sprayed at approximately monthly intervals with Teflon (or other detergent) to prevent insects climbing out of the tank. The light is turned on automatically at dusk and off at dawn. The water is treated with an anti-algal product to prevent algae from growing on the white surfaces and reducing reflectivity.

It is clearly preferable to have a permanent well-made light trap, underground electric cable, etc., and it is recommended that the above standard design be adopted at all light-trapping sites to ensure standard comparable results. Difficulty in procuring this design, however, should not be a reason for not conducting light-trap observations; a simple temporary alternative would be to dig a circular shallow pit of 300 × 50 cm, and cover it with a sheet of thick plastic (polythene sheeting). The basin so prepared is then filled with water containing a small amount of detergent and the lamp is suspended about 1 m above the basin from a light tripod (for instance three canes tied together).

APPENDIX 3 GRASSHOPPER AND LOCUST CONTROL CONDUCTED BY OCLALAV IN THE SAHELIAN COUNTRIES DURING THE 1972-1980 PERIOD (SUMMARY BASED ON THE OCLALAV MONTHLY REPORTS)

Explanation of abbreviations

Grasshoppers and locusts

Acr	*Acrotylus* sp.
Am	*Anacridium melanorhodon* (Tree Locust)
As	*Aiolopus simulatrix*
Cat	*Cataloipus* sp.
Cf	*Cataloipus fuscocoeruleipes*
Dax	*Diabolocatantops axilleri*
Chr	*Chrotogonus senegalensis*
Cyr	*Cyrtacanthacris aeruginosa*
Ka	*Kraussaria angulifera*
Klla	*Kraussella amabile*
Lm	*Locusta migratoria migratorioides* (African Migratory Locust)
Hd	*Hieroglyphus daganensis*
Het	*Heteracris* sp.
Oj	*Oedaleus johnstoni*
On	*O. nigeriensis*
Os	*O. senegalensis*
Ov	*Orthochtha venosa*
Pyr	*Pyrgomorpha* spp.
Sg	*Schistocerca gregaria* (Desert Locust)
Sph	*Sphingonotus* sp. (mainly *savignyi*)
Zac	*Zacompsa bivittata*
Zon	*Zonocerus variegatus*

Insecticides

D5, D20	Dieldrin 5%, 20%
Dz	Diazinon
Fe	Fenitrothion 50 or 100%
HCH	dust when in kg or t liquid when in litres
Mal	Malathion

Others

PV	National Plant Protection Service
ENS	Exhaust nozzle sprayer

Map references of localities given in Appendix 4

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
1972						
VII	Badiane 1507N/1553W 1524/ 1540, *Acr. Os*, millet, groundnuts. 30 ha HCH dusting		Niono, attacks on millet and sorghum seedlings by *Os, Het, Hd, Ka, Daz* continued until October and involved dry-season sorghum. Controlled 445 ha; 10 t HCH.			
IX-X		Djigueni, *Os* infestations			Agadès – Ingall, *Os* attacks on millet and sorghum	

