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FINAL REPORT OF CONSULTANT TO MOROCCO LOCUST PROJECT

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PART I: Effects of locust control on the non-target fauna and other components of the environment (end of TDY report

SUMMARY

This is the wrong time of the year to assess the impact of locust insecticides on the non-target fauna (October-December). All the sites visited in southern and southeastern Morocco had low insect diversity and generally low faunal activity other than locusts (Guelmim, Ouarzazate, Errachidia). I recommend therefore that the experiments begin in January in two locations one site in the Oued Draa and another in the arid steppe zone west of Errachidia. The initial trials should be in the form of simple split-block experiments with three replicates. Two sampling methods should be used to simultaneously sample flying and ground arthropods. The sites should preferably not be infested with desert locusts at the time of the experiment. This research must include a pesticide residue component (either in collaboration with the Plant Protection laboratory in Casablanca or with researchers at the I.A.V. Hassan II, Rabat). Vegetation, soil and water samples should be analyzed. With these initial results as a baseline, one can design other experiments to add complexity (the effect of overdosing, multipl pesticides, the presence of large numbers of locust carcasses in the spray block, effects on secondary consumers, etc.).

BACKGROUND

During the crisis interventions of the desert locust campaign last year (Fall 1987, Spring 1988) 1.45 million liters of pesticides and 1.9 million liters of potentially toxic organic solvent were sprayed over 2.8 million hectares of Morocco (see Annex, tables). USG donations made up 9% of pesticides sprayed. These activities were approximately evenly divided between spraying adult swarms (57%) and hoppers (43%). There are apparently no reliable data in the public domain concerning the possible effects of these actions on the environment, on non-target organisms, nor on the health of humans or domestic animals. USAID completed an Environmental Assessment document (EA) in May 1988 which, in part, recommended the present short-term TA for non-target monitoring and a simultaneous TA (Albert Fisher) to examine a range of issues relating to pesticide safety and handling. Approximately one million hectares have already been sprayed this season (Fall 1988).

CONSULTANT'S ACTIVITIES

Upon arrival in Rabat, I reviewed the scope of work with R. Hellyer (Project Officer) and J. Kitts (Project Coordinator) to set priorities. They asked me to concentrate on an experiment to assess the effects of pesticide spraying on the non-target fauna of a habitat typical of those receiving treatment: they suggested that the area around Guelmim would be suitable for the proposed trials, partly to take advantage of the U.S. funded aircraft to spray the plots. They asked me to observe and participate in ongoing control operations and that I would provide on-site assistance and training to GOM and USG personnel. I was to report by telephone weekly to Joe Kitts, or as needed. With this in mind, I travelled to Guelmim via Ait Melloul (Desert Locust Center) in the company of Ahmed Boughdad (Entomologist, GOM Plant Protection Service) who, as my designated counterpart, was to be primarily responsible for the day-to-day implementation of any field project. We spent ten days in Guelmim, during which time we:

- Had discussions with GOM Plant Protection and military officials.
- Observed PC operations.
- Observed an attempt to spray flying swarms with GOM Turbothrush.
- Observed GOM Royal Airforce C130 operations from the aircraft and the ground.
- Made observations on the effects of malathion and DDVP spraying in various spray blocks. Visual transects at 1 hour and 24 hours after spraying showed few effects in either case: insect activity was generally low. There was no obvious mortality of arthropods under rocks after DDVP application (ants, termites, scorpions, 1 species of carabid beetle, 3 species of spiders) nor of ant-nests on the surface. No effects were noted in malathion blocks other than a heavy kill of ants on the surface at the time of spraying. Very small numbers of tenebrionid beetles were found dead in both cases.
- Visited the range of natural habitats in the area (Oued Draa seasonal flood zone, semi-arid steppe, cultivated fields and associated fallows, sand dunes, and mountainous Argan tree/Euphorbia woodland).

Our work was greatly hampered by the onset of heavy rains, flooding of oueds and the consequent destruction of several bridges. It was apparent, however, that biological activity was at a low level (both nocturnal and diurnal insect activity and diversity were low). In addition, most suitable trial sites around Guelmim had already been repeatedly sprayed with malathion and/or DDVP. We finally decided that Guelmim was not a good place for trials and we went on to Ouarzazate when the roads permitted. We spent five days in Ouarzazate looking at various

places. Once again, insect diversity and activity were low and further heavy rain impeded work. From Ouarzazate we left for Errachidia where we spent another two days before returning to Rabat. The PC at Errachidia has a small research unit and we visited a series of possible trial sites in the company of one member, Ahmed Drouich, and a range management specialist, El Mostafa Darfaoui. Errachidia would be a good place for any trials: the PC is well organized, has a computerized inventory of all areas sprayed and a small, ongoing research component. There are suitable sites within easy reach of Errachidia.
In all, we spent twenty-two days looking at a series of habitats representing a range of semi-arid to arid biotopes. Almost all habitats are severely degraded: most usable arable land is under cultivation or in eroding fallows; there is heavy loss of plant biomass and species diversity because of fuelwood collection; and there is widespread overgrazing, again resulting in lowered plant diversity. Soils are fragile and eroding heavily. Thus, many of the areas covered by locust control are already drastically disturbed ecologically and have diminished plant and animal species diversity.

