PN-ABL

DYNAMAC
CORPORATION

Final Technical Report

Results of the Mali Pesticide Testing Trials Against the Senegalese Grasshopper

USAID Contract No. AFR-0517-C-00-7035-00
July 1988

Prepared by:
Dynamac Corporation
The Dynamac Building
11140 Rockville Pike
Rockville, MD 20852

In association with:
Consortium for International Crop Protection
4321 Hartwick Road, Suite 404
College Park, MD 20740

Prepared for:
U.S. Agency for International Development
African Grasshopper/Locust Pesticide Testing Project

PN-ABD-822
ISN 63711

July 1988

FINAL TECHNICAL REPORT

RESULTS OF THE MALI PESTICIDE TESTING TRIALS AGAINST THE SENEGALESE GRASSHOPPER

USAID Contract No. AFR-0517-C-00-7035-00

Prepared by:

Dynamac Corporation
The Dynamac Building
11140 Rockville Pike
Rockville, MD 20852

In association with:

Consortium for International Crop Protection
4321 Hartwick Road, Suite 404
College Park, MD 20740

Prepared for:

U.S. Agency for International Development
African Grasshopper/Locust Pesticide Testing Project

EXECUTIVE SUMMARY

During the months of August and September 1987, Dynamac Corporation, un contract to USAID, conducted field trials to test for the efficacy environmental impacts of eight pesticides used to control the Senegal grasshopper, Oedaleus senegalensis: bendiocarb, carbaryl, chlorpyrif diazinon, fenitrothion, lambda-cyhalothrin, malathion, and tralomethrin. study site consisted of 60 km^2 of typical Sahelian grassland near Nara northwestern Mali. Early successional grasses, ranging from 20 to 70 cm height, and scattered combretaceous shrubs characterized the landscape. T populations consisting of 63 to 95% adult Oedaleus senegalensis were trea at a mean density of 0.5 grasshoppers/m^2. All materials were applied ultra-low-volume (ULV) rates using TurboThrush S2RTs equipped with Micron AU5000 units. A set of preliminary trials was conducted to assure t adequate deposition was occurring and that the expected efficacy was be achieved with the reference chemicals fenitrothion and malathion. In Phase a randomized design of thirty-six 12-ha plots was used to determine efficacies and gross environmental impacts of the eight pesticides. Phase II trials, which were designed to test more thoroughly for environmental effects of four of these pesticides, fifteen 100-ha plots t encompassed a range of habitats including maturing crops were selected.

All materials were applied at the lower of two rates originally chosen the test. Preliminary trials were conducted to assure that proper drop size (100 to 150 microns), uniform coverage (narrow 40-m swaths), accura metering (repeated prespray calibration), and plot integrity (150-m buf zones) were obtained. During both phases, two flagging cars and minin flying heights (3 to 5 m) were used to obtain precise application to the te plots. The sprays were conducted during the favorable environment conditions of the early morning. Oil-sensitive cards and slides were used monitor spray deposition for coverage and drift.

The efficacy of the pesticides was determined by conducting grass- hopp counts 1 day before spraying and then 1, 3, 7, and 14 days after spraying. both Phases I and II, two 100- by 2-m transects were search

for live grasshoppers. Originally, forty 0.1 m^2 ring counts and visualized square meter counts were used to quantify grasshopper nymphs. However, when the population reached the adult stage, 100-m transect counts, as well as the visualized square meter counts, were used. In Phase I, all eight pesticides provided 80% or greater reduction of the grasshopper numbers by 1 day posttreatment. At day 3, the synthetic pyrethroids showed significantly less reduction than five of the materials, but this was possibly attributable to rain on the day they were sprayed. Carbaryl was the only material that showed an increase in control over the first week. Four pesticides -- malathion, chlorpyrifos, carbaryl, and lambda-cyhalothrin -- were selected for inclusion in Phase II trials based on efficacy and a desire to test a range of chemical types. In contrast to Phase I, a substantial portion (27%) of the grasshopper fauna in Phase II consisted of species other than Oedaleus senegalensis. The four pesticides exhibited approximately 70% or better control through the 7-day sample in both grassland and cropland. Lambda-cyhalothrin showed a significantly greater reduction of grasshopper numbers in both habitats at the 1-day counts.

The sampling for beneficial and nontarget insects utilized several counting and capture techniques to describe the affected fauna and to identify potential indicator species. Sweep-netting and malaise-trapping proved to be ineffective in collecting adequate numbers of insects. Pitfall traps collected large numbers of ground-dwelling beetles, but no significant treatment effect was discernible because of declining control levels. Sticky traps also collected substantial numbers of insects (principally small diptera and hymenoptera), but again, both the treatment and control numbers were too variable for an assessment of effects. Visual searches for live and dead insects sampled the widest range of taxa, but the numbers from this sampling program were too small to demonstrate differences among treatments. The harvester ant (Messor sp.) proved to be the best indicator species due to its abundance, wide distribution, and conspicuous activity. In both Phase I and Phase II, posttreatment counts of dead ants revealed substantial mortality as a result of several pesticides. Malathion-treated plots contained the greatest number of dead ants in both phases, and lambda-cyhalothrin plots

had few dead ants. Greater replication is recommended for the visual transect, sticky trap, and pitfall trap methods. We conclude that the assessment of impacts on indicator species, such as ants, is the most productive technique, and that the collection of millet heads would likely be a valuable method for analysis of the impact on important pest and beneficial species.

Carcass searches, conducted over a combined area of 700,000 m^2 for both phases, revealed no dead or injured vertebrate animals in either phase. At the same time, normal behavior was observed among 1569 live birds counted during 96 transect runs. Although the bird numbers were highly variable, reduced activity in chlorpyrifos-treated plots was discernible from the analysis of transect counts. In addition, moderate brain cholinesterase depression was observed in carbaryl-exposed birds. The numbers of other vertebrates were too low for an assessment of numerical changes, but rodents, birds, lizards, and frogs were collected from test plots and shown to possess relatively low pesticide residue levels. An analysis of samples of surface water, soils, forage grasses, and grain crops appears to demonstrate that residues declined to negligible levels within 7 days. No phytotoxicity was observed among the collected material or in visual surveys of the test plots. A detailed survey of the vegetation and ecosystem components of the test site did not identify any especially vulnerable habitats associated with the areas of grasshopper control. However, the rare Sahelian aquatic habitats (not present in the test area) should be given special consideration in general control programs.

The conclusions of this report are that all eight pesticides proved to be efficacious against the Senegalese grasshopper and that no dramatic environmental impacts were seen. The degree of differences in the impact on nontarget insects has not been determined, but differences in the selectivity of the pesticides appear to exist. We recommend that pesticide control strategies consider using low rates of pesticides (shown to be efficacious in this study), with specific monitoring for impacts on selected beneficial insects.

CONTENTS

	Page
EXECUTIVE SUMMARY	iii
LIST OF FIGURES	xii
LIST OF TABLES	xiv
PREFACE	xvii
1. INTRODUCTION	1-1
1.1 BACKGROUND	1-1
1.2 OBJECTIVE	1-2
1.3 PESTICIDE SELECTION	1-3
1.4 PROJECT CHRONOLOGY	1-8
2. ECOLOGICAL DESCRIPTION OF THE SITE	2-1
2.1 CLIMATIC AND PHYSIOGRAPHIC REGION	2-1
2.2 SOIL AND VEGETATION ZONE	2-1
2.3 FAUNA	2-2
2.4 AGRICULTURAL AND GRAZING USAGE	2-3
3. PRELIMINARY SURVEYS AND TESTING	3-1
3.1 SITE SELECTION	3-1
3.2 GRASSHOPPER POPULATIONS	3-2
3.2.1 SAMPLING METHODS	3-2
3.3 PRELIMINARY TRIAL PLOT DESIGN	3-4
3.4 PRELIMINARY TRIAL PESTICIDE APPLICATION	3-6
3.4.1 MATERIALS	3-6
3.4.2 APPLICATION EQUIPMENT	3-6
3.4.3 APPLICATION	3-6

CONTENTS (continued)

3.5 PRELIMINARY TRIAL EFFICACY EVALUATIONS 3-9
3.5.1 METHODS 3-9
3.5.2 RESULTS AND DISCUSSION. 3-9

3.6 TESTS OF APPLICATION METHODOLOGY 3-9
3.6.1 REINVASION OF PLOTS 3-9
3.6.2 DROPLET SIZE. 3-11
3.6.3 SPRAY COVERAGE. 3-11
3.6.4 DELAYED DELIVERY. 3-11
3.6.5 OUTPUT VOLUME 3-13
3.6.6 APPLICATION MODIFICATIONS 3-13

3.7 BACKGROUND SAMPLING OF BENEFICIAL AND NONTARGET INSECTS. . 3-14

3.8 BACKGROUND ENVIRONMENTAL IMPACT SAMPLING 3-14

4. PHASE I TRIALS. 4-1
4.1 TEST DESIGN. 4-1
4.1.1 PLOT DELINEATION. 4-1
4.1.2 PLOT SIZE AND ARRANGEMENT 4-1
4.1.3 HABITAT DESCRIPTION 4-4
4.1.4 ORDER OF TREATMENTS 4-4

4.2 PESTICIDE APPLICATION. 4-8
4.2.1 TREATMENTS AND RATES. 4-8
4.2.2 PESTICIDE HANDLING. 4-8
4.2.3 CALIBRATION OF EQUIPMENT. 4-10

4.3 EFFICACY DETERMINATIONS 4-13
4.3.1 METHODS 4-13

CONTENTS (continued)

Page

4.3.2 RESULTS 4-15
4.3.3 DISCUSSION. 4-23

4.4 IMPACTS ON BENEFICIAL AND NONTARGET INSECTS. 4-23
4.4.1 METHODS 4-23
4.4.2 RESULTS 4-24
4.4.3 DISCUSSION. 4-27

4.5 ENVIRONMENTAL IMPACTS. 4-30
4.5.1 METHODS 4-30
4.5.2 RESULTS 4-31
4.5.3 DISCUSSION. 4-31

4.6 RESIDUE SAMPLING 4-31
4.6.1 METHODS 4-31
4.6.2 RESULTS 4-32
4.6.3 DISCUSSION. 4-32

5. PHASE II TRIALS 5-1

5.1 TEST DESIGN. 5-1
5.1.1 PLOT DELINEATION. 5-1
5.1.2 PLOT SIZE AND ARRANGEMENT 5-1
5.1.3 HABITAT DESCRIPTION 5-3
5.1.4 ORDER OF TREATMENTS 5-5

5.2 PESTICIDE APPLICATION. 5-5
5.2.1 TREATMENTS AND RATES. 5-5
5.2.2 PESTICIDE HANDLING. 5-5
5.2.3 CALIBRATION OF EQUIPMENT. 5-6

CONTENTS (continued)

Page

5.2.4 FIELD APPLICATION 5-6

5.3 EFFICACY DETERMINATIONS. 5-10
5.3.1 METHODS 5-10
5.3.2 RESULTS 5-10
5.3.3 DISCUSSION 5-17

5.4 IMPACTS ON BENEFICIAL AND NONTARGET INSECTS. 5-17
5.4.1 SAMPLE DESIGN 5-17
5.4.2 RESULTS 5-19
5.4.3 DISCUSSION. 5-19

5.5 ENVIRONMENTAL IMPACTS. 5-26
5.5.1 METHODS 5-26
5.5.2 RESULTS 5-27
5.5.3 DISCUSSION. 5-33

5.6 RESIDUE SAMPLING 5-36
5.6.1 METHODS 5-36
5.6.2 RESULTS 5-37
5.6.3 DISCUSSION. 5-37

6. CONCLUSIONS 6-1
6.1 EFFICACY. 6-1
6.2 BENEFICIAL AND NONTARGET INSECTS. 6-1
6.3 ENVIRONMENTAL IMPACT. 6-2

7. REFERENCES. 7-1

APPENDICES

APPENDIX A. Detailed Observations of Ant Mortality During the Phase II Trials

APPENDIX B. Species List of Birds Observed Near the Test Site, Nara, Mali

APPENDIX F. Analysis of Variance (ANOVA) Tables for Efficacy Results

APPENDIX G. Detailed Analysis of the Pesticide Deposition Pattern Using 200 Spray Cards in a 4-ha Grid

APPENDIX I. Species List and Plates of Insects Collected Near the Test Site, Nara, Mali

APPENDIX L. Photographs of Each 100-ha Plot Used in the Environmental Trials

APPENDIX P. Plant Species Identifications Made in the Floral Analysis of Phase II Plots

APPENDIX R. Raw Data on Grasshopper Counts in Phase I and II

APPENDIX S. Species List of Mammals, Reptiles and Amphibians Observed Near the Test Site, Nara, Mali

APPENDIX T. Technical Plan for Testing Pesticides Against O. senegalensis for Both Environmental Impact and Efficacy in the Republic of Mali

APPENDIX V. Detailed Observations of Live and Dead Insects Made on Replicate Visual Transects in Phase II

APPENDIX W. Rainfall Data From Meteorological Station Near Test Site, Nara, Mali

APPENDIX X. List of Staff and Cooperating Personnel Involved in the Field Trials

APPENDIX Z. Pesticide Residue Levels Detected in 169 Samples of Eight Environmental Media

LIST OF FIGURES

Figure No.		Page
3-1	Preliminary Test Plots, Nara, Mali, 1987. Treatement Randomization	3-5
4-1	Location of Phase I (12 ha) Test Plots Along the Nara-Mourdiah Road	4-2
4-2	Dimensions of Typical Test Plot (12 ha) for Phase I Trials	4-3
4-3	Pnase I Efficacy in Grassland (Organophosphorous Compounds)	4-21
4-4	Phase I Efficacy in Grassland (Carbamates and Pyrethroids)	4-22
4-5	Mean Number of Ground-Dwelling Beetles per 20 Pitfall Traps, Phase I Efficacy Trials	4-26
5-1	Location of Phase II (100 ha) Test Plots Along the Nara-Mourdiah Road	5-2
5-3	Phase II Efficacy in Grassland	5-15
5-4	Phase II Efficacy in Cropland	5-16
5-5	Adundance of Insectivorous Birds from Transect Counts Before and After the Application of ULV Insecticides	5-31
5-6	Brain Cholinesterase (Che) Activity as a Function of Pesticide Residue Level (ppm) in 12 Live Birds	5-35

LIST OF FIGURES (continued)

Figure No.		Page
5-7	Pesticide Residue Levels in Grass and Soil (Carbaryl) . . .	5-39
5-8	Pesticide Residue Levels in Grass and Soil (Chlorpyrifos)	5-40
5-9	Pesticide Residue Levels in Grass and Soil (Malathion)	5-41
5-10	Pesticide Residue Levels in Grass and Soil (Lambda-Cyhalothrin)	5-42
5-11	Pesticide Residue Levels in Grass	5-43
5-12	Pesticide Residue Levels in Soil	5-44

LIST OF TABLES

Table No.		Page
3-1	Pesticide Efficacy Against *O. senegalensis* During Preliminary Trials in Nara, Mali, 1987	3-7
3-2	Field Conditions During Pesticide Application for the Preliminary Trials	3-8
3-3	Population Data (Numbers of Grasshoppers) for Untreated Checks During Preliminary Trials	3-10
3-4	Data from Nozzle, Swath Width, and Droplet Size Test	3-12
3-5	Droplet Size and Density Test	3-12
4-1	Habitat Characteristics of Each Plot	4-5
4-2	Habitat Characteristics Occurring in Replicate Plots Within Each Pesticide Treatment	4-7
4-3	Pesticide Formulations Used in the Mali Field Trials Against the Senegalese Grasshopper	4-9
4-4	Weather Data During Insecticide Application, Phase I, Nara, Mali, West Africa, 1987	4-11
4-5	Species Composition, Phase I, Nara, Mali, West Africa, 1987	4-14
4-6	Effect of Selected Insecticides on Numbers of Grasshoppers Using the m^2 Sampling Method, Phase I, Nara, Mali, West Africa, 1987	4-16

LIST OF TABLES (continued)

Table No.		Page
4-7	Effect of Selected Insecticides on Numbers of Grasshoppers Using the m^2 Sampling Method, Phase I, Nara, Mali, West Africa, 1987	4-18
4-8	Percentage Reduction of Grasshoppers, Using Transect Counts, by Selected Insecticides, Phase I, Nara, Mali, 1987	4-19
4-9	Number of Tenebrionids and Carabids per 20 Pitfall Traps per Two Replications for Each Treatment	4-25
4-10	No. of Dead Insects Recorded in a 200-m Transect (total for two replicates) 24 Hours Posttreatment	4-28
4-11	Harvester Ant Mortality (24 hours posttreatment) Following Applications of Eight Insecticides, Mali, West Africa, 1987	4-29
5-1	Weather Data During Insecticide Application, Phase II, Nara, Mali, West Africa, 1987	5-9
5-2	Effect of Selected Insecticides on Numbers of Grasshoppers, Phase II, Nara, Mali, West Africa, 1987	5-11
5-3	Grasshopper Species Composition in Crops and Pasture, Phase II, Nara, Mali, West Africa, 1987	5-12
5-4	Percentage Reduction of Grasshoppers by Selected Insecticides, Phase II, Nara, Mali, West Africa, 1987	5-14

LIST OF TABLES (continued)

Table No.		Page
5-5	The Average Number of Insects Trapped Using Zoecon Pheragon AM® Traps During a 24-hour Trapping Period on Three Sampling Dates, Nara, Mali, West Africa, 1987	5-20
5-6	The Impact of Four Insecticides Applied for Grasshopper Control on the Mortality of the Harvester Ant *Messor* sp., Nara, Mali, West Africa, 1987	5-21
5-7	Summary of Analysis of Variance Trap Data	5-23
5-8	Number of Total Birds (Total Species) From Phase II Transect Counts Before and After the Application of ULV Insecticides .	5-29
5-9	Counts of Insectivorous Birds From Transects Run Pre- and Posttreatment in Each of Three Replicate Plots for Four Pesticide Treatments	5-30
5-10	Significant Reduction in Bird Abundance Posttreatment	5-32
5-11	Pesticide Residue Levels (ppm) and Brain Cholinesterase (ChE) Activity of Birds on Plots Receiving Single Aerial Applications of ULV Pesticides	5-34
5-12	Mean Residue Levels (ppm) of Four Pesticides Found in Five Media and Relevant Tolerance Levels	5-38

PREFACE

This report presents the findings of the Mali field trials conducted as part of the USAID Africa Grasshopper/Locust Pesticide Testing Project. Upon completion of the Sudan field trials, the results from both the Mali and Sudan trials will be evaluated along with other relevant research. Then a final project report will be written that includes our recommendations concerning the use of pesticides for grasshopper and locust control in Africa.

We would like to thank the U.S. Agency for International Development Mission in Mali and the Government of Mali's Ministry of Agriculture for their invaluable help in the successful completion of this program. In particular, we appreciate the efforts of Deputy Mission Director Wilbur Thomas and Project Liaison Phil Michaud at AID/Bamako and Director Soumana Suntera and Project liaison Mousa Keita at the Ministry Crop Protection Service. In addition, we wish to thank Abdoulaye Sow and Boubaca Cisse for their expert advice in botany and toxicology, respectively, and our four counterparts, Cheick Oumar Daffe, Issa Dembele, Tamboura El Hadj, and Oumar Baba Toure, for their invaluable assistance in conducting the field trials.

1. INTRODUCTION

1.1 BACKGROUND

In 1985 and 1986, the return of normal rains to previously drought-stricken areas of Africa resulted in an emergence of major infestations of grasshoppers and locusts. In 1986, the infestation was unusually severe because it involved the rare appearance of numerous grasshopper species and the four major species of locusts most harmful to African agricultural production. In February 1987, the Africa Bureau of the U.S. Agency for International Development (USAID) issued a Strategy Paper that proposed several activities aimed at containing the initial emergency and establishing a program for long-term control and management of the pests.

That April, USAID issued a Request for Proposals (RFP) for a contractor to develop and execute a scientific program to study the efficacy and environmental impacts of certain pesticides under consideration for the control of locusts and grasshoppers in Africa. This testing program was to be part of the USAID effort to provide for "timely, efficient, and cost effective pest survey and control activities, that fully take U.S. environmental concerns and legislations into account." The RFP called for testing of eight pesticides on four species of locusts and the Senegalese grasshopper to monitor their effects on grasshopper/locust parasites and predators and other beneficial fauna and flora, and to determine pesticide residues on selected crops and other environmental substrates.

In response to the RFP, Dynamac Corporation, as the primary contractor, and the Consortium for International Crop Protection (CICP), as a subcontractor, submitted the technical proposal "Testing of Pesticides Against African Locusts and Grasshoppers." The proposal indicated that CICP would provide entomological and aerial application technical assistance, and Dynamac, as the primary contractor, would provide all other personnel and logistical support for completion of the

project. The contract was awarded in late spring. Plans were immediately initiated to conduct a test program against the Senegalese grasshopper, Oedaleus senegalensis. Target countries included Senegal and Mali. Efforts to gain AID/Dakar agreement were not successful, and arrangements were ultimately made to conduct the tests in Mali. The Technical Plan (see Appendix T) for testing pesticides in the Republic of Mali was prepared by Dynamac Corporation for AID/AFR/OEO on July 2, 1987.

The scientific team operated at a field site in Nara, Mali, between August 1 and October 8, 1987. This report presents the results of the field test in Mali. Additional information relating to the known literature on these pesticides will be included in the finished report on this project. At that time, the different field tests will be compared and final recommendations will be made to USAID.

1.2 OBJECTIVE

The testing program was directed at the abundant and widely distributed Senegalese grasshopper, Oedaleus senegalensis. The objective of this program was to perform a scientifically rigorous test, under African field conditions, on eight pesticides for their efficacy in controlling the grasshopper and for their impact on nontarget organisms and the environment. To achieve these two goals, four types of information had to be acquired:

1. Accurate measures of the reduction in grasshopper numbers attributable to the specific formulation and rate of each pesticide;

2. Data on the adverse effects of these pesticides on animals beneficial to the agricultural ecosystem, e.g., grasshopper predators/parasites and other arthropods affecting crop production;

3. Evidence of direct mortality or other acute effects on the full range of fauna and flora constituting the Malian grassland ecosystem; and

4. Determination of residue levels in important environmental substrates (e.g., soil, water, grasses, prey animals) and field crops.

This information will enable better assessment of the value of specific pesticide uses for control of the Senegalese grasshopper.

1.3 PESTICIDE SELECTION

USAID identified the following pesticides as candidates for the testing program following discussion with the U.S. Environmental Protection Agency, the Food and Agriculture Organization, and others:

Pesticide	Class
Carbaryl (Sevin)	Carbamate
Carbosulfan (Marshal, Advantage)	Carbamate
Chlorpyrifos (Dursban, Lorsban)	Organophosphorus
Lambda-cyhalothrin (Karate)	Pyrethroid
*Acephate (Orthene)	Organophosphorus
*Bendiocarb (Ficam)	Carbamate
*Diazinon (Diazinon)	Organophosphorus
*Propoxur (Baygon)	Carbamate
Fenitrothion (Sumithion)	Organophosphorus
Malathion (Malathion)	Organophosphorus

*Candidates for two open slots.

The following additional pyrethroid pesticides were proposed for consideration by their manufacturers:

Pesticide	Manufacturer	Date
Cyfluthrin (Baythroid)	Mobay	April 7, 1987
Alpha-cypermethrin (FASTAC)	Shell	May 21, 1987
Tralomethrin (Scout/Tralate)	DuPont	June 4, 1987

Based on a preliminary review of available information, the general characteristics of each pesticide class are presented below.

- Carbamates - The carbamates are residual insecticides of moderate to low mammalian toxicity (toxicity category II). The antidote is atropine (but not 2-PAM). The LD_{50} value (male rat, acute oral) for bendiocarb is 40 to 156 mg/kg; for carbaryl, 283 mg/kg; and for propoxur, 95 mg/kg. The dermal LD_{50} for these compounds is from 500 to 2000 mg/kg (toxicity category III). Carbamates are generally not oncogenic, but they are suspect teratogens and weak mutagens. They are rapidly excreted by animals, and they disappear from plants by mechanical attribution, volatilization, and uptake into the plant. These compounds do not seem to be appreciably photodegraded, but they are degraded by soil organisms through hydroxylation of the side chain and ring structures. The carbamates are of low toxicity to birds; moderate toxicity to fish; and high toxicity to honeybees, aquatic invertebrates, and estuarine organisms.

- Organophosphorus Compounds - These pesticides are broad-spectrum contact insecticides of high to moderate acute toxicity to mammals. The following LD_{50} values (male rat, acute oral), have been determined for those listed above: acephate, 866 to 945 mg/kg; chlorpyrifos, 97 to 270 mg/kg; diazinon, 300 to 400 mg/kg; fenitrothion, 800 mg/kg; and malathion, 1000 to 1375 mg/kg. Although some of the most highly toxic pesticides known are organic phosphates, compounds such as malathion are relatively safe to use. The organophosphorus compounds are photodegradable, but they can be leached into the soil where they tend to have rather long half-lives. The organophosphorus compounds are cholinesterase inhibitors; atropine and 2-PAM (pralidoxime chloride, iodide, or methanesulfonate) are the common antidotes. The effects of this group of pesticides are so varied that few generalizations are valid for all member compounds; however, the organophosphorus compounds tend to show little or no oncogenicity, teratogenicity, or mutagenicity. Environmental toxicity effects vary depending upon the compound. Diazinon, for example, is highly toxic to wildlife (birds, fish, aquatic invertebrates); applications to golf courses have caused serious bird kills. In contrast, aircraft have

applied malathion over broad areas of the United States to control imported fruitfly outbreaks with little or no evident environmental problems (except for damage to automobile paint). Chlorpyrifos, on the other hand, is highly toxic to wildlife and honeybees.

- Pyrethroids - These compounds are based on "pyrethrum," a naturally occurring insecticidal complex derived from certain species of chrysanthemum. Pyrethrum consists of pyrethrins (esters of pyrethrolone and chrysanthemic acid and pyrethroic acid), cinerins (esters of cinerolone and chrysanthemic acid and pyrethroic acid), and jasmolines (jasmoline and chrysanthemic acid and pyrethroic acid). They are characterized as being resistant to photodegradation, and they are applied at extremely low active ingredient dose rates (in the range of 0.05 to 0.3 lb active ingredient per acre). Like the organophosphorus compounds, the U.S. EPA classifies many pyrethroid products as Restricted Use Pesticides for some or all uses.

Of the chemicals listed above, six were identified for testing in the USAID Scope of Work: carbaryl, carbosulfan, chlorpyrifos, lambda-cyhalothrin, fenitrothion, and malathion. Fenitrothion and malathion were identified as potential test standards because of their widespread use for grasshopper and locust control in Africa. It was deemed essential that chemicals of known efficacy under the test conditions be included as a reference. Four chemicals were identified as candidates for the remaining two test positions: diazinon, bendiocarb, propoxur, and acephate. Three additional chemicals nominated by manufacturers did not appear in the USAID Scope of Work: cyfluthrin, alpha-cypermethrin, and tralomethrin.

A preliminary literature review and evaluation conducted for all candidate chemicals provided a basis for designing the field program and for selecting the eight pesticides to be used in the West Africa testing program.

It is the Africa Bureau Policy "that any AID-financed pesticide for locust/grasshopper control be registered with the EPA and have a tolerance established for at least one food use, or meet the established acceptable

daily intake and maximum residue levels recommended by the Joint Meeting on Pesticide Residues to the FAO/WHO Codex Committee on Pesticide Residues." The EPA registration and Codex status of the candidate pesticides are presented below:

Candidate Pesticide	EPA Registration	Food Crop Tolerance (40 C.F.R. 180) yes	Food Crop Tolerance (40 C.F.R. 180) no	FAO/WHO Codex ADI/MRL
*Carbaryl	✓	✓		✓
Carbosulfan	**pending		✓	✓
*Chlorpyrifos	✓	✓		✓
*Lambda-cyhalothrin	**pending		✓	✓
Acephate	✓	✓		✓
*Bendiocarb	✓		✓	✓
*Diazinon	✓	✓		✓
Propoxur	✓		✓	✓
*Fenitrothion	✓		✓	✓
*Malathion	✓	✓		✓
Alpha-cypermethrin			✓	
Cyfluthrin	**pending		✓	
*Tralomethrin	✓	✓		

*Proposed for West Africa testing program.
**Section 3 application submitted; data under review.

Manufacturers of these products were contacted to determine their continued interest in the testing program and to identify any logistical problems that would prohibit availability of their products within the appropriate timeframe for testing in West Africa. On the basis of product availability, satisfaction of the Africa Bureau technical criteria, general balance among the three classes of pesticides to be evaluated, and consideration of potential environmental impacts and efficacy as determined by the initial literature review, the following compounds were selected for field testing in West Africa:

Pyrethroid	Carbamate	Organophosphorus
Lambda-cyhalothrin (Karate)	Carbaryl (Sevin)	Chlorpyrifos (Dursban)
Tralomethrin (Scout/Tralate)	Bendiocarb (Ficam)	Diazinon (Diazinon)

Test Standard

Fenitrothion (Sumithion) - organophosphorus
Malathion (Malathion) - organophosphorus

6

The five candidate pesticides not selected for field testing in West Africa (carbosulfan, acephate, propoxur, alpha-cypermethrin, and cyfluthrin) will be placed on a backup list. Additional information on these chemicals will be requested from EPA and the manufacturers of the compounds. The rationales for eliminating these pesticides from the West Africa field testing program follow:

- Carbosulfan - This compound does not appear to completely satisfy the technical criteria. Although Codex ADI and proposed temporary MRL are established, EPA registration is still pending. The other members of the carbamate class selected for West Africa, carbaryl and bendiocarb, more fully satisfy the technical criteria because both have established Codex ADIs/MRLs and both have EPA registrations; carbaryl also satisfies the domestic food crop tolerance criterion. In addition, concern exists regarding the potential health and environmental toxicity of the major degradate of carbosulfan, carbofuran.

- Acephate - This compound was not recommended for field testing in West Africa for the following reasons: (1) there is no documented record of the manufacturer's expression of interest in participating in the field testing program; and (2) concerns exist for the potential health effects of acephate (i.e., the compound is a suspected human oncogen), and its metabolite methamidophos is highly toxic to birds.

- Propoxur - Propoxur was not recommended for inclusion in the West Africa field testing program because no documented record exists of the manufacturer's expression of interest in program participation. This chemical has been widely used in Africa for locust control; it is a good candidate for the East and Southern Africa field testing programs pending expression of interest by the manufacturer. EPA has expressed some concern regarding the potential oncogenic activity of the compound that needs to be addressed pending receipt of additional information.

- Alpha-cypermethrin - This compound was not selected because it does not appear to satisfy the technical criteria (i.e., no EPA registration or Codex tolerances). Concern has also been expressed regarding the mammalian toxicity of the compound. More data will be requested from the manufacturer.

- Cyfluthrin - Cyfluthrin does not satisfy the technical criteria as completely as the pyrethroids selected for testing. For example, tralomethrin has an EPA registration and an established domestic food crop tolerance. Lambda-cyhalothrin, like cyfluthrin, has an EPA registration pending, but unlike cyfluthrin, also satisfies the Codex tolerance criterion. Lambda-cyhalothrin has also been field tested in Africa for locust control. Cyfluthrin appears to be a good candidate for the East and Southern Africa field testing programs. By the time these programs are under way, the compound may more fully satisfy the AID technical criteria, e.g., the manufacturer has stated that pending receipt of domestic registration, an application will be made for domestic food crop tolerances. The manufacturer has also stated that approval of EPA registration is expected in the next several months. The manufacturer of cyfluthrin will provide information to update the status of this candidate for future use.

1.4 PROJECT CHRONOLOGY

1987

June 6 - 17	Initial meeting with AID/Senegal.
June 18 - 25	Initial meeting with AID/Mali.
June 27 - 29	Scouting trip to Nara.
June 30 - July 21	Negotiate with the Government of Mali on project protocol. Purchase equipment, vehicles, and supplies. Set up Bamako field office. Second scouting trip to Nara.
July 21	CICP team arrives.
July 27	Dynamac team arrives.

July 30	First party leaves for Nara to set up camp.
August 31	Scientific team leaves for Nara.
August 2 - 4	Survey area for flora and fauna.
August 5	Spray aircraft arrive.
August 5 - 18	Survey area for grasshoppers and identify preliminary test site.
August 9 - 13	Stake out experimental plots and develop spray protocol.
August 10 - 16	Confer with M. Keita of Nara Protection des Vegetaux (PV), J. Goodson of USAID, and N. Jago of the Tropical Development Research Institute (TDRI). Conduct background surveys.
August 17 - 21	Spray preliminary trial plots.
August 18 - 28	Sample for grasshoppers, nontarget insects, and vertebrates. Begin surveying and sampling of environmental plots.
August 26	Bamako meeting of West African countries affected by grasshoppers.
August 28	C. Castleton (USAID) visits site. Application problem is identified.
August 29 - September 3	Conduct application testing and modify spray methodology.
August 30 - September 6	Locate and mark Phase I plots. Collect baseline data.
August 30	Begin campaign spraying for PV.
September 7 - 11	Spray Phase I plots.
September 8 - 25	Posttreatment Phase I grasshopper and nontarget sampling.
September 15	Nara meeting with AID/Mali, FAO, PV.
September 17 - October 6	Perform residue sampling and vegetation analyses.
September 18 - 22	Spray Phase II plots.
September 19 - 29	Posttreatment Phase II efficacy and environmental sampling.

9

October 2	Ship first set of residual samples to Bamako.
October 8	Ship last set of residual samples to Bamako. Remaining scientific personnel leave Nara.
October 2 - 20	Use camp as base for USAID spray campaign.
October 15 - November 30	Write initial draft of Mali technical report.
October 30	Ship residue samples to Paris.
November 23	Residue samples arrive Miami.
December 3	Report to the FAO meeting in Rome.
<u>1988</u>	
April 15	Analysis of residue samples completed.

2. ECOLOGICAL DESCRIPTION OF THE SITE

2.1 CLIMATIC AND PHYSIOGRAPHIC REGION

The study area near Nara, Mali, lies at 15° north latitude within the tropical region known as the Sahel (arid subzone of the arid zone) (TAMS, 1983). From a geographic perspective, the Sahel is the area bordering the Sahara desert where open herbaceous formations and scattered woody plants occur. Climatic conditions include irregular rainfall, an 8-month-long dry season, annual rainfall between 250 and 550 mm, and 20 to 40 days of precipitation per year. The atmospheric currents known as the harmattan and the monsoon control the climate of this area. From September until May, the high-pressure centers of colder air to the north produce the harmattan, a dry season dominated by winds from the northeast. In June, as the intertropical front moves northward, the wet season begins with the monsoon bringing in humid air and isolated, intense thunderstorms. Physiographically, the Sahel is a grassland dotted with shrubs and small trees. The number of woody species is low; these consist principally of thorny acacias less than 5 m in height. Grass species from genera such as Aristida and Cenchrus form a generally continuous cover during the rainy season. Although relic species of a more humid regime can be found throughout the region, the current trend is toward even less vegetation as human and animal pressures coincide with the climate shift toward more arid conditions.

2.2 SOIL AND VEGETATION ZONE

The Nara site possesses a soil and vegetation profile that is representative of the region of northwestern Mali most subject to crop-damaging infestations of grasshoppers. The limited rainfall cycle and the hyperthermic soil-temperature regime have produced identifiable vegetation associations on a range of soil types. The principal soils are the ustalific haplargids with a minor constituent being the cambic cuirorthids. The predominant soil and vegetation unit has been described

(TAMS, 1983) as consisting of gently sloping plains of silty and loamy material that are well drained and moderately fine textured.

These soils support a scattered medium-to-tall shrub association dominated by Balanites aegyptiaca and a cover of annual grasses dominated by Schoenefeldia gracilis. The second important soil and vegetation unit consists of eroded dunes of moderately coarse textured soils. These dunes create a rolling landscape of open vegetation characterized by the scrub Combretum glutinosum and the grass Cenchrus biflorus. Less common are plains of loamy material supporting the large shrubs Pterocarpus lucens and Combretum micranthum. These areas are susceptible to sheet erosion and to surface sealing that can restrict plant emergence. The vegetation pattern is typically patchy with dense shrub areas intermixed with grasses or bare soil. Also infrequent are lands underlain by a hard lateritic cuirasse. Excessive draining and the loss of the surface horizon over shallow bedrock have produced a linear pattern of shrub patches dominated by Pterocarpus lucens and Combretum micranthum.

2.3 FAUNA

The region of scrub grassland surrounding Nara possesses a depauperate fauna compared to most regions of Africa. Due to the harsh physical conditions and to hunting pressure and habitat destruction, virtually no large mammals remain. The giraffes, duikers, antelope, kobs, hartebeestes, gazelles, hyenas, lions, and monkeys previously found have disappeared. A number of smaller mammals such as hyrax, aardvarks, porcupines, jackals, ratels, mongooses, caracals, bats, and genets may persist in remnants of native vegetation, but they are rare throughout the region. Hedgehogs, shrews, mice, gerbils, rats, hares, and ground squirrels are the only abundant mammals in most of the grassland areas.

Birds are much more numerous; over 100 species probably exist near Nara (see Appendix B). At least six species of weavers breed in the local grasslands and frequently attack crops (especially Quelea quelea). Many insectivorous species are also common, including the larks, rollers, bee-eaters, and egrets. The egrets are particularly noted for following grasshopper infestations, and they are likely adapted to the population cycles of these insects. The populations of insects, lizards, and small birds support a large and diverse group of raptors, including the ubiquitous grasshopper buzzard.

12'

The lizards are second only to birds as the most abundant vertebrate group. Five families are represented in the test program collection; however, four of these are represented by only a single species (see Appendix S). The agamids are ubiquitous in the area and possibly play an important role in the ecosystem. Snakes are less common; they are represented largely by the sand boa and carpet viper. Their principal prey are frogs and toads, which although limited in range to the ephemeral ponds, emerge in large numbers during the rainy season.

2.4 AGRICULTURE AND GRAZING USAGE

The lands north of Nara are virtually unsuitable for agriculture. The Nara region itself has been characterized (TAMS, 1983) as having a low production potential (generally unsuitable for cultivated crops) with moderate limitations for nonarable uses (usually suitable for forage plants and/or woodland; the uses are described as primarily climate limited and secondarily soil limited). This agropastoral region has a 30- to 75-day growing season during which farmers repeatedly plant crops following each rain. In good years, many late plantings will mature; in bad years, even the early plantings may fail. The local villagers and nomadic peoples graze goats, sheep, and cattle. Herds and whole encampments move southward as the dry season sets in. In addition to heavy grazing of the grasses (reductions to a few centimeters), many of the trees are regularly trimmed for animal forage. The areas adjacent to seasonal bodies of water are heavily used; in general, each large lake has a nearby village.

13'

3. PRELIMINARY SURVEYS AND TESTING

3.1 SITE SELECTION

Based on results of earlier egg pod surveys, Ian Mackay (AID/Bamako) predicted in early summer that the Nara-Dilly area would provide good conditions for pesticide testing. The villages of Nara and Dilly are located about 300 km north of Bamako. Visits by project personnel located a promising site for a base camp in proximity to the Nara airstrip. The general area consisted of flat, sandy soils covered with grasses and scattered thorn trees. Annual rainfall is in the 100- to 400-mm range, totaling 340 mm in 1986 and 275 mm through September 1987 (see Appendix W). The rainy season extends from June through September with mean monthly temperatures ranging from 30 to 35°C.

On August 2, Messrs. Duhart and Balmat of FAO reported that O. senegalensis counts in the Dilly area were reaching densities up to $50/m^2$. However, this site was 170 km from Nara. With the assistance of personnel from Nara Protection des Vegetaux (PV), a promising site was located 5 km north of the base camp. Unfortunately, the only access was via poorly drained bush-roads. Counts made on August 3 indicated densities of 20 to 30 (mostly 1st instar) hoppers/m^2. We calculated an infestation area of 4 km^2 and decided to limit plot sizes to 200 by 200 m (4 ha) with 50-m buffer zones. The plot design consisted of 17 treatments completely randomized within each of four blocks. As plots were staked out on August 8, we found that the population densities decreased to near zero in the western replicate plots near Keyban. The proximity to a 100-ha lake used by Keyban villagers created further concern.

An August 9th survey of a site 2 km south of Nara, about 25 minutes driving time from the base camp, revealed a relatively uniform distribution of hoppers at a density of about $10/m^2$. While the density was low, it was concluded to be adequate for Phase I testing. The Nara site was ecologically similar to the Keyban site and is described in detail in section 4.1.3. The road from the base camp to Nara and the

14

Mourdiah road south of Nara were open and, although rough, traversible throughout the tests. Plot to plot movement within blocks was either over sparsely wooded grassland or via an occasional donkey-cart trail.

The preliminary spray trials were set up on both sides of the Mourdiah road for the 5 km required to lay out the 17 treatment blocks needed. The additional area of suitable habitat (uniform grassland with scattered shrubs and trees) surrounding this site allowed us to conduct our Phase I trials with continued access from the Mourdiah road. The Phase I site had a greater proportion of cultivated fields than the preliminary site; nevertheless, the habitat was relatively homogeneous (see section 4.1.3) and contained adequate populations of O. senegalensis for a 36-plot design using 12-ha plots with 150-m buffer zones.

In selecting our site for Phase II testing, we searched the region around Nara for an area where 15 large (100 ha) plots could be located. This necessitated including a greater diversity of habitats both within and among plots. Unfortunately, adequate aquatic habitats were too scarce to include in a replicated design. Agricultural lands, however, were common, and each plot could be selected to include a substantial area of cultivated fields. An area along the Mourdiah road south of our Phase I site was chosen for Phase II, and single plots were designated on each side of the road where crops could be found. Although each plot differed in its vegetation profile, the disparity among plots was not distinct enough to warrant a blocked design. In essence, each plot was a unique combination of habitats (see section 5.1.3).