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
1973						
IX		4000 ha *Os* serious damage Kaedi and Ould Yinge	Nioro-Térékole, Gari serious damage to sorghum, 150 ha treated *Hd, Ka, Os*			Infestations of *Locusta*: NE **Nigeria, Chad**, control by OCLALAV requested by OICMA
X		Serious infestations *Os* Aleg - Assaba - Tagant - Kaedi - Bogue, 200 ha *Os, As, Sph, Pyr*	Térékolé 6, Kirgou, 250 ha			Controlled Chad Grédaye, 1260 ha Mariam, 360 ha Alkouk, 970 ha
XI	Podor - Matam, 3000 ha threatened *Os - As - Sph - Chr* - 10,000-30,000/ha		The whole of Mali west 300 ha, *Ka, Os, Hd*			
XII						Kouloudia, 6136 ha, Mora, 12 ha, Yagoua, 80 ha, Garoua, 610 ha, Moubi, 2500 ha Dikwa, 400 ha. Total: **Chad** 9198 ha, **Nigeria** 7576 ha, **Cameroon** 3100 ha
1974						
V			Térékolé, Yelimané, 300 ha *As*			**Chad** Kouloudia, *Cat* attacks on maize
VII-VIII	Boulel, heavy concentrations *Os*, serious damage resowing 500 ha of 12,000, Bakel 70 ha destroyed	Selibaby-Bouly, Aleg, Kiffa, *Os* 30-60/m^2	*Oj*, 1827/0202 50-100/m^2		Ouallam 1424/0205 2560 ha *Os* treated Magaria, Gouré, Nguigmi, Diffa *Os, On, Acr, Chr, Dax*, 2100 ha treated **Bénin** Niger valley 1142-9N 0332-39E 200 ha sorghum-maize 30-99% damage by *Hd, Cf*	
IX	Dagana; MBane, 10,000 ha invaded	SE Mauritania 15,000 ha infested *Os, Ka, Acr, Sph*, (1535-1544N 805-840W) swarm 80% *Os*, 20% *Sg*	Térékolé - Gari, infestation of *Os, Ka, Hd, Cat*. Nara, 60,000 ha *Os*	Gao - Watagouna, *Os*, damage 900 ha treated	N'Guigmi, 1675 ha 40-85% damage Diffa, 3100 ha millet, sorghum, cow peas *Os, On, Het*, 20-95% damage **Benin/Niger** aerial spraying Niger valley, 8-23 IX, 16,620 ha	**Chad** Kouloudia, 3115 ha *Cat, Cyr, Ka, As, Dax, Ov*

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
X	Aerial spraying Senegal valley both sides between Bakel – Ndioum – Olo Ologo) 9400 l D 10% 65,000 ha *Os, Ka, Hd, Cat, Het, Klla*, 30-40% average damage	Control: Kaedi, 1626 ha Mounguel, 16 ha; Boghe, 620 ha	Gari – Kirgou, 300 ha; Térékolé, 2000 ha Yelimané, 1300 ha	Ansongo – Watagouna, 8050 ha 3850 l HCH **Burkina Faso** Gorom-Gorom, Marcoy, damage 50% 1355 ha 1210 l HCH	**Niger east** aerial spraying 2020 ha 4000 l HCH Departure *Os* to Nigeria (see Popov, 1976) **Benin** 22,000 ha infested, serious damage millet, sorghum, maize Aerial spraying 18,000 l D	**Chad** Mongo 180 ha, Abeche 50, Biltine 50: *Os, As* – sorghum, millet 50-60% damage **Cameroon** treatments: Pouss, 1245 ha (air) Maroua (Bogo), 213 ha ENS Mora, 124 ha, Afade 662 ha *Os, Ka, Hd*
XI	Treated 45,300 ha 10,000 l D5 20,000 l Fe50	7600 ha 2600 l Mal 2320 l D5	Control in Mali west 700 kg HCH25			
XII	Reduction of laying *As, Os*	Kaédi – Boghé, 8050 ha treatment of dry-season crops; sorghum seedlings				
1975 V	Serious infestations *As, Pyr, Cat*, Senegal valley: Matam/Kanel, 10,000 ha 5-40/m^2 control by wheat bran/HCH bait Light infestations Tambacounda	North and south Aïoun first hatchings of *Os*, rains 9/10 V	Térékolé, 7500 ha infested *As*, Yaguine (1507/1043W) treatments by ENS	Gao/Ansongo, first *Os* infestations	Dosso, 21,000 ha infestations *Os*, attacks on millet	
VI		Whole valley surveyed infestations *As, Pyr, Cat* Tekane-Kaédi, 25,000 ha, Kaédi-Wompou, 27,000 ha, infestations *Os* Aioun	Generalised hatching Yelimané	Heavy infestations Gourma Adrar, O. Tarlit-Marat *Oj+As* treatments: 1050 ha **Burkina Faso** 420 ha *Os* treated	Filingué, *Os* 200 ha control, Dogondoutchi, *Os* 17,300 ha aerial spraying 18,200 l HCH 20% + ENS 5910 ha Maradi, *Os, Pyr, Acr* 1124 ha Gaya, *On, Cat, Pyr* 750 ha	Control 287 ha *Os, Cat* HCH dust
VII	Good rains: generalised infestations north of 14°N between 1400W and 1630W particularly in: Kaffrine, SE Kebemer, S. Linguere and 8700 ha Doli Ranch, Dagana – Podor. Control PV: motor dusters in Kaffrine-Louga.	Everywhere S of 18°N especially 1654/1434W. Boghe and Kaédi and the Tagant barrages especially *Os*	Térékolé, Gari Kirgou and Wadou valleys control by HCH teams		Control continues, total 5930 ha HCH 14,600 kg dust	