GENERAL DISCUSSION

Chemical control of locusts using organophosphorus, carbamate or synthetic pyrethroid insecticides is the only effective method available at the present time. Control operations in Morocco are assumed to have both a tactical component and a strategic one. The former is crop protection and aims at preventing damage to agricultural production at the local level (e.g. a subsistence farmer's olive trees) and at a national level (e.g. the Souss/Massa). The strategic component aims to systematically reduce locust numbers, presuming that this will eventually have an effect on the total number of locusts in subsequent generations by reducing the residual populations returning to the summer breeding areas of the Sahel. There is no convincing evidence of such an effect to date. To a first approximation, control of adult swarms can be considered tactical crop protection, whilst hopper control is of strategic interest (92 % of direct economic damage is attributable to adult swarms, only 8 % to hoppers. See, for example, the ODNRI Locust Handbook).

All insecticides can have a range of direct and indirect effects on both the living and on the non-living parts of a given environment. Secondary effects of locust control may arise in various ways, including:

- Inevitable side-effects resulting from the correct, judicious application of particular insecticides. These include direct mortality of non-target species, the possible intoxication of herbivores or of secondary consumers (insectivores and other carnivores), and any possible bioaccumulation.

- Effects arising from the misapplication of chemicals. This may involve such things as use of the wrong chemical for the job; overdosing due to incorrect calibration or poor technique; bad programming (wrong time of day, wrong map coordinates etc.); willful dumping of insecticide, etc.

- Environmental contamination by insecticides because of poor handling: poor transport, leakage and spills, carelessness.

- Accidents may result in massive contamination.

- Habitat damage during operations: vehicle use in fragile environments; oil-changes; fires and fuelwood cutting; hunting, campsites, garbage etc.

- Groundwater contamination by organic chemicals (including solvents).

Initial recommendations for addressing some of these effects in Morocco are presented in the next section.

RECOMMENDATIONS

- As a first step in examining the effects of spray operations I recommend that field trials begin in January at sites in the Oued Draa and at Errachidia. These should be in the form of small, split-block trials (3 replicates) to look at the effects of pesticides on the non-target arthropod fauna of two habitats, in the absence of locusts: a seasonal flood zone in the Oued Draa and an arid steppe area west of Errachidia, in the 80 mm mean annual rainfall zone. Insecticides to be tested are malathion and DDVP (Dichlorvos), and possibly deltamethrin (Decis) also (See Annex for Protocol). There are two possibilities: using 30 hectare blocks sprayed by aircraft, with 1 hectare sampling plots; or, if aerial spraying is not possible, using 0.25 hectare plots sprayed with a hand-held, battery-powered sprayer (Ulvamicron or equivalent). These trials must include a residue sampling component. The results of such an experiment should provide a baseline of data on the effects of correctly applied pesticide. With such results in hand it will be possible to ask a hierarchical series of more complex questions: what are the effects of overdosing? what is the effect of large numbers of poisoned locust carcasses? what are the long-term consequences of spraying, if any? I would suggest that USAID ask the Plant Protection that Ahmed Boughdad be designated principal investigator.

- These field trials should include collecting samples for pesticide residue analysis. It is important to develop further the Moroccan capability to monitor residues. The Agriculture laboratory in Casablanca is a service-oriented

laboratory that is responsible for a full range of analytical work: in such cases, research needs are often given a lower priority when there is a lot of commercial work to be done. I think that USAID should take the opportunity to support a specific project at the I.A.V. Hassan II, Rabat, to set up a research-oriented pesticide analytical facility which could process samples from these trials and from pesticide application trials. The GOM should be encouraged to use regional locust control personnel to set up a network supplying environmental samples to this research effort. The results of such a survey should be reported on a regular basis to all interested parties.

- In addition, you should suggest that the PCC alert all field personnel to look for cases of possible intoxication or death in insectivorous and carnivorous vertebrates. Any specimens should be gutted: if locusts are found in the digestive tract they should be sun-dried and sent to Rabat for examination, along with the head, wings etc. of the victim to permit identification, with details of the locality, circumstances, insecticide type etc. Birds are particularly important in this respect since they are noticeable, have high metabolic rates and often restricted diets, are sensitive to environmental toxins and have relatively specific habitat requirements. Particular attention should be paid to raptors (hawks and falcons), white stork (Ciconia ciconia) and the Houbara Bustard (Chlamydotis undulata). Such a national alert would greatly improve the chances of noticing problems, since the probability of finding anything during limited small-block trials is very low. This is an area in which I believe qualified Peace Corps volunteers could participate with success: Peace Corps is already involved in wildlife management activities in Morocco.

- A parallel project would be desirable to look at the abundance and diversity of pollinators, parasitoids and other small flying insects in the Tafilalet oasis and along the oases of the Vallee du Draa between Ouarzazate and Zagora. If sticky traps were used it would not be very time-consuming during the height of activities: the traps can be labelled, stored flat and examined at leisure later in the year. Traps could be cheaply mass-produced in Morocco since the sticky material is available in bulk from Bioquip Products ("Tanglefoot": Bioquip, Gardena, CA 90248).

- In addition to this pilot, small-plot project, I would suggest that the Mission support an entomologist specifically to follow any further projected large aircraft activities, with particular attention being paid to non-target effects particular to these sorts of operations.

