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

Report to FAO
by the
Pesticide Referee Group

Tenth meeting

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ABBREVIATIONS

a.i.	active ingredient
CCA	Caucasus and Central Asia
CLCPRO	Commission de lutte contre le criquet pèlerin dans la région occidentale
EFSA	European Food Safety Authority
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
PPE	Personal Protective Equipment
PRG	Pesticide Referee Group
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 Pesticide Referee Group (PRG) is an independent body of experts that advises FAO on the efficacy as well as the health and environmental risks of insecticides used in locust control. The PRG 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; and identifies gaps in knowledge and recommends further studies to be conducted. The PRG 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 PRG has no legal status. All uses of insecticides discussed in this report are fully subject to national legislation, regulation and registration.

3. The 10th meeting of the PRG was opened by Mr Mark Davis, Senior Officer Pesticide Management, and Ms Annie Monard, Senior Officer Locusts and Other Transboundary Plant Pests and Diseases, of the Plant Production and Protection Division of FAO. They noted that there had not been a PRG meeting for a decade, due to various reasons including the lack of new data on biological efficacy of insecticides for locust control. However, the need had been felt for a while to organize a PRG meeting to discuss different aspects of insecticide use in locust control.

4. It was emphasized that FAO had been developing and promoting preventive locust control strategies, which aim to minimize the use of insecticides and favour the application of biopesticides early in the locust population development. However, the use of chemical insecticides will continue to be needed during outbreaks or plagues. At the same time, FAO has been asked by its governing bodies to reduce the risks of pesticides in agriculture, with a particular focus on eliminating the use of highly hazardous pesticides. 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.

5. So far, the PRG has focussed on insecticides used in Desert Locust control. However, given the increasing 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 in Southern Africa – and the large quantities of insecticides used, the PRG was requested to broaden the scope of its advice to such other species, whenever possible.

6. Ms Monard and Mr Davis expressed their gratitude to the participants for making the effort to come at such short notice. They stressed that the advice of the PRG is considered very valuable both by FAO and by its member countries and that PRG recommendations tend to be taken into account in all FAO's locust control programmes.

7. The PRG was informed about recent use of insecticides against locusts. Organophosphates, in particular chlorpyrifos, malathion and fenitrothion, still dominate control operations against Desert Locust and Malagasy Migratory Locust. Pyrethroids, mainly deltamethrin, have been used on a fairly large scale in Desert Locust control; they dominate locust control in CCA (in particular alpha-cypermethrin and deltamethrin). Benzoyl-urea insect growth regulators have only been used on a large scale in Madagascar (in particular teflubenzuron). Fipronil is used much in barrier treatments in Australia, but not in Africa, the Middle East or CCA. The biopesticide *Metarhizium acridum* is used on a moderate scale in Australia but its use in other parts of the world is still very limited.

8. In preparing for this meeting, major pesticide manufacturing and formulating companies had been approached by FAO to obtain new field efficacy trials and environmental impact studies of insecticides for locust control. Of the 12 companies contacted, none provided new biological efficacy data, mainly because no such studies appeared to have been conducted by these companies. Some complementary environmental data were provided by one company.

9. In addition, FAO also contacted a total of 25 national locust control organizations, plant protection services and research institutions in locust-affected countries in Africa, the Middle East, the Caucasus, Central Asia, South-West Asia and Australia. This yielded a considerable number of publicly and privately funded studies on biological efficacy and environmental impact of locust and grasshopper control.

10. Finally, FAO searched a limited number of scientific journals that regularly publishes articles on locust control.

11. In total, 54 reports on biological efficacy or environmental impact were made available to the PRG for review. These are listed in Annex 2. Furthermore, a review of the efficacy of *Metarhizium acridum* against the Desert Locust, published in 2007, was also taken into account by the PRG.

12. The PRG noted with concern the lack of efficacy studies submitted by the pesticide industry, in particular of new insecticides which may be appropriate for locust control. The PRG recommended that FAO re-engage with pesticide industry and initiate a dialogue on how best to test and market new, low risk, insecticides for locust control.

13. During the first day of the meeting, representatives of CropLife International had been invited to discuss insecticide procurement and stock management procedure with the PRG, with the aim to reduce the risk of future accumulation of obsolete pesticides.

14. The members of the Pesticide Referee Group, and other participants in its meeting, are listed in Annex 1. Mr Peter Spurgin was elected Chairman of the present session of the Pesticide Referee Group.

IMPLEMENTATION OF PREVIOUS RECOMMENDATIONS

15. FAO informed the PRG about the implementation of its previous recommendations. Since the ninth session of the PRG, 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/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 PRG 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 PRG. The EMPRES-Western Region Programme, in particular, aims that by the end of 2017 at least 40% of locust targets will be controlled through barrier treatments with Insect growth regulators (IGRs), in those cases where IGRs can be used technically.

17. The PRG had recommended that FAO should use the full list of recommended insecticides in order to make the best choice for purchases, taking into account 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 PRG. It was noted, however, that in some regions the use of low risk insecticides such as IGRs or *Metarhizium* 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 PRG was informed about the new version of eLocust (eLocust3). This field data collection tool, used for Desert Locust survey and control operations, now includes a more extensive module on control and insecticide use. In conjunction with the new version of the RAMSES database, data collection and analysis will be greatly improved. FAO also indicated that a similar initiative on improving data collection had been taken in the Caucasus and Central Asia.

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

EFFICACY OF INSECTICIDES AGAINST LOCUSTS

20. The PRG took note of the fact that the FAO Insecticide Trials Database, which contains all efficacy trials submitted to the PRG since its first meeting, had been updated in 2009 with the studies evaluated during its ninth meeting.

21. The PRG discussed a review conducted by the Laboratory of Entomology at Wageningen University (Van der Valk & Van Huis 2009) of the efficacy of chemical insecticides against the Desert Locust. In the review, 160 efficacy trial reports were evaluated containing 1270 trial plots. All studies were assessed against a set of minimum quality requirements, mainly based on FAO guidelines for efficacy testing of insecticides for locust and grasshopper control. As a result, 60% of the reports, or 55% of the trial plots, were found not to meet these quality criteria. Of the remaining trials, about a quarter were conducted on various migratory locusts and the rest on (Sahelian) grasshoppers.

22. Whenever possible, (minimum) effective doses were estimated using regression analysis. Based on earlier PRG recommendations, adequate control of Desert Locust was defined as 90% mortality or population reduction. For those insecticides for which a (minimum) effective dose could be established using this methodology, it was very similar to the ones established by the PRG.

23. The PRG confirmed that the quality criteria defined in the review should be met in efficacy trials of insecticides for locust control (Annex 3). It expressed its concern that there had been no considerable improvement in the quality of the trials over time, in spite of the availability of relevant FAO guidelines. The PRG 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. The PRG 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).

24. Overall, 30 field efficacy studies had been compiled for review by the PRG (Annex 2). Details of these studies are listed in Annex 4. Four of the studies did not use an appropriate methodology for establishing effective dose rates. Of the remaining 26 studies, 14 did not meet the minimum quality criteria defined in Annex 3. Invariably, this was either because application rates were not measured or could not be deduced from the reported spray parameters, or because no control plots were used when testing slow-acting insecticides. Almost all (11) remaining reports concerned trials with *Metarhizium acridum*[1]. In one trial spinosad, malathion and diflubenzuron were tested; in another control operation fenitrothion and the binary insecticide fenitrothion+esfenvalerate were monitored (Table 1). Eight of the trials were conducted against locust species; the four others against Sahelian grasshoppers. The latter were used as supporting data. In addition to the trial reports listed in Annex 4, a review of the efficacy of *Metarhizium* against the Desert Locust, published since the previous PRG (Van der Valk, 2007), was also taken into account.

Table 1. Efficacy trials meeting the quality criteria in Annex 3 that were evaluated by the PRG.

Insecticide	Target species	Report code
Organophosphate (+pyrethroid)		
Malathion	Moroccan Locust (& mixed grasshoppers)	14-02
Fenitrothion	Red Locust	14-34
Fenitrothion + esfenvalerate	Red Locust	14-34
Benzoyl-urea		
Diflubenzuron	Moroccan Locust (& mixed grasshoppers)	14-02
Micro-organism derived		
Spinosad	Moroccan Locust (& mixed grasshoppers)	14-02
Entomopathogenic fungus		
Metarhizium acridum (IMI 330189)	Desert Locust	14-14, 14-37, R2007* (7 trials)
Metarhizium acridum (IMI 330189)	Red Locust	14-34, 14-38, R2007* (4 trials)
Metarhizium acridum (FI 985)	Migratory Locust	14-41
Metarhizium acridum (IMI 330189)	Malagasy Migratory Locust	14-49, 14-50
Metarhizium acridum (IMI 330189)	Senegalese grasshopper (& mixed grasshoppers) *[supporting data]*	14-10, R2007* (8 trials)
Metarhizium acridum (IMI 330189)	Mixed grasshoppers *[supporting data]*	14-39, 14-40, 14-43

* R2007 = *Metarhizium* review by Van der Valk (2007)

[1] The entomopathogenic fungus *Metarhizium acridum* was previously referred to as *Metarhizium anisolpliae* var. *acridum* (Bischoff JF, Rehner SA & Humber RA. 2009)

25. The only new insecticide submitted was spinosad, which had been tested against Moroccan Locust (Trial 14-02). Unfortunately, this trial was affected by rain and did not allow the establishment of an effective dose rate. Given that the health and environmental risks of spinosad are expected to be limited, the PRG recommended that further trials with this compound be conducted.

26. The use of fenitrothion + esfenvalerate was monitored against Red Locust in Tanzania (report 14-34). While this yielded good operational data, the results were insufficient to set an effective dose rate. Its use against locust swarms was considered interesting because knock-down prevents the swarm from leaving the treated area. The PRG recommended that further trials should be conducted for this specific use pattern. Operational use of this binary insecticide was also reported against Desert Locust from the Central Region. The PRG therefore invited further feedback on its use and possibly new studies on Desert Locust.

27. A considerable number of new studies with *Metarhizium* had been conducted. The trials against the Desert Locust (*Schistocerca gregaria*) confirmed the efficacy of the previously recommended rate of 50 g/ha (2.5 x 10^{12} spores/ha) of the isolate IMI 330189. No new data were made available to the PRG that would support a reduction of this rate against the Desert Locust.

28. Trials had been conducted with *Metarhizium* against Malagasy Migratory Locust (*Locusta migratoria capito*) at rates ranging from 54 to 100 g/ha. The results show that a rate of 50 g/ha (2.5 x 10^{12} spores/ha) of the isolate IMI 330189 would be sufficient to ensure adequate control. Operational monitoring of control of adults of the Migratory Locust (*Locusta migratoria*) in Timor Leste indicated that 50-60 g/ha of isolate FI 985 resulted in adequate control. However, data are insufficient to set a verified dose rate for this particular use.

29. Both efficacy trials and operational monitoring have been conducted with *Metarhizium* (isolate IMI 330189) against nymphs and adults of the Red Locust (*Nomadacris septemfasciata*). Although efficacy levels were variable, a dose rate of 50 g/ha (2.5 x 10^{12} spores/ha) appeared sufficiently robust under most conditions. It may be possible to reduce this rate to 30 g/ha (1.5 x 10^{12} spores/ha) in ideal situations, i.e. lower vegetation densities and/or adult locusts active above the vegetation canopy as low flying swarms which acquire spores through direct contact with the spray droplets.

30. Although the PRG does not establish verified dose rates for grasshopper control, it was noted that a dose rate of 25 g/ha (1.25 x 10^{12} spores/ha) of the isolate IMI 330189 had been shown to be effective against Senegalese grasshopper (*Oedaleus senegalensis*) and mixed populations of Sahelian grasshoppers. Lower rates were tested, but without showing consistent efficacy.

31. In a number of trials, *Metarhizium* had been tested in barrier treatments. The PRG does presently not recommend the use of *Metarhizium* in barrier treatments against the Desert Locust. There are no reliable data to support that barrier treatments with this entomopathogen are effective; primary impaction and secondary pick-up of the spores may be too limited for adequate control. Therefore, higher rates are likely to be needed in barriers, but that would defeat the purpose of bringing control costs down. The PRG noted that *Metarhizium* is targeted specifically at sensitive areas or early infestations during recession/outbreak periods, which are likely to be relatively small. Barrier treatments, on the other hand, tend to aim at large areas for which chemical insecticides, such as IGRs, are considered more appropriate.

32. 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 PRG did not consider that any modifications to this table – compared to the 2004 version – were justified, based on the new efficacy data that were made available at the present session. The recommended dose rates are expected to result in a minimum efficacy of 90% (mortality or population reduction), under most circumstances. In some situations where rapid kill is not essential, lower dosages of some listed insecticides may be effective. However, the final efficacy even of these lower rates should be ≥ 90%.

