PN-ABG-720

Consortium for International Crop Protection

4321 Hartwick Road, Suite 404, College Park, Maryland 20740 USA
Telephone: (301) 454-514. Cable: CONSORTICP
Telex: 5106013983

9 4142

69264

ENVIRONMENTAL ASSESSMENT

ANALYSIS OF AERIAL APPLICATION OF FENITROTHION ULV FOR LOCUST CONTROL IN SUDAN

SUDAN MULTI-DONOR LOCUST/GRASSHOPPER CONTROL PROGRAM

Prepared for: Food and Agriculture Organization, United Nations

Prepared by: Consortium for International Crop Protection
4321 Hartwick Road, Suite 404
College Park, Maryland 20740
USA

Report team: Lawrence J. Pinto
Jon B. Mann
Dale G. Bottrell

Report Date: February 1988

Member Institutions: University of California, Cornell University, University of Florida, University of Hawaii, University of Illinois, University of Maryland, University of Miami, University of Minnesota, North Carolina State University, Oregon State University, University of Puerto Rico, Purdue University, Texas A & M University, United States Department of Agriculture

TABLE OF CONTENTS

page

List of Tables iii

List of Figures iii

PART I
SUMMARY AND RECOMMENDATIONS 1

PART II
SUDAN MULTI-DONOR LOCUST/GRASSHOPPER CONTROL PROGRAM 8

A. Purpose 8
B. Affected Environment 12
C. Population 16

PART III
PURPOSE OF THE ENVIRONMENTAL ASSESSMENT 19

PART IV
PESTICIDE USE ASSESSMENT 20

A. Basis for Selection of Fenitrothion 20
B. Registration Status of Fenitrothion 21
C. Technical Data on Fenitrothion 21
D. Integrated Pest Management and Alternative Methods of Control 23
E. Application Methods and Equipment 25
F. Acute and Long-term Toxicological Hazards 28
G. Efficacy of Fenitrothion for Locust Control 32
H. Effect of Fenitrothion on Nontarget Organisms and the Natural Environment 33
I. Conditions of Insecticide Use 40
J. Availability and Effectiveness of Other Pesticides or Control Methods 41
K. Ability of the Republic of the Sudan to Regulate Distribution, Storage, Use, and Disposal of Pesticides 43
L. Provisions Made for Training Pesticide Handlers and Applicators 45
M. Monitoring the Use of Fenitrothion and the Effectiveness of Treatment 46

PART V
POTENTIAL IMPACT OF AERIAL LOCUST TREATMENTS WITH FENITROTHION ULV ON THE HUMAN ENVIRONMENT 47

PART VI
ALTERNATIVES TO INSECTICIDES FOR LOCUST CONTROL 47

PART VII
UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS 47

PART VIII
RELATIONSHIP BETWEEN SHORT-TERM AND LONG-TERM EFFECTS 48

PART IX
WAYS TO MINIMIZE OR AVOID ENVIRONMENTAL DAMAGE 50

PART X
LITERATURE CITED 52

PART XI
ACRONYMS, ABBREVIATIONS, AND GLOSSARY 55

PART XII
APPENDICES 61

A. Field Evaluation of the Environmental Impact of Aerial Applications of Fenitrothion 96 ULV for Locust Control 61

B. Persons Contacted 83

C. Fenitrothion Registration Standard (U.S. EPA) 85

List of Tables

Table 1. Decomposition of Fenitrothion Technical Grade at Different Storage Temperatures 23

Table 2. Acute Toxicity of Fenitrothion 96 ULV 29

Table 3. Endangered and Threatened Species in Sudan 38

Table 4. Liquid Pesticides Available for 1987 Locust/ Grasshopper Campaign as of 30 July 1987 42

List of Figures

Figure 1. Seasonal Distribution of Desert Locust in Sudan 10

Figure 2. Environmental Zones in Sudan 13

Figure 3. The Democratic Republic of Sudan 17

Figure 4. Predominant Patterns of Settlement 18

PART I
SUMMARY AND RECOMMENDATIONS

In 1986, locust and grasshopper populations soared and created problems in Sudan following a sequence of rains. An emergency Multi-Donor Locust/Grasshopper Control Program, funded by the United States Agency for International Development (AID), The Netherlands, and European Economic Community (EEC), and monitored by experts from the Food and Agriculture Organization of the United Nations (FAO), provided relief from August to December 1986.

In 1987, two follow-up programs were initiated. One program was a short-term emergency campaign similar to that launched in 1986. The other program was a medium term (3-year) project to provide resources, training, and standards for control needed to bolster Sudan's long-term capacity for dealing with locusts and grasshoppers.

Aerial applications of the insecticide fenitrothion ULV 96 is the primary control tactic used against locusts in the Sudan Multi-Donor Locust/Grasshopper Control Program. Fenitrothion is the subject of this environmental assessment. The purpose of the assessment was (1) to examine the foreseeable impacts on the human and natural environment of the insecticide and (2) to propose measures to reduce or eliminate negative impacts when possible. The assessment, conducted by the Consortium for International Crop Protection (CICP), involved a number of on-sight visits to Sudan and a series of field trials. The field trials are summarized in APPENDIX A. The persons contacted in APPENDIX B served as resources for much of the data presented in the document.

Aircraft and crews in the Sudan Multi-Donor Locust/Grasshopper Control Program are provided by the Desert Locust Control Organization for Eastern Africa (DLCO) and local private contractors. Aircraft provided by aerial spray contractors do not meet the standards necessary for safe operation. For example, a contract aircraft used in a field trial in this assessment did not have any charts or maps, insecticide pump, or safety equipment.

RECOMMENDATION: The Plant Protection Directorate (PPD) of Sudan's Ministry of Agriculture should require the aircraft contractors to provide safer and more sophisticated equipment on contract aircraft. At a minimum, the aircraft should have radios, detailed grid maps, extra pairs of rubber gloves and goggles, and an insecticide pump.

The potential human toxicological hazards from aerial locust treatment are (1) dermal exposure of the insecticide to loaders, (2) direct dermal and inhalation exposure of people present in spray sites, and (3) oral exposure from crop residues.

There appears to be little risk to the general public from fenitrothion applications, although any pesticide that introduced into the environment will pose at least a marginally increased risk to people in the area. The pesticides used in other control programs in Sudan, particularly in cotton, likely pose a much greater risk.

The major human health hazard identified was dermal exposure to insecticides by loaders and others. Insecticide concentrates and technical materials are handled without gloves and goggles and other required safety equipment. Pesticide loaders commonly contaminate themselves. Safety equipment has been provided to all PPD field offices involved in locust control but it is apparently rarely used.

RECOMMENDATION: Pesticide handlers should wear rubber gloves and goggles when loading spray tanks and performing other tasks that require the handling of concentrates or technical material.

RECOMMENDATION: Increased safety training for pesticide handlers including a yearly safety course.

RECOMMENDATION: Supervisors and program staff should insist that safety rules are followed and take disciplinary action if they are not.

RECOMMENDATION: Pesticide handlers should be monitored for cholinesterase depression.

Pesticide loaders in the program handle drums of fenitrothion carelessly, without regard to potential hazard. Drums are often simply dumped out of the back of a truck onto the ground.

RECOMMENDATION: Insecticide loaders should use an old tire as a cushion to minimize the risk of bursting a drum when unloading it from a vehicle.

Fenitrothion is generally applied at higher dosages than needed to provide satisfactory locust control. This practice of overdosing wastes the insecticide, is costly, and increases the threat of harm to the environment and human health.

RECOMMENDATION: Fenitrothion for locust control should only be used at recommended dosages. If it proves ineffective, another insecticide should be substituted.

The potentially most serious environmental effect of fenitrothion is harm to invertebrates in the spray area. Of major concern are the effects on predators, parasites, honey bees, and wild pollinators. In the field studies conducted in this assessment (APPENDIX A), the diversity and abundance of insects and other arthropods in treated fields was reduced significantly after aerial application of fenitrothion ULV.

RECOMMENDATION: Avoid treatment when possible at locations or at times when honey bees and other pollinators are active.

Birds may ingest insects that have been killed or contaminated by fenitrothion, they may be directly sprayed, they may breath the droplets, or they can absorb fenitrothion through their feet. Results of field tests to determine the effects of fenitrothion on birds were inconclusive (see APPENDIX A), but toxicological data in the literature indicate that the insecticide may harm bird populations.

RECOMMENDATION: Avoid treatment where there are large numbers of birds or where rare species are known to occur.

Maximum residue levels of fenitrothion detected on forage grass and Acacia leaves were roughly 100 ppm on the day of treatment during field trials. The levels quickly declined.

RECOMMENDATION: Allow at least 7 days to elapse before livestock are permitted to forage on grasses or fodder. Acacia foraging should not begin until 14 days post application.

The U.S. Department of Interior lists 11 endangered or threatened mammals in Sudan. The International Union for the Conservation of Nature and Natural Resources (IUCN) lists 12 species. Very little is known of their distribution within Sudan except in the most general terms.

RECOMMENDATION: Avoid treatments in areas of known rare or endangered or particularly sensitive nontarget species.

The water systems most likely to be impacted by locust control operations are the wadis, or seasonal watercourses that are scattered throughout desert locust areas. Little is known of the fish and invertebrate fauna inhabiting the wadis. Most published studies on fenitrothion's effects on aquatic systems report significant decreases in aquatic invertebrates after application to water but no mortality to fish.

RECOMMENDATION: Aerial sprays should not be made within 100 meters of active water sources such as wadis, rivers, irrigation canals, or water holes.

Fenitrothion's phytotoxicity to sorghum and other crops is a serious concern. In one field trial, aerial application of fenitrothion 96 ULV was toxic to durra sorghum. The dosage was 0.6-0.8 liter/ha, higher than the targeted dosage of 0.5 liter/ha because of poor equipment calibration. Sorghum leaves were burned and spotted in 30% of the sampled plants 24 hours post-treatment. Seven days after treatment 100% of the sorghum plants in the treated field had at least their upper leaves burned and shriveled.

RECOMMENDATION: Fenitrothion should not be used on sorghum or sesame until studies can determine a dose-response phytotoxicity effect to different stages of these crops.

Locust control operations in Sudan are integrated with the grasshopper and other pest control operations at regional stations. Pesticides, equipment, and personnel are assigned to whatever task takes priority. During outbreaks of other pests, locust survey and control operations often suffer.

RECOMMENDATION: Form a small locust unit within the Plant Protection Directorate with its own vehicles, radios, and survey, safety, and application equipment, that would not be used for other projects. This unit's job would be to (1) survey for locusts (2) control locusts during minor local outbreaks, and (3) direct and supervise locust control operations conducted by other PPD personnel and contractors during major locust outbreaks.

Presently, the only viable control method for locust control is insecticide treatment, and fenitrothion is the preferred insecticide in Sudan. Diazinon is sometimes substituted, especially in crop areas. However, it is slightly less effective and more expensive than fenitrothion. Malathion is occasionally used, but it is not very effective according to some locust experts. The pyrethroid insecticide Decis has also been used occasionally.

Some of the newer synthetic pyrethroids have potential against locusts, either alone or in combination with other insecticides. A 'cocktail' of synthetic pyrethroid and fenitrothion has been suggested; the pyrethroid to disorient the locust and keep it in the treatment area, and the fenitrothion to kill.

RECOMMENDATION: Alternative insecticides should be evaluated in the field as part of program operations.

However, insecticides alone are not the ultimate solution for locust control. Control strategies that emphasize careful monitoring, use of nonchemical methods, and selective applications of effective and safe insecticides should be encouraged.

RECOMMENDATION: The donors should sponsor research on biological control and other nonchemical methods, improved monitoring, and selective use of insecticides in integrated pest management systems.

The Pesticide Regulatory Section of the PPD regulates pesticides in Sudan under the authority of the Pesticides Act of 1974. Pesticide regulation is limited to registration, labeling, importation, and sale of pesticides.

RECOMMENDATION: Establish an office within the Plant Protection Directorate to monitor pesticide quality, transport, storage, use, and disposal.

Pesticide storage facilities are inadequate and often create toxic hazards to workers. Most have soil floors and some have grass or reed roofs. Metal drums of insecticide are often stored in the open in the sun and perimeter fences to keep out people and animals are sometimes absent or damaged. Some of the present facilities are located near or in residential areas.

RECOMMENDATION: Upgrade pesticide storage facilities to reduce the hazards to workers and the general population.

Another way to minimize risk associated with insecticides in storage would be to store less insecticides. The manufacturer could store the insecticide in its warehouses near the point of manufacture and ship the insecticide to Sudan from this "insecticide bank" as required.

RECOMMENDATION: Use an "insecticide bank" to reduce the amount of insecticide stored in Sudan.

Many outdated, unidentified, or environmentally unacceptable pesticides are stored in PPD facilities in Sudan. Examples are chlorinated hydrocarbon insecticides such as dieldrin. As these drums sit in the facilities they eventually are forgotten, or damaged, or even used when other pesticides are unavailable. Outdated drums of insecticide are a serious environmental hazard especially considering the location of many facilities near residential areas and water supplies.

RECOMMENDATION: Develop environmentally acceptable disposal programs to quickly reduce the amount of outdated and environmentally hazardous pesticides in storage.

Environmental considerations are not factored into the decision to spray or not to spray. The survey crews report locust density and whether swarms or bands are present. They do not describe the environmental conditions in the spray area.

RECOMMENDATION: During field surveys for locusts, the survey crew should note the presence of sensitive nontargets such as birds, pollinators, wildlife, and water supplies, and this information should be considered when making spray decisions and planning spray operations.

PART II
SUDAN MULTI-DONOR LOCUST/GRASSHOPPER CONTROL PROGRAM

A. Purpose

Locusts and grasshoppers have plagued Sudan and the rest of northern Africa throughout recorded history. The threat posed by these pests varies unpredictably from one year to the next as their populations respond to various environmental factors. The most important environmental factor is rainfall, particularly when it follows a period of extended drought.

Such was the case in 1986 when, following the severe drought in 1984 and 1985, a sequence of rains occurred in desert locust breeding areas throughout Sudan. Locust and grasshopper populations soared. Sudan's Plant Protection Directorate (PPD) of the Ministry of Agriculture was not prepared to launch an effective control campaign because of inadequate funding, insecticides, equipment, and organization (Klaus et al. 1987). An emergency multi-donor locust and grasshopper program, funded by the United States Agency for International Development (AID), The Netherlands, and European Economic Community (EEC), provided relief from August to December 1986. The donors supplied equipment and insecticides to PPD field stations in the infested areas. Experts of the Food and Agriculture Organization of the United Nations (FAO) monitored and directed the control operations.

In 1987, two follow-up programs were initiated. One program was a short-term emergency campaign similar to that launched in 1986. The other program was a medium term (3-year) project to provide resources, training, and standards for control needed to bolster Sudan's long-term capacity for dealing with locusts and grasshoppers (Klaus et al. 1987).

Both the short-term and medium-term projects have focused mainly on locusts, and in particular the desert locust (Schistocerca gregaria). Experts in Sudan disagree whether grasshopper control can be economically justified since there have been no cost-benefit studies of grasshopper control in crops, and economic thresholds are unknown. By contrast, few doubt the seriousness of locust outbreaks. A migrating swarm of locusts can destroy a farmer's crop

overnight. A major locust plague could cause severe crop losses throughout Sudan and "perhaps even a continental scale disaster" (Klaus et al. 1987).

Sudan is a preferred breeding area for the desert locust, the major locust species in Sudan and the focus of most of the survey and control operations of the Sudan Multi-Donor Locust/Grasshopper Control Program. At various times, the desert locust has migrated as far east as Pakistan, south as central Africa, west as Mauritania, and north as southern Europe. According to many locust experts, Sudan is a key to desert locust plagues in Africa. This pest normally peaks twice a year in Sudan--during the summer (August-September) and winter (October-January) as shown in Figure 1.