3.2 GRASSHOPPER POPULATIONS

3.2.1 Sampling Methods

Three methods of sampling, each with associated advantages and disadvantages, were used for indexing grasshopper populations: ring counts (RC), visualized square meter counts (VSMC), and transect counts (TC).

The RC method, as used by USDA/ARS (Onsager and Henry, 1977; Onsager, 1978), consisted of placing 0.1 m^2 rings in an appropriate distribution pattern in the test plots. The USDA protocol called for counts to be made 1 day pretreatment and then 7, 14, and 21 days posttreatment. The strategy used in the present trials consisted of placing forty 0.1 m^2 rings constructed of 0.64 cm polyethylene tubing

15

about 2.5 m apart in a 30-m diameter circle. The circle was placed in grassland at the center of each plot. Adjustments were made if the location consisted of bare ground or was under cultivation. Counts were made at 1 day pretreatment and at 1, 3, and 7 days posttreatment. As discussed later, the 14-day count was deleted in these preliminary tests. Modifications from the Mali Technical Plan (Appendix T) consisted of an estimated 30-m, rather than a 50-m, diameter circle; use of 0.1 m^2 rings rather than 0.25 m^2 rings; and addition of a 3-day posttreatment count. The sample circle was reduced to accommodate the reduced plot size. The 0.1 m^2 rings reflected USDA/ARS protocol, were easier to count, and used only half the amount of tubing. The 3-day sample provided additional information on speed of kill. The RC method is best suited to the assessment of immature stages of grasshoppers in short grasses. Adult forms are very active and usually desert the sample unit before it is possible to move close enough to make counts. Other disadvantages include placement difficulties in deep grass, mobility in windstorms, and attractiveness to local villagers or nomads. This method is most effective when used by experienced personnel, when hopper counts are low, and when grasses or crops are less than 25 cm high.

The VSMC method is used by PV scouts and involves the visualization of a square meter of plot in which the numbers of hoppers are counted. As a backup method to the RC method, 10 VSMC counts were made in each plot. These were selected by walking 15 paces outside the circle and randomly making 10 counts around the sample area. As will be shown, this method tended to underestimate populations of immature insects compared to the RC method and to overestimate populations of adults compared to the TC method.

The TC method was not used in the preliminary tests, but the deepening grass and the maturing population at the end of these trials necessitated a modification of the sampling system. The TC method, also used by PV scouts, consists of a visualized area 2 m wide by 100 m long. As the scout walks the 100 m, a count is made of the hoppers leaving the area. The system was modified by precisely measuring the 100-m length with a vehicular odometer, marking the ends with flags, and delineatingthe width with the tire tracks, which are nearly 2 m apart. This was shown to be an efficient method of counting mature populations; the only disadvantage was the disappearance of tracks.

Pretreatment counts were made between August 17 and August 23 using both the RC and VSMC methods. With the RC method, the population density consisted of 10.28 hoppers/m^2 (Standard Error (SE) = 0.126, Standard Deviation (SD) = 9.0). The VSMC method underestimated the population, as indicated by the RC method, producing a mean density of 4.74 hoppers/m^2 (SE = 0.126, SD = 2.9). This grasshopper population consisted almost exclusively (95%) of O. senegalensis. All instars were represented, but adults were very uncommon. The distribution of O. senegalensis was not uniform and densities were clumped, probably depending on grass cover, soil moisture, and other factors. Such clumping was found to occur even within a single circle of rings. It was concluded, however, that densities and distribution were adequate for efficacy testing.

3.3 PRELIMINARY TRIAL PLOT DESIGN

The plot layout was similar to that designed for the Keyban site. Each of four blocks contained a linear randomization of 17 treatments (Figure 3-1), including 7 pesticides, 2 to 3 rates, and 2 untreated checks per block (see section 3.4.1). For reasons of space, travel distance, and uniformity of grasshopper population, plot size was retained at 200 by 200 m with a 50-m buffer between blocks 1 and 2 and between blocks 3 and 4. Blocks 1 and 2 on the east side of the Mourdiah road were separated from Blocks 3 and 4 on the west side of the road by a minimum of 200 m. The buffer area between replications within the blocks was 67 m. Buffer zones were added to the protocol because the plot size was reduced from 16 ha to 4 ha. The size of the buffer zones was selected to allow for possible drift but to minimize possible sources of reinfestation.

The lack of landmarks and rolling nature of the terrain made the actual laying out and marking of plots difficult. Tall bamboo poles were required to flag the plots. The Mourdiah road provided some guidance, but it curved considerably and constant adjustments were necessary. Precise angles had to be determined for laying out plots, so a floating-dial sighting compass was used.

REPLICATION

BLOCK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	14	8	11	12	16	13	2	6	5	1	17	10	3	15	7	4
2	6	4	16	5	1	3	17	9	11	10	15	8	13	2	14	12
			N				MOURDIAH ROAD									
3	8	6	13	4	15	11	14	16	3	5	10	2	17	7	1	9
4	9	15	2	1	16	8	10	4	12	13	17	3	6	11	5	14

Treatment	No.	Rate
Bendiocarb	1	High
Bendiocarb	2	Low
Carbaryl	3	Very High
Carbaryl	4	High
Carbaryl	11	Low
L-cyhalothrin	5	High
L-cyhalothrin	6	Low
Tralomethrin	7	High
Tralomethrin	8	Low
Chlorpyrifos	9	High
Chlorpyrifos	10	Low
Fenitrothion	13	High
Fenitrothion	14	Low
Malathion	15	High
Malathion	16	Low
Untreated	12	-
Untreated	17	-

Figure 3-1. Preliminary test plots, Nara, Mali, 1987. Treatment randomization.

18

3.4 PRELIMINARY TRIAL PESTICIDE APPLICATION

3.4.1 Materials

The materials, formulations, and rates of application are shown in Table 3-1. Because diazinon was not available for the preliminary tests, an extra-high rate of carbaryl was tested and a second set of untreated checks was included. Carbaryl was diluted 4:1 with diesel, and the remaining products were applied without dilution.

3.4.2 Application Equipment

The aircraft used, TurboThrush S2RTs, are specially designed for the application of agricultural pesticides. Airspeed was 210 to 225 kph with a swath width of 30 to 50 m. The aircraft were equipped with eight Micronair AU5000 atomizer units (nozzles) spaced approximately 1.5 m apart on a regular spray boom. During the preliminary trials, the blade angles were set at 35° to obtain a speed of 8500 to 9000 rpms. This setting was determined to provide a droplet size of 100 microns. Boom pressure while operating was about 20 to 30 kpa (2 to 3 lbs psi). The Micronair units were controlled electronically to deliver preset amounts of material through the flowmeter according to the speed of the aircraft and the micronair blades. These units were calibrated in Zimbabwe and, because their pumps were air driven, it was not possible to recheck the calibrations on the ground. Swath width was selected at 50 m, and the flying height was 3 to 5 m to reduce drift to a minimum. Trees occasionally required a slightly higher altitude.

3.4.3 Application

In all applications two vehicles were used for flagging, one on the north side of the plot and one on the south side. These vehicles provided precise markers for the starting and stopping of sprays by the aircraft. All spray runs were made from north to south, i.e., perpendicular to the prevailing winds. Vehicles were equipped with wheel counters and calibrated to give a 50-m swath with 20 revolutions of the wheel. The method provided for maximum accuracy during the spray operations. Radio communications were unreliable between the aircraft and flagging crews, and careful preplanning was essential. The strategy was to spray in alternation between the east and west blocks to allow for repositioning of the vehicles with minimal delays to the aircraft. Data on spraying conditions for each treatment application are shown in Table 3-2.

19

Table 3-1. Pesticide Efficacy Against *O. senegalensis* During Preliminary Trials in Nara, Mali, 1987

Material	L/ha	g a.i./ha	Pre-trt.	Percent Reduction in Grasshopper Numbers: Days posttreatment: 1	3	7	14
Bendiocarb	0.50	100	300	57	46	62	N.M.
20%	0.25	50	138	+17	+24	21	N.M.
Chlorpyrifos	0.50	240	164	51	46	44	M
ULV 450	0.38	180	214	13	29	32	N.M.
Malathion	0.77	739	119	12	8	16	N.M.
96%	0.52	499	168	+9	2	28	N.M.
Fenitrothion	0.60	300	138	+9	33	54	M
L50	0.30	150	93	28	31	46	N.M.
L-cyhalothrin	0.75	30	164	23	43	73	M
4%	0.50	20	268	10	41	N.D.	N.M.
Tralomethrin	0.42	15	103	38	34	57	N.M.
3.75%	0.28	10	127	28	30	19	N.M.
Carbaryl	2.40	1120	146	16	42	77	M
4 oil	1.20	560	155	55	80	88	M
	0.60	280	132	32	61	76	M
Check 1	N.S.	N.S.	157	4, 17	20	25, 46	N.M.
Check 2	N.S.	N.S.	118	N.D.	1	15	N.M.

M = Observed mortality.
N.S. = Not sprayed.
N.D. = No data available.
N.M. = No mortality.

20

Table 3-2. Field Conditions During Pesticide Application for the Preliminary Trials

Date	Treatment (chemical/rate)		Temperature (°C)	Wind (mph)	Wind direction	Time
8/17	Bendiocarb High	78	25.5	2-3	W-SW	0640
	Bendiocarb High	80	26.5	3-4	W-SW	0615
8/18	Bendiocarb Low	82	28.0	3-4	W	0625
	Bendiocarb Low	80	26.5	3-4	W	0640
	Chlorpyrifos High	82	28.0	2-3	W	0810
	Chlorpyrifos High	84	29.0	3-4	W	0825
	Chlorpyrifos Low	87	30.5	5-6	W	0845
	Chlorpyrifos Low	88	31.0	6-7	W	0910
8/19	Malathion High	80	26.5	4-5	W	0740
	Malathion High	90	32.0	4-5	W	1700
	Malathion Low	90	32.0	4-5	W	1800
	Malathion Low	90	32.0	3-4	W	1822
	L-cyhalothrin High	80	26.5	2-3	SW	0700
	L-cyhalothrin High	80	26.5	2-3	SW	0709
	L-cyhalothrin Low	82	28.0	2-3	SW	0725
	L-cyhalothrin Low	81	27.0	3-4	SW	0735
	Tralomethrin High	84	29.0	3-4	W	0750
	Tralomethrin High	84	29.0	3-5	W	0800
	Tralomethrin Low	84	29.0	3-5	W	0810
	Tralomethrin Low	84	29.0	3-5	W	0823
8/21	Carbaryl High	80	26.5	5-6	SW	0855
	Carbaryl High	84	29.0	5-6	SW	0910
	Carbaryl Medium	86	29.0	5-6	SW	0916
	Carbaryl Medium	84	29.0	5-6	SW	0930
	Carbaryl Low	85	29.5	5-6	SW	0940
	Carbaryl Low	85	29.5	5-6	Sw	0950

21

3.5 PRELIMINARY TRIAL EFFICACY EVALUATIONS

3.5.1 Methods

Counting was facilitated by establishing four teams, one for each block. Each team consisted of a driver, a member of the technical team, and one Malian counterpart. This approach identified possible biases and allowed each team to gain familiarity with a specific block and to locate specific plots and sample areas with greater rapidity.

3.5.2 Results and Discussion

The results, as shown in Table 3-1, are presented as percent reduction over the pretreatment counts. Based on known results with the reference chemicals, i.e., malathion and fenitrothion, the observed mortality in these trials was considerably below expected levels. Generally, little mortality was observed until the 1-day count was made on the carbaryl treatments. Dead hoppers were observed with all three carbaryl rates, and to a lesser extent with chlorpyrifos, fenitrothion, and lambda-cyhalothrin. No mortality was observed among the remaining treatments. Except for lambda-cyhalothrin and carbaryl, it was clear by the 7-day counts that application problems existed and that a reexamination of procedures would be required before continuing.

3.6 TESTS OF APPLICATION METHODOLOGY

3.6.1 Reinvasion of Plots

The persistence of relatively high posttreatment grasshopper counts suggested the possibility of a reinvasion of the plots from buffer zones or other areas. This hypothesis was rejected, however, after examination of population counts in the untreated plots over the duration of the tests. Table 3-3 illustrates the relative consistency of counts within the several check plots over the duration of the test. The counts suggest that no major movement of hoppers occurred between plots, at least during the period of testing. Therefore, the failure of appreciable grasshopper control was most likely attributable to insufficient insecticide reaching the target. Between September 1 and 2, a series of tests was undertaken to determine the appropriate techniques required to assure proper deposition of the pesticides.

Table 3-3. Population Data (Numbers of Grasshoppers) for Untreated Checks During Preliminary Trials

Check No.	Date (August)	Rep. 1	Rep. 2	Rep. 3	Rep. 4
1	17	52	3	48	54
	20	44	1	40	65
	22	45	6	41	38
	24	29	9	31	56
	26	24	9	20	65
	28	23	7	27	27
2	23	33	6	3	43
	25	30	2	12	72
	27	30	6	7	57

23

3.6.2 Droplet Size

It was hypothesized that the small droplets (100 microns) were not reaching the ground area in adequate quantities due to the effect of wind or temperature. To test this hypothesis, droplet size was varied during sprays of single 16-ha test plots. Malathion was metered at a rate of 0.82 L/ha, and droplet sizes were targeted at 100 and 200 microns. The 100-micron size was not obtained; the actual sizes ranged from 171 to 247 microns. Mortality rates, while below those expected for this dosage, indicated that this range of droplet sizes was satisfactory for control (Table 3-4). In a subsequent and similar test (Table 3-5), no marked differences in mortality were observed between droplet sizes of 125 to 148 microns. A separate set of tests was conducted near the airstrip to determine the relationship between droplet size and penetration to the base of the grasses. Repeated flyovers were used to measure the density of droplets on horizontal and vertical spray cards. Significantly higher densities were achieved with the larger (150- to 200-micron) droplet size.

3.6.3 Spray Coverage

A second concern in achieving proper deposition of pesticide on treatment plots was the problem of uniform coverage across spray swaths. To minimize spray drift, the aircraft flew as low as possible (3 to 5 m) above the grass. With a 50-m spray swath and calm wind conditions, valleys of low-density coverage could occur between swaths. Repeated spray card trials revealed shallow valleys with 50-m swaths but no valleys with 30-m swaths. Both eight- and four-unit Micronair delivery produced adequate coverage, and the four-unit Micronair system was chosen for Phase I trials because it provided for higher output and greater reliability per nozzle.

3.6.4 Delayed Delivery

During the first 16-ha field test, it was noted that where sample rings and droplet cards were located along the northern edge of the replicates, there was no deposition of pesticide and thus no control. Dye card tests at the airstrip showed that a significant delay in spray release resulted when the air-driven pumps and spray valves were opened at the same time. However, the failure to achieve expected grasshopper reduction in the preliminary trials also occurred on plots where rings

Table 3-4. Data from Nozzle, Swath Width, and Droplet Size Test

Quadrat No.	Nozzle No.	Swath width (m)	Droplet target	Droplet actual	% Control
1	8	50	100	171	88
2	4	50	200	unknown	92
3	8	30	200	247	86
4	4	30	100	187	85

Table 3-5. Droplet Size and Density Test

Quadrat No.	Droplets	VMD	% Control
North 1	2.4	127	100
North 2	2.2	125	92
South 1	7.5	146	92
South 2	10.1	148	94

VMD = Volume median diameter.

were placed in the center (61 of 67 replicates). Although the delay was substantially reduced by leaving the pump running and turning on the delivery lever at the plot line, it was still apparent that more droplets were reaching the southern halves of the plots. The remaining 1-second delay from turnon to normal pesticide delivery could be accommodated by releasing the delivery lever approximately 50 m before crossing the northern plot line. In view of this delay, buffer zones for the Phase I trials were increased to 150 m to ensure plot integrity.

3.6.5 Output Volume

The low mortality seen at the higher malathion dosage and the low droplet densities recorded suggested that the rate of pesticide delivery was considerably less than that indicated by the flowmeter. A technique for checking the accuracy of the flowmeter was devised by Ken Rogers, Agricair. The method called for connecting a hose to the spray boom. The other end of the hose was placed in a Jerry Can hung in the spray hopper on bamboo poles. The plane was then flown for 1 minute with the pump operating. The amount of material collected in the Jerry Can was then measured with a graduated cylinder. It was found that the flowmeter in one of the aircraft was unreliable and that the meter in the other aircraft consistently overestimated output by 3.5 to 5.0 times, depending on the rate. The flowmeter was subsequently set at levels revised to include this correction factor, and accurate delivery was achieved.

3.6.6 Application Modifications

As a result of our investigations into the application procedure, the following modifications were made: recalibration of the flowmeter before each spray run with each material and rate using the technique described above; use of the money-lever instead of the fan brake; start of delivery 50 m from the edge of the plot; increasing droplet size to 150 microns; and reduction of the swath width to 40 m.

An empirical test of the droplet densities and coverage achieved by both the original and modified application procedures was conducted using a 4-ha grid of 200 spray cards. Deficiencies in the deposition pattern were evident from a graphical analysis of results of the original application technique (Appendix G). In particular, the northern half of the grid showed little or no deposition. Quadrat densities (as measured

26

by the mean of the spray card results on the four corners) were low (<7 drops/cm^2) throughout the grid. Deposition from the modified application technique was completely satisfactory, achieving a uniform coverage of high droplet densities (mean = 29.2 drops/cm^2, SD = 13.5).

3.7 BACKGROUND SAMPLING OF BENEFICIAL AND NONTARGET INSECTS

During the preliminary trials, attempts were made to (1) identify dominant insect species within several families that could be used as indicator species during the test trials; and (2) identify practical survey methods for detecting changes in the populations of these species. The techniques of sweep-netting, pitfall trapping, and malaise trapping were modified and tested to determine their usefulness. While sweep-netting did capture some parasitic wasps, the numbers obtained were very low. Furthermore, many plots contained cram-cram grass (Cenchrus biflorus), the spiked seeds of which inevitably rendered the nets useless. Locally fabricated malaise traps, captured only very few insects of interest, e.g., beeflies, and presented considerable difficulties in deployment. The pitfall traps were more successful because they captured large numbers of tenebrionid and carabid beetles. Predatory robberflies escaped the capture techniques and were recorded in only small numbers from visual transects. These transects, however, proved valuable as a sampling method for the carcasses of a variety of insects. Pollinators, unfortunately, were too rare for any sampling method. Lastly, an especially abundant indicator species, the harvester ant, Messor sp., was identified. The nest activity and worker mortality of these important insects were easily monitored.

3.8 BACKGROUND ENVIRONMENTAL IMPACT SAMPLING

During our first week at the field camp (August 2 through 8), the field team surveyed the surrounding area for birds and other wildlife. At various times of the day, the team visited the grassland, shrubland, and wooded swampy areas north of Nara and south of Keyban. Twenty-one species of birds were identified. Mist nets were set up to capture small cryptic species for identification. Live rodent traps were set out at dusk, and two species were captured. Regular evening visits to the camp's large fluorescent lamp revealed three frog and two snake species.

21

Before the initial spray trial, transect counts were run for birds and other animals along the north-south length of the plot layout. These counts consisted of seventeen 150-m transects performed at 100-m intervals on both sides of the Mourdiah road. All birds within 50 m of the transect lines were identified to species, and their location and behavior were recorded. Counts east of the road were made on the morning of August 16, and those on the west side were conducted first on the afternoon of August 16 and again on the morning of August 17. Mist nets were set up at one location on each side of the road to capture birds for identification. Eight species, including weavers, larks, and doves, were captured. In all, 21 species of birds and one species of lizard were seen. The transects covered the equivalent of 77.5 ha and recorded 1111 individual birds or 14.5 birds/ha. Because each sample run produced a different set of species, both spatial and temporal variations were identified as factors important to the final sampling program.

After completing the preliminary spray trials, each plot was sampled for a comprehensive record of all birds and other wildlife in the treatment area. Ninety-four transect counts were conducted between August 18 and 26, and 1534 individual birds and 31 species were recorded. The mean of 16.3 birds per transect had an SD of 27.0 for a coefficient of variation (c.v.) of 165%. Part of this variability was caused by the occasional recording of large flocks (50 to 150 birds) usually consisting of either weavers or egrets. Omitting the nine flocks of more than 50 birds reduced the mean number of individuals per transect to 9.0 and the c.v. to 117%. This indicated that bird abundance would vary considerably even within strict sampling constraints.

Also during the preliminary sampling program, a search technique was developed for carcasses and injured animals. Team members walked the 200-m transect with perpendicular forays alternatingly east and west at each of eight stations spaced 25 m apart. The observer walked each branch of the transect out and back over 25 m while looking continually to his right, so that he visually swept an area of 10 m on either side of the branch. Carcass searches of this type were conducted along with the bird census transects for a total of 94 searches. Three feathers were collected, but no carcasses or definitive signs of mortality were observed.

4. PHASE I TRIALS

4.1 TEST DESIGN

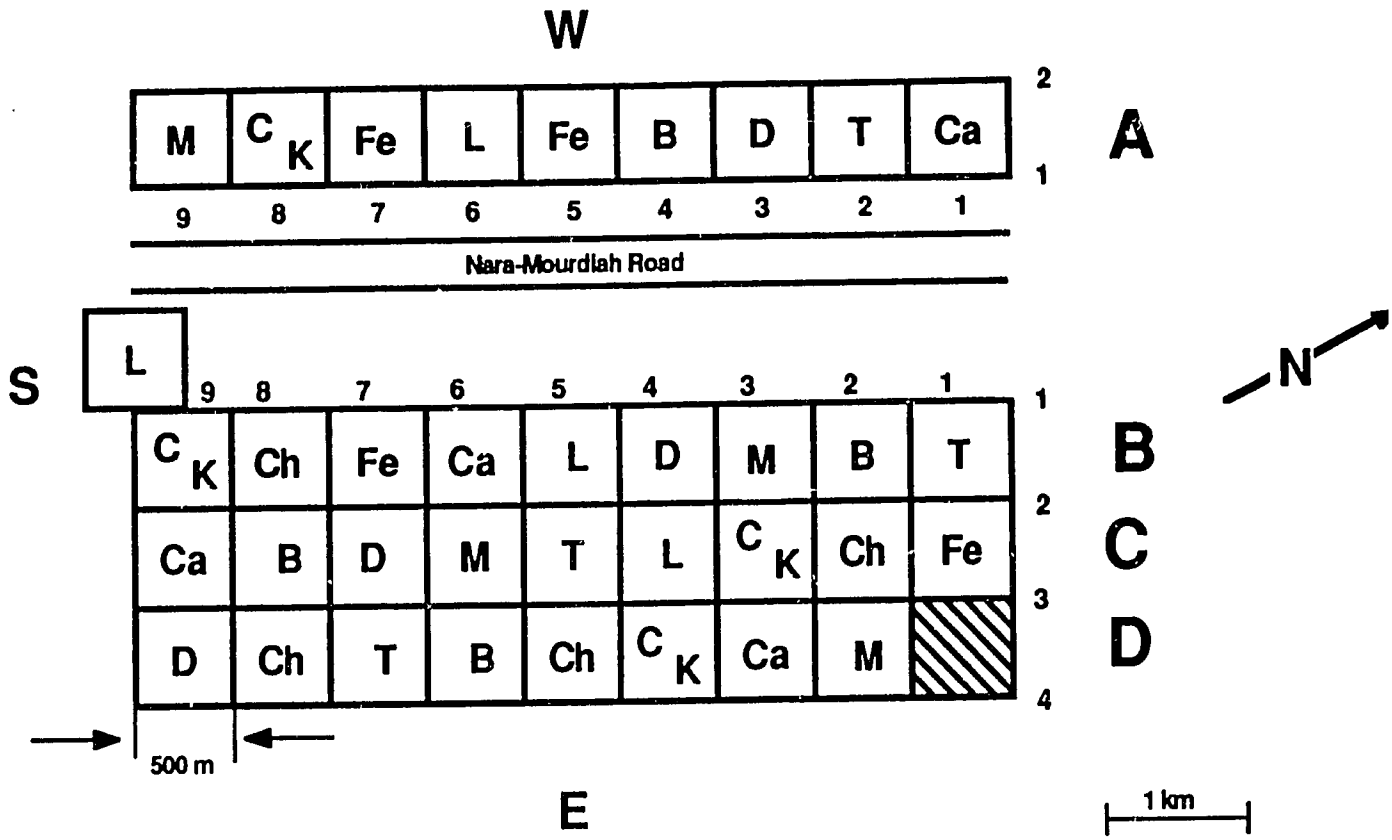
4.1.1 Plot Delineation

The areas east and west of the preliminary spray trial sites were chosen for the Phase I test. Consultation with the local crop protection service (Nara Protection des Vegetaux or PV), a survey with their chief prospector, and the field team's investigation of the surrounding area confirmed that this site had the greatest abundance of O. senegalensis. The fragility of this distribution of mobile adult grasshoppers, as stressed by N. Jago of the Tropical Development Research Institute (TDRI) and M. Kone of the Nara PV, required that the tests be conducted immediately on this site, even though the area of infestation was only 10 km^2 (1000 ha). This area would only accommodate 50 plots with large buffer zones (150 m). The populations on the west side of the Mourdiah road were decreasing rapidly, and half of the replicates from that side were moved to the east side before the spray trial was begun. The final design consisted of one row of nine replicate plots west of the Mourdiah road and three rows of nine replicate plots east of the road. The first plot of the easternmost row was replaced by an additional southerly plot because it consisted only of millet fields (Figure 4-1).

4.1.2 Plot Size and Arrangement

As a result of the preliminary spray trials and application testing, 12-ha plots were chosen with a minimum of 150-m buffer zones in all directions. Each plot measured 350 m on a side and was located 75 m from the vehicle tracks that denoted the lines between plots (Figure 4-2). Because the plots were located in an area of relatively homogeneous grassland, a completely randomized design was used for the assignment of treatments (see Figure 4-1). The plots were designated by the letters A, B, C, and D for the north-south rows and by the numerals 1 through 9 for the east-west lines. The treatments were assigned using a simple random number generator.

29



Abbreviations

Fe = Fenitrothion.
Ma = Malathion.
Ch = Chlorpyrifos.
Di = Diazion.
Be = Bendiocarb.
Ca = Carbaryl.
Lc = Lambda-cyhalothrin.
Tr = Tralomethrin.
C_k = Check (control).

Figure 4-1. Location of Phase I (12 ha) test plots along the Nara-Mourdiah road.

-30'

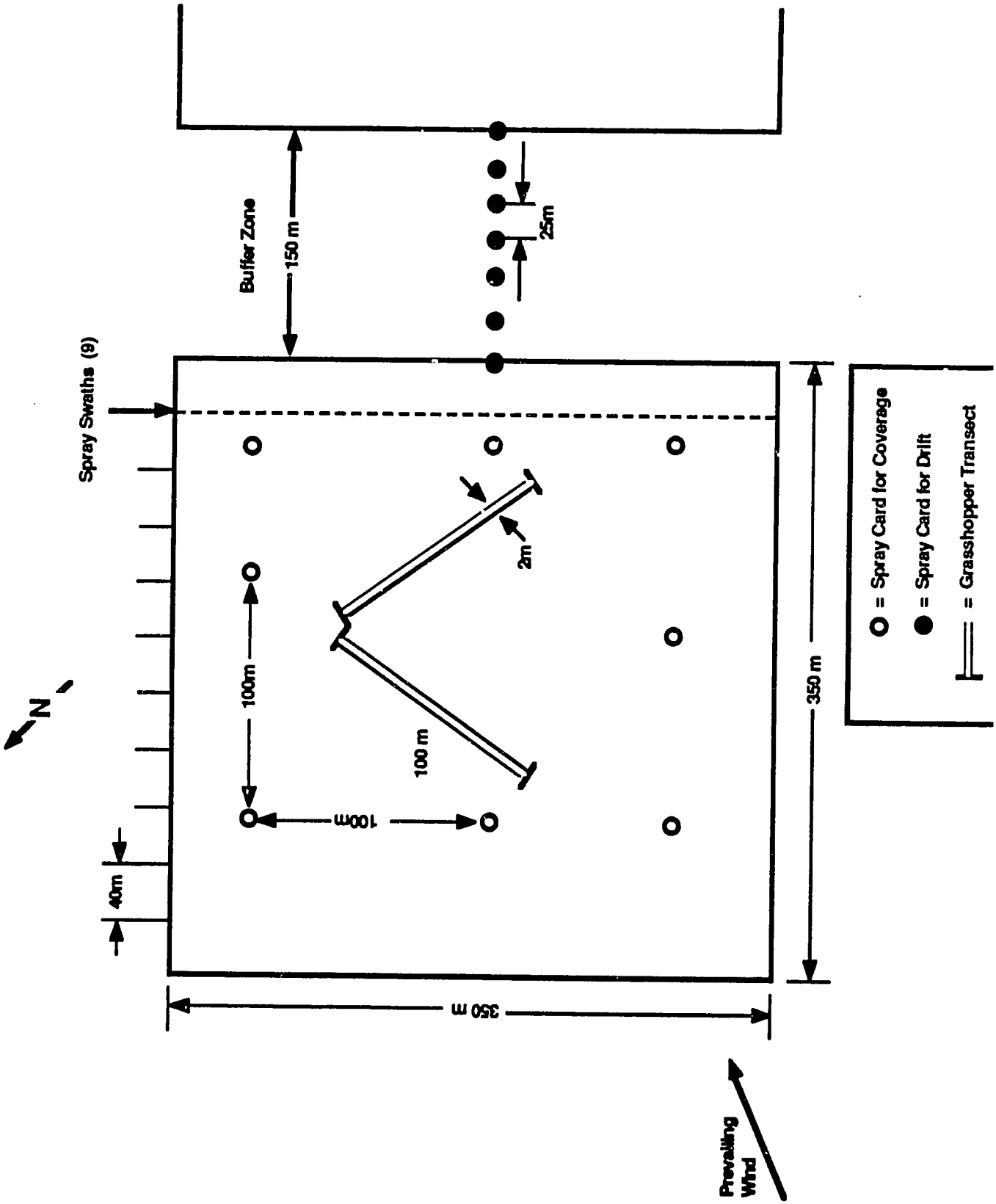


Figure 4-2. Dimensions of typical test plot (12 ha) for Phase I trials.

31

4.1.3 Habitat Description

Each 12-ha plot was surveyed for four habitat variables that can affect the abundance of grasshoppers: (1) the species of dominant grasses; (2) the heights of these grasses; (3) the number of shrubs and trees per hectare; and (4) the number of hectares in cultivation (Table 4-1). These data indicated a considerable homogeneity of habitats among the plots. The absence of significant zones of different vegetation types permitted the use of a completely randomized design. The range of habitat features represented in all the replicates of each treatment revealed no bias that might affect grasshopper numbers or treatment results (Table 4-2).

4.1.4 Order of Treatments

To reduce the confounding factors of temporal variation, the application of the test pesticides was completed as quickly as possible. Two pesticides were sprayed each morning and, with no spraying done on the third day, the treatments were completed in 5 days. Pesticides of similar chemical properties were applied on the same day to facilitate loading and calibration procedures. Daily wind and temperature variations prevented the application of more than two pesticides by limiting the favorable spray window to the early morning hours.

The sampling sequence duplicated the spray sequence in that counts or samples were made at set intervals after pesticide application and were thus not spaced more than 4 days apart for like samples under different treatments. In addition, sampling was done at the same time of day whenever possible. Evening samples were substituted for morning samples in some cases, but observations were not made at any time when abundance or behavior was expected to vary greatly from the usual pattern. While dramatic environmental and biotic changes occurred over the course of the rainy season, the restriction to 14-day sampling intervals likely produced unbiased estimates of the treatment effects.

Table 4-1. Habitat Characteristics of Each Plot

Plot No.	Dominant Grass Species	Grass Height (cm)	Number of shrubs/trees per ha	Number of hectares i cultivatic
A-1	Aristida mutabilis, Eragrostis tremula	20-50	15 shrubs	2
A-2	Aristida mutabilis, Eragrostis tremula	20-50	15 shrubs	0
A-3	Aristida mutabilis, Eragrostis tremula	20-50	10 shrubs	2
A-4	Aristida mutabilis, Eragrostis tremula, Dactiloctinium aegyptium	20-50	5 shrubs	0
A-5	Eragrostis tremula	40-50	30 shrubs	0
A-6	Cenchrus biflorus, Eragrostis tremula	50-70	30 shrubs	0
A-7	Eragrostis tremula	60-70	1 shrub 5 trees	4
A-8	Eragrostis tremula	70	5 trees	1
A-9	Eragrostis tremula	60	5 shrubs 1 tree	1
B-1	Aristida mutabilis, Eragrostis tremula	30-50	20 shrubs	2
B-2	Cenchrus biflorus	70	10 shrubs 1 tree	3
B-3	Cenchrus biflorus, Aristida mutabilis, Eragrostis tremula	50-60	10 shrubs	4
B-4	Eragrostis tremula	50	1 shrub	0
B-5	Aristida mutabilis	30-40	1 shrub	4
B-6	Cenchrus biflorus	50-60	1 shrub	0
B-7	Aristida mutabilis	40-60	1 shrub 1 tree	0

Table 4-1. Habitat Characteristics of Each Plot (Continued)

Plot No.	Dominant Grass Species	Grass Height (cm)	Number of shrubs/trees per ha	Number of hectares in cultivation
B-8	Eragrostis tremula, Aristida mutabilis	60	20 shrubs	0
B-9	Aristida mutabilis	50	12 shrubs	0
B-10	Aristida mutabilis	50	10 shrubs	0
C-1	Aristida mutabilis, Eragrostis tremula	20-50	5 shrubs	0
C-2	Aristida mutabilis	50	10 shrubs	0
C-3	Eragrostis tremula	40-50	1 shrub	0
C-4	Eragrostis tremula	40-60	10 shrubs	0
C-5	Cenchrus biflorus	30-50	1 shrub	0
C-6	Cenchrus biflorus	60-70	1 shrub	0
C-7	Cenchrus biflorus	60-70	20 shrubs	0
C-8	Aristida mutabilis, Eragrostis tremula	40-50	10 shrubs	0
C-9	Eragrostis tremula	60-70	1 shrub	1
D-2	Aristida mutabilis	30-40	10 shrubs	0
D-3	Eragrostis tremula	40-50	5 shrubs	2
D-4	Aristida mutabilis	40-60	10 shrubs	0
D-5	Cenchrus biflorus, Dactiloctinium aegyptium	30-50	5 shrubs	0
D-6	Cenchrus biflorus	60-70	1 shrub	2
D-7	Aristida mutabilis	60-70	10 shrubs	0
D-8	Cenchrus biflorus, Eragrostis tremula	60	5 shrubs	4
D-9	Aristida mutabilis	60	40 shrubs	3

Table 4-2. Habitat Characteristics Occurring in Replicate Plots Within Each Pesticide Treatment

Treatment	Grass Species	Range of grass height	Mean No. shrubs/ trees	Total hectares in culti-vation
Fenitrothion	Eragrostis tremula, Aristida mutabilis, Cenchrus biflorus	30-70	6.5	5
Malathion	Eragrostis tremula, Aristida mutabilis	20-70	10.8	7
Chlorpyrifos	Eragrostis tremula, Aristida mutabilis, Cenchrus biflorus, Dactiloctinium aegyptium	30-60	10.0	4
Diazinon	Aristida mutabilis, Eragrostis tremula, Cenchrus biflorus	20-70	17.8	5
Lamba-cyhalothrin	Aristida mutabilis, Eragrostis tremula, Cenchrus biflorus	30-70	12.8	4
Tralomethrin	Aristida mutabilis, Eragrostis tremula, Cenchrus biflorus Dactiloctinium aegyptium	20-70	11.5	2
Bendiocarb	Eragrostis tremula, Aristida mutabilis, Cenchrus biflorus	20-70	5.5	5
Carbaryl	Aristida mutabilis, Eragrostis tremula, Cenchrus biflorus Dactiloctinium aegyptium	20-70	6.5	5

35

4.2 PESTICIDE APPLICATION

4.2.1 Treatments and Rates

Eight pesticides were selected for testing (see section 1.3), and all were applied in the Phase I trials. Although each chemical was tested on an individual basis, four natural groupings of pesticides were designated for comparison within and between pairs: standard or reference chemicals (fenitrothion and malathion), other organophosphorus compounds (chlorpyrifos and diazinon), carbamates (bendiocarb and carbaryl), and synthetic pyrethroids (lambda-cyhalothrin and tralomethrin). Although each manufacturer recommended two rates (or a single rate that was halved for a second rate), the limited extent of the testable grasshopper populations only permitted the testing of a single rate in the replicated design of eight pesticides. The lower of the two designated rates was chosen for testing: fenitrothion at 150 grams active ingredient per hectare (g a.i./ha), malathion at 560 g a.i./ha, chlorpyrifos at 171 g a.i./ha, diazinon at 450 g a.i./ha, bendiocarb at 50 g a.i./ha, carbaryl at 288 g a.i./ha, lambda-cyhalothrin at 20 g a.i./ha, and tralomethrin at 10 g a.i./ha. The specific formulations used, the rates in liters per hectare, and the product trade names are given in Table 4-3.

4.2.2 Pesticide Handling

All materials supplied by the manufacturers were transferred by truck to the Nara field camp and stored in a protected area, which included a thatched roof to reduce daytime temperatures and a fence to restrict access. All chemicals were maintained in their original containers until they were loaded for spray operations. All used containers were marked and subsequently destroyed and buried. Carbaryl was diluted with diesel before spraying; all other pesticides were applied as received. Materials packaged in 1-, 5-, 20-, and 25-liter containers were poured directly into the airplane hopper. Manual wobble pumps were used to unload the 55-gallon containers. When possible, pesticide remaining in the hopper after the spray run was transferred back into the original containers; no recovered materials were used in the actual test trials. After each spray run, the delivery system was flushed with diesel (or with Solvesso after bendiocarb application). On the final day of Phase I spraying, the carbamates were applied. Bendiocarb was applied first. After draining

36

Table 4-3. Pesticide Formulations Used in the Mali Field Trials Against the Senegalese Grasshopper

Compound	Chemical Class	Trade name	Formulation	g a.i./ha[a]	L/ha[b]
Fenitrothion	Organophosphorus	Sumithion	L50	150	0.30
Malathion	Organophosphorus	Malathion	96% ULV	560	0.58
Chlorpyrifos	Organophosphorus	Dursban	450 ULV	171	0.38
Diazinon	Organophosphorus	Basudin	90 SCO	450	0.45
Bendiocarb	Carbamate	Ficam	20% ULV	50	0.25
Carbaryl	Carbamate	Sevin	4-Oil	288	0.60
Lambda-cyhalothrin	Pyrethroid	Karate	4% ULV	20	0.50
Tralomethrin	Pyrethroid	Scout	3.75% ULV	10	0.28

[a]Grams active ingredient per hectare.
[b]Liters per hectare.

and flushing with Solvesso, the carbaryl and diesel mixture was added. The pump was inspected after it failed to achieve a flowmeter reading. Apparently, it had been blocked by a white paste resulting from mixing of the carbaryl with the Solvesso remaining in the system. A complete flushing with diesel was performed before the final spray run.

4.2.3 Calibration of Equipment

In Phase I, the two pesticides from the same chemical pair were applied on the same day to facilitate handling and calibration procedures. Because each chemical pair possessed similar viscosities, the optimum flowmetering for both pesticides could be achieved. Before each spray run, the pesticide being used was separately calibrated using the Jerry Can method developed during our preliminary trial (see section 3.6.5). To spray the first test run at dawn, calibration for that chemical was performed the previous evening; the second pesticide was calibrated immediately after the morning's first spray run. A minimum of two flights (operating the winddriven Micronairs) were used to assure proper calibration. Our application methodology testing determined that a blade angle of 37.5 degrees and a flying speed of 210 kph should be entered into the computerized flowmeter. Finally, the correction indicated by the calibration procedure was applied to the flowmeter for an accurate output.

Flagging teams arrived on the site at first light to begin spraying between 0630 and 0730 hours. Two teams of two vehicles were used so that the sprayplane could move immediately to the second plot while the first team repositioned for the third spray. Each vehicle was equipped with a wheel counter that indicated 2.5 m for every wheel rotation. Communication with the pilot was possible for the flagging leader, but radio communication among most of the vehicles was unreliable. Careful planning and occasional visual signals were used in the flagging procedure.

