Evaluation of Field Trials Data on the Efficacy and Selectivity of Insecticides on Locusts and Grasshoppers

Report to FAO
by the
Locust Pesticide Referee Group

Eleventh Meeting (virtual)

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Food and Agriculture Organization of the United Nations

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ABBREVIATIONS

AChE	Acetyl-cholinesterase (enzyme breaking down neurotransmitter acetyl-choline)
a.i.	active ingredient
CCA	Caucasus and Central Asia
CIT	*Calliptamus italicus*
CLCPRO	*Commission de lutte contre le criquet pèlerin dans la région occidentale*
DLIS	Desert Locust Information Service of FAO
EFSA	European Food Safety Authority
EHS	Environmental, Health and Safety Standards
EIA	Environmental Impact Assessment
EMPRES	Emergency Prevention System
FAO	Food and Agriculture Organization of the United Nations
GHS	Globally Harmonized System of Classification and Labelling
IGR	Insect Growth Regulator
IOBC	International Organisation for Biological and Integrated Control
JMPR	FAO and WHO Joint Meeting on Pesticide Residues
JMPS	FAO and WHO Joint Meeting on Pesticide Specifications
LPRG	Locust Pesticide Referee Group (name as of 11th meeting)
PPE	Personal Protective Equipment
PRG	Pesticide Referee Group (name until 10th meeting)
PSMS	Pesticide Stock Management System
SAICM	Strategic Approach to International Chemicals Management
SDG	Sustainable Development Goal
UL	Ultra Low Volume (formulation)
ULV	Ultra Low Volume (application)
VMD	Volume Median Diameter
WHO	World Health Organization

INTRODUCTION

1. The Locust Pesticide Referee Group (LPRG), formerly Pesticide Referee Group (PRG) is an independent body of experts that advises FAO on the efficacy as well as health and environmental risks of insecticides used in locust control. The LPRG performs the following tasks:
   - reviews insecticide efficacy trial reports and establishes recommended dose rates against the Desert Locust and other species of locusts;
   - evaluates environmental impact studies and classifies insecticides with recommended rates as to their environmental and health risks;
   - reviews operational use of insecticides in locust control and possible constraints;
   - identifies gaps in knowledge and recommends further studies to be conducted.

   The LPRG advises on other matters pertaining to locust control as requested by FAO.

2. The resulting advice systematically lists insecticides suitable for locust control from the scientific point of view. The LPRG has no legal status. All uses of insecticides discussed in this report are fully subject to national legislation, regulation and registration.

3. Because of restrictions imposed on account of the COVID-19 pandemic, the 11th meeting took place in several virtual sessions between February and November 2021.

4. The meeting was opened by Mr Shoki AlDobai, Team Leader of Locusts and other Transboundary Plant Pests and Diseases. Mr AlDobai noted that there had not been a LPRG meeting since 2014 (PRG, 2014). However, in view of the massive Desert Locust upsurge across greater Eastern Africa, Southwest Asia and the Red Sea area in 2019 and 2020, there was an urgent need to organize a LPRG meeting to discuss aspects of insecticide use in locust control. Mr AlDobai pointed out that, similar to the previous reporting period, few solid data had been shared for review with the LPRG. However, stakeholders were invited to submit new data following an informal meeting of the LPRG in June 2020.

5. FAO expressed gratitude to the participants for taking part in the meeting despite the inconveniences caused by the pandemic. It was stressed that both FAO and its members value the advice of the LPRG and that LPRG recommendations tend to be considered in all of FAO's locust control programmes.

6. It was reiterated that FAO is promoting preventive locust control strategies which aim to minimize overall use of insecticides, eliminate the use of highly hazardous pesticides and favour the application of biopesticides early in the locust population development. As a result, less hazardous migratory pest control options will need to be identified whenever possible, which are operationally effective and sustainable in the long term. However, the use of chemical insecticides will continue to be required during outbreaks or plagues.

7. Initially, the LPRG focused on insecticides used in Desert Locust control. However, given the involvement of FAO in the management of other migratory locusts – e.g. Moroccan and Italian locust in the Caucasus and Central Asia (CCA), Migratory Locust in Madagascar, Red Locust and Brown locust in Southern Africa – and large quantities of insecticides used, the LPRG also provides advice on the management of such other species, whenever possible.

8. The LPRG was informed about the status of the ongoing Desert Locust upsurge and control. From January 2019 to January 2021, five million hectares have been treated. Approximately 46 percent of these treatments have taken place in Southwest Asia, 40 percent in East Africa and 14 percent in the Near East. ULV formulations of organophosphates and pyrethroids continue to be the mainstay of control. Some countries such as Somalia also use insect growth regulators and biopesticides (*Metarhizium acridum*[1]) at a large scale. EC formulations are also widely in use, particularly in Iran.

9. The introduction of several technical innovations has been reported, including the eLocust3 digital suite

1 Formerly classified as *Metarhizium anisopliae* var. *acridum* or *Metarhizium flavoviride*

of tools that supplement the original tablet version used by field officers to enter complete survey and control data. The new tools work on mobile phones and GPS for entering basic survey and control data, including crowd-sourcing. Moreover, improved climate predictions, earth observations (satellites) and drones are increasingly used for monitoring and early warning.

10. In preparing for the present meeting, major pesticide manufacturing and formulating companies (29 in total), national locust control organizations, plant protection services and research institutions in locust-affected countries (69 in total) had been approached by FAO in July 2020 to obtain new field efficacy trials and environmental impact studies of insecticides for locust control. However, only seven companies provided efficacy data. In addition, a limited number of publicly or privately funded studies on biological efficacy and environmental impact of locust and grasshopper control were received.

11. Moreover, FAO and the LPRG searched scientific journals that regularly publish articles on locust control and its environmental impact.

12. In total, 15 reports on biological efficacy, some of them just summary tables or statements, were made available to the LPRG for review (Annex 2). Of these, only six studies were done under field or semi-field conditions. In addition, 47 environmental impact studies had been reviewed, most of them scientific papers published before 2014, the year of the 10th meeting of the LPRG. They are included here to provide a full account of publicly available data on the topic of environmental impacts associated with insecticides used to control locusts. Reports and papers reviewed are listed in Annex 3.

13. Like at the 10th meeting, the LPRG noted with concern a dearth of efficacy studies submitted by the pesticide industry, in particular of new insecticides which may be appropriate for locust control. The LPRG recommended that FAO re-engaged with the pesticide industry and initiate a dialogue on how best to test and market new, low-risk insecticides for locust control.

14. The Locust Pesticide Referee Group members and other participants in its meeting are listed in Annex 1. Mr Peter Spurgin was elected Chairman of the 11th meeting, and Mr Ralf Peveling acted as the Secretary of the LPRG.

IMPLEMENTATION OF PREVIOUS RECOMMENDATIONS

15. FAO informed the LPRG about the implementation of its previous recommendations. Since the 9th meeting of the LPRG, the Desert Locust Guidelines had been published and are widely used by FAO in training and capacity building. The FAO guidelines for pesticide trials for locust control had also been updated. Various FAO and WHO specifications had been elaborated and adopted for UL formulations of insecticides used in locust control; however, for several insecticides listed as effective by the LPRG no appropriate specifications are available yet, hampering quality control of these products.

16. It was noted that barrier treatments are increasingly used in migratory locust control, as recommended by the LPRG. The aim of the EMPRES Western Region programme was that by the end of 2017, at least 40 percent of locust targets are controlled through barrier treatments with Insect Growth Regulators (IGRs), in those cases where IGRs can be used technically.

17. The LPRG had recommended that FAO should use the full list of recommended insecticides in order to make the best choice for purchases, considering not only efficacy but also human health and environmental risks. FAO indicated that it never purchases any other insecticides than those listed as effective by the LPRG. It was noted, however, that in some regions the use of low risk insecticides such as IGRs or entomopathogenic fungi was slow to take off.

18. With respect to its recommendation that FAO should collect operational data on the area treated,

the type and amount of insecticide used and the efficacy achieved during Desert Locust control operations to build up a centralised database, the LPRG was informed about the eLocust3 tablet that was introduced on 1 January 2015. This field data collection tool is used for Desert Locust survey and control operations and includes an extensive module on control and insecticide use. In conjunction with the new version of the RAMSES database, data collection and analysis has greatly improved. A similar eLocust3 version for mobile phones, eLocust3mPRO, will be available later in 2021 to further improve the collection of detailed survey and control data. FAO also confirmed that a similar initiative on improving data collection had been taken in the Caucasus and Central Asia.

19. The implementation of other previous LPRG recommendations are discussed in more detail below.

EFFICACY OF INSECTICIDES AGAINST LOCUSTS

20. The LPRG took note of the fact that the FAO Insecticide Trials Database, which contains all efficacy trials submitted to the LPRG since its first meeting, had not been updated since 2014. The LPRG recommended that FAO puts a mechanism into place for its maintenance, updating and accessibility.

21. The LPRG noted that quality criteria for insecticide efficacy field studies against the Desert Locust and other locusts and grasshoppers outlined in Annex 4 are rarely met. It reiterated its concern that there was no improvement despite the decade-long availability of FAO guidelines and concluded that this was partly due to the deterioration of control structures during the extended recession period. The LPRG stressed the importance of rigorous and scientifically sound efficacy testing to ensure thatdose recommendations are precise and robust and avoid wasting scarce trial resources. The LPRG recommended that FAO continues to actively disseminate the various guidelines for efficacy testing of insecticides for locust and grasshopper control (FAO 1991a, 1991b, 2005, 2006, 2007) and to hire consultants to support trials as needed.

22. Overall, eight field or semi-field efficacy studies had been compiled for review by the LPRG (Annex 2). Details of these studies are listed in Annex 5. Minimum quality criteria (Appendix 4) were only partially fulfilled by two studies and not fulfilled by two others. This was due to incomplete or erroneous reporting of spray parameters or dose rates. Moreover, plot sizes were generally small – in two cases not reported at all – and observation periods short, which may compromise the significance of the results. Most trials were done on active ingredients that have been in use for some time (Table 1). Studies using novel locust control agents such as pyrethrins and ammonium hydroxide were inconclusive and did not allow the derivation of verified dose rates. All trials were conducted against locust species.

23. The only new field-tested insecticide submitted for review (21-06) was chlorantraniliprole, an anthranilic diamide with a novel and specific mode of action (interaction with ryanodine receptors). Efficacy of this agent against the Desert Locust was high (nearly 100 percent at 48 hours) at the tested rate (24 g a.i./ha) though quality criteria were not fully met (e.g. pseudo-replication). Further trials using different field rates and being fully compliant with FAO guidelines are needed before establishing verified dose rates.

24. The same study tested spinosad at 15.1 g a.i./ha, yielding similar results. Again, submitted data did not allow to derive verified dose rates. Moreover, no UL formulations are available as yet.

25. With the exception of a field study of profenofos + cypermethrin against Tree Locust, no data on the efficacy of binary insecticides against Desert Locust had been submitted. The LPRG recommends that further information on the operational or experimental use against Desert Locust be gathered.

Table 1.
Efficacy trials meeting quality criteria in Annex 4 fully (21-01 to 21-04) or largely (21-05 and 21-06) that were evaluated by the LPRG.

Insecticide	Target species	Report code
Pyrethroid		
Deltamethrin	Brown Locust	21-01
Organophosphates (+ pyrethroid)		
Chlorpyrifos	Migratory Locust	21-04
Diazinon	Desert Locust	21-02
Malathion	Desert Locust	21-02
Profenofos + cypemethrin	Tree Locust	21-03
Anthranilic diamide		
Chlorantraniliprole	Desert Locust	21-06
Phenylpyrazole		
Fipronil	Desert Locust	21-02, 21-06
Micro-organism derived		
Spinosad	Desert Locust	21-06
Entomopathogenic fungus		
Metarhizium (IMI 330189 and EVCH077)	Desert Locust	21-05

26. One trial (21-02) tested blanket treatments of fipronil (4.7 – 7.8 g a.i./ha) and diazinon (300 – 500 g a.i./ ha) against a malathion standard (960 g a.i./ha) in Sudan. While both agents proved highly efficacious at medium and higher dose rates, the LPRG does not recommend using an organophosphate whose registration is phasing out worldwide. Likewise, the LPRG firmly advises against blanket treatments of fipronil irrespective of dose.

27. One field trial with *Metarhizium acridum* (isolate IMI 330189) against the Desert Locust in Morocco (21-05) confirmed the efficacy of the previously recommended rate of 50 g/ha (2.5 x 10^{12} spores/ ha). Another isolate (EVCH077) proved equally efficacious at the same rate. Reducing the rate to25 g/ha produced insufficient mortality (<90 percent) and is therefore not recommended. Nor is it recommended to double the dose, an occasional practice reported from the current Desert Locust campaign at the Horn of Africa.

28. The same trial simulated a barrier treatment against Desert Locust by exposing hoppers to treated vegetation one day after the application. The rationale, though unexplained, was presumably to test for secondary pick-up of spores as known from Sahelian grasshoppers. However, despite maximum exposure (hoppers were kept in enclosures erected on treated vegetation) mortality was too low (approx. 50 percent). The LPRG therefore maintains its previous recommendation not to use *Metarhizium acridum* in barrier treatments against the Desert Locust. Barrier treatments with chemical insecticides such as IGRs are considered more appropriate.

29. Verified dose rates, speed of action, and primary route of exposure of different control agents for the Desert Locust are given in Table 2. The LPRG did not consider that any modifications to this table – compared to the 2014 version – were justified, based on the new efficacy data that were made available at the present session. However, the LPRG decided to remove bendiocarb from the table (see paragraph 30). The recommended dose rates are expected to result in a minimum efficacy of 90 percent (mortality or population reduction) under most circumstances. In some situations where rapid kill is not essential, lower dosages of some of the insecticides listed may be effective. However, the final efficacy even of these lower rates should be ≥90 percent.

30. The LPRG recommends removing bendiocarb, the only carbamate insecticide, from Table 2, based on environmental and human health concerns. This follows the phase-out of all bendiocarb products by the manufacturer.

31. Suggested dose rates for other species of locusts are given in Table 3. New insecticides added to this table were the combination of profenfos + cypermethrin against Tree Locust and deltamethrin against Brown Locust. The LPRG recommends removing thiamethoxam + lambda-cyhalothrin from Table 3 owing to concerns about serious environmental hazards particularly to pollinators and insufficient environmental risk field data.

32. The LPRG acknowledges operational interest in conducting barrier treatments, with spray swaths at least 700 m apart. Based on experiences in Australia, where irregular blanket treatments with fipronil using a 300 m spray interval for an overall dose of 0.33 g a.i./ha has proved fully effective in controlling mobile bands of Australian plague locust nymphs, the presently recommended dose rate within the sprayed barrier of 4.2 g a.i./ha can likely be reduced. The LPRG therefore reiterates its recommendation that FAO investigate the possibility to conduct large-scale trials of barrier treatments with lower doses of fipronil, focussing on both efficacy and environmental impact. In the meantime, the LPRG has maintained the verified dose rate for fipronil in barrier treatments in Tables 2 and 3. Irregular blanket treatments with the IGR teflubenzuron (300–400 m spray interval with a 30 g/L formulation, resulting in an overall dose of 7.5 – 10 g a.i./ha) have been tested recently at the Horn of Africa at an operational scale against Desert Locust hopper bands composed of 2nd to 4th instar nymphs, with good results. Overall efficacy was consistently >95 percent after 12 days with the 300 m spray interval and after 24 days with the 400 m interval, over an infested area of 159 000 ha.