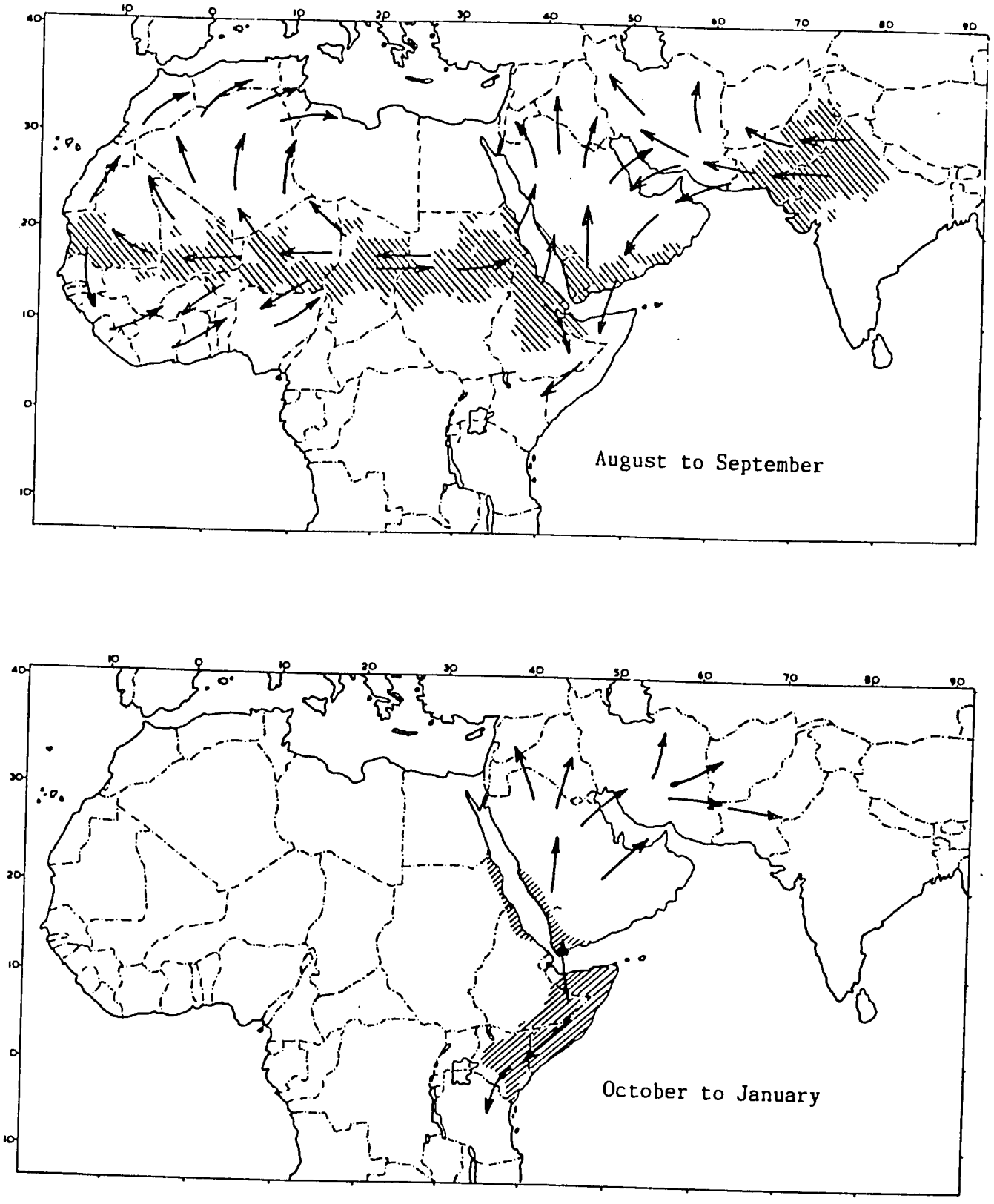


Figure 1. Seasonal Distribution of Desert Locust in Sudan (ALRC 1966)

The African migratory locust (Locusta migratoria) infrequently causes major problems in Sudan when swarms of gregarious forms enter the country from the west and south. The initial outbreak area has almost always been the middle Niger flood plain. The last major plague of African migratory locusts occurred 1929-1944. Much of Africa south of the Sahara was affected during this period (Chapman 1976). An unusually severe local outbreak of African migratory locust occurred in Sudan in 1985-1986 (Klaus et al. 1987).

Control of the African migratory locust was not a major objective of the 1987 program. Infestations were to be controlled on a fee basis only when requested by a grower. No policy has been established for the medium-term Sudan Multi-Donor Locust/Grasshopper Control Program concerning what control actions, if any, will be taken against the species during the next three years (Klaus et al. 1987).

Other locusts occasionally reach pest status in Sudan. Tree locusts (Anacridium spp.) are minor economic pests of trees which produce gum arabic, but migration patterns have not been studied and little is known about control. Local outbreaks are occasionally treated.

Locusts are often thought to be distinct from grasshoppers. In fact, they are true grasshoppers that change their behavior and appearance when they occur in large numbers. Locusts have two major phases: a solitary phase, and a gregarious phase. The two phases are morphologically different, but there are intermediate forms as well.

The phase of a locust depends on the environment experienced by an individual insect during its lifetime. Offspring of gregarious locusts are more likely to become gregarious than are offspring of solitary locusts. Locusts raised in crowded conditions are more likely to become gregarious than are those raised in isolation. Any physical factor that tends to concentrate locusts in the field--weather, patches of green in an otherwise barren area, or tall clumps of vegetation--may cause the locusts to begin to aggregate spontaneously. Aggregation behavior can lead to "gregarisation," the transformation of a group of solitary locusts into a gregarious population (Chapman 1976). This transformation may take from one to many generations.

Gregarious locusts are called swarms when they are composed of adults and bands when they consist of wingless nymphs (also called "hoppers"). Locusts in the gregarious phase can devastate crops and forage plants. Control is initiated against the gregarious phase when populations are concentrated.

A number of control options are available--baiting, ground control with knapsack sprayers or vehicle-mounted spray rigs, and ULV aerial application. ULV aerial application of fenitrothion is the primary control tactic used against locusts in the Sudan Multi-Donor Locust/Grasshopper Control Program and is the subject of this environmental assessment.

B. Affected Environment

The Republic of Sudan is the largest country in Africa and covers an area of 2.5 million square kilometers, almost one-third the size of the continental United States. Its ecology is extremely diverse--tropical rain forests and savanah in the south; scrubland, deserts (covering roughly 1/3 the total area of Sudan), and rolling hills in the center and north. Three geographic regions stand out: the northern desert, the plains, and the Sudd or swampy regions in the south. The country's soils can be divided geographically into three types: the sandy soils of the northern and west central areas, the clay soils of the central region, and the lateric soils of the south. The climate varies from hot, dry deserts of the north, which average less than 100 mm of rainfall annually, to wet monsoon areas in the south where rainfall averages 1200-1600 mm annually with an 11-month growing season (ALIC 1982). Figure 2 illustrates the diversity of Sudan's environment.

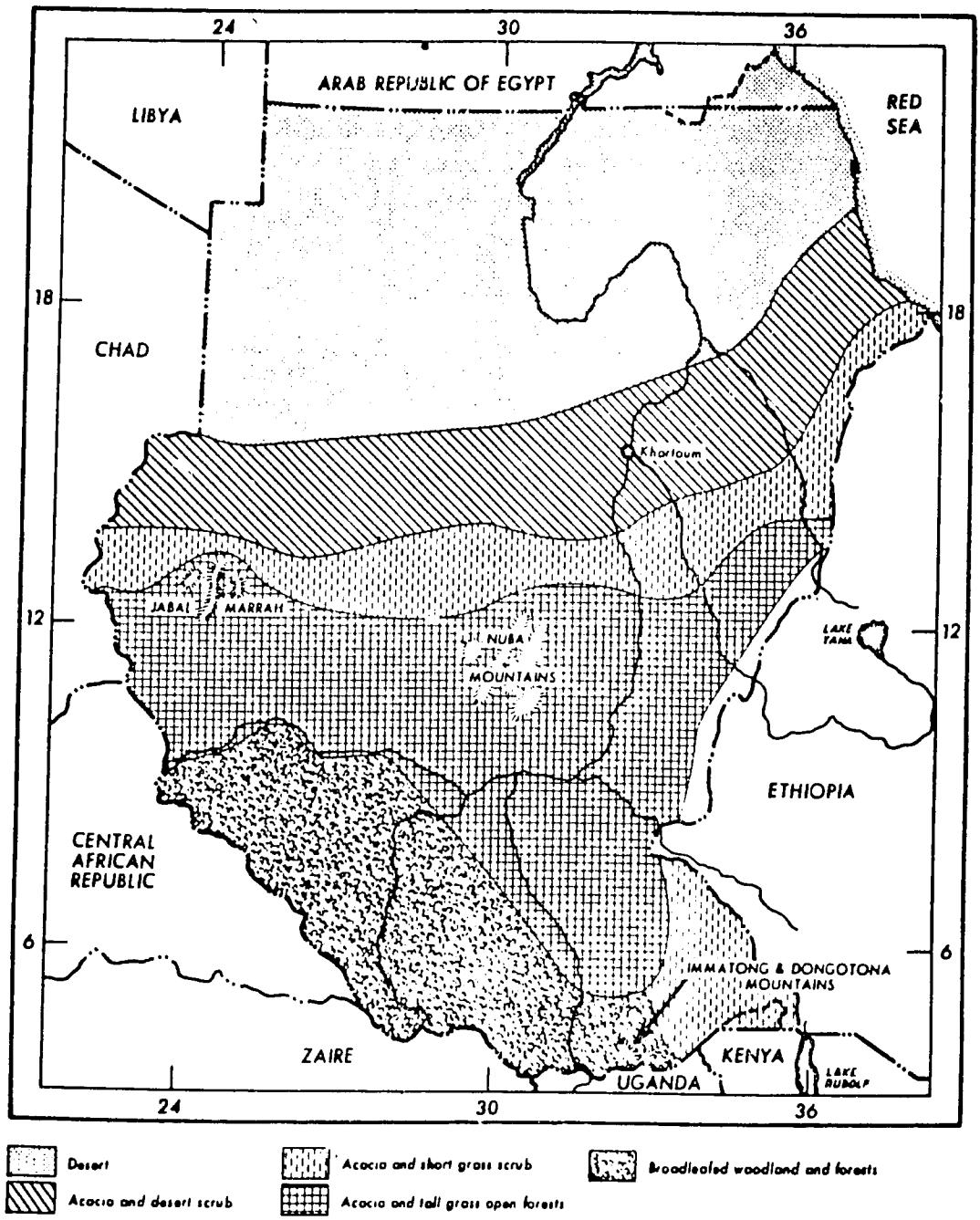


Figure 2. Environmental Zones in Sudan (Nelson et al. 1973)

Agriculture and livestock are the main sources of livelihood for about 80 percent of the people in Sudan. As much as one-half of Sudan's total land area is suitable for agriculture, but only about eight percent of this is actually used (ALIC 1982). Crop cultivation is split between a large and modern market-oriented sector of large-scale irrigated and rainfed farms located mostly in central Sudan, and small traditional farms located in other areas of the country where rainfall or other water supplies permit.

Commercial Rainfed Agriculture. The major crop in Sudan in terms of total area (six million feddans) and production is a drought-resistant variety of sorghum (durra), traditionally the country's staple cereal. Much of the sorghum is grown by the largely mechanized, rainfed operations of commercial growers in Kassala and Blue Nile provinces. Sesame, short-fiber cotton, and bullrush millet (dukhn) are also grown in these areas.

Commercial Irrigation Schemes. Large government-sponsored irrigation schemes (such as the Gezira scheme between the Blue and White Niles south of Khartoum and the Rahad scheme southeast of Wad Medani) utilize canals, pumps, and dams to provide a large portion of Sudan's agricultural production for export. Most of these schemes are located in central Sudan and use the waters of the Niles and their tributaries. There are also flush (or flood) irrigation schemes--most notably the Gash and Tokar delta systems--that depend on periodic flooding of their rivers to provide the necessary water for crops. The major crop in these schemes is cotton. More than 50% of Sudan's export earnings were provided by cotton in the early 1980's (USDS 1982).

Sugar has also become important in the Gezira and other schemes, and Sudan opened one of the world's largest sugar processing complexes in 1981 (ALIC 1982).

Traditional Agriculture. For the most part, traditional agriculture is rainfed cultivation of small plots and raising livestock. The crops depend on the location of the village but the most common in the central and northern provinces are durra sorghum, bullrush millet, sesame, groundnuts, beans, maize, and wheat.

Much of Sudan is more suited for grazing than cultivating. More than 50 million livestock animals (more than any other African country except Ethiopia) provide livelihood for more than 40% of Sudan's population. Estimates for 1981 indicated that Sudan had 18 million cattle, 18 million sheep, 13 million goats, and 2.6 million camels (Nelson 1982). Generally, camels are found in the more arid north while cattle are the main large grazing animals in the central and southern areas. Sheep are found mostly in the drier regions of the country north of the major cattle zones and goats are found everywhere.

Livestock graze natural pasture areas throughout the country. When these areas have been substantially reduced by agricultural development, or during times of poor pasture conditions, livestock are brought into agricultural areas to feed on crop residues and to water.

Forestry. Roughly 200 million feddans (1 feddan equals 1.038 acres or 4,200 square meters) of land in Sudan, or about 36% of the country, is forested. Major commercial uses of the forested areas are firewood gathering and gum arabic production.

National Parks and Protected Areas. Sudan has three national parks, 15 game preserves, and a number of sanctuaries and forest reserves. According to an environmental profile of Sudan (ALIC 1982), conservation in all protected areas is unsatisfactory and the status of game preserves uncertain. Protected areas that lie within regular desert locust breeding sites include the three game reserves in northern Sudan--Rahad, Sabloka, and Tokar Game Reserves. The Rahad Game Reserve has been extensively settled but most of its animals have disappeared. Sabloka was established to protect wild sheep but none apparently exist in the Reserve. The Tokar Reserve has significantly deteriorated.

The desert regions of northern Kordofan and Darfur still contain wildlife such as gazelles, and the Red Sea hills and western areas still contain game in sanctuaries (ALIC 1982).

Dinder National Park is the only park in northern Sudan. It covers 7,120 square kilometers and lies 406 kilometers southeast of Khartoum near the Ethiopian border.

The Wildlife Administration oversees the management of wildlife and parks, and enforcement of the Wild Animals Act. It is primarily a licensing and policing body and generally not concerned with management of habitats and animal populations (ALIC 1982).

C. Population

Sudan's population is about 20 million people, of which about 30% could probably be classified as urban. Average population density averages about 7 persons per square kilometer with rates of about 55 persons per square kilometer on arable land (ALIC 1982).

Most locust control operations take place in Kassala, Blue Nile, Kordofan, Darfur, and Northern provinces (see Figure 3). This area covers almost two-thirds of Sudan and includes most urban centers. Most of the Sudanese that live in this area (more than 13 million) are Arabic-speaking Muslims. Some are from distinct tribal groups, such as the camel-raising Kababish of northern Kordofan, Jaalin and Shaiqiyya (settled tribes living along rivers), the semi-nomadic Baggara of Kordofan and Darfur, the Hamitic Beja in the Red Sea area, and the Nubians of the northern Nile (USDS 1982).