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
1975						
VIII	OCLALAV: Doli, 45,562 ha 25,900l D5 by air. Elsewhere ground control by PV/ OCLALAV teams. Serious damage to seedlings - up to 6 resowings and even abandoning			**Mali east** continuation of control Ansongo 400 ha *Os*, HCH dusting by farmers **Burkina Faso** 800 ha, 1800 l HCH, Gorom, 800 ha *Os* treated	Gouré, 3865 ha *Os, Acr*, Goudoumaria, 465 ha Tahoua, 350 ha Gaya 1770 ha **Bénin** 1120 ha 1586 l HCH	Massakori *Os*, 330 ha PV/ OCLALAV farmers
1975 IX	Matam, 2640 ha, 1315 l Fe 50% ENS + PV 10 676 ha 11 740 kg HCH Podor: 2400 ha, 1200 l Fe50 *Os*	Timbedra - Amouj - Djigueni, *Os, Hd, As*, localised damage Dusting in progress Aïoun *Os* attacks, control	Aerial spraying 29,200 ha Nioro, Segala situation serious Yelimane - Nioro area, *Os, Ka, Hd*	Ansongo infestation *Os* 10,000 ha - controlled 3800 ha liquid HCH 16%	Diffa *Os, On* 2394 ha HCH control by OCLALAV/PV, serious damage	1320 ha *Os* damage, control HCH/D 20%
X	Kounguel 36,000 ha 1200 l Fe 50% 580 l D5 Senegal 4000 ha mixed HCH/D5 Senegal 8000 ha Total 12,000 ha 17,925 l insecticide Aircraft OCLALAV/France 2 Cessna Nahadji 1844-1322/Seme 32,000 ha 10,700 l Fe50 5285 l D5	Rkiz l830 ha 910 l Fe50 OSRO spraying with DC3 Matam/Kaedi, 13,000 ha Matam/Gorgol zone, 19,000 ha, Mbout, 32,000 ha, 47,525 l insecticide	Total areas controlled **Mali west** 89,600 ha-52,775 l insecticides Fe, D, HCH parathion 25%	Tilemsi *As* of no importance; Niger Valley, 3670 ha 2100 l HCH 16% *Os, As, Cat, Pyr, Het, Acr*	Diffa, 850 ha 1700 kg HCH, Zinder, 1600 ha 775 l Dz 880 kg HCH, *Os, On*	**North Cameroon** Logone, Birni, Afade, Kousseri, 900 ha 340 l Fe50
XI	River valley 11,000 ha 4800 ha D5 800 l Fe50 Ovalo area **Gambia** OCLALAV teams Saresoft - Dankunku 4500 ha Mal 3700 l	Dar el Barka valley - Boghe, 2000 ha 3200 l D5 2500 l Fe50-600 l Mal 50%	Térékolé, Kolombiné, Sénégal valleys: 10,600 ha 5200 Fe50			
1976 I	Swarm of *Am* M'Bake region, 4000 ha sprayed with 1100 l Fe100					