33. The speed of toxic action (e.g. knockdown, complete cessation of feeding) of the different compounds was defined as: fast (F=1–2 hours), moderate (M=3–48 hours) and slow (S>48 hours). Speed of action is generally determined by the class of the product, its dose rate, its inherent toxicity and the primary route of exposure. Synthetic pyrethroids produce a rapid sublethal knockdown effect, followed by a protracted paralysis after which the insect may die or partially recover depending on the dose received. Locusts that may partially recover usually die later without feeding. Some insecticides may not have such a rapid toxic effect but still adversely affect the behaviour of the locusts. Cessation of feeding can occur very quickly, even though death occurs later within the first day following treatment. Among the slower compounds listed in Tables 2 and 3 are the mycoinsecticide *Metarhizium acridum* and the benzoylureas (IGRs) which take a week or more to kill. To ensure that enough product is ingested and accumulated, the LPRG reaffirmed that early and intermediate hopper instars should be optimally targeted when using benzoylureas, although later instars are also affected. IGRs can also adversely affect adult locusts by reducing fecundity and fertility. Such products are particularly suitable for a proactive role within the confines of locust outbreak areas where barrier treatments are advisable. Further special considerations for insecticide groups are given in Annex 6.

34. Insecticides other than those listed in Tables 2 and 3 have been used against locusts and grasshoppers, but insufficient data are available to the LPRG to determine reliable effective dose rates. FAO should continue encouraging plant protection organisations, manufacturers and any other institutions to submit data on new or existing products for review. While experimental and operational field data are preferred, results from laboratory studies can also be included.

Table 2a.
Verified dose rates of different insecticides for control of the Desert Locust (*Schistocerca gregaria*).

Insecticide [1]	Class	Dose rate (g a.i./ha) [2]				Speed of action	Primary mode of action
		Blanket treatment		Barrier treatment (hoppers) [3]		at verified dose rates [4]	
		Hoppers	Adults	Intra-barrier	Overall		
Chlorpyrifos	OP	240	240			M	AChE inhibition
Deltamethrin	PY	12.5 or 17.5[5]	12.5 or 17.5 [5]			F	Na channel blocking
Diflubenzuron	BU	30	n.a.	100 [6]	14.3	S	Chitin synthesis inhibition
Fenitrothion	OP	400	400			M	AChE inhibition
Fipronil	PP			4.2	0.6	M	GABA receptor blocking
Lambda-cyhalothrin	PY	20	20			F	Na channel blocking
Malathion	OP	925	925			M	AChE inhibition
Metarhizium acridum (IMI 330189)	fungus	50	50			S	Mycosis
Teflubenzuron	BU	30	n.a.	n.d.		S	Chitin synthesis inhibition
Triflumuron	BU	25	n.a.	75 6	10.7	S	Chitin synthesis inhibition

Abbreviations: BU: benzoylurea, OP: organophosphate, PY: pyrethroid, PP: phenyl pyrazole; n.a. = not applicable; n.d. = not determined.
Notes:
[1] Bendiocarb is no longer listed because of environmental and health concerns.
[2] Application volumes for the recommended dose rates differ depending on the formulation available.
[3] Calculated dose rate applied over the total target area based on an average barrier width of 100 m and a track spacing of 700 m.
[4] Speed of toxic action: F=fast (1-2 hours), M=moderate (3-48 hours) and S=slow (>48 hours).
[5] The higher dose rate may be required if there is a risk of recovery of late instars or adults particularly at high temperatures (field observations confirm this requirement).
[6] Blanket and irregular blanket spray data and observations for other locusts suggest that effective dose rates for Desert Locust barrier treatments may be further reduced.

Table 2b.
Conversion table for different formulations of insecticides with verified dose rates for the Desert Locust control

Insecticide	**Dose** (g a.i./ha)	**Common formulation** (g a.i./L) 1	**Volume application rate** VAR (L/ha of formulation)
Chlorpyrifos	240.0	450	0.53
		240	1.00
Deltamethrin	12.5	25	0.50
		12.5	1.00
Diflubenzuron	30.0	60	0.50
Fenitrothion	400.0	1 000	0.40
		500	0.80
Fipronil (overall dose) 2	0.6	7.5	0.56
Lambda-cyhalothrin	20.0	40	0.50
Malathion	925.0	960	1.00
Metarhizium anisopliae (IMI 330189)	50.0	50.0	1.00
Teflubenzuron	30.0	50	0.60
Triflumuron	25.0	50	0.50

[1] These are examples of the most common formulation concentrations; other formulations may be marketed by the pesticide industry.2
[2]The current recommendation for Desert Locust is 0.6 g a.i. per protected ha applied as a single swath at a track interval of 700 m.

Table 3.
Suggested dose rates for the control of locust species other than the Desert Locust.

Insecticide[1]	**Class**	**Species**	**Dose rate** (g a.i./ha) [2]					**Remarks**
				Blanket treatment	**Barrier treatment** (hoppers) [3]		**Speed action at**	
			Hoppers	Adults	Intra-barrier	Overall[4]	verified dose rate[5]	
Chlorpyrifos	OP	LMC	240	240			M	
		DMA	120	120				
Chlorpyrifos + cypermethrin	OP + PY	LMC	120 + 14	120 + 14			F	
Profenofos + cypermethrin	OP + PY	AME	100 + 10	- [6]			F	
Alpha-cypermethrin	PY	CIT, DMA, LMI	15	15			F	
Deltamethrin	PY	LMC	15	15			F	
		LPA	17.5	17.5				
Diflubenzuron	BU	CIT, DMA	12	n.a.	24	12	S	Barrier ratio treated:untreated = 1:1 (irregular blanket spray)
		LMC			60	12		Barrier spacing 500–700 m
Fipronil	PP	LMC			7.5 [7]	1.1	M	Barrier spacing 700–1000 m
		CTE			1.0	0.33		Track spacing of 300 m
								(irregular blanket spray)
Metarhizium acridum (IMI 330189)	fungus	LMC	50	50			S	
		NSE	50 [8]	50 [8]				
Teflubenzuron	BU	LMC			50	10	S	Barrier spacing 500–700 m
		CIT, DMA, LMI	9	n.a.	18	9		Barrier ratio (irregular blanket spray)
Triflumuron	BU	LMC						
					50	10	S	Barrier spacing 500–700 m

Abbreviations:
BU: benzoylurea, OP: organophosphate, PY: pyrethroid, PP: phenyl pyrazole; n.a. = not applicable
AME = *Anacridium melanorhodon*, CIT = *Calliptamus italicus*, CTE = *Chortoicetes terminifera*, DMA = *Dociostaurus maroccanus*, LMC = *Locusta migratoria capito*,
LMI = *Locusta migratoria*, LPA = *Locustana pardalina*, NSE = *Nomadacris septemfasciata*
Notes:
[1] Thiamethoxam + lambda-cyhalothrin no longer listed because of high pollinator toxicity. Outdoor use of thiamethoxam is strongly restricted in many countries including the EU.
[2] Application volumes for the recommended dose rates differ depending on the formulation available.
[3] Calculated dose rate applied over the total target area based on the listed ratio treated:untreated.
[4] Overall dose rates of barrier treatments are given for the lowest barrier spacing value.
[5] Speed of toxic action: F = fast (1-2 hours), M = moderate (3-48 hours) and S = slow (>48 hours).
[6] Trials were done on hoppers only. Efficacy is likely to be similar in adults but would require further testing.7
[7] A lower dose rate is likely to be possible but requires confirmation.
[8] A reduction to 30 g/ha may be possible under ideal conditions.

APPLICATION CRITERIA

35. The LPRG continues to recommend ULV application as the standard technique to cope with the logistics of treating large areas with populations of locusts or grasshoppers, especially as these generally occur in remote areas without water. The application of about one litre per hectare is preferred to ensure that sufficient droplets are applied for adequate coverage. However, depending on what formulation is available and if calibration is accurate and vegetation is nottoo dense, a lower rate of down to 0.5 litres/ hectare is acceptable if aerially applied over largeareas. Such low volumes necessitate a narrow droplet spectrum to reduce waste of insecticidein large droplets. A range of 50-100 µm VMD (Volume Median Diameter) droplet spectrum using rotary atomisers is advocated. On the other hand, higher volume application rates(2 litres/hectare) may be more effective in very dense vegetation, e.g. as often encountered inRed Locust habitats.

36. Water-based formulations (e.g. emulsifiable concentrates, suspension concentrates, soluble concentrates, water-dispersible granules) are not recommended for ULV application, as the volatility is too high, in particular in hot climates. They may be used only if targets are toosmall for drift spraying, for example, when treating small and discrete patches of locusts, using manually operated knapsack sprayers.

37. The LPRG acknowledged that, for various reasons, water-based formulations are widely usedagainst locusts in Central Asia. Efforts should be made to assess whether lower volumes of water can be applied in combination with adding an evaporation retardant to the spray dilution.This may be particularly relevant in view of rising temperatures. However, the move towardsULV application, which started with the FAO regional programme in 2011, should clearly be continued.

38. The LPRG welcomed that never before had biopesticides been used on such a large operational scale as during the 2020/21 campaign against the Desert Locust in the Horn of Africa. However, indications have emerged that proper handling and use requirements were difficult to meet under operational conditions. Therefore, the LPRG reminded that the application of *Metarhizium*and similar biopesticides requires specific capability with respect to transport and storageof spores, identification of suitable targets, mixing and application of spray formulations, monitoring of efficacy and cleaning of equipment. The LPRG recommends that spray teams applying *Metarhizium* are specially trained and supervised to ensure optimal efficacy of this biopesticide. Furthermore, the Horn of Africa campaign should be taken as a learning case for biocontrol and subjected to a thorough analysis of success factors and impediments.

39. The use of *Metarhizium acridum* to control mobile Desert Locust swarms illustrates potentialproblems faced during operations using biopesticides. Owing to the relatively slow time to death (c.f. Table 2), the possibility exists of treated swarms moving considerable distances inthe days following spraying and being designated as targets again when located in new areas by control teams. Effective post-treatment monitoring of swarms can help alleviate this problem.This was demonstrated in North-eastern Somalia during June-July 2021 where 103 immature Desert Locust swarms with a total area of 41 000 ha were treated by air with *Metarhizium* applied at a dose of 50 g/ha (approx. 2.5 x 10^{12} spores/ha). Field assessments indicated that 80 percent mortality occurred after 14 days. Mapping of individual targets with the EarthRangerGIS tool (paragraph 44) allowed control teams to monitor swarm movements post-treatment,keeping the risk of resprays to a minimum.

40. In addition to overall blanket sprays, certain insecticides are considered efficacious as barrier treatments for control of locust hoppers. A barrier consists of a treated strip interspersed withan untreated larger area arranged so that hoppers are expected to move across and feed on treated vegetation and collect a lethal dose. The width of a barrier (one or more swath widths) and distance between barriers that have to be used will depend on the:

- mobility of the hoppers
- insecticide used (persistence)
- terrain/vegetation (vegetation density)
- wind speed and direction during application
- height of application

Highly mobile species may be controlled with a wide separation between barriers, while lessmobile species will require closer intervals. In some cases, the barriers will need to be arrangedin a lattice (grid) pattern to allow for any changes in direction of hopper movement.

41. Precise application recommendations that are valid under all circumstances cannot be given since they depend on local conditions. For Desert Locust, an indicative effective single swathwidth of up to 100 m and track spacing of 500-700m can be recommended. Indications existthat wider spacing may be effective for certain insecticides, but further studies are needed to determine if wider gaps between swaths will remain effective, as little is known about the rate at which hoppers detoxify and excrete insecticides recommended for barrier treatment.

42. Application techniques where spray drift from one barrier reaches to or overlaps with the subsequent one are considered as irregular blanket treatments rather than barrier treatments. InNorth America, such treatments are also known as reduced-agent area treatments (RAAT). Insome circumstances irregular blanket treatments can offer operational advantages over use of full cover blanket treatments (ability to cover much larger target areas with a given volume of pesticide), especially when treating less mobile nymphs in areas with sparse vegetation cover.

43. The LPRG appreciated that FAO spray aircraft contracts systematically include the requirement for a (D)GPS-based track-guiding system and on-board flow meter or flow controller, which allows correct application and precise recording of aerial control operations. The LPRG strongly recommended that all aircraft involved in locust control be equipped with such systems. Likewise, GPS spray tracking devices should also be used in ground treatments.

44. The LPRG welcomed FAO's introduction of the EarthRanger system which aggregates eLocust3 and other Desert Locust monitoring data to derive historical and current locationsof locust populations as a basis for improved monitoring, control and impact assessment. It recommended that such systems should be used when undertaking aerial control to improve fleet management, daily deployment, control operations and reporting.

POTENTIAL FOR DRONES TO CONTROL LOCUSTS

45. FAO has used a fixed-wing drone in surveys to obtain data on soil and vegetation conditions where locusts occur during recession to detect whether the locust population is increasing and could result in swarm formation. With the onset of swarms in Iran and Ethiopia, it had been impossible to examine areas of Saudi Arabia and the Yemen, from where swarms were moving east into India or south-west into Kenya and subsequently to Tanzania. At this stage, there were no plans by FAO to use drones to apply insecticides against locusts as operational guidelines were not available.

46. Several organisations and drone manufacturers offered to supply drones to spray areas. CABI used a multicopter drone in Kenya aiming to determine whether control of locusts was possible with it. The aim was to spray according to label recommendations, so various flight parameters were tried to determine which one was closest to the recommended dosage with different heights and flying speeds. Only emulsifiable concentrate insecticides mixed in water were applied, using hydraulic nozzles.

47. In India, the operation of drones was examined initially for spot application, including high trees, with ground control teams for effective control. Fifteen drones equipped with a 10 litre tank and supplied with eight batteries were used for spraying a mixture of two insecticides, lambda-cyhalothrin and deltamethrin supplied as EC formulations, using flat fan nozzles at 10 litres per ha. The mortality of locusts at various stages of development was between 50 percent to 90 percent.

48. Clearly further research is needed to develop a system with ULV sprays using rotary nozzles to apply insecticides, especially in remote areas where initial swarms are likely to develop. Formulation will be an important factor to avoid damage to the drone. At present, the small multi-copter drones do not have an adequate lifting and endurance capacity to treat more than a very small area. There are also questions about the durability of a drone in desert environments with sand and dust drawn across exposed electric motors from multi-rotor types, as well as the operational costs. Larger drones such as those used to treat rice fields in Japan since 1990 may be more appropriate.

HUMAN HEALTH RISKS

49. The LPRG classifies human health hazards of insecticide formulations which have a verified dose rate against the Desert Locust according to the *WHO Recommended Classification of Pesticides by Hazard* published in 2020 (WHO, 2020) for acute oral and dermal toxicity and the *Globally Harmonized System of Classification and Labelling of Chemicals* (GHS) published in 2019 (UNECE, 2019) for acute inhalation toxicity and other health hazards not covered by the WHO classification. As far as relevant to locust control, the LPRG included these aspects in its hazard classification (Table 4). The criteria used to classify health hazards of insecticides for locust control are provided in Annex 7.

50. The LPRG underlined that in principle insecticide formulations and not the active ingredients should be classified, as commercial formulations may contain co-formulants causing adverse health effects. However, when data on the formulation are not available, classifications will be extrapolated based on the a.i. alone. The LPRG welcomes comments and suggestions regarding the classification system for health hazards of locust control insecticides.

51. The LPRG confirmed the way in which hazard classifications is defined and used by FAO to recommend what type of operator should be authorized to handle which insecticides, and under what conditions of use and supervision. These recommendations are given in the *FAO Desert Locust Guidelines on Safety and Environmental Precautions* (FAO, 2003).

52. All insecticides with a verified dose rate against the Desert Locust (Table 2) were re-evaluated against the updated criteria of Annex 7. The main sources for the toxicity endpoints used in this re-evaluation were the European Union Pesticides Database, the OECD eChemPortal, and the IUPAC Pesticides Properties Database. The results are shown in Table 4.