33. The Wageningen University review (see paragraph 21) established an effective dose rate of chlorpyrifos against Moroccan Locust (*Dociostaurus maroccanus*) of 120 g a.i./ha, which was confirmed by the PRG.

34. Suggested dose rates for other species of locusts are given in Table 3. New insecticide-locust combinations added to this table were *Metarhizium* against Malagasy Migratory Locust and Red Locust, chlorpyrifos against Moroccan Locust and fipronil against Australian Plague Locust.

35. The PRG took note of the fact that the principal company marketing fipronil did not support its use anymore for locust control in Africa and the Middle East. However, the PRG considers there may still be an operational interest in conducting barrier treatments with fipronil against the Desert Locust, with spray swaths at least 700 m apart. Based on experiences in Australia, where irregular barrier 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 PRG therefore recommended that FAO investigate the possibility to conduct large-scale trials of barrier treatments with lower doses of fipronil focussing both on efficacy and environmental impact. In the meantime, the PRG has maintained the verified dose rate for fipronil in barrier treatments in Tables 2 and 3. Blanket treatments with fipronil are not recommended by the PRG.

36. 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. The 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 sufficient product is ingested and accumulated, the PRG reaffirmed that when using the benzoylureas the early and intermediate hopper instars should be optimally targeted, although later instars are also affected. Reports indicate that IGRs can adversely affect adult locusts by reducing fecundity and fertility. Such products are particularly suitable for a proactive role within the confines of the locust outbreak area where barrier treatments are advisable. Further special considerations for insecticide groups are given in Annex 5.

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

Insecticide	**Class**	**Dose rate** (g a.i./ha) [1]				**Speed of action** at verified dose rate [3]	**Primary mode of action**
		Blanket treatment		**Barrier treatment** (hoppers) [2]			
		Hoppers	Adults	Intra-barrier	Overall		
Bendiocarb	CA	100	100			F	AChE inhibition
Chlorpyrifos	OP	240	240			M	AChE inhibition
Deltamethrin	PY	12.5 or 17.5 [4]	12.5 or 17.5 [4]			F	Na channel blocking
Diflubenzuron	BU	30	n.a.	100 [5]	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 anisopliae (IMI 330189)	fungus	50	50			S	Mycosis
Teflubenzuron	BU	30	n.a.	n.d.		S	Chitin synthesis inhibition
Triflumuron	BU	25	n.a.	75 [5]	10.7	S	Chitin synthesis inhibition

Abbreviations: BU: benzoylurea, CA: carbamate, OP: organophosphate, PY: pyrethroid, PP: phenyl pyrazole; n.a. = not applicable; n.d. = not determined;

Notes: [1] Application volumes for the recommended dose rates differ depending on the formulation available.

[2] 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.

[3] Speed of toxic action: F = fast (1-2 hours), M = moderate (3-48 hours) and S = slow (> 48 hours).

[4] The higher dose rate may be required if there is a risk of recovery of late instars or at high temperatures.

[5] Blanket spray data and observations for other locusts suggest that effective dose rates for Desert Locust barrier treatments may be further reduced;

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

Insecticide	Class	Species	Dose rate (g a.i./ha) [1]				Speed of action at verified dose rate [3]	Remarks
			Blanket treatment		Barrier treatment (hoppers) [2]			
			Hoppers	Adults	Intra-barrier	Overall		
Chlorpyrifos	OP	LMC	240	240			M	
		DMA	120	120				
Chlorpyrifos + cypermethrin	OP + PY	LMC	120 + 14	120 + 14			F	
α-Cypermethrin	PY	CIT, DMA, LMI	15	15			F	
Deltamethrin	PY	LMC	15	15			F	
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 [4]	1.1	M	Barrier spacing 700-1000 m
		CTE			1.0	0.33	M	Track spacing of 300 m (irregular blanket spray)
Metarhizium anisopliae (IMI 330189)	fungus	LMC	50	50			S	
		NSE	50 [5]	50 [5]				
Teflubenzuron	BU	LMC			50	10	S	Barrier spacing 500-700 m
		CIT, DMA, LMI	9	n.a.	18	9		Barrier ratio treated:untreated = 1:1 (irregular blanket spray)
Thiamethoxam + λ-cyhalothrin	NN + PY	CIT, DMA, LMI	14.1 + 10.6	14.1 + 10.6				

Insecticide	**Class**	**Species**	**Dose rate** (g a.i./ha) [1]				**Speed of action** at verified dose rate [3]	**Remarks**
			Blanket treatment		**Barrier treatment** (hoppers) [2]			
			Hoppers	Adults	Intra-barrier	Overall		
Triflumuron	BU	LMC			50	10	S	Barrier spacing 500-700 m

Abbreviations:

BU: benzoylurea, CA: carbamate, NN: neonicotinoid, OP: organophosphate, PY: pyrethroid, PP: phenyl pyrazole; n.a. = not applicable.

CIT = *Calliptamus italicus*, CTE = *Chortoicetes terminifera,* DMA = *Dociostaurus maroccanus,* LMC = *Locusta migratoria capito,* LMI = *Locusta migratoria,* NSE = *Nomadacris septemfasciata*

Notes:

[1] Application volumes for the recommended dose rates differ depending on the formulation available.

[2] Calculated dose rate applied over the total target area based on the listed ratio treated:untreated

[3] Speed of toxic action: F = fast (1-2 hours), M = moderate (3-48 hours) and S = slow (> 48 hours).

[4] A lower dose rate is likely to be possible but requires confirmation.

[5] A reduction to 30 g/ha may be possible under ideal conditions.

37. Insecticides other than those listed in Tables 2 and 3 have been used against locusts and grasshoppers but insufficient data are available to the PRG to determine reliable effective dose rates. FAO should continue to encourage plant protection organisations, manufacturers, and any other institutions to submit data on new or existing products for review. This should include data from laboratory studies and field trials. In particular data from operational use of insecticides should be provided to FAO.

APPLICATION CRITERIA

38. The PRG 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 when calibration is accurate and vegetation is not too dense, a lower rate of down to 0.5 litres per hectare is acceptable if aerially applied over large areas. Such low volumes necessitate a narrow droplet spectrum to reduce waste of insecticide in large droplets, and 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 per hectare) may be more effective in very dense vegetation, e.g. as often encountered in Red Locust habitats.

39. 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 hot climates. They may be used only if the targets are too small for drift spraying, for example when treating small and discrete patches of locusts, using manually operated knapsack sprayers.

40. The PRG acknowledged that, for various reasons, water-based formulations are being used against locusts on a larger scale 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. The progressive move towards ULV application, which started with the FAO regional programme in 2011, should however be continued.

41. The application of *Metarhizium* requires specific capability with respect to storage of the spores, mixing of the spray formulation, monitoring of efficacy and cleaning of equipment. While not overly complicated, the PRG recommends that spray teams applying *Metarhizium* are specially trained and supervised to ensure optimal efficacy of this biopesticide.

42. In addition to overall blanket sprays, certain insecticides are also considered efficacious as barrier treatments for control of locust hoppers. A barrier consists of a treated strip interspersed with an 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:

    a) mobility of the hoppers

    b) insecticide used (persistence)

    c) terrain/vegetation (plant density)

d) wind speed and direction during application

e) height of application

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

43. 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 swath width of up to 100 m and track spacing of 500-700 m can be recommended. Indications exist that 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 the hoppers can detoxify and excrete insecticides recommended for barrier treatment.

44. 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.

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

HUMAN HEALTH RISKS

46. The PRG has always classified the insecticides which have a verified dose rate against the Desert Locust according to the *WHO Recommended classification of pesticides by hazard.* WHO published a new version of its classification in 2009 (WHO, 2009), with slightly amended classification criteria compared to the one used in the previous PRG session.

47. The PRG endorsed the way in which the hazard classifications it defines are used by FAO to recommend what type of operator is allowed 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).

48. The PRG discussed the *Globally Harmonized System of Classification and Labelling of Chemicals* (GHS) (UNECE, 2013), which is increasingly becoming the international standard for classification of pesticides. The GHS and the WHO classifications are similar, but not identical, with respect to acute toxicity. The GHS includes several health aspects which are not covered by the WHO classification. The PRG considered that those other health aspects, as far as relevant to locust control, should be included in the hazard evaluations of locust control insecticides.

49. An updated health classification system for insecticide formulation for locust control was proposed for use by the PRG, taking into account both on the 2009 version of the WHO Classification (for acute oral and dermal toxicity) and the GHS (for other health hazards). The criteria used to classify insecticides for locust control are provided in Annex 6. The PRG underlined that in principle insecticide formulations and not the active ingredients should be

classified, as commercial formulations may contain co-formulants which may cause adverse health effects. However, when data on the formulation are not (sufficiently) available, classifications will be extrapolated based on the a.i. alone. The PRG welcomes comments and suggestions regarding the updated classification system for health hazards of locust control insecticides.

50. All the insecticides with a verified dose rate against the Desert Locust (Table 2) were re-evaluated against the updated criteria of Annex 6. The main source for the toxicity endpoints used in this re-evaluation was the European Union Pesticides Database. The results are shown in Table 4.

51. In most cases, this did not lead to a change in operator code for locust control and its associated availability and use restrictions. However, the malathion formulation used in locust control was now evaluated as being a Skin Sensitizer Category 1. This lead to a change from the previous Operator Code B ("use by trained operators") to the new classification as Operator Code A ("use by trained and supervised operators").

52. The PRG 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 PRG 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.

53. The PRG 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 the 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 only be called for if occupational exposure would lead to unacceptable risk.

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

55. The PRG discussed a summary of preliminary results of the monitoring of blood cholinesterase inhibition in locust control personnel, indicative of exposure to organophosphate insecticides, which had been conducted in various countries. It noted the large variability in the results of these monitoring exercises, some suggesting over-exposure of staff while others appear to indicate only limited acute health risks. The PRG recommended that the health monitoring data collected so far be evaluated in detail, including the extensive dataset available in Australia. Results of this evaluation can be used to identify key factors affecting exposure to insecticides (e.g. insecticides, PPE, control practices, training, equipment) as well as best practices.

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

Insecticide	**Highest likely formulation concentration** (g a.i./L)	**LD_{50} of the a.i.** Oral [1] (mg/kg bw)	Dermal [2] (mg/kg bw)	Inhalation [2] (mg/L)	**WHO Hazard Class of the formulation** [3] Acute oral	Acute dermal	**GHS Hazard Category of the formulation** [3] Acute inhalation	**GHS Hazard Category of the formulation for other health aspects** [4]	**Locust control Operator Code**
Bendiocarb	200	55	566	0.55	II	III	3		**A**
Chlorpyrifos	450	135	>1250	>1.0	II	III	3		**A**
Deltamethrin	25	135	>2000	0.6	U	U	Unclassified [5]		**C**
Diflubenzuron	60	>4640	>2000	>2.5	U	U	Unclassified		**C**
Fenitrothion	1000	503	890	2.2	II	II	3		**A**
Fipronil	7.5	92	354	0.36	U	U	Unclassified	(STOT RE 1 [6])	**C**
Lambda-cyhalothrin	40	56	632	0.06	II	U	4		**A**
Malathion	960	2100	>2000	>5	III	III	5	Skin Sensitization 1	**A**
Teflubenzuron	50	>5000	>2000	>5	U	U	Unclassified		**C**
Triflumuron	50	>5000	>5000	>5	U	U	Unclassified		**C**

1. Data from the WHO Recommended classification of pesticides by hazard (2009).
2. Data from the EU Pesticides Database (http://ec.europa.eu/sanco_pesticides/public – Endpoint List in EU Review Report or EFSA Conclusion), if available; otherwise from the IUPAC Footprint database. (http://sitem.herts.ac.uk/aeru/iupac/index.htm) [last accessed 25 Jan 2015]
3. Calculated on the basis of the LD_{50} of a.i. and the highest likely formulation concentration.
4. Data from the EU Pesticides Database (http://ec.europa.eu/sanco_pesticides/public) [last accessed 22 Nov 2014]. Note: The EU applies the GHS classification.
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 12.5 mg/L.
6. STOT RE = Specific target organ toxicity following repeated exposure. The active substance of fipronil is classified as STOT RE - Cat. 1. However, the highest UL formulation concentration considered by the PRG is 7.5 g/L, which is below the cut-off value of 1% used by the GHS to trigger the classification of mixtures. Therefore fipronil formulations for locust control ≤ 7.5 g/L are not classified for this health aspect.

56. The PRG 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 or carbamate insecticides are used, blood cholinesterase 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. To be able to properly interpret the results of such health monitoring, the PRG supported the idea to collect individual insecticide use records of all pesticide applicators.