One vehicle was positioned on the north end of the plot, and a second vehicle was positioned on the south end. Both vehicles began on the eastern corners and moved west for each additional swath. Prevailing winds were from the west (Table 4-4); therefore, the plane flew successive north-to-south swaths while moving west. The flagging vehicles drove along a line centered within the buffer zone, approximately 75 m from the

Table 4-4. Weather Data During Insecticide Application, Phase I, Nara, Mali, West Africa, 1987

Date	Insecticide	Plot No.	Team No.	Temp. (°C)	Wind-speed (mph)	Direction	RH	Time (hours)
9/7	Malathion	A9	1	32	2-3	SW	N.D	0756
		C6	1	33	3-4	SW	N.D	0829
	Fenitrothion	B7	1	32	3-4	SW	N.D	0922
		A7	1	35	3-4	SW	N.D.	0950
		A5	1	38	3-4	SW	N.D.	1035
9/8	Chlorpyrifos	B8	1	29	2-3	SW	N.D.	0748
		D8	1	31	3-4	W	N.D.	0810
	Diazinon	D9	1	33	3-4	W	N.D.	0915
		C7	1	35	4-5	W	N.D.	0935
9/10	Tralomethrin	D7	1	27	1-2	SW	N.D.[a]	0707
		C5	1	28	1-2	W	N.D.[a]	0725
		B1	2	25	0	--[b]	79[a]	0652
		A2	2	28	2-4	SW	69[a]	0715
	Lambda-cyhalothrin	A6	1	32	3-4	SE	N.D.[a]	0845
		11	1	36	3-4	SE	N.D.[a]	0915
		C4	2	31	3-8	SE	54[a]	0814
		B5	2	33	3-5	SE	59[a]	0852
9/10	Bendiocarb	C8	1	28	2-3	SW	N.D.	0835
		D6	1	28	2-3	SE/SW	N.D.	0850
		A4	2	28	4-7	SE/SW	76	0832
		B2	2	30	2-5	SE	76	0902
9/11	Carbaryl	C9	1	32	5-7	SE	N.D.	1035
		B6	1	33	5-7	SE	N.D.	1050
		A1	2	32	6-10	SE	64	1036
		D3	2	32	4-10	SE	62	1107

[a]Slow, steady rain all afternoon and early evening beginning at approximately 1400 hours (2.54 to 3.81 cm).
[b]None.
N.D. = No data available.
RH = Relative humidity.

39

boundary of the test plot. Spray turnon was initiated an instant just before the plane passed over the vehicles; therefore, deposition began at the northern edge of the plot. Turnoff was accomplished before the plane reached the south flagging vehicle. A total of nine swaths of 40 m each (16 wheel counts) were flown over each plot.

A 200- by 200-m grid of nine spray deposition cards (positioned on 75-cm flags) was deployed in each plot before spraying. Where another test plot was located east of the plot being sprayed, a line of spray cards spaced 25 m apart was deployed across the buffer zone (150 m) perpendicular to the line of flight. Visual determination of the spray cards in the grid verified that adequate deposition was achieved for all chemicals. Unfortunately, the deposition of four chemicals (diazinon, carbaryl, lambda-cyhalothrin, and tralomethrin) was faint or ephemeral, and accurate readings of droplet density and droplet size were not possible.

Malathion produced the most readable deposits, registering droplet densities in the 15 to 40/cm^2 range and a mean droplet size (the volume median diameter or VMD) of 200 microns. Fenitrothion (delivered at 0.517 times the malathion rate) produced droplet densities of 5 to 15/cm^2 and a droplet size of 150 microns. A third organophosphorus compound, chlorpyrifos, produced less distinct deposits, registering a droplet density of 5/cm^2 and a droplet size of 100 microns. The last readable pesticide was bendiocarb, the carbamate, which produced a droplet density of 5 to 15/cm^2 and a droplet size of 120 microns.

Examination of the spray cards from the buffer zones verified that deposition did not drift into other test plots. In general, no drift deposition was observed farther than 75 m from the plot boundary. The low flying height (3 to 5 m above the grass) and the restriction of spray flights to periods of optimum weather conditions (0652 to 1107 hours) undoubtedly contributed to the lack of drift. Table 4-4 gives the exact weather conditions for Phase I sprays. The mean windspeed range was 4.6 to 7.4 kph (2.9 to 4.6 mph). The windspeed range included winds greater than 8 kph (5 mph) on only five plots ; no treated plots were downwind of these plots. The average temperature and relative humidity were 31°C and 67%, respectively.

40

4.3 EFFICACY DETERMINATIONS

4.3.1 Methods

4.3.1.1 Sampling Techniques

Based on the results obtained from sampling procedures employed in the preliminary trials, two sampling methods, visualized m^2 and 2- by 100-m transect, were used in Phase I. These techniques were employed at 1 day pretreatment and 1, 3, 7, and 14 days posttreatment for each of the eight insecticide treatments plus the untreated control plots. Since Phase I was primarily in an area known to have a complex of grasses and shrubs with few crops (see section 4.1.3 for a description of the vegetation within plots), sampling was conducted only in the grasses.

4.3.1.2 The Visualized m^2 Method

To make grasshopper counts using this sampling method, the evaluator entered the sampling area of each plot, the center of which was marked with surveyor flags prior to sampling, and slowly walked forward while visualizing a square meter area approximately 3 m ahead. As the evaluator approached the square meter area, the number of grasshoppers leaving the area plus those that remained were counted. No species differentiation was made at this time (a separate species evaluation study was conducted; see Table 4-5). The evaluator continued through the sampling area until all grasshopper square meter counts were made. The counts were recorded for later analysis. Three square meter counts were made on each plot for each sampling period. The height of the grasses on each plot probably affected the sampling accuracy, but replicates of varying grass heights were evenly distributed among the treatments (see section 4.1.3).

The transect counting method consisted of two 2- by 100-m (400 m^2) sampling areas per plot (see Figure 4-2). The transects were established prior to the initiation of sampling. The transect area was marked by using the wheels of a Toyota Landcruiser, which allowed for an area approximately 2 m wide from the outside of the wheel to the outside of the wheel. The vehicle was driven 100 m using the odometer on the vehicle, and both ends of the transect were marked with surveyor flags. The transects were arranged in a "V" pattern, with the point of the "V" being the end of one 2- by 100-m transect and the beginning of the other.

Table 4-5. Species Composition, Phase I, Nara, Mali, West Africa, 1987[1,2]

Species	% of Population
Oedaleus senegalensis (Krauss)	95
Others:	
Kraussaria angulifera (Krauss)	5
Kraussella amabile (Krauss)	
Acorypha clara (Walker)	
Acorypha glaucopsis (Walker)	
Acorypha picta (Krauss)	
Pyrgomorpha cognata (Krauss)	
Diabolocatantops axillaris (Thunberg)	
Aiolopus thalassinus (Fabricius)	
Aiolopus simulator (Walker)	
Acrotylus blondeli blondeli (Saussure)	
Cryptocatantops haemorrhoidalis (Krauss)	
Stenohippus sp.	
Acrida bi color (Thunberg)	
Eurysternacris brevipes (Chopard)	
Trilophidia conturbata (Walker)	
Schistocerca gregaria (Forskal)	

[1]Based on counts made by Issa Dembele, Malian PV official.
[2]Over 90% adults.

42

The evaluator walked down the middle of the transect and recorded the number of grasshoppers leaving the transect area on either side. The grasshoppers driven ahead of the evaluator were counted when they left the sides of the transect or left the transect at the end of the plot. A hand counter was used to keep track of the grasshoppers in each transect. Upon completion of transect counts, the number of grasshoppers was recorded. Transect sampling was utilized in each plot for each sampling period.

4.3.1.3 Sampling Procedure

Grasshopper counts were made in each plot at 1 day pretreatment and 1, 3, 7, and 14 days posttreatment by two teams of Malian PV officials designated as Team No. 1 and Team No. 2. The plots were divided in a manner that allowed each team to sample two of the four plots (replications) of each treatment. Since two treatments were applied per day during the treatment period in Phase I, each team evaluated four treatment plots (two plots of each of two treatments) plus one untreated plot per sampling period. The same team sampled the same area at each sampling period to assure consistency of sampling. Each team was responsible for making three square meter and two 2- by 100-m transect counts within each plot. The counts were made between 0700 and 1230 hours (see Appendix R for the actual counts). No significant change in the composition of the grasshopper population was noted within this time frame.

4.3.2 Results

The square meter and transect sampling methods gave comparable results, although the transect method provided for higher grasshopper counts. When the number of grasshoppers noted in the square meter area at each treatment was compared to the untreated square meter counts at 1 day pretreatment, none of the treatments was significantly different ($p = 0.05$ used as level of significance, all data) from another (Table 4-6). Following insecticide application, 1-day posttreatment counts showed that all of the treatments had significantly lower grasshopper numbers when compared to the untreated plot counts. However, although numerical differences were noted, none of the insecticides was significantly different from another. Some separation of treatments was observed at 3 days posttreatment. All treatments were significantly different from the untreated plots.

Table 4-6 . Effect of Selected Insecticides on Numbers of Grasshoppers Using the m^2 Sampling Method, Phase I, Nara, Mali, West Africa, 1987[1,2]

Treatment	Formulation	Rate L/ha[3]	$\bar{X}$[4] at No. Days Pre- and Posttreatment -1	+1	+3	+7	+14
Malathion	96%	0.58	18.0	0.3a[5]	0.3a	2.0	3.3
Fenitrothion	L50	0.50	9.8	0.3a	1.3a	1.5	4.3
Diazinon	90 SCO	0.45	12.0	1.0a	0.7a	1.7	2.3
Chlorpyrifos	450	0.38	11.3	3.0a	2.5ab	2.3	2.3
*L-cyhalothrin	4% ULV	0.50	9.0	1.7a	4.7b	4.3	3.7
*Tralomethrin	3.75%	0.28	7.3	1.0a	2.0ab	2.7	3.0
Carbaryl	4-Oil	0.60	5.3	1.3a	1.0a	2.0	0.7
Bendiocarb	20% ULV	0.25	5.7	2.7a	2.3ab	2.0	2.7
Untreated	N.S.	N.S.	13.0	9.3b	7.8c	6.3	6.3

[1]95% O. senegalensis, 5% made up of a complex of grasshoppers (see Table 4-5).
[2]Complex of grasses and shrubs, few crops.
[3]560, 150, 450, 171, 20, 10, 288, and 50 g a.i./ha, respectively.
[4]Each number represents the mean number of grasshoppers/m^2.
[5]Any two means followed by the same letter are not significantly different at the 0.05 level of probability, Duncan's Multiple Range Test.
N.S. = Not sprayed.

* Rain on the afternoon of application may have reduced efficacy of these pesticides.

In addition, significantly lower counts of grasshoppers were obtained for several of the treatments when compared to lambda-cyhalothrin. Malathion, fenitrothion, diazinon, and carbaryl plots had significantly lower 3-day posttreatment grasshopper counts when compared to this insecticide. Counts made 7 and 14 days following treatment were not significantly different from each other, although all treatments had numerically fewer grasshoppers than the untreated plots.

The results from transect counts showed that the 1-day pretreatment grasshopper counts in the plots to be treated with malathion were significantly higher than those in the plots for the other treatments and the untreated plot (Table 4-7). At 1 day posttreatment, all treatment plot grasshopper counts were significantly different from the counts in the untreated plots. However, as was noted for the square meter counts, none of the treatments was significantly different from another. At 3, 7, and 14 days posttreatment, no significant differences were observed between or among the various treatments and the untreated controls. However, numerical differences were noted. It appeared that carbaryl provided some residual control up to 14 days.

When the data for the transects were compared to determine percentage reduction of grasshoppers, all treatments provided 80% or greater reduction in the population when 1-day posttreatment counts were compared to pretreatment counts for each treatment (Table 4-8). At 3 days posttreatment, the grasshopper population was still reduced 80% or greater for all treatments except bendiocarb, lambda-cyhalothrin, and tralomethrin. At 7 days posttreatment, carbaryl, malathion, chlorpyrifos, and diazinon were still above 80% reduction of the original population. By 14 days, only chlorpyrifos was above 80%, although the other three were in the upper 70% range. It is important to note that although the percentage reductions shown in Table 4-8 provide useful information, numbers of grasshoppers determined at the posttreatment intervals should not be taken as percentage control. The percentages do not take into account movement of grasshoppers into or out of plots and natural mortality. Posttreatment counts in the untreated plots, when compared to the pretreatment untreated plot counts, indicate a general reduction in

45

Table 4-7. Effect of Selected Insecticides on Numbers of Grasshoppers Using the m^2 Sampling Method, Phase I, Nara, Mali, West Africa, 1987[1,2]

Treatment	Formulation	Rate L/ha[3]	$\bar{X}$[4] at No. Days Pre- and Posttreatment -1	+1	+3	+7	+14
Malathion	96%	0.58	273.0b	1.8[a]	8.0	40.0	53.0
Fenitrothion	L50	0.30	126.8a	14.5a	22.8	28.5	31.5
Diazinon	90 SCO	0.45	203.0a	9.0	14.7	33.0	48.0
Chlorpyrifos	450	0.38	150.8a	18.0	17.8	22.0	25.0
*L-cyhalothrin	4% ULV	0.50	139.0a	18.7a	48.0	52.0	67.7
*Tralomethrin	3.75%	0.28	96.7a	14.0a	36.0	43.7	46.7
Carbaryl	4-Oil	0.60	126.3a	18.3a	12.0	11.3	27.3
Bendiocarb	20% ULV	0.25	129.7a	19.7a	26.3	27.3	60.3
Untreated	N.S.	N.S.	189.3a	166.3b	151.0	114.0	106.0

[1]95% O. senegalensis, 5% made up of a complex of grasshoppers (see Table 4-5).
[2]Complex of grasses and shrubs, few crops.
[3]560, 150, 450, 171, 20, 10, 288, and 50 g a.i./ha, respectively.
[4]Each number represents the mean number of grasshoppers/400 m^2 transect.
[5]Any two means followed by the same letter are not significantly different at the 0.05 level of probability, Duncan's Multiple Range Test.
N.S. = Not sprayed.

* Rain on the afternoon of application may have reduced efficacy of these pesticides.

46

Table 4-8. Percentage Reduction of Grasshoppers, Using Transect Counts, by Selected Insecticides, Phase I, Nara, Mali, West Africa, 1987[1,2]

Treatment	Formulation	Rate L/ha[3]	% Reduction No. Days Posttreatment[4,5] +1	+3	+7	+14
Malathion	96%	0.58	99(0.5)[6]	97(1.4)a[7]	86(5.0)	78(8.7)
Fenitrothion	L50	0.50	83(4.5)	86(8.1)a	64(22.1)	60(20.4)
Diazinon	90 SCO	0.45	94(1.5)	92(1.5)a	84(3.4)	76(9.2)
Chlorpyrifos	450	0.38	85(4.2)	87(3.2)a	84(4.0)	83(1.5)
*L-cyhalothrin	4% ULV	0.50	86(4.2)	67(6.7)b	63(17.9)	51(18.3)
*Tralomethrin	3.75%	0.28	80(12.2)	60(8.0)b	50(10.1)	50(4.1)
Carbaryl	4-Oil	0.60	86(3.0)	90(0.9)a	91(0.6)	78(3.5)
Bendiocarb	20% ULV	0.25	83(8.6)	76(11.3)ab	74(16.1)	47(19.7)

[1]95% O. senegalensis, 5% made up of a complex of grashoppers, see Table 4-5.
[2]Complex of grasses and shrubs, few crops,
[3]560, 150, 450, 171, 20, 10, 288, and 50 g a.i./ha, respectively.
[4]Each percentage based on comparison of post treatment counts for each data for each treatment to pretreatment counts for each treatment. Percentage = reduction of original population. Percentages fo not take into account movement of grasshoppers into or out of plots and natural mortality, although the untreated plots sampled during the pre and post treatment periods would indicate a trend toward a reduction in population over time.
[5]The untreated plots contained 88% of the original pretreatment population counts at 1+, 80% at +3, 60% at +7, and 56% at +14 days.
[6]( ) = standard error of mean.
[7]Any two means followed by the same letter are not significantly different at the 0.05 level of probability, Duncan's Multiple Range Test.

* Rain on the afternoon of application may have reduced efficacy of these pesticides.

47

population over time: 88% of the original pretreatment population counts at 1 day posttreatment, 80% at 3 days posttreatment, 60% at 7 days posttreatment, and 56% at 14 days posttreatment.

Adjustment for the decline in grasshopper numbers on the control plots was accomplished by decreasing the expected number of grasshoppers (the pretreatment count) by the proportion that all controls dropped for that sample period. The 1- and 3-day posttreatment results were not greatly affected, but considerably lower percent reductions were calculated for the 7- to 14-day samples. Figures 4-3 and 4-4 present these adjusted figures for each pesticide treatment.

Inspection of these adjusted figures reveals a general similarity in the shape of the best performing pesticides. Three of the four organophosphorous compounds (malathion, chlorpyrifos, and diazinon) produced essentially the same gradual linear decline from a high initial reduction of grasshopper numbers. Fenitrothion, the carbamate bendiocarb, and especially the pyrethroids lambda-cyhalothrin and tralomethrin displayed a more rapid decline. Carbaryl, the other carbamate, was the only chemical to show an increase in control at a later time posttreatment.

When percentage reductions, uncorrected for the declining controls, were compared across treatments within sample dates, only the 3-day posttreatment percentage reduction means could be statistically separated (see Table 4-8). At the 3-day posttreatment sampling period, malathion, fenitrothion, diazinon, chlorpyrifos, and carbaryl provided a significantly higher percentage reduction of the grasshopper population than that noted for lambda-cyhalothrin and tralomethrin. The percentage reductions of grasshopper populations for the various treatments at 1, 7, and 14 days posttreatment were not significantly different. Numerically, however, malathion, diazinon, chlorpyrifos, and carbaryl gave 76% or better reduction for each of the posttreatment dates.

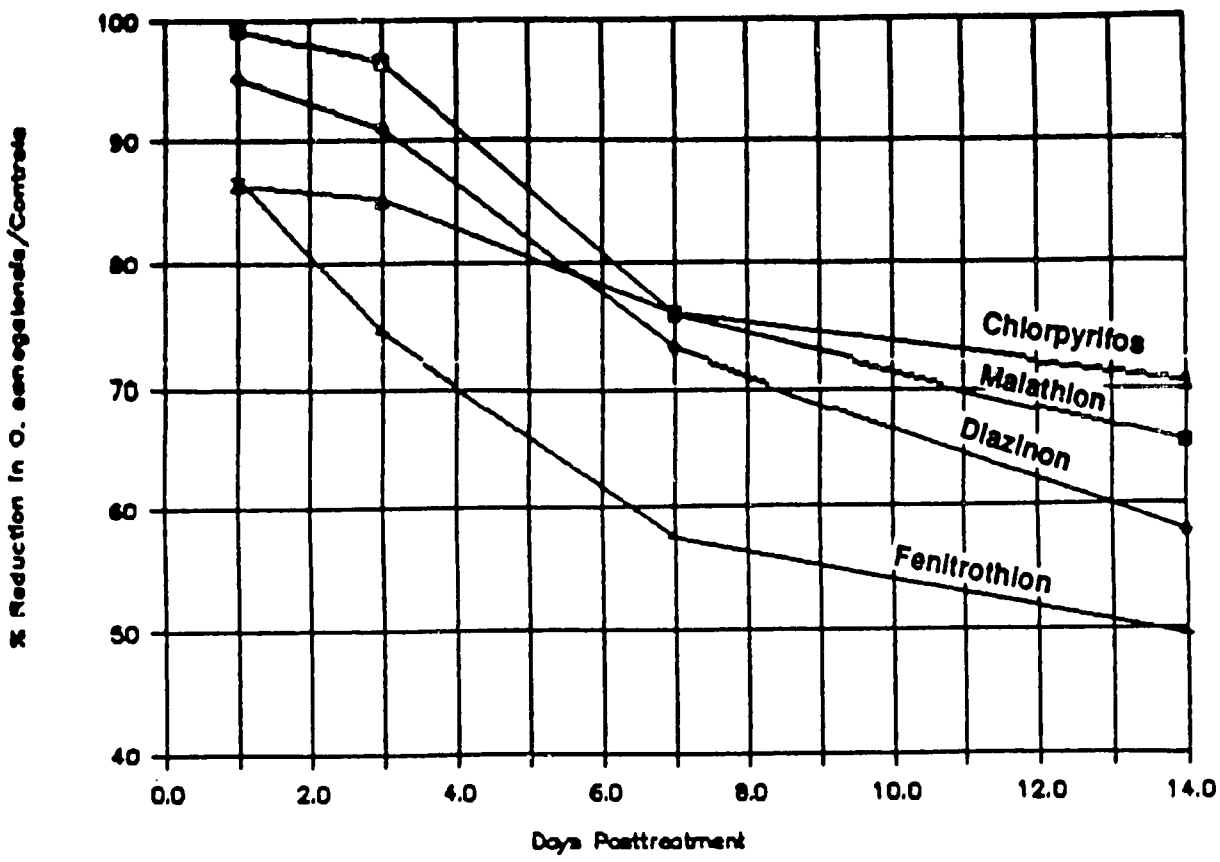


Figure 4-3. Phase I efficacy in grassland (organophosphorous compounds).

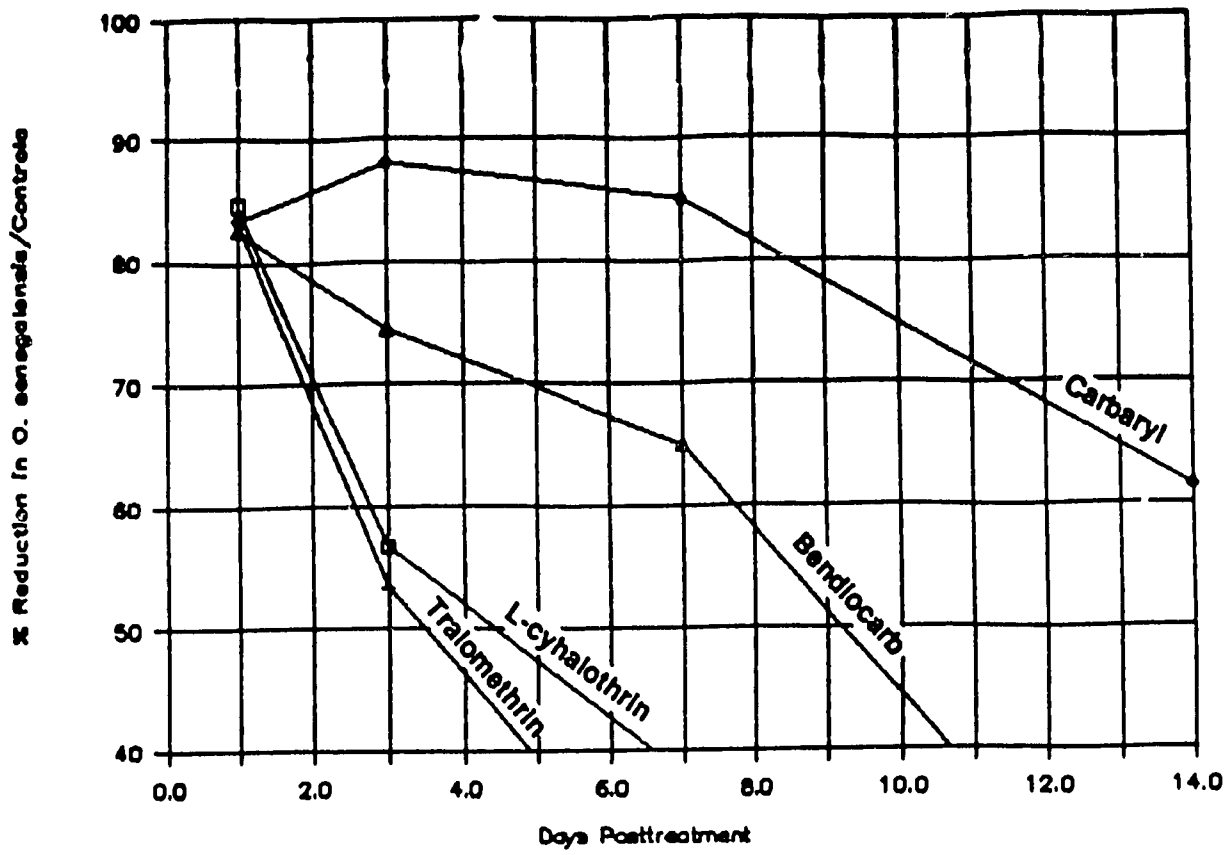


Figure 4-4. Phase I efficacy in grassland (carbamates and pyrethroids).

50'

4.3.3 Discussion

All eight treatments provided 80% or better reduction of the grasshopper population 1 day following treatment. The same was true at 3 days posttreatment for all chemicals except bendiocarb and the synthetic pyrethroids lambda-cyhalothrin and tralomethrin. It is possible that 4 hours of rain beginning 3 hours following treatment may have reduced the effectiveness of the synthetic pyrethroids (see Table 4-8). The good results obtained from the lambda-cyhalothrin treatments in Phase II (see section 5.3.2) support this observation.

Based on the results obtained from Phase I, it was decided that malathion and carbaryl should be further evaluated in Phase II. This was based on their slightly greater effectiveness when compared to the chemicals in their same chemical group, fenitrothion and bendiocarb. Chlorpyrifos was chosen over diazinon because its use is relatively new for grasshoppers and little environmental information is available under conditions within the Sahel. Lambda-cyhalothrin was chosen over tralomethrin not on the basis of efficacy, since their results were similar, but because it is not a domestically manufactured product (testing protocol suggested that at least one foreign-made chemical be included in Phase II).

4.4 IMPACTS ON BENEFICIAL AND NONTARGET INSECTS

4.4.1 Methods

Five sampling techniques were employed to obtain a variety of nontarget insects: sweep-netting, pitfall traps, transect walks, carcass surveys, and ant surveys. Only certain taxa were sufficiently abundant for numerical analyses. However, a syntopic collection of the majority of captured insects was produced as a reference for future studies.

Sweep-net sampling consisted of 10 sweeps at 10 locations selected along a 140-m V-shaped transect within 12-ha test plots. This method was used to provide relative estimates of parasitic wasps during Phase I evaluations. Pitfall traps were constructed of 12-ounce metal cans inserted into the soil so that the mouth was level with the soil surface. In the preliminary trials, 10 cans were equally spaced around a 17-m radius circle placed near the center of each of two replicates per treatment; however, in Phase I, 20 cans were placed in a 4- by 5-m grid spaced 10 m apart. Traps were kept in place for 24 hours before the

51

contents were counted and emptied. Both sweep-net and pitfall samples were taken at 1 day pretreatment and 5 days posttreatment.

Three survey methods were employed in addition to the above capture techniques. Transect walks were used to provide a relative estimate of robberfly populations (Diptera: Asilidae). Walks were conducted along the same V-shaped transects described above for sweep-netting, and the numbers of robberflies observed in a 10-minute period were recorded. In carcass searches, dead insects were counted along the 200-m transect used for counting O. senegalensis in Phase I. Additional searches were conducted along a 200-m transect in millet fields located no more than 100 m from the center of plots. Because of rapid removal by scavengers, counts were made at 24 hours posttreatment. Carcass surveys of the abundant harvester ant Messor sp. (Hymenoptera: Formicidae) were also conducted 1 day after spraying. Observations indicated that dead ants were carried outside the nest and dumped in a circular pattern around the entrance. Preliminary surveys of dead ants were based on a 1-m quadrat placed on the southwest aspect of the anthills so that the south edge of this quadrat included ant carcasses.

4.4.2 Results

The numbers of wasps sampled by sweep-netting were highly variable and generally too low to be statistically analyzed. Further, by late August and early September, seeds of the grass "cram-cram" (Cenchrus biflorus) completely covered the nets, making it difficult to count and remove individuals. Therefore, this sample method was abandoned and is not recommended for future use. Tenebrionids and carabids (coleoptera) were the dominant families found in the pitfall traps. Identification of these individuals to genus is presented in Appendix I. Table 4-9 shows the mean number of beetles sampled for the pre- and postspray sample dates. Mean beetle counts decreased over time at the same rate in both the spray and control plots (Figure 4-5). The nonsignificant interaction term in the analysis of variance (ANOVA) ($F = 0.39$, $df = 7.16$, $P = 0.894$) indicates that the lines shown in Figure 4-5 are essentially parallel and

Table 4-9. Number of Tenebrionids and Carabids per 20 Pitfall Traps per Two Replications for Each Treatment

Insecticide rate L/ha	Rep.	24-hour pretreatment count		5-day posttreatment count		Total No. insects trapped		Percent change posttreatment	
		Tenebrionids	Carabids	Tenebrionids	Carabids	Tenebrionids	Carabids	Tenebrionids	Carabids
Malathion	B3	15	2	3	1	18	3	80.0	50.0
0.58	C6	23	2	9	1	32	3	61.0	50.0
Fenitrothion	B7	27	1	17	2	44	3	37.0	+50.0
0.30	G1	35	1	25	4	60	5	28.6	+75.0
Diazinon	C7	18	3	10	0	28	3	44.4	100.0
0.45	B4	14	3	6	1	20	4	57.1	66.0
Chlorpyrifos	B8	25	0	8	2	33	8	68.0	+100.0
0.38	C2	27	13	7	1	34	14	74.1	92.3
L-cyhalothrin	C4	12	0	11	1	23	1	0.08	+100.0
0.50	B5	49	5	5	3	54	8	89.8	40.0
Tralomethrin	C5	26	4	5	0	29	4	80.7	100.0
0.28	B1	8	1	14	3	22	4	+42.9	+ 66.6
Carbaryl	B6	31	1	23	3	54	3	25.8	+ 66.6
0.60	D3[2]	--	--	--	--	--	--	--	--
Bendiocarb	C8	36	1	34	1	70	2	55.5	0.0
0.25	B2	11	2	7	1	18	3	36.3	50.0
Control	C3	18	13	7	1	25	14	61.0	92.3
	D4	15	4	6	1	21	5	60.0	75.0

[1]One day posttreatment counts unavailable.
[2]Only one replication included

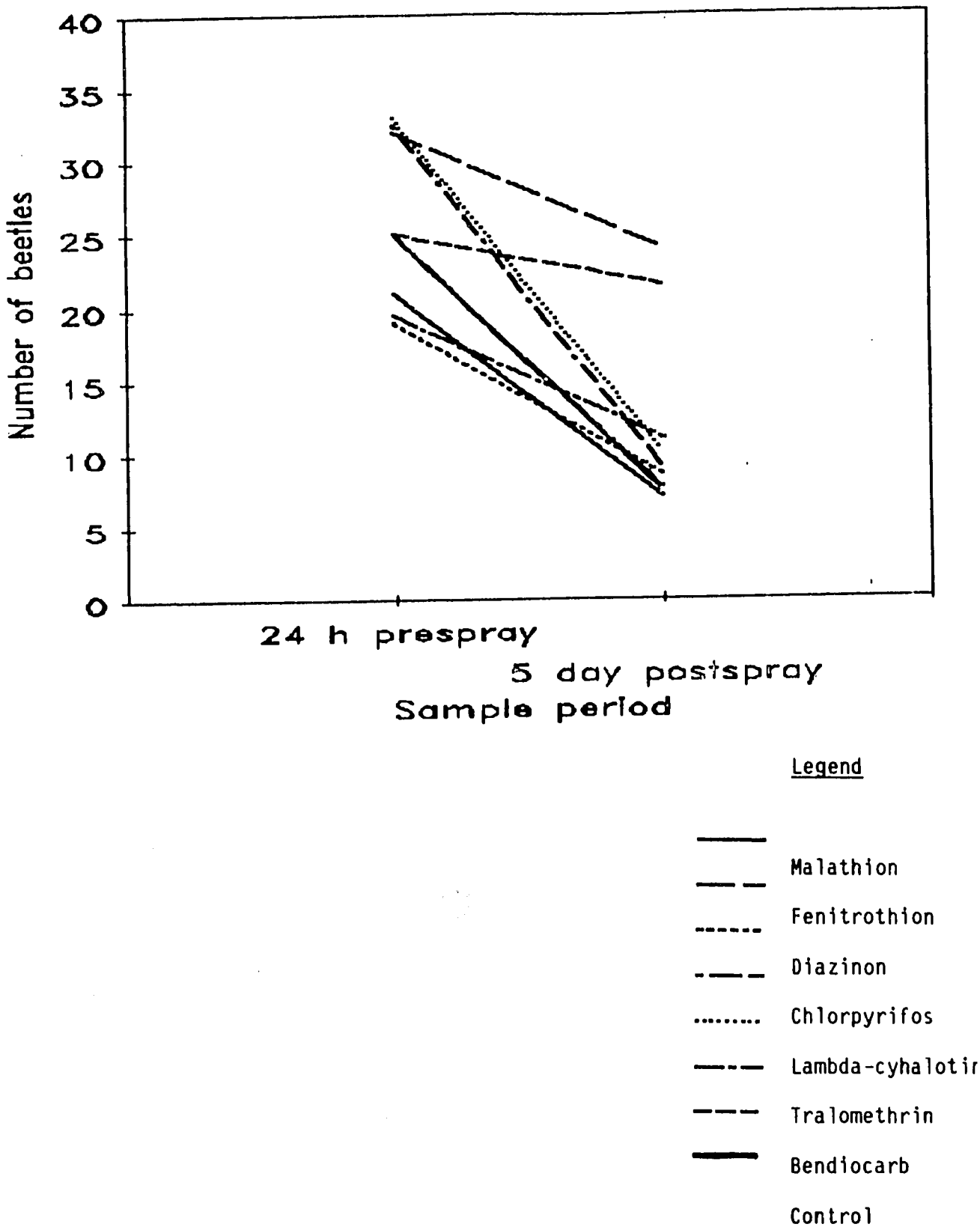


Figure 4-5. Mean number of ground-dwelling beetles per 20 pitfall traps, Phase I efficacy trials.

54

supports the null hypothesis of no significant impact resulting from spray applications. These data are puzzling in view of the results obtained from the transect walks and other cursory observations, which found numerous dead tenebrionids in some insecticide-treated plots. Southwood (1966) cautions that pitfall counts are subject to considerable spatial and temporal variability; however, increasing the replication and the number of observation dates can reduce such within-treatment variation.

Four species of robberflies (see Appendix I) were recorded from visual transects in the preliminary trials. However, their numbers were generally too low to be regarded as a reliable index of population levels. Nevertheless, because robberflies are recognized as predators of grasshoppers, this method should be pursued in the future, perhaps with longer transects. Robberflies were seldom observed during Phase I.

Carcass surveys showed that many test insecticides were indiscriminate in effect. In descending order of total nontarget insect kills (number dead), treatments were ranked as follows: malathion (38), carbaryl (34), diazinon (33), fenitrothion (23), chlorpyrifos (21), lambda-cyhalothrin (16), bendiocarb (10), tralomethrin (10), and control (9) (Table 4-10). However, with two replications these differences were not statistically significant ($F = 2.057$, $df = 8.9$, $P = 0.152$). Ant survey data indicated that not all insecticides tested were equally toxic to ants (Table 4-11). Malathion and diazinon produced dramatic kills. Extensive mortality was also recorded from bendiocarb plots. Other insecticides produced negligible kills. Impact on harvester ant populations could be minimized by applying insecticides between the periods of morning and afternoon foraging (i.e., between 0900 and 1600 hours).

4.4.3 Discussion

Fifteen families of insects were monitored using sweep-netting, pitfall traps, transect walks, and carcass surveys. Results from the transect and ant surveys indicated that many of the candidate insecticides produced broad-spectrum nontarget insect kills. However, some degree of selectivity was noted among these insecticides with respect to ant and tenebrionid mortality. Pitfall data showed considerable variation in trap catch between sample dates, which was independent of treatment effects.

Table 4-10. No. of Dead Insects Recorded in a 200-m Transect (total for two replicates) 24 Hours Posttreatment

Insecticide	Tenebrionid	Scoliid	Vespid	Lepidoptera	Carabid	Scarabaeid	Meloid	Sphecid	Parasitic wasps	Tachinid/ bombyliid	Tota
Malathion	19	1	-	2	3	4	-	5	1	3	38
Carbaryl	4	1	1	3	3	22	-	-	-	-	34
Diazinon	26	1	1	-	2	2	1	-	-	-	33
Fenitrothion	16	1	-	3	-	1	-	2	-	-	23
Chlorpyrifos	11	-	2	-	4	2	2	-	-	-	21
L-cyhalothrin	13	1	-	1	1	--	-	-	-	-	16
Bendiocarb	6	-	1	-	-	2	1	-	-	-	10
Tralomethrin	8	-	1	-	1	--	-	-	-	-	10
Control	7	-	-	-	1	1	-	-	-	-	9

56

Table 4-11. Harvester Ant Mortality (24 Hours Posttreatment) Following Application of Eight Insecticides, Mali, West Africa, 1987

Treatment	Diameter of hill (m)	Dead/m^2
Check	0.8	2
Check	1.0	29
Malathion	1.5	684
Diazinon	1.8	515
Diazinon	0.9	480
Bendiocarb	2.0	127
Bendiocarb	1.3	114
Chlorpyrifos	0.8	35
Chlorpyrifos	0.9	9
Tralomethrin	1.0	21
Lambda-cyhalothrin	1.2	0
Fenitrothion	3.6	15
Carbaryl	0.8	12

Therefore, no significant impact on ground-dwelling beetles could be inferred from these data. Counts of indicator species obtained through sweep-netting, transect walks, and malaise-trapping (Hymenoptera parasitica, Bombyliidae, and Asilidae) were too low to be statistically meaningful.

Three sampling techniques are recommended to obtain abundance estimates of these important groups. Beginning in September, predaceous (on grasshopper egg pods) beeflies (Bombyliidae) replaced robberflies as the dominant brachyceran diptera. Malaise traps modified from mosquito netting were effective in capturing beeflies, albeit in low numbers. Alternative trap designs should be selected with ease of placement in the field as a prime consideration. Light traps can be a valuable tool for monitoring aspects of insect activity and abundance. However, one must be cautious when interpreting results. Portable light traps should be considered for later studies. Attempts should be made to identify one or two indicator species that are present over several weeks. The light source intensity may need to be reduced to decrease the efficiency of the trap and the resulting volume of catch on any given night. Meloidae, an important and well-documented predatory group of grasshoppers, were fairly common throughout all of August and September. Dung beetles (Coleoptera: Scarabaeidae) were abundant over several weeks at a time. Light traps may be useful in monitoring population changes in this guild of insects, which plays a unique and important ecological role. Finally, trees in flower attract a large number of Scolidae and Meloidae. Counting carcasses under these trees could be a simple but useful technique for estimating impact.

4.5 ENVIRONMENTAL IMPACTS

4.5.1 Methods

Analysis of the habitat characteristics of the plots and informal observations of the birds present indicated the Phase I plots should contain a bird fauna essentially the same as that found during preliminary sampling. Between September 10 and 14, carcass searches and bird transect counts were performed along 300-m diagonal transects (with 12 perpendicular branches) through each plot. These searches and counts were conducted on all four replicates 3 days after the application of each pesticide. Searches and counts were done on control plots on each of the 4 sampling days.

In conjunction with the two 100-m grasshopper transects, searches for dead or dying animals were conducted within the 2-m transect width. Similarly, searches were done on 200-m transects within cultivated millet fields. Searches along the grasshopper transects were done before spraying, 1 day, 3 days, 7 days, and 14 days posttreatment. Crop field searches were done 24 hours after spraying. The combined area searched posttreatment along these transects was 61,000 m^2.

4.5.2 Results

The important result noted from the Phase I environmental impact sampling of vertebrate (principally bird) populations was the complete absence of any overt (i.e., severe acute) detrimental effects. No carcasses were found, and no debilitated or otherwise abnormal animals were observed.

4.5.3 Discussion

Many, if not most, of the birds observed in the Phase I counts frequently cover ranges beyond the 12-ha area of an individual plot. Therefore, mortalities or other results, if they occurred, could not have been ascribed to a particular treatment. However, no mortality was seen over the entire treated area of 900 ha, strongly suggesting that these pesticides caused no acute adverse effects.

4.6 RESIDUE SAMPLING

4.6.1 Methods

In Phase I, residue samples were limited to harvestable grains of sorghum and millet. The treatment samples included one reference chemical (fenitrothion) and four additional materials whose plots contained crops of sufficient maturity for meaningful analysis (bendiocarb, tralomethrin, lambda-cyhalothrin, and chlorpyrifos). It should be noted that three of the four pesticide treatments not selected for Phase II were included in this sampling.

The Phase I residue sampling was performed on October 3, 1987, 22 to 27 days after treatment. Twenty-five to 30 mature or nearly mature grain heads were randomly chosen from an 80- by 80-m area of sufficient size to represent two swath widths. Plastic gloves were employed during all

collection tasks, and tools used were washed before each sample was taken. Samples were placed in a cloth bag and kept cool until threshing. Hand-threshed grain was placed in glass jars with Teflon lids and kept frozen during storage. The frozen samples were packed in wet ice and flown from the field camp to Bamako. After storage in a second freezer, the samples were packed in dry ice and flown to Paris. Unfortunately, the samples thawed for an unknown period before arriving at the Miami laboratory 3 weeks after shipment.

4.6.2 Results

Due to container damage, laboratory analyses were not conducted on the potentially contaminated tralomethrin and bendiocarb samples. The residue levels found in the chlorpyrifos, fenitrothion, and lambda-cyhalothrin samples were all 1 ppb (0.001 ppm) or lower. The U.S. tolerance for chlorpyrifos residue levels in or on sorghum grain is 750 ppb (0.75 ppm).

4.6.3 Discussion

It is not possible to determine whether degradation of the pesticide residues occurred during shipment. However, these results seem to indicate that the pesticide residues likely to be found on harvested food grains, which were sprayed during the milky stage (i.e., 3 weeks prior to harvest), will be at least two orders of magnitude lower than the U.S.-mandated tolerances for grain crops.