53. Operator codes for locust control (Annex 7) defined in the previous report and associated availability and use restrictions remain unchanged. The LPRG reminded that the malathion formulation used in locust control was evaluated as being a Skin Sensitizer Category 1, leading to a change from the previous Operator Code B (“use by trained operators”) to the new Operator Code A (“use by trained and supervised operators”).

54. The LPRG noted that a hazard classification is an indication of the actual occupational and bystander risk that may occur in locust control. More precise estimates of health risks can only be obtained through an appropriate risk assessment using exposure models and/or by conducting exposure experiments. The LPRG therefore discussed various existing occupational exposure models used in pesticide registration in Europe and North America. It concluded that these models are likely not appropriate for the application practices, equipment and UL formulations encountered in locust control, except possibly certain modules on mixing/loading of spray equipment and aerial application models.

55. The LPRG recommended that FAO, in collaboration with WHO, conduct studies on occupational exposure to insecticides in locust control. Such studies should focus on, but not necessarily be limited to, the handling of insecticides during loading of spray equipment. Operator exposure during loading can be significantly minimised by closed transfer pumping of the insecticide formulation from the container to the sprayer tank. Studies on risks to bystanders would be called for upon evidence of critical exposure.

56. The LPRG commended the efforts made by certain locust control organizations to strengthen safety measures in relation to pesticide handling as well as the monitoring of occupational exposure of their staff.

57. The LPRG acknowledged that chlorpyrifos remains an attractive compound for Desert Locustcontrol due to its speed of action and lack of recovery after initial knock down. The product is relatively inexpensive and easy to purchase. However, there is increasing political and regulatory opposition to the molecule, drawing public criticism. This is because chlorpyrifos has been associated with neurological effects in children and has shown mutagenicity in vitro. Registration in the EUwas not renewed in January 2021 due to the risk of developmental neurotoxicity, chromosome aberration and DNA damage. Therefore, European partners are likely to end further use. Since August 2021 chlorpyrifos has been banned in the United States for all food crop uses, because of the neurotoxicological risks. The toxic effects of chlorpyrifos are associated with misuse, long-term exposure of professional handlers and re-entry workers, and non-occupational exposure of children. Specific attention should therefore be paid to proper use, storage and application practices, particularly those associated with food crops, or near to human habitation.

58. Environmental, Health and Safety (EHS) Standards for locust control have been developed for the Central Region, Madagascar and the Horn of Africa. Compliance ought to be monitored by specialist staff operating independently from application teams. EHS provide a comprehensive framework for pesticide management and campaign planning to ensure human health and environmental safety. They are based on both international conventions and national legislation and involve external and internal audits for quality control.

59. The LPRG underlined the great importance of regular health monitoring of locust control staff. Locust control organizations should ensure that medical examinations of all staff are done before, during and after control campaigns, irrespective of the types of insecticides used. When organophosphate insecticides are used, blood acetyl-cholinesterase (AChE) inhibition monitoring should always be conducted. It is essential that cholinesterase baseline levels are established prior to any exposure to these insecticides, even though this may sometimes be difficult when new or temporary control staff is involved. For non-organophosphorus insecticides with verified dose rates no such markers exist. To interpret results of health monitoring properly, the LPRG proposed collecting individual insecticide use records of all pesticide applicators.

Table 4.
Hazard classification of the insecticide formulations with a verified dose rate against the Desert Locust.

Insecticide[1]	**Highest likely formulation concentration**	**LD_{50} of the a.i.**[2]			**WHO Hazard Class of the formulation**		**GHS Hazard Category of the formulation**[3]	**GHS Hazard Category of the formulation for other health aspects**[4]	**Locust control Operator Code**
		Oral	Dermal	Inhalation	Acute oral	Acute dermal	Acute inhalation		
	(g a.i./L)	(mg/kg bw)	(mg/kg bw)	(mg/L)					
Chlorpyrifos	450	66	>1 250	>0.1	II	II	3		**A**
Deltamethrin	25	87	>2 000	0.6	U	U	Unclassified[5]		**C**
Diflubenzuron	60	>4 640	>2 000	>2.5	U	U	Unclassified		**C**
Fenitrothion	1 000	330	890	2.2	II	II	4	STOT SE 1[6]; oral, nervous system	**A**
Fipronil	7.5	92	354	0.36	U	U	Unclassified	Eye irritant 2	**C**
Lambda-cyhalothrin	40	56	632	0.07	U	U	4	STOT RE 1[6] oral, nervous system	**A**
Malathion	960	1178	>2 000	>5	II	II	4	Skin sensitization 1[7]	**A**
Teflubenzuron	50	>5 000	>2 000	>5	U	U	Unclassified		**C**
Triflumuron	50	>5 000	>5 000	>5	U	U	Unclassified		**C**

[1] Bendiocarb no longer listed because of environmental and health concerns. Owing to the availability of new data, oral toxicity data for some insecticides differ from those in previous reports.

[2] Data are from the IUPAC Footprint Database (EU Pesticides Database (europa.eu)). Units are body weight (bw) or volume of air (L).

[3] Calculated on the basis of the LD_{50} of a.i. and the highest likely formulation concentration according to WHO (2020).

[4] Data from the EU Pesticides Database (https://ec.europa.eu/food/plants/pesticides/eu-pesticides-database_en). The EU uses GHS classification (https://unece.org/ghs-rev8-2019) and the OECD eChemPortal (https://www.echemportal.org/echemportal/).

[5] The GHS does not provide numerical upper limits for Category 5 acute inhalation toxicity but suggests equivalent values as used for oral and dermal toxicity. Therefore, the upper Category 5 acute inhalation toxicity limit was set here at 17.5 mg/L.

[6] STOT = Specific Target Organ Toxicity; SE = Single exposure; RE = Repeated exposure; 1=H370, signal word “Danger”.

[7] Skin sensitization: 1=H317, signal word “Warning”.

60. In keeping with international guidance on the use of pesticides and toxic chemicals including the International Code of Conduct on Pesticide Management, the Strategic Approach to International Chemicals Management (SAICM), the Rotterdam and Stockholm Conventions, the UN Sustainable Development Goals (SDGs) and the Agroecological Principles put forwardby the High Level Panel of Experts on Food Security and Nutrition (HLPE) of the Committeeon World Food Security (CFS), the LPRG emphasized the need for risk reduction in the selection and use of pesticides for locust control. It was also noted that FAO is putting in place requirements and procedures for Environmental Impact Assessment (EIA) of projects and activities under its management. Within the EIA procedure, specific environmental and social standards will apply to all projects and activities where pesticide procurement and useis supported (FAO, 2015).

61. According to the FAO EIA Guidelines criteria, locust campaigns are generally considered to pose moderate environmental risks. However, particularly large-scale operations can potentiallyhave significant, negative environmental impacts and may therefore be classified as high riskevents. Mitigation of these risks can only be achieved through strict adherence to good practicesas stipulated in the Desert Locust Guidelines. The recent development and introduction of regional EHS Guidelines and Manuals is an important step forward in this respect (FAO, 2021).

62. Data on environmental hazard or risk submitted for review by the LPRG must be relevant for the area of application. The LPRG evaluates each environmental study against the quality criteria defined in Annex 4 (environmental field studies) and Annex 8 (environmental laboratory and semi-field studies). Only studies meeting these criteria have been included in the evaluation.

63. Data on ecological key taxa in locust areas are important for a proper risk assessment. With respect to the risk to non-target organisms, three main groups are distinguished: aquatic organisms, terrestrial vertebrates including wildlife, and terrestrial non-target arthropods. The aquatic fauna considered here is divided into fish and arthropods (crustaceans and insects). Terrestrial vertebrates include mammals, marsupials, birds and reptiles, while terrestrial arthropods particularly cover bees, natural enemies (antagonists) of locusts and other pests, and ecologically important soil insects (e.g. ants and termites). The LPRG considers the classified non-target organisms as reasonably representative of the fauna exposed to pesticides in locust habitats. In some cases, however, other non-target taxa such as amphibians or butterflies maybe of concern and require a specific risk assessment, as do multiple treatments within the samearea and season.

64. The risk classifications applied by the LPRG are brought in line as much as possible with accepted international classifications. The criteria used to classify environmental risks are summarized in Table 5. Widely used risk assessment methods, such as those agreed on by the European Food Safety Authority (EFSA) or the International Organization of Biological and Integrated Control (IOBC), are used as much as possible. Specific interpretations or modifications of certain of these schemes are discussed in the paragraphs below. Any assessments specifically designed and validated for locust areas were given priority.

65. With respect to the risk to terrestrial vertebrates, the classifications based on laboratory data are considered as resulting from direct exposure as a consequence of over-spraying. The resultsof this assessment were verified for some other possible routes of exposure whenever data were available. They included exposure of lizards and birds to spray residues in food items such as invertebrate prey or seeds. This resulted in the same classification as given for the risk of direct over-spraying. For some insecticides, toxicity data were available for marsupials, a group thathad not been studied previously. The LPRG recognises the great importance of such data forthe risk assessment of the insecticides in the ecological areas where these animals occur.

66. For classification of risks to honeybees, the widely accepted hazard ratio (HR, also known as exposure/toxicity ratio) is used (c.f. references provided in FAO's Pesticide Registrar Toolkit – Local Risk Assessment for Honeybees). The HR for honeybee is defined as the recommended dose rate (g a.i. / ha) divided by the contact or oral LD_{50} (µg a.i. per bee). Low risk to bees corresponds to a HR – or trigger value – of <50; high risk to a HR of ≥50. The risk to bee colonies (adults and brood) is derived from (semi-) field tests. Risk to non-target arthropods other than bees has been classified according to IOBC criteria and includes non-target arthropods other than those covered by the IOBC.

67. In this session of the LPRG, a total of 35 environmental field studies were reviewed. Ten did not meet the quality criteria for ecotoxicological field studies as presented in Annex 4 and were considered irrelevant to this report. One field study was reported twice. In addition, 11 laboratory-based or semi-field toxicity studies were reviewed, one study not meeting the quality criteria for laboratory toxicity studies in Annex 8 (i.e., Klimisch score 1 or 2). Therefore, 24 field studies and 10 toxicity studies were retained for evaluation (Annex 3), details of which are shown in Annex 9.1 and 9.2 for laboratory/semi-field and field studies, respectively.

68. The LPRG noted with concern the relatively large fraction of environmental studies that did not meet the minimum quality criteria. It therefore recommended that FAO elaborates guidance for experimental environmental field studies in locust control.

69. The environmental risk assessments have been conducted for the insecticides with a verified dose rate against the Desert Locust, at the dose rate recommended in this report and assuming Desert Locust habitats will be exposed. The risk of insecticides used against other locust species (Table 3) in other types of ecosystems has not been evaluated. Given the similarities in application rates, the LPRG considers the environmental risks summarized in Table 6 to be indicative of insecticide use against other locust species. However, the LPRG has not assessed the risk of insecticides against other locusts listed in Table 3 (chlorpyrifos + cypermethrin and alpha-cypermethrin) as these are not included in Table 2 (Desert Locust). The previously listed neonicotinoid thiamethoxam (in combination with lambda-cyhalothrin) is no longer listed because of its known high toxicity to pollinators.

70. The resulting risks to the different groups of non-target organisms are presented in Table 6, using three classes: low, medium and high risk. The assessment is based mainly on field data. If relevant field data were not available, assessments were based on exposure/toxicity ratios. Low risk means that no serious effects are to be expected. Medium risk means that effects of short duration are expected on a limited number of taxa. High risk means that effects of short duration are expected on many taxa, or that effects of long duration are expected on a limited number of groups. Results obtained from situations most representative of the expected field conditions are given more weight than other studies. Field studies (indicated with index 3 in Table 6) are more relevant than laboratory or semi-field studies (index 1 and 2 in Table 6). Results obtained with indigenous species from locust areas in the field or in the laboratory are considered to be more relevant than results obtained with species from elsewhere. Considerable progress has been made in this respect, in particular with regard to terrestrial and aquatic non-target arthropods, birds, reptiles and marsupials. However, toxicity data for reptiles, particularly important in locust habitats, remain scarce (EFSA 2018).

71. Since bendiocarb has been removed from Table 2 for environmental and health concerns it is also no longer included in Table 6. Otherwise, no changes in environmental risk classification were made.

72. The LPRG reaffirmed that locust-affected countries should follow national environmental policies and do local risk assessments, whenever possible, on insecticides which they plan to use in relation to locust control.

73. For ecological reasons, as well as from an economical point of view, barrier treatments are preferred over blanket treatments. At least half of the inter-barrier areas need to be completely uncontaminated by the insecticide if they are to function as true refugia. If that condition is not met, the resulting pattern would be one of irregular blanket treatment (see paragraph 32). The LPRG regretted that only few reports were submitted on the environmental impact of barrier treatments.

74. The LPRG welcomed the initiative of the CLCPRO to further develop the mapping of areas of specific ecological sensitivity to side-effects of insecticides for locust control, which resulted in six countries in the Western Region disposing of maps compatible with the RAMSES Geographical Information System (GIS).

75. In 2019, FAO published the Practical Guidelines on Pesticide Risk Reduction for Locust Control in Caucasus and Central Asia. They present the risks of insecticide handling and use during locust control campaigns, as well as measures that can be taken to minimize those risks. The guidelines rely on international best practices and FAO experience in other geographical areas, considering specific features of locust control in CCA. They are available in English and Russian as well as in Dari, Kyrgyz and Tajik.

76. Side-effects of locust insecticides on (agro-) ecosystems and associated services such as pollination, nutrient cycling or natural pest control are not systematically accounted for in the LPRG evaluation. Both natural (e.g. wildfires) or man-made (e.g. insecticides) disturbances may impoverish biodiversity and impair ecosystem services. While most systems recover quickly from such disturbances, precautions must be taken to safeguard their resilience and to avoid long-term effects. For example, decade-long control of grasshoppers in the US using malathion led to detrimental changes in grassland community composition and a predominance of economically harmful grasshoppers (pest resurgence). Studies in Senegal showed negative effects of locust insecticides on antagonists of acridids. Further studies in Senegal and Madagascar showed long-term effects on ants and particularly termites, which are essential for enhancing soil fertility. Studies of this kind are rare because of financial constraints and lack of expertise but are encouraged by the LPRG.

Table 5.
Classification criteria applied to assess the environmental risks listed in Table 6. See text for further explanations.

A. LABORATORY TOXICITY DATA

Group	Parameter	Risk class			Reference
		Low(L)	Medium (M)	High (H)	
Fish	Risk ratio (PEC[1]/LC_{50}[2])	<1	1-10	>10	FAO/Locustox[4]
Acquatic arthropods	Risk ratio (PEC/LC_{50}[2])	<1	1-10	>10	FAO/Locustox
Reptiles, birds, mammals	Risk ratio (PEC/LD_{50}[3])	<0.1	0.01-0.1	>0.1	EPPO[5]
Bees	Risk ratio (recommended dose rate/LD_{50})	<50	-	≥50	EPPO/EFSA[6]
Other terrestrial arthropods	Acute toxicity (%) at recommended dose rate	<50%	50-99%	≥99%	IOBC[7]

B. FIELD DATA (FIELD TRIALS AND MONITORED CONTROL OPERATIONS)

Group	Parameter	Risk class			Reference
		Low(L)	Medium (M)	High (H)	
Fish	Evidence of mortality	none	incidental	massive	LPRG8
Acquatic Arthropods	Population reduction	<50%	50-90%	>90%	LPRG
Reptiles, birds, mammals	Evidence of mortality	none	incidental	massive	LPRG
Bees	Evidence of mortality, reduction of colonies	not significant	-	substantial	EFSA
Other terrestrial arthropods	Population reduction	<25%	25-75%	>75%	IOBC

[1] PEC: Predicted Environmental Concentration after treatment at the recommended dose rate; [2] LC_{50}: median lethal concentration; [3] LD_{50} : median lethal dose; [4] FAO/Locustox: FAO Locustox project in Senegal (Everts et al., 1997, 1998); [5] EPPO: European and Mediterranean Plant Protection Organization (EPPO, 2003, 2010); [6] EFSA: European Food Safety Authority (2012); [7] International Organization for Biological and Integrated Control of Noxious Animals and Plants (Hassan, 1994); [8] LPRG: Locust Pesticide Referee Group.