- The problem of misapplication: the way to mitigate this is to spray out less chemical and do so under the correct conditions. If we assume that the delimitation and flagging of spray blocks will continue to be of generally poor quality, then the single most important factor is pilot experience. Well-trained, experienced, professional agricultural pilots should be used exclusively since they can compensate to some extent for poor flagging. The GOM should require contracting companies to provide high quality pilots, thus avoiding situations such as that at Errachidia of two Agricolair pilots with absolutely no relevant experience and not much chance of acquiring it correctly. The same remarks hold true in principle for Gendarmerie pilots. Military pilots must be given further instruction in agricultural flying.

- There is a continued need to improve spraying operations by training ground personnel (see Training, Part 2).

- A major source of environmental pollution is the late morning spraying of insecticide when atmospheric conditions are unstable and the product is unlikely to reach the target. Many "second loads" fall into this category and many aircraft are doing this under pressure to appear to be working harder: this represents as much as 1000 liters of pesticide per aircraft per operational day. Every effort must be made to avoid such activities.

- Insecticide handling, leakage etc. I discussed my observations with Albert Fischer and Joe Kitts. Relevant information is included in Fischer's report and will not be repeated here, except to note that a major reduction in insecticide loss during filling operations could be achieved by requiring "dry-break" closed system pumping for all aircraft. In addition, the Mission must make a firm decision about the disposal of U.S. donated barrels and begin doing something about it.

- Groundwater contamination: I would strongly recommend that USAID, in collaboration with GOM Service Hydraulique, support sampling groundwater in Ait Melloul for solvent contamination.

- Rare and endangered species and the application of insecticide in ecologically sensitive areas. These issues have already been addressed in the Environmental Assessment, to the extent possible at the present time.

- Bees: There can be economically important losses to honey production caused by pesticides and also indirect losses because of a reduction in pollination activities. In Ouarzazate Province, according to Dr. Ezzahiri (Chef, Service d'Elevage), beehives were severely affected during last year's operations: approximately 2500 hives were seriously damaged, out of a total estimated at 12 000. Samples of bees, honey and wax were sent to Casablanca for analysis: organophosphorus residues were found in the bees but not in the honey nor in the wax. Apparently, foraging bees picked up the insecticide and contaminated others when they returned to the hive. Apiculture is extensive: most families have 1-5 hives, usually located in the walls of the house. A few producers have up to 80 hives. Honey from this region is highly appreciated, the bees foraging mainly on wildflowers. In addition to their local economic value, the bees of this region are apparently a distinct race which is of great interest to the international beekeeping community because it is highly productive: the bees have a large foraging radius and long mouthparts. Experiments in crossing these bees with canadian bees are already underway, for example. Thus these bees are a valuable resource and I think USAID should support further research by Moroccan scientists to determine explicitly the impact that locust insecticides may be having on the Saharan race of bees and what can be done to mitigate any problems. Contact persons are: Dr Ezzahiri; Mr. M. Taziz, Apiculturist, Elevage Rabat; Mr M. Loumrhari, Bee Consultant, Apiservices Rabat, B. P. 66 Sidi Allal Bahraoui.

PART 2. Locust Operations (End of TDY report)

This is the follow-up to the various discussions I have had with R. Hellyer, Eric Loken and J. Kitts. As requested, I have tried to condense my remarks and suggestions and present them in rather summary form. This report is based on my limited participation in ongoing control operations whilst in the field working on the proposal for the non-target monitoring (see Part 1).

Control strategies are discussed in the Africa Programmatic Environmental Assessment (TAMS Report) and in the Morocco Project documents such as the Environmental Assessment. Chemical control - using organophosphorus, carbamate or synthetic pyrethroid insecticides - is the only effective method available at the present time. Control operations try to mitigate damage to agricultural production at the local level (i.e. a subsistence farmer's olive trees) and at a national level (i.e. protecting the Souss-Massa). In addition, there is the presumption that systematically reducing locust numbers in Morocco will eventually have a noticeable effect on the total number of locusts in Africa by reducing the residual populations returning to the summer breeding areas in the Sahel. This was apparently not the case for Morocco last campaign despite over 1.2 million hectares sprayed in late season. Swarm control is of immediate importance, as regards crop protection, since swarms are responsible for over 90 percent of economic damage. Although hoppers generally cause little economic damage, reducing their numbers may lower the eventual number of swarms formed.

The development of the Moroccan locust situation this season has been relatively straightforward up to now. Beginning in early October 1988 swarms of reproductively immature adults have been arriving on the southern edges of the Anti-Atlas and Atlas Mountains. Some of these swarms have reached the Souss Valley or penetrated the eastern Atlas Mountains (for example, around Rich, north of Errachidia), despite control efforts. Moroccan control efforts have been successful thus far in preventing any recorded, economically important damage to crops. All these swarms appear to originate from the southwest and are immature and in good physiological condition. Swarms mostly contain pink individuals with a few mature, yellow males and solitarious and transiens locusts also. All swarms seen in Morocco this season have these characteristics, in contrast to Fall 1987 when the swarms were mature locusts ready to lay. Many swarms are skirting the flanks of the Anti-Atlas, arriving on the plain around Errachidia through valleys to the southwest, for example. In the last ten days locust activity has increased in the east of the country (Bouarfa, Ain Shair, Tendrar, Ait Beni Mathar, Guercif), with swarms arriving from the southeast. Over a million hectares are reported sprayed to date. Reported new swarms were fewer