5. PHASE II TRIALS

5.1 TEST DESIGN

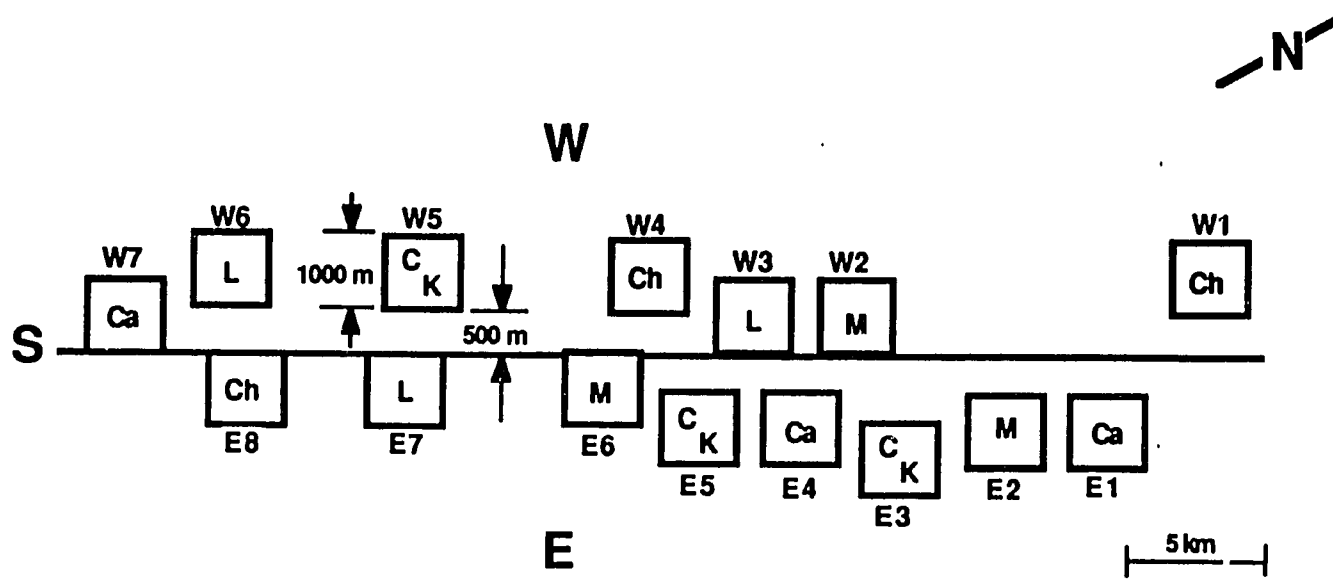
5.1.1 Plot Delineation

The area south of the Phase I study site was chosen for the location of the Phase II test plots. Aerial and ground surveys of the region (including the areas north of Keyban, south of the camp, and south of Nara) revealed insufficient aquatic habitats for their inclusion in the test design. The greatest variety of natural habitats and the best distribution of maturing millet and sorghum fields were found south of Nara and north of Goumbou. Using the Mourdiah road as a point of reference and as an access route to the site, single plots were marked on either side of the road where adequate cultivated fields could be found (Figure 5-1). The layout of 15 plots spanned the 20 km of mixed grassland and shrubland between the Phase I site and the town of Goumbou. Seven plots were located on the west side of the Mourdiah road and six plots on the east side.

5.1.2 Plot Size and Arrangement

Each plot measured 1 km (1000 m) on a side and encompassed 100 ha of grassland, shrubland, and cultivated fields. A minimum of 0.5 km (500 m) was maintained as a buffer zone between plots in both the east-west and north-south directions. Distances of up to 5 km occurred between plots separated by crop-free areas. Although each plot differed in its vegetation profile (see section 5.1.3), the site was not partitioned into distinct habitats requiring a blocked or stratified design. Insofar as each plot was essentially a unique combination of habitats, a completely randomized design was used (Figure 5-1). Three replicate plots for each treatment (spraying with malathion, chlorpyrifos, carbaryl, and lambda-cyhalothrin) and three replicate control plots were designated. The plots on the west side of the road were numbered in a north-south sequence W1 to

61



Abbreviations

Fe = Fenitrothion.
Ma = Malathion.
Ch = Chlorpyrifos.
Di = Diazion.
Be = Bendiocarb.
Ca = Carbaryl.
Lc = Lambda-cyhalothrin.
Tr = Tralomethrin.
C_k = Check (control).

Figure 5-1. Location of Phase II (100 ha) test plots along the Nara-Mourdiah road.

- 62

W7; those on the east side were numbered E1 to E8. The treatments were assigned using a simple random number generator. No like treatments were assigned to adjacent plots.

5.1.3 Habitat Description

Between September 29 and October 2, a detailed analysis of the vegetation and habitat characteristics of each Phase II plot was conducted. Dr. Abdoulaye Sow of the Mali Ministry for Livestock and Natural Resources provided invaluable expert descriptions and accurate species identifications of the relevant flora. Two strata, a grass stratum and a shrub stratum, were identified and described for each plot. In addition, each of the different habitats within the plots was analyzed and the general successional stages of these microsites recorded. Appendix P contains a list of the species identified in each plot.

The controls were plots E3, E5, and W5. Although principally grassland, each plot had distinctly different floral and habitat characteristics. The majority of plot E5 was a recent fallow ("jachere" or distinct stage in old field succession) dominated by the pioneer grass *Eragrostis tremula*. As was often the case in the "combretateous grassland" of the Phase II site, regrowths of the shrub, *Combretum ghasalense* were present. A second section of plot E5 consisted of sorghum fields with several invading weed species. The sandy soil and indurated alluvium that were present on most Phase II plots characterized plot E3. In addition, heavy grazing by livestock using this area as a crossroads ("bourtol") severely reduced the grass cover. Plot W5 was characterized by the presence of dunes with a remnant stream valley ("oued") between them. While the dunes contained the usual assortment of pioneering grass species seen on a typical recent fallow, the cooler habitat of the valley produced an abundance of *Sesbania sesban*. A sorghum field with a cultivated watermelon, *Citryllus clocynthia*, was also present.

The malathion-treated plots were E2, E6, and W2. All three plots were characterized as recent fallows on sandy soils. In plots E6 and W2, stems of harvested grain crops remained from previous years. The herbaceous weed *Striga hermontheca* was present in plot E6; cattle had acted as seed dispersers in plot E2 to produce subplots of *Borreia chaetocephala* within the fallow. All three plots contained

cultivated fields with a variety of adventitious weeds. Plot W2 had an especially diverse array of crops, including millet, Pennisetum typhoides, and two varieties of sorghum, Sorghum guinecensea ("Keminke") and S. cernuum dura ("Gadiaba").

The chlorpyrifos-treated plots were E8, W1, and W4. Plot W1 was predominantly an older fallow where Eragrostis tremula was virtually absent and Aristida mutabilis constituted about 80% of the grass cover. Regrowths of the common shrub and tree species and weed-invaded crop fields also occurred. Plot W4 contained a similar older fallow on a central dune. Depressions adjacent to the dune were partially cultivated with areas of recent fallow among millet and sorghum fields. Plot E8 was characterized by substantial shrub cover (Guiera senegalensis constituting 80% and Combretum ghasalense 20%) over most of the plot. The hydric character of the hollow that bounded this shrubland produced a diversity of herbaceous plants that formed seven distinct associations.

The carbaryl-treated plots were E1, E4, and W7. Both plots E1 and E4 were characterized as intermediate-age fallows with several species of grasses and forbs, including both Eragrostis tremula and Aristida mutabilis. Plot W7 differed from all other plots in the degree to which it had been modified by human exploitation. The sandy soil was interspersed with areas of bare bedrock and fields of intense cultivation, creating a mosaic of different land uses. The tending of millet and sorghum fields was accompanied by farming for okra, peanuts, and indigo. Many of the native shrubs and trees were cut for firewood and livestock forage. The remainder of the plot was in grasses, with Eragrostis tremula and Schoenefeldia gracilis in abundance.

The lambda-cyhalothrin-treated plots were E7, W3, and W7. Plot E7 was predominantly a shrub formation of Guiera senegalensis created by moisture runoff into a broad depression. An adjacent sandy dune supported a young fallow and cropland that was drying out due to the soil's poor moisture-holding capacity. Plot W3, characterized by a denser two-layer sandy soil of gray and red horizons, contained humid microdepressions and a substantial woody stratum of four species. The grass species included Shoenefeldia gracilis, Aristida mutabilis, and the unusual Schizachyrium sanguineum. In Plot W6 three distinct associations were identified: a young fallow containing stems of harvested grains, an older fallow, and a sorghum field with many adventitious weeds.

5.1.4 Order of Treatments

To reduce the confounding factors of temporal variation, the application of the test pesticides was completed as quickly as possible. One pesticide was sprayed each morning and, with no spraying done on the second day, the treatments were completed in 5 days. The sampling regime required same-day and 1-day posttreatment samples, thus preventing the application of more than one pesticide a day.

The sampling sequence duplicated the spray sequence in that counts or samples were taken at set intervals after pesticide application and were thus not spaced more than 4 days apart for like samples under different treatments. In addition, sampling was performed at the same time of day whenever possible. In some cases, evening samples were substituted for morning samples, but in no case were observations made when abundances or behaviors were expected to vary greatly from the usual pattern. While dramatic environmental and biotic changes occurred over the course of the rainy season, our restriction of sampling to 7-day intervals likely produced very little bias in the estimates of the treatment effects.

Appendix P contains species identifications made in each plot; Appendix L contains wide-angle photographs depicting the landscape and vegetation profile of each plot.

5.2 PESTICIDE APPLICATION

5.2.1 Treatments and Rates

Four pesticides (one from each chemical pair) were selected for testing in the Phase II trials: malathion (standard), chlorpyrifos (organophosphorus), carbaryl (carbamate), and lambda-cyhalothrin (synthetic pyrethroid). The low rates used in the Phase I trials were again applied in Phase II: malathion at 560 grams active ingredient per hectare (g a.i./ha), chlorpyrifos at 171 g a.i./ha, carbaryl at 288 g a.i./ha, and lambda-cyhalothrin at 20 g a.i./ha. The specific formulations used, the rates in liters per hectare, and the product trade names are given in Table 4-3.

5.2.2 Pesticide Handling

All materials supplied by the manufacturers were transferred by truck to the Nara field camp and stored in a temporary shelter. The shelter included a thatched roof to reduce daytime temperatures and a fence to restrict access. All chemicals were maintained in their original

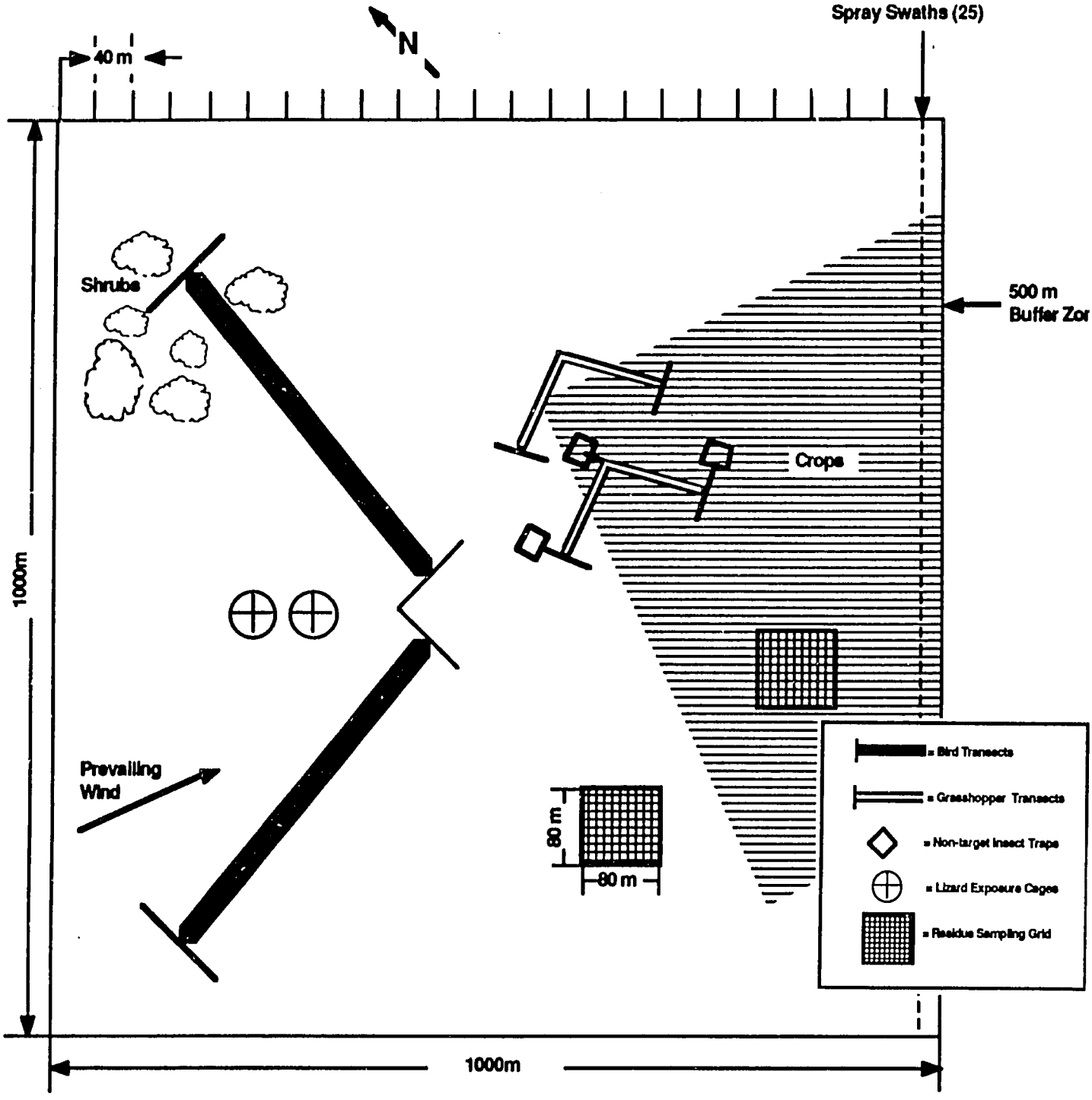


Figure 5-2. Dimensions of typical test plot (100 ha) for Phase II trials.

66

plane passed over the vehicles, and so that deposition began at the north edge of the plot. Turnoff was accomplished as the plane reached the south flagging vehicle. A total of 25 swaths of 40 m each (16 wheel counts) were flown over each plot.

A 200- by 200-m grid of nine spray deposition cards (positioned on 75-cm flags) was deployed in each plot before spraying. Drift was not measured because of the large ($\geq$500 m) buffer zones. Visual examination of the spray cards in the grid verified that adequate deposition had been achieved for all chemicals. Because of the difficulty in observing the deposition of carbaryl and lambda-cyhalothrin in Phase I, glass slides were used to record these sprays. Although deposition from these chemicals was more easily seen, the spreading and smearing of the droplets again prevented accurate readings of droplet density and droplet size. Again malathion produced the most readable deposits, registering a mean droplet density of 45/cm^2 and a mean droplet size (the volume median diameter or VMD) of 200 microns. Chlorpyrifos produced less distinct deposits, registering a droplet density of 10/cm^2 and a droplet size of 100 microns. As in Phase I, all application was accomplished within the window of favorable conditions in the early morning (0725 to 0945 hours). Table 5-1 gives the exact weather conditions for Phase II sprays. The mean windspeed range was 4.8 to 8.2 kph (3.0 to 5.1 mph). The average temperature and relative humidity were 27°C and 69%, respectively.

Table 5-1. Weather Data During Insecticide Application, Phase II, Nara, Mali, West Africa, 1987

Date	Insecticide	Plot No.	Team	Temp (°C)	Wind-speed (mph)	Direction	RH	Time
9/18	Malathion	E6	1	29	2	W	86	0801
		E2	2	27	0	--[4]	81	0725
		W2	2	31	0-3	SW	66	0945
9/18[1]							N.D.	
9/20	Chlorpyrifos	E8	1	27	7-10	SW	N.D.	0740
		W1	2	29	4-8	SW	66	0802
		W4	2	29	4-8	SW	64	0820
9/21[2]	Lambda-cyhalothrin	E7	1	23	2	SW	N.D.	0740
		W6	1	24	2	SW	N.D.	0825
		W3	2	23	0-4	SW	52	0820
9/21							N.D.	
9/22	Carbaryl	E1	1	27	5-7	SE	N.D.	0730
		E4	1	26	5-7	SE	N.D.	0830
		W7	2	29	5-8	SE	66	0835
9/23[3]							N.D.	

[1]Trace (less than 0.51 cm) of rain.
[2]Slight (0.51 to 1.27 cm) rain 3 hours after treatment.
[3]Slight (0.51 to 1.27 cm) rain from 0200 to 0600 hours.
[4]None.
RH = Relative humidity.

5.3 EFFICACY DETERMINATIONS

5.3.1 Methods

5.3.1.1 Phase II Sampling Techniques. In Phase II, only one grasshopper sampling technique was utilized, the 2- by 100-m transect. This proved to be the most effective sampling technique based on data generated in Phase I. Since both grasses (pasture) and crops were available in each plot in Phase II, the transect sampling procedure was used for both types of vegetation and analyzed separately. The sampling procedure was conducted by Malian PV officials at 1 day pretreatment and 1, 3, and 7 days posttreatment.

The transect method was the same as that used for Phase I. The "V" shaped arrangement was used, except that one side of the "V" was situated in the pasture, and the other in the crops. There were two sets of transects per plot, two for pasture (400 m^2) and two for crops (400 m^2).

5.3.1.2 Sampling Procedures. Grasshopper counts were made within the transects of each plot at 1 day pretreatment and 1, 3, and 7 days posttreatment. Four plots were sampled per sampling period (three replications of the treatment and one untreated plot). The counts were made from 0700 to 1230 hours (see Table 5-2 for actual counts). No significant change in the composition of the grasshopper population was noted within this time frame.

5.3.2 Results

Four insecticides were tested in the Phase II trials: malathion, chlorpyrifos, lambda-cyhalothrin, and carbaryl. Phase II was primarily designed to determine the effects of the various chemicals on the environment. However, efficacy against grasshoppers was also included. The grasshopper complex in Phase II was more diverse than in Phase I. *Oedaleus senegalensis* made up 63% of the population, *Krausella amabile* 12%, *Diabolocatantops axillaris* 8%, *Acorypha glaucopsis* 5%, *Ornithacris turbids cavrorai* 4%, *Kraussaria angulifera* 3%, and several species together 5% (see Table 5-3 for full species composition).

Pretreatment grasshopper counts for both crops and pasture showed no significant differences ($p = 0.05$ used as level for significance, all data)

69

Table 5-2. Effect of Selected Insecticides on Numbers of Grasshoppers, Phase II, Nara, Mali, West Africa, 1987[1]

Treatment	Formulation	Rate L/ha[2]	Crops[3] $\bar{X}$[4] No. Days Pre- and Posttreatment[5] -1,2	+1	+3	+7	Pasture[3] $\bar{X}$[4] No. Days Pre- and Posttreatment[5] -1,2	+1	+3	+7
Malation	96%	0.58	74.0	22.7b[6]	26.0ab	15.3	165.0	16.7a[6]	17.7a	22.0a
Chlorpyrifos	480	0.38	24.7	6.7ab	6.7a	4.7	116.3	20.0a	17.0a	21.3a
L-cyhalothrin	4% ULV	0.50	41.0	0.7a	4.3a	5.3	116.0	2.7a	8.0a	25.7a
Carbaryl	4-oil	0.60	40.0	7.7ab	2.7a	5.3	83.3	22.0a	15.7a	17.7a
Untreated	N.S.	N.S.	60.0	48.7c	46.3b	30.0	137.3	139.0b	80.7b	97.0b

[1]63% O. senegalensis, 12% K. amabile, 8% D. axillaris, 5% A. glaucopsis, and 12% complex.
[2]560, 171, 20, and 288 g a.i./ha, respectively.
[3]Complex of crops - millet, sorghum, peanuts, okra, cassava, watermelon; pasture - mixed grasses and shrubs.
[4]Each number represents the mean number of grasshoppers per 400 m^2 transect.
[5]Pretreatment counts for malathion taken 1 day prior to treatment, all others 2 days before.
[6]Any two means followed by the same letter are not significantly different at the 0.05 level of probability, Duncan's Multiple Range Test.
N.S. = Not sprayed.

10

Table 5-3. Grasshopper Species Composition in Crops and Pasture, Phase II, Nara, Mali, West Africa, 1987[1,2]

Species	% of Population
Oedaleus senegalensis (Krauss)	63
Kraussella amabile (Krauss)	12
Diabolocatantops axillaris (Thunberg)	8
Acorypha glaucopsis (Walker)	5
Ornithacris turbida cavroisi (Finot)	4
Kraussaria angulifera (Krauss)	3
Others:	
Cryptocatantops haemorrhoidalis (Krauss)	5
Anacridium melanorhodon melanorhodon (Walker)	
Cataloipus cymbiferus (Krauss)	
Hieroglyphus daganensis (Krauss)	

[1]Based on counts made by Issa Dembele, Malian PV official.
[2]Over 95% adults.

between treatments (see Table 5-2). At 1 day posttreatment, all treatments significantly reduced the grasshopper population in crops and pasture when compared to the untreated controls. At 3 days, only malathion was not significantly different from the untreated plots in the crops, while all were significantly different from the untreated plots in the pasture. The same was true at 7 days posttreatment in the pasture areas; however, no significant differences were noted in the crops at 7 days posttreatment.

As to percentage reduction in the grasshopper population within treatments, lambda-cyhalothrin and carbaryl gave the greatest reduction (1 day = 98%, 3 days = 92%, and 7 days = 91%, and 1 day = 79%, 3 days = 92%, and 7 days = 86%, respectively) in the grasshopper population in the crops through the three posttreatment sampling periods (Table 5-4). In pasture areas, all treatments provided for an adequate reduction in the population. It is important to note, as was the case in Phase I, that although the percentage reductions calculated in Table 5-4 provide useful information, numbers of grasshoppers determined at the posttreatment intervals should not be taken as percentage control. The percentages do not take into account movement of grasshoppers into or out of plots and natural mortality. Crop posttreatment counts in the untreated plots when compared to the pretreatment untreated plot counts indicate a general reduction in population over time: 81% of the original pretreatment population at 1 day posttreatment, 77% at 3 days posttreatment, and 50% at 7 days posttreatment. In pasture, when comparing untreated plot counts pre- and posttreatment, 101% of the pretreatment population was observed at 1 day posttreatment, 59% at 3 days posttreatment, and 69% at 7 days posttreatment.

Adjustment for the decline in grasshopper numbers in the control plots is reflected in Figures 5-3 and 5-4. Using these adjusted figures, habitat comparisons can be made for each of the four Phase II pesticides. While lambda-cyhalothrin again shows the steep decline in control seen in Phase I, it is equally effective in both grassland and crop field applications. The organophosphorus compounds, malathion and chlorpyrifos, reduced grasshopper numbers by 20% less in the crops as compared with the grassland. On day 3, carbaryl was more effective in the crops than in the grassland.

72

Table 5-4. Percentage Reduction of Grasshoppers by Selected Insecticides, Phase II, Nara, Mali, West Africa, 1987[1]

Treatment	Formulation	Rate L/ha[2]	Crops[3] % Reduction,[4] No. Days Posttreatment[5,6] +1	+3	+7	Pasture[3] % Reduction,[4] No. Days Posttreatment[5,6] +1	+3	+7
Malathion	96%	0.58	69 (15.0)b[7]	69 (16.6)	82 (7.6)	89 (4.0)ab[7]	87 (6.6)	84 (7.5)
Chlorpyrifos	450	0.38	69 (5.7)b	63 (11.9)	80 (2.3)	78 (8.9)b	85 (2.7)	83 (3.7)
L-cyhalothrin	4% ULV	0.50	98 (1.6)a	92 (4.0)	91 (4.8)	98 (1.6)a	93 (1.7)	79 (5.3)
Carbaryl	4 oil	0.60	79 (5.6)b	92 (3.9)	86 (1.2)	71 (8.4)b	82 (3.2)	81 (6.4)

[1]63% O. senegalensis, 12% K. amabile, 8% D. axillaris, 5% A. glaucopsis, and 12% complex.
[2]560, 171, 20, and 288 g a.i./ha, respectively.
[3]Complex of crops - millet, sorghum, peanuts, okra, cassava, watermelon; pasture - mixed grasses and shrubs.
[4]Arcsin transformation prior to ANOVA.
[5]Each percentage based on comparison of posttreatment counts for each date for each treatment to pretreatment counts for each treatment. Percentage = reduction of original population. Percentages do not take into account movement of grasshoppers into or out of plots and natural mortality, although the untreated plots sampled during the pre- and posttreatment periods would indicate a moderate trend toward a reduction in population over time.
[6]The untreated plots for crops contained 81% of the original pretreatment population counts at +1, 77% at +3, and 50% at +7 days; untreated plots for pasture contained 101% of the original pretreatment population counts at +1, 59% at +3, and 69% at +7 days.
[7]Any two means followed by the same letter are not significantly different at the 0.05 level of probability, Duncan's Multiple Range Test.

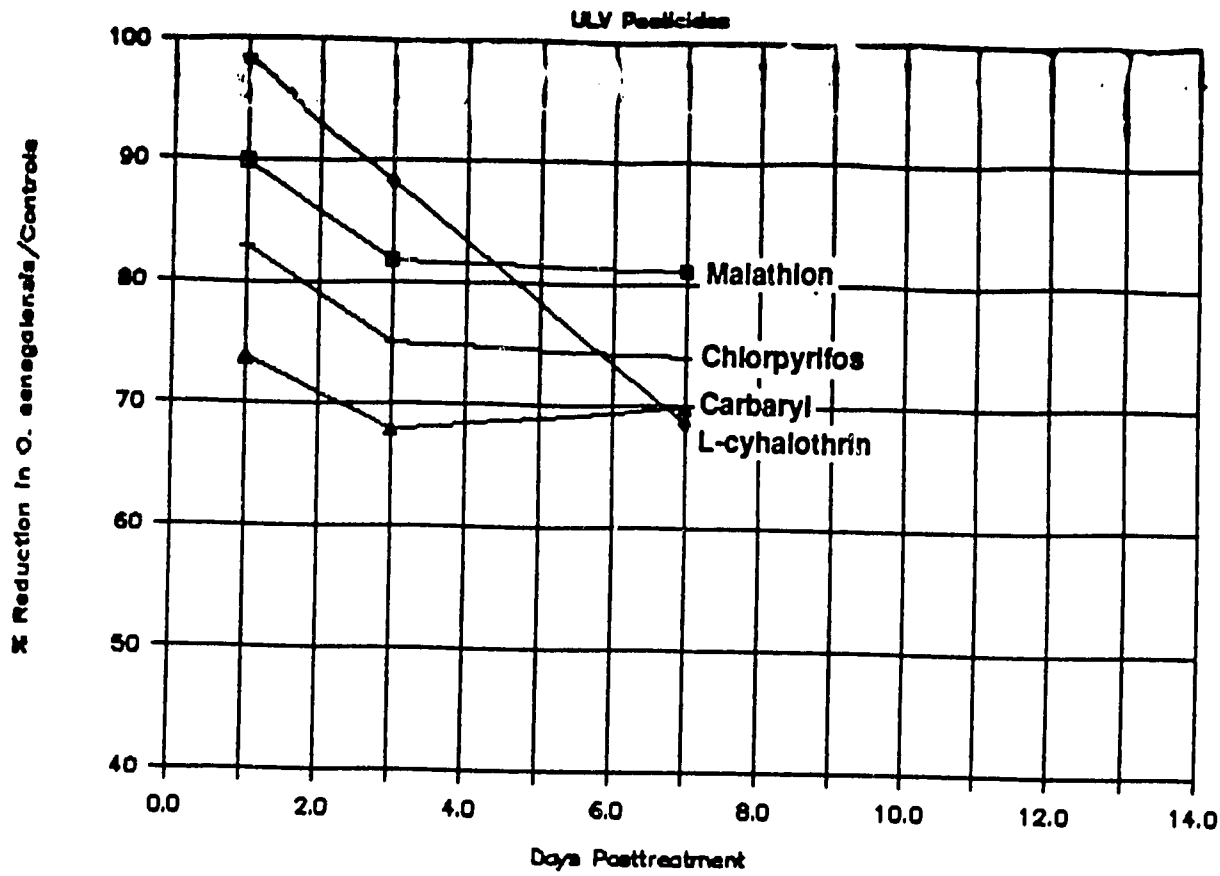


Figure 5-3. Phase II efficacy in grassland.

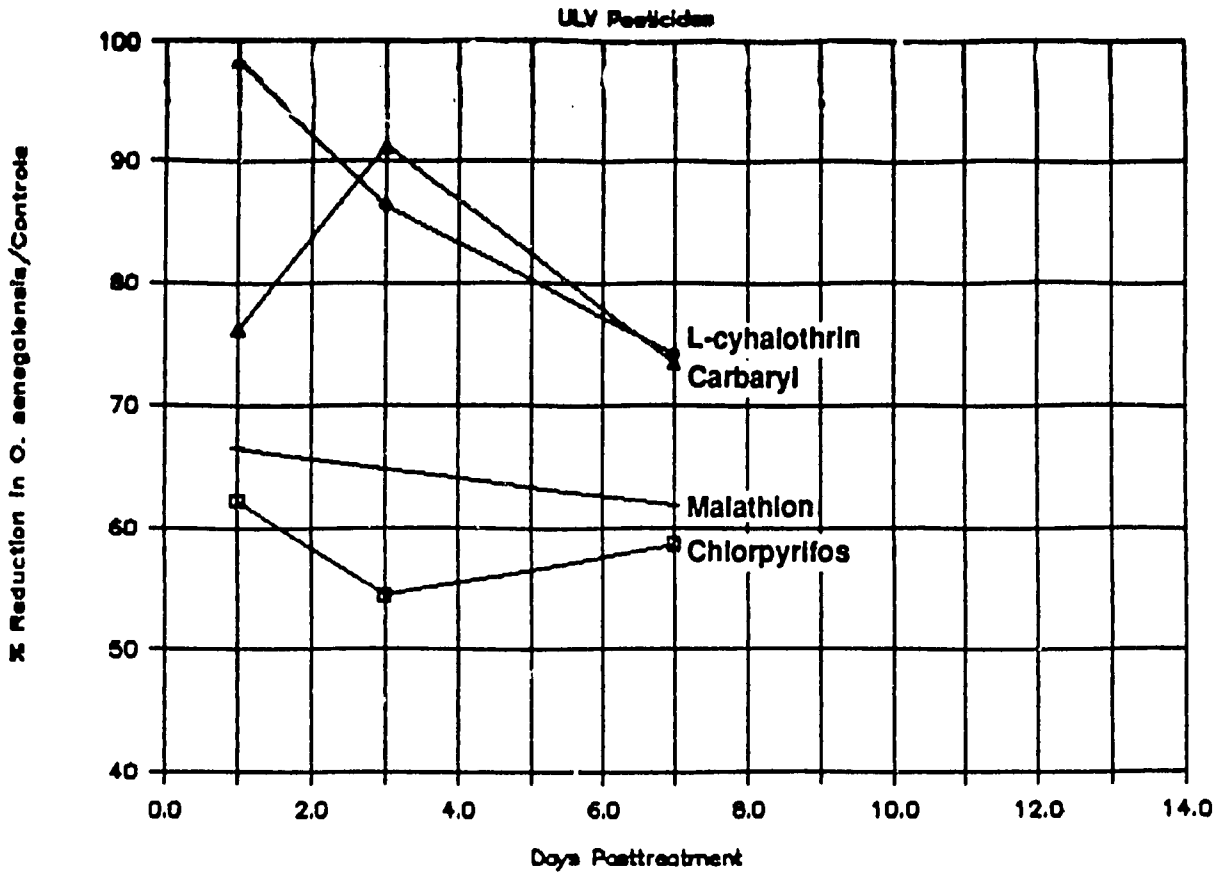


Figure 5-4. Phase II efficacy in cropland.

When percentage reductions unadjusted for control levels were compared across treatments within sample dates for both crops and pasture, only the 1-day posttreatment percentage reduction means could be statistically separated. For that sampling period in crops, only lambda-cyhalothrin provided a significantly higher percentage reduction of the grasshopper population than that noted for carbaryl, chlorpyrifos, and malathion. For the same sampling period in pasture, lambda-cyhalothrin provided significantly higher percentage reduction of grasshoppers when compared to carbaryl and chlorpyrifos. Lambda-cyhalothrin and malathion did not significantly differ. The percentage reductions of grasshopper populations for the various treatments at 3 and 7 days posttreatment for both crops and pasture were not significantly different. Numerically, however, lambda-cyhalothrin and carbaryl gave 79% or better reduction in the grasshopper population in crops for all sample dates, while all the treatments provided 71% or better reduction in pasture for the sample dates.

5.3.3 Discussion

As in Phase I, all treatments gave good control of grasshoppers in pasture. In crops, lambda-cyhalothrin and carbaryl were somewhat better than malathion and chlorpyrifos. However, based on a comparison of Phase I results to those obtained in Phase II, it would be difficult to choose any one insecticide over the others since some performed better in one phase test than the other. Based on efficacy, all appear to be viable insecticides for use in West Africa for the control of *O. senegalensis*.

5.4 IMPACTS ON BENEFICIAL AND NONTARGET INSECTS

5.4.1 Sample Design

The design of the evaluation of pesticide impact on nontarget insects was superimposed upon the evaluation design for the effectiveness of four pesticides (malathion, chlorpyrifos, lambda-cyhalothrin, and carbaryl) against grasshopper infestations. The design consisted of randomized treatments with three replications of each and a corresponding untreated control. Each treatment included cropland (sorghum or millet) in addition to grassland. Two 100-m transects in the cropland and two in the grassland were laid out in a "V" pattern in each plot. Only two replications of each pesticide treatment were used in studying the impact of

76

pesticides on nontarget species. One control plot was included on each sample date for each pesticide under study. This limitation was due to an insufficient number of traps. The three sampling techniques employed in each replicate at each sampling period were (1) sticky traps, (2) visual transects, and (3) ant surveys.

One of the transects in each plot was utilized in determining the impact of pesticides on nontarget insects. Zoecon Pheracon AM® Traps (sticky traps) were placed at the interface between cropland and grassland, at 100 m into the crop, and at 100 m into the grassland. The traps were stapled to bamboo flag stakes approximately 1 m above the ground and oriented parallel to the line of demarcation between crop and grassland. Each trap was left in the field for 24 hours on each of three sampling dates, 1 day pretreatment, 1 day posttreatment, and 7 days post-treatment. The traps were then collected and counted. Using a hand lens, the insects were identified to order and where possible to family. In addition, visual transects were used to provide a qualitative estimate of the number of live nontarget species as well as dead insects in the 2-m width along each transect. All counts were made per 10-minute walk on the sample dates described above.

Results of the Phase I trials indicated that the harvester ant, Messor sp. (Hymenoptera: Formicidae) was the dominant ant species in the test site. In addition, it appeared that the harvester ant provided a good indicator of the effect of pesticides. In Phase II, ant colonies were located in each of the test plots and marked. Activity of each of the colonies prior to treatment was noted, and a 1 m^2 quadrat was placed on the southwest aspect of the cone of each of the more or less circular ant hills. This area included the portion of the hill where the ants deposited debris from the colony, including dead ants. The radius of the ant hill was variable, so each was measured and staked for the 1 m^2 sample. All dead ants in the quadrat were recorded on each sample date.

The Phase I techniques of sweep-netting and pitfall-trapping were discontinued to concentrate on more efficient techniques and to increase the diversity of insects captured.

Dr. Wyman Nyquist, Department of Agronomy, Purdue University, developed an analysis of variance (ANOVA) model to be used in analyzing

the sticky trap data. This model provides an estimation of the error variance when there are two replicates of the treatment but only one replicate of the control.

5.4.2 Results

The results of trapping data are summarized in Table 5-5. Because of the low numbers of species trapped, the data were combined to provide a means of assessing the impact of pesticides on the total fauna trapped. The complex ANOVA model used permits the valid assessment of effects from several factors (Table 5-6). However, due to declining or variable controls, no differences among treatment effects, including controls, were significant. The sample date was the only significant factor affecting insect numbers. However, it should be pointed out that a number of different taxa were trapped including micro-hymenoptera, micro-diptera, homoptera (mainly aphidae and cicadillidae), coleoptera, staphlynidae, thysanoptera, large diptera (syrphidae) and hymenoptera (solitary bees), as well as occasional ichneumonidae.

The data from the visual transects, although including a wide variety of species, do not lend themselves to numerical analyses. See Appendix V for detailed observations made during the sampling.

Table 5-6 summarizes the information concerning the mortality of the harvester ant, Messor sp., resulting from the application of four pesticides for the control of grasshoppers (see Appendix A for the detailed observations). The data indicate that each of the pesticides caused an initial mortality of ants and with the exception of the lambda-cyhalothrin treatment, each continued to show activity at 7 days posttreatment. However, it should be noted that one of the anthill replicates in this treatment did not have as many active ants as the others. The data suggest that malathion and chlorpyrifos have the highest initial kill of ants. Carbaryl appears to be active for a longer period of time than the other materials.

5.4.3 Discussion

In general, the studies conducted in Mali in 1987 serve as a foundation for continuation of the project in future years. Because of the severe constraints on preparation time, it was impossible to meet the

able 5-5. The Average[1] Number of Insects Trapped Using Zoecon Pheragon AM® Traps During a 24-hour Trapping Period on Three Sampling Dates, Nara, Mali, West Africa, 1987

		Average Number of Nontarget Insects Trapped per 24 Hours per Sample Date								
	Rate	Pretreatment			1 day posttreatment			7 days posttreatment		
nsecticide	L/ha	A[2]	B	C	A[2]	B	C	A[2]	B	C
lalathion	0.58	9.5	13.5	11.5	6.0	6.5	6.0	10.0	9.0	4.0[3]
:ontrol		22.0	8.0	11.0	5.0	7.0	14.0	5.0	9.0	3.0
:hlorpyrifos	0.38	12.0	19.0	11.5	4.0	3.0	3.5	3.5	5.0	5.5
:ontrol		15.0	11.0	9.0	6.0	7.0	6.0[3]	6.0	8.0	9.0
-cyhalothrin	0.50	17.0	10.0	12.5	1.5	6.0	2.0	12.5	9.0	8.5
ontrol		15.0	11.0	9.0	5.0	9.0	3.0	6.0	8.0	9.0
arbaryl	0.60	5.5	4.5	2.0	4.5	4.5	4.0	32.5	19.5	18.5
ontrol		4.0	7.0	2.5[3]	6.0	7.0	6.0[3]	41.0[3]	18.0[3]	19.0[3]

Average of two replications, treated plots; only two check plots for the four treatments.
A,B,C sample sites: A in crop (sorghum and millet); B at border of crop and grass; C in grass pasture. All are set 100 meters apart.
Missing traps. Estimated values according to Snedecor (1957).

19

Table 5-6. The Impact of Four Insecticides Applied for Grasshopper Control on the Mortality of the Harvester Ant *Messor* sp., Nara, Mali, West Africa, 1987

Insecticide[1]	Rate L/ha	Average number of dead ants per m^2		
		1 day pretreat	1 day posttreat	7 days posttreat
Malathion	0.58	0.0	294.5	67.0
Control[2]		0.0	3.0	0.0
Chlorpyrifos	0.38	2.5	301.5	33.0
Control[2]		0.0	0.0	1.0
L-cyhalothrin	0.50	0.0	25.5	0.5
Control[2]		0.0	0.0	0.0
Carbaryl	0.60	0.0	96.5	36.0
Control[2]		0.0	0.0	0.0

[1]Average of two replications, treated plots; only two check plots for the four treatments.
[2]One replication of each control.

specifications as outlined in the Scope of Work. Because of the paucity of information and background materials available, as well as literature available in the field, it was not possible to consider "beneficial insects" as defined in the Scope of Work. However, the studies conducted in 1987 provide background biological information and are thought provoking with regard to future activities of a similar nature. Because of the constraints mentioned above, in addition to others to be elucidated below, efforts were made to gather as much information as possible during the short time period available and with the materials on hand. Thus, the Scope of Work was modified to conform with available time and materials.

The design employed in Phase II used sampling techniques that provided information regarding the relative abundance of "nontarget insects" before and after spraying and compared with untreated controls. As such, some of the information acquired is highly qualitative (visual transects) or grossly quantitative (sticky traps).

A number of factors affect the biological interpretation of relative population estimates (Southwood, 1978). These factors include the following:

1. Changes in actual numbers (population changes);
2. Changes in the numbers of insects in a particular stage;
3. Changes in activity following some change in environment;
4. The responsiveness of a particular sex and species to the trap stimulus; and
5. Changes in efficiency of the collecting methods employed.

With particular reference to the studies described here, it should be added that gross ecological differences in habitats were encountered between experimental plots (see section 5.1.3). Variability from all of these factors is reflected in the data acquired concerning the nontarget insect species and contributes to the high variance estimates due to nontreatment effects.

Table 5-7 summarizes the sticky trap catch data from each of the treatments compared with the controls. By combining the data acquired for different taxa, differences due to treatment effects on the total fauna could be determined. Due to the small numbers of any one taxa trapped, it

Table 5-7. Summary of Analysis of Variance of Trap Data

Source	Degrees of freedom	Sums of squares	Mean squares	F value	Level of Significance
Replication	0	--[2]	--	--	--
Insecticide (I)	3	67.2639	22.4213	1.1811	NS
Error (a)	0	--	--	--	--
Pure error (a)	4	36.2778	--	--	--
Trap position (P)	2	81.0278	40.5139[3]	2.1342	NS
I x P	6	152.8611	25.4769	1.3421	NS
Error (b)	0	--	--	--	--
Pure error (b)-2	8	211.2222	--	--	--
Sampling date (T)	2	1747.1111	373.5556	19.6786	**
Error (c)	0				
I x T	6	1436.4444	239.4074	12.6118	**
Pure error (d)-2	7[1]	81.5556	--	--	--
P x T	4	119.5556	29.8889	1.5745	NS
I x P x T	12	250.5556	20.8796	1.0999	NS
Error (e)	0				
Pure error (e)-2	10[1]	221.44	--	--	--
Pooled error	29	550.5000	18.9828	--	--
Total	64	3405.3194			

[1]Corrected degrees of freedom calculated on the basis of missing data.
[2]Not calculated.
**Significant at p=0.01 level of confidence.
NS=Not significant.