Note: As a result of a greater error associated with population estimates of terrestrial arthropods, the lower limits of the different risk classes are lower than for aquatic arthropods.

Table 6.

Risk to non-target organisms at verified dose rates against the Desert Locust (Table 1). Risk is classified as low (L), medium (M) or high (H). See Table 5 for the classification criteria.

Insecticide [#]	**Environmental risk**							
	Aquatic organisms		**Terrestrial vertebrates**			**Terrestrial non-target arthropods**		
	Fish	**Arthropods**	**Mammals**	**Birds**	**Reptiles**	**Bees**	**Antagonists**	**Soil insects**
Chlorpyrifos	M[3]	H[2]	L[3]	M[3]	M[3]	H[1]	H[3]	–
Deltamethrin	L[3]	H[3]	L[3]	L[3]	L[3]	H[1]	M[3]	M[3]
Diflubenzuron (blanket)	L[3]	H[3]	L1	L	-	L[1ϕ]	M[2]	M[3]
Diflubenzuron (barrier)*	L	(H)	L	L	-	L[ϕ]	L[3]	(M)
Fenitrothion	L[3]	M[3]	L[3]	M[3]	M[3]	H[1]	H[3]	H[3]
Fipronil (barrier)*	L	M[3]	M[3]	L[3]	M[3]	(H)	H[3]	H[3]
Lambda-cyhalothrin	L[2]	H[2]	L1	L[1]	-	H[1]	M[3]	H[3]
Malathion	L[2]	M[2]	L[3]	L[3]	-	H[3]	H[3]	H[3]
Metarhizium acridum (IMI 330189)	L[2]	L[2]	L1	L[1]	L[2]	L[3]	L[3]	L[3]
Teflubenzuron (blanket)	L[1]	H[2]	L1	L[1]	–	L[1‡]	M1	–
Triflumuron (blanket)	L[1]	H[2]	L1	L[1]	L[3]	L[1‡]	L[3]	L[3]
Triflumuron (barrier)*	L	(H)	L[3]	L[3]	L[3]	L[1‡]	L[3]	L[3]

The index next to the classification describes the level of availability of data:

[1] classification based on laboratory and registration data with species which do not occur in locust areas;

[2] classification based on laboratory data or small-scale field trials with indigenous species from locust areas;

3 classification based on medium to large scale field trials and operational data from locust areas (mainly Desert Locust, but also Migratory and Brown Locust).

[#] Bendiocarb is no longer listed because of environmental and health concerns. * If no field data are available, the risk of barrier treatments is extrapolated from blanket treatments. However, it is expected to be considerably lower if at least 50 percent of the area remains uncontaminated for a period long enough to allow recovery of affected fauna, and if barriers are not sprayed over surface water. Therefore, risk classes are shown in brackets unless the blanket treatment was already considered to pose low risk, and no reference is made to the level of data availability. More field data are needed to confirm that products posing a medium or high risk as blanket sprays can be downgraded to "L" when applied as barrier sprays; [ϕ] At recommended use, diflubenzuron is not harmful to the brood of honeybee. [‡] Benzoylureas are generally safe to adult worker bees but some may cause damage to the brood of exposed colonies; – insufficient data.

INSECTICIDE SELECTION

77. Locust control operations have to be carried out in a wide range of situations, varying from desert zones, grazing areas, ecologically sensitive ecosystems, to intensively cultivated farmland. In addition, locust control may be in response to emergency situations or be an attempt to carry out preventive control (see paragraphs 95–97). The choice of a particular insecticide and type of application (blanket vs. barrier) will depend on the particular circumstances and dominant features of the areas concerned. The FAO Desert Locust Guidelines on Control (FAO, 2001) and on Safety and Environmental Precautions (FAO, 2003) provide detailed guidance on choosing the appropriate insecticide for Desert Locust control.

78. The LPRG noted that locust control campaigns continue to rely heavily on organophosphate insecticides, presumably because these are readily available and at low cost. The LPRG stipulated that external costs such as removal of obsolete stocks or economic losses, e.g. endured by beekeepers should be accounted for. In view of increasing concerns about the use of synthetic insecticides and the absence of new products evaluated for locust control, emphasis should be given to the least toxic compounds already evaluated in relation to human health and environmental impact, provided they are effective against the locust target to be controlled. To give more guidance to locust-affected countries, insecticides with verified dose rates against the Desert Locust are presented as a priority list in Table 7. Carbamates are no longer listed because of environmental and health concerns (see paragraphs 30 and 71). In order to be able to use low-risk insecticides listed on this table, the LPRG recommended that countries should be encouraged by FAO to speed up the registration of IGRs and *Metarhizium*.

79. Thus, the application of *Metarhizium acridum* is considered to be the most appropriate control option, especially in riparian and similar sensitive habitats, despite its higher cost. It has the additional advantage that there is no problem associated with the disposal of stocks that are no longer viable for field use. Secondly, priority should be given to IGRs. Neurotoxic insecticides should only be used as a last resort when rapid control is needed to protect agricultural crops in the immediate environment of a locust population.

Table 7.
Priority list of insecticides to be used against locusts.

	Insecticide	Remarks
Priority 1	*Metarhizium acridum*	The mycoinsecticide has been shown to be effective in numerous trials and increasingly also in operational use. While the speed of action is slow compared to neurotoxic insecticides, it has the beneficial effect of posing very low risks to non-target organisms, including birds and reptiles ingesting treated locusts.
Priority 2	Insect Growth Regulators: diflubenzuron, teflubenzuron, triflumuron	Very low human toxicity (Table 4). These compounds are considerably less hazardous to use than neurotoxic insecticides, although certain non-target organisms may be adversely affected, especially aquatic arthropods. IGRs are particularly recommended for applications aimed at hoppers. They are slower acting compared to the insecticides listed in Priority 3.
Priority 3	The neurotoxic insecticides currently approved for use in locust control are listed in relation to their human toxicity but adjusted in relation to the concentration of the spray and dose applied per hectare.	
	A) Phenyl pyrazoles: fipronil	Low acute human toxicity (Table 4). This insecticide applied in a UL formulation (<10 g/l) has been shown to be effective at doses of <1.0 g a.i./ha against hoppers.
	B) Pyrethroids: deltamethrin, lambda-cyhalothrin	Deltamethrin: Low human toxicity (Table 4). This insecticide used in a UL formulation (<30 g/l) has been shown to be very effective against adults and hoppers at 12.5 – 17.5 g a.i./ha. Lambda-cyhalothrin: Moderate human toxicity (Table 4). This insecticide has shown similar activity to deltamethrin in a UL formulation (<50g/l) and applied at 20 g a.i./ha against adults and hoppers.
	C) Organophosphates: malathion, fenitrothion, chlorpyrifos	These insecticides may be used as a last resort when rapid control is needed to protect crops in the immediate environment of a locust population. Malathion: slight acute human toxicity but may cause skin sensitization (Table 4). Available in a UL formulation (925 g/l) and has been used extensively against (adult) locusts at ~925 g a.i./ha). Fenitrothion: Moderate human toxicity. This insecticide has been extensively used at 400 g a.i./ha against adults and hoppers. Chlorpyrifos: Moderate human toxicity (see paragraph 57). This insecticide has been extensively used at 240 g a.i./ha against adults and hoppers.

INSECTICIDE PROCUREMENT AND STOCK MANAGEMENT

80. After the 2003-2004 Desert Locust outbreak, a Pesticide Stock Management System (PSMS) has been deployed particularly in CLCPRO countries. From 2007 to 2017, all locust control pesticide stocks had been inventoried and recorded in PSMS. This allowed pesticides close to their expiry date to be sampled and analysed for compliance with original specifications. As a result, the usability of pesticides had been extended by up to ten years (i.e. chlorpyrifos) and prevented them from becoming obsolete. In addition, PSMS along with stock and quality controls have allowed excess pesticides in one country to be diverted (triangulated) to another country where a need had arisen. This has reduced the risk of pesticide stocks becoming obsolete, saved the cost of procurement of new pesticides and ensured rapid delivery. In 2017, the use of the PSMS has been discontinued owing to data security issues, leaving a big gap in pesticide monitoring and management. In 2021, FAO embarked on establishing a new Locust Pesticide Management System (Locust PMS) designed as a web-based application hosted by a cloud server. The system also accommodates survey, safety as well as spray data from locust-affected countries. The LPRG welcomed FAO's initiative.

81. The LPRG reminded that efforts to avoid creation of obsolete stocks must continue during the ongoing Desert Locust outbreak despite logistic and security constraints. If obsolete pesticides accrue, new funds will need to be secured to dispose of them safely. However, the LPRG also stressed that countries are responsible for preventing the creation of obsolete pesticide stocks and for disposing of those stocks when they are created[1]. Donors should comply with good practices such as the OECD DAC Guidelines on Pest and Pesticide Management (OECD, undated), and recipient countries should be in a position to refuse unsolicited donations of pesticides or donations of inappropriate pesticides. The WHO guidelines for donations of medicines and medical equipment provide useful information in this respect (WHO, 2011a, b).

[1]Disposal operations also include toxic waste such as solvents emanating from the treatment of containers, contaminated soil, wash-water and protective gear

82. The LPRG emphasized that future provision of pesticides for locust control should:

- ensure supply mechanisms designed to prevent overstocking and obsolescence;
- use improved stock and quality control systems to reduce obsolescence;
- relocate unused stocks to other locust-affected countries if possible (triangulation);
- ensure coordination among donors to prevent inappropriate or excess supplies;
- be based on needs assessments using quality forecasting data (e.g. from the Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases).

83. For locust insecticides not readily available on the market, the LPRG recommends seeking agreements with suppliers to ensure rapid formulation of active ingredients or, in the case of biologicals, stockpiling minimum amounts of product. The potential of regional pesticide banks should also be explored.

INSECTICIDE FORMULATION QUALITY AND PACKAGING

84. The LPRG stressed that only products with verified dose rates should be used because of efficacy, toxicity and environmental concerns. The common names of listed insecticides, or in the case of biologicals, the appropriate isolate, should be given in FAO publications. However, the LPRG recognizes that different formulations of the same active ingredient, sold under different trade names, may have very different properties which may influence efficacy as well as health or environmental effects. Therefore, company-dependent product specifications should be available for all active ingredients for which the LPRG recommends a dose rate.

85. FAO requires that all pesticides procured by the Organization comply with its own specification, or in the absence of such a specification, the pesticides procured must comply with the specification of the product registered in the recipient country. Compliance must be certified by an independent accredited laboratory.

86. The LPRG reminded that JMPS specifications (FAO/WHO Joint Meeting on Pesticide Specifications) should be available for all chemical insecticides listed for locust control in Tables 2 and 3.

87. The LPRG received only circumstantial evidence of UL formulations damaging spray equipment during the current Desert Locust campaign. However, the LPRG underlined that this risk prevails as most aircraft spray tanks and equipment are intended for high volume, water-based pesticides and may not resist solvents in more concentrated UL formulations. The LPRG therefore recommended that in the procurement of UL formulations, suppliers should indicate all solvents in the formulation and certify that these do not damage the spray equipment.

88. The LPRG upheld its previous recommendation that a dialogue between spray equipment manufacturers and pesticide manufacturers should be organised or facilitated to identify solvents that must be avoided in UL formulations for locust control.

89. The LPRG reminded that metal insecticide drums must comply with quality specifications to prevent breakage, insecticide loss and environmental contamination. It is recommended to use reinforced steel drums meeting international standards. The LPRG stressed that UN requirements for pesticide packaging, as specified under the UN Recommendations for the Transport of Dangerous Goods, must be met when purchasing and transporting insecticides for locust control. Furthermore, operatorsshould be trained in the proper handling of drums.

WAITING PERIODS

90. The LPRG discussed the lack of information on livestock withholding periods, re-entry periods for persons, and pre-harvest intervals when using UL insecticides against locusts. Even though locust control often occurs in grazing areas, and may also be conducted in crop areas, many pesticide registration authorities in locust-affected countries have not established waiting periods specifically for locust control, with the notable exception of Australia. Furthermore, pesticide manufacturers often do not indicate waiting periods on the labels of locust control insecticides, and if so, recommendations are usually based on residue data for different formulations, crops, uses or regions. Those may not necessarily be relevant to the conditions encountered in locust control.

91. The LPRG stressed that establishing waiting periods is the responsibility of national or regional pesticide registration authorities. However, it recognized that FAO has much experience in pesticide residue evaluation, in particular through the FAO/WHO Joint Meeting on Pesticide Residues (JMPR). The LPRG therefore reiterated that a review be conducted by FAO of available data on withholding periods, re-entry intervals and pre-harvest intervals for insecticides used in locust control, including data that may be extrapolated to locust control insecticide formulations and use conditions. Provisional waiting periods should be proposed on the basis of existing information and knowledge gaps should be identified.

TRAINING

92. The LPRG underlined the continued importance of training and capacity building of staff to ensure that locust management is effective and does not pose undue risks to human health and the environment. It welcomed the planned establishment of a Training Centre in Sudan and recommended that countries and FAO maintain their emphasis on, and where possible, further strengthen training in good locust management practices. It also acknowledged FAO's initiative to use the 2020-21 Desert Locust upsurge in the Horn of Africa as an opportunity to train "new generation locust experts" in affected countries. The LPRG urged that FAO and the concerned national and regional institutions ensure that training contents are updated on a regular basis to cover the latest techniques and equipment.

EVALUATION AND MONITORING

93. The LPRG expressed its concern that too few reports on operational monitoring of locust control are being submitted. This holds particularly for newer products such as *Metarhizium* which has been used for the first time at an operational scale during the 2020-21 Desert Locust outbreak. The LPRG stressed the importance of monitoring the efficacy of at least some of the applications conducted during a control campaign, as recommendations of verified dose rates are largely based on controlled field trials. Feedback from control operations such as received from North-eastern Somalia in 2021 (see paragraph 39) is considered essential to validate dose recommendations. The LPRG therefore reiterated its previous recommendation that control organizations conduct operational monitoring of the efficacy of locust control and report the results to FAO.

94. As pointed out repeatedly, in view of the difficulty in quantifying the level of control achieved due to the mobility of locusts, attention should be given to appoint designated teams whose task it would be to monitor control efficiency. In addition to evaluating the level of control achieved, the teams would provide data on environmental and health effects observed in the localities treated. This is considered to be especially important where several sprays may be applied to the same area. The position of treated areas should be recorded using eLocust3/eLocust3mPRO technology for Desert Locust control (see paragraph 18) or other suitable Global Positioning Systems (GPS) and stored in a Geographical Information System.

TOWARDS PREVENTIVE LOCUST CONTROL

95. Since 1978, FAO's Desert Locust Information Service (DLIS) has constantly monitored the weather, ecological conditions and locust infestations throughout the recession area to provide situation assessments and forecasts on the scale, location and timing of breeding and migration to affected countries. DLIS issues monthly bulletins, supplemented by updates, alerts and warnings as part of the early warning system to support preventive control. DLIS also provides operational advice during emergency control campaigns. DLIS, in cooperation with international partners, continues to invest in improved monitoring, reporting and forecasting by adopting and integrating the latest technologies and innovations.