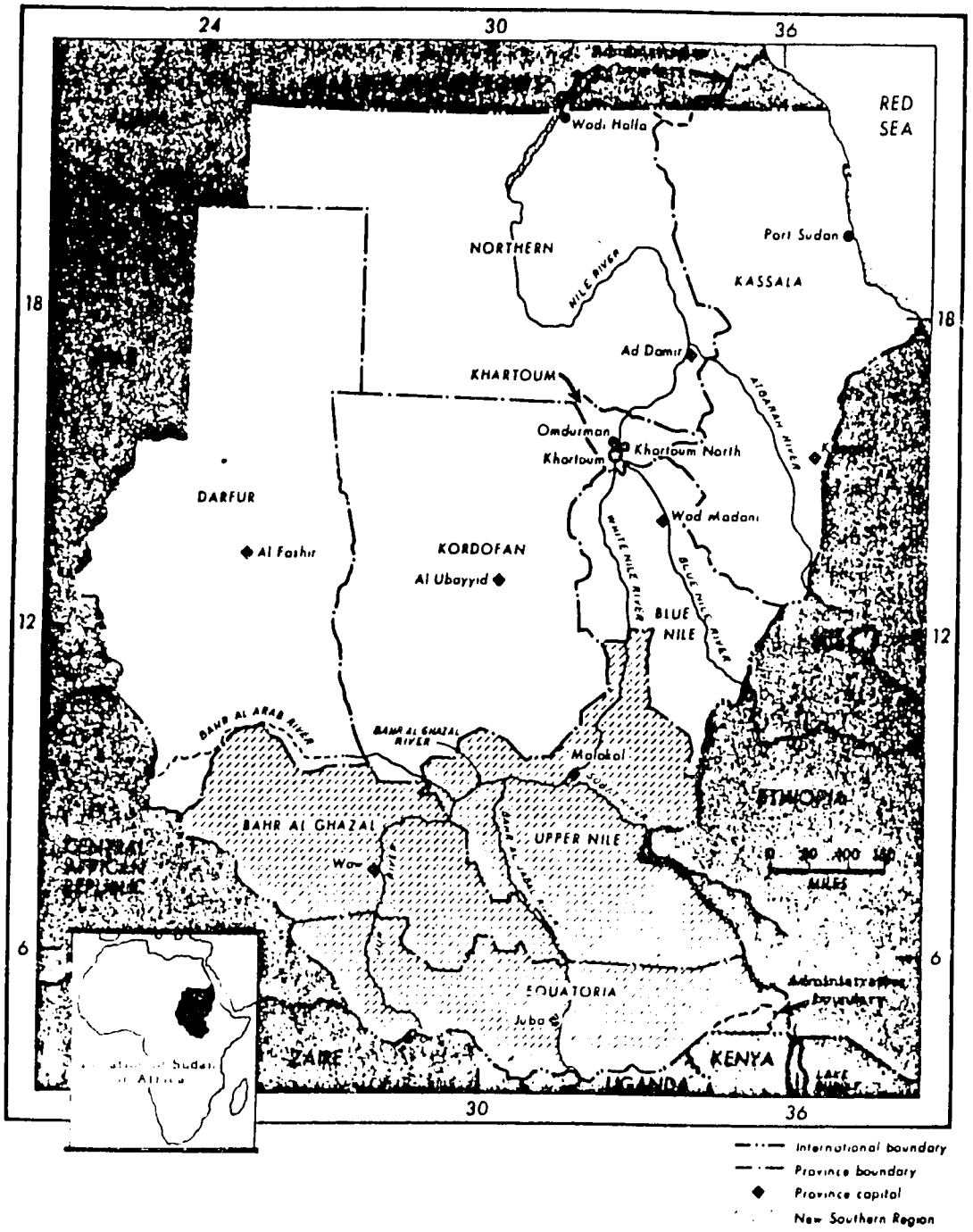


Figure 3. The Democratic Republic of Sudan (Nelson et al. 1973)

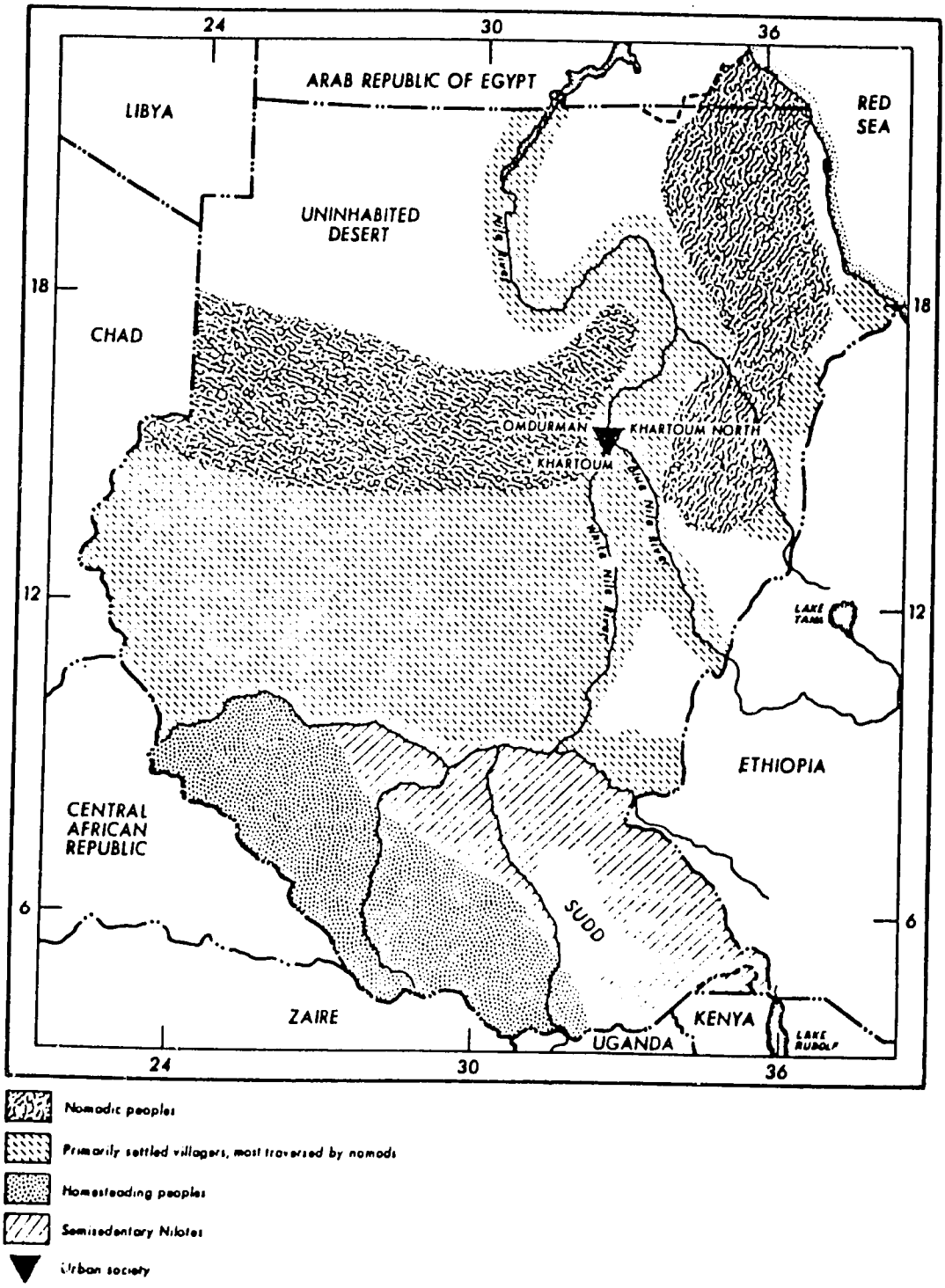


Figure 4. Predominant Patterns of Settlement (Nelson et al. 1973)

PART III
PURPOSE OF THE ENVIRONMENTAL ASSESSMENT

The purpose of the environmental assessment was (1) to examine the foreseeable impacts on the human and natural environment of insecticides used for locust control under the Sudan Multi-Donor Locust/Grasshopper Control Program, and (2) to propose measures to reduce or eliminate negative impacts when possible. The environmental assessment was prepared at the request of FAO Rome and the Steering Committee of the Program in Sudan.

To gather information for this assessment, the Consortium for International Crop Protection (CICP) observed program operations, inspected facilities, interviewed workers, and conducted field trials to determine the environmental effects of aerial applications of fenitrothion 96 ULV. For the field trials, the insecticide was applied by aircraft to a series of test blocks containing sorghum, forage grass, and mixed acacia scrub. The objectives of the trials were to (1) determine the effects on nontarget beneficial species of predators, parasites, pollinators, and wildlife present in treated fields, (2) determine the time required for the beneficial species to recover, (3) determine any nonreversible impacts on beneficials, and (4) measure fenitrothion residue levels through time in forage grasses, *Acacia* leaves, sorghum heads, sorghum leaves, and soil. Materials, methods, and results of the field trials are presented in APPENDIX A.

PART IV
PESTICIDE USE ASSESSMENT

The assessment of fenitrothion was based on U.S. Agency for International Development (AID) guidelines as set forth in Title 22 of the U.S. Code of Federal Regulations, Part 216, Environmental Procedures.

A. Basis for the Selection of Fenitrothion

The planning document for the multi-donor program specified fenitrothion as the major insecticide for locust control because, "It is effective, it has some residual effect (it has a 'half life' under hot dry conditions of about 3 days), it is reasonably cheap, it is not highly toxic to humans and, if applied properly, does not harm the environment." Diazinon appeared to be the second choice but was considered "slightly less effective, (is) less persistent and usually slightly more expensive" (Klaus et al. 1987). Malathion was characterized as not very effective, although inexpensive and safe.

Choice of insecticide to be used in a large-scale program such as the locust program in Sudan should be based on (1) effectiveness against the target pests under prevailing environmental conditions, (2) the country's capability for storing, handling, and disposing of the insecticide, (3) degree of hazard to pesticide handlers and general public, (4) social and economic impacts, (5) ability of the insecticide's suppliers to deliver quality products and technical support, (6) host country and donor regulations, and (7) compatibility with integrated pest management (IPM). These concerns are addressed in this document.

Fenitrothion (both ULV and EC) was the primary insecticide used by the program for locust control in 1987. It was applied from the ground or from the air. Other insecticides were sometimes used and these are discussed more fully on pages 41-42.

B. Registration Status of Fenitrothion

Products containing fenitrothion are registered in more than 60 countries for use on crops, ornamental plants, stored grain, forestry, and livestock; in homes for public health; and for locusts and grasshoppers (Sumitomo n.d.). Fenitrothion has been used intensively in Canada as a replacement for DDT for the control of spruce budworm. In the United States it is registered for use in forestry and in public health (total 11 registrations). There is only one established U.S. food additive tolerance (for residues of fenitrothion in wheat gluten imported from Australia).

A registration standard was issued for fenitrothion by the U.S. Environmental Protection Agency (EPA) in 1987, and EPA identified certain data gaps which the manufacturer must fill. The fenitrothion registration standard is presented in APPENDIX C.

For locusts and grasshoppers, fenitrothion has been recommended or registered in Ethiopia, Kenya, Saudi Arabia, Sudan, Senegal, Chad, Niger, Pakistan, Zaire, Australia, Mali, Libya, Thailand, Ivory Coast, Zimbabwe, and Argentina. It is the main insecticide used by the Australian Plague Locust Commission for control of the Australian plague locust by aerial application (Gordon 1981). Fenitrothion is approved and registered for use against locusts and grasshoppers by the Pesticide Regulatory Section of the Plant Protection Directorate of Sudan's Ministry of Agriculture.

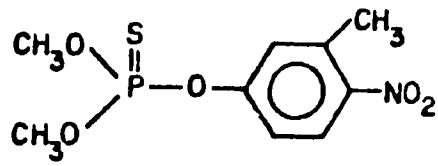
C. Technical Data on Fenitrothion

Fenitrothion is an organophosphorous insecticide with the following chemical and physical characteristics. Unless otherwise specified, the data are from the manufacturer (Sumitomo n.d.).

Chemical Name:	IUPAC:	O,O-Dimethyl O-(4-nitro-m-tolyl) phosphorothioate
	CA:	O,O-Dimethyl O-(3-methyl-4-nitrophenyl) phosphorothioate

Common Name: fenitrothion (ISO, BSI, BPC)

Structural Formula:



Formula:	$C_9H_{12}NO_5PS$	Formula Weight:	277.23
CAS Number:	122-14-5	WHO Number:	OMS-43
Appearance:	Pale brown liquid	Odor:	Faint

Melting Point: 0.3°C

Boiling Point: 140-145°C at 0.1 mm Hg (decomposition)
118°C at 0.01 mm Hg (EPA 1987)

Density:	1.3227	Flash Point:	157° C
Vapor Pres.:	1.37×10^{-4} mm Hg/20°C	Viscosity:	37.6 cP/22°C

Solubility: Soluble in alcohols, cellosolves, esters, aromatic hydrocarbons, vegetable oils at 22 C. Slightly soluble in aliphatic hydrocarbons and almost insoluble in water

Compatibility: Compatible with most conventional pesticides. However, the chemical half life of fenitrothion is reduced in alkaline solution, so it should be used as soon as possible when mixed with alkaline materials.

Photo-decomposition: Subject to degradation by ultraviolet radiation and sunlight

Stability: Stable over 2 years under normal storage. However, decomposition increases with temperature as can be seen in Table 1.

Table 1. Decomposition of Fenitrothion Technical Grade at Different Storage Temperatures

Storage temperature (°C)	Fenitrothion contents after days					
	0	10	20	30	60	90
40°	95.4	--	--	95.2	95.1	95.0
50°	--	95.2	94.9	94.4	--	--
60°	--	95.2	94.2	--	--	--

Source: Muramoto 1976

D. Integrated Pest Management and Alternative Methods of Control

Integrated pest management uses a variety of biological, cultural, and chemical methods integrated into a cohesive scheme designed to provide long-term protection. IPM's goal is to suppress and maintain target pest populations below defined economic injury levels. Pesticides are used only when necessary after the pests have surpassed the "economic threshold," the pest density or amount of pest damage at which costs of control just equal returns. IPM has provided cost-effective, environmentally sound solutions for a wide variety of pests and crops. IPM strategies have not been devised to combat locusts. There are a number of nonchemical methods of control, but these have yet to be combined with insecticides into IPM systems.

Before the development of synthetic insecticides, standard methods of control were to beat on nymphal bands with sticks, or to direct the bands into pits where they could be burned. These methods were labor intensive but often successful on a local scale (Chapman 1976). The only protection against adult locusts was lighting fires or making as much noise as possible.

A number of biological control agents (pathogens, parasites, and predators) attack the locusts. Predators and parasites may destroy about 40% of locust eggs at 'normal' densities (AID 1987), but the overall effect of these natural controls is not well understood. The most important predator on eggs of the desert locust appears to be the larva of a

Calliphorid fly (Stomorhina lunata) and it seems to be attracted to locust swarms about to oviposit. In field studies, S. lunata-induced mortality in the locust population averaged 20%, but reached almost 100% in some cases (Chapman 1976).

Spiders, robber flies, dragonflies, and birds prey on locust nymphs and adults but probably do not play a highly significant role in controlling outbreaks. Occasionally, fungi attack locusts and may cause high mortality (Chapman 1976).

Two pathogens--the protozoan Nosema locustae and the fungus Entomaphaga grylli--attack locusts. The limited research on use on N. locustae in Africa has been promising. However, there is little research now underway on N. locustae or other biological control agents.

One component of integrated pest management included in the Sudan Multi-Donor Locust/Grasshopper Control Program involves monitoring the locust populations. Survey crews regularly inspect potential locust breeding areas for bands and swarms. Nomads and villagers are often used as resources in monitoring, helping to pinpoint potential outbreak areas.

Control of the locust population is recommended when large bands or swarms are located. However, there is no predetermined threshold density used to trigger an insecticide application. The decision to apply an insecticide is more often based on a judgment value of the inspector or station entomologist in charge, or on the availability of spray planes, insecticides, etc.

Klaus et al. (1987) suggested the following guidelines for controlling locusts in a recession rather than an outbreak stage. The guidelines emphasized the importance of surveillance. The following measures were recommended for the Sudan Multi-Donor Locust/Grasshopper Control Program:

1. Conduct regular surveys in the Red Sea coastal plain are between October and April;

2. Conduct regular surveys in the central and northern belt area, particularly Darfur, between June and October;

3. Control bands and small swarms arising from local breeding in the Red Sea coastal plain area (perhaps 1 year in 3) and in the summer breeding areas (perhaps 1 year in 5);

4. Direct larger-scale control campaigns against bands and swarms in the same areas (perhaps 1 year in 6 or 1 year in 10);

5. Control outbreaks from winter/spring breeding, mainly in central and western Sudan, between June and September (perhaps 1 year in 10 or 1 year to 15).

E. Application Methods and Equipment

Insecticides used in the Sudan Multi-Donor Locust/Grasshopper Control Program are applied from the ground or air. Small hopper bands are treated by ground teams using knapsack sprayers or spreading a poisoned bait. These application methods are generally not used on a large scale.

When affecting larger areas, the hoppers are treated from the ground using sprayers mounted on wheelbarrows or sometimes motor vehicles (pickup's, station wagons). These sprayers are designed to apply emulsifiable concentrates of insecticides mixed with water. Ground ULV application equipment such as spinning cage (Micronair) or spinning disc (Micro Ulva) are effective and have been used. However, spray specialists working on the multi-donor program have reported frequent breakdowns with this equipment.

Bands or swarms covering 1 square kilometer or more are generally controlled by aerial ULV application of fenitrothion. According to FAO locust control specialists associated with the multi-donor program, aerial applications for locust control should be made only in a steady wind. This type of application is called "drift application" because the insecticide droplets drift with the wind into the vegetation. Some consider this method of application too hazardous because of the potential problem of insecticide drift into nontarget areas. However, FAO experts report that with a steady wind the pilot actually has greater control over placement of spray in the target zone.

The spray is applied only when the wind velocity is 3 meters per second or more and from a constant direction. The planes fly at a height of 5 meters. The insecticide is applied in droplets 100 microns and larger.

Klaus et al. (1987) recommended the following requirements for spray aircraft used in the program:

* Micronair atomizers
* variable flow restrictors leading to each atomizer (to control insecticide flow)
* flow meters
* in-flight flow regulation
* fuel capacity allowing a flight time of at least 4 1/2 hours.

However, aircraft in the the Aerial Aviation Section of the Plant Protection Directorate do not meet these requirements. Aircraft used in the program had to be secured from the Desert Locust Control Organization for Eastern Africa (DLCO) and private contractors. DLCO and the private contractors supplied the pilots, engineers, and maintenance crews also.

