EVALUATION OF FIELD TRIAL DATA ON THE EFFICACY AND SELECTIVITY OF INSECTICIDES ON LOCUSTS AND GRASSHOPPERS

Report to FAO by the PESTICIDE REFEREE GROUP

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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INTRODUCTION

1. The 6th meeting of the Pesticide Referee Group was opened by Dr. N. van der Graaff, Chief Plant Protection Service. He mentioned that, since the last meeting, there had been an upsurge in Red Locust activity in southern Africa. He requested that the Group, in addition to its principal focus on the Desert Locust, also evaluate data on other migratory locusts including the Red Locust. Mr van der Graaff noted that donors and locust-affected countries remained very concerned about the impact of insecticides on the environment. He stressed the need for the Group to take particular note of ecotoxicological data in their evaluations. He welcomed Mr. Mohamed Abdallahi Ould Babah to the Group as a representative of locust-affected countries and Mr. Gordon Hooper as observer from the Australian Plague Locust Commission. He thanked members of the Group for their participation and for the advice they also provided to FAO in between meetings.

2. The Pesticide Referee Group (members in Appendix I) evaluated 18 new reports from the Agrochemical Industry, together with 10 resubmitted results. Apart from the submissions by the Lubilosa project concerned with the mycoinsecticide *Metarhizium flavoviride*, no other new product was submitted. Most of the reports provided additional data on insecticides previously considered by the Group. In addition the Group considered two reports on ecotoxicological data prepared by FAO (reports and summary data are listed in Appendix II, III and IV).

3. The Group gave particular attention, at FAO's request, to the ecotoxicological data and rearranged the presentation of its advice to give greater recognition to differences between the insecticides listed, ecosystems affected and control strategies adopted. The terms of reference of the Group were modified by FAO accordingly (Appendix V).

4. To clarify the procedures used by the Group in its evaluation of insecticide efficacy data on locusts, the original criteria established in 1989 were reviewed and slightly modified. A full description of these criteria can be found in Appendix VI.

EFFECTIVE INSECTICIDES AND ENVIRONMENTAL EVALUATION

5. In extending the consideration of application and efficacy to include an environmental impact assessment, it was important to assess what data had been submitted to the Group. Table 1 includes all the insecticides that had been listed in Tables 1, 2 and 3 of the previous report of the Group. Table 1 now shows which insecticides have verified effective dose rates, toxicity and environmental impact data, and large scale operational data. This table was generated in order to identify gaps in data availability specifically related to locust control. The environmental impact data have been sub-divided into laboratory toxicity data, small scale field impact data, and environmental impact data from large scale tests in locust affected areas. This is one area where data gaps are very apparent.

6. In Table 1 the first column of environmental data ("registration, laboratory") concerns data that are generally required for registration purposes in OECD countries. These data are not specific for locust control. For this report environmental data have been used from the TOXIS database located at the National Institute for Public Health and the Environment (The Netherlands). Data were not available for three mixtures that manufacturers proposed for use in locust control. The second environmental column ("locust areas, small scale") is composed of data from laboratory tests with indicator species from the locust-affected areas and small scale field tests, often using the same species. This dataset originates from reports from the Locustox Project[1] in Senegal, and reports submitted to FAO by pesticide companies and research institutes from different countries in Africa. The data are fewer than for the previous column because the studies have generally been limited to the compounds for which dosages had been previously verified. The third environmental column ("locust areas, large scale") represents large scale field data. This is the smallest dataset. However, the pesticides which are presently most commonly used are included in this set, viz. chlorpyrifos, deltamethrin, diflubenzuron, fenitrothion and malathion. Sources of the latter two datasets are given in Appendix IV.

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[1] The Locustox project (GCP/SEN/041/NET) assesses the environmental hazards of anti-locust pesticides in Senegal and Mauritania both in the field and laboratory assays.

Table 1. Availability of data for insecticides submitted for use in Desert Locust control

Insecticide	Confirmed effective dosage	Large scale operational data	Environmental data		
			registration laboratory	locust areas small scale	locust areas large scale
Bendiocarb	+	?	+	+	-
Carbosulfan	-	-	+	-	-
Chlorpyrifos	+	+	+	+	+
Cypermethrin + profenofos	-	-	-	-	-
Deltamethrin	+	+	+	+	+
Diflubenzuron	+	+	+	+	+
Esfenvalerate+fenitrothion	-	-	-	-	-
Fenitrohion	+	+	+	+	+
Fipronil	+	-	+	+	-
Lambdacyhalothrin	+	-	+	+	-
Malathion	+	-	+	+	+
Metarhizium flavoviride	+	-	+	+	-
Phoxim + propoxur	-	-	-	-	-
Pyridaphenthion	-	-	+	-	+
Teflubenzuron	+	-	+	-	+
Triflumuron	+	-	+	-	+

Note: + = data available; - = incomplete data available

7. Verified dose rates and assessment of speed of action and environmental risks are given in Table 2. This table has been expanded from the previous Group reports in order to give a more complete evaluation of the insecticides and provide a means of identifying suitable products for different control situations. Specific explanations of these tables are given below.