ENVIRONMENTAL EVALUATION

57. 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 and the emerging strategy of the Sustainable Development Goals (SDGs), the PRG 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 a specific Environmental and Social Standard on Pest and Pesticide Management will apply to all projects and activities where pesticide procurement supply and use is supported (FAO, 2014). This would apply to all locust control operations.

58. Table 6 provides an indication of the environmental risk (low, medium or high), as assessed by the PRG, based on information obtained from appropriate field or laboratory studies. The PRG 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.

59. Data on environmental hazard or risk submitted for review by the PRG must be relevant for the area of application. The PRG evaluates each environmental study against the quality criteria defined in Annex 3 (environmental field studies) and Annex 7 (environmental laboratory and semi-field studies). Only studies meeting these criteria have been included in the evaluation.

60. 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 cover bees, natural enemies (antagonists) of locusts and other pests, and ecologically important soil insects (e.g., ants and termites). The PRG 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 may be of concern and require a specific risk assessment, as do multiple treatments within the same area and season.

61. The risk classifications applied by the PRG 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.

62. 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 results of 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 risk of direct over-spraying. For some insecticides, toxicity data were available for marsupials, a group that had not been studied previously. The PRG recognises the great importance of such data for the risk assessment of the insecticides in the ecological areas where these animals occur.

63. For classification of risks to honey bees, the widely accepted ”hazard ratio“ is used, which is defined as the recommended dose rate (g a.i. per ha) divided by the LD_{50} (µg a.i. per bee). Low risk to bees corresponds to a hazard ratio <50; high risk to a hazard ratio of >50. The risk to bee colonies (adults and brood) is derived from (semi-)field test data. 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.

64. In this session of PRG a total of 26 environmental studies were reviewed, of which 16 were field studies or observations. Three studies were reported in more than one report, while one did not meet the quality criteria for ecotoxicological field studies as presented in Annex 3. In addition, 10 laboratory-based and semi-field toxicity studies were reviewed, one of which was recorded twice and three did not meet the quality criteria in Annex 7 (i.e. Klimisch score 1 or 2). Therefore, 12 field studies and 6 toxicity studies were retained for the evaluation, details of which are shown in Annex 8 and 9.

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

66. The evaluation of environmental data in this session of the PRG resulted in a reclassification of two compounds: both deltamethrin and lambda-cyhalothrin were reclassified for risks to bees. The hazard quotient for these compounds with respect to acute contact toxicity to adult bees being >50, both are now classified as highly toxic to bees ('H'). No other change in environmental risk classification was made.

67. 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 in other types of ecosystems has not been explicitly evaluated. However, given the similarities in application rates, the PRG considers the environmental risks summarized in Table 6 also to be indicative of insecticide use against other locust species. Countries are encouraged, nonetheless, to conduct their own, locally specific, environmental risk assessments.

68. 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.

69. 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. The PRG regretted that only few reports were submitted on the environmental impact of barrier treatments.

70. The PRG 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 database.

71. In 2003, FAO published the 6th Volume of the Desert Locust Guidelines – Safety and Environmental Precautions. The guidelines address major environmental and human health risks related to Desert Locust control and give guidance on risk reduction procedures and approaches for operational health and environmental monitoring. Since the publication of these guidelines, considerable experience has been gained with many of the issues covered in the guidelines and some described techniques and recommendations may need to be reviewed. Furthermore, certain risk reduction advice for other locust species may be different from the Desert Locust. The PRG therefore recommended that FAO assess the possibility to update this volume of the guidelines.

INSECTICIDE SELECTION

72. 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. 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.

73. The PRG noted that locust control campaigns had relied heavily on organophosphate insecticides presumably due to availability and relatively low purchase cost without consideration of the external costs such as the removal of obsolete stocks. In view of international concerns about the use of 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 that has to be controlled. To give more guidance to locust affected countries, the insecticides with verified dose rates against the Desert Locust are presented as a priority list in Table7.

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]
Aquatic arthropods	Risk ratio (PEC/LC_{50})	<1	1-10	>10	FAO/Locustox
Reptiles, birds, mammals	Risk ratio (PEC/LD_{50}[3])	<0.01	0.01-0.1	0.1	EPPO[5]
Bees	Risk ratio (recommended dose rate/LD_{50})	<50	-	>50	PRG[6]/EFSA[7]
Other terrestrial arthropods	Acute toxicity (%) at recommended dose rate	<50%	50-99%	>99%	IOBC[8]
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	PRG
Aquatic arthropods	Population reduction	<50%	50-90%	>90%	PRG
Reptiles, birds, mammals	Evidence of mortality	none	incidental	massive	PRG
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); [6] PRG: Pesticide Referee Group; [7] EFSA (2012); [8] International Organization for Biological and Integrated Control of Noxious Animals and Plants (Hassan, 1994).

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
Bendiocarb	M [2]	L [3]	M [1]	L [3]	–	H [1]	H [3]	M [3]
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]	L [1]	L [1]	–	L [1 ϕ]	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]	L [1]	L [1]	–	H [1]	M [3]	H [3]
Malathion	L [2]	M [2]	L [3]	L [3]	–	H [3]	H [3]	H [3]
Metarhizium anisopliae (IMI 330189)	L [2]	L [2]	L [1]	L [1]	L [2]	L [3]	L [3]	L [3]
Teflubenzuron (blanket)	L [1]	H [2]	L [1]	L [1]	–	L [1 ‡]	M [1]	–
Triflumuron (blanket)	L [1]	H [2]	L [1]	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).

* 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% 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. Risk classes are therefore 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 honey bee. [‡] Benzoylureas are generally safe to adult worker bees but some may cause damage to the brood of exposed colonies; – insufficient data.

74. Thus application of *Metarhizium acridum* should be considered to be the most appropriate control option, especially in riparian and similar sensitive habitats, despite its higher costs. It has the additional advantage in that there is no problem associated with the disposal of stocks which are no longer viable for field use. Secondly priority should be given to IGRs and the neurotoxic insecticides only to 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 limited operational use. While the speed of action is slow compared with neurotoxic insecticides, it has the beneficial effect of being very low risk to non-target organisms, including birds and reptiles which ingest the treated locusts.
Priority 2	Insect Growth Regulators – diflubenzuron; teflubenzuron; triflumuron	Very low human toxicity (Table 4). These compounds are considerably less hazardous to use compared with neurotoxic insecticides, although there are some adverse effects on certain non-target organisms, especially aquatic arthropods. IGRs are particularly recommended for applications aimed at locust 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 (<10g/l) has been shown to be effective at doses of < 1.0 gram a.i./ha against hoppers.
	B) Pyrethroids – deltamethrin, lambda-cyhalothrin	Deltamethrin: Low human toxicity (Table 4). This insecticide used in a UL formulation (< 30g/l) has been shown to be very effective against adults and hoppers at 12.5 – 17.5g/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 20g/ha against adults and hoppers.
	C) Carbamates – bendiocarb	Moderate human toxicity (Table 4). Although this insecticide has not been used much in operational control programmes, studies have shown it is effective against locusts in formulations containing 200g/l at 100g a.i./ha against adults and hoppers.
	D) Organophosphates – malathion, fenitrothion, chlorpyrifos	These insecticides may be used as a last resort when rapid control is needed to protect agricultural 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 (925g/l) and has been used extensively against (adult) locusts at ~925g/ha). Fenitrothion: Moderate human toxicity. This insecticide has been extensively used at 400g/ha against adults and hoppers. Chlorpyrifos: Moderate human toxicity. This insecticide has been extensively used at 240g/ha against adults and hoppers.

INSECTICIDE PROCUREMENT AND STOCK MANAGEMENT

75. Since the 2003-2004 Desert Locust outbreak, significant progress has been made in managing pesticide stocks. The Pesticide Stock Management System (PSMS) has been deployed in all Desert Locust affected countries. All locust control pesticide stocks have been inventoried and recorded in PSMS. This has allowed pesticides close to their expiry date to be sampled and analyzed for compliance with their original specification. As a result, the usability of many pesticides has been extended over several years and prevented them from being considered obsolete. In addition, PSMS, stock control and quality control have allowed excess pesticides in one country to be 'triangulated' to another country where a need has arisen. This has reduced pesticide stocks in countries where they might have become obsolete over time, and saved the cost of procurement of new pesticides in several cases as well as allowing rapid delivery of the pesticides. It is noted that the cost of transporting pesticides by air is high.

76. Nevertheless, despite all efforts, new obsolete pesticides have been created in most Desert Locust affected countries. New funds will need to be secured to dispose of these obsolete pesticides safely. In the interests of sustainability, the PRG stressed that countries should take responsibility for preventing the creation of obsolete pesticide stocks and also for disposal of those stocks when they are created [2]. Donors should comply with good practice 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. WHO informed that their international guidelines for donations of medicines and medical equipment might also provide useful elements (WHO, 2011a, b).

77. The PRG emphasized that future provision of pesticides for locust control should:

- consider alternative supply mechanisms that are designed to prevent overstocking and obsolescence;
- use improved stock and quality control systems to reduce obsolescence;
- ensure effective coordination among donors to prevent oversupply and inappropriate supply of pesticides;
- be based on needs assessments using high quality forecasting data such as that generated by EMPRES.

78. Discussions with representatives of CropLife International resulted in a recommendation on the part of the PRG that a workshop should be organized within six months, to which a broad range of stakeholders should be invited to discuss mechanisms for the timely provision of locust control solutions.

79. In view of developments in the forecasting of locust outbreaks, FAO, in collaboration with Commissions and donors, should consider developing a system to determine the phasing of procurement of insecticides to manage stocks available in locust affected countries and avoid the presence of large stocks that become obsolete and require disposal at high cost. Emphasis should continue to be placed on relocation of unused stocks by the process of triangulation to other locusts affected countries, where possible.

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

INSECTICIDE FORMULATION QUALITY

80. The PRG stressed that only products with established 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 PRG 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. So for optimal reliability and acceptable risk, company-dependent product specifications should be available for all active ingredients for which the PRG recommends a dose rate.

81. FAO now 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 that was registered in the recipient country. The compliance must be certified by an independent accredited laboratory.

82. The PRG noted that JMPS specifications do not yet exist for several of the insecticides listed for use in locust control by the PRG. The PRG therefore encourages pesticide industry to submit requests for such specifications to FAO/WHO Joint Meeting on Specifications (JMPS).

83. The PRG discussed problems encountered with the compatibility of certain UL formulations of IGRs with spray equipment, leading to severe damage to aircraft spray tanks. It underlined that most aircraft spray tanks are intended for high volume, water-based pesticides and may not resist solvents in more concentrated UL formulations. The PRG therefore recommended that in the procurement of UL formulations the supplier should indicate all solvents in the formulation and should certify that they do not affect the spray equipment used in locust control.

84. Furthermore, the PRG recommended that a meeting be organized between spray equipment manufacturers and pesticide manufacturers to identify solvents that must be avoided in UL formulations for locust control.

85. The PRG took note of recent field reports indicating that the metal drums in which UL formulations had been supplied had not always been of sufficient quality, which has led to breakage, insecticide loss, and environmental contamination. As a result, FAO reviewed the technical requirements of pesticide drums for locust control and recommends reinforced steel drums meeting international standards. The PRG stressed that UN requirements for pesticide packaging, as specified under the UN Recommendations for the Transport of Dangerous Goods, should always be met when purchasing and transporting insecticides for locust control.

WAITING PERIODS

86. The PRG discussed the lack of appropriate livestock withholding periods, re-entry periods for persons, and pre-harvest intervals, for locust control with UL insecticides. In spite of the fact that 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 such waiting periods specifically for locust control, with the notable exception of Australia. Pesticide manufacturers often do not indicate waiting periods on the labels of locust control insecticides, and if they do, the recommendations are generally based on residue data for

different formulations, crops, uses or regions. Those may not necessarily be relevant to the conditions encountered in locust control.

87. The PRG stressed that establishing waiting periods is the final responsibility of national or regional pesticide registration authorities. However, it also recognized that FAO has much experience in pesticide residue evaluation, in particular through the FAO/WHO Joint Meeting on Pesticide Residues. The PRG therefore recommended that a review be conducted by FAO on available data on withholding periods, re-entry intervals and pre-harvest intervals for the insecticides used in locust control, including data that may be extrapolated to locust control insecticide formulations and use conditions. The PRG suggested that FAO assess whether provisional waiting periods can be proposed on the basis of existing information and identify gaps in knowledge.

TRAINING

88. The PRG discussed the great importance of training and capacity building of all staff to ensure that locust control is effective and does not pose undue risks to human health and the environment. The PRG recommended that countries and FAO maintain their emphasis on, and where possible further strengthen, training in good locust control practices. The PRG also 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

89. The PRG welcomed the fact that various reports it received concerned operational monitoring of locust control. The PRG stressed the importance of monitoring the efficacy of locust control operations, because the recommendations of effective dose rates tend to be based mostly on controlled field trials. Feedback on the efficacy of insecticides against locusts under operational conditions was considered essential to assess the robustness of the dose recommendations. The PRG therefore reiterated its previous recommendation that locust control organizations conduct operational monitoring of the efficacy of locust control and report the results to FAO.