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
IV	Idem Sine Saloum, 3000 ha 800 l Fe100, 8030 kg HCH dust			**Burkina Faso** Gorom Gorom, *Am* swarm reported		
VIII	*Am* 48 ha-111 l Fe100±D5	Calm	Calm			
IX	400 ha *Os* treated with HCH **Gambia** *Hd, Ka*, 3369 ha including *Amsacta* and meloids)	Aïoun - Nema, *Os* control Néma 240 ha *Os, As* x 1200 kg HCH dust 1702 N 1501 W	Infestations Sg		Infestations *Sg* Control September 865 ha x 570 l D5	
X	Jenoï - Sapo, 5841 ha sprayed with 945 l Mal+126 l Didigam **Senegal** Bakel - Goudiry, 1523 ha 1609 l HCH, 600 l Mal50 2088 ha 4125 kg HCH Sebikotane, Pout 15,000 ha *Ka, Cat, Hd, Zac*	800 ha *Os* (30.X)		Infestations *Sg* Control October 28,485 ha x 5805 l D5 1350 l D20 Good rains Adrar 15-16, 28-29 October	Infestations *Sg* Control October Tamesna 16,610 ha × 12,300 l D5 Aïr 2213 ha × 1500 l D5 400 l D20	
XI	Aerial barrier spraying vegetable crops Sebikotane - Kirene - Tamna, 1400 ha × 325 l Fe100, 925 l D5	*As* patchy, Achram barrage *Am*, 400 ha controlled, 1000 kg HCH dust in Aïoun by OCLALAV/PV		Control *Sg* November 22,860 ha × 1600 D5+1840 l D20	**Niger** 17,960 ha × 13,100 l D5	
XII	Control of groundnuts in Ngaparou/Bandia, 140 ha against *Ka*, 130 l mixture Fe100 D5			Control *Sg* 9750 ha × 400 l D5 1550 l D20	Control *Sg* 14,660 ha × 3330 l D5 1032 l D20 Aïr 330 ha × 300 l D5	
1977 I				Swarm *Am* controlled in Gao, 200 l HCH u/v		
VIII	**Gambia - Senegal** deficient rainfall	*Os* low density deficient rainfall	Deficient rainfall green vegetation patchy. Concentrations of *Hd, Os*, 880 ha controlled at Djelimahel and Wadou		Tahoua 7500 ha infested by *Os*, 2880 ha controlled by OCLALAV/PV farmers	

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
X	Cap Vert - Thiès 40,000 ha *Ka infestations in horticultural and citrus crops 4000 ha treated; 1660 l D5, Fe50, Mbidi 1604-1456 nymphs, Am*, 112 ha 280 l D5 Fe100	Djigueni 975 ha infested *Os*, control HCH 3900 kg dust	Wadou/Térékolé important concentrations *Os, Hd, Ka*, crops controlled 600 ha	Ansongo Region controlled *Os*, 6950 ha	Important infestations *Os*, Tanut Zinder; night flights control 10,620 ha (HCH 6180 l Dz 7530 l) Decline grasshopper numbers second fortnight October (Probable departure to Nigeria)	**North Cameroon** N'Gama *Os, Ka, Cat*, 1540 ha controlled 760 l Fe50
XI	Invasion irrigated crops, orchards, serious damage citrus, cassava	Swarm *Anacridium*	Decrease *Kr, Hd, Cat*, serious attacks *As*, Yaguine–Gori			**North Cameroon** Makari, attacks *Kr, Cat, Os*, 1355 ha controlled with 685 l Fe50
XII	By air: Pout - Kirène, 5400 ha 2700 l Fe50 By ground: Pout - Kirène, 730 ha HCH dust and liquid River valley, attack *As, Cat*; control PV **Senegal** control continued Cap Vert region, 50 ha and River valley 30 ha December			**Burkina Faso** Markoye, (1818/0009W) control 5600 ha *Os, Pyr* millet in milky grain stage		
1978 VI		*Os* infestations in 1430-1600N	0955-1055W 40,000 ha infested Yelimane - Nioro, *As*, Yaginé - Térékolé 2000 ha treated with HCH liquid and dust		*Os* Maradi, 1000 ha control Fe50 PV aerial spraying Dosso, Niamey, Zinder, Maradi	
VII	*Ka, Os, Zac* infestations at Thiès. Damage to millet 10-20%, control by PV/OCLALAV Continuation of control against *Os, Ka, Hd, Cat, Zac*	Amrich, 1545N-1026W flights of *Os* SE - NW over 10 km control. OCLALAV/PV 300 ha 1160 kg HCH Control *Os* Touil, Aïn Farba 600 ha 920 kg HCH	Yelimané *Os* over 15,000 ha Térékolé, *As, Ka, Os*	Adrar, O. Tissealin/Tadelok 1940N 0215E; *Oj* 100 ha	Gouré-Tanout, 19,660 ha control by OCLALAV	**Chad** damage Massaguet/Massakori, *Os, Cat, Locusta* 15,600 ha millet seedlings