96. Simultaneous survey and control operations are crucial for early detection and containment of locust populations in remote and inaccessible arid areas (see paragraphs 45–48). In 2020, the use of small multicopter drones for survey and control was reported from Kenya and India. This revealed major problems due to spray equipment not fitted to apply ULV sprays. The scale of the area to be treated indicated a need for larger drones with rotary nozzles and spray tracking systems. Advances in early warning, survey and control operations, combined with the use of biopesticides and IGRs, constitute the basis for preventive measures and an alternative to conventional insecticides for locust control.

97. A successful preventive locust control strategy will require well-trained staff for surveys and appropriate spray equipment accessible to locust-affected countries and regional locust control organizations. The Locust PMS (see paragraph 80) will provide a global dynamic database on necessary parameters to improve triangulation of pesticides, safety, spray and survey equipment among countries to prevent locust populations from developing into an upsurge. Locust PMS should be operational in 2022 in most locust-affected countries.

RECOMMENDATIONS

98. The Locust Pesticide Referee Group made the following recommendations:

- **a.** In view of a dearth of efficacy studies submitted by the pesticide industry, in particular of new and low-risk insecticides holding potential for locust control, the LPRG recommended that FAO continues to engage with the pesticide industry and initiate a dialogue on how best to test and further develop such insecticides for locust control.

- **b.** The LPRG recommended that FAO puts a mechanism into place for the maintenance, updating and accessibility of the FAO Insecticide Trials Database, which contains all efficacy trials submitted to the LPRG since its first meeting but has not been updated since 2014.

- **c.** The LPRG stressed the importance of rigorous and scientifically sound efficacy testing, to ensure that dose recommendations are precise and robust, and to avoid wasting scarce trial resources. Therefore, the LPRG recommended that FAO continues to actively disseminate the various guidelines for efficacy testing of insecticides for locust and grasshopper control.

- **d.** The LPRG recommended that FAO continues encouraging plant protection organisations, manufacturers, and any other institutions to submit efficacy data on new or existing products for review.

- **e.** The LPRG noted that possibly due to a prolonged recession period without suitable locust populations, few trials of new insecticides were possible. Some data was submitted based on laboratory tests or semi-field trials with sprays applied within a limited area. Further efficacy trials with less toxic insecticides such as spinosad, chlorantraniliprole or pyrethrins need to be conducted to provide sufficient data to recommend an effective dosage. As extracts from plants such as pyrethrins are known to break down when exposed to sunlight, development of an appropriate formulation is essential to ensure greater persistence of deposits under field conditions.

- **f.** The LPRG pointed out that better surveillance of locusts allows earlier and more targeted preventive control with less harmful products.

- **g.** The LPRG recommended that spray teams applying biopesticides are specially trained and supervised to ensure optimal efficacy. Furthermore, the Horn of Africa campaign should be taken as a learning case for biocontrol and subjected to a thorough analysis of success factors and impediments.

- **h.** To ensure correct application and precise recording of aerial control operations, the LPRG recommended that all aircraft involved in locust control are equipped with a (D)GPS-based track guiding and logging system as well as an onboard flow meter. Vehicle equipment used to apply insecticides should also be equipped with a GPS spray tracking device so that areas treated with ground equipment are also recorded.

- **i.** The LPRG further recommended wider use of EarthRanger or similar systems aggregating eLocust3/eLocust3mPRO and other Desert Locust monitoring data to derive historical and current locations of locust populations as a basis for improved monitoring, control and impact assessment. It also recommended that such systems be used when undertaking aerial control to improve fleet management, daily deployment, control operations and reporting.

- **j.** The LPRG recommended that the potential for drones both to survey and to control locusts be further investigated.

- **k.** The LPRG stipulated that Environmental, Health and Safety (EHS) Standards must be followed and monitored by specialist staff operating independently of application teams. Control organizations must ensure that medical examinations are done of all staff before, during and after control campaigns, irrespective of the type of insecticide used. When using organophosphates, blood acetyl-cholinesterase inhibition monitoring should be conducted. Individual insecticide use records of all pesticide applicators should be collected to be able to properly interpret the results of such health monitoring. The LPRG also recommended to systematically collect and analyse health and environmental monitoring data from locust control operations worldwide.

l. In view of the low quality of many environmental impact studies, the LPRG proposed that FAO elaborates guidance for experimental environmental field studies in locust control.

m. The LPRG recommended that FAO updates the Desert Locust Guidelines – Safety and Environmental Precautions, taking account of the Practical Guidelines on Pesticide Risk Reduction for Locust Control in Caucasus and Central Asia (FAO, 2019). The aim is to ensure up-to-date risk reduction advice and monitoring techniques related to locust control, and to include control of other locusts than the Desert Locust

n. For countries to have access to low-risk insecticides, the LPRG recommended that countries are encouraged to speed up the registration of IGRs and *Metarhizium*.

o. The LPRG stressed that countries are responsible for preventing the creation of obsolete pesticide stocks and for disposing of those stocks when they are created. It further emphasized that donors should comply with good practices such as the OECD DAC Guidelines on Pest and Pesticide Management, and recipient countries should be able to refuse unsolicited donations of pesticides or donations of inappropriate pesticides.

p. The LPRG emphasized that future provision of pesticides for locust control should:

- ensure supply mechanisms designed to prevent overstocking and obsolescence;
- use improved stock and quality control systems to reduce obsolescence;
- relocate unused stocks to other locust-affected countries if possible (triangulation);
- ensure coordination among donors to prevent inappropriate or excess supplies;
- be based on needs assessments using quality forecasting data (e.g. from the Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases).

q. The LPRG reminded that JMPS specifications (FAO/WHO Joint Meeting on Pesticide Specifications) should be available for all chemical insecticides listed for locust control.

r. The LPRG recommended that in the procurement of UL formulations of insecticides suppliers should indicate all solvents in the formulation and certify that these do not damage spray equipment. Furthermore, the LPRG upheld its previous recommendation that a dialogue be organized or facilitated between spray equipment manufacturers and pesticide manufacturers to identify solvents that must be avoided in UL formulations for locust control.

s. With the aim to propose provisional withholding periods, re-entry intervals and pre-harvest intervals for the insecticides used in locust control, the LPRG reiterated its previous recommendation that FAO should conduct a review of available data on such waiting periods, including data that may be extrapolated to locust control insecticide formulations and use conditions.

t. In view of the great importance of training and capacity building of staff to ensure that locust control is effective and does not pose undue risks to human health and the environment, the LPRG recommended that countries and FAO maintain their emphasis on, and where possible further strengthen, training in good locust control practices. This also includes the need to raise awareness amongst communities in areas where locust control is taking place.

u. The LPRG reiterated its previous recommendation that control organizations conduct operational monitoring of the efficacy of locust control and report the results to FAO for verification of recommended dose rates, using eLocust3/eLocust3mPRO or other GPS technologies for GIS mapping and analysis.

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Annex 1 – Participants of the 11th LPRG meeting

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Annex 2 – Studies on insecticide efficacy reviewed by the LPRG

The efficacy reports (EF) listed in this annex refer to field or semi-field trials (e.g. field enclosures). Owing to the low number of submissions, laboratory experiments (LE) for efficacy against locusts and grasshoppers are also included to indicate current testing interest. However, results are not considered to establish or revise verified dose rates.

Report #	Company/Institution (country of study)	Year of publication	Author(s) – as applicable	Title (Remarks)	Insecticides	Study type
21-01	BioScience Research CC (South Africa)	2020	COETZEE, C. ROUX, P.	The efficacy of Acendis deltamethrin 17.5 g/L UL applied at Ultra Low Volume against Brown Locust (*Locustana pardalina)* in the Great Karoo of South Africa	Deltamethrin Esfenvalerate (standard)	EF
21-02	Plant Protection Directorate – Khartoum North (Sudan)	2015	MAHGOUB, M. M. TALAL, M. A. KHIDER, A. R. RAWDA Y. E. H.	Evaluation of Fipro 12.5 UL (fipronil) and Zynon 800 UL (diazinon) against the Desert Locust (*Schistocerca gregaria*)	Fipronil Diazinon Malathion (standard)	EF
21-03	Plant Protection Directorate – Khartoum North (Sudan)	2017	MAHGOUB, M. M. T. Ali, M. MONTASIR, A. IBRAHIM, G. A.	Evaluation of Polytnour 220 UL (profenfos + cypermethrin) against the Tree Locust (*Anacridium melanorhodon melanorhodon*)	Profenfos + cypermethrin	EF
21-04	Centre National Antiacridien, Division Expérimentation (Madagascar)	2016	RABEMIAFARA, L. H. Z.	Résultat d'essai – Efficacité biologique d'un produit acridicide	Chlorpyrifos (2 commercial formulations)	EF
21-05	Centre National de Lutte Antiacridienne (Morocco)	2020	BOUAICHI, A.	Développement d'un modèle prédictif pour la mise en œuvre des traitements en barrières à l'aide *Metarhizium acridum* contre les bandes larvaires du criquet pèlerin *Schistocerca gregaria* Part of the results of above-mentioned report also presented in separate report entitled: Evaluation des effets de deux doses de *Metarhizium acridum* (Novacrid ®) 25 et 50 g de conidies / hectare sur les larves du criquet pèlerin *Schistocerca gregaria* dans les conditions semi-naturelles au Parc de Souss-Massa Agadir Maroc	*Metarhizium acridum* (2 commercial fungal isolates)	EF (semi-field)
21-06	Beni-Suef University, South Valley University, Plant Protection Research Institute, General Department for Locust and Agro-aviation's Affairs (Egypt)	2019	SOLIMAN, M. M. M MOHANNA, K. M. ABDEL-FATTAH, T. A. MOUSTAFA, O. R. M.	Efficacy of some pesticide alternatives on the Desert Locust *Schistocerca gregaria* (Forskål) under laboratory and field conditions. *International Journal of Agricultural Science* 1 (1): 46–55	Chlorantraniliprole Spinosad Fipronil	EF (small-scale) and LE
21-07	Ministry of Agriculture (Russian Federation)	2020		Summary of Ministry on the efficacy of imidacloprid in grasshopper and locust control (data from 2015 – 2020)	Imidacloprid	EF
21-08	Ministry of Agriculture (Azerbaijan)	2020		Statement of Ministry on common insecticides for grasshopper control	Cypermethrin Alpha-cypermethrin	Not applicable

Report #	Company/Institution (country of study)	Year of publication	Author(s) – as applicable	Title (Remarks)	Insecticides	Study type
21-09	Bioscience Research Laboratory Group, Ishihara Sangyo Kaisha (ISK) Ltd. (Japan)	2020		Efficacy of chlorfluazuron and cyclaniliprole against locusts and grasshoppers	Chlorfluazuron Teflubenzuron (standard) Cyclaniliprole Cyhalothrin (standard)	LE
21-10	Kapi Ltd. (Kenya)	2020	OJIAMBO, R.	Bio-efficacy studies of pyrethrins on the Desert Locust (Forskål) under laboratory conditions	Pyrethrins Fipronil	LE
21-11	Adama (Israel)	2020		Laboratory study to evaluate the efficacy of Mavrik (Tau-fluvalinate) for the control of adult locust (*Locusta migratoria*)	Tau-fluvinate Chlorpyrifos (standard) Cypermethrin (standard) Lambda-cyhalothrin (standard)	LE
21-12	International Centre of Insect Physiology and Ecology (Kenya)	2020	SUBRAMANIA, S. AKUTSE, K. KHAMIS, F. KIMEMIA, J. OMBURA, L. WAFULA, S. NIASSY, S. DUBOIS, T. EKESI, S.	Screening for effective and temperature-tolerant strains of entomopathogenic fungi for management of the Desert Locust *Schistocerca gregaria* (Draft paper under review during time of submission) Report of laboratory trials carried out on the biological effectiveness of biopesticides for Desert Locust (Brief summary of main findings of the above-mentioned paper)	*Metarhizium acridum* *Metarhizium pinghaense* *Beauveria bassiana*	LE
21-13	Biozyme Labs (USA)	2020		Biorepel – Organic formulation for pest removal in crops	Repellent	No data
21-14	University of Nairobi, Department of Plant Science and Crop Protection, Efficacy Trials Unit (Kenya)	2021		Efficacy of Flower DS (pyrethrins 4%) in the control of Desert Locust (2 trial report)	Pyrethrins Chlorpyrifos (standard)	EF (semi-field) and LE
21-15	Ministry of Environmental Protection and Agriculture of Georgia / Shield Ltd. (Georgia)	2020		Test results of drug "Shield" against locusts In field conditions	Ammonium hydroxide Deltamethrin (standard)	EF

Annex 3 – Studies on environmental impact reviewed by the LPRG

The environmental impact reports (EN) listed may be either field or semi-field studies or laboratory experiments, if relevant for locust control.

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides[1]
21-01	Centre National de Lutte Antiacridienne, Niger Institut Agronomique et Vétérinaire Hassan II, Morocco (Niger)	2015	MAMADOU, A. MAZIH, A.	Évaluation des effets des pesticides utilisés en lutte chimique contre le Criquet pèlerin sur les fourmis au Niger. *Journal of Applied Biosciences* **88**: 8144– 8153	Fenitrothion Chlorpyrifos
21-02	Research Centre, Agriculture and Agri-food Canada Canadian Wildlife Service, Canada (Canada)	1996	MARTIN, P. A. JOHNSON, D. L. FORSYTH, D. J.	Effects of grasshopper-control insecticides on survival and brain acetylcholinesterase of pheasant (*Phasianus colchicus*) chicks *Environmental Toxicology and Chemistry* **15**: 518–524	Chlorpyrifos
21-03	University of Wyoming (USA)	2006	SMITH, D. I. LOCKWOOD, J. A. LATCHININSKY, A. V. LEGG, D. E.	Changes in non-target arthropod populations following application of liquid bait formulations of insecticides for control of rangeland grasshoppers *International Journal of Pest Management* **52**: 125–139	Diflubenzuron Malathion
21-04	AFRC Institute of Arable Crops Research, UK International Institute of Biological Control, Benin (UK)	1994	MOORE, D. BATEMAN, R. P. CARRECK, N. L.	Laboratory testing of a mycopesticide on non-target organisms: the effects of an oil formulation of Metarhizium flavoviride applied to Apis mellifera *Biocontrol Science and Technology* **4**: 289–296	*Metarhizium acridum*
21-05	University of Wyoming, USA (USA)	1999	NORELIUS, E. E. LOCKWOOD, J. A.	The effects of reduced agent-area insecticide treatments for rangeland grasshopper (Orthoptera: Acrididae) control on bird densities *Archives of Environmental Contamination and Toxicology* **37**: 519–528	Fipronil Malathion

[1]Studies may cover a range of insecticides. Here, only those listed in Table 2 are mentioned.