8. The speed of action of the different compounds varies from fast ("F": < 6 hours), medium ("M": 7-48 hours) to slow ("S": > 48 hours) in Table 2. Generally speed of action is determined by the nature of the product and is also influenced by the type of habitat in which control operations are carried out. For example, dose transfer in grassy areas may be both by direct droplet impingement and also by secondary pickup from the sprayed grass. Among the slower compounds listed in Table 2 is the mycoinsecticide *Metarhizium flavoviride* which has first to penetrate the cuticle and develops inside the locust body cavity. It may take a week or more to kill. The IGRs, diflubenzuron, teflubenzuron and triflumuron are similarly slow and affect the nymphal stage of the locust only at the time of the moult. The time of treatment in relation to the next moult may therefore important. The organophosphates, chlorpyrifos, fenitrothion and malathion together with the carbamate bendiocarb as well as the phenyl pyrazole, fipronil, produce a moderate to rapid rate of kill. The two synthetic pyrethroids, deltamethrin and lambdacyhalothrin exhibit the fastest action. First signs of toxicity may appear within an hour or so following treatment.

Table 2. Dose rates and evaluation of speed of action, environmental risk and acute toxicity to humans of insecticides for which verified dose rates have been established by the Pesticide Referee Group. All data refer specifically to the Desert Locust. Environmental risk is assessed at the dose rates listed in the table. WHO toxicity class is calculated for a 0.5 litre/ha formulation. See text for further explanations.

Insecticide	Dose (g ai per ha)			Speed of action	Environmental risk			WHO toxicity class
	overall (blanket)		barrier treatment					
	hoppers	adults	hoppers		aquatic	wildlife	beneficials	(human)
Bendiocarb	100	100		F	L	L	M	II
Chlorpyrifos	240	240		M	H	H	M	II
Deltamethrin	12.5	12.5		F	H	L	H	II
Diflubenzuron	60	n/a		S	H	L	L	U
Diflubenzuron			100	S	H	L	L	
Fenitrothion	450	450		F	M	H	M	II
Fipronil	6.25	6.25		M	L	L	H	II
Fipronil			12.5	M	L	L	M	
Lambdacyhalothrin[1]	20	20		F	H	L	H	II
Malathion	925	925		F	M	L	H	III
Metarhizium flavoviride[2]	100	100		S	L	L	L	—
Teflubenzuron	30	n/a		S	H	L	L	U
Teflubenzuron			not determined	S	H	L	L	
Triflumuron	37.5	n/a		S	H	L	L	U
Triflumuron			75-100	S	H	L	L	

Note: n/a= not applicable; speed of action: F=fast, M=moderate, S=slow; environmental risk: L=low, M=moderate; H=high; WHO class: II=moderately hazardous, III= slightly hazardous, U=unlikely to present acute hazard in normal use.

1 Where the "lambda" isomer is not registered in a country, cyhalothrin is applied at 40g ai/ha

2 Strain IMI 330189

9. With respect to the hazard to non-target organisms, three main groups are distinguished, viz. aquatic fauna, wildlife and beneficial invertebrates. Aquatic fauna includes fish, crustaceans (shrimps and plankton) and insects. Wildlife includes mammals and birds, and beneficials cover bees, natural enemies of locusts and other pests, and ecologically important invertebrates (eg. soil fauna). This generalisation has been made for pragmatic reasons, i.e. the availability of data and convenience for the user. If, however, data are available on specific subgroups that are of importance, they are addressed in the text.

10. The risk of each compound for the three groups of non-target organisms is presented in Table 2 using three classes: low, medium and high risk, as usual in environmental risk assessment in Europe. Results from the situations most representative of the expected field conditions are always given more weight than other studies. Field studies are more decisive than laboratory or semi-field studies; African results are more decisive than European results.

11. For aquatic fauna the low risk class represents a reduction of field populations of 0-50% and a laboratory toxicity (EC_{50}: median effective concentration) for indigenous species of >50 mg/l. I f no data are available from the field or from tests with indigenous species, TOXIS data indicating a hazard ratio (predicted environmental concentration divided by the no effect concentration; PEC/NEC) of <500 are considered to reflect low toxicity for invertebrates. For fish a hazard ratio <1 has been classified as low. The low classification for situations where apparent effects occur or are to be expected is justified by the consistent observation, in the field, of rapid recovery of affected invertebrate populations (i.e. effects not extended beyond one growing season). The medium risk class has been given to compounds showing reductions in the field of 51-90% and a laboratory toxicity of 1-49 mg/l (EC_{50}). In the absence of these data, a TOXIS derived PEC/NEC ratio of 500-1000 indicates medium risk. The high risk classification has been given to compounds showing an effect on aquatic invertebrates of 91-100%, a laboratory based toxicity of <1 mg/l (EC_{50}) or a hazard ratio value (PEC/NEC) from the TOXIS database >1000. When hazard to fish has been proven in the field, the compound is classified as highly hazardous for aquatic ecosystems.

12. Wildlife toxicity classes have been given according to the following criteria. Whenever significant mortality among mammals or birds has been observed in large scale, well conducted, field trials the compound is classified as presenting high risk. If no such data are available, this classification is based on a hazard ratio of >1. In this group no medium risk classification has been defined.

13. Risk to beneficial arthropods has been classified according to the following criteria. Risk to bees is classified according to their hazard ratio, as defined by EPPO (European Plant Protection Organization): the recommended dose (g ai/ha) divided by the LD50 (microgram ai/bee). Low risk to bees corresponds to a hazard ratio <500; high risk to a hazard ratio of >500. It is acknowledged that this classification deviates from usual in Europe, where the threshold for the hazardous classification is at a hazard ratio of 50. The European threshold includes a safety factor of about 10. As the evaluations here are very rough, the safety factor is dropped. Risk to beneficial invertebrates other than bees has been classified as follows. Effects observed in the field prevail over laboratory data. Field data are available for all compounds listed in Table 2. Low risk is assigned when reduction in populations is <50%; medium risk when reduction is 51-90%; high risk at reductions >90%. For the final classification the most sensitive group (bees or other benefícals) was considered as indicative. Acute effects only were taken into account and recovery was not taken into consideration.