during the last week in November: there appears to have been a period of calm coinciding with widespread rains and cooling temperatures. However, intense swarm activity has been reported to OFDA along the Senegal-Mauritania border and swarms were reported moving north along the Mauritanian littoral belt above Nouakchott. There are reports of rainfall in west-central Mauritania (23-24 degrees north) so some swarms may breed there. This and continued cooling may slow down or prevent some of these swarms from entering Morocco: one can expect swarm incidence in southern Morocco to drop dramatically in the next ten days. One should be alert to the possibility that successful breeding in central and northern Mauritania could result in a replay of last campaign's massive movements into Morocco in March-April 1988. A credible forecast is impossible without good survey information from Mauritania. Control operations are ending in the Adrar des Iforas of Mali: this area will probably have produced only a small number of swarms. The situation with the massive locust populations in the western part of Soudan is unclear for the moment. It seems that the Moroccans have already decided to prepare for the worst case scenario - basically a replay of last season - which may be prudent since there appears to be a developed upsurge that may continue for some time to come.

SURVEY

The Moroccans are using a network of vehicle teams to survey and follow locust swarms. These teams report by radio to regional Command Posts where the results are tabulated and the decisions are made as to what action should be taken. All information is passed to the central Command Post in Rabat. The system is basically well organized and logistics are good. Ground survey teams are aided by helicopters to target their activities: helicopters are used especially in difficult terrain. Based on my observations of the system working in Guelmim, Ouarzazate and Errachidia and based on conversations with the pilots who end up spraying the designated blocks, I think it would be worthwhile to provide survey teams with good compasses and training in map-reading and position reporting.

In addition, I think the GOM should consider using small, good visibility high-wing spotter aircraft to detect and follow moving swarms. These aircraft are much less expensive to operate than helicopters, and would free helicopters for vital activities. Finally, I would like to suggest that the GOM research the possibility of using their existing radar capability to develop a swarm early warning system. Radar tracking of swarming insects in flight has been successful and there are several papers on the subject (I believe information would be available from the FAO Locust offices in Rome).

SPRAY BLOCK DELIMITATION AND FLAGGING

This is the weakest part of all spraying operations and it requires a constant effort to keep standards from dropping. Block marking may be adequate but it is rare to see swath flagging since it requires considerable manpower, time and organization. The first and most important point is that the pilots and ground teams must be properly trained (see below). In addition, it is essential to have ground to air radio contact between the flagger and the aircraft. Blocks are marked mostly with smoke (usually burning tires) which can work quite well if the pilots and ground crew have previously agreed on a standard layout. GOM does not appear to be using the smoke flares provided by USAID. I think that all vehicles to be used for flagging should have the roofs painted gloss-white with a large red cross and should each have a powerful, portable blue strobe light. Each flagging team should have a ground/air VHF radio.

In the interim, every effort should be made to assure that only trained and experienced, professional agricultural pilots are contracted, since they can sometimes compensate somewhat for poor or non-existent flagging.

In addition, each spray-block team should be supplied with instruments to record the wind, relative humidity and air temperature at the beginning and end of each treatment. These data must be collected for every treatment to help, at least, retrospective analysis of problems. Instruments needed are a hand-held windmeter (anemometer), compass (wind direction) and a robust psychrometer (which can be used for temperature and humidity). Care should be taken to supply metric system instruments.

TRAINING

The GOM has a continuing programme for different sorts of personnel participating in locust control activities. Any USAID sponsored training should be slotted into the calendar of these activities: asking short-term TA's to attempt to organize training courses at the height of operations is not profitable. I see a need for training in three major areas:

- A discussion of the basic principles of agricultural spraying for military and Gendarmerie pilots (and some contractor). Such a course should include the participation of an experienced, articulate spray-pilot (preferably French or Arabic speaking). An outline of some course topics is given in the Annex, along with a copy of a supplementary text that has been used in USAID sponsored courses in the Sahel.

- A course in spray zone delimitation, marking and swath-flagging for ground crews. This should include use of a compass, map reading and position reporting. It should also include a round-table discussion with pilots (what can be seen from the air?etc.). There must be practical field work and problem solving during the training.

- A decision-making/operational management workshop for PC field managers, to bring together the best ideas from the different PC's.

APPLICATION METHODS AND PESTICIDES

USAID has been receiving conflicting reports that malathion is not performing well for settled swarm control in some instances. Mr Hellyer asked me to try to collect information on the problem whilst in the field. I watched several applications of malathion and DDVP with this in mind but was only able to collect useful data in limited instances (see below). The problem appears to be quite a complex one. One aspect is that malathion was being applied, in some cases, under completely the wrong conditions (low temperature and high humidity). Unfortunately in corollary, during this time of the year in Morocco when temperatures are high enough for good malathion action (above 25 degrees C), atmospheric conditions are often too unstable for good deposition of the insecticide, limiting opportunities for correct application. When malathion is correctly applied against desert locusts and the insecticide contacts the insects, kills are acceptable (90-95 %), although the full effect may take two to three days to manifest itself, like many other organophosphorus pesticides, such as fenitrothion. The actual toxicity of malathion is not in doubt at this point and it seems highly unlikely that any resistance is involved. It is important to note that it is difficult to estimate mortalities in the field, particularly for the slower acting insecticides and accurate assessment requires rather careful and often time-consuming work. There is a definite tendency to unwittingly overestimate the numerical effect of rapid action pesticides, such as DDVP or Karate, because even somewhat lower mortalities are quite spectacular visually: I feel it is virtually impossible to distinguish, say, sixty percent from ninety percent by visual estimation when the total number of locusts is very great. It is quite difficult to estimate the number of locusts leaving the sprayed area. DDVP does seem to be more effective than malathion in swarm spraying: the material has a very high specific toxicity to desert locusts (the amount for single drop toxicity is ten times lower than for malathion, for example. See: MacCuaig, 1983, FAO Insecticide Index). Very careful quantitative studies are urgently needed to resolve some of these questions.