92

is unlikely that sticky traps are adequately sensitive to detect species differences. However, it appears that these traps do provide information on insecticide impact on the faunal complex normally trapped by this method. In this study, the major problem with sticky traps was the low numbers of insects trapped and the narrow range of species captured. More traps per treatment would alleviate some of the problems, but would not, in all probability, change the taxa captured. However, sticky traps remain a useful tool in assessing the impact of pesticides. Windspeed and direction, rainfall, and temperature are all important factors in the efficiency of catch using sticky traps and need to be considered in evaluating the catch during any trapping period.

Visual transects can be useful but are subject to changes in efficiency of search from one habitat to another. This variation was present in the current study, but the relatively low abundance of live or dead insects observed was more important. For this reason, the information presented above is qualitative rather than quantitative. Given the high densities of insects, e.g., grasshoppers, visual transects provide an excellent means of determining quantitative relative abundance of animals. Unfortunately, in this study the number of insects observed from transects was low and did not add substantially to the determination of insecticidal impact.

Based on information obtained in 1987, it appears that the harvester ant, Messor sp., is a good indicator species that can be used for estimating the impact of insecticides on nontarget organisms. However, our observations indicate that exposure of the colony to the spray application will influence the mortality significantly; that is, the more the colony is exposed, for example in short grass, the more likely there will be high mortality. In this study, only one colony per plot was used in estimating mortality. Analysis of additional colonies per treatment would provide a better estimate of mortality and provide a better statistical basis for evaluating pesticide treatment. A measure of density or activity (e.g., counting dead ants along a designated length of one or more forage trails) is needed for a better estimate of the impact of insecticide applications. This technique should be considered in future experimental designs.

is unlikely that sticky traps are adequately sensitive to detect species differences. However, it appears that these traps do provide information on insecticide impact on the faunal complex normally trapped by this method. In this study, the major problem with sticky traps was the low numbers of insects trapped and the narrow range of species captured. More traps per treatment would alleviate some of the problems, but would not, in all probability, change the taxa captured. However, sticky traps remain a useful tool in assessing the impact of pesticides. Windspeed and direction, rainfall, and temperature are all important factors in the efficiency of catch using sticky traps and need to be considered in evaluating the catch during any trapping period.

Visual transects can be useful but are subject to changes in efficiency of search from one habitat to another. This variation was present in the current study, but the relatively low abundance of live or dead insects observed was more important. For this reason, the information presented above is qualitative rather than quantitative. Given the high densities of insects, e.g., grasshoppers, visual transects provide an excellent means of determining quantitative relative abundance of animals. Unfortunately, in this study the number of insects observed from transects was low and did not add substantially to the determination of insecticidal impact.

Based on information obtained in 1987, it appears that the harvester ant, Messor sp., is a good indicator species that can be used for estimating the impact of insecticides on nontarget organisms. However, our observations indicate that exposure of the colony to the spray application will influence the mortality significantly; that is, the more the colony is exposed, for example in short grass, the more likely there will be high mortality. In this study, only one colony per plot was used in estimating mortality. Analysis of additional colonies per treatment would provide a better estimate of mortality and provide a better statistical basis for evaluating pesticide treatment. A measure of density or activity (e.g., counting dead ants along a designated length of one or more forage trails) is needed for a better estimate of the impact of insecticide applications. This technique should be considered in future experimental designs.

Our studies indicate a need to determine other key indicator species to be included in continued studies of pesticide impact. However, the phenology of the indicator species must be carefully considered. Judging from observations in 1987, one could sample sorghum and/or millet to determine aphid infestations and at the same time determine rates of parasitism. In addition, predation by syrphid larvae (observed in 1987) and, potentially, by coccinellids (none observed on aphid colonies in 1987) could be recorded. Infestation of millet heads by meloid beetles was observed, but at levels too low to use these beetles as indicator species. Further exploration of meloids as an indicator species seems warranted, particularly because of the role these insects play as predators of the egg pods of grasshoppers. Quantitative information concerning the relative abundance of meloids can be acquired using light traps if a technique can be developed to reduce long-range captures.

Sampling of millet head borers (Rhaguva sp.) could provide information on the role of parasitism in control of this pest, and further, provide information regarding the impact of insecticides on the parasitic fauna. However, during Phase II of the 1987 operations, live head borers had apparently left the heads and entered the soil for pupation. Dead head borers were found in tunnels and cause of death has yet to be determined. Parasites did emerge from some specimens, and these will be identified to species if possible. The timing of spray activities will be crucial to the well-being of parasites of Rhaguva, i.e., spraying at or near the time of parasite emergence from their hosts could cause significant mortality. Whether sampling of Rhaguva earlier in the season would provide an estimate of parasitism and time of parasite emergence needs to be determined. Another question to be answered is whether spraying in one year has an effect on parasitic fauna found in the following year.

One of the difficulties encountered in 1987, which will continue to cause problems with sampling procedures, is the compression of biological phenology events into a relatively short span of time. Insects trapped one week may not be present, or may be present in lesser or greater numbers, one week later. This needs to be considered in any sampling routine, but the impact is greater in the highly seasonal environment of

the Sahel. Another problem is the extreme diversity of habitats encountered across the research area. Even with greater replication, much of the variation may be unavoidable, since the species composition may be different from one plot to the next. The grouping of data, as done for sticky traps this year, will likely be required of any sampling program.

5.5 ENVIRONMENTAL IMPACTS

5.5.1 Methods

5.5.1.1 Sampling Techniques. Preliminary surveys using several sampling techniques were conducted between August 26 and September 17 at the Phase II plots. Rodent livetraps and snaptraps were baited with cheddar cheese or an oatmeal and peanut butter combination. Grids of 16 traps at 10-m intervals were located in sheltered areas among sparse thickets in four different plots. Three nights of trapping were conducted on each site. Only four animals were captured in 192 trapnights: three slender gerbils (*Taterillus gracilis*) and one four-toed hedgehog (*Erinaceus albiventris*). Lines of six mist nets were set up on the same four plots and opened for three mornings each over a period of 2 weeks. During some mornings, no birds were captured after the nets had been open for 4 hours. No more than three birds were captured in one morning and, in general, the capture rates were too low to obtain relative measures of abundance. Counts from bird transects were lower per area than those in Phase I, but with two 400-m transects per plot, sufficient numbers could be obtained for analysis. Like the populations of mammals, reptile numbers were too low to sample quantitatively. The decision was made to collect lizards and frogs, which would be exposed to the spray and subsequently monitored for direct mortality and pesticide residue levels.

During the week prior to the application of the pesticides in Phase II, pretreatment bird transects were run on each plot. Where possible, two counts (1 week and 1 day prespray) were made on each plot. In all cases, 1 day pretreatment counts were completed on each plot. The bird transects were arranged in a "V" of two 400-m branches at an angle of $\geq 90°$ and centered in the middle of the plot. Numbered tags were placed at 16 stations (marking 25-m intervals) along each transect so that the location of each bird could be recorded. Birds up to 50 m away were included in the counts. The counts were made between 0800 to 1130 hours

and 1550 to 1830 hours. The majority of the counts were performed before 1000 hours, and in no case was the temperature above 35°C. For each treatment, the replicates were sampled in random order and no treatment included counts from only a single time period. Posttreatment counts were made both 1 day and 7 days after spraying.

As in Phase I, carcass searches were conducted in conjunction with the bird transects, grasshopper transects, and nontarget insect transects. Along the grasshopper and nontarget insect transects, counts were made on days 1, 3, and 7 posttreatment. A total of 254,000 m^2 or 22.4 ha were searched for carcasses. A third technique for assessing environmental impact was exposure of lizards and frogs or toads to the pesticides. One individual of each taxa was collected from the surrounding area and placed in 5.7-liter plastic tubs that had been inserted into the ground and covered with 0.635-cm mesh polyethylene hardware cloth. The animals were given soil and water and placed on each plot the afternoon before the spray. Each pair was checked 1 day posttreatment for mortality and collected 3 days posttreatment and frozen for residue analysis. Also 3 days posttreatment, four birds were captured in mist nets on a single plot taken from each set of replicates . They were then frozen for determinations of brain cholinesterase activity as well as residue analysis. These and additional samples of soils, grasses, and water were collected for residue analysis as an integral part of the environmental impact assessment (see section 5.6).

5.5.2 Results

As in Phase I, no carcasses or injured animals were found. No abnormal behavior was noted during our transect searches and, in general, normal bird activity levels and behavior were observed on each plot. At least one lizard and one frog or toad survived 3 days posttreatment and displayed normal vigor in each of the four pesticide treatments. However, two lizards and six frogs were found dead in the tubs. The greater incidence of amphibian mortality argues for exposure to the sun as the cause of death rather than direct pesticide toxicity. Five of the six dead frogs were completely dried and brittle. Residue levels ranging from 0.001 to 0.033 ppm were found in the 18 lizards and frogs collected 1 to 3 days after exposure.

On the bird transects, a total of 1352 individual birds from 46 species were seen. Due to the temporal variation and natural habitat variability, the number of birds counted varied widely, averaging 16.1 birds and 4.1 species per transect (Table 5-8). One source of the variation was the sporadic appearance of flocks containing from 50 to 200 birds, principally mixed species flocks of weavers, and, rarely, conspicuous groups of cattle egrets and black kites. When only the birds that include insects in their diet were included, the variation caused by large congregations of weavers was reduced (Table 5-9). Separate analyses of variance were performed on each sample date (days pre- or posttreatment), and all yielded nonsignificant results. Graphic representation of the treatment means for each sample date revealed a pattern of higher bird counts for the 1-day posttreatment sample as compared to the 1-day pretreatment and 7-day posttreatment counts (Figure 5-5). Means from the three replicates of the malathion and carbaryl treatments mimicked this "humped" pattern. Lambda-cyhalothrin displayed a static pattern of nearly equal mean counts over the three sample dates. Chlorpyrifos exhibited a consistently decreasing pattern with both posttreatment counts lower than the pretreatment count.

A separate analysis of this pattern using additional data on the 7-day pretreatment bird counts was performed using the principles of Before-and-After-Control-Impact (BACI) comparison of treatment versus control plot differences taken before and after the suspected impact (Stewart-Oaten et al., 1986). The counts from three chlorpyrifos-treated plots and from two replicate control plots were combined into mean bird numbers for each of four time periods (sampled within 2 to 3 days of each other). The differences between treatment and control means were calculated for the four sample periods: 1 week pretreatment, 1 day pretreatment, 1 day posttreatment, and 1 week posttreatment (Table 5-10). Under the assumption that, without treatment, the relationship between these two sets of plots (chlorpyrifos and control) remained the same over the 2-week period, this test provides evidence of a significant treatment

Table 5-8. Number of Total Birds (Total Species) From Phase II Transect Counts Before and After the Application of ULV Insecticides

Treatment	Plot	Transect	1 day pre-treatment	1 day post-treatment	7 days post-treatment
Malathion	E2	S	2(2)	13(4)	7(3)
		NE	2(2)	28(7)	1(1)
	W2	N	7(6)	9(4)	2(2)
		SW	6(4)	15(6)	18(5)
	E6	SE	94(7)	130(8)	3(1)
		W	4(3)	2(1)	4(3)
Chlorpyrifos	W1	NE	4(2)	1(1)	9(6)
		W	17(6)	4(2)	1(1)
	W4	W	13(7)	13(6)	4(4)
		N	4(2)	3(3)	3(3)
	E8	W	22(8)	11(5)	0(0)
		N	15(5)	28(10)	7(4)
Lambda-cyhalothrin	W3	NE	14(6)	28(6)	28(9)
		S	23(5)	5(5)	8(5)
	E7	W	3(1)	8(5)	16(5)
		S	2(1)	19(3)	11(3)
	W6	SW	15(5)	13(5)	18(4)
		NW	21(8)	10(4)	7(3)
Carbaryl	E1	E	5(4)	1(1)	2(2)
		SE	6(3)	6(2)	2(2)
	E4	NW	4(3)	0(0)	13(4)
		E	3(3)	6(1)	0(0)
	W7	W	76(10)	87(11)	80(11)
		N	117(7)	43(5)	24(8)
Control	E2	NW	5(2)	40(7)	5(3)
		SW	3(2)	11(4)	10(4)
	E5	N	11(6)	2(1)	1(1)
		W	3(3)	4(2)	27(3)

Table 5-9. Counts of Insectivorous Birds From Transects Run Pre- and Posttreatment in Each of Three Replicate Plots for Four Pesticide Treatments

'eatment	Plot	Transect	Pretreatment	1 day post-treatment	7 days post-treatment
ılathion	E2	S	2	13	4
		NE	2	24	1
	W2	N	7	9	2
		SW	6	15	5
	E6	SE	19	25	2
		NW	4	2	4
lorpyrifos	W1	NE	1	1	7
		W	13	4	1
	W4	W	13	13	4
		N	4	3	3
	E8	W	18	9	0
		N	14	19	7
mbda-cyhalothrin	W3	NE	9	20	18
		S	17	4	8
	E7	W	0	8	4
		S	2	2	11
	W6	SW	7	9	3
		NW	8	2	5
rbaryl	E1	E	3	1	2
		SE	6	6	2
	E4	NW	4	0	11
		E	3	6	0
	W7	W	8	16	11
		N	18	2	2
ıtrol	E3	NW	5	21	0
		SW	2	10	7
	E5	N	6	2	1
		W	3	4	2

.90'

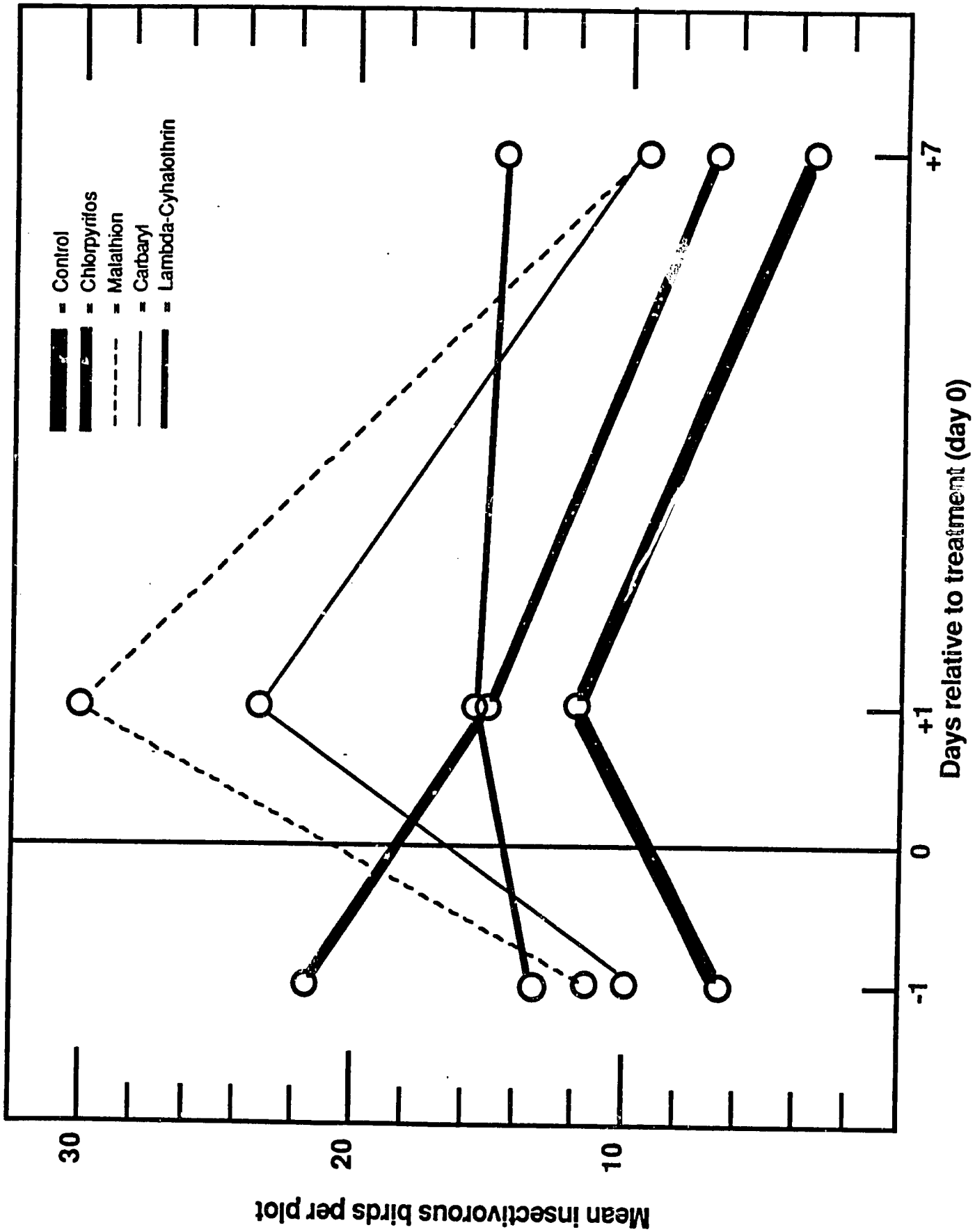


Figure 5-5. Abundance of insectivorous birds from transect counts before and after the application of ULV insecticides.

Table 5-10. Significant Reduction in Bird Abundance Posttreatment[a]

	All birds:				Insectivorous birds:			
	-week	-day	+day	+week	-week	-day	+day	+week
Chlorpyrifos	15.0	13.3	10.0	4.0	11.0	9.8	7.0	3.0
Control	9.0	3.0	14.2	11.0	8.2	2.2	9.0	1.2
Difference	6.0	10.3	-4.2	-7.0	2.8	7.6	-2.0	-1.8
Mean difference	8.15		-5.60			5.20		-1.90
SD	3.04		3.39			1.98		0.14
Test of variance homogeneity (F)		1.535					24.2	
p		>25%					15%	
T test for significant (t) difference		8.68					5.36	
p		0.015 two-tail					0.04 two-tai	
		0.008 one-tail					0.02 one-tai	

[a]Samples: Just before treatment; 1 week earlier.
Just after treatment; 1 week later.

"Simultaneous" samples defined to fit relevant time-frame of 2 to 3 days.

92

effect. The order of the counts reversed after the application of chlorpyrifos, so that the treatment plots had higher counts than the control plots before but lower counts after. Even with the low power of this test, the results are strong enough to produce a significant difference.

The pesticide residues found in live birds, collected under each treatment at 3 days postspray, ranged from 0.001 to 0.468 ppm (Table 5-11). The residues of the carbaryl-treated birds were more than 30 times as high as those exposed to the other pesticides. Determinations of brain cholinesterase activity were performed for the organophosphorus compound malathion and the carbamate carbaryl. Unfortunately, a laboratory error prevented the chlorpyrifos-exposed birds from being analyzed. Birds from the lambda-cyhalothrin plot (not a cholinesterase inhibitor) were used to set control ChE levels that were independent of storage conditions of the samples. The cholinesterase activity in the malathion-exposed birds was at the same level as that in the control birds. However, the birds exposed to carbaryl exhibited significantly less enzyme activity. This was likely due to the greater pesticide residue levels found in these birds. A consideration of the residue level explained 90% of the variation (correlation coefficient $r = 0.95$) in the cholinesterase activity (Figure 5-6).

5.5.3 Discussion

The absence of direct mortality or obvious injury to any birds supports the conclusion that no acute adverse effects resulted from these pesticides applied at these rates. The bird transect data reveal an activity change in chlorpyrifos-treated plots that is not explainable by time of day or other sampling confoundments. However, without corresponding cholinesterase activity measures, it is impossible to rule out alternative hypotheses for the decrease in bird activity. Cholinesterase depression (>50%) was observed in three of four carbaryl-exposed birds. No difference in bird activity was observed on the carbaryl plots. The question of whether subtle effects may result from these pesticides, especially on rare species, remains unresolved.

Table 5-11. Pesticide Residue Levels (ppm) and Brain Cholinesterase (ChE) Activity of Birds on Plots Receiving Single Aerial Applications of ULV Pesticides

Pesticide	Sample	ChE 1	ChE 2	Mean ChE	% Depression*	Residue
Carbaryl	2034	12.1	13.4	12.75	57.5000	0.400
Carbaryl	2035	7.3	8.8	8.05	73.1667	0.468
Carbaryl	2036	15.6	12.4	14.00	53.3333	0.335
Carbaryl	2037	21.8	28.9	25.35	15.5000	0.199
L-Cyhalothrin	2022	28.9	34.4	31.65	0.0000	0.001
L-Cyhalothrin	2023	24.2	23.6	23.90	20.3333	0.001
L-Cyhalothrin	2024	30.5	24.4	32.45	0.0000	0.045
L-Cyhalothrin	2025	36.6	29.7	33.15	0.0000	0.001
Malathion	2005	32.7	32.5	32.60	0.0000	0.030
Malathion	2006	48.4	43.0	45.70	0.0000	0.001
Malathion	2007	32.6	34.4	33.50	0.0000	0.016
Malathion	2008	29.3	31.4	30.35	0.0000	0.005

*Depression of brain cholinesterase activity as a percent of the average value for untreated birds (30 μmoles/gram/minute)

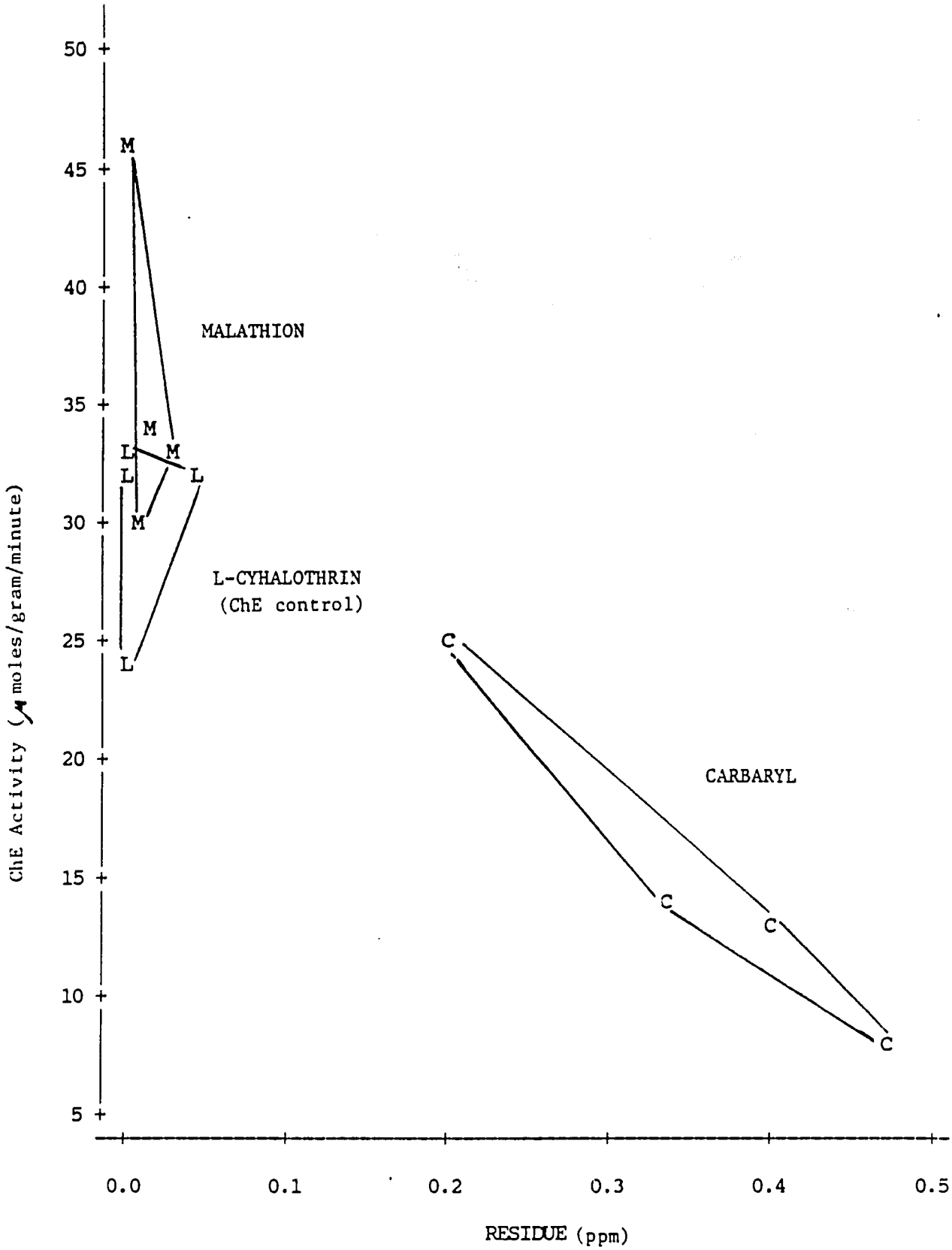


Figure 5-6. Brain cholinesterase (ChE) activity as a function of pesticide residue level (ppm) in 12 live birds.

95

5.6 RESIDUE SAMPLING

5.6.1 Methods

In Phase II, samples of surface water, soils, and forage grasses were taken at regular intervals after pesticide application. Grain crop samples were harvested at maturity. Soil sampling was divided into two categories, soil from cropland (cultivated fields) and soil from rangeland (natural grassland). In both cases, plastic scoops were used to remove a 2-cm-deep section of topsoil. Sixteen to 20 samples (scoops) were collected from an 80- by 80-m grid, i.e., were of sufficient size to represent two swath widths. The soil was mixed in a bucket and placed in glass bottles with Teflon lids. As with all such samples, the bottles were kept in an insulated chest until frozen 1 to 3 hours later. Plastic gloves were worn during all phases of the operation and discarded after use. Plastic scoops were disposed of after each replicate sample. Buckets were washed after each replication. Control samples were taken from each of three untreated plots to establish a baseline residue concentration. Samples from treated plots were taken on the day of application, 1 day posttreatment, and 7 days posttreatment.

As described in section 4.6.1, all samples were kept frozen in freezers or in chests packed with ice during storage and transport. However, the samples thawed for an unknown period of time owing to an unexpected 3-week delay in arrival at the laboratory. EPA-approved laboratory practices, including storage, preparation, and analysis, were maintained by the Miami team. Standard gas-liquid chromotography procedures were used, as were electron-capture techniques.

Samples of forage grasses were taken from treated plots on the day of application, 1 day posttreatment, and 7 days posttreatment. Within an 80- by 80-m grid, 16 to 20 cuttings of 10-cm-wide bunches were made at 5 cm above the ground using grass shears. The samples were placed in a cloth bag during collection; they were then mixed and placed in glass jars with Teflon lids, kept cool, and frozen. After each sample interval, the cloth bags and plastic gloves were discarded and the grass shears were washed. Samples of surface water were collected by dipping glass jars at five locations along the margin of the pond. Due to the scarcity of these ponds, only one replicate of each treatment was sampled. The ponds were less than 1 m deep and ranged in area from 20 to 100 m^2.

96

One or both of the principal grain crops, millet and sorghum, were sampled from every plot. The samples were taken between October 2 and 6, 14 days postspray for all treatments. The majority of the sampled grains were at the peak harvest stage (some fields had been already harvested); however, some samples included grain in the dough stage. As with the Phase I grain samples, procedures to prevent contamination among the insecticides were followed during collection, and the samples were stored frozen.

5.6.2 Results

Mean pesticide residue levels differed significantly ($p < 0.05$) among the four pesticides and among the five principal environmental substrates or media (Table 5-12). The greatest difference was the relatively higher residue levels found on the grasses as compared to the other media. While the carbaryl residues were highest among the pesticides on the birds at 3 days postspray, the malathion residues were greatest across all sampling periods for the cropland and rangeland soils. The residue levels in grasses and crops did not differ significantly among the pesticides.

The rate of residue decline was significant for all four pesticides on rangeland soils (the proportion of variance explained ranged from 0.43 to 0.92). However, each pesticide showed a different decline curve, with some displaying greater drops between days 0 and 1 versus days 1 and 7 (see Figures 5-7 through 5-12). Specifically, the variation in residue decay rates produced significant differences among chemicals and media at days 1 and 7 that did not exist at day 0.

5.6.3 Discussion

Although the integrity of the residue samples was not ensured, the data appear to be good indicators of the actual residue levels in the field. The rapid decline in residue levels for all these pesticides indicates that by 7 days after application, the harvestable grasses and grains are well below the U.S. tolerances set by EPA. In soils, the levels were initially low and showed a pattern of rapid breakdown. There appears to be very little opportunity for biomagnification of these pesticides. In two cases, chlorpyrifos and lambda-cyhalothrin, residue

91

Table 5-12. Mean Residue Levels (ppm) of Four Pesticides Found in Five Media and Relevant Tolerance Levels*

Pesticide (application rate)	Days[1]	Medium: Grass	Soil C[2]	Soil G[3]	Crop[4]	Bird[5]	U.S. tolerance for related commodity
Malathion (560 g/ha)	0	0.586	3.520	0.951	--	--	135.00 Grass
	1	0.100	1.701	0.452	--	--	
	3	--	--	--	--	0.012	4.00 Poultry
	7	0.362	0.003	0.002	--	--	
	14	--	--	--	0.0902	--	8.00 Sorghum
Chlorpyrifos (171 g/ha)	0	4.750	0.097	0.024	--	--	4.00 Alfalfa
	1	4.753	0.043	0.013	--	--	
	3	--	--	--	--	0.004	0.50 Poultry
	7	1.123	0.005	0.005	--	--	
	14	--	--	--	0.059	--	0.75 Sorghum
Carbaryl (288 g/ha)	0	1.667	0.373	0.251	--	--	100.00 Grass
	1	0.659	0.149	0.069	--	--	
	3	--	--	--	--	0.350	5.00 Poultry
	7	0.942	0.086	0.047	--	--	
	14	--	--	--	0.168		10.00 Sorghum
L-cyhalothrin (20 g/ha)	0	0.170	0.002	0.003	--	--	0.05 Cottonseed
	1	0.231	0.004	0.002	--	--	
	3	--	--	--	--	0.012	
	7	0.035	0.002	0.001	--	--	
	14	--	--	--	0.003	--	0.05 Cottonseed

[1]Number of days following pesticide application (0 = 6hour sample).
[2]Soil sampled from within cultivated rows of grain crops.
[3]Soil sampled from an area of natural grass.
[4]Threshed grains of mature millet and sorghum.
[5]Live birds (mostly weavers) caught in mist nets on a single plot.

*Each value represents the average of three samples taken from replicate plots that received identical aerial applications.

98

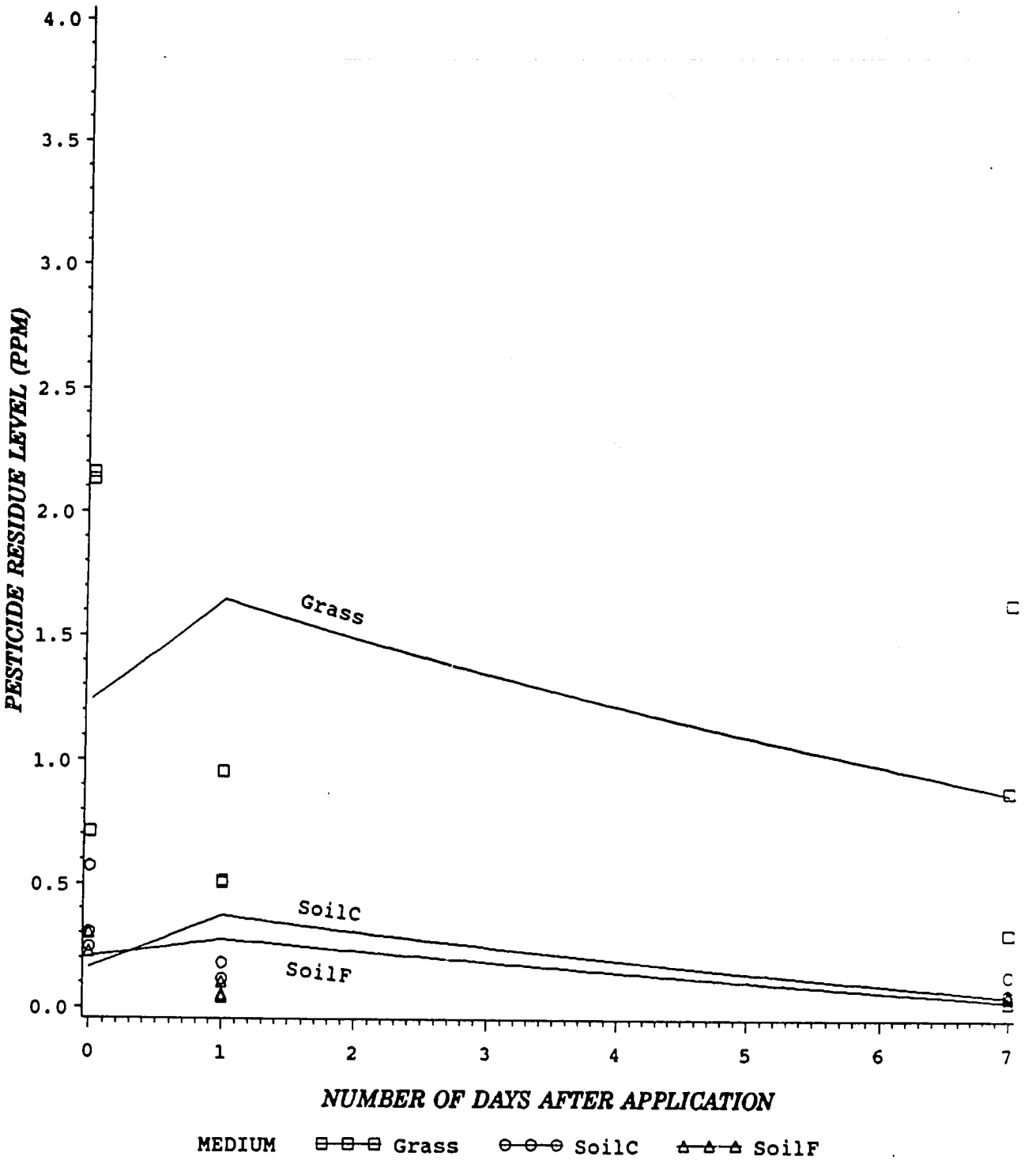


Figure 5-7. Pesticide residue levels in grass and soil (carbaryl).

99

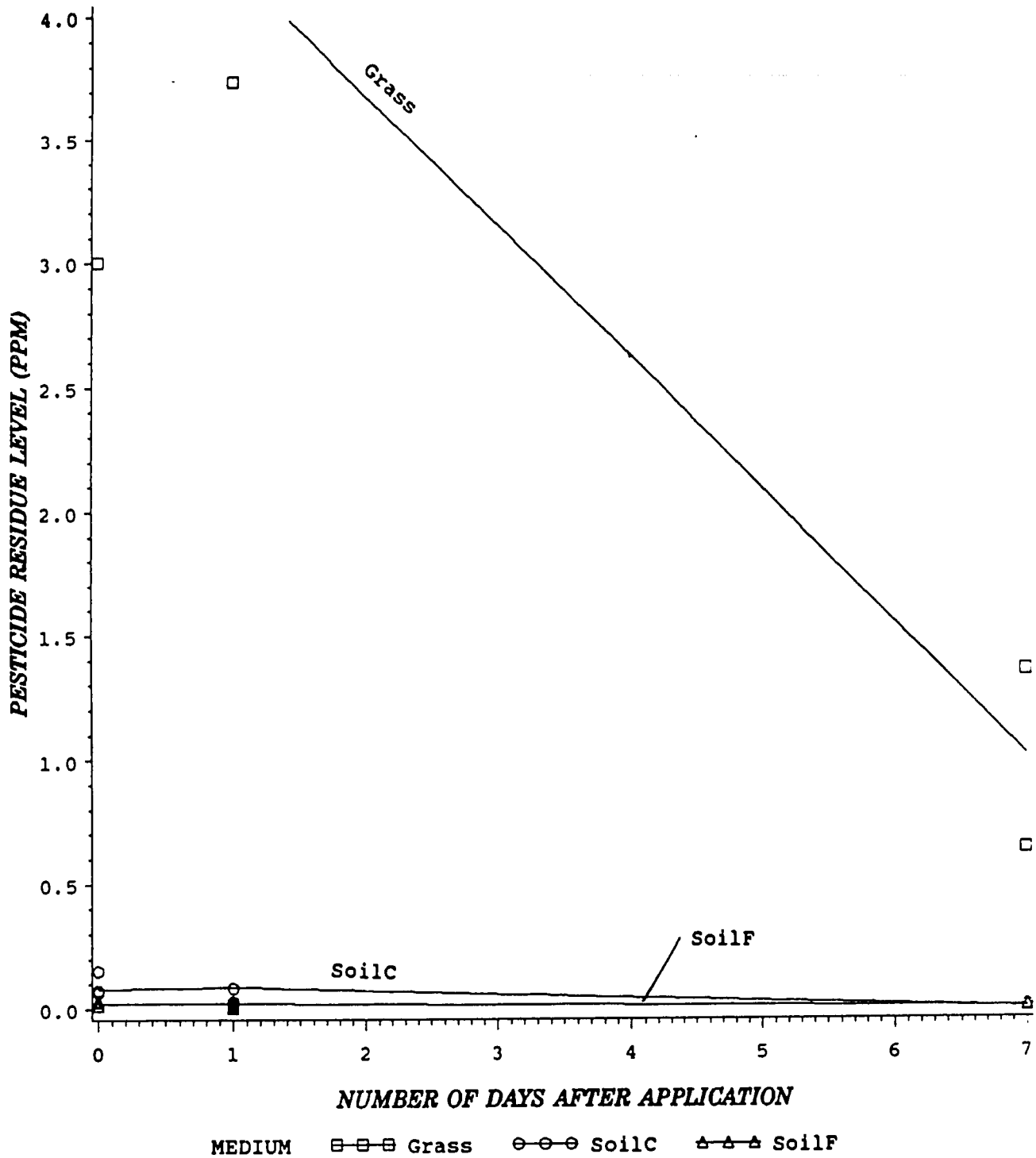


Figure 5-8. Pesticide residue levels in grass and soil (chlorpyrifos).

100

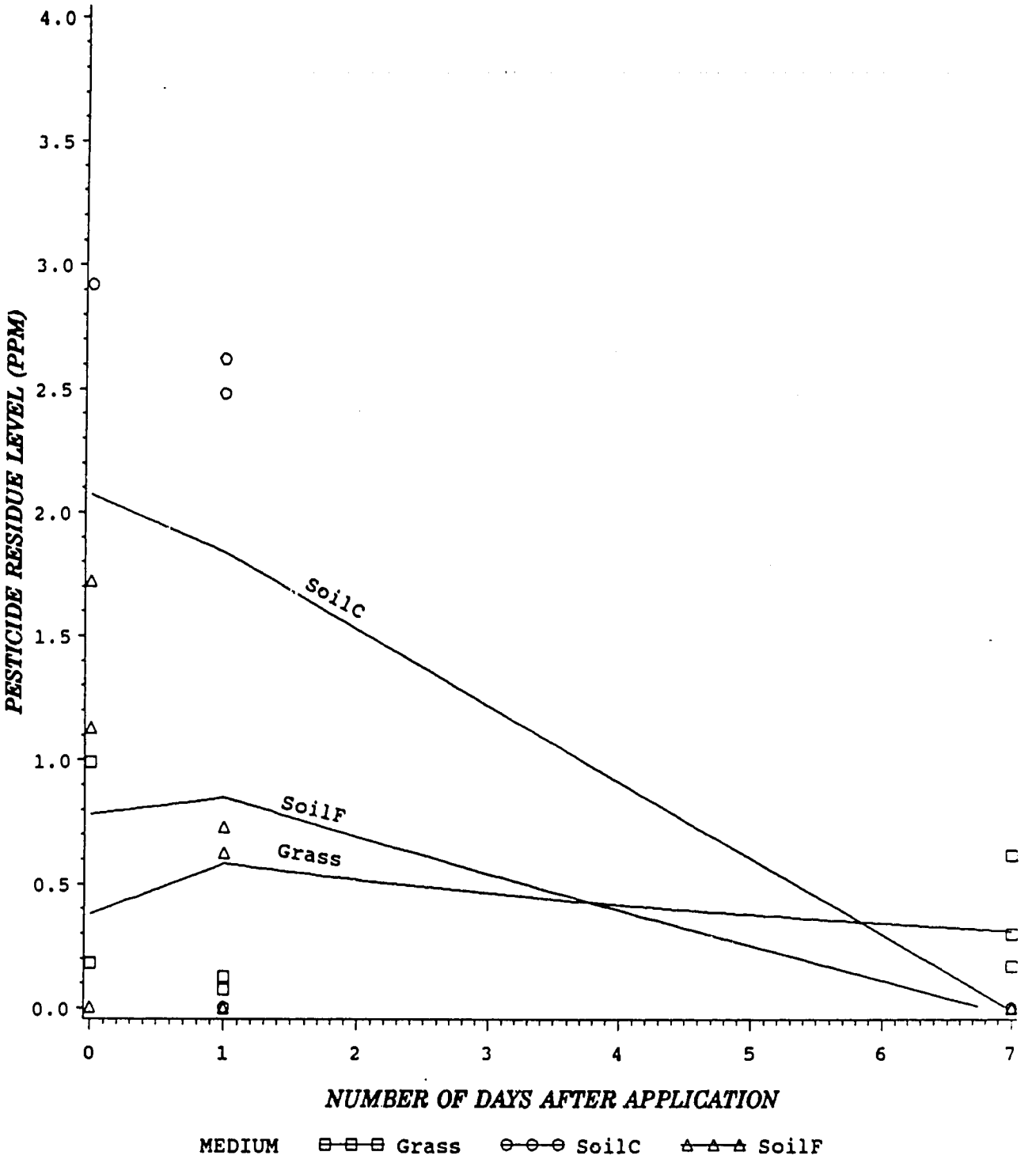


Figure 5-9. Pesticide residue levels in grass and soil (malathion).