14. Three compounds are considered to present a low risk to aquatic ecosystems: bendiocarb, fipronil and *Metarhizium flavoviride*. Fenitrothion and malathion are of medium hazard and the other compounds are highly hazardous. Fish mortality has been observed after locust control with chlorpyrifos. Birds are at risk when fenitrothion and chlorpyrifos are used. Beneficial arthropods, including bees, are least at risk when IGRs and *Metarhizium flavoviride* (strain IMI 330189) are applied. The risk to honey bee brood from IGRs does not appear from these figures but does exist. However, from field experience in Europe, the IGR diflubenzuron is known as not presenting a hazard to honey bee brood in practice. Deltamethrin presents a medium risk and the other compounds a high risk to this group of beneficial arthropods. In general, the risk of barrier treatments is much less compared to blanket sprays; the hazard to affected populations being compensated by the possibility of a recovery through recolonisation from untreated between-barrier areas.

15. Information summarised in Table 2 does not cover all relevant environmental effects. Long term effects and the risk of residues in livestock in treated areas are not taken into account. The risk for bio-accumulation has not been studied as a separate issue for any of the insecticides under consideration. Suitable indications, however, can be derived from the K_{ow} (octanol-water partition coefficient), as these are known from the TOXIS database. High K_{ow}-values indicate a possibility of bio-accumulation while low values indicate that there is no risk for bio-accumulation. The highest values are with the pyrethroids, lambda-cyhalothrin and deltamethrin. For deltamethrin, extensive use has confirmed that this risk is not real. All other insecticides have K_{ow} values much

below those of the pyrethroids. These are therefore considered as posing no significant risk for bio-accumulation with the exception of chlorpyrifos and fipronil. For lambda-cyhalothrin, chlorpyrifos and fipronil more (experimental) data are required in order to dismiss a possible risk of bio-accumulation. Livestock grazing on recently treated vegetation may accumulate residues in the meat. Precise data on these risks are not known to the Group, but this risk needs further attention. FAO is recommended to provide the necessary information for the next meeting of the Group.

16. The Group recommends only use of products with established dose rates because of efficacy, toxicity and environmental concerns. The common name of listed insecticides should be given in FAO publications. Different formulations of the same active ingredient can often have very different properties, so increased reliability of locust and grasshopper control may be expected from established products obtained from manufacturers which have already provided products that meet the specifications required for ULV application. The use of micro encapsulated formulations was reconsidered but the use of a water-based formulation cannot be recommended.

OTHER INSECTICIDES

17. Insecticides other than those listed in Table 2 have been used against locusts and grasshoppers but insufficient data are available to determine reliable effective dose rates. FAO should continue to encourage plant protection organisations, manufacturers, and any other institutions to submit for review information on new or existing products. This should include data from laboratory studies, field trials, or from operational uses on grasshoppers as well as locusts.

18. The Group noted the continuing need for obtaining repeatable field trial data for other locust species. Recent experience with aerial spraying of Red Locust swarms in Southern Africa has highlighted the urgent need for optimising dosage rates of some of the newer compounds as well as tried and tested compounds, like fenitrothion. The Group urges the countries concerned and industry to carry out trials against this species.

19. The Group also noted that there had been little further progress into the use of combinations, eg. deltamethrin + pyridaphenthion, since the last meeting. By combining a reduced amount of an appropriate pyrethroid with an organophosphate, more effective control may be obtained with a reduced insecticide load per hectare. This may also reduce environmental damage in sensitive wetland areas such as where the Red Locust occurs. The chemical industry should therefore be encouraged to proceed with further development work on such combinations.

APPLICATION CRITERIA

20. The logistics of treating large populations of locusts or grasshoppers, especially in remote areas without water has necessitated ultra-low volume (ULV) as the standard application technique. A narrow droplet spectrum is essential with such a low volume to reduce wastage of insecticide in large droplets likely to fall onto bare soil or due to small droplets dispersed beyond the treated area. Environmental pollution is minimised, therefore, if the droplet size spectrum (VMD) is optimised at 50 - 100 mm. However, with this narrow droplet spectrum the volume of application also needs careful consideration to ensure the probability of spray droplets impacting either directly on the insects or the vegetation on which they are resting or feeding. For logistic reasons and to reduce the cost of transportation of UL insecticide to the site of application, 0.5 l/ha has been a preferred volume rate. However, inadequate control of locusts has sometimes been reported when only 0.5 litres per hectare has been applied, indicating too few droplets for adequate coverage. Thus the preferred volume for locust and grasshopper control is one (1) litre per hectare, especially when using ground equipment. The lower rate is normally more successful when aerially applied accurately over large areas, i.e. calibration is good and the vegetation is not too dense.