Another part of the problem may have to do with ULV application itself. ULV application aims to distribute insecticide evenly across the sprayed area and the product acts in two ways: direct contact with the target insects at the time of application kills or incapacitates a certain percentage; then subsequent contact with the insecticide deposited on the surface of vegetation affects a further proportion (when the insects move through or feed on the treated vegetation). In a classic ULV application this latter component is very important. If the target insects are homogeneously/randomly distributed, the first component of mortality can be quite high since it is basically a result of the relation between droplet distribution and insect distribution. If however, the insects are highly clumped or somehow protected during the initial chemical application then their subsequent contact is the more important component. Insecticide that lands on bare soil has no further action on the target locusts to all intents and purposes. Roosting locusts tend to be very clumped, in many cases: if they occupy say twenty percent of the horizontal cross-sectional area of the spray-block, then the initial contact action will involve approximately that proportion of the dose applied. This means that the effective dose is actually one fifth of the applied dose. Many of the areas where adult locusts roost have less than ten percent vegetation cover, so a lot of the insecticide is absorbed immediately into the ground. Even when the vegetation index is higher, contact between adult locusts and treated vegetation is lower than with many other pest species since they tend to take flight rather abruptly after warming up in the morning, leaving the treated area. With short residual-time insecticides the probability that any locusts will recontact sprayed vegetation is rather low. There are clearly fundamental limitations in many instances to using ULV spraying for controlling swarms and the problem may be exacerbated by the temperature/humidity requirements of malathion. In many cases one is only using the initial contact action of the insecticide during spraying: this can be effective if the locusts happen to be settled uniformly across the ground (e.g. the Plage Blanche situation. See below). Efficacy may be much lower if the locusts are highly clumped in a few trees surrounded by bare ground. Increasing the dosage (volume per hectare) would probably help somewhat but a limit is reached very quickly and such an increase also increases the real volume of "wasted" insecticide, resulting in more environmental pollution. These problems with ULV treatment of settled swarms are not new but there has been very little useful research conducted on these sorts of operational problems since the days of dieldrin: it would be most interesting to conduct such research on application of organophosphorus chemicals during the life of the Project.

Concerning malathion, Ahmed Boughdad and I collected preliminary but unambiguous data as follows: On 14 November, 1988 we arrived in the spray zone near Guelmim well ahead of the aircraft and collected a control sample of 215 insects. We watched the spraying by the two US-financed Turbothrushes and talked with the pilots on VHF. We verified that the malathion was getting to the ground, partly by noting good deposits on the consultant's glasses! Outside air temperature was 21-22 degrees centigrade and coverage looked good to us and to the pilots, both experienced in applying malathion. We later verified the calibration (0.8 liters/ha) and confirmed flight height at 3-4 meters. We waited until the insects began to fly before collecting a sample of 209 locusts from the central part of the sprayed area where we were sure the insecticide had arrived on target. The insects were divided into groups and kept in clean cotton bags. Mortalities were 33 % after 7.5 hours and 50.5 % after 24 hours (Control - 0 % and 1.4 % respectively). When one takes into account the highly clumped distribution of the locusts in the area sprayed, this may be the best one can expect in overall mortality under these conditions. Our attempts to duplicate these observations were unsuccessful: we had hoped to obtain comparable data for DDVP, for example.

Last season, on the other hand, malathion was sprayed on a widely settled swarm on the Plage Blanche under ideal temperature conditions, with excellent mortalities resulting (George Cavin, pers comm, and the pilots, pers comm).

Observing a clear case of misuse, we arrived several minutes after the DC-7 had completed spraying about 3000 hectares near Tazenakht (Ouarzazate). At the end of the spraying the OAT was 12 degrees centigrade. The ground team had been in radio contact with the aircraft during treatment but did not know it was too cold to treat. It began raining about an hour after spraying. Mortality after 32 hours was 12.5 %.

The problem of low mortality during ULV spraying of settled swarms may not be unique to malathion and malathion may not be giving worse results than any other insecticide under the circumstances but improvements must be made. Malathion is still a very useful chemical, with a number of very desirable characteristics from USAID's point of view (Ease of handling, low mammalian toxicity, source of origin etc.).

Several things can be done:

- All personnel working with malathion should be given better instructions in its use. Unfortunately, American Cyanamid has not published literature on malathion for locust/grasshopper use (in English or French), unlike all other major manufacturers of locust insecticides.