90. As pointed out previously, in view of the difficulty in quantifying the level of control achieved due to the mobility of locusts, attention should be given to appoint specially 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 any 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 demarcated by using global positioning systems (GPS) and the information stored in a geographical information system.

RECOMMENDATIONS

91. The Pesticide Referee Group made the following recommendations:

- ▷ In view of the lack of efficacy studies submitted pesticide industry, in particular of new insecticides which may be appropriate for locust control, the PRG recommended that FAO re-engage with pesticide industry and initiate a dialogue on how best to test and market new, low risk, insecticides for locust control.

- ▷ The PRG 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 and therefore recommended that FAO continues to actively disseminate the various guidelines for efficacy testing of insecticides for locust and grasshopper control.

- ▷ Given operational and/or environmental and human health interests, the PRG recommended that further efficacy trials with spinosad and with fenitrothion + esfenvalerate be conducted. Furthermore, the PRG recommended that FAO investigates the possibility to conduct large-scale trials of barrier treatments with fipronil at lower dose rates than currently recommended, focussing both on efficacy and environmental impact.

- ▷ The PRG recommended that FAO should continue to encourage plant protection organisations, manufacturers, and any other institutions to submit efficacy data on new or existing products for review.

- ▷ To be able to ensure correct application and precise recording of the aerial control operations, the PRG strongly recommended that all aircraft involved in locust control come equipped with a (D)GPS-based track-guiding and logging system as well as an on-board flow meter. In addition, application tracking using a GPS should also be used in ground treatments.

- ▷ The PRG recommended that FAO, in collaboration with WHO, conduct studies on occupational exposure to insecticides in locust control.

- ▷ The PRG underlined the great importance of regular health monitoring of locust control staff and recommended that locust control organizations ensure that medical examinations are done of all staff before, during and after control campaigns, irrespective of the types of insecticides used. When organophosphate or carbamate insecticides are used, blood cholinesterase inhibition monitoring of should always be conducted. To be able to properly interpret the results of such health monitoring, the PRG supported the idea to collect individual insecticide use records of all pesticide applicators.

- ▷ With the aim to identify key factors affecting exposure to insecticides as well as best practices, the PRG recommended that the health monitoring data of locust control collected so far be evaluated in detail, including the extensive dataset available in Australia.

- ▷ In view of improving the quality environmental impact field studies in locust control, the PRG recommended that FAO elaborates guidance for such studies.

- ▷ The PRG recommended that FAO assesses the possibility to update the Desert Locust Guidelines – Safety and Environmental Precautions, with the aim 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.

- ▷ In view of international concerns about the use of insecticides and the absence of new products evaluated for locust control, The PRG underlined that in selecting insecticides for locust control priority should always be given to the least toxic compound with regard to human health and environmental impact, provided it is effective against the locust target that has to be controlled.

- ▷ The PRG stressed that countries should take responsibility for preventing the creation of obsolete pesticide stocks and also for disposal of those stocks when they are created. It further emphasized that donors should comply with good practice such as the OECD DAC Guidelines on Pest and Pesticide Management, and recipient countries should be in a position to refuse unsolicited donations of pesticides, or donations of inappropriate pesticides.

- ▷ The PRG emphasized that future provision of pesticides for locust control should:
  - consider alternative supply mechanisms that are designed to prevent overstocking and obsolescence;
  - use improved stock and quality control systems to reduce obsolescence;
  - ensure effective coordination among donors to prevent oversupply and inappropriate supply of pesticides;
  - be based on needs assessments using high quality forecasting data such as that generated by EMPRES.

- ▷ The PRG recommended that a workshop be organized within six months, to which a broad range of stakeholders should be invited to discuss mechanisms for the timely provision of locust control solutions.

- ▷ Since JMPS specifications do not yet exist for several of the insecticides listed for use in locust control, the PRG encouraged pesticide industry to submit requests for such specifications to FAO/WHO Joint Meeting on Specifications (JMPS).

- ▷ To avoid damage to spray equipment by UL insecticide formulations, the PRG recommended that in the procurement of insecticides the supplier should indicate all solvents in the formulation and should certify that they do not affect the spray equipment used in locust control. Furthermore, the PRG recommended that a meeting be organized between spray equipment manufacturers and pesticide manufacturers to identify solvents that must be avoided in UL formulations for locust control.

- ▷ With the aim to propose provisional withholding periods, re-entry intervals and pre-harvest intervals for the insecticides used in locust control, the PRG recommended that FAO conduct a review on available data on such waiting periods, including data that may be extrapolated to locust control insecticide formulations and use conditions.

- ▷ 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 PRG recommended that countries and FAO maintain their emphasis on, and where possible further strengthen, training in good locust control practices.

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Annex 2 – Studies on insecticide efficacy and environmental impact reviewed by the PRG

The efficacy reports (EF) listed in this annex refer field or semi-field trials (e.g. field enclosures); laboratory experiments for efficacy against locusts and grasshoppers are not included.

The environmental impact reports (EN) listed may, however, 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**	**Study type** [3]
14-01	Centre National de Lutte Antiacridienne & Direction de la Protection des Végétaux, des Contrôles Techniques et de la Répression des Fraudes (Morocco)	2004	MOUHIM Ahmed, CHIHRANE Jamal & AFRAS Ahmed	Impact des insecticides utilisés en lutte antiacridienne [Chlorpyriphos (Dursban 240 UBV) et Malathion 96 UBV] sur l'environnement : Etude des effets sur le Criquet pèlerin et la faune non cible.	Chlopryrifos Malathion	EF, EN
14-02	Centre National de Lutte Antiacridienne (Morocco)	2007	CNLAA	Evaluation des effets de trois doses de spinosad R 125 g/l ULV (12, 25 et 45 g.m.a/ha) sur le Criquet marocain et les criquets sédentaires dans la région d'Imi N'Tanout, Maroc	Spinosad Diflubenzuron Malathion	EF, EN
14-03	Université Gaston Berger & Service de la Protection des Végétaux (Niger)	2013	BAL Amadou Bocar & SIDATI Sidi Mohamed	Réduction des doses efficaces d'insecticides contre les larves de criquet pèlerin (*Schistocerca gregaria* Forskål, 1775 : Orthoptera, Acrididae) par utilisation de quantités réduites de phénylacétonitrile *Biotechnol. Agron. Soc. Environ.* 17(4): 572-579	Phenyl-acetonitrile (PAN) Lambda-cyhalothrin Malathion Chlorpyrifos	EF
14-04	Oklahoma State University (USA)	2004	AMARASEKARE Kaushalya G & EDELSON JV	Effect of temperature on efficacy of insecticides to differential grasshopper (Orthoptera: Acrididae) *J. Econ. Entomol.* 97(5): 1595-1602	Diflubenzuron Azadirachtin *Beauveria bassiana* Spinosad Endosulfan Esfenvalerate Naled	EF

[3] EF = Efficacy study; EN = Environmental impact study

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides	Study type [3]
14-05	National Research Center, & Al- Azhar University (Egypt)	2013	SHARABY Aziza, GESRAHA Mohamed A, MONTASSER Sayed A, MAHMOUD Youssef A, IBRAHIM Sobhi A.	Combined effect of some bio-agents against the grasshopper, Hetiracris littoralis under semi-field condition IOSR Journal of Agriculture and Veterinary Science 3(5): 29-37	*Euphorbia pulcharrima* (extract) *Allium sativum* (garlic) (essential oil) *Steinernima carpocapsae* (nematode) *Heterorhabditis bacteriophora* (nematode)	EF
14-06	China Agricultural University (China)	2012	GUO Yanyan, AN Zhao & SHI Wangpeng	Control of grasshoppers by combined application of *Paranosema locustae* and an Insect Growth Regulator (IGR) (Cascade) in Rangelands in China *J. Econ. Entomol.* 105(6): 1915-1920	*Paranosema locustae* Flufenoxuron Malathion	EF
14-07	AGRIVET & Direction de la Protection des Végétaux (Madagascar)	2014	RAMANGASON Honoré Mamitiana	Test d'efficacité du produit WOPRO-TEFLUBENZURON 50G/L ULV de la société AGRIVET/SIMONI qui est un dérégulateur de croissance des insectes (IGR) sur des bandes larvaires du criquet migrateur : *Locusta migratoria capito* en traitement en barrières.	Teflubenzuron (2 commercial formulations)	EF
14-08	Centre National de Lutte Antiacridienne (Mauritania)	2007	BARRY Adama Abdoulahi	Rapport de mission – période du 30 novembre au 10 décembre 2007 (Efficacité de Green Muscle contre les larves dans les conditions normales et sous les paramètres opérationnels)	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-09	Centre National de Lutte Antiacridienne (Mauritania)	2008	BARRY Adama Abdoulahi	Rapport de mission – période du 24 mars au 2 avril 2008 (Efficacité de Green Muscle contre les larves dans les conditions normales et sous les paramètres opérationnels)	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-10	Institut Agronomique et Vétérinaire Hassan II (Thesis) (Senegal) *(= study 14-31*)	2009	GUEYE Youssoupha	Etude de l'efficacité d'un micopesticide (Green Muscle R) OF vis-à-vis d'une population acridienne et des auxiliaires naturels au centre du Sénégal	*Metarhizium acridum* (not in FAO 2007 review)	EF, EN
14-11	Institut Agronomique et Vétérinaire Hassan II (Thesis) (Niger)	2010	DAOUDA Issaka	Comparaison des effets de trois doses de *Metarhizium anisopliae* var. *acridu*m sur les larves du troisième stade du Criquet pèlerin (*Schistocerca gregaria* Forskal, 1775) en milieu semi-naturel et au laboratoire	Metarhizium acridum Chlorpyrifos (not in FAO 2007 review)	EF

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides	Study type [3]
14-12	Institut Agronomique et Vétérinaire Hassan II (Thesis) (Morocco)	2010	IDRISSA Mamadou	Etude de la vulnérabilité du Criquet pèlerin (*Schistocerca gregaria.* Forskål, 1775) aux effets de *Metarhizium anisopliae var acridum* dans les conditions semi-naturelles	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-13	Fondation Agir pour l'Education et la Santé & Direction de l'Agriculture & Centre National de Lutte Antiacridienne (Mauritanie)	2010	MULLIÉ Wim C, OULD MOHAMED Sid'Ahmed, BARRY Adama, ETHEIMINE Mohamed, OULD ELY Sidi, KOOYMAN Christiaan	Traitement en barrière avec Green Musche® (*Metarhizium acridum*) : Exposition expérimentale des nymphes de *Schistocerca gregaria* et comparaison avec un traitement en couverture totale	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-14	Centre National de Lutte Antiacridienne (Mauritania) *(= study 14-15)*	2011	OULD MOHAMED Sid'Ahmed, OULD ELY Sidi et OULD ABDELFETAH Nourdine	Traitement en barrière avec Green Muscle® (*Metarhizium acridum*) sur des taches larvaires du Criquet pèlerin (*Schistocerca gregaria*), Mauritanie	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-15	Institut Agronomique et Vétérinaire Hassan II (Thesis) (Mauritania) *(= study 14-14)*	2011	ABDEL VETAH Nourdine	Evaluation de l'efficacité et de la rémanence d'un traitement en barrière par *Metarhizium anisopliae* var. *acridum* (Green Muscle ®) contre les tâches larvaires du Criquet pèlerin dans les conditions naturelles en Mauritanie.	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-16	Centre National de Lutte Antiacridienne, University of Khartoum, Université Hassan 1er (Sudan)	2014	OULD ATHEIMINE Mohamed, BASHIR Magzoub Omer, OULD ELY Sidi, KANE Cherif Mohamed Habib, OULD MOHAMED Sid'Ahmed, OULD BABAH Mohamed Abdallahi & BENCHEKROUN Mounsif	Efficacy and persistence of *Metarhizium acridum* (Hypocreales: Clavicipitaceae) used against desert locust larvae, *Schistocerca gregaria* (Orthoptera: Acrididae), under different vegetation cover types *International Journal of Tropical Insect Science* **34(2):** 106–114	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-17	Institut Agronomique et Vétérinaire Hassan II (Thesis) (Morocco)	2003	IDRISSI RAJI Lahcen	Etude de l'impact du Malathion et de la Deltamethrine (en formulation Ultra Bas Volume UBV/ULV) sur l'abeille domestique, *Apis mellifera* L., dans les conditions semi-naturelles	Malathion Deltamethrin	EN
14-18	Universität Basel & Centre de Lutte Antiacridienne (Mauritania)	2003	PEVELING Ralf & DEMBA Sy Amadou	Toxicity and pathogenicity of *Metarhizium anisopliae* var. *acridum* (Deuteromycotina, Hyphomycetes) and fipronil on the fringe-toed lizard *Acanthodactylus dumerlii* (Squamata, Lacertidae) *Environmental Toxicology and Chemistry* 22(7): 1437–1447	*Metarhizium acridum* Fipronil	EN