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides[1]
21-06	University of Lethbridge, USA Universit Saskatchewan, Canada Mycotech Corporation, USA Montana State University (USA, Madagascar)	2002	JOHNSON, D. L. SMITS, J. E. JARONSKI, S. T. WEAVER, D. K.	Assessment of health and growth of ring-necked pheasants following consumption of infected insects or conidia of entomopathogenic fungi, *Metarhizium anisopliae* var. *acridum* and *Beauveria bassiana*, from Madagascar and North America *Journal of Toxicology and Environmental Health* - **Part A 65**: 2 145–2 162	*Metarhizium acridum*
21-07	Direction de la Protection des Végétaux Centre de Recherches en Ecotoxicologie pour le Sahel (Niger)	2009	MAMADOU, A. SARR, M.	Impact of two insecticides used in the control of the Desert Locust on *Psammotermes hybostoma* Desneux (Isoptera: Rhinotermitidae) in Niger	Fenitrothion Chlorpyrifos
21-08	Swedish University of Agricultural Science (Sudan)	2011	ERIKSSON, H. WIKTELIUS, S.	Impact of chlorpyrifos used for Desert Locust control on non-target organisms in the vicinity of mangrove, an ecologically sensitive area *International Journal of Pest Management* **57**: 23–34	Chlorpyrifos
21-09	University of Wollongong Australian Plague Locust Commission University of Adelaide (Australia)	2002	MILNER, R. J. LIM, R. P. HUNTER, D. M.	Risks to the aquatic ecosystem from the application of *Metarhizium anisopliae* for locust control in Australia *Pest Management Science* **58**: 718–723	*Metarhizium acridum*
21-10	University of Basel, Switzerland KVL, Denmark (Benin)	2002	STOLZ, I. NAGEL, P. LOMER, C. PEVELING, R.	Susceptibility of the hymenopteran parasitoids *Apoanagyrus* (= *Epidinocarsis*) *lopezi* (Encyrtidae) and *Phanerotoma* sp. (*Braconidae*) to the entomopathogenic fungus *Metarhizium anisopliae* var. *acridum* (Deuteromycotina: Hyphomycetes) *Biocontrol Science and Technology* **12**: 349–360	*Metarhizium acridum*
21-11	Locustox project, FAO / Min. of Agriculture, Dakar (Senegal)	1999	DANFA, A VAN DER VALK, H.C.H.G	Laboratory testing of *Metarhizium* spp. and *Beauveria bassiana* on Sahelian non target arthropods *Biocontrol Science and Technology* **9**: 187–198	*Metarhizium acridum*

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides[1]
21-12	Montana State University, USA Eastern New Mexico University, USA Département de la Protection des Végétaux, Madagascar (Madagascar)	2002	IVIE, M. A. POLLOCK, D. A. GUSTAFSON, D. L. IVIE, LA DONNA L. RASOLOMANDIMBY, J. SWEARINGEN, W.D.	Field-based evaluation of biopesticide impacts on native biodiversity: Malagasy Coleoptera and anti-locust entomopathogenic fungi. *Journal of Economic Entomology* **95**: 651–660	*Metarhizium acridum*
21-13	NRI, UK (Madagascar)	1996	TINGLE, C.	Sprayed barriers of diflubenzuron for control of the Migratory Locust (*Locusta migratoria capito* (Sauss.)) [Orthoptera: Acrididae] in Madagascar: Short-term impact on relative abundance of terrestrial non-target invertebrates *Crop Protection* **15**: 576–592	Diflubenzuron
21-14	South Dakota State University (USA)	1991	QUINN, M. A. KEPNER, R. L. WALGENBACH, D. D. NELSON FOSTER, R. BOHLS, R. A. POOLER, P. D. REUTER, K. C. SWAIN, J. L.	Effect of habitat characteristics and perturbation from insecticides on the community dynamics of ground beetles (Coleoptera: Carabidae) on mixed-grass rangeland *Environmental Entomology* **20**: 1 285–1 294	Malathion
21-15	University of Basel Centre de Lutte Antiacridienne, Nouakchott, Mauritania (Mauritania)	1997	PEVELING R. DEMBA SY A.	Virulence of the entomopathogenic fungus *Metarhizium flavoviride* Gams and Rozsypal and toxicity of diflubenzuron, fenitrothion-esfenvalerate and profenofos-cypermethrin to nontarget arthropods in Mauritania *Archives of Environmental Contamination and Toxicology* **32**: 69–79	*Metarhizium acridum* Diflubenzuron
21-16	Department of Zoology, Division of Biology, University of Oslo, Norway (Mali)	1993	KROKENE, P.	The effect of an insect growth regulator on grasshoppers (Acrididae) and non-target arthropods in Mali *Journal of Applied Entomology* **116**: 248–266	Teflubenzuron
21-17	Cirad-Gerdat-Prifas (Burkina Faso)	1997	BALANÇA, G. DE VISSCHER, M.-N.	Effects of very low doses of fipronil on grasshoppers and non-target insects following field trials for grasshopper control *Crop Protection* **16**: 553–564	Fipronil

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides[1]
21-18	FAO COPR/National Resources Institute (UK) Wageningen University & Research (Netherlands) Direction Générale de la Protection des Végétaux (DGPV), Niamey, Niger (Niger)	2021	MULLIÉ, W.C. CHEKE, R.A. YOUNG, S. IBRAHIM, A. B. MURK, A. J.	Increased and sex-selective avian predation of Desert Locusts *Schistocerca gregaria* treated with *Metarhizium acridum* *PloS One* **16**: 0 244 733.	*Metarhizium acridum*
21-19	Locustox project, FAO Min. of Agriculture, Dakar, Senegal (Senegal)	2001	LAHR, J. BADJI, A. MARQUENIE, S. SCHUILING, E. NDOUR, K. B. DIALLO, A. O. EVERTS, J.W.	Acute toxicity of locust insecticides to two indigenous invertebrates from Sahelian temporary ponds *Ecotoxicology and Environmental Safety* **48**: 66–75	Fenitrothion Chlorpyrifos Malathion Deltamethrin Lambda-cyhalothrin Diflubenzuron Teflubenzuron Triflumuron Fipronil *Metarhizium acridum*
21-20	Deutsche Gesellschaft für Technische Zusammenarbeit (GiZ), Universität des Saarlandes, Germany (Mauritania & Madagascar)	1997	PEVELING, R. HARTL, J. KÖHNE, E.	Side-effects of the insect growth regulator triflumuron on spiders In: Krall S., Peveling R., Ba Diallo D., Eds. *New Strategies in Locust Control.* Birkhäuser Verlag, pp 345–359	Triflumuron
21-21	University of Basel, Switzerland Département de la Protection des Végétaux, Madagascar (Madagascar)	1999	PEVELING, R. RAFANOMEZANTSOA, J. J. RAZAFINIRINA, R. TOVONKERY, R. ZAFIMANIRY, G.	Environmental impact of the locust control agents fenitrothion, fenitrothion-esfenvalerate and triflumuron on terrestrial arthropods in Madagascar *Crop Protection* **18**: 659–676	Fenitrothion Triflumuron

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides[1]
21-22	University of Basel NRI, UK Département de la Protection des Végétaux, Madagascar (Madagascar)	2003	PEVELING, R. MCWILLIAM, A. N. NAGEL, P. RASOLOMANANA, H. RAHOLIJAONA RAKOTOMIANINA, L. RAVONINJATOVO, A. DEWHURST, C. F. GIBSON, G. RAFANOMEZANA, S. TINGLE, C.	Impact of locust control on harvester termites and endemic vertebrate predators in Madagascar *Journal of Applied Ecology* **40**: 729–741	Fipronil Triflumuron
21-23	Locustox project, FAO Min. of Agriculture, Dakar, Senegal (Senegal)	1999	VAN DER VALK, H.C.H.G. NIASSY, A.	Does grasshopper control create grasshopper problems? -Monitoring side-effects of fenitrothion applications in the western Sahel *Crop Protection* **18**: 139–149	Fenitrothion
21-24	Centre National de Lutte Antiacridienne, Morocco (Morocco)	2010	M. BAGARI M.Z. ATAY-KADIRI Z. GHAOUT S. CHIHRANE J.	The effects of chlorpyrifos and deltamethrin, insecticides used against the Desert Locust (*Schistocerca gregaria* Forskål) on non-target insects under natural conditions in Morocco	Chlorpyrifos Deltamethrin
21-25	All-Russian Institute for Plant Protection VIZR (Russia)	2000	SOKOLOV, I.M.	How does insecticidal control of grasshoppers affect non-target arthropods? In: Lockwood J.A., Latchininsky A.V, Sergeev. M.G., Eds. *Grasshopper and grassland health*. Kluwer Ac Pub, pp 181-192	Fipronil Chlorpyrifos
21-26	Plant Protection Research Inst. Pretoria, South Africa (South Africa)	1998	STEWART, D.A.B.	Non-target grasshoppers as indicators of the side-effects of chemical locust control in the Karoo, South Africa *Journal of Insect Conservation* **2**: 263–276	Deltamethrin

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides[1]
21-27	Locustox project, FAO Min. of Agriculture, Dakar, Senegal (Senegal)	2000	LAHR, J. DIALLO, A.O. GADJI, B. DIOUF, P. S. BEDAUX, J.J.M. BADJI, A. NDOUR, K. B. ANDREASEN, J. E. VAN STRAALEN, N. M.	Ecological effects of experimental insecticide applications on invertebrates in Sahelian temporary ponds *Environmental Toxicology and Chemistry* **19**:1 278–1 289	Fenitrothion Diflubenzuron Deltamethrin
21-28	Centre National pour la Lutte Antiacridienne, Morocco, (Morocco)	2009	(anon.)	Etude d’impact d’un traitement en barrières à grande échelle du Nomolt ® (IGR’s ; teflubenzuron) sur la faune non-cible dans les aires de reproduction printanières du criquet pèlerin au Maroc.	Teflubenzuron
21-29	Direction de la Protection des Végétaux, Niger Centre de Recherches en Ecotoxicologie pour le Sahel, Niger (Niger)	2019	MAMADOU, A. DOUMMA A. MAZIH A.	Impact of pesticides used to control Desert Locust on the gathering activity of wild bees on flowers of Acacia at Niger 13th International Congress of Orthopterology, Rabat, Morocco	Chlorpyrifos Fenitrothion
21-30	University of Wollongong, Australia Australian Plague Locust Commission Texas Tech University, USA (Australia)	2006	MAUTE, K. FRENCH, K. STORY, P. BULL, C. M. HOSE, G. C.	Short and long-term impacts of ultra-low-volume pesticide and biopesticide applications for locust control on non-target arid zone arthropods *Agriculture, Ecosystems and Environment* **240**: 233243	*Metarhizium acridum* Fipronil
21-31	University of Wollongong & Australian Plague Locust Commission & Texas Tech University (Australia)	2016	WALKER, P.W. STORY, P.G. HOSE, G.C.	Comparative effects of pesticides, fenitrothion and fipronil, applied as ultra-low volume formulations for locust control, on non-target invertebrate assemblages in Mitchell grass plains of south-west Queensland, Australia *Crop Protection* **89**: 38-46	Fipronil Fenitrothion

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides[1]
21-32	FAO / CERES-Locustox Foundation, Dakar, Senegal NRI, UK DGPV, Niamey, Niger Wageningen U&R, The Netherlands (Niger)	2021	MULLIÉ, W.C. CHEKE, R.A. YOUNG, S. IBRAHIM, A.B. MURK, A.	Increased and sex-selective avian predation of Desert Locusts Schistocerca gregaria treated with Metarhizium acridum. *PLoS ONE* **16(1)**: e0244733	*Metarhizium acridum*
21-33	FAO / CERES-Locustox Foundation, Dakar, Senegal (Senegal)	2002	DANFA, A. BA, A.L. VAN DER VALK, H. ROULAND-LEFÈVRE, C. MULLIÉ, W.C. EVERTS, J.W.	Long-term effects of chlorpyrifos and fipronil on epigeal beetles and soil arthropods in the semi-arid savannah of Northern Senegal. In: Everts J.W., Mbaye D., Barry O., Mullié W.C., Eds. *Environmental Side-Effects of Locust and Grasshopper Control*, Vol 4. FAO CERES-Locustox Foundation, Dakar, Senegal, pp 184 - 209	Fipronil
21-34	Australian Plague Locust Commission University of Wollongong Australia (Australia)	2016	STORY, PAUL G. FRENCH, K. ASTHEIMER, L.B. BUTTEMER, W.A.	Fenitrothion, an organophosphorus insecticide, impairs locomotory function and alters body temperatures in *Sminthopsis macroura* (Gould 1845) without reducing metabolic rates during running endurance and thermogenic performance tests. *Environmental Toxicology and Chemistry* **35(1)**: 152–162	Fenitrothion

Annex 4 – Quality criteria for efficacy and environmental impact field studies

Minimum quality criteria that the reports of efficacy field trials and environmental field studies should meet to be used in the evaluation by the LPRG.

Criteria	Efficacy trials			Environmental field studies		
	Selection		Conditions/remarks	Selection		Conditions/remarks
	mandatory	conditional		mandatory	conditional	
Trial design						
Untreated control plot(s) used		X	If field mortality assessments are carried out; *and* Unless insecticide has a fast (1-2 hours) or moderate (2-48 hours) speed of action	X		Sufficient control observations in time and/or space to allow for a proper analysis of results [1]
Untreated control cage(s) used		X	If cage mortality assessments are carried out	X		
Plot size reported	X			X		
Barrier width reported or can be estimated		X	For barrier treatments and RAAT[2]			
Barrier spacing reported		X	For barrier treatments and RAAT			
Environmental conditions						
Vegetation type & height reported		X	For evaluation of the effect of environmental conditions on efficacy	X		Dominant plant species
Wind speed during application reported		X	For evaluation of the effect of environmental conditions on efficacy			
Temperature during application reported		X	For evaluation of the effect of environmental conditions on efficacy		X	If prolonged observation period
Rainfall during 3 days after treatments reported		X	For evaluation of the effect of environmental conditions on efficacy; *and* Unless trial was carried out in the dry season		X	If prolonged observation period
Insects/Non-target organisms						
Species reported	X			X		Justification of species selection
Stage(s) reported	X		Unless target is a mixed grasshopper population			

[1] Sufficient pre-treatment observations are crucial.
[2] Reduced Agent-Area Treatment (RAAT) uses less insecticide, e.g. by increasing track spacing; resembles irregular blanket treatment (see paragraph 42)

Criteria	Efficacy trials			Environmental field studies		
	Selection		Conditions/remarks	Selection		Conditions/remarks
	mandatory	conditional		mandatory	conditional	
Insecticide						
Trade name or manufacturer reported	X					
Type of formulation reported	X			X		
Concentration of a.i. in product reported	X			X		
Diluent & dilution ratio reported		X	If product is applied diluted			
Application						
Type/model of sprayer/atomiser reported	X					
Height of atomiser reported		X	For evaluation of application technique on efficacy; *and* Unless height can be estimated from the description of the sprayer platform			
Sprayer platform reported (i.e. hand-held, vehicle or aircraft)		X	For evaluation of application technique on efficacy; *and* Unless atomiser height is reported	X		
Volume application rate reported or can be calculated	X			X		
Area dosage measured		X	Unless area dosage can be calculated from the main application parameters	X		
Main application parameters reported (i.e. flow rate, sprayer speed & track spacing)		X	Unless area dosage is measured			
Deposition or residues measured in/on vegetation, soil, water				X		
Efficacy/mortality assessment						
Method of field mortality/effect assessment reported		X	If field population assessments are carried out	X		Including sub-lethal effects
Method of cage mortality/effect assessment reported		X	If cage mortality assessments are carried out	X		Including sub-lethal effects
Observation of a dose-related response					X	If effect of more than one dose is being studied
Observation of recovery in space or time					X	In prolonged studies

Annex 5 – Summary of data from efficacy trial reports

Report	Insecticide		Target species [1]	Stage [2]	App.[3]	Repl.4	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [5]		Meets Annex 4 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M6	earliest >90%	highest observed		
								Rate	Volume	Rate	Volume					
21-01	Deltamethrin	Ascendis Deltanex 17.5 UL	LPA	Ad	H	1	0.08	17.5	1.0			M	2d	95% at 3d	Yes	Randomized complete block design, data reported for each block (replicate) separately 10 x 1 m^2 counts/plot Esfenvalerate used as standard;
	"	"	"	Ad	"	"	0.09	"	"			"	<1d	100% at 2d		
	"	"	"	L4–L5 and Ad	"	"	0.09	"	"			"	3d 2d	91% at 3d 98% at 3d		
	"	"	"	L4–L5 and Ad	"	"	0.2	"	"			"	3d 3d	95% at 3d 96% at 3d		
21-02	Fipronil	Fipro 12.5 UL	SGR	L4–L5	V	3	0.5	4.69	0.375			N		78% at 2d	Yes	Mortality assessed in caged hoppers collect-ed after treatment; Observation period: 2 days;
	"	"	"	"	"	"	"	6.25	0.500			"		100% at 2d		
	"	"	"	"	"	"	"	7.81	0.625			"	1d	100% at 2d		
	Diazinon	Zynon 800 UL	SGR	L4–L5	V	3	0.5	300	0.375			N		56% at 2d		
	"	"	"	"	"	"	"	400	0.500			"	1d	91% at 2d		
	"	"	"	"	"	"	"	500	0.625			"	<1d	99% at 2d		
	Malathion	Malathion VAP 96% UL	SGR	L4–L5	V	3	0.5	960	1.0			N	<1d	97% at 2d		
21-03	Profenfos + cypermethrin	Polytnour 220 UL	AME	L4–L5	V	3	0.5	75+7.5	0.375			N		52% at 3d	Yes	Mortality assessed in caged hoppers collect-ed after treatment; Observation period: 3 days;
	"	"	"	"	"	"	"	100+10	0.500			"		90% at 3d		
	"	"	"	"	"	"	"	125+12.5	0.625			"		97% at 3d		
	Profenfos + cypermethrin	Cyprofen C220 UL	AME	L4–L5	V	3	0.5	100+10	0.500			"	1d	92% at 3d		