- Flagging teams must be equipped with windmeters and psychrometers and relevant data must be recorded for all spraying: at least this will allow retrospective analysis. In addition, ground teams must be encouraged to use informed discretion to abort spraying if warranted: we must get away from the idea that the cumulative number of hectares sprayed is a measure of effectiveness.

- A series of carefully designed and controlled field experiments should begin immediately, to study objectively malathion's effectiveness under Moroccan conditions. Clear comparisons should be made with other insecticides currently being used such as DDVP, deltamethrin, fenitrothion etc. Care will be needed to separate the effects of application methods themselves, vegetation structure etc. Because of the very great difficulties posed by tracking swarms to collect postmortem data, it would be preferable to adopt the method of collecting control and treated insects from spray blocks and keeping them to track mortality (suitable cylindrical cages can be made from mosquito-netting or cotton fabric 1.5 meter by 1 meter. These are inexpensive, easy to transport and wash). For an initial study, any cage effect can be ignored. Mortality estimates of highly mobile targets by visual examination are unreliable: people unintentionally overestimate the mortality caused by DDVP, for example, because the results are so spectacular but it is difficult to distinguish between 60% and 90% at high swarm densities, when large numbers of insects leave the spray zone in either case. The results of such studies should allow one to list clear guidelines for the use of malathion against swarms, if such use is thought to be warranted.

- Malathion use against settled swarms should be limited, to the extent possible, pending the results of further field studies. Malathion should not be applied when humidity is high and temperatures are below 22 degrees centigrade. Since the Moroccans claim good results against hopper bands with malathion, I suggest that the stocks be kept for this purpose.

- In addition to malathion, USAID should encourage an objective assessment of other possible insecticides for use in Morocco, particularly deltamethrin (Decis) and bendiocarb (Ficam) which apparently have low mammalian toxicities. Also, it may be worthwhile trying a combination "cocktail" of malathion and lambdacyhalothrin (Karate) for swarm control.

- Since the objective assessment of these application problems is so important ,it would appear to be worthwhile for USAID to consider incorporating an ongoing program of operational research into the present project, rather than just settling for a piecemeal approach.

In addition, there is the continued problem of pesticide being sprayed later in the day when atmospheric conditions do not allow the chemical to reach the ground (second loads). Aircraft were flying late morning loads regularly in Guelmim, with 20-30 minute ferry times (including the US-financed Turbothrushes). This is a waste of insecticide and is a needless environmental burden. One should not underestimate the magnitude of this: it represents up to 1000 liters of pesticide per aircraft per day.

The above remarks apply to aerial spraying: there are also some particular problems associated with ground spraying. I think that USAID must continue to stress that aerial spraying is still the preferable method for treating large swarms, whilst ground spraying can in many circumstances be a mainstay of hopper control. It is more difficult to avoid overdosing when using ground equipment, it results in higher pesticide exposure to workers and requires more manpower, vehicles etc. The problem can be illuminated by a case history: I watched the treatment of 300 hectares of settled swarms outside Errachidia, applying 4% DDVP using motorized backpack sprayers and a truck-mounted exhaust nozzle sprayer. The operations were generally well-done, with personnel wearing proper protective equipment etc. Approximately twenty people were involved in these activities from 0500hrs to 0930hrs. Although the spraying was generally good, there were a number of bands treated twice, some applications at right angles ("to make sure") and one worker inadvertently sprayed another. If the same number of people had been used to flag this block correctly, a Pawnee aircraft could have done the job better in terms of mortality, a lot faster and with less pesticide exposure to workers and the environment. The organizers of this exercise told me that they did not have the manpower for proper aircraft flagging and that the pilots did a good job without flagging.

Further research is needed to determine the impact of ground spraying: we saw areas with chemical damage to perennial vegetation resulting from last season's actions, most likely the result of overdosing of 4% DDVP during ground operations. In one such area of about 100 hectares southwest of Errachidia the trees and bushes had not recovered ten months later and there were still piles of untouched locust carcasses lying about. The Plant Protection Service is aware of the problem but further study is needed to see if habitat damage is a general result of ground treatment.

TECHNICAL ASSISTANCE AND RESEARCH

Research is needed on insecticide use and application methods under Moroccan conditions and long-term studies need to be done on the environmental consequences of chemical application. In a separate report I have suggested starting such research - in the present context of crisis intervention against invading swarms - with a pilot experiment on non-target organisms in early 1989; an initial residues-analysis study to include groundwater; and a look at bees. These activities should form the basis for an explicit, long-term environmental component to the Locust Project, to be funded for the duration of USG participation in locust control and designed accordingly. Such a plan should support development of a Moroccan capability to do the following:

- a consecutive series of observations and experiments on non-target organisms.

- establish a country-wide sampling network for residues, with regular reporting of the results.

- a separate look for groundwater contamination by pesticides and organic solvents.

There will be a need for USG technical assistance also in areas such as pesticide trials; training in operations and pesticide management; environmental evaluation; and loss assessment. I feel it would be much more effective to program a long-term Technical Assistance position into the project rather than a series of short-term TA's. Such a person would have the time to develop a deeper working relationship with her colleagues; prepare a comprehensive package for research and training to fit into the Moroccan work calendar; and participate seasonally in crises and in problem-solving. Any technical assistants should work out of the Desert Locust Centre at Ait Melloul, and one task should be to develop a proposal to improve the research and information-gathering capabilities of the Centre.