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides	Study type [3]
14-19	University of Wollongong & Texas Tech University (Australia)	2004	BAIN David, BUTTEMER William A, ASTHEIMER Lee, FILDES Karen, & HOOPER Michael J.	Effects of sublethal fenitrothion ingestion on cholinesterase inhibition, standard metabolism, thermal preference, and prey-capture ability in the Australian Central Bearded Dragon (*Pogona vitticeps*, Agamidae) *Environmental Toxicology and Chemistry* 23(1): 109–116	Fenitrothion	EN
14-20	Direction de la Protection des Végétaux & Université Abdou Moumouni & Institut Agronomique et Vétérinaire Hassan II (Niger)	2005	Abdou MAMADOU, Ahmed MAZIH & Alzouma INEZDANE	L'impact des pesticides utilisés en lutte contre le criquet pèlerin (*Schistocerca gregaria* Forskal, 1775) (Orthoptera, Acrididae) sur deux espèces de *Pimelia* (Coleoptera, Tenebrionidae) au Niger *VertigO – La revue en sciences de l'environnement* 6(3): 1–8	Chlorpyrifos Fenitrothion	EN
14-21	Texas Tech University (Thesis) (Australia)	2005	SZABO Judit K	Avian-locust interactions in eastern Australia and the exposure of birds to locust control pesticides.	Fipronil	EN
14-22	University of Wollongong & Australian Plague Locust Commission & Texas Tech University (Australia)	2006	FILDES Karen, ASTHEIMER Lee B, STORY Paul, BUTTEMER William A & HOOPER Michael J	Cholinesterase response in native birds exposed to fenitrothion during locust control operations in Eastern Australia *Environmental Toxicology and Chemistry* 25(11): 2964–2970	Fenitrothion	EN
14-23	University of Wollongong (Thesis) (Australia)	2008	FILDES Karen J	Pesticide exposure in free-living native birds and the effects of acute dosing of fenitrothion and fipronil on physiological performance in selected species	Fenitrothion Fipronil	EN
14-24	International Centre of Insect Physiology and Ecology (ICIPE) (Kenya)	2008	BASHIR Magzoub	Ecotoxicological studies on PAN (PR 37288) – Progress report: October 2007 - March 2008	PAN	EN
14-25	Centre National de Lutte Antiacridienne (Morocco)	2009	Centre National de Lutte Antiacridienne	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	EN
14-26	University of Wollongong (Australia)	2008	FILDES Karen, ASTHEIMER Lee B & BUTTEMER William A	The effect of acute fenitrothion exposure on a variety of physiological indices, including avian aerobic metabolism during exercise and cold exposure *Environmental Toxicology and Chemistry* **28(2):** 388–394	Fenitrothion	EN

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides	Study type [3]
14-27	Universidad Nacional Autónoma de México, Universidad Autónoma del Estado de Morelos, Universidad Autónoma Metropolitana-Xochimilco (Mexico)	2009	TORIELLO Conchita, PEREZ-TORRES Armando, VEGA-GARCIA Fabiola, NAVARRO-BARRANCO Hortensia, PEREZ-MEJIA Amelia, LORENZANA-JIMENEZ Marte, HERNANDEZ-VELAZQUEZ Victor, MIER Teresa	Lack of pathogenicity and toxicity of the mycoinsecticide *Metarhizium anisopliae* var. *acridum* following acute gastric exposure in mice *Ecotoxicology and Environmental Safety* **72:** 2153–2157	*Metarhizium acridum*	EN
14-28	Centre National de Lutte Antiacridienne (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.	Deltamethrin Chlorpyrifos	EN
14-29	Australian Plague Locust Commission, University of Wollongong & Texas Tech University (Australia)	2011	STORY Paul, HOOPER Michael J, ASTHEIMER Lee B, & BUTTEMER William A	Acute oral toxicity of the organophosphorus pesticide fenitrothion to fat-tailed and stripe-faced dunnarts and its relevance for pesticide risk assessments in Australia *Environmental Toxicology and Chemistry* 30(5): 1163–1169	Fenitrothion	EN
14-30	Australian Plague Locust Commission & Environment Canada (Australia)	2013	STORY Paul G, MINEAU Pierre, MULLIÉ Wim C	Insecticide residues in Australian Plague Locusts (*Chortoicetes terminifera* Walker) after ultra-low volume aerial application of the organophosporus insecticide fenitrothion *Environmental Toxicology and Chemistry* **32(12):** 2792–2799	Fenitrothion	EN
14-31	Ministry of Agriculture (Senegal) (= *study 14-10*)	2010	MULLIE Wim C & GUEYE Y	Does bird predation enhance the impact of Green Muscle® (*Metharizium acridum*) used for grasshopper control?	*Metarhizium acridum* (not in FAO 2007 review)	EF, EN
14-32	Australian Plague Locust Commission (APLC) & Universität Basel (Australia)	2011	STEINBAUER MJ & PEVELING R	The impact of the locust control insecticide fipronil on termites and ants in two contrasting habitats in northern Australia *Crop Protection* 30: 814-825	Fipronil	EN
14-33	Chongqing University (China)	2008	PENG Guoxiong, WANG Zhongkang, YIN Youping, ZENG Dengyu, XIA Yuxian	Field trials of *Metarhizium anisopliae* var. *acridum* (Ascomycota: Hypocreales) against oriental migratory locusts, *Locusta migratoria manilensis* (Meyen) in Northern China *Crop Protection* 27**:** 1244– 1250	*Metarhizium acridum* (not in FAO 2007 review)	EF, EN

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides	Study type [3]
14-34	FAO (Tanzania)	2009	SPURGIN PA & CHOMBA RSK	Report on Red Locust Control Operations in Western Tanzania.	*Metarhizium acridum* (not in FAO 2007 review) Fenitrothion Fenitrothion + esfenvalerate	EF
14-35	University of Wollongong, Australian Plague Locust Commission, University of Adelaide (Australia)	2008	BUTTEMER William A, STORY Paul G, FILDES Karen J, BAUDINETTE Russell V, ASTHEIMER Lee B	Fenitrothion, an organophosphate, affects running endurance but not aerobic capacity in fat-tailed dunnarts (*Sminthopsis crassicaudata*). *Chemosphere* 72: 1315–1320	Fenitrothion	EN
14-36	Plant Protection Research Institute (Egypt)	2005?	ABDELATIF Gamal M	Effect of Green Muscle on locust and grasshoppers – Final report	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-37	FAO (Mauritania)	2006	KOOYMAN C, MULLIE WC & OULD MOHAMED S'A	Essai de Green Muscle sur des nymphes de croquet pèlerin dans la zone de Benichab, Ouest de la Mauritanie. (Octobre – novembre 2006)	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-38	FAO (Tanzania)	2009	KOOYMAN Christiaan	Consultancy on the use of Green Muscle for the control of Red Locust (*Nomadacris septemfasciata*). (13 January to 12 February 2009)	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-39	Fondation Agir pour l'Education et la Santé (Senegal)	2007	MULLIE WC	Observations sur l'utilisation du Green Muscle™ (*Metarhizium anisopliae* var. *acridu*m) en lutte antiacridienne au Sénégal en 2007	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-40	Ministère de l'Agriculture (Senegal) (*part is reported in 14-10 & 14-31*)	2009	MULLIE WC & GUEYE Y	Efficacité du Green Muscle (*Metarhizium anisopliae* var. *acridum*) en dose réduite en lutte antiacridienne au Sénégal en 2008 et son impact sur la faune non-cible et sur la prédation par les oiseaux	*Metarhizium acridum* (not in FAO 2007 review)	EF, EN
14-41	FAO (Timor Leste)	2007	SPURGIN P	Report to FAO on aerial control operation with a biopesticide (Green Guard ULV), to limit an outbreak of migratory locust in the Western districts of Timor Leste. 12 May – 14 June 2007	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-42	CERES/Locustox (Senegal)	2008	SENGHOR E, NDIAYE M. GUEYE PS & Sow PC	Effets de la combinaison de Green Muscle (GM) et du phenylacetontrile (PAN) sur *Apis mellifera*, *Trachyderma hispida*, *Acanthodactylus dumerili* (Milne Edwards 1829), *Tilapia nilotica*, *Anisops sardeus* et *Caridina africana*.	*Metarhizium acridum* Phenylacetonitrile (PAN)	EN

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides	Study type [3]
14-43	Ministère de l'Agriculture, des biocarburants et de la pisciculture (Senegal)	2010	MULLIE WC & GUEYE Y	L'impact du Green Muscle® *Metarhizium acridum* sur le peuplement acridien et ses prédateurs à Khelcom, Sénégal, après deux traitements consécutifs sur deux ans.	*Metarhizium acridum* (not in FAO 2007 review)	EF, EN
14-44	CERES/Locustox (Senegal)	undated	SENGHOR Emmanuel	Test de sensibilité de l'abeille africaine (Apis mellifera) vis-à-vis la combinaison Green Muscle et du Phenylacetonitrile (PAN)	*Metarhizium acridum* Phenylacetonitrile (PAN)	EN
14-45	--cancelled--					
14-46	Natural Resources Institute, FAO & DPV (Niger)	2006	CHEKE Robert A, MULLIE Wim C & BAOUA IBRAHIM Abdou	Avian predation of adult Desert Locust *Schistocerca gregaria* affected by *Metarhizium anisopliae* var. *acridum* (Green Muscle®) during a large scale field trial in Aghéliough, northern Niger, in October and November 2005	*Metarhizium acridum*	EN
14-47	Institut National de la Protection des Végétaux (Algeria)	2011	CHAOUCH Abderrezak	Essai d'un biopesticide « *Metarhizium acridum* » sur les larves du criquet maroccain *Dociostaurus maroccanus* Thunb. 1815 en conditions naturelles dans la région de Marhoum de la Wilaya de Sidi Bel Abbes (Algérie) Mai 2011.	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-48	Centre National de la Recherche Appliquée au Développement Rural (FOFIFA) (Madagascar)	2009	RAJAONARISON JH Jocelyn, RAHALIVAVOLONONA Njaka, RAMILIARIJAONA Saholy N, RAKOTONDRAZAKA Alphonse	Mise en place et suivi du test de comparaison sur l'efficacité biologique de deux isolats du champignon *Metarhizium anisopliae* var. *acridum* : IMI 330189 et SP9 sur les populations larvaires de *Locusta migratoria capito*	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-49	Centre National de la Recherche Appliquée au Développement Rural (FOFIFA) & Direction de la Protection des Végétaux (DPV) & Centre National Antiacridien (CNA) (Madagascar)	2010	RAJAONARISON JH Jocelyn, RAVOLASAHONDRA M Florentine, RAOULT Ibramdjee RAKOTONDRAZAKA Alphonse	Démonstration de l'efficacité du biopesticide *Metarhizium anisopliae* var. *acridum* souche IMI 330189 dans les parcelles d'Ampingabe du Fokontany d'Ambanira de la commune rurale d'Andranovory	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-50	Centre National de la Recherche Appliquée au Développement Rural (FOFIFA) (Madagascar)	2011	RAJAONARISON JH Jocelyn, RAHALIVAVOLONONA Njaka, RANDRIAMAROLAHY Fidèle	Rapport sur l'efficacité biologique du Green Muscle™ (*Metarhizium anisopliae* var. *acridum* : IMI 330189) mis en suspension dans 1 litre de gasoil pour le contrôle des populations larvaires du Criquet migrateur malgache *Locusta migratoria capito*.	*Metarhizium acridum* (not in FAO 2007 review)	EF

Report #	Company/Institution (country of study)	Year of publication	Author(s)	Title [Remarks]	Insecticides	Study type [3]
14-51	BASF – Australia, University of Wyoming – USA, Centre for ecostrategic Studies – Georgia & Uzbek Research Institute of Plant Prtection – Uzbekistan (Georgia & Uzbekistan)	undated	Hunter, Latchininski, Abashidze, Gapparov, Nurzhanov, & Medetov	The efficacy of *Metarhizium acridum* against nymphs of the Italian locust, *Calliptamus italicus* L. (Orthoptera: Acrididae) in Uzbekistan and Georgia	*Metarhizium acridum* (not in FAO 2007 review)	EF
14-52	Université de Niamey (Niger)	2013	KADRI Aboubacar, ZAKARI Moussa Ousmane, MAMADOU Abdou, HAMÉ Abdou Kadi Kadi, GAMATCHÉ Idrissa	Effet biocide des insecticides organophosphorés sur un complexe de sauteriaux dans le département de Gouré au Niger. *Annales de l'Université Abdou Moumouni*, XIV-A **:** 1-12	Fenitrothion Chlorpyrifos	EF
14-53	Institut Agronomique et Vétérinaire Hassan II (Thesis) (Niger)	2007	MAMADOU Adou	Les effets environnementaux de la lutte chimique contre le Criquet pèlerin (*Schistocerca gregaria* Forskal, 1775) (Orthoptera, Acrididae) dans la vallée de Tafidet au Niger	Fenitrothion Chlorpyrifos	EN
14-54	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. *African Entomology* 17(2): 147-153	Fenitrothion Chlorpyrifos	EN
14-55	Direction de la Protection des Végétaux – Niger & Institut Agronomique et Vétérinaire Hassan II & Centre National de Lutte Atiacridienne (Niger)	undated	MAMADOU Adou, MAZIH Ahmed, GHAOUT S & HORMATALLAH Abderrahime	Etude de l'impact des pesticides utilisés en lutte contre le criquet pèlerin (*Schistocerca gregaria* Forskal 1775) (Acrididae : Orthoptera) sur deux espèces de *Prionyx* (Hymenoptera, Sphecidae) dans l'Aïr (Niger) *Actes de l'Institut Agronomique et Vétérinaire* (Maroc) 25(1-2) : 59-62 {published?}	Fenitrothion Chlorpyrifos	EN

Annex 3 – 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 PRG.