21. Control by means of barrier spraying is more complex since many more variables need to be optimized than in the case of blanket treatment. The availability of a choice of insecticides for barrier treatments has emphasised the need for more information on the width of each barrier and distance between barriers for different locust species, hopper stages and persistence of recommended§ dosages on vegetation. Highly mobile stages may be controlled with a wide separation between barriers while the more sedentary species may be more effectively controlled if treated barriers are close together. Treatment depends on vegetation type and plant density, wind direction, the development stage of the target and its mobility. This variability makes

extrapolation from one situation to another difficult, especially when trial data applicable to grasshoppers is presented. Good results have been obtained with barriers of diflubenzuron, triflumuron and fipronil.

22. In a protocol for IGR barrier treatment for Desert Locust band control a cross wind barrier width of 50 m has been recommended with a 1000 m spacing between barriers to accommodate the increased mobility of Desert Locust bands. Treatment should be made against the early hopper instars and rotary atomisers are recommended for application. The results of such trials need to be urgently monitored and reported back to the Group to assist in the development of an adequate methodology on the use of barrier treatments for locust control.

23. In listing certain insecticides as suitable for locust and grasshopper control, it is essential that the formulation meets the specifications for ultra-low volume application. In particular low volatility and low viscosity are important criteria so that the appropriate droplet size spectrum is achieved at the flow rate required to apply the recommended dosage. Products causing corrosion to application equipment should also be avoided. FAO should establish formal specifications for these formulations.

24. There has been no major development of equipment since the workshop in Cairo at which equipment manufacturers demonstrated and discussed suitability of ground ULV sprayers for locust and grasshopper control although improvements in existing equipment have been made. The importance of accurate application to minimise wastage and environmental pollution in conjunction with ease of operation of the equipment cannot be overemphasised. The Group stressed the need for training to achieve more accurate applications and welcomed provision of training courses under the EMPRES programme.

SPECIAL CONSIDERATIONS FOR CERTAIN INSECTICIDES

25. The pesticides are divided into the following groups: organophosphates, pyrethroids, carbamates, a combination of these products, insect growth regulators (IGRs), phenyl pyrazoles, biological insecticides (e.g. mycoinsecticides) and botanicals. Special consideration about their suitability for control purposes and conditions of use are given.

Organophosphates, carbamates, pyrethroids and combination products

26. Organophosphates, carbamates, pyrethroids and combination products have many aspects in common. They have a broad spectrum activity, exhibit moderate to fast action and are therefore suitable for use in emergency situations. They work mainly by contact action and are most effective during a short period, so need to be targeted directly to the insect. Locusts exposed to treated vegetation are also affected for a limited period of time after spraying. The need to apply the spray directly on a target requires intensive efforts to identify and delimit suitable targets (hopper bands and swarms). These insecticides are particularly suitable for "crop protection", i.e. killing locusts menacing neighbouring crops directly.

Insect growth regulators

27. The IGRs considered here all belong to the benzoyl urea group. Apart from triflumuron no new data were submitted. Some (e.g. hexaflumuron) are not yet included for lack of locust efficacy data. IGRs of course are suitable only for control of hopper bands, as adult insects will not be affected. Their slow action makes them unsuitable for crop protection. However, their fairly narrow spectrum of activity (=high selectivity) make them attractive from an environmental point of view, but due to adverse effects on crustaceans, spraying of surface waters must be avoided at all costs. The benzoyl ureas have a long persistence on foliage which offers possibilities for barrier spraying aimed at hopper control. If IGRs are used in barrier treatments, their selectivity and the large untreated areas left between treatments reduces environmental impact .

Phenyl pyrazoles

28. Several additional reports were received to substantiate the effectiveness of fipronil. It works both by contact and ingestion. In combination with its persistence on foliage (minimum 3 weeks) and high activity, fipronil is very effective. The minimum effective dose rate for full cover sprays has, for the time being, been set at rate 6.25 g ai/ha, but this should be further optimized. Fipronil is a broad spectrum insecticide. There is a dosage/time to mortality factor when using it and lower dosages than 6.25 g ai/ha may be used if a longer time to complete mortality of the locusts is acceptable. Ecotoxicological aspects have been considered, but more field investigations are needed. Initially barrier treatments would be the preferred option to minimise the area treated and reduce environmental impact.

Biological insecticides

29. A large dossier of information on the biological insecticide *Metarhizium flavoviride* (strain IMI 330189) was presented with good evidence of its effectiveness using ground and aerial equipment against the Desert Locust, Brown Locust and in limited tests against other species of acridids. This myco-insecticide has been shown to produce excellent kills for a biological product. Its slow rate of action is however a disadvantage and locust control operators are likely to experience a challenge to distinguish between treated and untreated targets. The mobility of Desert Locust targets even in their nymphal stages is expected to present a problem. Its application in environmentally sensitive wildlife areas (e.g. national parks, game ranches, wetlands etc.), where chemical control may be unacceptable, and in areas where residues of chemical insecticides in products such as meat are unacceptable, is recommended.

30. More research into speeding up the rate of action and improving the spore quality required for formulation needs looking into. The problem of commercial production to ensure adequate stocks of product at short notice needs to be intensified. Further research is needed to optimize this technology.

Botanical insecticides

31. No further relevant data on the botanical insecticides (*Azadirachta indica* and *Melia volkensii*) was received, and no recommendations can therefore be made.

POSSIBLE USE PATTERNS

32. Locust control operations have to be carried out in a wide range of situations, varying from desert areas, environmentally sensitive nature reserves to intensive farming areas. In addition Desert Locust control could be in response to emergency situations or be an attempt to carry out preventive control. When the insecticides with recommended dosages are considered in the context of the ecotoxicological data, the choice of a particular insecticide will depend on the significance of specific data and the dominant characteristics of the ecosystem.