[1] Target species: AME = *Anacridium melanorhodon melanorhodon*, CIT = *Calliptamus italicus*, SGR = *Schistocerca gregaria*, LMC = *Locusta migratoria capito*, LPA = *Locustana pardalina*
[1] L = larvae, Ad = adult
[2] Application methods: A = aerial, V = vehicle-mounted, H = hand-held
[4] Number of replicates
[5] % population reduction (corrected for changes in control) at number of days after treatment N = nominal application rate, M = measured application rate
[6] N = nominal application rate, M = measured application rate
[7] CFU = Colony Forming Unit

Report	Insecticide		Target species [1]	Stage [2]	App.[3]	Repl.4	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [5]		Meets Annex 4 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M6	earliest >90%	highest observed		
								Rate	Volume	Rate	Volume					
21-04	Chlorpyrifos	Wopro Chlorpyri-fos-éthyl 240 ULV	LMC	L–Ad	H	4	1.0	240	1.0			N		Nymphs: 94% at 2d Adults: 99% at 2d	Yes	2 separate ex-periments with 2 formulations of chlorpyrifos; Separate transect counts of hoppers and adults along plot diagonals before and after treatment Observation period: 2 days No control plots;
	"	Agrifos 240 UL	"	"	"	"	"	"	"			"		Nymphs: 97% at 2d Adults: 100% at 2d		
	Chlorpyrifos	Wopro Chlorpyri-fos-éthyl 240 ULV	LMC	L–Ad	H	4	1.0	240	1.0			N		Nymphs: 99% at 2d Adults: 99% at 2d		
	"	Agrifos 240 UL	"	"	"	"	"	"	"			"		Nymphs: 99% at 2d Adults: 99% at 2d		
21-05	*Metarhizium acridum*	Green Muscle 50×10^{12} CFU[7]/g	SGR	L4	H	1	1	50	1			N		Direct ≈ 70% at 18d ≈ 90% at 20d Residual ≈ 50% at 20d when exposed on day after treatment	Partly	Reared hoppers treated in the field (direct) or exposed to treated natural vegetation (residual) in small cages (40 x 40 x 40 cm); Pseudo-replicates consisting of repli-cate cages placed on treatment plots; Comparison of dense and sparse vegetation Effect (mortality) not corrected for control;
	"	"	"	"	"	"	"	100	?			"	18d	≈ 94% at 18d		
	"	Novacrid 5×10^{10} CFU/g	"	"	"	"	"	25	?			"		≈ 85% at 20d		
	"	"	"	"	"	"	"	50	1			"		≈ 82% at 20d		
21-06	Chlorantranilip-role	Coragen 20% SC	SGR	L3–5 and Ad	H	1	0.25	24.0	0.12			N		98% at 2d	Partly	4 cages per plot stocked with locusts from treated or con-trol plots; Rate for spinosad at volume of formula-tion applied likely lower;
	Spinosad	Tracer 24% SC	"	"	"	"	"	15.1 (14.4 ?)	0.06			"	1d	99% at 2d		
	Fipronil	Coatch 20% SC	"	"	"	"	"	0.4	0.031			"	1d	100% at 2d		

Report	Insecticide		Target species [1]	Stage [2]	App.[3]	Repl.4	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [5]		Meets Annex 4 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M6	earliest >90%	highest observed		
								Rate	Volume	Rate	Volume					
21-14	Pyrethrins	Pyrethrins	SGR	L3-4 (?)	H	3	?	?	5.60			N		100% at 1d	No	Semi-field cage trials Hoppers presumably spayed in small cages or arenas; Only average size of test groups given (≈ 500 hoppers/cage); Analysed pyrethrins concentration more than twofold higher than label rate, resulting in overdosing; Volume given for chlorpyrifos resulting in higher dose rate; No ULV application; Inherent toxicity of carrier spray oil D-C-Tron Plus not tested;
	"	"	"	"	"	"	?	?	7.50			"		100% at 1d		
	"	"	"	"	"	"	?	225 (?)	9.20			"		100% at 1d		
	Chlorpyrifos	Ranger 480 EC	"	"	"	"	?	300 (?)	0.84			"		100% at 1d		
21-15	Ammonium hydroxide	Shield 20%	CIT	L3-5	V	1	4 (?)	100	1.0			N		95% at ?	No	Exact plot size not clear; No control plots; Transect counts mentioned but results are for caged samples Very low efficacy of toxic standard;
	Deltamethrin	Decis 2.5%	"	"	"	"	"	17.5	0.7			"		16% at ?		

Annex 6 – Special considerations for insecticide groups

Insecticides listed in the report are divided into the following groups: organophosphates, pyrethroids, benzoylureas, phenyl pyrazoles and biological insecticides (e.g. mycoinsecticides). Carbamates are no longer considered as the only product, bendiocarb has been removed from the list of insecticides with verified dose rates. Special consideration about their suitability for control purposes and conditions of use are given.

Organophosphates and pyrethroids

Organophosphates and pyrethroids have some aspects in common. They have a broad-spectrum activity, exhibit moderate (OPs) to fast (pyrethroids) action and are therefore suitable for use in emergency situations. They work mainly by contact action and are most effective during a short period of time, 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, by contact and ingestion. The need to apply the spray directly on a target requires intensive efforts to identify and delimit appropriate targets (hopper bands and swarms). These insecticides are particularly suitable for swarm control and direct crop protection. The pesticides constitute a medium to high risk to aquatic invertebrates, especially crustaceans when pyrethroids are used, and to terrestrial non-target arthropods. Moreover, OPs may affect birds and reptiles.

With respect to human toxicity, OPs can be acutely toxic but also show chronic effects after recovery of an acute intoxication. Spray operators may be exposed to organophosphate insecticides, especially when filling sprayers with the formulated product. Operator protection with coveralls, gloves, boots and face shields is therefore required. Operators must be trained and subject to mandatory health monitoring. If blood levels of acetyl-cholinesterase (AChE), an enzyme breaking down the neurotransmitter acetyl-choline, fall significantly, they must be given rest or alternative tasks until they are fully recovered. Toxicity varies strongly between the OP insecticides, with particular care needed when using chlorpyrifos and fenitrothion. Chemical transfer by pumps with closed coupling to the container is essential to minimize exposure.

Benzoylurea insect growth regulators

Benzoylurea IGR insecticides have shown to be very effective against locust hoppers. Their action is slow, which makes them unsuitable for immediate crop protection. They are persistent on foliage and their fairly narrow spectrum of activity makes them attractive from an environmental point of view. However, due to adverse effects on crustaceans, spraying of surface waters must be avoided. They are most effective when applied against hoppers up to the 4^{th} instar, but later instars can be affected. Fecundity and fertility may be influenced by treatment of adults and hatching of eggs be reduced, but this effect was not considered when setting effective dose rates. Benzoylureas should be used primarily as barrier treatments. However, blanket treatments at a lower dose can also be effective.

Phenyl pyrazoles

The effectiveness of fipronil by contact and stomach action was confirmed in large-scale applications against the Australian Plague Locust using irregular blanket treatments. Dosages of 0.33 g a.i. per protected hectare with swaths up to 300 m apart were used. Movements of Desert Locust hopper bands may allow wider track spacing (700 m). The width of the untreated area will also depend on whether the insects are able to degrade the insecticide. Good efficacy at high temperatures may also be due to toxic metabolites. The toxic effect is not so immediate as with certain other insecticides but affected locusts cease feeding rapidly. The persistence of fipronil is comparable to that of benzoylureas. However, due to its broad-spectrum activity and the high risk of long-term effects in soil insects such as termites, fipronil should only be applied as a barrier treatment. Spray drift on to the inter-barrier area must be minimised to reduce environmental impact. As with IGRs, contamination of surface waters must be avoided because of high toxicity to crustaceans.

Biological insecticides

A considerable body of field data confirms the efficacy of the biopesticide *Metarhizium acridum* isolate 330189 against the Desert Locust, Malagasy Migratory Locust and Red Locust. The isolate FI 985 is widely used against Australian Plague Locust and has shown to be effective against Migratory Locust in the Pacific. New isolates are showing promise for future commercialisation. The efficacy of *Metarhizium* is influenced by the ambient temperature, with growth of the fungus slowing down/halting below 20°C as well as above 37°C. In practice, in many locust-affected regions, temperatures will not often be beyond these critical limits the entire day (i.e. hot days followed by cold nights), and fungal growth will continue, though at a lower speed.

Metarhizium acridum is very specific to locusts and grasshoppers, and non-target organisms are not affected by this biopesticide, except possibly other Orthoptera. The use of *Metarhizium* in ecologically and otherwise sensitive areas is therefore recommended. Human health risks are very low, though special care should be taken when handling the dry spores to avoid inhalation and possible allergenic effects.

Improved formulations of this biopesticide are now available, reducing the risk of clogging of spray equipment. Training in the storage, handling, mixing and application of *Metarhizium* is required, however, to ensure optimal efficacy.

Annex 7 – Updated LPRG health hazard classification of insecticide formulations for locust control

Health hazards						Use recommendations for locust control [3]	
Acute tocicity		Skin corrosion/ irritation or Serious eye damage/ eye irritation *GHS*	Respiratory or skin sensitization *GHS*	Germ cell mutagenicity or carcinogenicity or reproductive toxicity *GHS*	Specific target organ toxicity – single or repeated exposure *GHS*	Operator code	Availability and use restrictions
Oral Dermal WHO[1]	**Inhalation** *GHS* [2]						
Class Ia & Ib	Category 1 & 2		Respiratory sens. Category 1A & 1B	Mut. Category 1A & 1B Canc. Category 1A & 1B Repr. Category 1A & 1B			Not recommended for locust control
Class II	Category 3 & 4	Eye – Category 1 Skin – Category 1A & 1B & 1C	Skin sensitization Category 1A & 1B	Mut. Category 2 Canc. Category 2 Repr. Category 2	STOT SE Category 1 STOT RE Category 1	A	Trained and supervised operators who are known to observe precautionary measures strictly prescribed
Class III	Category 5	Eye - Category 2A & 2B Skin - Category 2			STOT SE Category 2 & 3 STOT RE Category 2 & 3	B	Trained operators who observe routine precautionary measures
Class U	Unclassified	Unclassified	Unclassified	Unclassified	Unclassified	C	General public, respecting standard general hygenic measures and observing instructions for use given on the label

[1] According to the WHO Classification of Pesticides by Hazard (WHO, 2020)

[2] According to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (UNECE, 2019)

[3] According to the FAO Desert Locust Guidelines – Safety and Environmental Precautions (FAO, 2003)

Annex 8 – Quality criteria for laboratory toxicity studies

The quality of laboratory and semi-field toxicity studies was classified according to the widely used system described by Klimisch et al. (1997). Studies to which Reliability 1 and 2 apply have been used for the LPRG evaluation.

Category of Reliability

Reliability 1: Reliable without restriction

- Guideline study (OECD, etc.)
- Comparable to guideline study
- Test procedure according to national standards

Reliability 2: Reliable with restrictions

- Acceptable, well-documented publication/study report which meets basic scientific principles
- Basic data given: comparable to guidelines/standards
- Comparable to guideline study with acceptable restrictions

Reliability 3: Not reliable

- Method not validated
- Documentation insufficient for assessment
- Does not meet important criteria of today's standard methods
- Relevant methodological deficiencies
- Unsuitable test system

Reliability 4: Not assignable

- Only short abstract available
- Only secondary literature (review, tables, books, etc.)

Annex 9.1 – Summary of data from environmental laboratory and semi-field toxicity studies

Record	Insecticide	Formulation	Test species	Origin of test species	No.	Exposure	Dose	Interval between observations	Endpoint	Parameters	Results
21-02	Chlorpyrifos	Lorsban 4E	Ring-necked pheasant (chicks) *Phasianus colchicus*	R	F 6 M 6	Contact + ingestion	Equiv. of 279 and 1,116 g a.i./ha	48h	Mortality, AChE	Survival, feeding	No significant effect at both dosages; no effect in group fed with diseased prey
21-04	*Metarhizium acridum*	Experimental formulation	*Apis mellifera*	C	25 bees/ cage, 30 cages	Exposure to spray	a. 16 000 conidia cm2 b. 164 000 conidia cm2 c. oil (control)	3,4,5,6,7,8,9,10,11,12	Mortality	Numbers, infections	a : no mortality b: 20 % mortality
21-06	*Metarhizium acridum*	Experimental isolates (4)	Ring necked pheasant *Phasianus colchicus*	C	F 18 M 18	Food		9,17,25d	Health, growth	Weight, tarsal length, histopathological effects	No effects
21-09	*Metarhizium acridum*	Green Guard	Mayfly nymph *Ulmerophlebia* sp.	C	4x5	Exposure to spray	$2x10^6$ conidia/ml	14d	Survival	Death	No effect
21-09	*Metarhizium acridum*	Green Guard	Rainbow fish *Melanotaenia duboulayi*	R	4x5	Water	$2x10^6$ conidia/ml	14d	Survival	Death	No effect
21-09	*Metarhizium acridum*	Green Guard	Water flea *Ceriodaphnia dubia*	R	4x5	Water	1 and $2x10^6$, conidia/ml; .2, 2.5, 5 x 5 x 10^5; 1.5, 3, 6 x 10^4 conidia/ml	24, 48, 72, 96, 120, 144, 168, 192h	Survival	Death	Mortality function of concentration: 100% at 48h at $2x10^6$; NOEC $6x10^4$
21-10	*Metarhizium acridum* IMI 330 189	Technical formulation	*Apoanagyrus lopezi* and *Phanerotoma* sp. (*Hymenoptera: Encyrtidae*)	R	10x30	Residual exposure	10^3 conidia	Necropsy at 3, 10, 17 and 21d	Survival	Mycosis, longevity	Slight but significant effect
21-10	*Metarhizium acridum* IMI 330 189	Technical formulation	*Apoanagyrus lopezi* (Hymenoptera: Encyrtidae)	R		Residual exposure	10^3 conidia	3 x 3 weeks	Beneficial capacity on *Phenacoccus manihoti* (Cassava mealybug)	Sex ratio, longevity, parasitisation activity	No effect
21-10	*Metarhizium acridum* IMI 330 189	Technical formulation	a.c. *Pimelia senegalensis* b. *Trachyderma hispida*	C	a. 3x10 b. 10	a,b. Topical c. Food	2.5 x 10^6 conidia/insect	a.11-15d	Survival	Death, sporulation of *M. var. acridum*	No effect