The DLCO assists member countries in controlling locust outbreaks (particularly the desert locust) when they cannot control the outbreaks themselves. However, who has control over the DLCO aircraft in a host country is not clear. Sudan's Plant Protection Directorate assumes that it has control over the use of the aircraft in Sudan and that it also determines what areas are sprayed. However, DLCO also assumes the same responsibilities. At times, DLCO is overburdened and not able to meet all requests for aircraft and insecticide (Klaus et al. 1987). Thus, conflicts arise concerning the location of DLCO aircraft and what areas should be sprayed.

A DLCO aircraft participated in one of the field trials for this environmental assessment. The twin engine Britten-Norman Islander was equipped with sophisticated navigation equipment and multiple radios, and was well maintained.

Aircraft supplied by the private contractors do not meet the standards of the DLCO aircraft. Aircraft contracted from Yaddum Pest Control (a Sudan firm) in 1987 were not equipped with radios and relied on magnetic compasses for navigation.

A Yaddum aircraft used in one of the field trials (Fletcher FU24) had no navigation charts or pesticide safety equipment. Contract aircraft were not equipped with lights. In October 1987, one of the Fletcher's crashed while attempting a night landing, killing both the pilot and engineer.

Protective Equipment. Observations in 1987 showed that pesticide safety equipment is rarely used. During the first spray trial to assess fenitrothion, there was no pump to load the Fletcher aircraft with insecticide. The fenitrothion container (200-liter drum) was rolled on its side until the bung (stopper) was at its highest point and then opened. The pesticide loaders did not wear gloves. Food and oil tins were quickly put under the bung, filled, and then handed to a loader on top of the aircraft who poured the fenitrothion 96% ULV into the tank through the upper vent. About one-half liter spilled on the ground during the loading operation, and the loader's hands and forearms were wet with pesticide. There was no water or soap available at the airfield. Approximately 1 liter was also spilled onto the aircraft around the canopy. The pilot complained that he got some fenitrothion on his clothes when he climbed into the aircraft and he smelled the fenitrothion throughout the flight.

During the second spray trial, the DLCO pilot and engineer insisted the loaders use a pump instead of simply pouring the pesticide into the aircraft. The loader handling the pump did not have any rubber gloves and got fenitrothion on his hands and arms. Water and soap were available this time in a nearby hanger.

Safety equipment has been provided to all PPD field offices but is apparently rarely used. A number of factors discourage use of this equipment. One, much of the equipment is locked up and unavailable when needed. Two, some of it has disappeared. Three, supervisors do not enforce use of the safety equipment. Four, pesticide handlers do not think that use of the safety equipment is necessary. And five, much of the gear is uncomfortable or not suited for the high temperatures that characterize Sudan.

A recent donation (August 1987) of equipment from Italy illustrates a problem. The donation included 200 protective masks, 1,000 filters for the masks, 400 pairs of rubber

boots, 400 pairs of rubber gloves, and 1,200 overalls. The masks were heavy-duty rubber and too hot for use in locust control programs. The overalls' synthetic plastic did not "breathe" and was therefore unsuitable for the hot conditions in Sudan. In fact, wearing the overalls could lead to heat exhaustion. The rubber gloves--probably the most important safety equipment to use when handling fenitrothion 96 ULV--were household quality rather than industrial quality. They did not provide adequate protection from hand to elbow.

In later sections, this document offers specific recommendations on safety equipment, training, and supervision needed to minimize the hazards to pesticide handlers.

F. Acute and Long-term Toxicological Hazards

The acute toxicity of fenitrothion to various animals is presented in Table 2.

Table 2. Acute Toxicity of Fenitrothion 96 ULV

Animal	Sex	Route	LD50 (mg/kg body wt.) (unless specified)
Rat	m	oral	330
	f	oral	800
	m	dermal	890
	f	dermal	1200
	m	intraperitoneal	148
	f	intraperitoneal	461
	m	subcutaneous	840
	f	subcutaneous	1300
	m	8-hour inhalation	+ 186 mg/cu m
	f	8-hour inhalation	+ 186 mg/cu m
Mouse	m	oral	1030
	f	oral	1040
Guinea Pig	m	oral	1850
Cattle (Holstein)	f	oral	+ 300
Sheep	m	oral	+ 700
	f	oral	+ 5000 per animal
Pig		oral	788.5
Chicken	m	intracutaneous	667.7
	f	oral	523.4
Mallard ducks	m&f	oral	100-150 /1 1190 /2
Bobwhite quail		oral	23.6 /2
Japanese quail	m	oral	115
	f	oral	140
Ringneck pheasant	m&f	oral	34.5
Brook trout		96 hr. LC50	1.7 ppm /2
Bluegill		96 hr. LC50	3.8 ppm /2

Source: All Sumitomo (n.d.) except for 1/ Keith and Mulla 1966 and 2/ EPA 1987.

In humans and animals, fenitrothion is absorbed through one or more pathways and converted to fenitrooxon. Fenitrooxon inhibits the enzyme acetylcholinesterase in the peripheral nervous system and to some extent in the central nervous system. This causes an accumulation of excessive levels of acetylcholine and produces the typical symptoms of organophosphorous poisoning (Gordon 1981).

The potential human hazards from aerial locust treatment are (1) dermal exposure of the insecticide to loaders, (2) direct dermal and inhalation exposure of people present in the spray sites, and (3) oral exposure from crop residues.

In this assessment, the major human health hazard identified was dermal exposure to loaders. As discussed on pages 27-28, these workers rarely wear safety equipment such as rubber gloves when working with fenitrothion. The manufacturer recommends rubber gloves and goggles and U.S. EPA requires protective clothing statements for all products containing fenitrothion (EPA 1987).

As shown in Table 2, fenitrothion has an acute rat dermal LD50 of 890-1200 mg/kg of body weight. If we assume that fenitrothion's toxicity to humans is about the same, a dose of 60 grams would have a 50% probability of killing a 60 kg human. This is equivalent to about 47 ml (about 3 tablespoons) of fenitrothion 96 ULV.

Cholinesterase depression and symptoms of poisoning would occur at much lower doses. Frequent exposure increases the risk of poisoning. The manufacturer warns that "repeated inhalation of or skin contact with the product may, without symptoms, progressively increase susceptibility to poisoning" (Sumitomo n.d.). The workers in the Sudan Multi-Donor Locust/Grasshopper Control Program have not been checked for cholinesterase depression. Monitoring of insecticide handlers' cholinesterase levels should be incorporated into the program.

Recent human epidemiological evidence and a dog chronic feeding study have implicated fenitrothion in causing human eye effects, such as retinal degeneration and myopia (EPA 1987).

As noted above, the pesticide loaders handle the drums of fenitrothion carelessly, without regard to potential hazard. During one spray trial, a 200-liter drum of fenitrothion ULV and a drum of aviation gas were transported to the airfield in a pickup truck. Neither drum was tied down and they bounced and banged together as the truck travelled on the unimproved road.

At the airfield the drums were simply tipped out of the truck and onto the crushed stone tarmac. No cushioning tire was used, as is usually recommended. Even with a tire about 5% of drums handled this way will probably burst (Klaus et al. 1987). At the second spray trial the loaders were not going to use a cushioning tire until a FAO consultant (M. Gorta) forced them to do so.

Another potential human health hazard is direct exposure of the public to aerial sprays. People are often present during treatment and children especially are difficult to keep out of the treatment site. Gordon (1981), made some estimates concerning such exposures. He determined that when fenitrothion is applied aerially at a rate of 280 g/ha, 2.5-15 mg would be expected to land on an unprotected adult during the application. In Sudan the dosages applied are higher, ranging 435-635 g/ha (340-500 ml of 96 ULV/ha) and, in fact, some of the applications observed for this assessment ranged up to 1000 g/ha.

Taking the worst case--a naked person exposed to the high dose of 1000 g/ha--the direct exposure conceivably could reach 60 mg. This is one thousandth of the dermal LD50 value extrapolated from rodent data (Table 2). Under actual field conditions, the exposure would probably be less. Sudanese generally cover most of their bodies with clothing which would provide some protection.

Another mode of exposure for people directly in the ULV spray is inhalation. Gordon (1981) also made some estimates concerning inhalation exposure:

> "If the volume of air inhaled by an adult human of 70 kg-bw is 8.8 L or 264 L in 30 minutes, the aerial concentration of fenitrothion, as applied insecticide, giving .22 mg/kg/30 minutes would be 59 mg a.i./m . On the basic assumption of equal susceptibility of rats and humans, this means that if an adult human was confined in an atmosphere

containing 59 mg a.i./m fenitrothion mist, no depression of plasma cholinesterase activity nor any clinical signs of toxication would be developed."

Fenitrothion is registered for use on a wide variety of food crops around the world, including cereals, maize, vegetables, and fruits. It is also registered for use as a treatment to stored grain. Based on the residue studies conducted in Sudan (see APPENDIX A), significant residues are not likely to be ingested unless the treated crops are harvested and eaten immediately after treatment. In the studies reported in APPENDIX A, the highest residue recorded on sorghum heads immediately after treatment was about 60 ppm. Someone eating 1 kilogram of raw sorghum would ingest 60 mg of fenitrothion. On the basis of equal susceptibility of humans and rats, this is about one quarter of one percent of the LD50 dose for a 70 kg human.

Fenitrothion for locust control in the Sudan Multi-Donor Locust/Grasshopper Control Program is mostly used in noncrop areas and pastureland. Recent concerns over its phytotoxic effects on drought resistant durra sorghum and other crops have discouraged use on crops (see APPENDIX A).

G. Efficacy of Fenitrothion for Locust Control

Fenitrothion is currently the insecticide most widely used for locust control in Africa and Australia. FAO consultants with the Sudan Multi-Donor Locust/Grasshopper Control program chose fenitrothion because it was relatively inexpensive, reasonably safe, and effective (Klaus et al. 1987). It is the primary insecticide used by the Australian Plague Locust Commission for control of the Australian plague locust (Chortoicetes terminifera) by aerial spraying (Gordon 1981). In Sudan in 1987, fenitrothion gave 60-95% control when directed against the desert locust (unpubl. repts., Sudan Multi-Donor Locust/Grasshopper Control Program).

The LD99 for locusts ranges from 5.5 mg/kg for migratory locust adults to 35 mg/kg for desert locust adults over a period of 0.5-6.0 days (FAO 1978).

It requires up to five times the dosage of fenitrothion to kill migrating swarms or bands of desert locusts than it does to kill locusts that remain in one spot and feed on treated vegetation (Klaus et al. 1987). This may be the reason that PPD often applies fenitrothion at 0.5 liters per hectare (0.635 kg/ha), higher than the dosage specified by the manufacturer and by FAO locust experts working in the program (see APPENDIX A). In fact, interviews with program workers during this assessment indicated that application dosages sometimes exceeded 2.0 liters of fenitrothion per hectare.

Fenitrothion for locust control should only be used at recommended dosages, currently 0.3-0.5 kilogram of technical fenitrothion per hectare (equivalent to 0.24-0.39 liter/ha of 96 ULV). If fenitrothion is ineffective at those dosages, another insecticide should be used.

H. Effect of Fenitrothion on Nontarget Organisms and the Natural Environment

Invertebrates. Any pesticide may harm the environment. The potentially most serious effect of fenitrothion appears to be harm to invertebrates in the spray area. Abrupt and significant reduction of nontarget species following fenitrothion application has been reported (Freitag and Poulter 1970; Weinberger et al. 1981; Varty 1976). Large numbers of nontarget insects are killed for 2-4 days (Varty 1976), although the actual effects of the population reduction last much longer.

Of major concern is fenitrothion's effects on predators, parasites, honey bees, and wild pollinators. The Australian Plague Locust Commission concluded that "where wild pollinators are actively foraging, population reductions can result from topical applications of fenitrothion" (Gordon 1981). Fenitrothion is also highly toxic to honey bees (LD50 0.04 ug/bee) (Anderson and Atkins 1968). Thus, spray applications are likely to kill honey bees and probably other pollinators active in the treatment area. Treatment should be avoided whenever possible at locations and times when honey bees and other pollinators are active.

Freitag and Poulter (1970) reported that application of fenitrothion to a mixed boreal forest in Canada suppressed

populations of six predatory species (five carabid beetles and a spider). The populations remained suppressed a year after treatment. Carter and Brown (1973) reported a similar effect on predators called harvestmen (Phalangida, or daddy-long-legs). Fenitrothion reduced the harvestmen population 60% and in the year following treatment the population still had not rebounded fully. Other studies have suggested similar effects, but no long term studies from desert areas similar to Sudan could be identified.

Two factors may tend to reduce fenitrothion's impacts on invertebrates in the spray area. First, treatments are not made frequently. Several years may lapse between treatments at a particular site. Second, the area treated is relatively small when compared to the area treated in programs such as area-wide grasshopper control programs in Africa or the spruce budworm control program in Canada. The average size of a locust treatment block (aerial application) in Sudan in 1987 was 2-3 square kilometers. The relatively small size of the treated area may allow nontarget species to reestablish quickly, but there are no data to support this.

One aspect of this assessment was to obtain Sudan-specific information on the effects of fenitrothion. In field studies conducted in Sudan in 1987 (APPENDIX A), the diversity and abundance of insects and other arthropods in treated fields was reduced significantly by aerial applications of fenitrothion ULV. In forage grass treated at 0.6-0.8 liters per hectare, the number of individual arthropods dropped by 97% and the number of species dropped by 90% one day after treatment. Seven days after treatment the arthropod population in the treated field was still only 4% the size of the population in the control field. In Acacia, fenitrothion at 0.51-0.57 liters per hectare reduced the number of invertebrate species in the fields by 50% after one day and 60% after 8 days. Total individual invertebrates were reduced by 59% and 83% during the same time periods.

Birds. Effects on birds are more difficult to quantify. Birds can easily move into or out of a treatment area, sick birds may leave an area, and migratory fluctuations, induced behavior changes, variable climatic conditions, and the activity of scavengers can mask the insecticide effects (Gordon 1981).

Birds may ingest insects that have been killed or contaminated by fenitrothion, they may be directly sprayed, they may breath the droplets, or they can absorb fenitrothion through their feet. The U.S. Environmental Protection Agency considers fenitrothion "highly toxic to upland gamebirds and slightly toxic to waterfowl" (EPA 1987).

Gordon (1981) reviewed the effects of fenitrothion on birds. Most of the available data were collected from studies with passerine birds in Canadian forests. The studies indicated an obvious dose/response to the fenitrothion treatments: no effect at 70 or 133 g/ha; behavioral changes and reduced singing at 138 g/ha; some juvenile mortality at 206 and 275 g/ha; some adult mortality at 550 g/ha; and significant population declines at 670 g/ha. Busby et al. (1983) suggested that a dosage of 300 g/ha may be near the threshold for causing acute responses in forest passerines.

However, Spray et al. (1987) did not find aerial applications of fenitrothion (300 g/ha) to have major effects on bird populations in a scottish pine plantation. Five species of passerine birds were studied. The study concluded that there were no effects to the birds from direct exposure to fenitrothion treatment, secondary poisoning (feeding on fenitrothion-exposed prey), or decreased abundance of insect prey.

This assessment sought to acquire Sudan-specific information concerning the effects of fenitrothion on birds. In one of the field tests (see APPENDIX A), diversity and numbers of birds were less in the treated field than in the untreated field. However, no bird mortality or negative effects on bird behavior were observed. As mentioned earlier, monitoring bird populations for insecticide effects is a difficult undertaking. Small-scale studies such as conducted here will only detect major and rapid bird kills. Therefore, no conclusions were drawn from the field trials concerning the effects of fenitrothion on birds.

Dosages of fenitrothion used in the Sudan Multi-Donor Locust/Grasshopper Control Program are often above the threshold levels for bird mortality suggested by Busby et al. (1983) and Gordon (1981). Further, in most locust areas of Sudan there is no protective forest canopy such as is found in forests in Canada and Europe. Thus, treatments to low vegetation and scrub at the high dosages often used in

Sudan for locust control are more likely to kill or harm birds than are the lower dosages normally used in a forest.

Livestock. Maximum residues on forage grass and *Acacia* leaves was roughly 100 ppm on the day of treatment during field trials (see APPENDIX A). When fed on *Acacia* bushes with 1,000 ppm fenitrothion, goats suffered no depression of blood AChE activity (FAO 1978). When lactating goats were treated with 0.5 mg/kg of fenitrothion for 7 days no fenitrothion or fenitrooxon was found in milk, urine, feces, organs, or tissues (Mihara et al. 1978).

Thirty calves confined on a pasture treated with 756 g/ha of fenitrothion, with initial residues on grass at 11.8 ppm, contained 0.01 ppm of fenitrothion residues in meat and fat on day 1. No residues were found in meat after the third day, and only 0.004 to 0.007 ppm were found in the fat on the third day (Miyamoto 1969).