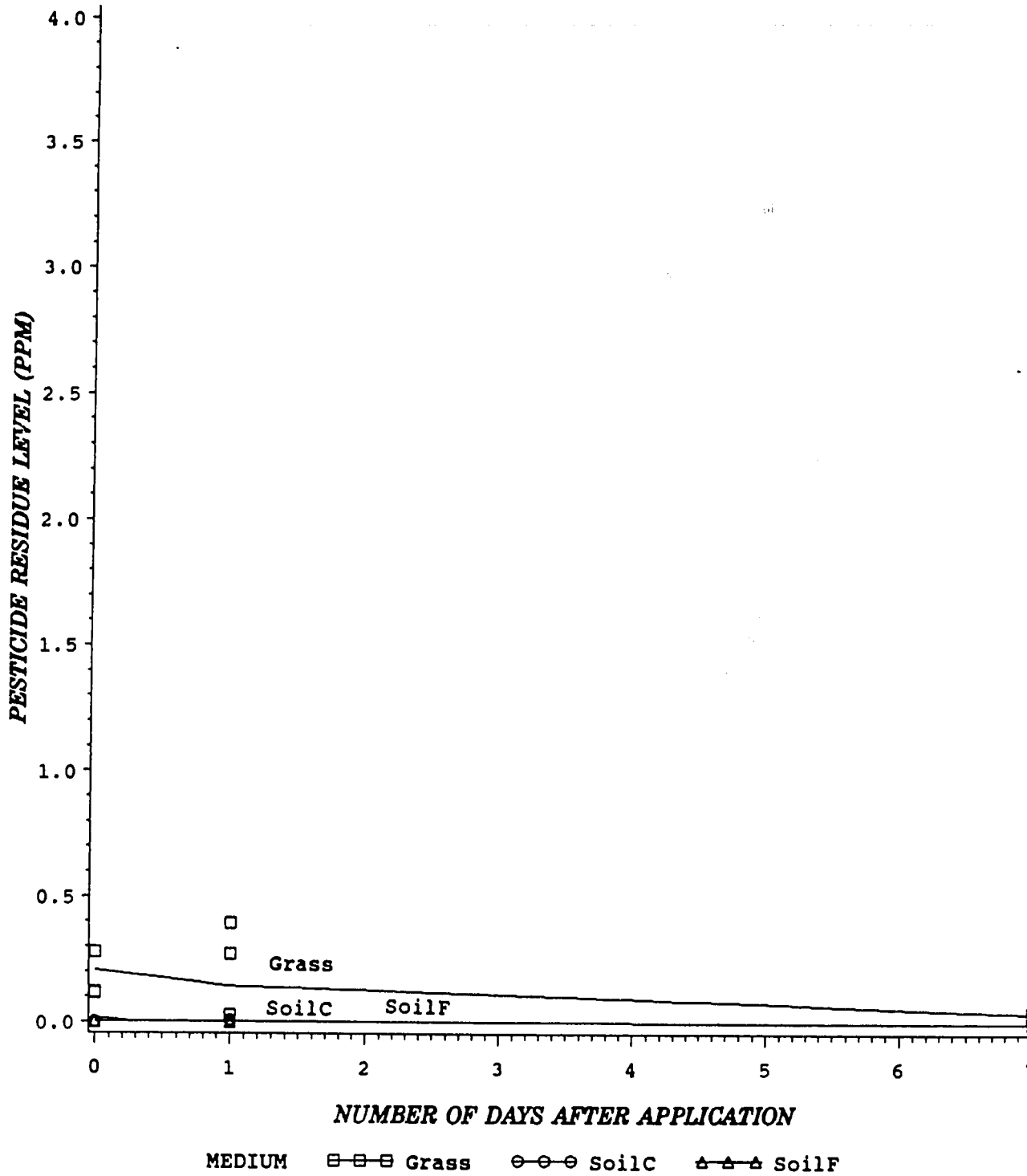


Figure 5-10. Pesticide residue levels in grass and soil (lambda-cyhalothrin).

102

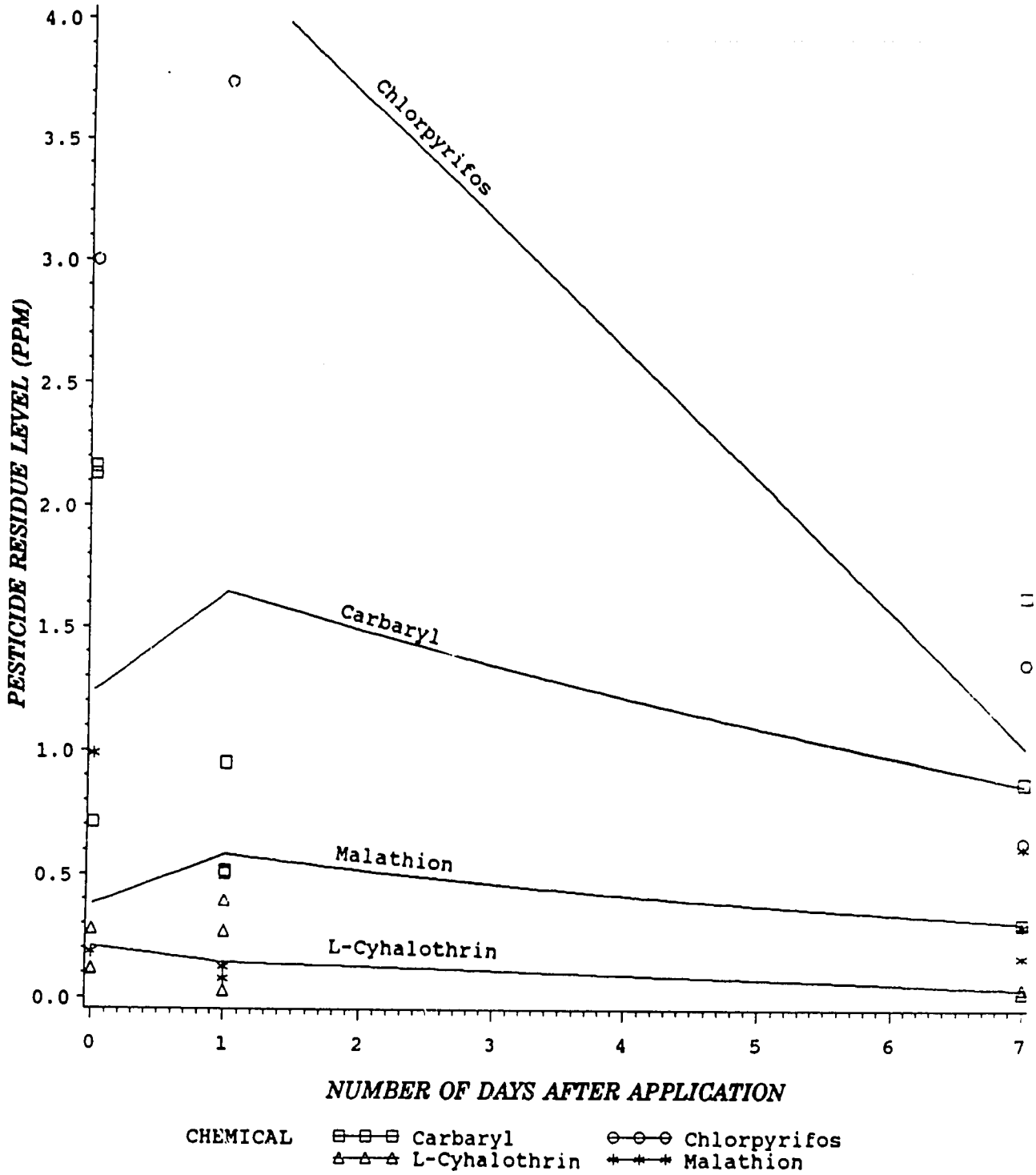


Figure 5-11. Pesticide residue levels in grass.

103

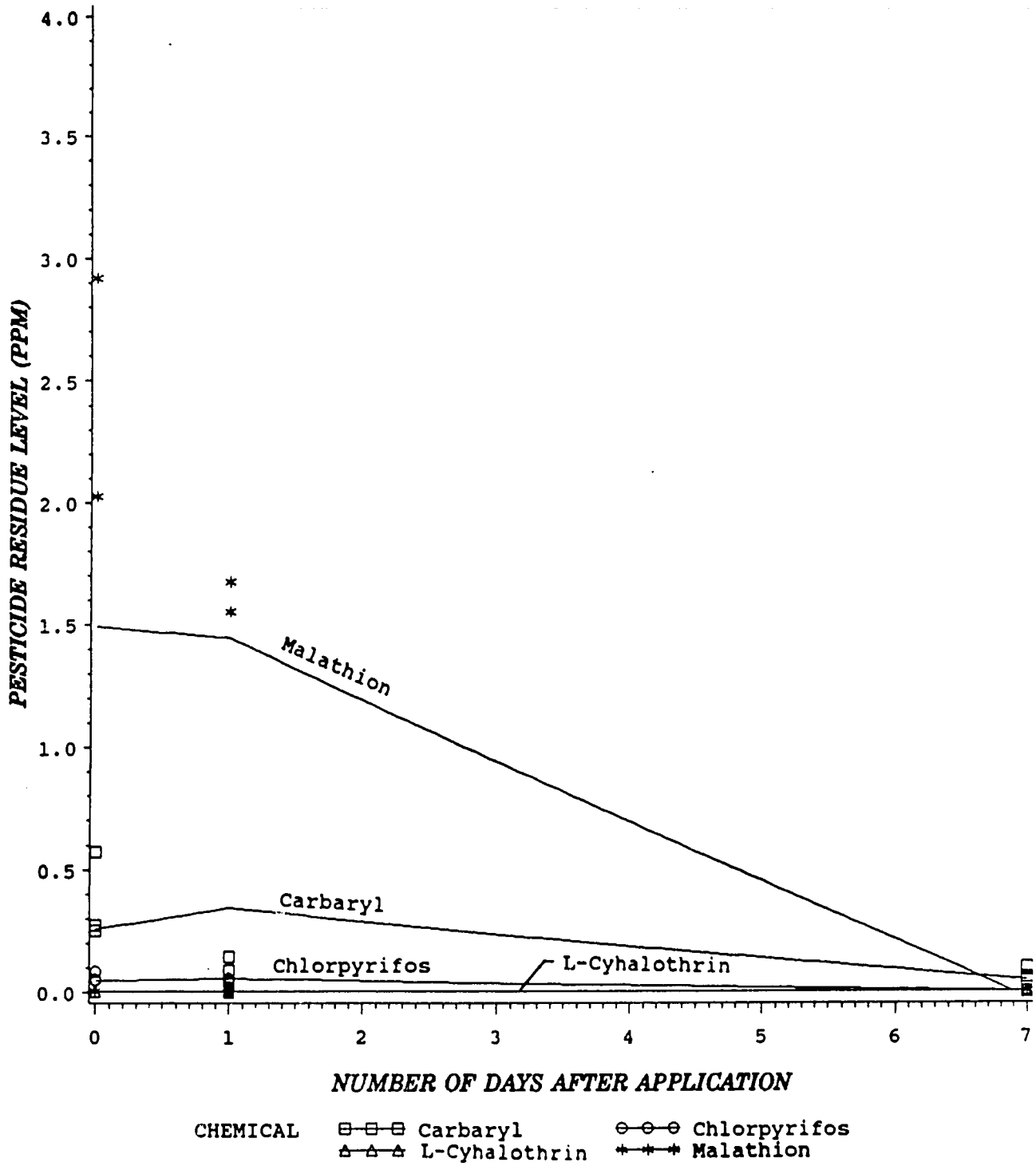


Figure 5-12. Pesticide residue levels in soil.

- 104

levels in grasses at days 0 and 1 were at or above the tolerance limits. The mean chlorpyrifos residue on grass of 4.75 ppm for day 0 and 1 slightly exceeded the tolerance of 4 ppm established for alfalfa. The mean lambda-cyhalotrin residue on grass of 0.20 ppm for day 0 and 1 was higher than the U.S. tolerance of 0.05 ppm currently applied to cottonseed.

These results support the conclusion that single applications of these pesticides on semiarid grasslands of the Sahel pose little hazard to the local population or to the environment. It is recommended, however, that crop harvesting and livestock grazing be restricted for at least 2 days after spraying with chlorpyrifos and possibly lambda-cyhalothrin.

6. CONCLUSIONS

These conclusions are based solely on the results of the Mali field trials.

6.1 EFFICACY

All eight chemicals were shown to be efficacious against the Senegalese grasshopper at the rates applied. Although initial reductions in grasshopper numbers varied from 80 to 99%, in most instances the degrees of control were not statistically different. Apparent differences among the pesticide treatments became greater with increasing time postspray. Carbaryl was the only chemical to show an increase in control over time. The pyrethroids appeared to show the most rapid decline in control. Percent reductions in grasshopper numbers were less in Phase II than in Phase I, especially in crop fields, for three of the four chemicals. Phase II treatment plots contained a wider range of grasshopper species, some of which may have been less sensitive to the applied pesticides. In addition, the organophosphorus compounds were less efficacious in the crop fields than in the grasslands.

The most important result of these efficacy trials is that relatively low rates proved to be effective in reducing grasshopper numbers to acceptable control levels. We recommend that these rates replace the higher rates currently in use, and that research into the use of even lower rates be pursued.

6.2 BENEFICIAL AND NONTARGET INSECTS

Differences among treatments were not distinguishable for most of the insect taxa sampled. Experimentation with several sampling methods indicated that for the fauna studied and the habitat sampled, sweep-netting, malaise-trapping, and transect walks produced too few records for comparative analysis. Pitfall-trapping was effective in capturing adequate numbers of ground-dwelling beetles, and sticky trap collection was adequate for small diptera and hymenoptera. Unfortunately, the variability in these data and the coincidence of declining controls precluded a determination of significant treatment

effects. Although the subjective judgment of the investigators was that the numbers of live insects decreased after application of the pesticides, only in the case of harvester ant colonies were deaths dramatic enough to reveal a significant effect of treatment. While all colonies likely survived, substantial worker ant mortality was observed for the organophosphorus compounds and the carbamates. The pyrethroids did not produce a significant number of deaths. In the Phase II results, numbers of dead ants declined rapidly by the seventh day for all four chemicals.

The difficulty in making an adequate assessment of the adverse impact on nontarget insects cannot be overstated. We recommend that specific sampling procedures be developed for the grasshopper predators and parasites whose ecology has been adequately described. The number of treatment replicates and control samples should be increased so that family-level effects can be distinguished and then related to important species of the same family. Lastly, indicator species (especially important ecosystem-level predators or scavengers) should be designated and thoroughly sampled to determine the precise effects of the pesticide applications.

6.3 ENVIRONMENTAL IMPACT

No dead or moribund reptiles, birds, or mammals were observed during exhaustive searches of all treatment plots. Although most vertebrate taxa were too uncommon to sample effectively, investigators counted over 1500 birds without observing any abnormal behaviors. Two results, reduced bird activity in chlorpyrifos plots and depressed brain cholinesterase levels in carbaryl-exposed birds, point to potentially adverse, although likely transient, effects on the avifauna. However, the residue levels in birds, as in all the environmental substrates, were low relative to known hazardous levels. Indeed, all of the residue measures for malathion and carbaryl were very much below accepted levels. The only cautions that appear to be needed are against same-day or 1-day postspray harvesting or grazing following chlorpyrifos and lambda-cyhalothrin applications. An important result was the demonstration of substantial pesticide breakdown within 7 days. The lack of dramatic acute effects and the evidence of rapid breakdown of the

107

pesticide suggest that single applications of malathion, chlorpyrifos, carbaryl, and lambda-cyhalothrin can be performed safely in grassland or agricultural areas subject to Senegalese grasshopper infestation.

7. REFERENCES

Anderson, D. R., Laake, J. L., Crain, B. R., and K. P. Burnham. 1976. Guidelines for line transect sampling of biological populations. U.S. Fish & Wildlife Service, Office of Biological Services, Utah.

Anonymous, 1987 (Feb.) Africa Bureau, Locust/Grasshopper strategy paper, Agency for International Development, February.

Anonymous, 1987 (Apr.) USAID Request For Proposals to develop and execute a locust/grasshopper pesticide testing program in Africa.

Anonymous, 1987 (May) Technical Proposal - Testing of Pesticides Against African Locusts and Grasshoppers. Dynamac Corporation, Rockville, MD.

Anonymous, 1987 (Jul.) Technical plan for testing pesticides against O. senegalensis for both environmental impact and efficacy in the Republic of Mali. Dynamac Corporation, Rockville, MD.

Batten, Anne, 1969. The Senegalese grasshopper, Oedaleus senegalensis (Krauss) Jr. Appl. Ecol. 6:27-45.

Booth, A. H. 1960. Small mammals of West Africa. Longmans. London.

Cansdale, G. S. 1961. West Africa snakes. Longmans. London.

Cavin, George E. 1986. Evaluation of insecticides for grasshopper control. Sahel Region. Unpublished CICP Report.

Cheke, R. A. et. al. 1980a. Oedaleus senegalensis (Krauss) (Orthoptera: Acrididae: Oedipodinae) An account of the 1977 outbreak in west Africa and notes on eclosion under laboratory conditions. Acrida 9:107-32.

Cheke, Robert A. et. al. 1980b. An ecological study of the egg-pods of Oedaeus senegalensis (Krauss) (Orthoptera:Acrididae) Jr. Nat. Hist. 14:363-71.

Fishpool, L. D. C. and R. A. Cheke, 1983. Protracted eclosion and viability of Oedaleus senegalensis (Krauss) eggs. (Orthoptera:Acridae) Ent. Monthly Magazine. 119:215-9.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley & Sons. New York.

Haltenorth, T and H. Piller 1970. A field guide to the mammals of Africa including Madagascar. Collins London.

Hill, E. F. and W. J. Fleming. 1982. Anticholinesterase poisoning of birds: Field monitoring and diagnosis of acute poisoning. Env. Toxicol. and Chem. 1:27-38.

Huddleston, E. W. et.al., 1987. Comparison of a wind-assisted dispersal technique and aerial application for range caterpillar (Lepidoptera: Saturnidae) management. Jr. Econ. Entomol. 80:226-9.

Jaques, H.E. 1947. How to know the insects. W.C. Brown, Pubuque, Iowa.

Karr, J., Jr. 1981. Surveying birds with mist nets. Avian Biology No. 6:62-67.

Launois, M. 1979. An ecological model for the study of the grasshopper, Oedaleus senegalensis in west Africa. Phil. Trans. R. Soc. London. B. 287:345-55.

McEwen, L. C., DeWeese, L. R., and P. Schladweiler. 1986. Bird predation on cutworms (Lepidoptera: Noctuidae) in wheat fields and chlorpyrifos effects on brain cholinesterase activity. Environ. Entomol. 15:147-151.

Medler, J.T. 1980. Insects of Nigeria -- check list and bibliography. Memoirs of Amer. Entonol. Inst. No. 30. Ann Arbor, Michigan

Onsager, J. A. and J. E. Henry, 1977. A method for estimating density of rangeland grasshoppers in experimental plots. Acrida 6:231-7.

Onsager, Jerome A. 1978. Efficacy of Carbaryl applied to different life stages of rangeland grasshoppers. Jr. Econ. Entomol. 71:269-73.

Otter, James, 1986. Preliminary report. Insecticide trials on grasshoppers in Mali. Unpublished. ICI Report.

Popov, G. 1986. Campagne de lutte contre les sauteriaux (1986) essai des pesticides realize a Nara (Mali) du 8 Aug. - 18 October. Unpublished FAO Report.

Rosenvear, D.R. 1969. The rodents of West Africa. Trustees of the British Museum (Natural History) No. 677.

Serle, W. and G. J. Morel. 1977. A field guide to the birds of West Africa. Collins. London.

Snedecor, George W. 1957. Statistical Methods. The Iowa State College Press, Ames, Iowa. 534pp.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman. San Francisco.

Sountera, Soumana. 1986. Rapport Sur L'essai de chlorpyrisos 24 ULU Sur Sauteriaux au Mali. M.O.A. Operation Protection Semences e t Recoltes (Mimeo. Report)

Southwood, T. R. E. 1978. Ecological methods: with particular reference to insect populations. 2nd edition, University Printing House, Cambridge, 524 pp.

110

Stewart-Oaten, A. and W. W. Murdoch. 1986. Environmental impact assessment: "Pseudoreplication" in time? Ecology 67: 929-940.

TAMS. 1983: Mali land and water resources. Published for the Government of Mali. Tippetts-Abbeπ -McCarthy-Statton.

APPENDIX A

Detailed Observations of Ant Activity and Mortality During the Phase II Trials

APPENDIX A. Detailed Observations of Ant Activity and Mortality During the Phase II Trials

Ant Survey:

Malathion

One day pre-treatment

E-2, Cone size 1.5 m in diameter

No dead ants observed in 1.0 m quadrant; colony active with many ants foraging

E-6, Cone size 1.7 m in diameter

No dead ants observed in 1.0 m quadrant; active colony

E-3, Control, Cone size 1.5 x 1.7 m

No dead ants observed

Colony active and foraging. Another colony observed near crop

transect also actively foraging.

One day post-treatment

E-2, 279 dead ants/m^2 at outer margin of cone. Many dead ants along forage trail. Little activity.

E-6, 310 dead ants/m^2 at margin of cone.

Dead ants along forage trail.

E-3, Control, 3 dead ants/m^2 at margin of cone. Colony active and foraging

Seven day post-treatment

E-2, 103 dead ants/m^2. No colony activity.

E-6, 31 dead ants/m^2 at margin of cone. No activity; no live ants at or near the nest. Heavy rain may have removed dead ants from E-2 and E-3.

E-3, Control, No dead ants/m^2. Ants actively by foraging.

Chlorpyrifos

One day pre-treatment

E-8, Cone size 1.3 m^2 in diameter;

5 dead ants/m^2 at margin of cone. Colony active.

W-4, Cone size 1.4m^2 in diameter;

No dead ants observed. Colony actively foraging

W-5, Control, 1.0 m^2 in diameter. Colony not active but obviously had been earlier in day.

One day post-treatment

E-8, 203 dead ants/m^2; many dead ants beyond the margin of the ant hill.

Many dead ants along the forage trail.

W-4, 400 dead ants/m^2; many dead ants along the forage trails.

W-5, Control, No dead ants/m^2. Colony active but not many ants foraging

Seven day post-treatment

E-8, No dead ants/m^2; dead ants had been removed or wind blown to the grassy margin of the ant hill. Colony appeared weakened with more small workers than observed in pre-treatment survey. Established another m^2 quadrant at colony margin in grass, 65 dead ants at interface with grass. Two other colonies were observed; one at interface with grass and sorghum field was very active with new excavation, and another in sorghum which was also very active.

W-4, One (1) dead ant/m^2; colony not very active, but evidence of new excavation. A new entrance-exit being formed at margin of the cone. Newly dead ants along the forage trail. Newly discovered ant colony at north side of sorghum field, not previously seen, was very active with new excavation. Live and newly dead ants along the forage trail.

W-5, Control, 2 dead ants/m^2; no dead ants observed at colony margin. Colony not very active but much new excavation was noted around the cone.

Lambda-cyhalothrin

One day pre-treatment

E-7, Cone size 1.2 x 1.1 m; No dead ants observed/m^2, colony actively

foraging.

W-3, Cone size 1.0 m^2 in diameter; No dead ants observed/m^2, colony not very active.

W-5, Control, Cone size 1.0m^2 in diameter; No dead ants observed/m^2, colony active.

One day post-treatment

E-7, 48 dead ants/m^2; no live ants observed, dead ants along forage trail.

W-3, 3 dead ants/m^2 and one (1) live ant; Dead ants along forage trail and many dead at interface between grass and bare ground around ant hill. Apparently the wind had blown ants to grassy margin.

W-5, Control, No dead ants observed; Colony actively foraging.

Seven day post-treatment

E-7, One (1) dead ant/m^2; Colony actively foraging on trails. Noted ants foraging on a newly dead grasshopper.

W-3, No dead ants/m^2; A few newly dead ants at the far margin of colony and at interface with grass. Not much activity in this or another colony observed. Evidence of new excavation however.

W-5, Control, No dead ants observed; colony not very active but much new excavation.

<u>Carbaryl</u>

One day pre-treatment

E-4, Cone size 1.6 m^2 in diameter; Active colony with ants on forage trail

W-7, Cone size 1.4 m^2 in diameter; Colony very actively foraging.

E-3, Control, Cone size 1.5 x 1.7 m; Ants actively foraging

One day post-treatment

E-4, 10 dead ants/m^2; Very high wind may have blown dead ants away from quadrant area of colony but none observed. Ants actively foraging on trail.

W-7, 183 dead ants/m^2; Colony actively foraging, and a few dead ants along forage trail.

E-3, Control, No dead ants observed/m^2, ants actively foraging. A second colony actively foraging also.

Seven day post-treatment

E-4, No dead ants/m^2; a few dead ants at far margin of colony area at interface with grass; workers removing dead from entrance of next. This colony was exposed at interface of sorghum and grassland.

W-7, 72 dead ants/m^2; additional dead ants at the margin of colony at interface with grass. These were newly dead, perhaps 24 hours or less. Colony not very active. However, another colony observed in sorghum was very active and no dead ants were observed along 25 m of forage trail.

E-3, Control, No dead ants/m^2.

It appears that the exposure of these colonies may have played a role in the impact of the pesticide.

APPENDIX B

Species List of Birds Observed Neat the Test Site, Nara, Mali

APPENDIX B. Bird List
(observed in region surounding Nara, Mali, West Africa)

ARDEIDAE

CATTLE EGRET *Ardeola ibis*
GREEN-BACKED HERON *Butorides striatus*
GREAT WHITE EGRET *Egretta alba*
GOLIATH HERON *Ardea goliath*

ANATIDAE

EGYPTIAN GOOSE *Alopochen aegyptiaca*
SPUR-WINGED GOOSE *Plectropterus gambensis*

ACCIPITRIDAE

NUBIAN VULTURE *Aegypius trachelictus*
BROWN HARRIER EAGLE *Circaetus cinereus*
GABAR GOSHAWK *Melierax gabar*
GRASSHOPPER BUZZARD *Butastur rufipennis*
RED-TAILED BUZZARD *Buteo auguralis*
BLACK KITE *Milvus migrans*
BLACK-SHOULDERED KITE *Elanus caeruleus*
SWALLOW-TAILED KITE *Elanus riocourii*

FALCONIDAE

LANNER FALCON *Falco biarmicus*

PHASIANIDAE

DOUBLED-SPURRED FRANCOLIN *Francolinus bicalcaratus*

OTITIDAE

BLACK-BELLIED BUSTARD *Eupodotis melanogaster*

BURHINIDAE

SENEGAL THICK-KNEE *Burhinus senegalensis*
SPOTTED THICK-KNEE *Burhinus capensis*

CHARADRIIDAE

BLACK-HEADED PLOVER *Vanellus tectus*
FORBES' BANDED PLOVER *Charadrius forbesi*
BLACK-WINGED STILT *Himantopus himantopus*

COLUMBIDAE

SPECKLED PIGEON *Columba guinea*
RED-EYED DOVE *Streptopelia semitorquata*
MOURNING DOVE *Streptopelia decipiens*
VINACEOUS DOVE *Streptopelia vinacea*
LONG-TAILED DOVE *Oena capensis*
RED-BILLED WOOD-DOVE *Turtur afer*

CUCULIDAE

LEVAILLANT'S CUCKOO *Clamator levaillantii*

STRIGIDAE

BARN OWL *Tyto alba*

CAPRIMULGIDAE

STANDARD-WING NIGHTJAR *Macrodipteryx longipennis*

APODIDAE

EUROPEAN SWIFT *Apus apus*
WHITE-RUMPED SWIFT *Apus caffer*
LITTLE AFRICAN SWIFT *Apus affinis*

ALCEDINIDAE

MALACHITE KINGFISHER *Alcedo cristata*
SENEGAL KINGFISHER *Halcyon senegalensis*

MEROPIDAE

WHITE-THROATED BEEEATER *Merops albicollis*

CORACIIDAE

ABYSSINIAN ROLLER *Coracias abyssinica*
BLUE-BELLIED ROLLER *Coracius cyanogaster*

UPUPIDAE

HOOPOE *Upupa epops*

BUCEROTIDAE

GREY HORNBILL *Tockus nasutus*
RED-BEAKED HORNBILL *Tockus erythrorhynchus*

PICIDAE

CARDINAL WOODPECKER *Dendropicos fuscescens*

ALAUDIDAE

SINGING BUSH-LARK *Mirafra javanica*
RUFOUS-NAPED LARK *Mirafra africana*
CHESTNUT-BACKED FINCH LARK *Eremopterix leucotis*

HIRUNDINIDAE

EUROPEAN SWALLOW *Hirundo rustica*
FANTI ROUGH-WINGED SWALLOW *Psalidoprocne obscura*

LANIIDAE

FISCAL SHRIKE *Lanius collaris*
WOODCHAT SHRIKE *Lanius senator*

STURNIDAE

PURPLE GLOSSY STARLING *Lamprotornis purpureus*
LONG-TAILED GLOSSY STARLING *Lamprotornis caudatus*
CHESTNUT-BELLIED STARLING *Spreo pulcher*

CORVIDAE

PIED CROW *Corvus albus*
BROWN-NECKED RAVEN *Corvus ruficollis*

TURDIDAE

RUFOUS SCRUB-ROBIN *Cercotrichas galactotes*

SYLVIIDAE

MELODIOUS WARBLER *Hippolais polyglotta*
EUROPEAN WHITETHROAT *Sylvia communis*
DESERT FANTAIL WARBLER *Cisticola aridula*
GREY-BACKED CAMAROPTERA *Camaroptera brachyura*

EMBERIZIDAE

ROCK BUNTING *Emberiza tahapisi*

FRINGILLIDAE

GREY CANARY *Serinus leucopygius*

PLOCEIDAE

SLENDER-BILLED WEAVER *Ploceus luteolus*
VITELLINE MASKED WEAVER *Ploceus velatus*
VILLAGE WEAVER *Ploceus cucullatus*
BLACK-FACED DIOCH *Quelea quelea*
YELLOW-CROWNED BISHOP *Euplectes afer*
YELLOW-MANTLED WHYDAH *Euplectes macrourus*
BUFFALO WEAVER *Bubalornis albirostris*
SPARROW WEAVER *Plocepasser superciliosus*
GREY-HEADED SPARROW *Passer griseus*
BUSH-SPARROW *Petronia dentata*
PIN-TAILED WHYDAH *Vidua macroura*
BROAD-TAILED PARADISE WHYDAH *Vidua orientalis*

ESTRILDIDAE

CUT-THROAT WEAVER *Amadina fasciata*
BLACK-RUMPED WAXBILL *Estrilda troglodytes*

APPENDIX F

Analysis of Variance (ANOVA) Tables for Efficacy Results

APPENDIX F. Analysis of Variance (ANOVA) Tables for Efficacy Results

ANOVA
Phase I - m^2 Grasshopper Counts

-1 Day (Pretreatment)

Source	df	SS	MS	F	Levels for significant F
Treatments	8	448.2	56.0	1.50 NS	.05 = 2.40 *
Error	22	823.5	37.4		.01 = 3.45 **
Total	30	1,271.7			

+1 Day (Post Treatment)

Source	df	SS	MS	F
Treatments	8	243.1	30.4	7.25 **
Error	22	92.2	4.2	
Total	30	335.3		

+3 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	8	168.4	21.1	4.97 **
Error	22	93.3	4.2	
Total	30	261.7		

+7 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	8	72.9	9.1	1.49 NS
Error	22	134.5	6.1	
Total	30	207.4		

+14 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	8	68.3	8.5	1.24 NS
Error	22	151.7	6.9	
Total	30	220.0		

ANOVA
Phase I - 400 m^2 Transect Grasshopper Counts

-1 Day (Pretreatment)

Source	df	SS	MS	F	Levels for significant F
Treatments	8	84,104.5	10,513.1	0.82 NS	.05 = 2.40 *
Error	22	282,198.3	12,827.2		.01 = 3.45 **
Total	30	366,302.8			

+1 Day (Post Treatment)

Source	df	SS	MS	F
Treatments	8	81,793.0	10,224.1	3.03 *
Error	22	74,216.5	3,373.5	
Total	30	156,009.5		

+3 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	8	61,597.2	7,699.6	2.13 NS
Error	22	79,678.8	3,621.7	
Total	30	141,276.0		

+7 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	8	27,088.5	3,386.1	1.81
.05 = 2.40				
Error	22	41,087.0	1,867.6	
Total	30	68,175.5		

+14 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	8	19,168.3	2,396.0	1.46
.05 = 2.40				
Error	22	36,209.7	1,645.9	
Total	30	55,378.0		

ANOVA
Phase I - % Reduction Based On 400 m^2 Transect Grasshopper Counts

+1 Day (Post Treatment)

Source	df	SS	MS	F	Levels for significant F
Treatments	7	1,046.4	149.5	1.44 NS	.05 = 2.54 *
Error	19	1,967.1	103.5		.01 = 3.77 **
Total	26	3,013.5			

+3 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	7	3,775.6	539.4	4.32 **
Error	19	2,372.6	124.9	
Total	26	6,148.2		

+7 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	7	4,547.2	649.6	1.10 NS
Error	19	11,218.4	590.4	
Total	26	15,765.6		

+14 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	7	5,603.9	800.6	1.05 NS
Error	19	14,487.8	762.5	
Total	26	20,091.7		

ANOVA

Phase II - % Reduction Based On 400 m^2 Transect Grasshopper Counts, Pasture

+1 Day (Post Treatment)

Source	df	SS	MS	F	Levels for significant F
Treatments	3	0.3513	0.1171	5.22 *	.05 = 4.07 *
Error	8	0.1795	0.0224		.01 = 7.59 **
Total	11	0.5308			

+3 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	3	0.0558	0.0186	1.66 NS
Error	8	0.0894	0.0112	
Total	11	0.1452		

+7 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	3	0.0144	0.0048	0.20 NS
Error	8	0.1871	0.0234	
Total	11	0.2015		

ANOVA
Phase II - Transect Grasshopper Counts, Pasture

-1,2 Days (Pretreatment)

Source	df	SS	MS	F	Levels for significant F
Treatments	4	10,903.6	2,725.9	0.89 NS	.05 = 3.48 *
Error	10	30,646.0	3,064.6		.01 = 5.99 **
Total	14	41,549.6			

+1 Day (Post Treatment)

Source	df	SS	MS	F
Treatments	4	37,389.6	9,347.4	6.92 **
Error	10	13,505.3	1,350.5	
Total	14	50,894.9		

+3 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	4	10,660.4	2665.1	36.8 **
Error	10	724.0	72.4	
Total	14	11,384.4		

+7 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	4	13,716.9	3429.2	11.49 **
Error	10	2,984.0	298.4	
Total	14	16,700.9		

ANOVA

Phase II - % Reduction Based On 400 m^2 Transect Grasshopper Counts, Crops

+1 Day (Post Treatment)

Source	df	SS	MS	F	Levels for significant F
Treatments	3	0.4427	0.1476	4.99 *	.05 = 4.07*
Error	8	0.2364	0.0295		.01 = 7.59**
Total	11	0.6791			

+3 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	3	0.3696	0.1232	2.16 NS
Error	8	0.4573	0.0572	
Total	11	0.8269		

+7 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	3	0.0705	0.0235	1.01 NS
Error	8	0.1852	0.0232	
Total	11	0.2557		

ANOVA
Phase II - Transect Grasshopper Counts, Crops

-1,2 Days (Pretreatment)

Source	df	SS	MS	F	Levels for significant F
Treatments	4	4,432.3	1,108.1	1.26 NS	.05 = 3.48*
Error	10	8,786.7	878.7		.01 = 5.99**
Total	14	13,219.0			

+1 Day (Post Treatment)

Source	df	SS	MS	F
Treatments	4	4,485.6	1,121.4	12.36 **
Error	10	907.3	90.7	
Total	14	5,392.9		

+3 Days (Post Treatment)

Source	df	SS	MS	F
Treatments	4	4,241.7	1,060.4	5.09 *
Error	10	2,082.7	208.3	
Total	14	6,324.4		

+7 Days (Post Treatment)

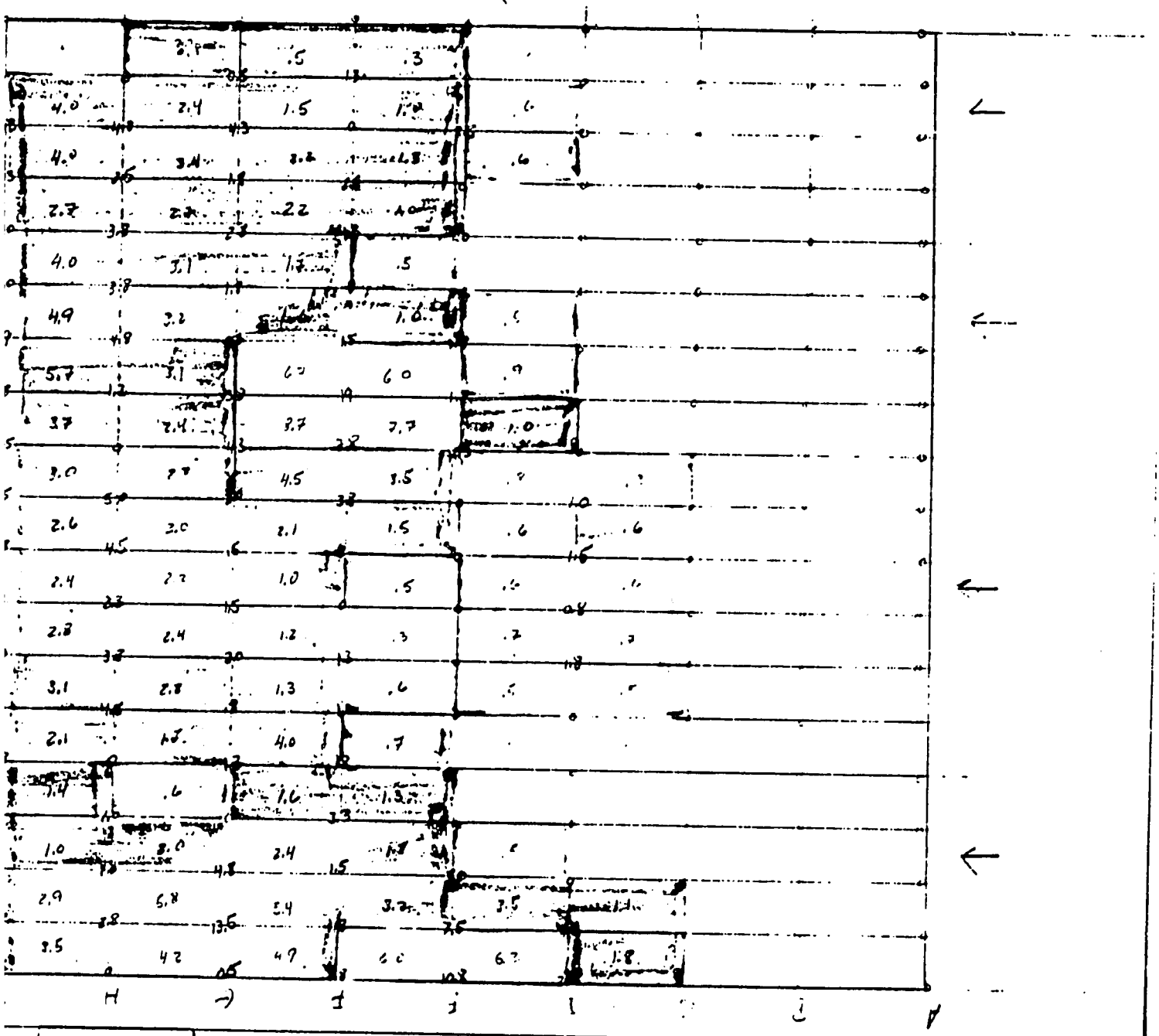
Source	df	SS	MS	F
Treatments	4	1,433.1	358.3	2.28 NS
Error	10	1,570.7	157.1	
Total	14	3,003.8		

APPENDIX G

Detailed Analysis of the Pesticide Deposition Pattern Using 200 Spray Cards on a 4-ha Grid

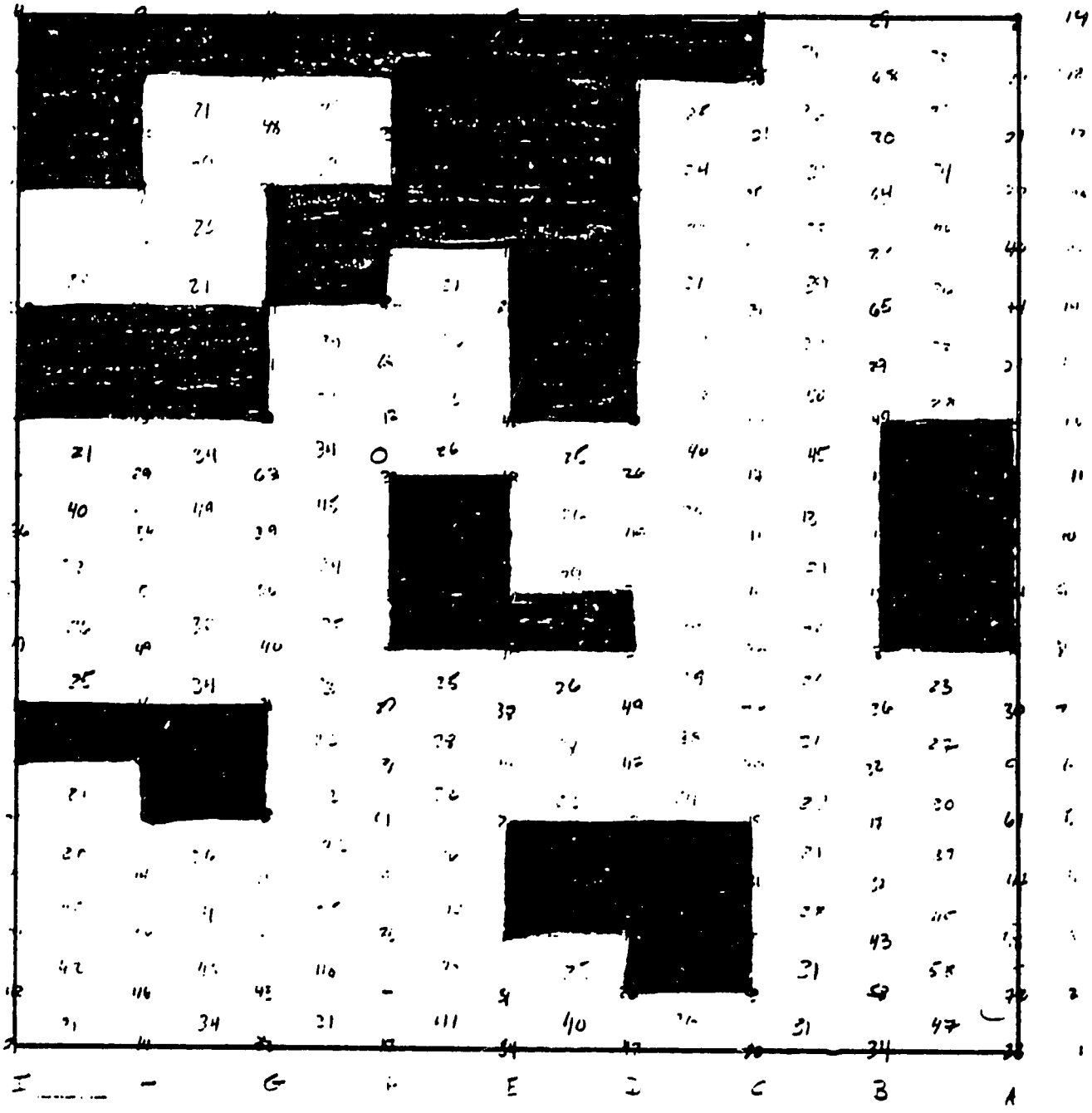
Appendix G. Detailed analysis of the pesticide deposition pattern using 200 spray cards on a 4 ha grid.