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
VIII	Thiès – Diourbel, 19,654 ha: 16,000 l Mal50, Fe50, D5 + control by PV		Kirane OCLALAV/PV 2000 kg HCH dust *Kr, Hd, Cat,* damage in Kayes, 7000 ha; Segala, 15,000 ha; Yelimane, 30,000 ha; aerial spraying pursued by OCLALAV/OICMA/PV	Ouatagouna Labbezanga, 1500 ha *Os* control PV/OCLALAV Infestation *As* Abeibara (Adrar), Gargouna, August 7000 ha *Os*; 715 ha control 1500 l HCH September **Burkina Faso** Markoye, 1439 0002E 1800 ha *Os* 330 l Fe100	*Os*, Tanout – Gouré – Mainé, control, OCLALAV 24,860 ha × 3800 l Fe100 + Syst 1000 l	Control *Os* continues in Massaguet, 11,500 ha 2700 l D5 2460 l D20 September. Total 5835 ha 2280 l D20 Karal, *Ka, Cat + Lm* control PV
IX	Seyal River valley controlled by PV	Aïoun – Kiffa – Nema, heavy attacks *Os, Hd, Klla*, 5200 ha 1000 l Fe, 400 l HCH, 1900 kg HCH			**Niger east** aerial control PV, OCLALAV teams	
X	Pout – Bandia (1434/1701), *Ka, Cat*, 100 ha 55 l Fe50	Flights *Os*, Assaba, 20, 120 ha controlled 10,170 l 7200 kg various insecticides	Segala – Yelimane – Nioro – Kayes, Total 74,500 ha 35,300 l various insecticides *Ka, Hd, Os,* serious damage to rain crops and to seedlings dry-season (decrue) cultivations	**Mali east** Adrar *Os, Oj, Pyr*, 340 ha control Gossi: *Os, Acr, Ka, Cat*, 700 ha 1000 l HCH **Burkina Faso** 2500 ha × 360 l Fe100	**Niger** *Am* at N'Guigmi	**Cameroon** Massari, 1600 ha *Ka, Cat* infestations Kousseri, *Os, Cat, Ka, As*, 4450 ha 2850 **Chad** 15 ha *Os*
XI	*Os, As,* infestations Senegal River valley	1625N 0940W (Néma), *Os*, 1440 ha 1605N 1135W Sani, 840 ha: 2080 kg HCH, 520 l HCH, 100 l Fe	BogoFele 1502N 0675W 400 ha baiting OCLALAV/PV	**Mali** in Tafidet, 1632N 0021E Tin Kouraten, 1547/0112 500 ha *Os*, 775 l HCH		
1979 III				Goa, numerous *As, Acr*, recorded in light trap (21-27 March)	Important population *Am*, Zinder	
V					Swarm *Am*, 1307N/0145E and 1250/0140	