33. Where there are especially sensitive ecological areas such as nature reserves or agricultural areas specialising in "organic" farming, the development of mycoinsecticides is particularly welcome although they are not yet in commercial production. In other areas where effects on non-target organisms including grazing areas need to be minimised, preference will be for benzoyl ureas, provided the treatments avoid any sensitive aquatic ecosystems. These insecticides ideally will be applied as barrier treatments, but are only applicable where there are hoppers up to the 4th instar, as these insecticides are not sufficiently effective on the last stage hoppers and are not active against flying adults. Use in recession areas away from crops is recommended. Where there are major infestations of hopper bands the alternative to the benzoyl ureas is fipronil, at 12.5 g ai/treated hectare in barriers 1 km apart, at an approximate dosage of 1 g ai / protected ha, to minimise harmful effects to non-target organisms. In agricultural areas with crops at risk, priority will be given to insecticides with a more rapid action, particularly pyrethroids and certain organophosphates. In some areas preference will be for pyrethroids to avoid the risk of organophosphate poisoning of farm workers and others in the vicinity of a treated area.

EVALUATION AND MONITORING

34. The Group noted that considerable difficulty was still being experienced by field operators in attempting to quantify the level of control achieved. This was especially true of the more mobile adult stage. Following treatment of Red Locust adult swarms in floodplain grasslands with compounds with moderately fast action (first signs of toxicity after >2 hours), sprayed locusts flew out of the spray blocks making conventional methods of assessing the kill almost impossible. More development work on this matter is urgently needed so as to provide control managers with better methods of estimating kill and assessing their control efficiency. The Group recommended that during control campaigns, attention be given to appointing specially designated operation research teams whose task it would be to monitor control efficiency and to assist campaign directors in evaluating the level of control achieved. This would ensure confidence in a given active ingredient dose rate.

35. The Group reviewed a report by PRIFAS on guidelines and protocols used for efficacy testing of insecticides for locust control. It was suggested that such comments be taken into account in view of an earlier recommendation to reissue the FAO guidelines for field trials on Desert Locusts, other migratory locust species and grasshoppers.

36. In view of the concern about possible environmental effects of insecticides, the locality and extent of a treated area needs to be recorded. In particular where several sprays may be applied, for example a series of barrier treatments aimed at control of hopper bands, the position of treated areas can be demarcated by using global positioning systems (GPS) and information stored in a geographic information system (GIS). This will be particularly relevant to application of residual deposits, such as benzoyl-urea insecticides in areas with temporary aquatic ecosystems, to monitor any long term effects.

37. The increased availability of GPS linked to GIS now provides better means of maintaining exact records of areas treated so that the long-term impact on locusts and non-target organisms could be evaluated. FAO should be encouraged to extend their "SWARMS" database (Schistocerca Warning Management System) to include information on the use of insecticides. Similar data will be required on the impact of mycopesticides in areas treated several times to assess whether the intensity of outbreaks in breeding areas can be reduced

EMPRES

38. The Group welcomed the development of the FAO EMPRES project (Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases - Desert Locust Component) not only in the Central Region, but also its extension in West Africa and the future development in South West Asia. In particular the Group was concerned that there would be continuity in efforts to improve the forecasting of potential locust outbreaks so that, whenever possible, hopper band populations in recession areas would be prevented from developing into plagues. Furthermore evaluation of existing operational control programmes is needed to assess their effectiveness and to establish whether under large scale conditions the accuracy of application can be improved and dosages of insecticides reduced.

39. It is important to recognise that the dosages listed are considered to be effective under a wide range of conditions and that the probability of successfully reducing these dosages will depend on the accurate timing and treatment of the most susceptible stage. However, it is essential to ensure that control of the most tolerant stages can be achieved. Particular care must be taken when considering reducing dosage rates.

40. Strategy development for control of locusts is an important part of EMPRES. New possibilities for control of locusts as identified by the Group, in particular barrier treatments, may appear relevant for EMPRES strategy development.

RECOMMENDATIONS

41. The previous meeting made several recommendations. Where they have yet to be fully implemented, they are repeated below.

1. FAO should prepare specifications for the formulations of efficacious insecticides for locust control and publish this information. FAO should also finalize and publish the pesticide data sheets for these insecticides.

2. In view of the importance of minimizing environmental contamination and overall costs of locust control, more attention is needed on training to ensure greater accuracy of pesticide application.

3. In view of the need to monitor control operations, it is important for each locust-affected country to field a team which is responsible for this monitoring, separate from those involved in control operations. Optimal use should be made of technologies such as GPS/GIS to facilitate maintaining records. Information obtained on the control operations should be included in a database, such as the FAO "SWARMS" system, to allow for long term assessments.

4. Given the potential importance of barrier treatments to control hopper bands, FAO should encourage the development of models to optimize the possibilities for use of insecticides as barriers.

5. FAO should obtain data on residues in produce for human consumption or cattle food resulting from locust control treatments with special reference to the more persistent insecticides.

6. FAO should update and publish the existing guidelines on trials for the efficacy evaluation of locust insecticides and stimulate the provision of data especially where gaps of information were identified, and extend the knowledge of effects on the environment.

7. FAO should continue to encourage the development of more selective insecticides and application techniques to minimise the environmental impact of chemical control.