Record	Insecticide	Formulation	Test species	Origin of test species	No.	Exposure	Dose	Interval between observations	Endpoint	Parameters	Results
21-10	*Metarhizium acridum* conidia: IMI 330 189, IMI 191 609 *Metarhizium* sp. blastospores: DSM 113 36 *Metarhizium* spp. conidia: 9 isolates *Beauveria bassiana* conidia: IIBC 193 825	Mixed with canola oil	a. *Bracon hebetor,* b. *Apoanagyrus lopezi*	R	a. 6 b. 10	Residue (continuous and temporary)	$5x10^{12}$ conidia/Ha (equiv.)	4 x 2d	Survival	Survival time (d), sporulation	Both species: survival 1.6 - 4.1 d; Sporulation in 10 – 50% of test insects
21-15	a. *Metarhizium acridum* (strain Mfl 5) b. Diflubenzuron	a. Technical formulation b. Dimilin 6OF	larval *Pharoscyamus anchorago* F. (Coleoptera: Coccinellidae)	C	30	a. Deposit b. Residue	a.2.5 x 10^9 BS1/g (1994) and 1.7 x 10^{10} BS/g (1995) = 2.5 x 10^4 BS/ cm^2. b.0.6 µg a.i./cm^2	Daily after 44h exposure on treated leaves until moulting into the adult stage	Mortality, development	Individual count	a. No effect at low dosage, slight effect at high dosage b. 80% mortality
21-15	*Metarhizium acridum* (strain Mfl 5)	Technical formulation	*Trachyderma hispida* (Tenebrionidae)	C	40	Topical	2.5 x 10^3, 2.5 x 10^4, and 2.5 x 10^5 BS/individual	30d	Mortality		No effect
21-15	*Metarhizium acridum* (strain Mfl 5)	Technical formulation	*Thanatus* sp. (Arachnidae) sub-adult	C	60	Topical	250 and 2,500 BS/spider.	15d	Mortality, infection		No effect
21-9	a. Fenitrothion b. Chlorpyrifos c. Malathion d. Bendiocarb e. Propoxur f. Deltamethrin g. Lambda-cyhalothrin h. Diflubenzuron i. Teflubenzuron j, Triflumuron k. Fipronil l. *Metarhizium anisopliae* var. *acridum*	Sumithion Sumithion Dursban Fyfanon Ficam Unden Decis Karate Dimilin Nomolt Alsystin Regent Green Muscle	*Streptocephalus sudanicus* (shrimp); *Anisops sardeus* (backswimmer)	C	6x10 per test	Water	5 conc.	24h, 48h	Incapacity, mortality		*S. sudanicus* EC50 48h range: 67,750 – 0.018 (µg/L) = Malathion – Deltamethrin *A. sardeus* LC50 48h range: 1,937 – 0.12 (µg/L) = Diflubenzuron - deltamethrin

[1] Blastospores are fungal propagules circulating in the hemolymph of infected insects that can be produced in fermenters and developed into mycoinsecticides.

R = Reared; C = Caught from the wild

F = Female; M = Male

Record	Insecticide	Formulation	Test species	Origin of test species	No.	Exposure	Dose	Interval between observations	Endpoint	Parameters	Results
21-20	Triflumuron	Alsystin	*Peucetia* sp.	C	30	Topical	doses 0.1, 0.5 and 2.5 µg a.i./cm² (=field dose times 1/5, 1 and 5)		Mortality, impaired moulting		LC50=0.9 µg a.i./ cm², no effect on moulting; highly toxic
21-35	Fenitrothion	ULV	Striped-faced dunnart *Sminthopsis macroura*	C	7-15	Gavage	90 mg/Kg BW	3d	a. Locomotory & thermogenic functions, b. Metabolic performance, c. Body mass, D Anemic response e. Neurotoxicity	a. Running endurance & shivering thermogenesis b. PMRtemp c. Weight d. Hematocrit & hemoglobin levels f. Plasma & brain AChE	a.- 80% b. no effect c: no effect d.no effect e. no effect f.- 50% & - 45%

Annex 9.2 – Summary of data from environmental field studies

Report	Insecticide Common name	Insecticide Formulation & rate (g a.i./Ha)	Species / taxa	Location	Plot size & repetitions	Observations pre- and post-treatment	Method(s)	Effect & recovery
21-01	Chlorpyrifos Fenitrothion	a. Chlorpyrifos, rate 225 b. Fenitrothion, rate 450	1. *Polyergus* (Formicidae) 2. *Camponotus* (Formicidae) 3. *Trachimyrmex* (Formicidae)	Niger, Vallée du Tafidet	3 x 16 Ha	-4, 1, 4, 8, 12, 16, 20, 24, 28, 34, 38, 40	Pitfall traps	Both pesticides: 1. Reduction 100%; recovery 28d 2. Reduction 100%; recovery >40d 3. Reduction 100%; recovery 36d
21-03	a. Diflubenzuron: a.1 RAAT: 33%, 17.5g a.2 Standard rate, decreased coverage: 25%, 17.5 g a.3 Decreased rate, standard coverage 33%: 13 g b. Malathion: b.1 Traditional blanket: 693 g b.2 Traditional rate, decreased coverage: 50%, 693 g b.3 Standard rate, decreased coverage: 80%, 346.5 g b.4 Standard rate, decreased coverage: 50%, 346.5 g b.5 Traditional rate, decreased coverage: 33% 693g	Dimilin 2L; 17.5 g Barriers: 33% Decreased Rate: 25% Fyfanon UL; 693, 346.5 g: 33, 50, 80, 100%	Formicidae, Carabidae, Vespidae, Apoidea, Arachnida Heteroptera, Diptera	Lingle, Wyoming, USA	No data	11 to 23h; 7d before and 7d after dosing	Sweep nets, sticky and pitfall traps	a.1 – 3, b.1 – 5: Diptera: significant decrease at 2 + 3 w, a.1 – 3, b.1 – 5: Heteroptera: significant decrease at 1 + 2 w a1 – 3: Formicidae: significant decrease
21-05	a. Fipronil b. Malathion	Adonis; 4 g a.i./ha: 33% Fyfanon 342 g a.i./Ha: 80%	Birds: all spp.	SE Wyoming, USA	a. 347 Ha b. 243 Ha Control 259 Ha	a. -1, 1,3,7,14,28d b. 2,6,14,21d	Transect counts	a: No reduction b: 20% reduction
21-07	a. Fenitrothion b. Chlorpyrifos	a. Sumithion 450 b. Dursban 225	*Psammotermes hybostoma* (Isoptera: Rhinotermitidae)	Niger, Vallée du Tafidet	Test field 3 x 9 ha	-15,15,30,45,60,75,90d	Foraging activity	a.:–75% at day 30, recovery at day 75 b.: –49% at day 33, recovery at day 90

Report	Insecticide Common name	Insecticide Formulation & rate (g a.i./Ha)	Species / taxa	Location	Plot size & repetitions	Observations pre- and post-treatment	Method(s)	Effect & recovery
21-08	Chlorpyrifos	Dursban 324	Prawn (Penaeidae); *Metapenaeus monoceros* (Tenebrionidae); Hoopoe lark, *Alaemon alaudipes;* *Antlion Cueta* spp.	Suakin, Sudan	Test fields 2 x 88 Ha	13w pre-spray, 8w post spray	Trapping	Significant reduction in all taxa
21-12	Metarhizium acridum (indigenous isolates SP3 and SP9) *Beauveria bassiana*	Technical formulation	Coleopteran spp.	Toliara, Madagascar	2x1 Ha plots	5, 10, 15	Pitfall taps, flight nets	Statistical effect of isolate SP3 *M. acridum* on Coleoptera species number; no effect of isolate SP9 and *B. bassiana*
21-13	Diflubenzuron	Dimilin@ 95 barriers 500m	All spp. caught	Toliara, Madagascar	20 and 5 Km^2 areas	1994 16/3 – 27/7; 5 pre-, 9 post-treatment	Sweep nets	No effect between barriers; within barriers: Acrididae, lepidopterans, spiders, gryllids and heteropterans not or slightly affected
21-14	Malathion	(unknown) 653	Coleopterans	Butte County, South Dakota, USA	29 blocks 0.75 Ha	Weekly intervals 23/6 - 28/8 1986, and 1/7 - 24/8 1987	Pitfall traps	Recovery of beetle community after effect of pesticide depends on floral cover
21-16	Teflubenzuron	Technical formulation 2.3, 4.8, 5.3 and 16.4 g a.i./Ha	17 taxa from different orders	Gori Banda, Mali	1 x 12 Ha plots / treatment	12d pre-treatment; 26d post-treatment	Sweep nets, pitfall traps, 40 traps/plot	Out of 17 taxa effect in spiders, mantids, hemipterans, lepidopterans, dipterans
21-17	Fipronil	(unknown) 1 & 2 g a.i./Ha	All coleopterans; flying insects	Niamey, Niger	4x4, 2x9, 1x10 Ha plots	1x pre-treatment, 8x post-treatment (day 32)	Pitfall traps, Malaise traps, yellow discs	Effect in 8 most abundant spp: 68-99% @ 2-11d, recovery within 28d (both dosages)
21-18	*Metarhizium acridum*	Green Muscle 107 g viable conidia/Ha	Insectivorous birds	Agadez, Arlit, Niger		6 counts pre-treatment; 12 counts post-treatment	Parts of DL in bird pellets	Strong indication that predation enhances effect of pesticide
21-21	Fenitrothion Triflumuron	a. Sumithion 400 g a.i./H b. Alsystin 50 g a.i./Ha	Non-target insect fauna	Toliara, Madagascar	16 and 400 Ha	1 month pre-treatment, 3 months post-treatment	Direct + residue, pitfall traps, sweep nets, Malaise traps	Fenitrothion: reduction >75% in springtails, ants, *Zophosis madagascariensis* (Tenebrionidae) Triflumuron: effect >60% on Lepidoptera
21-22	Fipronil	Regent a. Barriers 7.5 g a.i./ Ha b. Blanket 3.2-4 g a.i./Ha	Non-target insects, mammals, lizards	Madagascar a. Ankazoabo b. Malaimbandy	a. 45 km^2 (overall protected) b. 2 x 1 km^2	Trapping a & b: 1 week pre-treatment, up to 10m (a) or 23w (b) post-treatment; Termite activity: a: 1d, 3m, 6m + weekly counts b: 1w pre- and 1,8,16,22,24 w post-treatment + 3d counts	Harvester termite: activity and mortality Lizards: transect counts Tenrecs: traps	Termite: (a) 45% reduction, lasting at least 10m; (b) 80-91% reduction, lasting at least 6m; Lizards (b.): 45-52% reduction, >6m Tenrecs (b.): 100% reduction, 4m

Report	Insecticide Common name	Insecticide Formulation & rate (g a.i./Ha)	Species / taxa	Location	Plot size & repetitions	Observations pre- andpost-treatment	Method(s)	Effect & recovery
21-22	Triflumuron	Alsystin Barriers 50 g a.i./Ha	Non-target insects, mammals, lizards	Ankazoabo, Madagascar	65 km^2 (overall protected)	1 week pre-treatment, up to10 m post-treatment	Harvester termite: activity and mortality Lizards: transectcounts Tenrecs: traps	No effects
21-23	Fenitrothion	Sumithion 250-1,250 g a.i./Ha	Tenebrionids	Northern Senegal	26 treatments, various sizes	1991: 9 treatments; 1992 : 16 treatments, each including control, before and after treatmentsampling	Egg pods predated	9% effect
21-24	a. Chlorpyrifos b. Deltamethrin	a. Dursban b. Decis a. 240 g a.i./Ha b. 12.5 g a.i./Ha	Coleopterans hymenopterans,spiders	Merzouga, Morocco	2 x 3x1Ha	2d pre-, 9d post-treatment	Pitfall traps	Hymenopterans most affectedby both treatments; no recovery in 9d
21-25	a. Fipronil b. Chlorpyrifos	(no data) a. 4 g a.i./Ha 1. Blanket 2. Barrier b. 205 g a.i./Ha Chlorpyrifos = positive control Chlorpyrifos = positive control	11 taxa	Irkutsk, Russia	30Ha plots	1d pre and 21d post-treatment	Sweep nets,Pitfall traps	Comparative data: 1. Effect fipronil > effect chlorpyrifos: Lygaeidae, Muscidae, Ichneumonoidea, Miridae, Chrysomelidae, Agromyzidae, Pyralidae; 2. Effect fipronil < effect chlorpyrifos: Lycosidae,Cydnidae, Cicadellidae 3. Effect fipronil = effect chlorpyrifos: Carabidae, Thomisidae, Chalcidoidea
21-26	Deltamethrin	7 g UL 17.5 g a.i./Ha	30 spp. non-target grasshoppers	Karoo, South Africa	3 sites; 3x50x50m plots	1,6,17,27,64,106,254,362 d post-treatment	Visual counting	Effect on numbers >I year. Spp. composition not changed

Report	Insecticide Common name	Insecticide Formulation & rate (g a.i./Ha)	Species / taxa	Location	Plot size & repetitions	Observations pre- and post-treatment	Method(s)	Effect & recovery
21-27	a. Fenitrothion b. Bendiocarb c. Deltamethrin Diflubenzuron	a. Sumithion b. Ficam c. Decis d. Dimilin a. 500g a.i./Ha b. 200 g a.i./Ha c. 15 g a.i./Ha 450 g a.i./Ha	Zooplankton, macro- invertebrates, residues	Fété Olé, Senegal	5 ponds per treatment	2 samples/w; 4,5 w pre- and 8 w post-treatment.	Netting	a. Half-lives b. a. 34h c. b. 17d d. c. <<24h e. d. <<24h f. Effect a. Zooplankton, backswimmers b. least effect of all compounds c. Backswimmers, zooplankton, shrimps Crustaceans only Recovery: not in crustaceans
21-28	Teflubenzuron	Nomolt 45.6 g a.i./Habarriers	Butterflies, dipterans: asilids, bombyliids; bees, ants, coleopterans: tenebrionids, meloids	El Maâder El Kebir, Morocco	2,400 Ha (treated) 1,000Ha (control)	6w pre- and 4w post- treatment	Pitfall traps, yellow trays	Effect only in coccinellids
21-29	a. Chlorpyrifos b. Fenitrothion	a. Dursban b. Sumithion a. 225 g a.i./Ha b. 450 g a.i./Ha	Wild bees	Agadez, Niger	9 Ha plots	4d pre-, 60d post-treatment	Yellow trays	Reduction 100% in 1 (a) and 5 (b) days; recovery in a and bon day 28
21-30	a. *Metarhizium acridum* b. Fipronil	a. Green Guard b. Adonis a. Blanket 0.6L/Ha b. 0.25 – 1.25 g a.i./Ha barriers	Reptile community	Broken Hill, NS Wales, Australia	3 sites within each treated block with 6x5traps	December 2012 – February 2014	Pitfall traps	Slight effect in *Metarhizium* treated areas; communities notaffected more than by seasonalchanges
21-31	a. Fenitrothion b. Fipronil	a. Sumithion b. Regent a. 267 g a.i./Ha b. 1.25 g a.i./Ha	Non-target insects	South-west Queensland, Australia	a. 20 Km^2 b. 4.76 Km^2	1d pre-, 3,7,39,189,414d post-treatment	Yellow trays, Malaise traps,pitfall traps	For both insecticides: Flyinginsects: effect up to 79d Epigeal insects: effect up to 189d
21-32	*Metarhizium acridum*	Green Muscle	Birds	Arlit, Niger	525 Ha	1m after treatment	Daily transect counting, collection of pellets	Increased predation by falconson S. gregaria

21-33	Fipronil	Regent 12 g a.i./Ha	Termites, ants	Northern Senegal	26 treatments, varying sized fields	Number of observations: Pre-treatment 16, post-treatment: 22, January 1995 – January 2000	Pitfall traps, Pearce traps, Berlese traps	Termites reduced by 70%. in 1996; full recovery in 2000 Ants: 40% reduction in 1996; duration 12 months; not fullyrecovered in 1999