Date	Senegal/Gambia	Mauritania	Mali west	Mali east/Burkina Faso	Niger/Benin	Chad/Cameroon
VI	River valley infestation *As* Ndiongui	Aleg, *As*, no damage	*As, Os, Dax, Klla, Pyr*, 12 ha control 30 kg HCH 25	**Mali east** *Oj, Ochrilidia* in l'Adrar		
VII	*Zon*, damage to cassava, potatoes Ndombo island 57 kg HCH patches *Os* controlled Adrao-Fanaye	Karakoro, *Os* no damage	Despite drought infestations *Hd, Ka, Ov* at Wadou 5000 ha *Zon, Cat, Klla* Infestations Kayes, Segala, Nioro, Niogomera, 80,000 ha control 1425/1124W 14,400 ha 8000 l Fe 32,628 ha 22,566 l Fe100 & 50	*Oj, Os, Pyr, Cochr*, Adrar valleys. **Burkina Faso** Markoye, 900 ha *Os, Acr, Dax* 2665 ha in August Gourma, *Os* Adrar: *Os+Oj+Lm*; serious damage to pastures	Say. Aerial spraying **Bénin** Malanville, *Hd, Cf, Ov*, control PV+OCLALAV	
VIII						
IX						
X		Kobonni, *Os, Hd, Dax*, 190 ha 800 kg HCH			655 ha 1295 1 HCH	
1980 VI			First hoppers *Os*, Yélimane			
VII	Rainfall deficit			Good rains Adrar - Ar - Tamesna, *Oj, Os, As, Sg*, infestation 5000-30,000 ha over 510 ha 255 l D5 Adrar		
VIII	Good general rains			*Oj, Os* infestation 1758N 0032E 200 ha 100 l D		
IX	**Senegal/Mauritania** calm	Arrival *Sg* swarms 10 September	*Os, Hd, Cat, Ka*, Segala, 4000 ha Yelimané 5000, Nioro, 3000 ha infestation. Control PV 69,000 kg HCH Aerial spraying OCLALAV 34,000 ha Fe100 5600 l D5 3300 l	Infestation *Sg*. Adrar - ► Timetrine local 800 ha *Oj, Os, As*, Ansongo - Anderanboukane, *Os* serious damage 1550 ha 3860 l HCH OCLALAV/PV	Tamesna N, in Abangharit Gouré, *Os, Dax, Acr, Pyr, Cat*, 20,330 ha 3195 Fe50 3450 Fe100 240 l HCH 2300 ha 1150 l Fe	
X		Reproductions *Sg*				
XI		Infestations grasshoppers Selibaby - Maghama Control *Sg*		Control *Sg*. **Burkina Faso** Markoye, *Os, Dax, Cat*, 4000 ha Control by farmers	Control Sg	

APPENDIX 4 GAZETTEER OF LOCALITIES

Mali West/Centre

Bambara Maundé	1551N	0247W
Bogofélé	1502N	0657W
Garé	1510	1053
Kirané	1525	1014
Kolombiné	1500	1057
Nara	1510	0717
Niogomera	1426	1124
Niono	1415	0600
Nioro	1514	0935
Térékolé	1505	1050
Wadou	1540	0952
Yaguiné	1507	1043
Yelimané	1508	1034
Ségala	1432	1058

Mali East

Adrar des Iforhas:		
Abeibara	1906N	134E
Aguelhoc	1928	052
O. Eloudj	1927	037
O. Marat	1927	037
O. Tarlit	1925	035
Anderamboukane	1526N	302E
Ankoum	1515	043
Ansongo	1540	030
Daoga	1553	014
Firthindi	1524	045
Gangaber	1622	005
Gao	1616	003W
Gargouna	1556N	013E
Gossi	1549N	117W
Herba	1531N	033E
In Delimane	1552N	131E
Labbezanga	1457	042
Menaka	1555	224
Ouatagouna - Watagouna	1511	043
Tabango	1546	022
Tabrichat	1744	012
Tacharane	1610	004
Tin Aouker	1648N	008E