ANNEX 1

TABLES: SUMMARY OF INSECTICIDE USE IN 1987-88 CAMPAIGN
(Source: GOM Campaign Report, September 1988)

INSECTICIDES USED:	VOLUME IN LITERS:
DDVP (Technical Grade)	88,702
Fenitrothion ULV 500	120,600
Fenitrothion ULV 1000	407,290
Malathion ULV 96%	781,561
Carbaryl 40	42,784
Diazinon 900	8,200
Karate 40	8,900
Solvent (HAN)	1,900,000

For a total of 1,458,037 liters of pesticides and 1,900,000 liters of solvent.

TREATMENT AREAS IN HECTARES:

POSTE COMMANDE	AERIAL TX	GROUND TX	TOTAL	%
Guelimim	759,789	138,050	897,839	31.92
Tata	314.466	120,508	434,974	15.46
Laayoune	35,440	117,041	152,481	5.42
Dakhla	8,300	108,710	117.010	4.16
Ouarzazate	345,041	166,388	520,429	18.50
Errachidia	147,643	157,746	305,389	10.86
Bourfa	219,813	136,975	356,788	12.68
Oujda	2,400	25,872	28,272	1.00
TOTAL	1,841,892	971,290	2,813,182	100.00

ANNEX 2

OUTLINE AND PROTOCOL FOR A PILOT EXPERIMENT TO ASSESS THE EFFECTS OF LOCUST SPRAYING ON THE NON-TARGET ARTHROPOD FAUNA IN MOROCCO

DEFINITIONS

STUDY SITES: Sites should be in the general areas undergoing spraying, should be ecologically representative and preferably not infested with desert locusts. One site should be located in the Oued Draa seasonal flood zone and another in the arid steppe west of Errachidia. The exact sites for the experiments should be chosen by the principal investigator in January, from the range of possible sites visited.

EXPERIMENTAL UNIT: Split block.

REPLICATION: 1 malathion sub-block, 1 DDVP sub-block, 1 control sub-block, matched as closely as possible for physical and biological characteristics.

SAMPLING METHODS: Ground arthropods will be sampled using pitfall traps: buckets inserted flush with the ground surface that will be emptied daily. The traps will have square, white painted covers (30 x 30 cm). Small flying insects will be monitored using TRECE sticky traps mounted on 1 meter poles. Residues will be sampled on soil, water and vegetation (annual and perennial). Other sampling methods can be added if time is available.

OUTLINE

SURVEY: Identify suitable homogeneous sites of approximately 100 hectares. Map area and inform local authorities of site locations.

DELIMIT AREAS: Define blocks, sample plots and mark with flags on stakes.

For aerial spraying, delimit two 30 hectare blocks for treatment and a 30 hectare control block which should be upwind of treated areas. There should be at least 500 meters wide buffer zones between treated areas.

For spraying with a hand-held, battery-powered ULV sprayer (Ulva-micron or equivalent), delimit 1 hectare plots.

DESCRIPTION OF SITES: A detailed description of physical characteristics, soil, vegetation, animal and/or human use, etc... Begin daily recording of temperature (maximum/minimum), humidity, rainfall, and the condition of the sky.
PRE-SPRAY ACTIVITIES: Take samples of vegetation, soil and water for residue analysis (follow whatever protocol is requested by

Plant Protection Casablanca laboratory or researchers at I.A.V. Hassan II, Rabat). Flag blocks for spraying with 1 x 2 meter white flags on 3 meter poles. Install pitfall traps, stakes for sticky traps. 10 pitfall traps should be installed at 15 meter intervals along the vertexes of a triangle i.e. 3 radial 45 meter transects. 9 sticky trap sites should be assigned randomly. Unambiguously mark any other equipment calibration on a separate check plot. Begin separate test to establish best interval for changing sticky traps (1 day, 2 days, etc.).

When all this has been done, decide on date of spraying and then begin pre-spray data collection (5 days before, 1 day before).

AERIAL SPRAYING: Spray units of 30 hectares (1000 x 300 meters) with each chemical (malathion and DDVP) at rates currently used. Malathion 96% ULV: 0.75 liters/ha (885 g active ingredient/ha). DDVP (Dichlorvos) 20%: 1 liter/ha (200 g active ingredient/ha). Control pilot should be upwind of spray plots. Staggered plots with 500 meter buffer zones. A line of spray cards perpendicular to the swath to monitor deposit (150 meter line at 5 meter intervals, horizontal and vertical cards at height of 20 cm. Vertical cards should be less than 6 mm wide). Minimize drift, VMD 80-120 um. Aircraft height should be 3-4 meters, no wind.

GROUND SPRAYING: Spray 1 hectare plots with Ulvamicron (fresh batteries). Monitor deposit with cards. The same cautions apply as with aerial application.

IMMEDIATE POST-SPRAY: Qualitative assessment of any mortality; collect cadavers for reference at 1, 12 and 24 hours. Install sticky traps and check pitfall covers.

SAMPLING: Three replicates. 9 one hectare plots, each with 10 pitfall traps and 9 sticky traps located in the central part of sprayed areas to minimize any edge effects.

SAMPLING FREQUENCY: Sample intervals of -5, -1, 0, 1, 5, 10, and 15 days post-spray. Pitfall traps emptied daily (early morning).