8. FAO should continue to encourage environmental impact assessments of insecticides used in locust control and extend the ecotoxicological database specific to the locust situation.

9. FAO should make the work of the Pesticide Referee Group more widely known in the context of general crop protection.

APPENDIX I

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APPENDIX II

Reports submitted to the Pesticide Referee Group in December 1996

NO	TITLE	EXECUTOR	COUNTRY	PESTICIDES	REMARKS
EFFICICACY STUDIES					
88.36	Résultats de l'essai d'efficacité pratique du FASTAC ULV, réalisé en décembre 1998 au Maroc....	IRPV Guelmine	Morocco	alpha-cypermethrin	
96.1	Aerial spray trials with deltamethrin UL against Red Locust adults in the Buzi floodplains, Mozambique	PPRI	Mozambique	deltamethrin fenitrothion	
96.19	Laboratory determination of the LD50 and LD90 values for deltamethrin against sixth instar Red Locust nymphs	PPRI	South Africa	deltamethrin	initial field test included
96.20	Red Locust spray trials with deltamethrin in the Buzi area, Sofala Province, Mozambique, January 1996	PPRI	Mozambique	deltamethrin cyfluthrin	
96.21	Aerial control of a Red Locust swarm with deltamethrin UL in Zimbabwe	PPRI	Zimbabwe	deltamethrin	
96.4	Principaux résultats expérimentaux obtenus au Niger sur les effets du fipronil sur des locustes et des sautériaux	DFPV/PRIFAS	Niger	fipronil	mostly semi-field cage work
96.5	L'efficacité du fipronil en traitement en barrières contre les bandes larvaires du criquet pèlerin, Schistocerca gregaria (Forskal, 1775) en conditiones réelles d'opérations antiacridiennes	PRIFAS	Mauritanie	fipronil	
96.6	Rapport d'essai fipronil	DPV	Madagascar	fipronil	
96.7	Les effets de très faibles doses de fipronil sur les diverses espèces de sautériaux et d'insectes non cibles	PRIFAS	Niger	fipronil	
96.8	Field testing of fipronil 12.5 ULV against adult desert locust in the Red Sea coast of Sudan	PPD/DLCO	Sudan	fipronil diazinon	
96.9	Effets du fipronil sur les bandes larvaires et les jeunes ailés du criquet pèlerin (Schistocerca gregaria Forskal) et son impact sur la faune non-cible	CNLA	Morocco	fipronil	
96.10	Effets du fipronil sur le criquet marocain (Dociostaurus maroccanus) en association avec les sautériaux et son impact sur les insectes non-cibles	CNLA	Morocco	fipronil	
95.6	Essai sur l'efficacité du fipronil en lutte contre les sautériaux au Niger	DPV	Niger	fipronil fenitrothion	
96.11	Lutte contre le criquet nomade (Nomadacris septemfasciata) sur canne à sucre. Essai mis en place méthode de lutte	FDGDEC	La Réunion	fipronil fenitrothion	
96.12	Field trials of fipronil UL against brown locust nymphal bands in the Karoo, South Africa	PPRI	South Africa	fipronil fenitrothion	
96.13	Essais d'appâts au fipronil sur les sautériaux en un locuste (Locusta migratoria migratorioides), Massakory, Tchad	DPV/PRIFAS	Chad	fipronil	trial with baits
96.14	Etude de la bio-efficacité du fipronil à l'égard des ravageurs de caféiers: Hypothenemus hampei et Zonocerus variegatus	IRAD	Cameroun	fipronil	cage trial/summary report
96.15	Field test of fipronil for control of rangeland grasshoppers in Wyoming (USA): implications for reduced agent/area treatments	Univ. Wyoming	USA	fipronil carbaryl malathion	
96.16	Les effets du fipronil (en concentré emulsionnable) sur sautériaux en Sibérie	VIZR/PRIFAS	Russia	fipronil chlorpyrifos	
93.11	Infection of Schistocerca gregaria (Orthoptera: Acrididae) hoppers by Metarhizium flavoviride (Deuteromycotina: Hyphomycetes) conidia in an oil formulation applied under desert conditions	DFPV/IITA	Mauritania	*Metarhizium flavoviride*	
95.7	Operational scale applications of entomopathogenic fungi for control of Sahelian grasshoppers	DFPV/IITA/Univ. London	Niger	*Metarhizium flavoviride*	
93.12	Control of grasshoppers, particularly Hieroglyphus daganensis, in northern Benin using Metarhizium flavoviride	IIBC/IITA/DFPV	Benin	*Metarhizium flavoviride*	
95.8	Etudes socio-économiques sur l'utilisation de Metarhizium flavoviride Gams&Rozsypal en milieu paysan au Sahel	SNPV/IITA	Niger	*Metarhizium flavoviride*	
95.9	Metarhizium flavoviride (FI985) as a promising mycoinsecticide for Autralian acridids	CSIRO	Australia	*Metarhizium flavoviride*	
95.10	Aerial spray trials against brown locust (Locustana pardalina, Walker) nymphs in South Africa using oil-based formulations of Metarhizium flavoviride	PPRI/IIBC	South Africa	*Metarhizium flavoviride*	
95.11	Control of hopper bands of Schistocerca gregaria with the entomopathogenis fungus Metarhizium flavoviride in the North-East of Mauritania in April 1995	IITA	Mauritania	*Metarhizium flavoviride*	