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 [4]
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[1]			
Barrier spacing reported		X	For barrier treatments and RAAT[1]			
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; & 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

[4] Sufficient pre-treatment observations are crucial.

Criteria	Efficacy trials			Environmental field studies		
	Selection		Conditions/remarks	Selection		Conditions/remarks
	mandatory	conditional		mandatory	conditional	
Stage(s) reported	X		Unless target is a mixed grasshopper population			
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

Criteria	Efficacy trials			Environmental field studies		
	Selection		**Conditions/remarks**	**Selection**		**Conditions/remarks**
	mandatory	conditional		mandatory	conditional	
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

[1] RAAT = reduced agent area treatment

Annex 4 – Summary of data from efficacy trial reports

Report	**Insecticide**		**Target species** [5]	**Stage** [6]	**App.** [7]	**Repl.** [8]	**Plot size** (ha)	**Application rate** [g a.i./ha] and/or [L formulation/ha]					**Effect** [% at dAT] [9]		Meets **Annex 3** criteria	**Remarks**
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
14-01	Chlorpyrifos	Dursban 240 UL	SGR	L4 (B)	A	1	2000	240?	1?			N	3d	100% at 5d	No	Effect on within-band density
	Malathon	Malathion 96 UL	SGR	L4 (B)	A	1	2000	960?	1?			N	1d	100% at 5d		Persistence of effects assessed in cages
14-02	Spinosad	Tracer 125 UL	DMA + MG	L2 - Ad	H	3	0.5	13	1.06			M		18% at 8d	Yes	5-10 mm of rain on day of treatment may have reduced efficacy
	Spinosad	Tracer 125 UL	DMA + MG	L2 - Ad	H	3	0.5	26	1.07			M		36% at 8d		Cannot be used because of the rain during and after treatment
	Spinosad	Tracer 125 UL	DMA + MG	L2 - Ad	H	3	0.5	45	0.94			M		60% at 8d		
	Malathion	Malathion UL 960	DMA + MG	L2 - Ad	H	3	0.5	602	0.62			M		68% at 8d		
	Diflubenzuron	Dimilin OF 6	DMA + MG	L2 - Ad	H	3	0.5	29	0.95			M		63% at 8d		
14-03	l-cyhalothrin	Karate 50 UL	SGR	L3	H	3	$20\ m^2$	20	0.4			N	4d	90% at d	No	PAN = 2-phenylacetonitrile (>98% purity)
	l-cyhalothrin	Karate 50 UL	SGR	L3	H	3	$20\ m^2$	10	?			N		35% at 6d		Small field enclosures
	l-cyhalothrin + PAN	Karate 50 UL + PAN	SGR	L3	H	3	$20\ m^2$	10+10	?			N		80% at 6d		Mortality % uncorrected for control; control mortality always < 10%
	Malathion	Malathion 500 UL	SGR	L3	H	3	$20\ m^2$	1000	2			N	1d	100% at 2d		
	Malathion	Malathion 500 UL	SGR	L3	H	3	$20\ m^2$	500	?			N		60% at 2d		
	Malathion + PAN	Malathion 500 UL + PAN	SGR	L3	H	3	$20\ m^2$	500+10	?			N	2d	98% at 4d		
	Chlorpyrifos	Dursban 480 UL	SGR	L3	H	3	$20\ m^2$	240	0.5			N	1d	98% at 3d		
	Chlorpyrifos	Dursban 480 UL	SGR	L3	H	3	$20\ m^2$	120	?			N		50% at 4d		

5 Target species: SGR = *Schistocerca gregaria*, DMA = *Dociostaurus maroccanus*, MG = mixed grasshoppers, MDI = *Melanoplus differentialis*, HLI = *Heteracris littoralis*, MPA = *Myrmeleotettix palpalis*, LMC = *Locusta migratoria capito*, LMM = *Locusta migratoria manilensis*, EPL = *Euprepocnimes plorans*, *NSE* = *Nomadacris septemfasciata*, LMI = *Locusta migratoria migratoroides*, DHA = *Dasyhippus harbipes*

6 L = larvae, Ad = adult

7 Application methods: A = aerial, V = vehicle-mounted, H = hand-held

8 Number of replicates

9 % population reduction (corrected for changes in control) at number of days after treatment

10 N = nominal application rate, M = measured application rate

Report	**Insecticide**		**Target species** [5]	**Stage** [6]	**App.** [7]	**Repl.** [8]	**Plot size** (ha)	**Application rate** [g a.i./ha] and/or [L formulation/ha]					**Effect** [% at dAT] [9]		Meets **Annex 3** criteria	**Remarks**
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
	Chlorpyrifos + PAN	Dursban 480 UL	SGR	L3	H	3	20 m^2	120+10	?			N		88% at 5d		
14-04	Diflubenzuron		MDI	L											n.a.	Not further reviewed: Only caging conducted, also in the field
	Azadirachtin		MDI	L3												
	Beauveria bassiana		MDI	L3												
	Esfenvalerate		MDI	L3												
	Spinosad		MDI	L3												
	Endosulfan		MDI	L3												
	Naled		MDI	L3												
14-05	Garlic oil		HLI	L1											n.a.	Not further reviewed: Only caging conducted, also in the field Application rates not reported
	Euphorbia extract		HLI	L1												
	Steinermia carpocapsae		HLI	L1												
	Heterorhabdatis bacteriophora		HLI	L1												
14-06	Malathion	Malathion 45% EC	MPA + DHA + MG	L3	V?	3	50	675				N	12 d	94% at 31d	No	Mortality is control-corrected. Infection rates determined.
	Flufenoxuron	Cascade 5%; bran bait	MPA + DHA + MG	L3	V?	3	50	1.88				N		65% at 31d		
	Flufenoxuron		MPA + DHA + MG	L3	V?	3	50	3.75				N		29% at 31d		
	Flufenoxuron		MPA + DHA + MG	L3	V?	3	50	7.5				N		64% at 31d		
	Paranosemae locustae	Bran bait	MPA + DHA + MG	L3	V?	3	50	7.5×10^9 sp/ha				N		41% at 31d		
	Paranosemae locustae +	Bran bait	MPA + DHA + MG	L3	V?	3	50	7.5×10^9 + 3.75				N		64% at 31d		

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets Annex 3 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
	flufenoxuron		MPA + DHA + MG	L3	V?	3	50	$15x10^9$ + 3.75				N		68% at 31d		
			MPA + DHA + MG	L3	V?	3	50	$22.5x10^9$ + 3.75				N		65% at 31d		
14-07	Teflubenzuron	WOPRO Teflubenzuron 50 g/L UL	LMC	L1-L3 (B)	A	1	4.5 ?			16.5		N	5–7d	100% at 7–8d	No	Barrier width : barrier spacing = 7m : 50m But barrier width was shown to be at least 50 m, with oil-sensitive papers. (=full cover spray?) Plot size unclear. To be tested on larger scale; cannot halve the dose rate on this basis.
	Teflubenzuron	Nomolt 50 UL	LMC	L1-L3 (B)	A	1	4.5 ?			16.5		N	6d	100% at 6–7d		
14-08	*Metarhizium acridum*	Green Muscle OF (diluted with diesel oil)	SGR (solitary)	L1-L5, Ad	H	1	1.8	53	1			M	3d	96% at 4d	No	Operational monitoring No untreated control Likely impact of bird predation on affected larvae
14-09	*Metarhizium acridum*	Green Muscle OF (diluted with diesel oil)	SGR (solitary)	L1-L5, Ad	H	1	3.75	50	2			N	?	?	No	Operational monitoring Temp: 27–34 °C Rate calibrated as 1.8 L/ha Thermoregulation observed 100% sporulation in incubated larvae
14-10	*Metarhizium acridum* *(= study 14-31)*	Green Muscle OF (diluted with diesel oil)	OSE & MG	?	V	3	400	25 ($1.25x10^{12}$ sp/ha)	1			M		84% at 15d	Yes	Germination: 90% viable Temp.: 15–40 °C No statistical difference

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets Annex 3 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
			OSE & MG	?	V	3	400	50 (2.5x10^{12} sp/ha)	1			M		87% at 18d		in efficacy between doses 80% sporulation in incubated insects Persistence of activity > 18 dAT
14-11	*Metarhizium acridum*	Green Muscle OF (diluted with diesel oil)	SGR	L3	H		0.0016	6 (3x10^{11} sp/ha)	2			N		33% at 10d	No	Small field enclosures Germination: 87% viable Temp: 23–37 °C Several rain events after treatment; reduced efficacy? Mortality % uncorrected for control; control mortality always < 6%
			SGR	L3	H		0.0016	12 (2.5x10^{11} sp/ha)	2			N		55% at 10d		
			SGR	L3	H		0.0016	50 (2.5x10^{12} sp/ha)	2			N		66% at 10d		
	Chlorpyrifos	Dursban 240 UL	SGR	L3	H		0.0016	240	1			N	2d	100% at 2d		
14-12	*Metarhizium acridum*	Green Muscle OF	SGR												n.a.	Not further reviewed: Caging in lab. after treatment in the field Application rate not clear.
14-13	*Metarhizium acridum*	Green Muscle OF	SGR	L4 – L5											n.a.	Locusts caged on and next to treated barriers. Methodology not appropriate to set application rates Blanket treatment reported in 14-37

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets Annex 3 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
14-14	*Metarhizium acridum* *= study 14-15*	Green Muscle OF	SGR	L3 – L4	V	1	160			31		M		48h exposure: 0 – 20% at 2 d	Yes	Locusts caught and caged after 24 or 48 h in the field. Germination: 97% viable Temp:20–35 °C (average) Groups of transiens hoppers not very mobile Further trials required on gregarious populations
14-15	*= study 14-14*															
14-16	*Metarhizium acridum*	Green Muscle OF	SGR	L3 – L4	H	3	4 m^2 Low or high vegeta-tion density	50?	1 or 2			N	12d	75 – 91 % at 14d	No	Locusts caged on treated vegetation. Germination: 91% viable Temp: 23–48 °C No sign. effect of vegetation cover or volume applic. rate on % mortality. Persistence assessed.
14-31	*= study 14-10*															
14-33	*Metarhizium acridum*	Strain CQMa102 Oil-miscible suspension (diluted with soybean oil, water & emulsifiers)	LMM	L2 – L4	H	16	~10	2.5x10^{12} sp/ha	1			N		75 – 82% at 13d	No	Trials in 4 regions and 2 different years. Locusts collected after 24 hours in sprayed field and caged on unsprayed vegetation for 12 more days. Mortality not control corrected; control mortality < 4%
			LMM	L2 – L4	H	16	~10	3.3x10^{12} sp/ha	1			N	11–13d	91 – 94% at 13d		
			LMM	L2 – L4	H	16	~10	5x10^{12} sp/ha	1			N	9–13d	93 – 97% at 13d		
			LMM	L2 – L5	H	16	59 – 131	3.3x10^{12} sp/ha	1			N	11–15d	90 – 96% at 15d		Effect on density assessed in field