Figure G1. Deposition pattern on a 200 spray card grid of the original (unmodified) application procedure.



0	N
[illegible]	Droplet density distribution of malathion applied 0.8 L/Ha with 50 M swaths using 8 Micronair. All spray's adjusted for 100µ Pump for brake released immediately prior to beginning of plot. Plane height 3 M; speed 140 mph. 2-Sept.-1987; 0900 H, 88°F; 55% RH, winds west 5 mph.
6-10	
[illegible]	
21-40	

Figure G2. Deposition pattern on a 200 spraycard grid of the modified application procedure. 3-IX-87



0

6-10

21-40

Droplet density distribution of distribution applied at 0.8L/ha with 40M swath using 8 Micronair AU5000's adjusted for 100µ. Spray lever released 50M before edge of plot. Boom height 3M; speed 140 km/h 3 Sept. 1987; 07:45 h; 56°F, 70% RH, winds 8 km/h from west.

132

APPENDIX I

Species List and Plates of Insects Collected Near the Test Site, Nara, Mali

APPENDIX I. Key to Insects Collected in Nara, Mali, West Africa
August 6 - September 14, 1987

Plate 1

A. Trox sp.
B. Trox sp.
C. Trox sp.
D. Copris sp.
E. Ceroctis sp.
F. Cylindrothorax sp.
G. Mylabris bifasciata
H. Psalydolyta vestita
I. Coryna argentata
J. Cylindrothorax sp.
K. Cylindrothorax sp.
L. Ceroctis sp.
M. Mesostenopa sp.
N. Sepidium sp.
O. Zophosis quadrilineata
P. Zophosis sp.
Q. Erodius sp.
R. Diodontes sp.
S. Pimelia senegalensis
T. Pimelia sp.
U. Oenera hispidum

A-D Coleoptera: Scarabaeidae
E-L Coleoptera: Meloidae
M-U Coleoptera: Tenebrionidae

Plate 2

A. Harpalinae
B. Calosoma senegalensis
C. Haplotrachelus sp.
D. Graphipterus obsloletus
E. Scolia sp.
F. Timulla sp.
G.
H.
I.
J.
K.
L.
M. Anthrax sp.
N. Exoprosopa notabilis
O. Exoprosopa sp.
P. Systoecus sp.
Q.
R.
S.
T.
U.
V.

A-D Coleoptera: Carabidae
E Hymenoptera: Scoliidae
F Hymenoptera: Mutillidae
G-L Diptera: Asilidae
M-S Diptera: Bombyliidae
T-V Diptera:

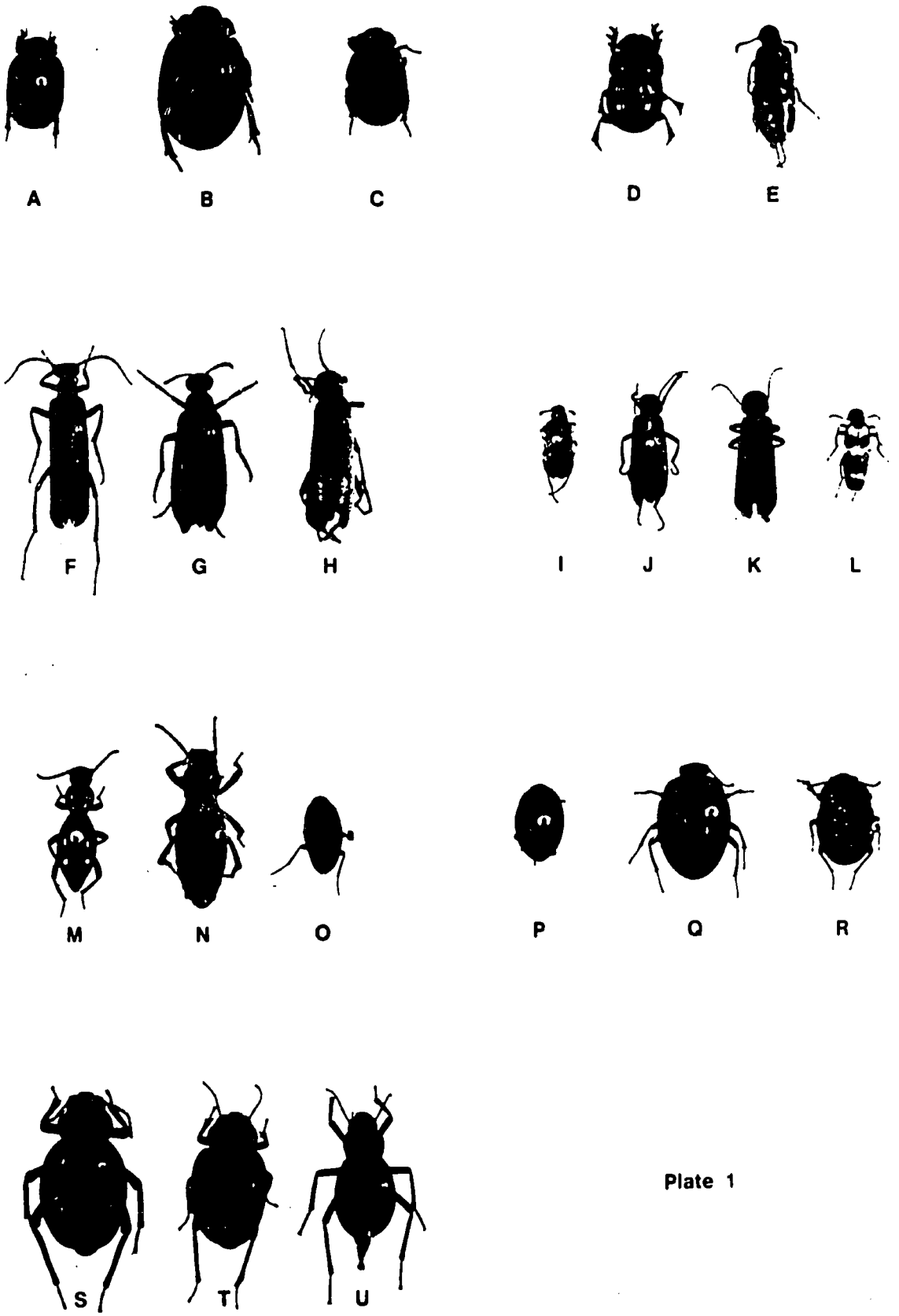
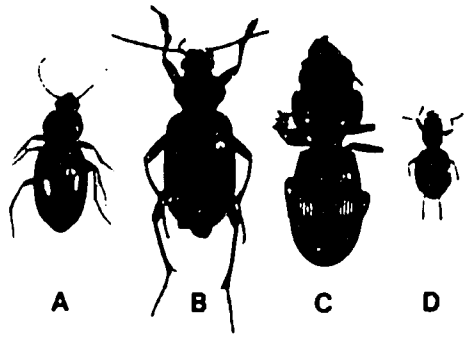
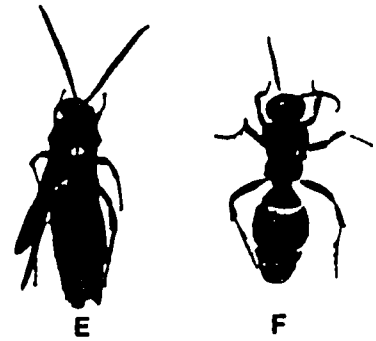
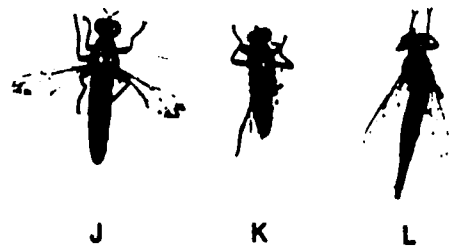
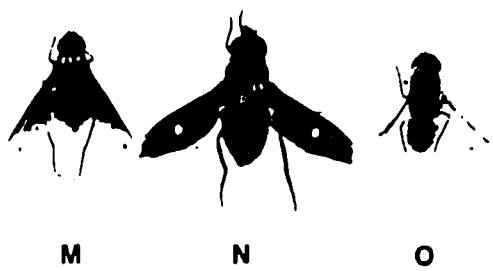


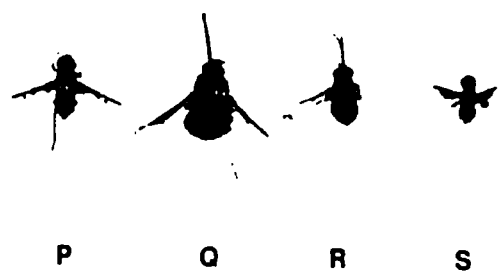
Plate 1











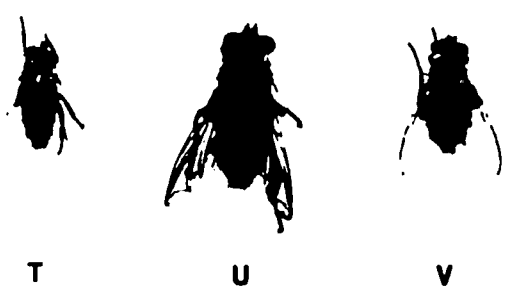
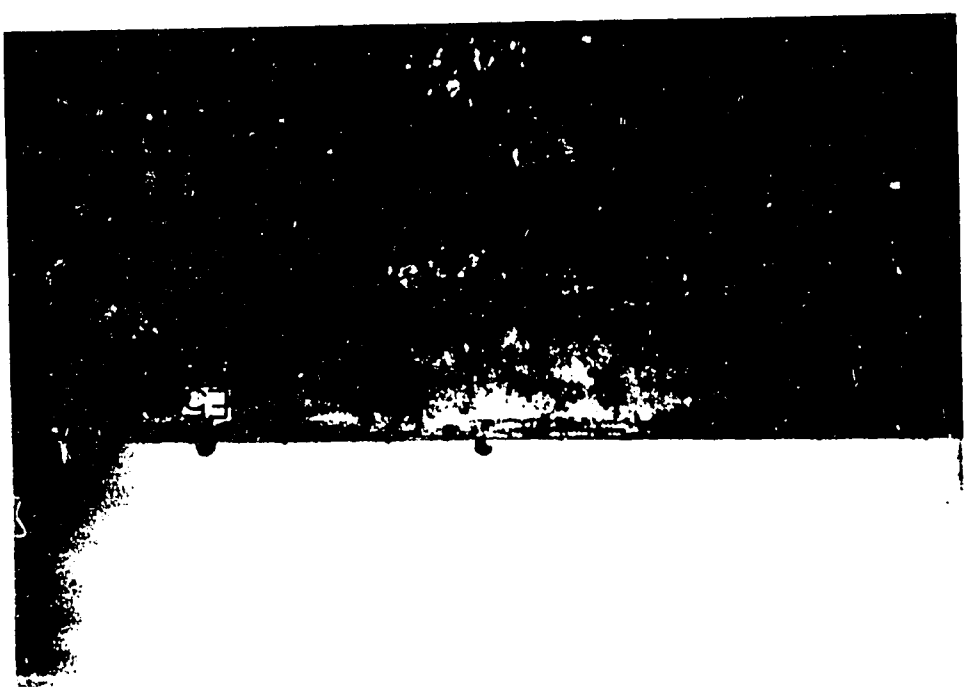


Plate 2

APPENDIX L

Photographs of Each 100-ha Plot Used in the Environmental Trials

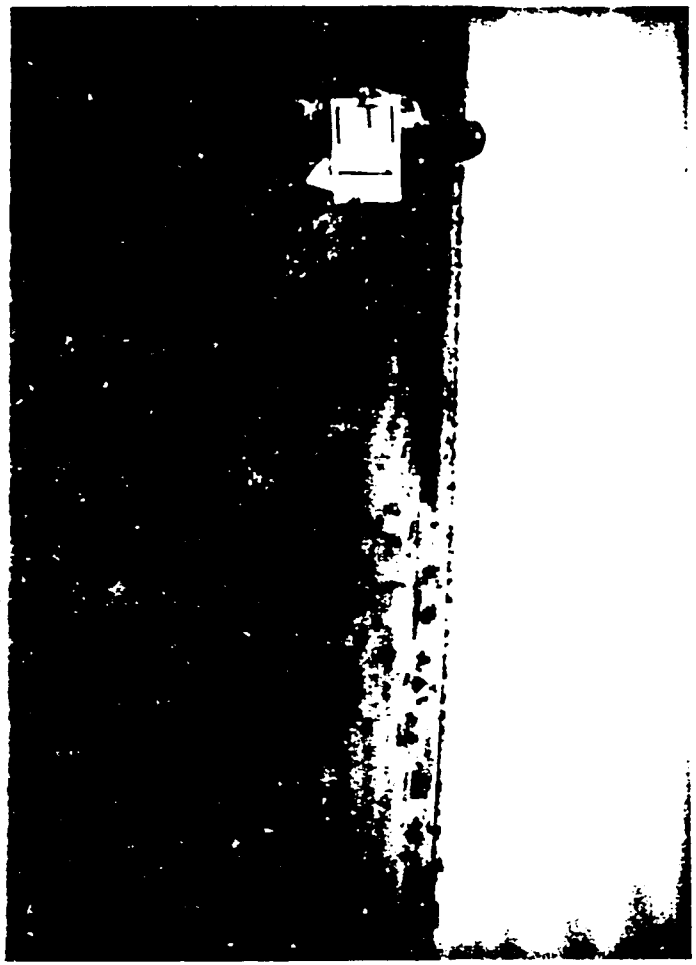


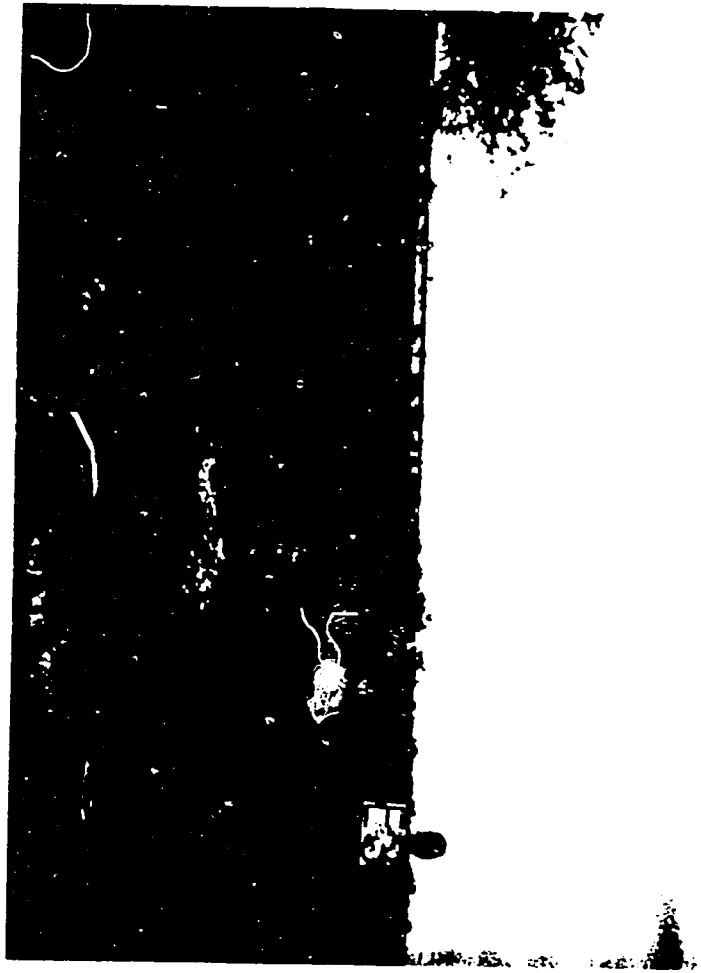
M2

M7

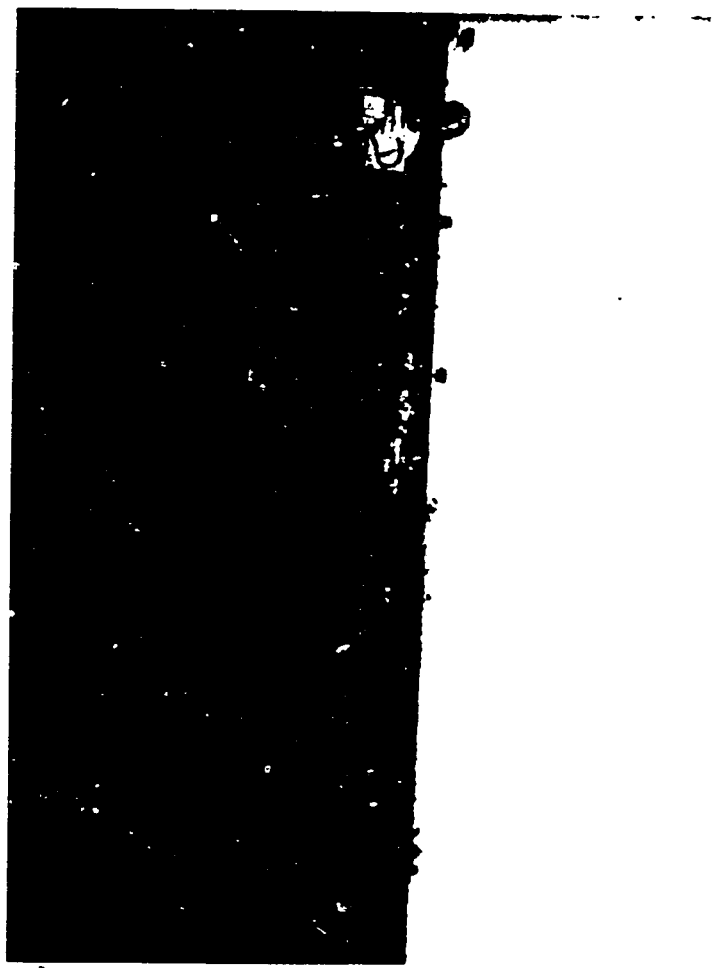
M4

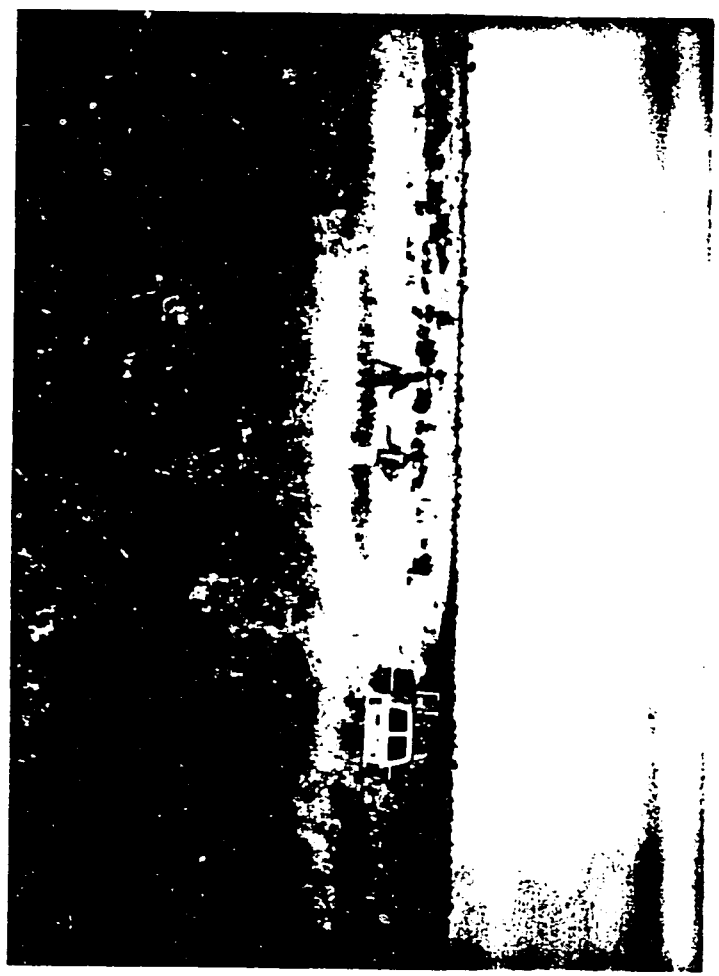
Best Available Document



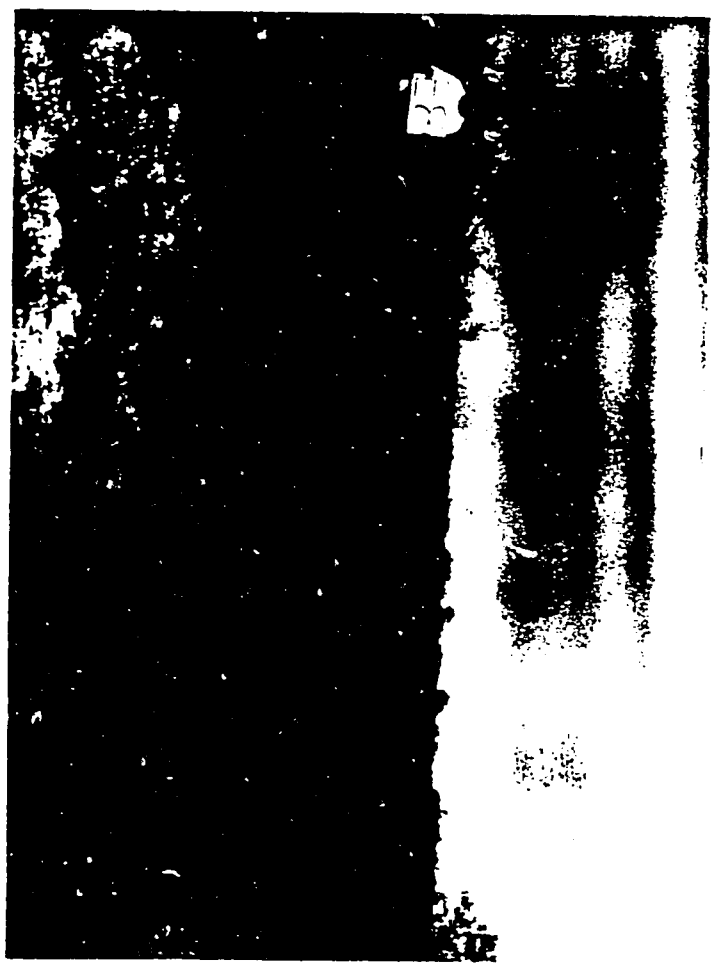


Best Available Document





Best Available Document



APPENDIX P

Plant Species Identifications Made in the Floral Analysis of Phase II Plots

APPENDIX P. Plant Species Identifications Made in the Floral Analysis of Phase II Plots

E1

Grassy stratum
Aristida mutabilis
Eragrostis tremula
Polycarpea linearifolia
Diheteropogon amplectens
Alysicarpus zeyheri
Alysicarpus ovalifolius

Woody stratum
Cobretum ghaselense
Comiphora africana
Guiera senegalensis

E2

Woody stratum
Combretum ghasalense
Guiera senegalensis
Commiphora africana

Grassy stratum

E2-1
Aristida mutabilis
Schoenefeldia gracilis
Polycarpea spp.
Borreria sp.
Diheteropogon sp.
Cassia mimosoides
Polycarpea linearifolia

E2-2
Sorghum guinecensea (sorghum)
Pennisetum typhoides (millet)
Colocynthis vulgaris
Ipomoea dichroa
Euphorbia prostrata
Sesamum alatum (germinating)
Phyllanthus pentandrus
Eragrostis tremula

E3

Woody stratum
Combretum ghasalense
Accacia spp

Grassy stratum

E3-1
Eragrostis tremula
Schoenefeldia gracilis
Cenchrus bliflorus
Aristida mutabilis
Borreria chaetocephala
Borreria radiata

E3-2
Pennisetum typhoides (millet)
Sorghum guinecensea (sorghum)

E4 Grassy stratum
Aristida mutabilis
Schoenefeldia gracilis
Eragrostis tremula
Dactyloctenium aegyptium
Chloris prieurii
Brachiaria xantholenca
Alysicarpus zeyheri
Zornia glochidiata

Woody stratum
Cobretum ghasalense
Guiera senegalensis

E5 Grassy stratum
E5-1 Eragrostis tremula
Polycarpea linearifolia
Rogeria adenophylla

E5-2 Eragrostis tremula
Mitacarpus scaber
Ipomea dichroa
Phyllanthus pentandrus
Borreria radiata

E6 Grassy stratum
E6-1 Eragrostis tremula
Striga hermontheca

E6-2 Pennisetum typhoides (millet)
Sorghum guinecensea (sorghum)
Monechma ciliatum
Phyllanthus pentandrus
Ipomoea dichroa
Mitracarpus scaber
Cucumus melo var agrestis

E7 Woody stratum
Guiera senegalensis
Pterocarpus lucens
Sterculia setigera

Grassy stratum
E7-1 Ctenium elegans
Diheteropogon hageurupii
Zornia glochidiata
Polycarpea linearifolia
Cassia mimosoides

E7-2 Eragrostis tremula
Polycarpea linearifolia
Schoenefeldia gracilis
Pennisetum typhoides (millet)
Sorghum guinecensea (sorghum)

E8 <u>Woody stratum</u>
Guiera senegalensis (80%)
Combretum ghasalense (20%)

<u>Grassy stratum</u>

E8-1 Brachiaria xantholenca
Eragrosis temula
Aristida mutabilis
Striga hermontheca
Polycarpea linearifolia
Polycarpea corymbosa var sub-linearifolia
Borreria radiata
Schoenefeldia gracilis
Ctenium elegans

E8-2 Ctenium elegans
Borreria radiata
Cassia mimosoides
Aristida stipoides
Striga hermontheca
Eragrostis tremula
Polycarpea linearifolia

E8-3 Aristida mutabilis
Schoenefeldia gracilis
Polycarpea linearifolia

E8-4 Zornia glochidiata
Aristida mutabilis
Aristida sp.

E8-5 Borreria sp.
Aristida mutabilis
Ctenium elegans
Brachiaria xantholeuca
Chloris pilosa
Chloris prieurii

E8-6 Zornia glochidiata
Schoenefeldia gracilis
Eragrostis tremula
Brachiaria xantholeuca
Panicum leatum

E8-7 Zornia glochidiata
Eragrostis tremula

W1 Grassy stratum
Aristida mutabilis (80%)
Combretum ghasalens
Guiera senegalensis
Commiphora africana

W1-1 Schoenefeldia gracilis
Polycarpea linearifolia
Striga aspera

W1-2 Sorghum guinecensea (sorghum)
Pennisetum typhoides (millet)
Ipomoea dichroa
Ipomcea pes-tigridis
Phyllanthus pentandrus
Commelina forskalei
Eragrostis tremula
Digitaria adscendens

W2 Grassy stratum
W2-1 Ergrostis tremula

W2-2 Sorghum guinecensea (sorghum)
Sorghum cernuum dura (sorghum)
Sesbania sesban
Eragrostis tremula
Ipomoea pes-tigridis

W3 Grassy stratum
Schoenefeldia gracilis
Aristida mutabilis
Schizachyrium sanguineum
Polycarpea spp.
Zornia glochidiata

Woody stratum
Sclerocarya birrea
Combretum ghasalense
Sterculia setigera
Guiera senegalensis

Grassy stratum
W4 W4-1 Pennisetum typhoides (millet)
sorghum guinecensea (sorghum)
Pancraticum trianthum
Eragrostis tremula
mitacarpus scaber

W4-2 Aristida mutabilis
Ctenium elegans
Borreria sp.

W4-3-1 Eragrostis tremula
Striga hermonthec
Tephrosia spp.
Indigofera spp.
Polycarpea linearifolia

W4-3-2 Sorghum guinecensea (sorghum)
Pennisetum typhoides (millet)
Pancrathium trianthum
Eragrostic tremula
Mitracarpus scaber

W5 <u>Grassy stratum</u>

W5-1 Cenchrus bifloris
Eragrostis tremula
Elionurus elegans
Borreria sp.
Polycarpea linearifolia
Striga hermontheca
Sesbania sesban
Cassia mimosoides
Zornia glochidiata
Pennisetum pedicellatum

W5-3 Sorghum guinecensea (sorghum)
Mitracarpus scaber
Citryllus colocynthus (watermelon)
Digitaria adscendens

W5-4 Sesbania sesban
Cyperus rotundus

W6 W6-1 <u>Grassy stratum</u>
Cenchrus biflorus
Schoenefeldia gracilis
Alysicarpus zeyheri
Dicoma tomentosa
Borreria stachydea
Indigofera sp.
Eragrostis tremula
Impomoea kotschyana
Stylochiton warnecki
Impomoea dichroa
Commelina forskalei
Cucumus melovariete agrestis
Sesbania sesban

<u>Woody stratum</u>
Combretum ghasalense
Guiera senegalensis
Acacia seyal

W6-2 Grassy stratum
Schoenefeldia gracilis
Cenchrus biflorus
Schizachyrium sanguineum
Borreria radiata
Aristida mutabilis
Cassia mimosoides
Alysicarpus zeyheri
Walteria indica

Woody stratum
Combretum ghasalense
Guiera senegalensis

W6-3 Grassy stratum
Sorghum guinecensea (sorghum)
Ipomoea dichroa
Kohautia gonfusa
Eragrostis tremula
Borreria radiata
Mollugo nudicaulis
Monechma ciliatum
Sesbania sesban
Pancrathium trianthum

W7 Grassy stratum
Schoenefeldia gracilis
Eragrostis tremula
Zornia glochidiata
Borreria radiata

Woody stratum
Acacia raddiana savi
Balanites aegyptiaca
Banhinia refescens

Crops
Pennisetum typhoides (millet)
sorghum vulgare (sorghum)
Hibiscus esculentus (okra)
Indiagofera tinctoria (indigo)

APPENDIX R

Raw Data on Grasshopper Counts in Phases I and II

APPENDIX R. Raw Data on Grasshopper Counts in Phases I and II

Table R1. Grasshopper counts, raw data, Phase I , Nara, Mali, West Africa, 1987.

	3 m^2 Counts					400 m^2 Counts				
Trt. #[1]	P	+1	+3	+7	+14	P	+1	+3	+7	+14
1	10	1	0	1	6	223	3	14	16	33
	27	0	1	2	2	526	0	12	68	50
	9	0	0	1	1	116	0	6	10	20
	26	0	0	4	4	227	4	0	66	109
2	16	1	3	4	6	274	9	40	39	38
	2	0	0	0	5	39	8	1	41	49
	8	0	0	0	1	59	13	1	1	19
	13	0	2	2	5	135	28	49	33	20
3	4	0	0	1	1	35	3	4	5	10
	18	1	0	3	2	256	9	17	58	16
	14	2	2	1	4	318	15	23	36	118
	--	--	--	--	--	--	--	--	--	--
4	12	1	0	4	2	175	18	16	39	36
	9	2	0	2	2	96	18	9	22	16
	9	4	5	2	2	89	22	20	12	16
	15	5	5	1	3	243	14	26	15	32
5	--	--	--	--	--	--	--	--	--	--
	4	0	4	7	5	139	8	59	100	119
	14	3	6	4	4	169	26	63	41	46
	9	2	4	2	2	109	22	22	15	38
6	10	0	2	4	3	123	11	52	55	53
	6	0	2	3	2	118	9	30	42	59
	6	3	2	1	4	49	22	26	34	28
	--	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--
	4	1	0	2	1	140	25	11	11	37
	1	0	1	0	0	110	9	12	10	26
	11	3	2	4	1	129	21	13	13	19
8	--	--	--	--	--	--	--	--	--	--
	9	4	4	2	4	172	26	25	16	55
	1	2	3	2	3	89	29	41	52	82
	7	2	0	2	1	128	4	13	14	44
9	11	7	4	2	0	168	79	27	32	68
	23	13	12	13	14	433	400	382	228	92
	7	4	5	8	7	100	87	120	169	218
	11	13	10	2	4	56	99	75	27	46

-- = missing data.

[1]1=Malathion, 2=Fenitrothion, 3=Diazinon, 4=Chlorpyrifos, 5=Lambda-cyhalothrin, 6=Tralomethrin, 7=Carbaryl, 8=Bendiocarb, and 9=Untreated.

Table R2.Grasshopper counts, raw data, Phase II, Nara, Mali, West Africa, 1987.

Trt. #[1]	Crop Counts[2] P	+1	+3	+7	Pasture Counts[2] P	+1	+3	+7
1	31	4	1	1	225	10	7	4
	125	24	37	26	148	27	15	41
	36	40	40	19	122	13	31	21
2	5	2	3	1	57	22	10	6
	30	10	9	7	141	25	26	23
	39	8	8	6	151	13	15	35
3	19	1	0	2	92	0	3	11
	19	0	2	0	118	1	10	24
	85	1	11	14	138	7	11	42
4	25	8	4	4	51	22	7	3
	42	8	2	5	99	30	24	24
	53	7	2	7	100	14	16	26
5	45	49	39	15	242	230	75	115
	65	59	28	18	101	112	89	71
	70	38	72	57	69	75	78	105

[1]1=Malathion, 2=Chlorpyrifos, 3=Lambda-cyhalothrin, 4=Carbaryl, and 9=Untreated.
[2]400 m^2.

APPENDIX S

Species List of Mammals, Reptiles, and Amphibians Observed Near the Test Site, Nara, Mali

APPENDIX S. Species List of Mammals, Reptiles, and Amphibians Observed Near the Test Site, Nara, Mali

Common name	Scientific name
MAMMALS	
Common genet	*Genetta genetta*
Western ground squirrel	*Euxerus erythropus*
Whyte's hare	*Lepus whytei*
Four-toed hedgehog	*Erinaceus albiventris*
Slender gerbil	*Taterillus gracilis*
Common rat	*Rattus rattus*
REPTILES	
Large spiny lizard	*Agama agama*
Small spiny lizard	*Agama boueti*
Chameleon	*Chameleo africanus*
Skink	*Sphenops delislei*
Night gecko	*Stenodactylus petrii*
Monitor lizard	*Varanus exanthematicus*
Carpet viper	*Echis leucogaster*
Sand boa	*Eryx muelleri*
AMPHIBIANS	
Bullfrog	*Rana occipitalis*
Striped frog	*Ptychadena trinodis*
Spadefoot frog	*Tomopterna cryptotis*
Large toad	*Bufo pentoni*
Red-legged toad	*Bufo wazae*

APPENDIX T

Technical Plan for Testing Pesticides Against *O. Senegalensis* for Both Environmental Impact and Efficacy in the Republic of Mali

TECHNICAL PLAN
FOR
TESTING PESTICIDES AGAINST *O. SENEGALENSIS*
FOR BOTH ENVIRONMENTAL IMPACT
AND EFFICACY
IN THE REPUBLIC OF MALI

PREPARED BY:

DYNAMAC CORPORATION
ROCKVILLE, MARYLAND

FOR:

USAID
BUREAU FOR AFRICA
OFFICE OF EMERGENCY OPERATIONS

JULY 2, 1987

This report outlines a technical plan for testing the efficacy of eight pesticides on the Senegalese grasshopper (Odaelus Senegalensis) in Nara-Dilly area of Mali, and for monitoring the effects on beneficial flora and fauna, determining pesticide residuals, and assessing possible effects of bioaccumulation and magnification.

The plan is organized as follows:

I. Purpose
II. Selection of Test Chemicals
III. Schedule
IV. Efficacy Testing
V. Impacts on Beneficial Insects and Arthropods
VI. Impacts on Fauna and Flora
VII. Residuals
VIII. Safety Procedures
IX. Staffing
X. Reporting

I. PURPOSE

The project proposed for Mali is part of a larger USAID scientific program to test the efficacy and environmental effects of certain pesticides used, or being considered for use by the U.S., other international donors, and African countries to combat the threat of grasshoppers and locusts. The program is being coordinated with other pesticide testing programs through the Food and Agriculture Organization, Rome. The findings are expected to contribute to decisions concerning the pesticides to be used in future AID-funded control programs, and will also contribute information for use by other donors and African countries.

The program will consist of projects in three zones of Africa: West Africa, East Africa, and Southern Africa. The Republic of Mali is being proposed as the site of the West African project.

157

The program will work on four species of locusts and the Senegalese grasshopper. It will:

A. Test the efficacy of eight pesticides,

B. Monitor the effects of the pesticides on beneficials, including grasshopper/locust predators and parasites, and other beneficial fauna and flora.

C. Monitor and estimate any impact of residues of the pesticides in the environment.

II. SELECTION OF TEST CHEMICALS

A. AID identified the following pesticides as candidates for the testing program following discussion with the U.S. Environmental Protection Agency, the Food and Drug Organization, and others:

Pesticide	Class
Carbaryl (Sevin)	Carbamate
Carbosulfan (Marshal, Advantage)	Carbamate
Chlorpyrifos (Dursban, Lorsban)	Organic Phosphate
Lambda-cyhalothrin (Karate)	Pyrethroid
*Acephate (Orthene)	Organic Phosphate
*Bendiocarb (Ficam)	Carbamate
*Diazinon (Diazinon)	Organic Phosphate
*Propoxur (Baygon)	Carbamate
Fenitrothion (Sumithion)	Organic Phosphate
Malathion (Malathion)	Organic Phosphate

*Candidates for two open slots.

B. The following additional pyrethroid pesticides were proposed for consideration by their manufacturers:

Pesticide	Manufacturer	Date
Cyfluthrin (Baythroid)	Mobay	April 7, 1987
Alpha-cypermethrin (FASTAC)	Shell	May 21, 1987
Tralomethrin (Scout/Tralate)	DuPont	June 4, 1987

C. Based on a preliminary review of available information, the general characteristics of each pesticide class are presented below:

- Carbamates - The carbamates are residual insecticides of moderate to low mammalian toxicity (toxicity category II). Atropine (but not 2-PAM) is the antidote. The LD_{50} (male rat, acute oral) for bendiocarb is 40-156 mg/kg; for carbaryl is 283 mg/kg; and for propoxur is 95 mg/kg. The dermal LD_{50} for these compounds will run 500 to 2000 mg/kg (toxicity category III). They are generally not oncogenic but are suspect teratogens and weak mutagens. They are rapidly excreted by animals, disappear from plants by mechanical attribution, volatilization, and uptake into the plant. They do not seem to be appreciably photodegraded, but are degraded by soil organisms through hydroxylation of the side chain and ring structures. The carbamates are of low toxicity to birds, moderate toxicity to fish, and high toxicity to honeybees, aquatic invertebrates and estuarine organisms.

- Organic Phosphates - These pesticides are broad-spectrum contact insecticides of high to moderate acute toxicity to mammals. Of those in the above list, the LD_{50} (male rat, acute oral, mg/kg) values are: acephate, 866-945; chlorpyrifos, 97-270; diazinon, 300-400; fenitrothion, 800; and malathion, 1000-1375. Some of the most highly toxic pesticides known are organic phosphates, and yet compounds such as malathion are relatively safe to use. The organophosphates are cholinesterase inhibitors: atropine and 2-PAM (pralidoxime chloride, iodide or methanesulfonate) are the common antidotes. This group of pesticides is so broad that few

generalizations are valid for all member compounds; however, the organic phosphates tend to show little or no oncogenicity, teratogenicity or mutagenicity. Environmental toxicity effects vary depending upon the compound. Diazinon, for example is highly toxic to wildlife (birds, fish, aquatic invertebrates); its use has caused serious bird kills after applications to golf courses. In contrast, malathion has been applied by aircraft over broad areas of the United States for control of imported fruitfly outbreaks with little or no evident environmental problems (except for damage to automobile paint). Chlorpyrifos is highly toxic to wildlife and honeybees. The organic phosphates are photodegradable, but can be leached into the soil where they tend to have rather long half-lives.