Cows treated with 3 mg/kg/day of fenitrothion for 7 days excreted 0.003 mg/kg of aminofenitrothion (a metabolite of fenitrothion) in fresh milk. Lactating cows fed for 8 weeks on silage from corn treated with 1.1, 2.2, and 3.4 kg/ha fenitrothion excreted residues of aminofenitrothion (0.001-0.005) only at the highest dose (Lenck et al. 1971).

Tolerances have not been established for fenitrothion residues on fodder. Based on tolerances set for similar organophosphates, and the residues determined from the field tests (APPENDIX A), at least 7 days should elapse after treatment before animals are permitted to forage on grasses or fodder treated with fenitrothion. *Acacia* foraging should not be allowed for 14 days following application.

Wildlife. The status of wildlife is uncertain in potential desert locust treatment areas in central, eastern, and northern Sudan. Because of the rapid increase in livestock over the past several decades, the large native mammals have been drastically reduced in numbers. According to a recent environmental review of Sudan (ALIC 1982), a 1976 aerial survey of Northern Darfur Province could find only five species of large mammals, including three species of gazelle. Southern Darfur Province has many more mammals, but most have undergone severe reductions in range during the past 75 years. In Khartoum province, the only large mammal left is a gazelle listed as "very rare." Gazelles,

antelope, and other native wildlife could feed on vegetation in green areas that had been treated for locust control. Data are not available to show fenitrothion's effects to these kinds of animals.

Locust treatments should be avoided in areas of known rare or endangered species, or particularly sensitive nontarget species, without consultation with appropriate officials or specialists. In the United States, endangered species label restrictions are required on fenitrothion products to protect endangered and threatened species in forest areas (EPA 1987).

The U.S. Department of Interior lists 11 endangered or threatened mammals in Sudan. The International Union for the Conservation of Nature and Natural Resources (IUCN) lists 12 species. These are presented in Table 3. Very little is known of their distribution within Sudan.

Table 3. Endangered and threatened species in Sudan

Scientific Name	Common Name	Status IUCN	Status USDI
MAMMALS			
Manis temminckii	Scaly anteater		E
Equus asinus	African wild ass	X	E
Acinonyx jubatus	Cheeta	X	T
Dugong dugong	Dugong		E
Loxodonta africana	African elephant	X	E
Gazella leptoceros	Slender-horned gazelle	X	E
Addax nasomaculatus	Addax	X	
Oryx dammah	Scimitar-horned oryx	X	
Alcelaphus buselaphus tora	Tora hartebeest	X	E
Panthera pardus	Leopard	X	E
Cerathotherium simum cottoni	Northern white rhinoceros	X	E
Diceros bicomis	Black rhinoceros	X	
Equus grevyi	Grevy's zebra		T
Pan troglodytes	Chimpanzee	X	
Lycaon pictus	African wild dog	X	
BIRDS			
Falco peregrinus	Eurasian peregrine falcon		E
REPTILES			
Crocodylus niloticus	Nile crocodile	V	E

X = listed (status not given); V = vulnerable
T = threatened; E = endangered

Source: ALIC 1982

Aquatic Systems. The Nile and its tributaries are the most prominent surface water feature of Sudan, and the majority of the country lies within the Nile drainage basin (ALIC 1982). But the water systems most likely impacted by locust control operations are the wadis, or seasonal watercourses scattered throughout desert locust areas.

The larger wadis include the Gash in Kassala Province, the Baraka draining to the Red Sea, and a number in the Jebel Marra area of Darfur. Little is known about the fish and invertebrate fauna inhabiting the wadis, or for that matter, the aquatic fauna in the Nile drainage system (ALIC 1982). Gordon (1981) reported that fenitrothion caused significant decreases in aquatic invertebrates when applied to water. However, he found few studies which showed that fenitrothion caused mortality in fish. The U.S. Environmental Protection Agency considers fenitrothion to be moderately toxic to both warm-water and cold-water fish (EPA 1987).

To prevent damage to water ecosystems, aerial spraying should not be conducted within 100 meters of active water sources such as wadis, rivers, irrigation canals, or water holes.

Crops. Fenitrothion's phytotoxicity to sorghum and other crops is a concern of farmers in the Gedaref area. Because of phytotoxicity, the insecticide is rarely applied to drought-resistant sorghum in Australia (Gorta, personal communication 1987). However, the fenitrothion technical manual supplied by Sumitomo Chemical Corporation makes no mention of sorghum phytotoxicity.

In one field trial conducted for this environmental assessment (see APPENDIX A), aerial application of fenitrothion 96 ULV was toxic to durra sorghum. The dosage was 0.6 -0.8 liters/ha, higher than the targeted dosage of 0.5 because of poor equipment calibration. Sorghum leaves were burned and spotted in 30% of the sampled plants 24 hours post-treatment. Seven days after treatment 100% of the sorghum plants in the treated field had at least their upper leaves burned and shriveled.

Fenitrothion should not be used on sorghum or sesame until studies can determine a dose-response phytotoxicity effect to different stages of these crops. Treatment of these crops should be made with an alternative insecticide such as diazinon.

Some forage grasses might have been burned by the fenitrothion spray during the trial, but this effect was not as pronounced as those to durra sorghum. Similar effects have been reported by station entomologists with PPD.

I. Conditions of Insecticide Use

Pesticides in the locust/grasshopper control campaign are used by field personnel of the Plant Protection Directorate of the Ministry of Agriculture, Food, and Natural Resources of the Government of Sudan. The PPD has a staff of 56 entomologists, 655 technicians, and 2370 others working in ten organizational sections (e.g., Locust Control Section, Vertebrate Pest Control Section, Pesticide Regulatory Section, Pesticide Residue Analysis Section) operating in twenty provincial field stations in five regions and in Khartoum. There is also a Pesticide Residue Laboratory and a Formulation Laboratory at Wad Medani.

Locust control operations in Sudan are integrated into the grasshopper and other pest control operations at regional stations. Pesticides, equipment, and personnel are therefore assigned to whatever task takes priority. For example, when insecticide was needed in November 1987 for locust field tests, no drums of fenitrothion could be located at field stations at Kassala and Blue Nile Provinces. Hundreds of the drums were on the locust control inventory, but the insecticide had been transferred to nearby agricultural schemes to control other pest outbreaks.

To avoid these kinds of problems with redistributed resources, and to insure that locust control workers are competent, safety oriented, and motivated, various specialists have recommended that a "locust unit" be formed within the Locust and Grasshopper Control Section of PPD. According to Klaus et al. (1987), the unit would deal on a day-to-day basis only with locust control and be stationed at three locations covering prime locust areas--Red Sea coast, central, and western, with seasonal redeployment to likely locust breeding areas.

The unit would consist of a Head, an Information Officer, a Pesticide Application Officer, eight Field Officers, drivers, and would have its own vehicles, radios, survey and application equipment, etc. This unit's job would be to (1) survey for locusts (2) control locusts during minor local outbreaks, and (3) direct and supervise locust control operations conducted by other PPD personnel and contractors during major locust outbreaks.

J. Availability and Effectiveness of Other Pesticides or Control Measures

Chemical control is the only known method for successfully controlling locust outbreaks. Small farmers generally apply dusts into infested fields or along the borders of those fields. BHC has been widely used in Sudan for this purpose. Another chlorinated hydrocarbon insecticide, dieldrin, has also been used (applied to large areas using truck-mounted sprayers).

Nonchemical control measures and potential tactics were discussed on pages 23-24. At this time, the only viable control method for locust control is insecticide treatment, and fenitrothion is the primary insecticide used by the Sudan Multi-Donor Locust/Grasshopper Control Program. However, alternatives to fenitrothion are available.

Diazinon is sometimes substituted, especially in crop areas. However, it is slightly less effective and more expensive than fenitrothion (Klaus et al. 1987). Diazinon is considered highly toxic to upland game birds (EPA 1987). In 1986, the summer locust campaign used roughly 230 thousand liters of insecticides. Over 110 thousand liters of fenitrothion ULV, 46 thousand liters of diazinon ULV, and 26 thousand liters of diazinon EC were used (Klaus et al. 1987).

Malathion is occasionally used for locust control in Sudan, but is "not very effective" according to locust experts (Klaus et al. 1987). The pyrethroid insecticide Decis has also been used occasionally.

Table 4 shows liquid insecticides available in Sudan for locust control in 1987.

Table 4. Liquid Pesticides Available for 1987 Locust/ Grasshopper Campaign as of 30 July 1987

Pesticide	1986 Left over	1987 Stocks	Awaiting Clearance
Fenitrothion ULV	34,000 /1	28,600	52,000
Fenitrothion EC		106,000	
Diazinon ULV	5,000		
Diazinon EC	110,000		
Malathion EC	25,000		
Decis ULV	27,000		

1/ in liters

Source: Internal records, 1987 Sudan Multi-Donor Locust/Grasshopper Control Program

Sudan is one of the few places where baiting is still used as a standard control for locusts and grasshoppers. Baiting is generally considered to be more effective against grasshoppers than locusts. Baits made from old stocks of BHC are currently used in Sudan. However, environmental concerns over this chlorinated hydrocarbon insecticide have led to its replacement with propoxur and bendiocarb from donations. As of 15 November 1987, US/AID for 1987 had donated 450 metric tons of 2% propoxur; the Netherlands had donated 95 metric tons of 1% bendiocarb. The effectiveness of these substitutes is currently being evaluated (against grasshoppers) by a Dutch consultant in Sudan.

Some of the newer synthetic pyrethroids have potential against locusts, either alone or in combination with other insecticides. A 'cocktail' of synthetic pyrethroid and fenitrothion has been suggested; the pyrethroid to disorient the locust and keep it in the treatment area, and the fenitrothion to kill (Klaus et al. 1987). This and other alternative chemical controls should be evaluated in the field against locusts as a part of program operations.

K. Ability of the Republic of Sudan to Regulate Distribution, Storage, Use, and Disposal of Pesticides

Large quantities of pesticides are used in Sudan. The bulk of the pesticides are used on cotton grown in large irrigation schemes such as Gezira and Rahad. The total area devoted to cotton exceeds 1 million feddans (ALIC 1982). Over forty different pesticide products are used on cotton (7 classified by WHO as highly or extremely hazardous) and the schemes averaged 7-9 treatments per season in 1985. The most important pesticides in terms of total volumes applied are the insecticides endosulfan, aldicarb, and deltamethrin/dimethoate (de Jong-Boon et al. 1986).

For the past thirty years the government of Sudan has been actively engaged in control of Quelea quelea aethiopica, a major bird pest of cereals. The Quelea program has emphasized protecting crops near breeding or roosting sites in savanna areas, especially during the period September through November. Approximately 20,000 liters of Queletox (fenthion 60%--also classified as highly or extremely hazardous) are used annually to control this pest (FAO 1981).

Zinc phosphide is used to control rodents in fields and storage areas. In 1983/84 the agricultural schemes used 37 tons of this product (de Jong-Boon et al. 1986). Water hyacinths are controlled in the White Nile and its tributaries by annual applications of 600 tons of 2,4-D. Sandflies, vectors of leishmaniasis, are controlled with malathion and DDT. Malaria control programs use large quantities of malathion, fenitrothion, and DDT to control Anopheles mosquitoes; 120 tons of fenitrothion were sprayed in homes at Gezira Menagil and over 4600 tons of DDT used in the Rahad scheme for malaria control in 1985 (de Jong-Boon et al. 1986). Insecticide use against locusts has been detailed elsewhere in this document.

The Pesticide Regulatory Section of the PPD regulates pesticides in Sudan under the authority of the Pesticides Act of 1974. Pesticide regulation is limited to registration, labeling, importation, and sale of pesticides.

There is a current proposal in Sudan, however, to establish a pesticide safety office within the PPD. The office would

be responsible for monitoring pesticides similar to the way the Environmental Protection Agency monitors pesticides in the United States. The office would monitor storage and transportation of pesticides; train PPD storekeepers, pesticide loaders, and pesticide applicators; dispose of obsolete or illegal pesticides;and provide emergency services such as cleaning up after serious pesticide spills. Another responsibility would be to monitor the quality of formulations of pesticides residues in food commodities.

If this office were implemented and funded it would be a positive benefit to health and environment in Sudan. It would have, of course, a much bigger scope than locust and grasshopper control.

There is also a proposal by The Netherlands to upgrade Sudan's pesticide storage facilities. Prepared in July/August 1987 by 'Group 5 Consulting Engineers' for the Medium-Term Locust/Grasshopper Control Program, the proposal calls for over six million dollars U.S. (combined local and hard currency) to construct new or rebuild old facilities at approximately 30 locations in Sudan.

Pesticide storage facilities need upgrading. Current facilities are inadequate and often create toxic hazards to workers. Most have soil floors and some have grass or reed roofs. Metal drums of insecticide are often stored in the open in the sun and perimeter fences to keep out people and animals are sometimes absent or damaged. Some of the present facilities are located near residential areas--sometimes right in town centers. It is not unusual to see damaged and leaking drums in the storage areas. More often than not these drums were not labeled.

Another way to minimize the environmental risk inherent in storing insecticide in Sudan is to store less insecticides in the country. The manufacturer would store the insecticide in its warehouses near the point of manufacture. The manufacturer would ship the insecticide to Sudan from this "insecticide bank" as required. The manufacturer can move some of the insecticide to other customers when needed, on approval from Sudan, after which the insecticide is replaced with fresh stock. This procedure can prevent a drum of insecticide from being in storage past its shelf life.

The insecticide bank also makes it easier to control the insecticides provided by donors for locust control, preventing them from being transferred to other areas for control of other pests.

Many outdated, unidentified, or environmentally unacceptable pesticides are stored in PPD facilities in Sudan. Included are chlorinated hydrocarbon insecticides such as dieldrin. As these drums sit in the facilities they eventually are forgotten, or damaged, or even used when other pesticides are unavailable. Outdated drums of insecticide are a serious environmental hazard especially considering the location of many facilities near residential areas and water supplies.

A pilot disposal program using a portable incinerator to destroy unusable pesticides was approved in 1987. The incinerator is the property of Shell of Sudan and, according to Shell's specialists, the contents of an average drum can be incinerated in about one-half hour using a 1 to 1 ratio of diesel fuel to pesticide. Current plans call for the incinerator to be located near Malakia, roughly 15 km from Wad Medani and about 5 km from the nearest village. The incinerating operation is to be monitored by specialists from PPD.

The U.S. Environmental Protection Agency recommends that pesticide incinerators reach a minimum temperature of 1200 F and the pesticides have a residual time in the flame of 1.5 seconds for a 99% combustion. The Agency further recommends that metallic compounds should not be incinerated. To avoid damage to crops, herbicides should not be incinerated near agricultural fields.

L. Provisions Made for Training Pesticide Handlers and Applicators

As mentioned earlier in this report, good safety practices are lacking in the locust control operations. Corrective action is needed to improve the safety of workers.

The action should have two components. A pesticide training course should be mandatory for all workers every year. The course could be combined with training on locust biology, control, and logistics, but it should not get second

billing. It should include information on safely storing, transporting, loading, using, and disposing pesticides. It should also include segments on calibrating and using equipment and avoiding accidents. Most of all, the importance of safety should be emphasized.

Just as important as training is safety enforcement. It should be made clear that safety violations will not be tolerated. Supervisors should be held accountable for providing safety equipment to workers and making sure that the equipment is used.

Creating a separate locust unit as described earlier would simplify both training and enforcement of good safety practices.

M. Monitoring the Use of Fenitrothion and the Effectiveness of Treatment

There presently is no permanent infrastructure monitoring the use and effectiveness of treatments for locust control. In general, storekeepers keep track of their inventory and pesticide workers report estimates of pesticide use on a particular infestation to the Station Head. However, since it may take 48 hours for significant mortality to occur in locusts, in remote areas workers have normally moved on before the results of the treatment are apparent. Even when an assessment is made of the effectiveness of treatment, it is usually more of an "eyeball" estimate of kill (e.g., roughly 70% control) rather than actual counts of live and dead locusts. In agricultural areas, growers often provide similar rough estimates.

Environmental considerations are not factored into the decision to spray or not to spray. Locust survey crews report locust density and whether swarms or bands are present. They do not describe the environmental conditions in the spray area. During field surveys for locusts, the survey crew should note the presence of sensitive nontargets such as birds, pollinators, wildlife, and water supplies, and this information should be considered when making spray decisions and planning spray operations. After treatment, significant impacts to nontarget species should be brought to the attention of PPD in Khartoum.

PART V
POTENTIAL IMPACT OF AERIAL LOCUST TREATMENTS WITH FENITROTHION 96 ULV ON THE HUMAN ENVIRONMENT

The potential impacts of aerial applications of fenitrothion 96 ULV on human health were discussed on pages 28-32. To summarize, the major human health hazard identified in this assessment was dermal exposure to fenitrothion by pesticide handlers and loaders. Most of these individuals use the insecticides incorrectly and few use safety equipment.