95.12	Trial of Metarhizium flavoviride on Schistocerca gregaria hopper bands	IITA	Mauritania	*Metarhizium flavoviride*	summary report
96.17	Field trial on tree locusts near Tendelti, Sudan, September 1996	IIBC/PPD	Sudan	*Metarhizium flavoviride*	
96.18	Results of a medium scale field trial in Niger to compare operational control of Oedaleus senegalensis with Metarhizium flavoviride and fenitrothion	IITA/DPV	Niger	*Metarhizium flavoviride* fenitrothion	summary only
91.4	The effect of an insect growth regulator on grasshoppers (Acrididae) and non-target arthropods in Mali	Univ. Oslo	Mali	teflubenzuron	journal publication of previously submitted and reviewed study
96.2	The effects of triflumuron (Alsystin) on hopper bands of Schistocerca gregaria	GTZ	Mauritania	triflumuron	
96.3	Alsystin - an environmentally friendly insecticide for the control of plagues of locusts	Dorow	various	triflumuron	review paper, containing detailed trial descriptions
ENVIRONMENTAL STUDIES					
--	Evaluation of ecotoxicological data from affected countries of insecticides against locusts and grasshoppers	FAO/Locustox project	various	various	FAO working document
--	Ranking of pesticides used in locust control in relation to ecotoxicological data and ecosystems	RIVM	--	various	FAO working document
OTHER REPORTS					
	File to support the use of PENNCAP M foer locust control	ELF ATOCHEM	--	micro-encapsulated methyl-parathion	Toxicology and registration data
	Consultancy visit to Tajikistan to assist with FAO/UNDP-funded locust control campaign	NRI	Tajikistan	diflubenzuron chlorpyrifos	operational data on barrier treatment with IGR
	Results of trials in Morocco	CNLA/Dow Elanco	Morocco	chlorpyrifos	operational data
	Methodes d'étude de l'efficacité des insecticides contre les acridiens	PRIFAS	--	--	review of efficacy trial guidelines for locusts and grasshoppers

APPENDIX III:

Summary of data from efficacy trial reports listed by insecticide as discussed in the 1996 Group meeting

INSECTICIDE	CLASS	APP. RATE (g ai/ha)	CONTROL 24 hrs (%)	SPECIES	SPRAYER	VOL RATE (l/ha)	PLOT SIZE (ha)	REPL-ICS	REPORT CODE	COMMENTS
alpha-cypermethrin	PY	30	95@96h	SGR	aerial	0.5	400	1	88.36	supporting data
deltametrhrin	PY	35	>90@72h	NSE	aerial	2.8	33-36	3	96.1	good test on adult red locust
		-	-	NSE	topical	-	-	1	96.19	lab. study
		17.5	26	NSE	solo micronair	2.5	0.25	2	96.20	
		20	72	NSE	solo micronair	2.8	0.25	2	96.20	
		30	90@72h	NSE	aerial	2	100	1	96.21	some data on non-target organisms
fipronil	PPZ	1,2,4 and 8	100@96h	various	rotary atomiser	-	-	-	96.4	semi-field/cage trials
		1.96/protected ha	>95@3d	SGR	aerial	-	***	1	96.5	barrier treatment (330-1080m spacing)
		1.03/protected ha	100@2d	SGR	aerial	-	***	1	96.5	barrier treatment (1180-2610m spacing)
		0.81/protected ha	>95@7d (larv.)	LMI	aerial	-	1260	1	96.6	barrier treatment (700m spacing)
		1/protected ha	>95@3d (larv.)	LMI	aerial	-	910	1	96.6	barrier treatment (700m spacing)
		4	91	LMI	micro-ulva	1.22	9	1	96.6	full cover treatment (100% mortality of locusts introduced @14d on plot
		0.57, 1, 1.2, 2	>95@5d	mixGH	micro-ulva	1-1.2	4 and 9	1	96.7	data on non-target arthropods
		6.25	97-100	SGR	ulvamast	0.5	-	1	96.8	1 cage showed only 38% mort.@30h
		7.65	>95@48h	SGR	ENS	1	31	1	96.9	100% mort. of locusts introduced @14d on plot
		3.8-4	99@72h for DMA	DMA+mixGH	micro-ulva	1	1	4	96.10	
		4, 6, 8	94-97@7d	OSE+mixGH	micro-ulva	0.9-2	1	3	95.6	
		6	>95@7d	NSE	aerial	3 and 9	6 and 7	2	96.11	insecticide mixed zith oil at 2 rates
		4, 7.5, 10	>95@72h	LPA	micro-ulva	1-2.5	0.1-0.3	24	96.12	70% mort.@25d in persistence trial
		5.5-19.5	>95@5d	OSE+mixGH	by hand	10-20kg/ha	0.5-1	1	96.13	baits; 6 dose rates tested
		10-25	100@10h	ZVA	matabi	300	-	2	96.14	EC formulation, cage trials
		1.5/protected ha	76-79@4-13d	usaGH	aircraft	1	16	1	96.15	barrier treatment (90m spacing)
		3.7-6.4	>80@6d	rusGH	air/tractor	28-670	1.2-10	2	96.16	EC formulations
Metarhizium	MYC	$1x10^{12}$-$5x10^{12}$	90-100	SGR	micro-ulva	2	0.1-2.5	4	93.11	
flavoviride		$5x10^{12}$	90-100	SGR	ulva+	2	0.75-2	3	95.7	
(note: app. rate in spores/ha)		$4.2x10^{12}$-$5x10^{12}$	80@21days	OSE	ulvamast	2	49	3	95.8	population lower than in fenitrothion plots
		$3.7x10^{12}$-$4.7x10^{12}$	>95@14d	LPA	ulva+	2	0.1	5	95.10	
		$1.9x10^{12}$-$3x10^{12}$	85-98@21d	LPA	aerial	1 and 2.5	0.1-10	10	95.10	
		$3x10^{10}$	80-100	CTE	-	-	1	-	95.9	several small trials
		$5x10^{12}$	75@18d	AMM	mistblower	5	6-25	3	96.17	