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets Annex 3 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
			LMM	L2 – L4	A	8	~375	3.3×10^{12} sp/ha	1			N	13d	93% at 15d		Effect on density assessed in field and mortality in cages. Malathion caused “dramatic reduction at 1d, and recovery at 12d
	Malathion	Malathion 40%	LMM	L2 – L4	A	8	~375	600	1			N	?	?		
14-34	*Metarhizium acridum*	Green Muscle TC	NSE	Ad	A	4	655 - 4300	43 - 57	1			M	--	28 – 62% at ~16d. ~67% (popula-tion estimate)	Yes	Operational monitoring. Locusts collected after 3 days in sprayed field and caged on unsprayed vegetation Remaining locusts were sprayed with Sumicombi
	Fenitrothion + esfenvalerate	Sumicombi 50 UL (feni 490 + esfen 10)	NSE	Ad	A	1	993	368 + 7.5	0.75			M		~50% in dense vegetation “Adequate” in light vegetation		
			NSE	Ad	A	1	1000	490 + 10	1			M		>90% under all conditions		
			NSE	Ad	A	1	3900	475 + 10	0.97			M		“Effective” control		
	Fenitrothion	Fenitrothion UL 79%)	NSE	Ad	A	1	2800	431	0.5			M		~90% at 7d		
14-36	*Metarhizium acridum*	Green Muscle Diluted with vegetable oil	SGR	L5 – Ad	H	2	0.25	25				N		76% at 21d	No	After spraying, locust caged onto treated vegetation. Mortality not control corrected; control mortality < 12%
			SGR	L5 – Ad	H	2	0.25	50				N	21d	90% at 21d		
			SGR	L3 – L5	H	1	4	25				N		71% at 17d		After spraying, locust caged onto treated
			SGR	L3 – L5	H	1	4	50				N		88% at 17d		

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets **Annex 3** criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
		Diluted with diesel oil	SGR	L3 – L5	H	1	4	25				N		82% at 17d		vegetation. Mortality not control corrected; control mortality ~35%
			MG	?	H		0.1 – 0.45	50				N		70-84% at 17d		After spraying, locust caged onto treated vegetation. Mortality not control corrected; control mortality ~30-40%
			MG	?	H		0.1 – 0.45	25				N		70-75% at 17d		
		Diluted with diesel oil	EPL	L2 – L4	H	1	0.25	25				N		82% at 17d		After spraying, locust caged onto treated vegetation. Mortality not control corrected; control mortality ~16-20%
		Diluted with vegetable oil	EPL	L2 – L4	H	1	0.25	25				N		64% at 17d		
			EPL	L2 – L4	H	1	0.25	50				N		90% at 17d		
14-37	*Metarhizium acridum*	Green Muscle OF Diluted in diesel oil	SGR	L2	H	12	0.25 - 8	50				N	4d	100% of bands disappeare d at 4-8d Cages: Mortality 15-72%	Yes	Hopper band mortality observations & Caging on untreated?? Vegetation germination check: 95% viable Temp: 20–40 °C Mortality not control corrected; control mortality 10-48% Increased bird predation observed on sick locusts
14-38	*Metarhizium acridum*	Green Muscle OF Diluted in diesel oil	NSE	L2 – L4 (B)		1	800	27.4	0.81			M		84 – 93% at 15-1 d	Yes	Operational monitoring. Germination: 71% viable. 2 days after spraying, locust caged onto untreated vegetation.
			NSE	L2 – L4 (B)		1	360	34.3	0.94			M		84% at 15d		
			NSE	L2 – L4 (B)		1	440	34	0.93			M		96% at 12d		

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets Annex 3 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
			NSE	L2 – L4 (B)		1	400	32.2	0.88			M		96% at 12d		Mortality not control corrected; control mortality 15
14-39	*Metarhizium acridum*	Green Muscle Diluted in vegetable oil + diesel	MG	Mix	V	1	35	36	0.7			M		75% at 15d	Yes	3 days after spraying, locust caged onto untreated vegetation. Mortality control corrected Quality of product is questionable (some germination rates very low) Temp: 25–34 °C Persistence checked First plot received rain on day of treatment
			MG	Mix	V	1	41	49	0.98			M		65% at 9d		
14-40	*Metarhizium acridum* (*part is reported in 14-10 & 14-31 – here only additional data*)	Green Muscle Diluted in vegetable oil + diesel	MG	MIx	A	1	1200	25				M	~15d	95% at 22d	Yes	Operational monitoring. Field observations of population reductions. Control plots fairly stable.
			MG	MIx	A	1	1200	50				M	~18d	95% at 22d		
			MG	MIx	A	1	1200	100				M	~18d	95% at 22d		
14-41	*Metarhizium acridum*	Green Guard UL (Strain FI 985) in vegetable oil	LMI	Ad (S)	A	many	612	50	0.75			M		High mortality (important reduction in swarms and subsequent nymph population)	Yes	Operational monitoring. Germination: 79-85% viable.
			LMI	Ad (S)	A	many	1706	60	0.9			M		High mortality		
14-43	*Metarhizium*	Green Muscle	MG	Mix	V	3	400	19	1			M		79% at 25d	Yes	Most plots same as

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets **Annex 3** criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
	acridum	Diluted in vegetable oil + diesel	MG	Mix	V	3	400	37.5	1			M		81% at 25d		treated year earlier (reported in 14-10) Germination: 79-90% viable. Grasshopper density assessments; control corrected population reduction Persistence assessed
			MG	Mix	V	3	25	11.5 – 14	0.9 – 1.1			M		89% at 48d		Germination check: 79-90% viable. Grasshopper density assessments; control corrected population reduction Persistence also assessed
			MG	Mix	V	3	25	23.5 – 27.5	0.9 – 1.1			M		88% at 48d		
14-47	*Metarhizium acridum*	Green Muscle	DMA	L3-L4	V	1	10	25	2			N	9d	100% at 9d	No	Germination: 97% viable Temp.: 10 – 35 °C Hopper bands observed in field Hoppers caged onto plot after treatment ($4m^2$)
			DMA	L3-L4	V	1	10	50	2			N	9d	100% at 9d		
			DMA	L3-L4	V	1	10	75	2			N	8d	100% at 8d		
14-48	*Metarhizium acridum*	Green Muscle	LMC	L2-3	H	4	0.01-0.06	100	2			N	?	100% at 4d	No	Germination: 89% viable Cage mortality assessments; no mortality in control cages Persistence assessed
		SP9	LMC	L2	H	4	0.01-0.19	100	2			N	?	100% at 7d		Germination: 82% viable Cage mortality assessments; no mortality in control cages Persistence assessed

Report	**Insecticide**		**Target species** [5]	**Stage** [6]	**App.** [7]	**Repl.** [8]	**Plot size** (ha)	**Application rate** [g a.i./ha] and/or [L formulation/ha]					**Effect** [% at dAT] [9]		Meets **Annex 3** criteria	**Remarks**
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
14-49	*Metarhizium acridum*	Green Muscle	LMC	L3	H	1	10	62.5	1.25			M		88% at 7d	Yes	Germination: 81% viable Field density assessment; control plot mortality only until 3 days AT Cage assessment, but method not described
			LMC	L3-Ad	H	3	0.1 - 7	100	2			N		5 – 77% at 3d		Field density assessment, but only until 3 days AT No control plots
14-50	*Metarhizium acridum*	Green Muscle	LMC	L3-4	H	5	37 ha (total)	54	0.54			M	9d (field) 8d (cages)	100% at 9d (field) 100% at 8 d (cages)	Yes	Germination: 87% viable Field density and cage assessments Control density stable Max. control mortality in cages = 10%
14-51	*Metarhizium acridum*	Green Guard	CIT (Uzbekist.)	L4	H	3	3	50	0.5 in 100 L water			N		69-70% at 14d	No	Field density assessments Control density 10-19% reduced
				L (early instar)	H	1	?	25	0.25 in 100 L water			N		71% at 16d		Field density assessments Control density stable
				L (early instar)	H	1	?	50	0.5 in 100 L water			N	16d	90% at 16d		
			CIT (Georgia)	L?	H,V	4	3-7	50	0.5 in 100 L water			N		77-86% at 14d (field)		Field density and cage assessments. Cage mortalities, control corrected, similar to field reductions, but at 10d AT
				L?	H,V	2	?	50	0.5 in 100 L water			N		66-83% at 14d (field)		

Report	Insecticide		Target species [5]	Stage [6]	App. [7]	Repl. [8]	Plot size (ha)	Application rate [g a.i./ha] and/or [L formulation/ha]					Effect [% at dAT] [9]		Meets Annex 3 criteria	Remarks
	Common name	Formulation						Blanket		Intra-barrier		N/M [10]	earliest > 90%	highest observed		
								Rate	Volume	Rate	Volume					
				L?	V	?	?	50	0.5 in 100 L water			N		74-83% at 14d		No details about application methods
14-52	Chlorpyrifos	Pyrical 240 UL	OSE + Mix GH	L + Ad	H	3	4	240	1			N	21d	92% at 21d	No	Field density assessments. Population reduction not control-corrected; control plot reduction max. 15% Persistence also assessed in cages
		Pyrical 480 UL	OSE + Mix GH	L + Ad	H	3	4	240	0.5			N		88% at 21d		
		Dursban 240 UL	OSE + Mix GH	L + Ad	H	3	4	240	1			N	21d	90% at 21d		
	Fenitrothion	Fenical 400UL	OSE + Mix GH	L + Ad	H	3	4	400	1			N	21d	89% at 21d		

Annex 5 – Special considerations for insecticide groups

Insecticides listed in the report are divided into the following groups: organophosphates, pyrethroids, carbamates, benzoylureas, phenyl pyrazoles and biological insecticides (e.g. mycoinsecticides). Special consideration about their suitability for control purposes and conditions of use are given.

Organophosphates, carbamates and pyrethroids

Organophosphates, carbamates and pyrethroids have many aspects in common. They have a broad-spectrum activity, exhibit moderate (OPs) to fast (carbamates, 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 acetyl-cholinesterase AChE levels in the blood 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, but, 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 is not an effect taken into account in 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 barrier 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.

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. 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 6 – Updated PRG health hazard classification of insecticide formulations for locust control

Health hazards						**Use recommendations for locust control** [3]	
Acute toxicity		**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 sens. – 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 hygienic measures and observing instruction for use given on the label

1 According to the WHO Classification of Pesticides by Hazard (WHO, 2009)

2 According to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (UNECE, 2013)

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

Annex 7 – 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 PRG 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 standard methods

—Relevant methodological deficiencies

—Unsuitable test system

Reliability 4: Not assignable

—Only short abstract available

—Only secondary literature (review, tables, books, etc.)

Annex 8 – Summary of data from environmental laboratory and semi-field toxicity studies

Report	Insecticide		Test species		No. of animals per group		Exposure route	Dose	Interval between observa-tions	Endpoint [1]	Parameter(s)	Results	Remarks
	Common name	Formulation & concentration (g/L)	Name	Source [2]	M [3]	F							
14-17	Deltamethrin, Malathion	a. Deltamethrin 12,5 g/L b. Malathion 960 g/L	Honeybee *(Apis mellifera)*	R	Bee hives		Direct (spray) Ingestion (pollen)	a. 2x 12.5 g/ha b. 2x 960 g/ha	7d	STD [4]	Mortality Foraging	a. Increase in mortality Reduction of foraging 40% b. Increase of mortality 15x Reduction of foraging 87%	Standardized semi-field test. Protocol CEB 230/EPPO170
14-18	Fipronil	Adonis 10 UL	Fringe-toed lizard (*Acantho-dactylus dumerili)*	C	a. 10 b. 12	a. 10 b. 12	a. Control-led diet (housefly) b. Gavage	30 mg/kg b.w.	24h	Toxic limit dose	Activity, Bodyweight Food consumption Survival	No effect on activity. Bodyweight: -20% Mortality: 25-50% of test animals	Exposure under field conditions (14-21): < 1% of effective dose in this study
14-18	*Metarhizium acridum* (active and Deactivated)	Green Muscle	Fringe-toed lizard (*Acantho-dactylus dumerili)*	C	a.22 b.18 c.14	a.16 b.15 c.12	a. Inhalation b. Gavage c. Feeding (diseased prey)	10^7 conidia/g b.w.	24h	Toxic limit dose	Locomotor activity; feeding activity; food consumption; body weight; liver-to-body weight ratio; Gross necropsy: abnormalities associated with fungal infections	In gavaged lizards: Reduction of feeding activity and liver-to-body weight ratio of female survivors with active and deactivated spores	No effect in group fed with diseased prey.