Fenitrothion applied for locust control appears to present little risk to the general public. However, it should be stressed that any pesticide will pose some risk to people in the treated area. The pesticides used in other control programs in Sudan, particularly in cotton, would pose a much greater risk than fenitrothion applied to control locusts would.

Recommendations to reduce human risk from locust control operations are presented in PART IX.

PART VI
ALTERNATIVES TO INSECTICIDES FOR LOCUST CONTROL

Cultural, mechanical, and biological controls as they relate to locusts are discussed on pages 23-24. The only alternatives to chemical locust control available at this time are the traditional mechanical controls that show some success on a small scale but which are unable to constrain outbreaks. Research on biological control shows some promise and is discussed on page 24.

PART VII
UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

Aerial applications of fenitrothion 96 ULV, as well as other insecticides, formulations, and techniques used in locust control, will probably have significant effects on some nontarget organisms. The field tests conducted for this assessment and studies of fenitrothion's environmental

effects on forest ecosystems in Canada and Europe strongly suggest that predators, parasites, honey bees, pollinators, and other beneficial organisms will be negatively affected by fenitrothion. However, more research is needed.

The research should incorporate replicated long-term trials and be conducted over a period of three years or longer. The trials should document the immediate effects as well as effects over time. The studies should be conducted by a local university such as the University of Khartoum.

Another probable unavoidable adverse environmental effect is illness or mortality to birds in the sprayed areas. Field trials to detect environmental impacts on birds from insecticide applications may require significant resources and manpower. Studies should consider bird insectivores, herbivores, predators, and migrants separately since the insecticide effects are likely to differ between these different groups.

As discussed in this assessment, the fenitrothion dosages used by PPD are often higher than those recommended by the manufacturer and the FAO locust experts working in the program. Reducing the dosage to the recommended level would help to reduce the environmental impacts on birds and invertebrates in the treatment area.

PART VIII
RELATIONSHIP BETWEEN SHORT-TERM AND LONG-TERM EFFECTS

PART VII discussed unavoidable adverse effects and the uncertainty of the long-term effects of insecticide treatments on invertebrate organisms. There are also short-term effects associated with unpredictable events such as spray plane crashes or fire in storage areas or accidental spills in water systems. These effects have to be weighed against the potential benefits of preventing a major locust plague.

If the program averted a locust plague the benefits would be major. If the program fell short in averting a plague the benefits would be considerably less. Therefore, weighing the long-term vs short-term effects, the costs and the benefits, depends on the decisionmaker's opinion of the

locust program's capability to control serious locust outbreaks.

PART IX
WAYS TO MINIMIZE OR AVOID ENVIRONMENTAL DAMAGE

PART IX presents, in capsule form, the recommendations that have been made throughout the document. The pages in the document where the recommendations have been discussed are listed in parentheses.

1. Further research on biological methods of locust control such as release of Nosema or the fungus Entomaphaga grylli (see pages 23-24).

2. Require more sophisticated equipment on contract aircraft. At the very least the contract aircraft should have radios, detailed grid maps identical to those used by ground personnel, extra pairs of rubber gloves and goggles, and an insecticide pump (pages 25-27).

3. Pesticide loaders should wear rubber gloves and goggles when loading tanks or otherwise handling concentrates or technical material (pages 27-28, 30).

4. Avoid direct exposure of people and animals to aerial spray (page 31-32).

5. Wait seven days to harvest crops after application with fenitrothion (page 32; APPENDIX A) (although see recommendation # 10 below).

6. Avoid treatment in areas where rare or endangered species occur and in sensitive ecological areas (pages 33-38).

7. Avoid treatment at locations or at times when honey bees and other pollinators are active (pages 33-34).

8. Avoid treatment where there are large numbers of nonpest birds or where rare species are known to occur (pages 34-36).

9. Recommend that herdsman wait 7 days before permitting livestock to forage on treated grasses or sorghum fodder, and 14 days on Acacia (page 36 and APPENDIX A).

10. Do not apply fenitrothion to sorghum or sesame; use diazinon or another substitute to avoid phytotoxicity (page 39).

11. Form a small locust unit within PPD whose only job is to survey for and control locusts (pages 40, 46).

12. Establish an office within PPD whose job would be as the Environmental Protection Agency's in the U.S.--to monitor pesticides every step from transport to storage to use to disposal (pages 43-44).

13. Upgrade PPD pesticide storage facilities (page 44).

14. Expand the pilot disposal program to eliminate the hazards associated with out-of-date and environmentally unsound pesticides (page 45)

15. Emphasize safety training for pesticide handlers including a minimum of a yearly safety course (pages 45-46).

15. Supervisors and program staff should insist that safety rules be followed and take disciplinary action if they are not (page 46).

16. Apply the fenitrothion at the recommended dosages of 0.3-0.5 kg/ha (0.24-0.39 liters/ha of 96 ULV); if this is ineffective, another insecticide should be substituted (pages 31-33).

16. Pesticide workers should be monitored for cholinesterase depression (page 30).

17. Use an "insecticide bank" to minimize the amount of insecticide stored in Sudan (pages 44-45).

18. Record information on sensitive nontarget species (such as birds, pollinators, and wildlife) and water supplies during regular field surveys for locust activity (page 46).

19. Do not apply fenitrothion over water. Establish 100 meter buffer zones around active water holes, canals, wadis, rivers, and any other ecologically sensitive locations (pages 38-39).

20. Insecticide loaders should use an old tire as a cushion when unloading drums from vehicles to reduce the risk of them bursting (page 31).

21. Alternative chemical control measures for locust control should be investigated as part of program operations (pages 23-24, 47).

PART X
LITERATURE CITED

AID. 1987. Locust/grasshopper strategy paper. Africa Bureau, U.S. Agency for International Development. Washington DC. 61 pp.

ALIC. 1982. Draft environmental profile of the Democratic Republic of Sudan. Arid Lands Information Center, Office of Arid Land Studies, University of Arizona, Tucson, Arizona. AID RSSA SA/TOA 77-1, NPS CX-0001-0-003, US Man and Biosphere Secretariat. September 1982. 302 pp.

ALRC. 1966. The locust handbook. The Anti-Locust Research Centre, Ministry of Overseas Development. London. Sponsored by the Food and Agriculture Organization of the United Nations and the United Nations Special Fund Desert Locust Project. 276 pp.

Anderson, L.D. and E.J. Atkins. 1968. Pesticide usage in relation to beekeeping. Annual Rev. Entomol. 13:213-238.

Busby, D.G., P.A Pearce, N.R. Garrity, and L.M. Richards. 1983. Effect of an organophosphate insecticide on brain cholinesterase activity in white-throated sparrows exposed to aerial forest spraying. J. Applied Ecology 20:255-263.

Carter, N.E. and N.R. Brown. 1973. Seasonal abundance of certain soil arthropods in a fenitrothion-treated red spruce stand. Canadian Entomologist 105:1065-1070.

Chapman, R.F. 1976. A biology of locusts. The Institute of Biology's Studies in Biology No. 71. Edward Arnold Publishers, London. 67 pp.

de Jong-Boon, C., I.M. Mohamed, M.E. Hajfarah, D.K. Ageer, R.A. Banaga, and F.M. Osman. 1986. Use of pesticides in the third world, with particular reference to the Sudan. Paper presented at the Global Development Conference, University of Maryland, USA. September 1986.

EPA. 1987. Fenitrothion registration standard. EPA Pesticide Fact Sheet No. 142. U.S. Environmental Protection Agency. Washington DC. 6 pp.

FAO. 1978. Report on the use of alternative insecticides for locust control. TF/AFR.40(SWE). Food and Agricultural Organization of the United Nations, Rome. 39 pp.

FAO. 1981. Sudan: report of survey on plant protection 10-26 November 1980. Action Program for Improved Plant Protection. United Nations Development Programme. Food and Agriculture Organization of the United Nations. Rome. 85 pp.

Freitag, R. and F. Poulter. 1970. The effects of the insecticides Sumithion and phosphamidon on populations of five species of carabid beetles and two species of lycosid spiders in northwestern Ontario. Canadian Entomologist 102:1307-1312.

Gordon, K. 1981. The fate of fenitrothion in the environment and its effect on organisms. Technical Report No. 3, December 1981. Australian Plague Locust Commission. Canberra, Australia. 149 pp.

Keith, J.O. and M.S. Mulla. 1966. Relative toxicity of five organophosphorus mosquito larvicides to mallard ducks. J. Wildlife Manag. 30:553-563.

Klaus, S.A., P. Symmons, J.H. Oudejans, and T. van den Dool. 1987. Sudan multi-donor locust/grasshopper control: designs for a 1987 emergency campaign and for a medium term project. FAO Report, February 25, 1987.

Lenck, D.B., J.C. Johnson, M.C. Bowman, F.E. Know, and M. Beroza. 1971. Fenitrothion residues on corn silage and their effects on dairy cows. J. Econ. Enotmol. 64:1394-99.

Mihara, K., Y. Okuno, Y. Misaki, and J. Miyamoto. 1978. J. Pestic. Sci. 3:233-38

Miyamoto, J. 1969. Mechanism of low toxicity of Sumithion towards mammals. Residue Reviews 25:251-64.

Muramoto, N. 1976. Formulation of Sumithion. Residue Reviews 60:29-38.

Nelson, H.D. 1982. Sudan, a country study. Area handbook series. DA pam; 550-27. American University (Washington DC), Foreign Area Studies. 365 pp.

Nelson, H.D., M. Dobert, G.C. McDonald, J. McLaughlin, B.J. Marvin, and P.W. Moeller. 1973. Area handbook for the Democratic Republic of Sudan. DA Pam 550-27. American University (Washington DC), Foreign Area Studies. 351 pp.

Spray, C.J., H.Q.P. Crick, and A.D.M. Hart. 1987. Effects of aerial applications of fenitrothion on bird populations of a scottish pine plantation. J. Applied Ecology 24:29-47.

Sumitomo. (n.d.). Sumithion technical manual. Sumitomo Chemical Co., Ltd. Osaka, Japan.

USDS. 1982. Sudan background notes. Bureau of Public Affairs, United States Department of State. November 1982.

Varty, I.W. 1976. Side effects of pest control projects on arthropods other than control species. Aerial Control of Forest Insects in Canada. M.L. Prebble (ed.). Canada Forest Service Department Publication.

Weinberger, P., R. Greenhalgh, R Moody, and B. Boulton. 1981. Fenitrothion as a wide-ranging perturbation factor in the environment. Pages 155-176 in Stress Effects on Natural Ecosystems, G. Barrett and R. Rosenberg (Eds.). John Wiley & Sons Ltd.

PART XI
ACRONYMS, ABBREVIATIONS, AND GLOSSARY

Acacia	A genus of chiefly tropical trees and shrubs; source for gum arabic.
African migratory locust	*Locusta migratoria*.
a.i.	Active ingredient.
AID	United States Agency for International Development.
Aminofenitrothion	A metabolite of fenitrothion.
Australian plague locust	*Chortoicetes terminifera*.
Bands	Groups of gregarious locust nymphs (hoppers).
Beneficial species	Parasites and predators that help to control pests; also pollinators, and other organisms beneficial to man.
Biological Control	The use of natural enemies--predators, parasites, or disease agents--to control pests.
BSI	British Standards Institute.
Bullrush millet	Dukhn; a drought resistant variety of millet grown in Sudan.
CA	Chemical Abstracts.
CAS Number	Unique Chemical Abstracts Service number given to each chemical substance.
Chlorinated hydrocarbon	A family of synthetic organic pesticides which are chemically similar and contain chlorine.
Cholinesterase	Acetylcholinesterase; an enzyme in animals that helps regulate the activity of nerve impulses.

Cholinesterase depression	Reduced cholinesterase level sometimes due to exposure to organophosphate or carbamate pesticides.
CICP	Consortium for International Crop Protection.
Cultural control	Crop management and other practices that make the environment less favorable for pests. Examples include field sanitation, crop rotation, diversification, harvesting practices, and trap crops.
Desert locust	*Schistocerca gregaria*.
DLCO	Desert Locust Control Organization for East Africa.
Drift application	A type of ULV application where the pesticide droplets drift with the wind into the vegetation.
Dukhn	Bullrush millet; a drought resistant variety of millet grown in Sudan.
Durra sorghum	A drought resistant variety of sorghum grown in Sudan.
EC	Emulsifiable concentrate; a pesticide formulation with a non-water soluble pesticide combined with an emulsifier and dissolved in a liquid solution.
Economic injury levels	The lowest pest density at which pest control becomes economically justified; the maximum numbers of a pest that a particular resource (such as a crop) can tolerate without economic loss.
Economic threshold	The pest density at which control measures should begin to prevent a pest population from reaching the economic injury level.
EEC	European Economic Community.
Endangered species	A species in danger of extinction.
Entomaphaga grylli	A fungus that attacks locusts.

EPA	United States Environmental Protection Agency.
FAO	Food and Agriculture Organization of the United Nations.
Feddan	A unit of measurement equal to 1.038 acres or 4,200 square meters.
Fenitrooxon	A metabolite of fenitrothion.
Flush irrigation	Irrigation systems that depend on periodic flooding of rivers or deltas.
Fodder	Food for livestock.
g	Gram.
Gezira scheme	A large irrigated agricultural development scheme between the Blue and White Niles south of Khartoum.
Gregarious phase	Locusts in the gregarious phase aggregate together and may form large swarms of adults or bands of nymphs. Gregarious locusts are morphologically different from locusts in the solitary phase.
GTZ	Gesellschaft fur Technische Zusammenarbeit (German Agency for Technical Cooperation).
Gum arabic	A gum exuded by Acacia trees and used in pills, emulsions, mucilage, candies, and as a thickener.
ha	Hectare.
Half life	The time it takes for a pesticide to be reduced to half of its initial residue.
Hoppers	Locust nymphs.
Insecticide bank	Insecticides purchased by a country but stored by the manufacturer near the point of manufacture and shipped to the country as needed.
Integrated Pest Management	Employment of a variety of biological, cultural, and chemical control methods integrated into a cohesive management

	scheme designed to maintain pest populations at levels below those causing economic injury.
Invertebrates	Animals without backbones such as insects, spiders, worms.
ISO	International Organisation of Standardization.
IUCN	International Union for the Conservation of Nature and Natural Resources.
IUPAC	International Union of Pure and Applied Chemistry.
kg	Kilogram.
kg-bw	Kilogram body weight.
LC50	A concentration of a substance that kills 50% of a population of test animals. Usually expressed in parts per million over a certain time period (such as 96 hours).
LD50	A dose of a substance that kills 50% of a population of test animals; usually expressed in milligrams of pesticide per killogram of body weight.
mg	Milligram.
ml	Milliliter.
Micronair	Brand name of a spinning cage ULV pesticide applicator.
Micro Ulva	Brand name of a spinning disc ULV pesticide applicator.
Monitoring	Continuous sampling of pests, natural enemies, pesticide residues, health indicators, etc., during a control program.
Nontarget species	Any organism other than the target pest that may be injured by a pesticide application.
Nosema locustae	A protozoan parasite of locusts.

Nymphs	Immature wingless locusts also called hoppers.
Organophosphate	A common class of pesticides derived from phosphoric acid esters.
Passerine birds	Birds in the order Passerformes including perching birds and songbirds.
Phytotoxic	Harmful to plants.
Phytotoxicity	Injury to plants caused by a chemical or other agent.
Plague	A massive outbreak of locusts covering a large geographic area and often lasting for years or decades.
PPD	Plant Protection Directorate of Sudan's Ministry of Agriculture and Natural Resources.
PPM	Parts per million.
Pyrethroid	A synthetic pesticide similar in chemical structure to pyrethrins.
Quelea	*Quelea quelea aethiopica*, a major bird pest of cereals in Sudan.
Queletox	An avicide containing fenthion to control *Quelea*.
Rahad scheme	A large irrigated agricultural development scheme on the Rahad River.
Registration standard	All pesticides registered by the U.S. Environmental Protection Agency must meet certain toxicological and ecological standards for use. A registration standard is issued for pesticides for which EPA has determined that data gaps exist.
Residue	Traces of a pesticide that remain on an object or food product after it has been treated.
Silage	Fodder prepared by storing and fermenting green forage plants.

Solitary phase	Locusts in the solitary phase do not aggregate together and are morphologically different from those in the gregarious phase.
Steering Committee	Representatives of the Government of Sudan and donors who direct the Sudan Multi-Donor Locust/Grasshopper Control Program.
Swarms	Groups of gregarious adult locusts.
Threatened species	A species vulnerable to reductions in distribution or possible extinction; a species listed as threatened under the U.S. Endangered Species Act of 1973.
Tolerance	The amount of a pesticide residue that can remain on any food that is to be eaten by humans or livestock.
Tree locusts	*Anacridium* spp.
ULV	Ultra-low volume; an application technique using equipment that applies very small quantities of almost pure toxicant.
Variable flow restrictor	A controller that regulates pesticide flow on application equipment.
Wadis	Seasonal watercourses in desert or semi-desert areas.
WHO	World Health Organization.
Wild Animals Act	Sudan legislation governing the management and protection of wildlife.