INSECTICIDE	CLASS	APP. RATE (g ai/ha)	CONTROL 24 hrs (%)	SPECIES	SPRAYER	VOL RATE (l/ha)	PLOT SIZE (ha)	REPL-ICS	REPORT CODE	COMMENTS
triflumuron	IGR	50 and ?	80 (barrier)	SGR	micro-ulva	-	-	-	96.2	barrier spacing 100m
			90 (roosting)		solo	-	-	-	96.2	
		12-100	>90 at higher rates	SGR+GH	ulva and solo	various	various		96.3	review paper reports 1991-1995 trials

SPECIES KEY

AME = Anacridium melanorhodon
CTE= Chortoicetes terminifera
DMA= Dociostaurus maroccanus
HDA = Hieroglyphus daganesnis
NSE = Nomadacris septemfasciata
LMI = Locusta migratoria
LPA = Locusta pardalina
OSE = Oedaleus senegalensis
SGR = Schistocerca gregaria
mixGH = mixture; no predominant specs.
usaGH = USA grasshoppers
rusGH= Russian grasshoppers

CONTROL KEY

20 - 30 = range of mortality
20/30 = mortality of two species
80@2d= 80% control after 2days
>95@48h= more than 95% control after 48 hours

INSECTICIDE KEY

Py = Pyrethroid
IGR = Insect growth regulator
PPZ = Phenyl pyrazole
MYC = mycopesticide

APPENDIX IV

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APPENDIX V

TERMS OR REFERENCE

1. To evaluate, at least once a year, pesticide trial reports on Desert Locusts and other migratory locusts, with reference to the following:

    a) satisfactory trial technique (eg. number of replicates, method of measuring mortality, application technique).

    b) validity of the report (methods and procedures fully described).

    c) effective kill at the dosages used.

    d) health and environmental implications.

2. On the basis of the above, and relevant information on large scale control operations, prepare a list of pesticides and dosages efficacious for operations against Desert Locusts and other migratory locusts, and appraise them according to their health and environmental risk.

3. Compile a list of pesticides that warrant further evaluation either from the point of view of efficacy or environmental side-effects, and specify the trials required (laboratory, field, small scale, large scale).

4. Provide FAO with advice on pesticides, when required between meetings.

5. Prepare a report covering the above points.

Members (not more than 5), appointed on a personal basis, should be impartial and objective in their assessments and should have at least one of the following qualifications:

- should have experience of locust field work.
- should be actively involved in locust control in a locust-affected country.
- should have experience in pesticide application and evaluation.
- should have environmental/ecotoxicological experience.

APPENDIX VI

EVALUATION OF PESTICIDES FOR LOCUST CONTROL

The following criteria are provided to determine which insecticides should be evaluated for locust control.

1. The pesticide (or pesticides, if a mixture is proposed) must be registered for use on food crops or rangeland in at least one OECD (Organisation for Economic Cooperation and Development) country. In addition, at least an experimental use permit will have to be agreed on by the host country for the pesticide trial.

   Innovative approaches such as mycoinsecticides may also be considered.

2. The active ingredient should not have been classified as a Group 1, 2A or 2B compound by the WHO/International Agency for Research on Cancer (IARC).

3. The pesticide, in its expected most concentrated formulation for locust control (ie formulated to be applied as 0.5- 1 l/ha) should not fall in WHO acute toxicity class 1A or 1B.

4. As application is often through ULV methods, for practical purposes, application rates should not exceed approximately 1,000 g ai/ha. There is a high likelihood that topical LD_{50}'s derived in the laboratory which exceed 35 ug/g body weight (late instar *S. gregaria* larvae) will result in too high field application rates. As a rough guidance, pesticides which would justify further field testing should therefore preferably have a topical LD_{50} below 35 ug/g.

   The above only refers to contact chemical pesticides. For pesticides whose action is primarily through ingestion, no guidance limit can be given as this strongly depends on the persistence of the compound under relevant field conditions and the rate of excretion from the insect body.

5. Field trials will be carried out according to the FAO Guidelines for field testing of pesticides for locust control. The objective of the trials should be to determine the lowest dose rate to achieve a reliable level of control for a given species.

6. For a given species, two independent small-scale trials and at least one large operational scale trial are considered a minimum requirement for a valid determination of a recommended dose rate. The small scale trials should result in a dose recommendation. The large-scale trial is staged to confirm the dose rate under semi-operational conditions. Under certain circumstances, to be decided by the Group, results obtained with one species of locust or grasshopper may be extrapolated to another species.

7. In future assessments of locust insecticides, consideration will be given to appropriate ecotoxicological data.

(Note: These criteria have been slightly modified from the FAO Expert Meeting on the Evaluation of Pesticides for Locust Control; FAO, Rome, 2 February 1989. They now replace the criteria listed in the report of the above mentioned expert meeting).