1 Indicator of toxicity
2 C = Caught in the wild; R = Reared
3 M = male; F = female
4 STD = Single dose toxicity

Report	Insecticide		Test species		No. of animals per group		Exposure route	Dose	Interval between observa-tions	Endpoint [1]	Parameter(s)	Results	Remarks
	Common name	Formulation & concentration (g/L)	Name	Source [2]	M [3]	F							
14-19	Fenitrothion	Sumithion ULV	Central bearded dragon (*Pogona vitticeps*)	C	a. 3 b. 8 c. 7	a. 4 b. 0 c. 2	Gavage, single dose	a. control b. 2mg/kg c. 20mg/kg	11 to 23h; 7d before and 7d after dosing	DRT[5]	Thermal preference; standard metabolic rate; prey-capture ability;	No effect	
14-19	Fenitrothion	Sumithion ULV (93%)	Central bearded dragon (*Pogona vitticeps*)	C	a. 3 b. 8 c. 7	a. 4 b. 0 c. 2	Gavage	a. control b.2mg/kg c. 20mg/kg	0, 2, 8, 24, 120, 504h	DRT	Plasma total cholinesterase (ChE)	-19% at 2h in 2 mg/kg -68% at 8h; depressed up to 21d at 20 mg/kg	Effect of blood sampling on metabolic parameters not tested
14-23 14-26	Fenitrothion	Technical solution	House sparrow (*Passer domesticus*)	C	8		Gavage	30, 60, 100 mg/kg b.w.	2, 6, 14, 21d	DRT	Peak metabolic rate [6]	Dose related Reduction 18-58%; Recovery <20d	
14-23 14-26	Fenitrothion	Technical solution	House sparrow (*Passer domesticus*)	C	8		Gavage	30, 60, 100 mg/kg b.w.	2, 6, 14d	DRT	blood haemoglobin content	At 100 mg/kg: reduced at 48h	
14-23 14-26	Fenitrothion	Technical solution	Zebra finch (*Taeniopygia guttata*)	R	8		Gavage; single dose	3 mg/kg	2, 6, 14, 21d	SDT	Peak metabolic rate	Reduction during 3d	
14-23 14-26	Fenitrothion	Technical solution	Zebra finch (*Taeniopygia guttata*)	R	8		Gavage; single dose	3 mg/kg	2, 6, 14, 21d	SDT	blood haemoglobin content	No effect	
14-23 14-26	Fenitrothion	Technical solution	King quail (*Coturnix chinensis*)	R	8		Gavage; single dose	26 mg/kg bw	2, 6, 14, 21d	SDT	Peak metabolic rate	No effect	
14-23 14-26	Fenitrothion	Technical solution	King quail *(Coturnix chinensis)*	R	8		Gavage; single dose	26 mg/kg bw	2, 6, 14, 21d	SDT	Peak metabolic rate	Reduction 23%, recovery at 6d	

5 DRT = dose-related toxicity

6 The parameters measured in this study are aerobic metabolism during cold exposure, peak metabolic rate during flight, blood haemoglobin content, plasma cholinesterases (AChE, ChE) and body weight. The parameters mentioned here are those considered most relevant for the evaluation.

Report	Insecticide		Test species		No. of animals per group		Exposure route	Dose	Interval between observa-tions	Endpoint [1]	Parameter(s)	Results	Remarks
	Common name	Formulation & concentration (g/L)	Name	Source [2]	M [3]	F							
14-23 14-26	Fenitrothion	Technical solution	King quail *(Coturnix chinensis)*	R	8		Gavage; single dose	26 mg/kg bw	2, 6, 14d	STD	Blood haemoglobin content	Reduced at 48 h	
14-27	*Metarhizium acridum* Strain EH-502/8 Viable spores		Young adult CD-1 mice	R	36	36	Gavage	10^8 conidia	Necropsies at 3, 10, 17 and 21d	STD	Gross pathological changes in liver, spleen, kidney, brain, lung, representative lymph nodes	No effect	Microbial Pesticide Test Guidelines (EPA)
14-27	*Metarhizium acridum* Strain EH-502/8 Non-viable spores		Young adult CD-1 mice	R	12	12	Gavage	10^8 conidia	Necropsies at 3, 10, 17 and 21d	STD	Gross pathological changes in liver, spleen, kidney, brain, lung, representative lymph nodes.	No effect	Microbial Pesticide Test Guidelines (EPA)
14-29	Fenitrothion	(mixed with canola oil)	a. Fat-tailed dunnart *(Sminthopsis crassicaudata)* b. Stripe-faced dunnart *(S. macroura)*	C	a. 0 b. 4	a. 9 b. 7	Gavage	single-ordered dose progression, individu-ally 175-310 mg/kg	48h, 14d	LD_{50} HD_5 comparison to present level [7]	Survival AChE, ChE Toxicological signs	HD_{05} value reduced from 177 mg/kg to 93.5 mg/kg	OECD Guideline 425
14-35	Fenitrothion	(mixed with canola oil)	Fat-tailed dunnarts (*Sminthopsis crassicaudata)*	C	26		Gavage	30 mg/kg	4 x 2d	Effect	a. aerobic metabolism during cold exposure b. exercise performance	a. no effect b. 50% reduction during 5d post-exposure	

7 HD_5 = Dose hazardous at LD_{50} level to 5% of all species within a phylum (Aldenberg et al., 2002)

Annex 9 – Summary of data from environmental field studies

A: Study setup

Report #	Insecticide		Ecosystem	# Plots	Plot size (ha)	Application rate (g a.i./ha)			Barrier width : spacing [m : m]	App. [1]
	Common name	Formulation & concentration (g/L)				Blanket	Intra-barrier	N / M [2]		
14-01	Malathion	96 UBV	Semi-desert	3	2000	960				A
14-01	Chlorpyrifos	Dursban 240UBV	Semi-desert	3	2000	240				
14-02	Spinosad	125	Savanna	4	0.5	12, 24, 48				H
14-10	*Metarhizium acridum*	Green Muscle® OF	Savanna	6	400	25, 50				V
14-21	Fipronil	Adonis 3UL	Crop land		800		0.42 - 1.25	N	100-300	A
14-22	Fenitrothion	n.d. [3]	Desert, savanna	3	330, 707, 824	267				A
14-25	Teflubenzuron	Nomolt 50 ULV	Savanna	2	2400	--	45.6	M	700	V
14-28	Chlorpyrifos	Dursban 240 ULV	Savanna	3	1	237		M		V
14-28	Deltamethrin	Decis 25ULV	Savanna	3	1	21-41		M		H
14-30	Fenitrothion	n.d.	Farm land	3	70-200	260				A
14-32	Fipronil	Adonis 3UL	Grazing land	12	34-105	1.25				A
14-43	*Metarhizium acridum*	Green Muscle OF	Savanna	6	400	18.75, 25, 37.5, 50				V
14-46	*Metarhizium acridum*	Green Muscle OF	Savanna	1	500	$2.5*10^{12}$ conidia ha^{-1}				V
14-53 14-54 14-55	I. Fenitrothion II. Chlorpyrifos	I. Fenitrothion 50 UL II. Dursban 450 UL	Desert	3	16	I. 450 II. 225				H

1 Application method: A = aerial application; V = vehicle mounted application; H =hand-held application

2 N = nominal application rate; M = measured application rate

3 n.d. = no data

B. Results

Report #	Insecticide	Rate (g a.i./ha)	Taxon	Parameter	Sampling methods	Sampling frequency and duration				Significant effect? [4]	Max. change at time AT [5]	Time to recovery	Remarks
						Before treatment		After treatment					
						#	period [6]	#	period				
14-01	Malathion	960	a. Birds b. Coleoptera c. Ants	Population effect	a. visual counts b,c. pitfall traps	2	2d	4	2d	a. no b. no c. yes	n.d.	>7d	
14-01	Chlorpyrifos	240				2	2d	4	2d	a. no b. no c. no	--	--	
14-02	Spinosad	12, 25, 45	Hymenoptera	Population effect	Yellow tray	1	2d	4	2d	Yes, at 45g/ha	2d	6d	
14-10	*Metarhizium acridum*	50	Honeybees	activity	Apiscan bee activity counter	6	d	17	d	no	--	--	
14-10	*Metarhizium acridum*	18.75, 25, 37.5, 50	Acridivorous birds	Population effect	Transect counts	1	d	6	d	Yes [7]	--	--	
14-21	Fipronil	0.42 - 1.25 [8]	(Food items)	Residues in avian food	Collection by hand			3-4	1-2d	n.a.	Highest concentrations: a. Seed: <851µg/kg b. Insects: <12.5µg/kg		Residues in seed exceed the $HD_5$9 by ~5% , possibly representing a (minor) hazard to granivorous birds
14-22	Fenitrothion	267	Masked woodswallow *(Artamus personatus)*	Inhibition of Plasma ChE, BChE, AchE	Mist net	4	1 week .	4	day 1, 2, 3, and 5	No	--	--	

4 Statistically significant effect of treatment, based on statistics calculated by study author.

5 Maximum population depression (-) or increase (+)

6 Overall duration of sampling (d = day, wk = week; m = month)

7 Lesser Kestrel, White-throated Bee-eater and Blackheaded Plover increased in numbers

8 Barrier treatment

9 HD_5 = hazardous dose for 5% of the species based on LD_{50} data (Luttik & Aldenberg, 1996)

14-22	Fenitrothion	267	White-browed woodswallow (*Artamus superciliosus*)	Inhibition of Plasma ChE, BChE, AChE	Mist net	4	1 week .	4	day 1, 2, 3, and 5	No	--	--	
14-22	Fenitrothion	267	White-winged triller *(Lalage sueurii)*	Inhibition of Plasma ChE, BChE, AChE	Mist net	4	1 week .	4	day 1, 2, 3, and 5d	P<0.02	n.d.		
14-22	Fenitrothion	267	Zebra finch *(Taeniopygia guttata)*	Inhibition of Plasma ChE, BChE, AChE	Mist net	1	1-4d	4	1, 2, 3, and 5d	P<0.001	n.d.		
14-22	Fenitrothion	267	Granivorous birds, 5 spp	Inhibition of Plasma ChE, AChE	Mist net	1	1-4d	4	1, 2, 3, and 5d	yes	ChE: -33; AChE: -25	>5d	
14-22	Fenitrothion	267	Honey eaters, 6 spp	Inhibition of Plasma ChE, AChE	Mist net	1	1-4d	4	1, 2, 3, and 5d	yes	ChE: -36; AChE: -13	>5d	
14-22	Fenitrothion	267	Insectivorous birds, 20 spp	Inhibition of Plasma ChE, AChE	Mist net	1	1-4d	4	1, 2, 3, and 5d	yes	ChE:-35; AChE:-48	>5d	
14-25	Teflubenzuron	45.6	Diptera, Hymenoptera Lepidoptera Coleoptera	Population effect	Pitfall trap, yellow tray	14	2d	8	2d	no			
14-28	Chlorpyrifos	237	Non-target invertebrates	Population effect	Yellow tray, transect counts	1	2d	9	2d	yes	Hymenoptera [10] -61.0 % (d1, p<0.05). Diptera -80 % (d1)	n.d.	
14-28	Deltamethrin	21-41	Non-target invertebrates	Population effect	Yellow tray, transect counts	1	2d	9	2d	yes	Hymenoptera -68.0% (d+9) Diptera -87 % (d+3)	n.d.	

10 Most outspoken of the measured effects

14-30	Fenitrothion	260	Locust, for residues		Collected by hand			4-6	2-36h	n.a.	Maximum residues live/debilitated locusts: 32mg/kg; dead locusts: 40mg/kg		Highest residue level <0.1 mg/kg bw; NOAEC birds [11]: 17 mg/kg bw. The residues in locusts in this study do probably not represent a risk to birds
14-32	Fipronil	1.25	Termites Ants	Activity, abundance, diversity	Pitfall traps, baits, repair of burroughs	Var.	1-7d	varia ble	7d; 3 months	yes	n.a.	>1 year	Effect observed on all parameters, but strongly dependent on soil type
14-43	*Metarhizium acridum*	18.75, 25, 37.5, 50	Parasitism	# parasites per eggpod	Manual collection of pods, laboratory identification of parasites	6	24h	17	24h	Yes [12]	n.d.	--	
14-46	*Metarhizium acridum*	$2.5x10^{12}$	Acridivorous birds	Predation of locusts	Transect counts	4	24h	10; 23	24h	Weak evidence of increased numbers of 3 acridi-vorous spp.			
14-53 14-54 14-55	I. Fenitrothion II. Chlorpyrifos	!.225 II.450	a. Non-target (beneficial) invertebrates b. Gerbils c. Lizards	a. Population effect b,c. Activity & population effect c. Cadavers	a. Yellow trays, Pitfall traps, termite traps b. Sherman traps c. Transect counts & searches	1	n.d.	90	24h	I and II: a. yes b. no c. yes	I and II: a. Pimelia spp, Sphecids, Termites:≤90%; Bees:100%; b: none c. At d15: -60%; Cadavers: 12x more in chlorpyrifos than in fenitrothion treated plots	I and II: a. Pimelia spp., Termites >90d; Sphecids: >60d; Bees: 28d c. 0d	

11 NOAEC = No Observed Adverse Effect Concentration for the most sensitive toxic effect: reproductive toxicity.

12 The percentage of egg pods being predated was higher in treated plots than in controls. Predators responsible for this increase were *Bombyliidae (Diptera)*