PART XII
APPENDICES

APPENDIX A

Field Evaluation of the Environmental Impact of Aerial Applications of Fenitrothion 96 ULV for Locust Control

CICP Environmental Assessment Team
Sudan Multi-Donor Locust/Grasshopper Control Program

13 September - 2 October 1987
4 November - 25 November 1987

INTRODUCTION

As part of the Sudan Multi-Donor Locust/Grasshopper Control Program, the CICP Environmental Assessment Team evaluated the environmental impact of aerial applications of fenitrothion 96 ULV for locust control. The insecticide was applied by spray plane to a series of test blocks in crop and animal forage areas. Beneficial insects and other nontarget organisms inhabiting the blocks were monitored before and after application and at regular intervals following application so as to determine negative impacts. Pesticide residues were monitored in soil, plant material and crop material.

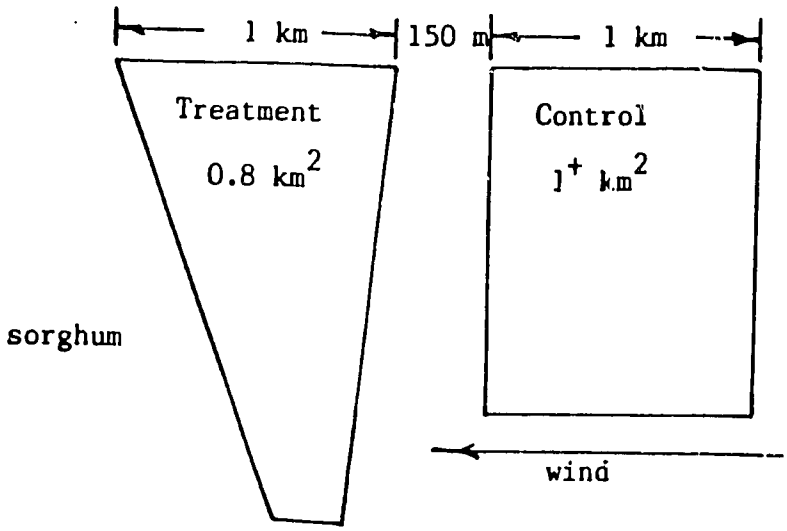
The objectives were to: (1) determine the impact of fenitrothion on nontarget species of predators, parasites, pollinators, and wildlife; (2) determine the time required for the beneficial species to recover; (3) determine any non-reversible impacts on the beneficial species; (4) determine pesticide residue accumulation and dissipation; and (5) to gather information on pesticide handling and use for incorporation into the environmental assessment.

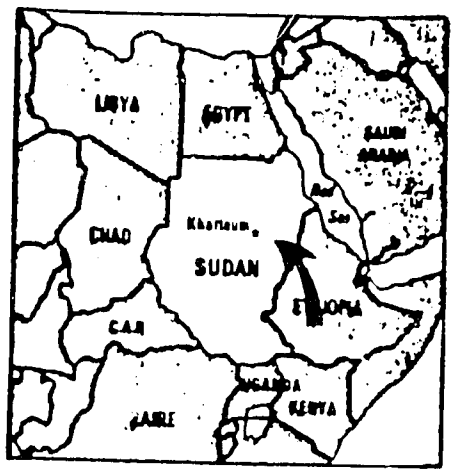
MATERIALS AND METHODS--TRIAL 1

On 18 September 1987, Dr. Munir Gabra Butrous of the Plant Protection Division of the Ministry of Agriculture and CICP environmentalist L. Pinto traveled to the Gedaref area of eastern Sudan to set up spray trials to assess the environmental impact of aerial applications of fenitrothion 96 ULV for locust control. The plan was to spray test blocks of one square kilometer each in sorghum, sesame, and animal forage areas.

However, Dr. Gassim Abdel Ghani, Head of the Gedaref PPD Station, warned that previous use of fenitrothion in the Gedaref area had demonstrated phytotoxicity to sorghum and sesame. There were measurable yield losses. Discussion with growers in the area reinforced this warning. The growers would not grant permission to apply fenitrothion on their fields because of concerns over phytotoxicity.

Therefore, the staff of the Gedaref PPD Station located a test site for testing environmental effects in a crop without putting a grower's crop at risk. The site was a forage grass area on a prison farm with volunteer sorghum scattered throughout the fields. The treatment test field was 80 hectares while the control field was 100 hectares. There was a buffer zone of 150 meters between the fields (see Figure 1).





Test Site

FIGURE 1. Test plots, Gedaref area, September 1987.

The test field was treated on 21 September 1987 by Capt. Yasif Sallem of Yadum Pest Control. The inflight observer was Inspector Mirghani of Gedaref PPD. The treatment began at 07:11 and ended at 07:27 after 14 application swaths. The temperature at the time of treatment was approximately 27°C (80°F), the wind from the south at 4-6 knots (2-3 meters per second). The sky was clear.

The aircraft parameters were as follows:

MODEL: Fletcher FU24
SPRAY EQUIPMENT: 4 Micronair 5000's
TRACK WIDTH: 20 meters
FLOW RATE: 1 liter per minute
SPEED: 90 knots (46 meters per second)
TOTAL APPLICATION: 50-64 liters *
DOSAGE: 0.6-0.8 liters per hectare **

* the range results from inaccuracy in flow meter operation
** the target dosage was 0.5 liters per hectare

The schedule for trial 1 was as follows:

September 19	Set-up test blocks; residue presamples
September 20	Nontarget presamples; observe loading procedures
September 21	Spray test block; residue samples
September 22	1-day post samples, nontarget and residue
September 23-28	Process samples
September 29	7-day samples, nontarget and residue
September 30	Process samples
October 1	Process samples
October 5	14-day residue samples PPD
October 12	21-day residue samples PPD (if necessary)

The sampling scheme was as follows:

Nontarget:

Five (5) sets of 100 sweep samples per plot to determine abundance of key nontarget species (see below) and general diversity.

Twenty (20) random samples of 1 meter square areas per plot to determine nontarget mortality. This sampling method had to be dropped because it was unworkable in the spray plot. The insects apparently were dying inside deep cracks and crevices in the soil and thus could not be counted.

One (1) transect per plot for live and dead bird counts. Each transect was 30 meters wide and 500 meters long. No dead, moribund, or abnormal birds were observed in the treated field. Few birds were present in either field.

Residues:

Subsamples were taken at 6 sites on 2 diagonals through the test plot. Each diagonal comprised one sample for the analysis. Samples were taken of soil (0-3 inches), forage grass (100 gms), sorghum leaves (100 gms), and sorghum heads

(100 gms). Duplicate samples were taken for analysis in the U.S. and Sudan.

MATERIALS AND METHODS--TRIAL 2

The original plan for this trial was to study the effects of fenitrothion on nontarget organisms in large spray blocks after actual locust control sprays at the Red Sea coast. (The Red Sea coast area is the major winter breeding site for the desert locust in Sudan). However, the winter control campaign had not yet begun and so the plan had to be modified.

Radio queries to PPD field offices uncovered no suitable sites for running the field trials; most areas were dry and without green vegetation. Rainfall data supplied by the Meteorological Bureau suggested that the Gedaref area of eastern Sudan was the only accessible area of Sudan with significant rainfall in the previous four to six weeks, so this area was selected for aerial survey.

On 12 November 1987, Pinto flew to the Gedaref area of eastern Sudan to attempt to find a suitable test site. Accompanying Pinto was FAO consultant Mark Gorta (Team Leader for the Sudan Multi-Donor Locust/Grasshopper Control Program), and Dr. Butrous, Pesticide Chemist with the Plant Protection Directorate (PPD) of the Ministry of Agriculture. The aircraft was provided by the Desert Locust Control Organization (DLCO-EA), and was piloted by Captain Kitenda Kit R.A. with Engineer Gurmail Singh.

No green forage grass areas were located. The ground was barren or the vegetation was senescent except for the irrigation schemes on the way (Gezira, Rahad) and fields containing Acacia scrub, a natural forage for goats, camels, and other animals. (Acacia was not considered as a site for a trial earlier because the thorns make it difficult to sample.)

Potential Acacia field sites were identified from the air about 8 kilometers from Gedaref at a heading of 220 magnetic. Later, Gorta, Munir, and Pinto drove to the site in a PPD vehicle and determined that the sites were suitable for the tests. A treatment field and a control field were

marked off (see Figure 2). The area of each was approximately 70 hectares.

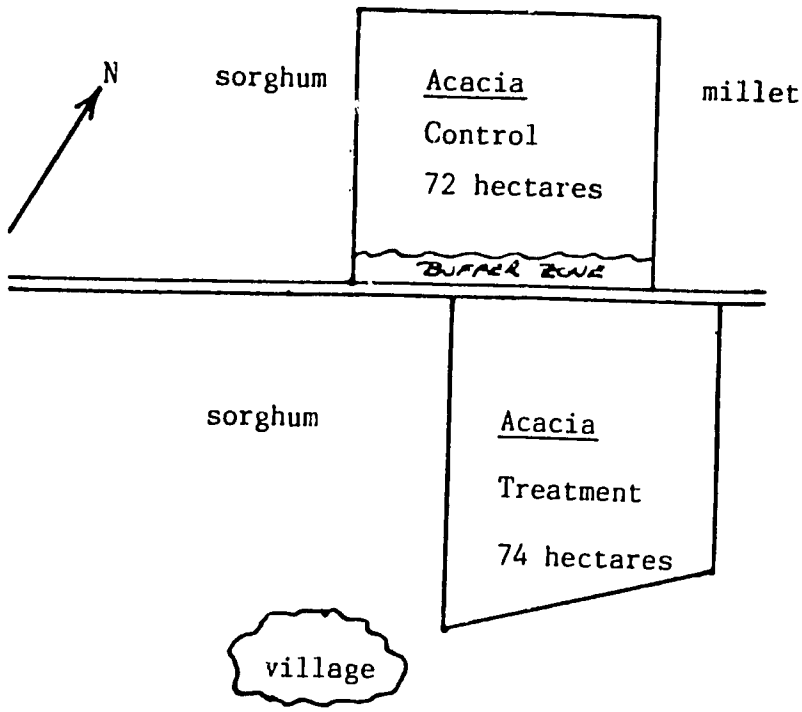


FIGURE 2. Acacia test plots, Gedaref area, November 1987.

The test field was treated on Friday, November 13, 1987 by the DLCO Islander (Capt. Kitenda, Eng. Singh). Munir was the in-flight observer; Gorta and Pinto marked the swath width with the PPD Landrover. The treatment began at about 9:10 a.m. and ended at 9:30 after 11 application swaths. The temperature at time of treatment was 32°C, humidity 23%, and the wind NNE (40%), wind speed ranging 8-16 knots (4-8 m/sec). There were 10% high patchy clouds in an otherwise clear sky.

The aircraft parameters were as follows:

MODEL: Britten-Norman Islander, twin engine
SPRAY EQUIPMENT: 2 Micronair AU3000's
TRACK WIDTH: 75 meters
FLOW RATE: 14.7-16 liters per minute
SPEED: 110 knots (56 meters per second)
TOTAL APPLICATION: 36 liters *
DOSAGE: 0.51-0.57 liters per hectare **

* actual tank-drained measure
** the target dosage was 0.5 liters per hectare

The sampling and treatment schedule was as follows:

November 12	Set-up test blocks, nontarget presamples.
November 13	Spray test block; 0-day residue samples
November 14	1-day post samples, nontarget and residue;
November 20	7-day residue samples
November 21	8-day nontarget samples *

* Unable to take 7-day nontarget samples on morning of 20 November because of PPD scheduling conflict

The sampling scheme was as follows:

Nontarget:

No sweep samples could be taken because of the *Acacia* thorns.

Twenty (20) random samples of 1 meter square areas per plot to determine nontarget mortality. This sampling method had to be dropped because it was unworkable in the spray plot. Nontarget insects and other arthropods [other than tree locusts and flies (*Musca* sp., prob. *sorbens*)] were uncommon, and crawling insects that died apparently did so deep in cracks and crevices in the soil and thus could not be counted.

Two (2) transects per plot for insects and other arthropods. Each transect was 2 meters wide and 230 meters long.

Ten (10) pitfall traps per field, 18-hour duration.

Two (2) transects per plot for birds and other vertebrates. Each transect was 30 meters wide and 230 meters long. No dead birds or other vertebrates were noted on any transects.

Residues:

Acacia leaves were sampled on two transects through the test plot. Each transect was one sample. Each sample consisted of about 100 grams of leaf material. Samples were analyzed at the University of Miami for fenitrothion residues.

Nine droplet cards were placed on the ground and in vegetation just before treatment to determine the range of droplet sizes and spray coverage.

RESULTS AND DISCUSSION

Effects on Nontarget Species

The diversity and abundance of insects and other arthropods in forage grass was reduced significantly after aerial application of fenitrothion 96 ULV as shown in Table 1 which presents composite data for the species taken by sweep samples. Total number of insects in the treated field dropped 97% and the number of species dropped 90% one day after treatment. One week after treatment, the number of species represented in sweep samples from the treated field averaged 17% of those from the control field; the total number of arthropods per sample in treated fields was only 4% of those in control fields.

Table 1. Diversity and Abundance of Nontarget Arthropods in Forage Grass Treated With Fenitrothion and Control

Date	Treatment /1	No. of Species Per 100 Sweeps	No. of Individuals Per 100 Sweeps
9/19	control	37	146
	control	21	131
	control	41	288
	control	41	274
	control	30	108
	Average	34	189
9/19	fenitrothion	41	183
	fenitrothion	19	81
	fenitrothion	33	138
	fenitrothion	29	143
	fenitrothion	35	146
	Average	31	138
9/22	control	29	130
	control	32	166
	control	17	118
	control	26	179
	control	28	130
	Average	26	145
	fenitrothion	3	3
	fenitrothion	4	4
	fenitrothion	4	7
	fenitrothion	1	1
	fenitrothion	3	5
	Average	3	4
9/29	control	23	172
	control	20	136
	control	29	123
	control	27	242
	control	19	304
	Average	24	195
	fenitrothion	2	4
	fenitrothion	8	11
	fenitrothion	3	12
	fenitrothion	2	2
	fenitrothion	6	7
	Average	4	7

1/ Aerial treatment 9/21, 0.6-0.8 liters/ha fenitrothion 96 ULV

The dosage targeted for the trial was 0.5 liters per hectare, based on PPD recommendations and the common practice in the Gedaref area for locust control. This dosage is higher than the 0.24-0.39 liter per hectare dosages (equivalent to 0.3-0.5 kilogram per hectare) recommended by the manufacturer (Sumitomo n.d.) and by the FAO consultants working in the program. Moreover, the actual dosage of fenitrothion that was applied to the treatment field was even higher; either 0.6 or 0.8 liter per hectare, depending on the method of calculation. The discrepancy between target and actual dose was probably due to faulty calibration of the aircraft's spray equipment.

Objectives of this field trial were to (1) determine the time required for the beneficial species to recover after application of fenitrothion and (2) determine any non-reversible impacts on these species. Neither objective could be met because of the ephemeral nature of the vegetation. Fourteen days after the treatment the vegetation had nearly disappeared from lack of water; what little was left was dried out and unsuitable for sweep samples (residue samples were taken). There was no insect activity in the either field.

Table 2 presents data from transects to determine abundance of invertebrates and birds in treatment and control fields of Acacia in Field Trial 2. The invertebrate predators are represented by the families Araneidae, Lynyphiidae, Coenagrionidae, and Syrphidae; parasites by Braconidae. Based on the transect data for the invertebrates, fenitrothion treatment reduced the total number of species by 50% after one day and 60% after 8 days, when compared with the control field. Total individual invertebrates were reduced by 59% and 83% during the same time periods.

The transect data on birds suggests a reduction in species diversity and abundance in treated fields. However, no bird mortality or changes in bird behavior were observed during

or after treatment. The limited nature of the trial and the low numbers of birds prevented an adequate measure of fenitrothion's effects on bird populations.

Table 2. Number of Invertebrates and Birds in Treatment and Control Fields of *Acacia* Treated with Fenitrothion.