Burkina Faso

Gorom Gorom	1426N	0014W
Dori	1403N	0002W
Markoye	1439N	0002E

Mauritania

Achram	1747N	1159W
Aioun el Atrouss	1640	0937
Aleg	1703	1355
Amel	2059	1206
Amouj	1713	1245
Amrich	1545	1026
Amrij	1633	0758
Assaba	1630	1200
Boghé - Bogué	1635	1416
Bouly	1519	1148
Dar el Barka	1641	1442
Djigueni	1544	0840
Kaedi	1609	1330
Karakoro	1530	1135
Kiffa	1637	1124
Kobenni	1555	0925
Maghama	1531	1251
Mounguel	1625	1308
Nabadji	1844N	1322W
Néma	1637	0715
Olo Ologo	1639	1433
Rkiz (Lac)	1650	1519
Sélibaby	1510	1211
Tagant	1731	1207
Timbedra	1615	0810
Touil	1532	1007
Wompou	1508	1243

Senegal

Adrao	1630N	1515W
Badiane	1507	1553
Bakel	1454	1227
Bandia	1437	1702
Boulel	1524	1540
Dagana	1631	1530
Dakar (Cap Vert)	1438	1727
Diourbel	1530	1530
Doli	1447	1550
Fanaye	1633	1514
Goudiri	1411	1243
Kaffrine	1406	1533
Kanel	1445	1630
Kirene	1439	1702
Kounguel	1359	1448
Louga	1537	1613
Matam	1540N	1315W
Mbake	1448	1555
Mbidé	1604	1456
Ndoumbo (Ile)		
Ndioum	1400	1440
Ngaparou	1428	1704
Podor	1640	1457
Pout	1446	1704
Sébikotane	1445	1708
Siné Saloum	1400	1550
Tambacounda	1347	1340
Tamna (lac)	1453	1704
Tiès	1445	1650

Niger

Ayorou	1444N	0055E
Bani Bangou	1503	0224
Beylandé	1245	0252
Diffa	1340	1230
Dogondoutchi	1338	0402
Dokimana	1302	0220
Falmey	1236	0251
Famalé	1433	0105
Filingué	1421	0319
Gaya	1153	0327
Goudoumaria	1342	1110
Gouré	1500	1045
Guesselbodi	1326	0222
Magaria	1315N	0915E
Mainé	1400	0713
Mainé Saroa	1313	1202
Maradi	1415	0715
Nguigmi	1415	1307
Niamey	1331	0207
Ouallam	1423	0209
Saga	1327	0207
Say	1307	0221
Tahoua	1454	0516

Niger (contd)

Tamou	1245	0211
Tillabery	1413	0127
Tondi Kiwindi	1428	0202
Zinder	1500	1030

Cameroon

Afadé	1213N	1438E
Garoua	0913N	1322E
Kousseri	1205	1456
Logone (river)	11-12N	1510E
Maga	1048N	1456E
Makari	1232	1432
Maroua	1035	1420
Mora	1103	1408
N'gamé	1041	1442
Pouss	1050	1503
Waza	1124	1434
Yagoua	1023	1513

Gambia

Dankunku	1334N	1519W
Jenoi	1329	1534
Sapu	1333	1454
Saresofi	1325	1431

Nigeria

Dikwa	1201N	1355E
Gulumba	1143	1410
Maiduguri	1153	1316
Marte	1222	1350
Potiskum	1130	1103

Chad

Abéché	1349N	2049E
Biltine	1432	2055
Kouloudia	1301	1516
Manga	1300	2107
Massaguet	1225	1527
Massakori	1300	1544
Ndjamena	1210	1459
Ouadaï	13 N	21 E

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