DATA ANALYSIS: Population counts, enumerated by taxa (taxonomic level to be decided). Data will be interpreted using appropriate linear models (ANOVA, comparison of means).

SUPPLEMENTARY ACTIVITIES: Qualitative observations on other taxa, including vertebrates. Taxonomic inventory of study area. General insect collecting in adjacent matched sites, including light trapping, beating, malaise trap, for baseline faunal information. Investigate other possible methods of monitoring e.g. blacklight transects for scorpions, constant time counts of bees visiting bushes, robber fly transects, etc...

DISCUSSION

These activities will probably require the full time participation of at least two people per site. Time required to collect the data is the constraint. I estimate at least one week to delimit areas, install traps, stakes, etc. Approximately two weeks for sampling and another week for analysis and write-up (longer if taxonomic work is needed). It should be possible to spray both chemicals in one morning (30 ha each).

The ground fauna will be sampled with the pitfall traps whilst the sticky traps will catch small flying insects. Larger flying insects are not being sampled. Neither sweep-netting nor light trapping are valid quantitative techniques and are not recommended for a study of this sort. It might be possible to identify indicator species to use as monitors: they should ideally be easily located, identifiable, regularly distributed and numerous enough to provide a valid sample. I predict that whatever sampling is done, the results will prove to be highly variable in space and time. This problem can only be solved by much more intensive sampling.

MATERIALS LIST FOR SMALL-BLOCK TRIALS

Maps, large blank sheets for mapping site
Marking stakes, 60 cm long, and paint
Flag poles (3 m) and 1 x 2 meter white flags (20)
Compass or 90 degree prism
Measuring tape or rope (30 m)
Notebooks, pens, pencils
Recording forms and clipboards
Field tags, marking pens
Spray cards (3 packets)
Spray card holders, 30 cm wire (45)
Pliers and roll of wire
Sticky traps (300)
Stakes, 1 meter painted (100)
Pitfalls: 100 plastic buckets (20 cm x 18 cm)
100 covers, painted plywood 30 cm x 30 cm
nails for feet
Picks and shovels
Plastic bags (500)
Alcohol, ethanol 95% (2 liters)
Measuring cylinder 500 ml
Rubber gloves
Bucket
Collecting light
Insect nets
Killing bottles
Insect pins and boxes
Flashlights, batteries
Maximum-minimum thermometer
Psychrometer
Raingauges
Hand-held windmeter
2 hand click counters
2 10-gallon ice-chests (transporting residue samples)
200 20 cm x 30 cm plastic bags (for samples)
2 20-liter water bottles
2 Ulvamicron sprayers
4 sets of batteries for sprayers

ANNEX 3

The following is a summary of the main topics to be covered in an introductory course on aerial spraying (reference should be made to Castel's paper on aerial spraying - I left a copy with Joe Kitts, USAID, Rabat).

RESUME DES POINTS CLEFS

SEANCE DE FORMATION AU SUJET DU TRAITEMENT AERIEN

UBV (Ultra Bas Volume = ULV (Ultra-Low Volume)

Des produits ULV sont des formulations particulieres et tres concentrees.

En traitement ULV on se sert du vent naturel et un souffle produit par l'avion pour creer un tourbillon di'insecticide qui va permettre aux gouttelettes de penetrer dans la vegetation.

But de l'application: repartir le plus regulierement possible la matiere active et contacter tous les insectes cibles avec la quantite de produit necessaire pour les tuer.

De nombreux facteurs vont intervenir sur la repartition de la puverisation (qui vont determiner la qualite d'une application).
- Le volume
- Les conditions meteos
- Les gouttelettes - nombres, tailles, spectre
- La hauteur et la vitesse du vol
- La precision du vol

EXPLIQUER ET ELABORER:

o Le volume: cela est faible en ULV (une moyenne environ 0.5 - 1.0 litre a l'hectare). Question d'economiser et rentabilite. Cela exige une application precise.

o Les conditions meteorologiques:
  -Le vent: essentiel de comprendre que l'ULV est une pulverisation en derive controlee. Le vent est donc l'un des principaux vehicules pour transporter des gouttelettes vers la cible (avec le souffle d'avion et la gravite). La trajectoire d'une gouttelette varie avec le diametre, la hauteur du vol et la vitesse du vent.

  -La temperature et conditions thermiques

  -L'hydrometrie

o Les gouttelettes:
  -Nombre: on compensera le faible volume en ULV en augmentant le nombre de gouttelettes (diminution

de la taille). En divisant le diametre par deux, on obtient huit fois plus de gouttelettes, a partir du meme volume (relation cubique).

-Taille ideale: 80-120 um

-Spectre: la repartition des gouttelettes en nombre et en taille autour d'une moyenne. Le rapport VMD/NMD permet de juger l'homogeneite du spectre (1 a 3 optimale).

VMD = Diametre median du volume (c'est a dire le diametre autour duquel se partage d'une facon egale le volume total).

NMD = Diametre median du nombre

- La hauteur du vol et la vitesse
- La precision du vol: le traitement efficace depend de recouvrements reguliers et successifs (andains). Question surtout de guidage et l'experience du pilote.
- Comment assurer une bonne couverture: l'importance de balisage et jallonage.
- Problemes pratiques sur le terrain
- Controle de la qualite d'application