Invertebrate species	DAY 0 (Before Treatment)				Day 1				Day 7			
	Transect 1 Control	Transect 2 Control	Transect 1 Treated	Transect 2 Treated	Transect 1 Control	Transect 2 Control	Transect 1 Treated	Transect 2 Treated	Transect 1 Control	Transect 2 Control	Transect 1 Treated	Transect 2 Treated
Araneidae (orb weaver spider)			1									
Linyphilidae, (sheetweb weaver spider)	3	5	12	1		1	1	1		1		
Pieridae	1	1	1	2	1	3				1		
Coenagrionidae	3	2		6	5			2	4	2		
Braconidae		1		1					5	2	1	
Nymphelidae	1							1				
Araneidae Species 2		1										
Pyrrhocoridae		1			1	1						
Myrphidae	2				1	2				1		1
Pyralidae (grass moth)						1	2			2		
Pyralidae Species 2 (Pyralinae)						1			4	1		1
Gelechiidae												1
Gelechiidae Species 2												
TOTAL SPECIES	6	5	3	4	4	6	2	3	3	7	1	3
TOTAL INDIVIDUALS	11	10	14	10	8	9	3	4	13	10	1	3

Bird species 1/												
Mourning dove (*Streptopelia decipiens*)	2		7	2		1	2	1	1			
Laughing dove (*Stigmatopelia senegalensis*)		1	1					1				
Chanting goshawk (*Melierax musbatus*)			1									
Grey shrike (*Lanius excubitor*)	3	2	1	1	6		2		2	2		1
Ethiopean swallow (*Hirundo aethiopica*)				1			1		5			1
Pied crow (*Corvus albus*)							2				2	
Bush sparrow (*Cymnoris dentata*)	1	1			2				1			
Common sparrow-hawk (*Accipitor nisus*)										1		
Kite (*Milvus migrans*)									1			1
Unidentified black bird									1			
TOTAL SPECIES	3	3	4	3	2	1	4	2	6	2	1	3
TOTAL INDIVIDUALS	6	4	10	4	8	1	7	2	11	3	2	3

1/ Field identifications were not made or verified by an ornithologist

Table 3 presents data from pitfall trap collections in the same trial. The most noticeable difference between treatment and control related to the presence of ants (Formicidae). Fifty ants were collected from pitfall traps in the control field and only one ant was collected from traps in the treated field.

Table 3. Pitfall Trap Collections/1 from Treatment and Control Fields

	DAY 1 Control	DAY 1 Treated	DAY 7 Control	DAY 7 Treated
1	Lepismatid 2 Gryllid 2			Gryllid 1
2	Formicid-A 1 Formicid 3 Thomisid 1			Lepismatid 1
3	Formicid-C 2	Lepismatid 1 Gryllid 1 Collembola 1	MISSING	
4	Formicid-C 2	Staphylini 1	Formicid B 5 Clerid 1 Gryllid 2	MISSING
5	Formicid-C 1			
6		Collembola 1		
7	Gryllid 1 Collembola 1 Chrysomel. 1		Acarina 1	
8	Lepismati-B 1 Formicid-D 1 Thomisid 1	Gryllid 1 Lycosid 1	Collembola 1 Formicid-B 9 Pyrrhocorid 1	Gryllid 1 Thomisid 1
9	Formicid-A 1 Mirid 1	Lycosid 1 Lepismatid 1 Gryllid 1		
10	Formicid-A 1	Formicid-B 1	Formicid-B 24 Carabid 1	
Av. # species	1.7	1.1	1.0	0.4
Av. # individ's	2.3	1.1	5.0	0.4

1/ Number of each species per trap per day.

OTHER FINDINGS

Key Species:

The following fly parasites of locusts are considered key beneficial species: Stomorhina lunata, which attacks the eggs of the desert locust; Systoechus somali, a bombylid whose larvae feed on desert locust eggs; Symmictus costatus, a nemestrinid whose larvae attacks locust nymphs; and Blaesoxipha filipjevi, a sarcophagid that attacks locust nymphs and adults. These parasites are often found in close association with locusts. S. lunata, probably the most important insect enemy of the desert locust, is rarely found isolated from swarms of egg-laying locusts (ALRC 1966).

None of the beneficial species listed above were found in the control or treatment fields for either spray trial, probably due to the absence of desert or migratory locusts in the test area.

7-Week Nontarget Samples From Trial 1

The forage grass fields from the September spray trial were revisited in November 1987 to determine the status of the vegetation and to take samples of nontarget organisms. There were no plants or insects to sample in any fields.

Forage grasses and crops in eastern and central Sudan are green and growing for only about . months of the year. This seasonal variability of grasses and crops--the resources used by locusts and nontarget species alike--makes it difficult to determine long-term insecticide effects. It is also relevant to environmental risk resulting from insecticide application. Fenitrothion for locust control is applied during the short period when these arid areas are green; at the same time and in the same place where other living things (pollinators, birds, livestock, predators, people, etc.) are active.

Phytotoxicity in Sorghum in Trial 1

Fenitrothion 96 ULV applied at 0.6-0.8 liter per hectare caused phytotoxicity to durra sorghum. Sorghum leaves were burned and spotted in 30% of the plants 24 hours post-treatment. Seven days after treatment 100% of the sorghum plants in the treated field were affected with at least the upper leaves burned and shriveled. On the downwind field border the fenitrothion mist had drifted about 30 meters into an adjacent sorghum field. Plants in this drift area also were damaged. No burn was evident in the rest of the untreated fields.

It appeared that some forage grasses also were damaged by the treatment, although this damage was much less clear. These grasses had dried and shriveled in the treated fields but this may have been drought related. The grasses in the untreated field exhibited similar drying, but to a lesser degree. According to Dr. Gassim Abdel Ghani of the Gedaref PPD station (personal communication 1987), fenitrothion has caused "scorching" in forage grass fields in the past.

Phytotoxicity from fenitrothion apparently has been documented in drought resistant sorghum in Australia. However, the manufacturer (Sumitomo Chemical Co., Ltd., Osaka, Japan) makes no mention of this in the Sumithion (fenitrothion) technical manual (Sumitomo n.d.).

According to interviews with PPD field personnel, large fields of crops are rarely treated in locust control in Sudan. However, small stands of sorghum, millet, and sesame are often found in forage grass fields, Acacia fields, and other locust habitats. Phytotoxicity field tests should be run in durra sorghum in Sudan to determine the dose response of burning and yield loss (if any) from fenitrothion applications. Perhaps the manufacturer would be willing to fund such trials through the Plant Protection Department.

Until then, any large-scale treatment of sorghum or sesame should be made with an alternative insecticide such as diazinon that is not phytotoxic to the crops. (However, diazinon is highly toxic to birds and should not be applied where birds are present.)

Efficacy Against Tree Locusts in Trial 2

There is no good method for quantifying mortality in tree locusts from aerial insecticide application in an actual field operation. The kill of tree locusts in the treated field appeared uneven. A rough estimate of percent reduction in the treated field ranged from 90% in the center of the field down to 60% or less in the third of the field bordering the road. That more live locusts were present in this area of the field could have indicated uneven insecticide application or it could have indicated immigration of tree locusts from the control field. The nine spray droplet cards placed in the treatment field suggested uneven application. There were also fewer dead locusts on the ground near the road which also suggests uneven kill.

The high dosage of fenitrothion applied to the treatment fields (in both trials above the maximum recommended dose of the manufacturer) should be considered when interpreting any of the results reported in this document. What also must be considered, however, is that overdosing is commonly practiced in locust control efforts in Sudan. The environmental effects reported here are probably representative of the impacts from aerial applications of fenitrothion in the Sudan Multi-Donor Locust/Grasshopper Control Program.

RESULTS OF RESIDUE ANALYSIS

FENITROTHION 96 ULV USED IN LOCUST CONTROL IN SUDAN, AFRICA

Samples collected September 18-26, 1987 in Sudan were shipped to Miami frozen, packed with Dry Ice. Crop samples were extracted as per the U.S. Official Method - A.O.A.C. 29.011(d), followed by analysis using G.L.C.-F.P.D. The Wad Medani Lab used a solvent modification which would not effect the extraction efficiency. Soil samples were extracted by an exhaustive (Soxhlet) method.

Samples were collected the day before spray application (-1), the day of spraying (0), the day after (+1), after 7 days (+7), and after 14 days (+14). Twenty-one (21) day samples were not analyzed since nothing was detected after 14 days. The University of Miami laboratory only received samples through +7 days. The Medani laboratory split each sample in half and analyzed duplicates of most samples.

Acacia leaf samples collected by Larry Pinto November 3-11, 1987 were preserved in alcohol to facilitate passage through U.S. Customs and were carried to the U.S. by Pinto. The alcohol was drained and analyzed and the results added to the results of the leaves analyzed by A.O.A.C. 29.011(d) Method.

Samples of Soil, Sorghum Grain and Grass were spiked at 30 ppm by the Wad Medani Lab with the following recoveries:

PRODUCT	SPIKE (ppm)	RECOVERY (%)
Soil	30	92.5
Sorghum Grain	30	91.9
Grass	30	96.3

RESIDUES FROM SAMPLES ANALYZED AT THE
UNIVERSITY OF MIAMI, USA AND
WAD MEDANI RESIDUE LAB, SUDAN

SPL NO	PRODUCT	DAY	FENITROTHION (ppm)	
			MIAMI	WAD MEDANI
# 2	Sorghum Grain	-1	N.D.*	N.D.*
# 1	Sorghum Grain	0	27.5	22.7
	Sorghum Grain	0	---	39.9**
# 3	Sorghum Grain	0	53.6	59.8
# 4	Sorghum Grain	+1	16.0	25.8
	Sorghum Grain	+1	---	24.2**
# 5	Sorghum Grain	+1	10.7	15.4
	Sorghum Grain	+1	---	15.8**
# 6	Sorghum Grain	+7	0.10	0.02
# 7	Sorghum Grain	+7	2.79	N.D*
	Sorghum Grain	+14	---	N.D.*
	Sorghum Grain	+14	---	N.D.*
#10	Sorghum Stock	-1	N.D.*	N.D.*
#11	Sorghum Stock	0	220	187
	Sorghum Stock	0	---	170**
#12	Sorghum Stock	0	269	316
	Sorghum Stock	0	---	472**
#13	Sorghum Stock	+1	38.9	50.0
	Sorghum Stock	+1	---	41.0**
#14	Sorghum Stock	+1	48.0	76.8
	Sorghum Stock	+1	---	64.5**
#15	Sorghum Stock	+7	1.36	0.04
#16	Sorghum Stock	+7	1.95	0.08
	Sorghum Stock	+14	---	N.D.
	Sorghum Stock	+14	---	N.D.
#55	Forage Grass	-1	N.D.*	N.D.*
#56	Forage Grass	0	89.1	66.3
	Forage Grass	0	---	85.0**
#57	Forage Grass	0	41.4	117
	Forage Grass	0	---	111**
#58	Forage Grass	+1	36.4	30.7
	Forage Grass	+1	---	44.9*
#59	Forage Grass	+1	29.8	61.7
	Forage Grass	+1	---	40.7**
#60	Forage Grass	+7	4.76	0.61
#61	Forage Grass	+7	2.91	0.81
	Forage Grass	+14	---	N.D.*
	Forage Grass	+14	---	N.D.*
	Forage Grass	+14	---	N.D.*
	Forage Grass	+14	---	N.D.*

*N.D. - None Detected Above Limit of Detection (0.02 ppm)
**Duplicate (Sample split in half and analyzed twice)

RESULTS (Cont'd.)

SPL NO	PRODUCT	DAY	FENITROTHION (ppm)	
			MIAMI	WAD MEDANI
	Soil	-1		N.D.*
	Soil	0		28.3
	Soil	0	---	22.3**
	Soil	0		22.3
	Soil	0	---	22.3**
	Soil	+1		3.33
	Soil	+1	---	3.33**
	Soil	+1		5.20
	Soil	+1	---	4.00**
	Soil	+7		0.25
	Soil	+7	---	0.25*
	Soil	+7		0.61
	Soil	+14	---	N.D.*
	Soil	+14	---	N.D.*
	Soil	+14	---	N.D.*
	Soil	+14	---	N.D.*
A	Acacia Leaves	0	93.8	---
B	Acacia Leaves	0	31.3	---
A	Acacia Leaves	+1	14.5	---
B	Acacia Leaves	+1	9.41	---
A	Acacia Leaves	+7	4.60	---
B	Acacia Leaves	+7	8.45	---

*N.D. - None Detected Above Limit of Detection (0.02 ppm)
**Duplicate (Sample split in half and analyzed twice)

DISCUSSION

Fenitrothion is not registered for use in the U.S.A., so a tolerance has not been established. However if we look at the toxicities and tolerances of organophosphates that are registered for use on sorghum in the U.S.A., some conclusions on relative danger can be established.

Pesticide	LD_{50}	Tolerance	Product
Demeton	3-12 mg/kg	0.2 ppm	Sorghum Grain
		0.2 ppm	Sorghum Fodder
Metasystox	64 mg/kg	0.75 ppm	Sorghum Grain
		2 ppm	Sorghum Fodder
Ethion	200 mg/kg	2 ppm	Sorghum Grain
		2 ppm	Sorghum Fodder
Fenitrothion	800 mg/kg	------	-------

Fenitrothion is less toxic than Ethion which has a 2 ppm tolerance on Sorghum Grain and Fodder. From the results of the analyses, it might be recommended that at least 7 days elapse after fenitrothion application before crops be harvested or animals be permitted to forage on grasses or sorghum fodder. It would not be expected for fenitrothion to translocate from soil to plants, but for complete safety, it might be recommended that crops not be planted in fields within 14 days after fenitrothion treatment for locust control. Acacia foraging should be permitted only after 14 days post application.

ACKNOWLEDGMENT

We thank the personnel of the Plant Protection Directorate, Sudan Ministry of Agriculture and Natural Resources for their generous cooperation, and the Pesticide Residue Laboratory at Wad Medani for providing laboratory facilities to analyze residue samples. We also thank Dr. Munir Gabra Butrous for his critical assistance in conducting the field evaluations.

APPENDIX B

PERSONS CONTACTED

Plant Protection Directorate, Sudan

Abdel Latif Ali Zaroug	Acting Director
Abdel Moim Ali Ahmed	Inspector, Kassala Station
Abdel Rahman Kheir	Station Head, Shendi Station
Adel Omer Ahmed	Plant Protection Specialist, Khartoum
Ahmed Hassan Abdel Aizez	Inspector, Kassala Station
Ali Mohamed Ali	Station Head, Kassala Station
Gassim Abdel Ghani	Station Head, Gedaref Station
Hamza Osmun	Inspector, Kassala Station
Hassan Hamid Medani	Head, Pesticide Stores Section
Ibrahim Mohed Nur	Inspector, Gedaref Station
Idris Sabir	Station Head, Au Duwem Station
Ikhlas Ali Mohamed	Inspector, Khartoum
Karrar, A.H.	Head, Locust/Grasshopper Section
Mirghani	Inspector, Gedaref Station
Mounis Mohamed Abdel Faraq	Inspector, Wad Medani Residue Laboratory
Munir Gabra Butrous	Pesticide Chemist
Safi Mohamed El Mahdi	Entomologist, Gedaref Station
Shaaban Ibrahim Shaaban	Director, Wad Medani Residue Laboratory
Shaaban Shahata	Field Officer, Khartoum

FAO Consultants

Joseph Gergis Awad	Survey and Reporting Specialist
Mark Gorta	Locust Control Specialist, Team Leader 9/27-12/87
Hassan Abbas El Tom	Operations Advisor
Mohamed Mounzer Imam	Spray Machinery Specialist
Laurence McCulloch	Locust Control Specialist, Team Leader 6/87-9/87
Phil Symmons	Locust Control Specialist
Larry Schuurman	Logistics

FAO Staff

E. de las Casas	Plant Protection, Rome
Magdy Ghieth	Project Officer, Sudan

USAID

Bessie Boyd	AID Africa Bureau (AFR/TR/PRO) Washington
Carrol Collier	Bureau of Science and Technology, Office of Agriculture, Washington
Catherine Farnsworth	Assist. Government Development Officer, Sudan
Anita Mackie	Government Development Officer, Sudan

Others in Sudan

Prof. Beshir	University of Khartoum
Gunther Hanrieder	DLCO/GTZ, Khartoum
Ibrahim El Khalil Ibrahim	Shell Co. of Sudan
Capt. Kitenda Kit R.A.	DLCO Pilot
Chriistian Kooyman	Consultant to Dutch Ministry of Foreign Affairs
Pim Plantinger	Netherlands Embassy
Yassif Sallem	Yaddum Pest Control Pilot
Samir Sir El Khatim	Director, DLCO Khartoum Regional Station
Gurmail Singh	DLCO Engineer
Roelph Smit	EEC Sudan
G. Walter-Echols	Team Leader GTZ Sudan

Others in U.S.

John Buursink	TAMS Rural Development, Washington
Pat Matteson	Environmental Consultant, NC
George Schaefers	Cornell University