- Pyrethroids - These compounds are based on "pyrethrum," a naturally-occurring insecticidal complex derived from certain species of chrysanthemum. Pyrethrum consists of pyrethrins (esters of pyrethrolone and chrysanthemic acid and pyrethroic acid), cinerins (esters of cinerolone and chrysanthemic acid and pyrethroic acid), and jasmolines (jasmoline and chrysanthemic acid and pyrethroic acid). They are characterized as being resistant to photodegradation, and are applied at extremely low active ingredient dose rates (in the range of 0.05 to 0.3 lb a.i./acre). They generally have low mammalian toxicities. Like the organophosphates, many pyrethroid products are classified by the EPA as Restricted Use Pesticides for some or all uses.

D. Of the chemicals listed above, six were identified for testing in the AID Scope of Work: Carbaryl, Carbosulfan, Chlorpyrifos, Lambda-cyhalothrin, Fenitrothion, and Malathion. Four chemicals were identified as candidates to fill the remaining two testing positions: Diazinon, Bendiocarb, Propoxur, and Acephate. Three additional chemicals nominated by manufacturers did not appear in the AID Scope of Work: Cyfluthrin, Alpha-cypermethrin, and Tralomethrin, .

A preliminary literature review and evaluation was conducted on all candidate chemicals as a basis for designing the field program and for selection of the eight pesticides to be used in the West Africa testing program.

It is the Africa Bureau Policy "that any AID-financed pesticide for locust/grasshopper control be registered with the EPA and have a tolerance established for at least one food use, or meet the established acceptable daily intake and maximum residue level recommended by the Joint Meeting on Pesticide Residues to the FAO/WHO Codex Committee on Pesticide Residues." The EPA registration and Codex status of the candidate pesticides are presented below:

Candidate Pesticide	EPA Registration	Food Crop Tolerance (40 CFR 180)		FAO/WHO Codex ADI/MRL
		yes	no	
Carbaryl*	✓	✓		✓
Carbosulfan	pending**		✓	✓
Chlorpyrifos*	✓	✓		✓
Lambda-cyhalothrin*	pending**		✓	✓
Acephate	✓	✓		✓
Bendiocarb*	✓		✓	✓
Diazinon*	✓	✓		✓
Propoxur	✓		✓	✓
Fenitrothion*	✓		✓	✓
Malathion*	✓	✓		✓
Alpha-cypermethrin			✓	
Cyfluthrin	pending**		✓	
Tralomethrin*	✓	✓		

*Proposed for West Africa testing program.
**Section 3 application submitted; data under review.

Manufacturers of these products were contacted to determine their continued interest in the testing program and identify any logistical problems that would prohibit their product from being available within the appropriate timeframe for testing in West Africa. On the basis of product availability, satisfaction of the Africa Bureau technical criteria, general balance among the three classes of pesticides to be evaluated, and consideration of potential environmental impacts and efficacy as determined by the initial literature review, the following compounds were selected for field testing in West Africa:

161

Pyrethroids	Carbamates	Organophosphates
Lambda-cyhalothrin (Karate)	Carbaryl (Sevin)	Chlorpyrifos (Dursban)
Tralomethrin (Scout/Tralate)	Bendiocarb (Ficam)	Diazinon (Diazinon)

Test Standards

Fenitrothion (Sumithion) - organophosphate
Malathion (Malathion) - organophosphate

The five candidate pesticides not selected for field testing in West Africa, Carbosulfan, Acephate, Propoxur, Alpha-cypermethrin, and Cyfluthrin, will be placed on a backup list. Additional information on these chemicals will be requested from EPA and the manufacturers of the compounds. The rationales for the elimination of these pesticides from the West Africa field testing program follow:

- Carbosulfan - This compound does not appear to completely satisfy the technical criteria. Although Codex ADI and proposed temporary MRL are established, EPA registration is still pending. The other members of the carbamate class selected for West Africa, Carbaryl and Bendiocarb, more fully satisfy the technical criteria in that both have Codex ADIs/MRLs established and both have EPA registrations; Carbaryl also satisfies the domestic food crop tolerance criterion. In addition, there is concern for the potential heath and environmental toxicity of the major degradate of carbosulfan, carbofuran.

- Acephate - This compound was not recommended for field testing in West Africa because: (1) there is no documented record of the manufacturer's expression of interest in participating in the field testing program; and (2) there are concerns for the potential health effects of acephate (i.e., the compound is a suspected human oncogen) and its metabolite methamidophos is highly toxic to birds.

162

- Propoxur - Propoxur was not recommended for inclusion in the West Africa field testing program because there is no documented record of the manufacturer's expression of interest in participating in the program. This chemical has been widely used in Africa for locust control; it is a good candidate for the East and Southern Africa field testing programs pending expression of interest by the manufacturer. EPA has expressed some concern for the potential oncogenic activity of the compound that needs to be addressed pending receipt of additional information.

- Alpha-cypermethrin - This compound was not selected because it does not appear to satisfy the technical criteria (i.e., no EPA registration or Codex tolerances). Concern has also been expressed about the mammalian toxicity of the compound. More data will be requested from the manufacturer.

- Cyfluthrin - Cyfluthrin does not satisfy the technical criteria as completely as the pyrethroids selected for testing. For example, Tralomethrin has an EPA registration and a domestic food crop tolerance established. Lambda-cyhalothrin, like Cyfluthrin, has an EPA registration pending, but unlike Cyfluthrin, also satisfies the Codex tolerance criterion. Lambda-cyhalothrin has also been field tested in Africa for locust control. Cyfluthrin appears to be a good candidate for the East and Southern Africa field testing programs. By the time these programs are underway, the compound may more fully satisfy the AID technical criteria; e.g., the manufacturer has stated that pending receipt of domestic registration, an application will be made for domestic food crop tolerances. The manufacturer has also stated that EPA registration is expected to be approved in the next several months. We will continue discussions with the manufacturer of Cyfluthrin in order to update the status of this candidate for future use.

III. SCHEDULE

A. The test mission would break down into two phases involving small (16ha) and large (256ha) plot trials. Each phase will involve site survey and delineation, spray activities and the actual efficacy and environmental sampling. The timeframe of the Phase 1 (small plot) trials is 10 days for survey and pretest sampling, 12 days for spray and 40 days for posttest sampling. Since spraying and sampling occur simultaneously, approximately 50 days will be spent on this trial series. The Phase 2 (large plot) trials will take approximately 36 days to complete. These numbers are approximations and could vary either way by as much as 20 percent. We believe though, that the Dynamac field team would be in the country on the order of 95 days.

B. The field testing schedule, which is governed by rainfall patterns and subsequent grasshopper outbreaks is expected to be approximately as follows:

- Small Plot Trials: Mid-July - Early September
- Large Plot Trials: Mid-September - Mid-October

However, the presence of testable populations may in actuality require departing from the above schedule. Flexibility will be required to account for this.

C. For the Phase 1 tests in the Nara-Dilly area, plots will be selected to the extent possible that have a significant percent under agricultural cultivation. This will permit testing under the same conditions that are expected to be encountered in the control campaign.

For the Phase 2 tests, it is anticipated that a major percent of the test plots will be grassland, because of the larger areas involved.

IV. EFFICACY TESTING

A. The efficacy testing protocols outlined below reflect discussions with USDA/APHIS or USDA/ARS personnel.

1. Experimental Design

The preliminary design allows for the evaluation of at least eight of the most promising materials under "Small Plot" conditions. Plot size should be 16 ha. (39.5 acres). Treatments will total 16 (8 insecticide x 2 dosage rates) each to be replicated 4 times in a randomized complete block design.

Those materials offering greatest promise on the basis of small plot tests will be retested in "Large Plots." Should the Phase 1 tests warrant, at least three of the "experimental" pesticides and one "test standard" will be included in Phase 2. Plot size in this instance will be 256 ha. (633 acres), and each treatment will be replicated three times. One dosage rate will be tested. This will be the lowest rate to prove effective (80% kill or better) in the Phase 1 trials. As above, a complete block design will be utilized, but there will be subsampling within each plot.

2. Data Analysis

As with plot design, analysis of the data will concur with the protocol and recommendations of USDA/ARS and USDA/APHIS. This will include an analysis of variance with a mean separation using the Duncan Multiple Range Test and a probability level of 0.05.

3. Application Parameters

a. Application Rates - Application rates will be in accordance with the manufacturer's recommendations for the maximum ULV dosage rate. Where the manufacturer has also recommended an alternative, lower rate for testing, this will serve as the

second application rate. Where this has not been done, we will use 50 percent of the recommended dosage for the alternate rate. Application will be with micronair nozzles to achieve uniform droplet size.

b. Serial Treatments - The series of treatments for each pesticide will be made in early morning or late afternoon to minimize spray drift caused by inversions and midday winds.

c. The application will be done in accordance with U.S. standards concerning narrow swath width, precision spraying. However, modifications may be necessary to take into account wind speed.

4. Evaluation Procedures

a. Sample Unit - The sample unit consists of a 0.25 m^2 ring. Forty such rings will be placed at random in a 50-meter diameter circle, i.e., about three meters apart on center.

b. Sample Interval - Target species will be counted at four intervals, including a pretreatment count, i.e., one to two days before treatment as well as at one, seven, and 14 days following treatment.

c. Controls (untreated checks) - Eight sample sites will be randomly located in the proximity of the test block. Using the 40-ring system, these sites will be sampled at the intervals discussed above. Statistical corrections will be used to account for normal population variations.

d. Developmental Stage, Species, Density - One hundred standard samples will be taken in the control areas at each sampling interval. Total grasshopper/locust counts will be made and tabulated according to life stage and species. Depending on population characteristics, the sample units may require modification.

e. Deposition and Droplet Size - To ensure a reasonable basis of comparison, it is necessary to validate spray deposition and droplet size. A suitable technique involving oil- or water-sensitive cards will be used. Ten cards per plot will be distributed just prior to application. Data will be reported as droplets per cm^2, volume median diameter, and droplet size spectrum in 50 micrometer-size classes.

f. Large Plots - Testing of large plots will begin approximately 14 days after completion of small plot testing. The above procedures will be duplicated in the large-plot tests. However, each large plot will be subdivided into quadrants, and each quadrant will be sampled as above.

VI. IMPACTS ON BENEFICIAL INSECTS AND ARTHROPODS

A. We will also evaluate the impact of the candidate pesticides on beneficial insects and related arthropod species. The beneficials will include grasshopper parasites and predators as well as parasites and predators contributing to the balance of other potential arthropod pest species.

B. In the absence of reliable information on the life histories and role of beneficials, the initial sampling plan is a general one. This will involve sampling closely linked to the efficacy testing as follows:

1. Baseline data for the control or check sites will be developed in collaboration with efficacy studies. Utilizing sweep samples (100 sweeps per sample area), pitfall traps ten meters apart in a 4 x 4 inch grid, and visual transects over 25m length by 1m wide, eight sites will be sampled in proximity to the test block. Sample intervals will be the same as those used in the efficacy tests.

2. Identical procedures will be followed in the pesticide test sites. Samples will be drawn from the center of the test plots at intervals of 1 to 2 days pretreatment and at 1, 7, and 14 days post-treatment. As in the efficacy tests, subplots will be sampled in the large plot tests.

3. The monitoring will also include an evaluation of each pesticide's impact on indicator species or other arthropod predators and parasites (i.e., those affecting species other than grasshoppers and locusts) and non-predatory or parasitic insect species (e.g., indicator food chain species).

C. Although the initial plan for monitoring impacts on beneficials is a generalized one, this will be paralleled by literature searches and consultations to identify important key or indicator species, vulnerable life stages, and other specific information. This review may lead to modifications in the monitoring program, or to recommendations concerning protection of beneficials in spraying programs.

VII. IMPACTS ON FAUNA AND FLORA

A. The following design for impacts on fauna and flora and for residual sampling (Section VII) is based on an initial review of available environmental effects and fate data for the candidate pesticides. The design outlined here is conservative; i.e., in the absence of sufficient information, worst-case assumptions were used, leading to sampling of all significant parameters and potential effects on all organisms (see Table 1). However, it should be noted that, although all the pesticides are potentially toxic to fish and aquatic invertebrates, we do not expect to encounter significant aquatic habitats in the Nara-Dilly test area.

It should be noted that additional information is expected to be available from EPA and the pesticide manufacturers. This information has been requested. The design will be modified appropriately upon review of these additional data. The design will also have to be modified when site-specific information becomes available, i.e., during the baseline evaluations of the selected test sites.

Table 1

Potential Sampling Parameters for Pesticides Selected for Mali

Candidate pesticide	Non-target Effects on: Fish	Aquatic invertebrates	Non-target insects	Birds	Mammals & livestock	Plants & algae	Residue Samples: Soil	Water*	Crops/ forage	Sediment	Milk
Bendiocarb[a]	X	X	X	X							
Carbaryl[b]	X	X	X			X		X	X		
Chlorpyrifos[c]	X	X	X	X						X	X
Diazinon[d]	X	X	X	X	X				X		
Fenitrothion[e]	X	X	X	X	X	X			X	X	
Lambda-cyhalothrin[f]	X	X	X		X			X	X		X
Malathion[g]	X	X	X								
Tralomethrin[h]	X	X	X		X		X	X	X	X	X

*Surface water and ground water, as appropriate.

[a]Environmental fate: Mobile; low bioaccumulation potential; rapid field dissipation. Environmental and health effects: Moderately toxic to mammals, toxic to fish, birds, pollinators. Acute oral LD_{50} rats 40-156 mg/kg. LC_{50} fish 0.7-1.0 mg/L. LD_{50} honeybee 0.1 ug/bee. Avian LD_{50} 3.1-137 mg/kg.

[b]Environmental fate: Moderately mobile in soils; mobile in runoff; not expected to contaminate ground water; rapid field dissipation; low bioaccumulation potential. Environmental and health effects: toxic to aquatic organisms and terrestrial non-target insects. Not phytotoxic; relatively non-toxic to birds. Acute oral LD_{50} rats 500-850 mg/kg. LC_{50} fish 1-10 mg/L. Avian LD_{50} 800 - >2000 mg/kg. LC_{50} aquatic invertebrates 1.7-1900 ug/L.

[c]Environmental fate: Persistent in soil for 1-2 months; sorbs to sediment/organics; immobile; fairly high bioaccumulation potential (BCFs 100-2000); fate data limited. Environmental and health effects: Non-phytotoxic. Toxic to aquatic organisms, terrestrial invertebrates, birds, wildlife. Acute oral LD_{50} rat 135-163 mg/kg. LC_{50} aquatic organisms 0.176 ppb-3.2 ppm. Avian LD_{50} 17.7-76.6 mg/kg.

[d]Environmental fate: Hydrolysis important fate mechanism; may sorb to organic matter; relatively non-persistent and immobile; low bioaccumulation potential. Environmental and health effects: Toxic to birds, aquatic organisms, terrestrial invertebrates, livestock. Special Review initiated by EPA in 1985 based on hazard to non-target birds from use on golf courses and sod farms. Acute oral LD_{50} rats 300-850 mg/kg. LC_{50} aquatic organisms 0.8-1700 ug/L. Avian LD_{50} 3.54-4.33 mg/kg.

[e]Environmental fate: Moderately mobile; quick field dissipation; low bioaccumulation potential; sorption to sediments/organic matter. Environmental and health effects: Toxic to aquatic organisms, birds, terrestrial invertebrates, mammals, plants. Acute oral LD_{50} rat 504-800 mg/kg. LC_{50} aquatic organisms 0.003-12 mg/L. Avian LD_{50} 23.6-1662 mg/kg.

[f]Environmental fate: Limited fate data available. Relatively immobile in soils. Field dissipation 14-60 days. Environmental and health effects: limited data available. Restricted use pesticide. Use of protective clothing and equipment required. Human flaggers are prohibited unless in totally enclosed vehicle. Following data for analog cypermethrin: Nonphytotoxic. Toxic to fish and aquatic organisms. Hazard to humans and domestic animals. Acute oral LD_{50} rats 250-310 mg/kg.

[g]Environmental fate: Moderate soil sorption. Rapid biodegradation, field dissipation (10-14 days). Low bioaccumulation potential. Environmental and health effects: Toxic to aquatic organisms and terestrial non-target insects. Acute oral LD_{50} rats 1000-1375 mg/kg. LC_{50} aquatic organisms 3.2-520 ug/L. Avian LD_{50} 167-1485 mg/kg.

[h]Environmental fate: Limited data available. Expected to be persistent, sorb to soils and sediments, and have potential to bioaccumulate on basis of chemical structure. Toxic to aquatic organisms and non-target insects. Acute oral LD_{50} rat 99.2-157.3 mg/kg.

B. Phase 1 (Small Plots)

1. Baseline Data

Small plot study sites (16 ha) will be selected to provide plots which are representative of areas subject to grasshopper infestations. In a typical savanna environment, two habitat types will be identified (open grassland and partly wooded grassland) in addition to cultivated fields. These habitats will be designated as blocks and two replicate plots for each treatment will be randomly assigned to each block. Two control plots will be selected from each habitat block.

The control plots and three treatment plots representing the range of habibat variability in each block will be subjected to baseline surveys. The physical characteristics at each plot will be recorded, i.e., topography, hydrology, soil types, meteorological conditions, and vegetation structure. Dawn and dusk visual surveys for animals (e.g. birds, mammals, reptiles, amphibians) will be performed along 400 m transects within each plot for five consecutive days. On each plot a 120 m mist net line will be run at dusk to census birds. Also on each plot a live-trap line (20 stations with 2 traps each) will be run at dusk.

These surveys will provide an inventory of plant and animal species, an identification of dominant species, and estimates of population sizes.

2. Posttreatment Sampling

Aerial spraying will treat 8 small (16 ha) plots per day. On the day of spraying, transect (400 m) surveys will be run on all 8 plots to record animals numbers and observe behavioral effects. On the following day, complete carcass searches will be performed on each plot. Where more than one death is observed for a species all carcasses (up to five) will be preserved for assays of pesticide residues.

On the 8th day posttreatment for each set of 8 plots, a second transect survey will be run. On the 16th day posttreatment, a third transect survey will be run. On control plots and those treatment plots sampled for baseline data, birds will be mist netted and small animals live-trapped on posttreatment days 1 and 14.

C. Phase 2 (Large Plots)

1. Baseline Data

Phase II study sites (256 ha) will be large enough to encompass all habitat types so that all replicates of all treatments can be randomly assigned. Two control plots will be designated. The baseline data from the small plot phase will have identified the general characteristics and principal plant and animal components of these plots. Preliminary sampling in the large plot phase will concentrate on obtaining good estimates of population size for birds, small mammals, and lower vertebrates. Surveys for all animals will be made along 800 m transects for each plot on two different days. Mist nets will be run in a loop at 240 m on each plot to capture and release small birds. Live trap lines (40 traps) will be run on each plot for 3 consecutive days. Mark-recapture (Bailey triple-catch) techniques will provide population estimates and produce marked individuals for posttreatment recapture. Pitfall traps (20 buckets along 20 m of flashing) will be run for 3 days in each plot. Captures will be marked.

2. Posttreatment Sampling

Aerial spraying will treat 2 large (256 hr) plots per day. Carcass searches will be done in each of 4 quadrants within each plot. Surveys along transects of 800 m will be run in each plot on posttreatment days 1, 3, 7, and 14. Bird mist-netting, mammal live-trapping and pitfall-trapping will be performed on each pair

172

of plots at posttreatment day 7. Each census technique will be applied to the control plots. In addition, carcass searches will be done on controls to determine the level of natural mortality and the efficiency of searching.

VII. RESIDUALS

Based on the characteristics of the chemicals to be tested and the low application rates involved in ULV application, we do not anticipate encountering significant residue problems. Nevertheless, "worst case" assumptions will be followed in the sampling program.

Therefore, the program will involve collecting a full suite of residual samples from: crops, soil, livestock milk, water and affected wildlife. Crop residuals will be sampled just prior to harvesting. The results of these analyses will be combined with information obtained from the literature reviews to provide best estimates of any potential bioaccumulation problems.

Procedures for conducting the residual sampling are set forth in Appendix I. It should be noted that all the crops and substrates listed in Appendix I will not be directly applicable to the tests in the Nara-Dilly area. The Appendix has been prepared to support the overall African program which will involve a wider range of ecological conditions.

VIII. SAFETY PROVISIONS

The following provisions will be made to assure safety of the project personnel and the Malian population in adjacent areas:

A. The pilots and applicator are certified for spray application of pesticides. As certified operators, they will be required to adhere to approved practices in handling and applying the pesticides.

B. All project staff will receive on-site training in safety procedures. The Manager, Field Operations will be responsible for providing the training.

C. During the spray operations, we will work with the representatives of the Plant Protection Service to assure that the population in the area concerned is aware of the activity and takes proper precautions to minimize exposure of humans and domestic animals. The test plots will be selected to avoid spraying in close proximity to villages, and pilots will be instructed to avoid spraying large herds of cattle.

IX. STAFFING

Staffing for the Nara-Dilly operation will be as follows:

A. Management and Coordination

- Manager, Field Operations - J. Atchue
- Logistics Coordinator - A. Stancioff
- Peace Corps Volunteer

B. Efficacy Testing and Beneficials Team

- Leader - G. Schaefers
- Members - D. Kolodny-Hirsh
  R. Campbell

C. Environmental Impact Team

- Leader - M. Southerland
- Members - G. Steiger
  J. Evans

D. Aerial Spraying

- o Pilots (2)
- o Mechanic

E. Participation by Government of Mali

It has been proposed that the Government of Mali participate, if possible, by:

- o Provision of six counterpart personnel (agricultural and environmental scientists) from appropriate ministries.
- o Assignment of a liaison officer to work with the Manager, Field Operations in maintaining communications and expediting clearances.

F. Other

We anticipate some additional on-site personnel, such as observors from some chemical companies and FAO.

X. Reporting

All field results will be fully documented. A report on the field tests will be prepared for USAID and presented to FAO in December 1987. Copies will be provided in French for the Government of Mali. The findings will be incorporated into a comprehensive final report at the completion of the overall African program.

APPENDIX V

Detailed Observations of Live and Dead Insects Made on Replicate Visual Transects in Phase II

APPENDIX V. Detailed Observations of Live and Dead Insects Made on Replicate Visual Transects in Phase II

Visual Transects:

Malathion

One day pre-treatment count;

E-2, No dead insects observed along transect in sorghum or field. Live insects observed flying, yellow pierid butterflies, bomhyliids, syrphids; live ant lion larvae.

E-6, No dead insects observed. Live insects observed flying in both millet and grassland, yellow pierid butterflies, bombyliids, assilids, other diptera, scolid wasps, live ant lion larvae.

E-3, Control, No dead insects observed. Live insects as above in both millet and field.

One day post-treatment count;

E-2, Dead insects, Sorghum transect

1 tenebrionid - large

1 small carabid

2 yellow pierid butterflies

2 diptera, bombyliid, 1 muscoid

Dead insects, Field transect - No dead insects observed

E-6, Dead insects, Millet transect

1 clerid beetle

1 carabid

1 tenebrionid - small brown

2 scarabids

3 yellow pierid

Field transect - No dead insects observed. As many flying lepidoptera as observed dead.

E-3 Control - Millet and Field - No dead insects observed. Species composition similar to that of pre-treatment sample.

Seven day post-treatment; E-2, E-6, E-3 - No dead insects observed. Live bombyliids, syrphids, tenebrionids, yellow pierids. Collected six (6) dead larvae (*Rhaguva?)* from ten (10) millet heads in treated plot (E6). Also collected three (3) dead larvae from control plot. No live larvae observed. However, the one generation per year had probably begun pupation at the sample date. Cause of death to be determined.

Chlorpyrifos

One day pre-treatment count;

E-8, No dead insects observed along transect in sorghum or in field. Live tenebrionids, scoliid wasps, pierids (two species) observed in sorghum. Reduviids, wild bees, pierids, scoliids and diptera active in grassland along transect.

W-4, No dead insects observed. Very few active insects in etiehr the crop or field. Pierids and tenebrionids observed in sorghum. In the grassland occasional bombyliid and pierids were observed, solitary bees, tenebrioniids.

W-5, control, No dead insects observed. Active insects were observed in

sorghum and grassland transects, comprised of many small diptera, few assilids, bombyliids, yellow pierids, and an occasional tenebrionid.

The three sites were quite different ecologically and this will be refelcted in the ecological consideration of research plots. W-4 had much shorter and sparce grasses compared to E-8, while W-5 was different in elevation and available soil moisture where sorghum was growing. Sorghum planted on low ground benefited more from available rainfall and the crop was much better appearing than those with greater moisture stress.

One day post-treatment count;

E-8, Dead insects, crop transect -

2 yellow pierids

1 scarabid

Flying and active - numerous syrphids and bombyyliids

Field transect - No dead insects

W-4, Dead insects, crop transect -

1 dead yellow pierid,

live bomhylids and other diptera.

Field transect - No dead insects observed

W-5, Control - no one day post-treatment count because of darkness. See below.

Seven day post-treatment count;

E-8, Sorghum transect, No dead insects observed. Live insects comprised three species of lepidoptera, syrphids, bombyliids, other muscoid diptera, a few tenebrionids.

Field transect, No dead insects observed. Live insects constituted yellow pierids, occasional assilids and bomhyliids.

W-4, Crop transect, no dead insects observed. Live diptera other than syrphids and/or bombyliids, one live solitary wasp. No dead insects observed on field transect.

W-5, Control, Sorghum transect, Live syrplid, live yellow pierids.

Field transect - Live yellow pierids.

Lambda-cyhalothrin

One day pre-treatment count;

E-7, Sorghum transect - No dead insects observed. Live tenebrionid, solitary bees, scoliid wasps and bombyliids.

Field Transect - numerous small diptera, yellow pierids, few bombyliids and assilids noted.

W-3, No dead insects observed on either crop or grasland transects.

Observed live yellow pierids, syrphid flies, solitary bees in each transect. Bombyliids were more scarce than in other plots.

W-5, Control, No dead insects observed. Active insects were observed along each transect and were comprised of small diptera, few assilids, yellow

pierids, bombyliids, and an occasional tenebrionid.

One day post-treatment count;

E-7, Dead insects, Crop transect

8 scarabids

Dead insects, Field transect

1caterpillar (noctuid)

1 tenebrionid

W-3, Dead insects, Sorghum transect

3 scarabids

1 himipteran

Dead insects, Field transect

1 tenebrionid, large

Observed live bee, *Apis* sp.

W-5, Control, No dead insects observed.

Crop transect, live yellow pierid, live diptera, in addition to scoliids.

Field transect, two species of butterfly, one in addition to common yellow pierid. Live grasshoppers in each transect.

Seven day post-treatment count;

E-7, Dead insects, Sorghum transect

21 scarabids

2 large tenebrionids

Live insects included

1 ant lion adult

3 small tenebrionids.

Field transect - No dead insects observed. No live insects seen; however, sampling was made in early morning and in addition plant cover was drying up.

W-3, Sorghum transect

30 dead scarabids, some moribund, and ants actively foraging on caraasses. Live insects included 2 small tenebrionids on scarabid carcasses; numerous diptera, 3 syrphids and others; 2 yellow pierids. Field transect - No dead insects observced. Three (3) live bombyliids.

W-5, Control - Many small diptera, assilids, bombyliids, yellow pierids in both transects. No dead insects observed.

Carbaryl

One day pre-treatment count;

E-4, No dead insects observed in either sorghum or field transects. Only live insects observed were grasshoppers.

W-7, No dead insects observed along either transect. Little activity of live insects because of lateness of the day, after 6:00 pm, and nearly dark.

W-5, Control, No dead insects observed along either transect.

Sorghum transect - Live insects observed, yellow pierid and another species, scoliid wasp, many diptera, grasshoppers. Field transect - live yellow pierid, many grasshoppers, more than in field.

One day post-treatment count;

E-4, Sorghum transect, no dead insects observed.

Field transect, No dead insects observed.

No live insects observed along either transect probably because of high wind estimated 20-30 mph and relatively cool temperature and rain previous evening.

W-7, Dead insects, Sorghum transect,

25 scarabids

1 yellow pierid

Live insects observed comprised 2 live scoliid wasps.

Dead insects, Field transect

17 dead scarabids

2 dead tenebrionids

One live dragon fly observed.

W-5, Control, Sorghum transect - No dead insects observed. Live insects comprised live scoliid, live diptera, yellow pierids and grasshoppers.

Field transect - No dead insects observed. Live insects observed were yellow pierid and a second species not previously observed.

Seven day post-treatment count;

E-4, Sorghum transect, No dead insects observed. Live syrphids, live hymenoptera and yellow pierid butterflies.

Checked five aphid infested sorghum whorls and there was an average

of 2 live syrphid larvae per whorl and which were actively feeding. Field transect, No dead insects observed. Only live grasshoppers were observed. Grass along transect as well as the balance of the field was very dry.

W-7, Sorghum transect, No dead insects. Live yellow pierids, live syrphid. Field transect, 5 newly dead scarabids

W-5, Control, Sorghum transect, No dead insects observed. Live insects consisted of 1 syrphid adult, and 2 yellow pierids. Field transect, No dead insects observed. Live insects comprised 5 yellow pierids, 2 bombyliids, 1 syrphid adult, 1 wild bee.

APPENDIX W

Rainfall Data From Meterological Station Near Test Site, Nara, Mali

1987 Rainfall in MM. Nara, Mali

Dates	May	June	July	Aug.	Sept.	Oct.
1						
2			10.2			
3				28.7	6.7	
4		0.9				
5		2.7		6.3		
6						
7		1.9		16.6		
8		0.4			6.0	
9		tr.	24.3			
10				14.1	21.1	
11		3.5				
12						
13			2.8	9.7		
14			11.0			
15					3.3	
16		1.5	29.2			
17						
18		2.6				
19					12.0	
20			5.2	1.9		
21		16.9				
22					2.9	
23	0.3			13.3		
24						
25		10.7		8.7		
26						
27						
28						
29						
30						
31						
Total	0.3	41.1	82.7	99.3	52.0	

APPENDIX X

List of Staff and Cooperating Personnel Involved in the Field Trials

APPENDIX X. List of staff and cooperating personnel involved in the field trials.

STAFF

Atchue, Joseph	Field Operations Manager, Dynamac Corp.
Campbell, Bob	Pesticide Application Specialist, CICP
Daffee, Cheick Oumar	Entomologist, SRCVO
Dembele, Issa	Entomologist, P.V., Mali
Edwards, Rich	Efficacy Leader, Purdue Univ., CICP
El Hadj, Tamboura	Direction Natl. Elevage, Mali
Evans, Jeffery	Pesticide Residues specialist, Dynamac
Fraser, Ian	Mechanic, Agricaire, Zimbabwe
Hirsch, Allan	Project Manager, Dynamac Corporation
Hughes, James	Junior Pilot, Agricaire, Zimbabwe
Kolodny-Hirsch, Doug	Entomologist. Md. Dept. Agric., CICP
Michaud, Claudette	Administrative Asst., Dynamac Corp.
Paschke, Don	Entomologist, Purdue Univ, CICP
Rogers, Ken	Senior Pilot, Agricaire, Zimbabwe
Short, Mike	Office Manager, Bamako, Dynamac
Sissoko, Mamadou	Translator, Dynamac
Schaefers, George	Efficacy Team Leader, Cornell Univ., CICP
Southerland, Mark	Environment Team Leader, Dynamac Corp.
Stancioff, Andrew	Chief of Party, Dynamac Corporation
Steiger, Greg	Field Biologist, Dynamac Corporation
Toure, Oumar Baba	Lab. Central Veterenaire, Mali

COOPERATING PERSONNEL

Atwood, Tracey	Agric. Devel. Officer, USAID/Bamako
Arnold, Douglas	Comptroller, USAID/Bamako
Balmat, Maurice	Entomologist, FAO, Mali
Castleton, Carl	ODR, USAID/Washington
Cisse, Boubacar	Chief Toxicologist, Mali
Duhart, Mr.	Entomologist, FAO, Mali
Goodson, Jeff	Env. Officer REDSO-West Africa
Ireland, Mike	Project Management, USAID/Bamako
Jacquette, Arlene	USIS, Bamako
Jago, Nick	Entomologist, TDRI, Mordiah, Mali
Keita, Moussa	Project Liaison, P.V., Mali
Kone, Ihrahina	P.V. Officer, Nara, Mali
MacKay, Ian	Entomologist, USAID/Bamako
Michaud, Phil	Project Liaison, USAID/Bamako
Popov, George	Grasshopper Consultant, FAO, Mali
Settle, Bill	Entomologist, U.C. Davis
Sissoko, Mousa	P.V. Mordiah, Mali
Sow, Abdoulaye	Chief Botanist, Mali
Suntera, Soumana	Director, P.V., Mali
Tamboro, Goru	Grasshopper prospector, P.V. Nara, Mali
Thomas, Wilbur	Deputy Director, USAID/Bamako

APPENDIX Z

Pesticide Residue Levels Detected in 169 Samples of Eight Environmental Media

APPENDIX Z. Pesticide Residue Levels Detected in 169 Samples of Eight Environmental Media

CHEMICAL	SAMPLE#	MEDIUM	PLOT	DAYSPOST	RESIDUE (PPM)
Chlorpyrifos	0027	Grass	W4	0	6.50
Chlorpyrifos	0030	Grass	E8	0	3.00
Chlorpyrifos	0034	Grass	W4	1	7.66
Chlorpyrifos	0037	Grass	W4	1	2.86
Chlorpyrifos	0040	Grass	E8	1	3.74
Chlorpyrifos	0094	Grass	W4	7	0.74
Chlorpyrifos	0097	Grass	W4	7	1.99
Chlorpyrifos	0100	Grass	E8	7	0.64
Chlorpyrifos	0139	Sorghum	W4	14	0.036
Chlorpyrifos	0140	Sorghum	W4	14	0.053
Chlorpyrifos	0141	Millet	E8	14	0.087
Chlorpyrifos	2012	Toad	W4	1	0.033
Chlorpyrifos	2013	Lizard	E8	1	0.002
Chlorpyrifos	2015	Birdv	E8	3	0.004
Chlorpyrifos	2016	Birdv	E8	3	0.004
Chlorpyrifos	2017	Birdv	E8	3	0.003
Chlorpyrifos	2018	Birdv	E8	3	0.004
Chlorpyrifos	2019	Hoppers	E8	2	0.023
Chlorpyrifos	0025	SoilC	W1	0	0.065
Chlorpyrifos	0026	SoilF	W1	0	0.031
Chlorpyrifos	0028	SoilF	W4	0	0.013
Chlorpyrifos	0029	SoilC	W4	0	0.153
Chlorpyrifos	0031	SoilF	E8	0	0.028
Chlorpyrifos	0032	SoilC	E8	0	0.074
Chlorpyrifos	0035	SoilF	W1	1	0.010
Chlorpyrifos	0036	SoilC	W1	1	0.030
Chlorpyrifos	0038	SoilF	W4	1	0.005
Chlorpyrifos	0039	SoilC	W4	1	0.018
Chlorpyrifos	0041	SoilF	E8	1	0.025
Chlorpyrifos	0042	SoilC	E8	1	0.082
Chlorpyrifos	0095	SoilF	W1	7	0.004
Chlorpyrifos	0096	SoilC	W1	7	0.006
Chlorpyrifos	0098	SoilF	W4	7	0.004
Chlorpyrifos	0099	SoilC	W4	7	0.004
Chlorpyrifos	0101	SoilF	E8	7	0.006
Chlorpyrifos	0102	SoilC	E8	7	0.004
Chlorpyrifos	6001	Sorghum	D8	25	0.001
Chlorpyrifos	6002	Millet	D8	25	0.001
Chlorpyrifos	6005	Millet	A5	26	0.001
Malathion	0004	Grass	E2	0	22.5
Malathion	0007	Grass	W2	0	1.15
Malathion	0010	Grass	W2	0	0.83
Malathion	0010	Grass	E6	0	0.242
Malathion	0014	Grass	E6	0	0.123
Malathion	0014	Grass	E2	1	0.125
Malathion	0017	Grass	W2	1	6.12
Malathion	0020	Grass	E6	1	0.075
Malathion	0020	Grass	E6	1	0.076
Malathion	0084	Grass	E2	7	0.618
Malathion	0087	Grass	W2	7	0.170
Malathion	0090	Grass	E6	7	0.300

APPENDIX Z. (continued)

CHEMICAL	SAMPLE#	MEDIUM	PLOT	DAYSPOST	RESIDUE (PPM)
Malathion	0135	Sorghum	E2	14	0.089
Malathion	0136	Sorghum	W2	14	0.011
Malathion	0136	Sorghum	W2	14	0.020
Malathion	0137	Sorghum	E6	14	0.166
Malathion	0138	Millet	E6	14	0.265
Malathion	2001	Lizard	E2	3	0.003
Malathion	2002	Frog	E2	3	0.014
Malathion	2003	Hoppers	E6	3	0.002
Malathion	2004	Frog	E6	3	0.014
Malathion	2009	Lizard	E6	3	0.020
Malathion	2010	Lizard	W2	4	0.003
Malathion	2011	Frog	W2	4	0.010
Malathion	0005	SoilF	E2	0	1.72
Malathion	0006	SoilC	E2	0	4.12
Malathion	0008	SoilF	W2	0	1.13
Malathion	0009	SoilC	W2	0	2.92
Malathion	0011	SoilC	E6	0	.
Malathion	0012	SoilF	E6	0	0.004
Malathion	0015	SoilF	E2	1	0.730
Malathion	0016	SoilC	E2	1	2.62
Malathion	0018	SoilF	W2	1	0.625
Malathion	0019	SoilC	W2	1	2.48
Malathion	0021	SoilF	E6	1	0.001
Malathion	0022	SoilC	E6	1	0.003
Malathion	0085	SoilF	E2	7	0.004
Malathion	0086	SoilC	E2	7	0.002
Malathion	0088	SoilF	W2	7	0.001
Malathion	0089	SoilC	W2	7	0.003
Malathion	0091	SoilF	E6	7	0.001
Malathion	0092	SoilC	E6	7	0.003
Karate	0044	Grass	W3	0	0.115
Karate	0047	Grass	E7	0	0.277
Karate	0050	Grass	W6	0	0.118
Karate	0054	Grass	W3	1	0.394
Karate	0057	Grass	E7	1	0.271
Karate	0060	Grass	W6	1	0.028
Karate	0104	Grass	W3	7	0.045
Karate	0107	Grass	E7	7	0.026
Karate	0142	Sorghum	W3	14	0.006
Karate	0143	Millet	W6	14	0.001
Karate	0144	Millet	E7	14	0.001
Karate	2021	Frog	W3	3	0.005
Karate	2026	Gerbil	W3	4	0.003
Karate	2028	Lizard	W6	3	0.001
Karate	2029	Frog	E7	3	0.017
Karate	2030	Lizard	E7	3	0.017
Karate	2031	Frog	E7	1	0.007
Karate	2041	Hoppers	W3	7	0.001
Karate	2041	Hoppers	E7	7	0.001
Karate	2041	Hoppers	W6	7	0.001
Karate	0045	SoilF	W3	0	0.002
Karate	0046	SoilC	W3	0	0.002
Karate	0048	SoilF	E7	0	0.003

APPENDIX Z. (continued)

CHEMICAL	SAMPLE#	MEDIUM	PLOT	DAYSPOST	RESIDUE (PPM)
Karate	0049	SoilC	E7	0	0.002
Karate	0051	SoilF	W6	0	0.003
Karate	0052	SoilC	W6	0	0.001
Karate	0055	SoilF	W3	1	0.004
Karate	0056	SoilC	W3	1	0.001
Karate	0058	SoilF	E7	1	0.002
Karate	0059	SoilC	E7	1	0.002
Karate	0059	SoilF	W6	1	0.002
Karate	0062	SoilC	W6	1	0.009
Karate	0105	SoilF	W3	7	0.001
Karate	0106	SoilC	W3	7	0.001
Karate	0108	SoilF	E7	7	0.001
Karate	0109	SoilC	E7	7	0.003
Karate	0111	SoilF	W6	7	0.001
Karate	0112	SoilC	W6	7	.
Carbaryl	0078	SoilF	E4	1	0.106
Carbaryl	0079	SoilC	E4	1	0.180
Carbaryl	0081	SoilF	W7	1	0.044
Carbaryl	0082	SoilC	W7	1	.
Carbaryl	0114	SoilF	E1	7	0.060
Carbaryl	0115	SoilC	E1	7	0.135
Carbaryl	0117	SoilF	E4	7	0.030
Carbaryl	0118	SoilC	E4	7	0.060
Carbaryl	0120	SoilF	W7	7	0.052
Carbaryl	0121	SoilC	W7	7	0.062
Carbaryl	2032	Lizard	W7	3	0.005
Carbaryl	2033	Toad	W7	3	0.001
Carbaryl	2034	BirdW	W7	3	0.400
Carbaryl	2035	BirdW	W7	3	0.468
Carbaryl	2036	BirdW	W7	3	0.335
Carbaryl	2037	BirdW	W7	3	0.199
Carbaryl	2038	Lizard	E4	3	0.001
Carbaryl	2039	Frog	E4	3	0.003
Carbaryl	2040	Frog	E4	3	0.001
Carbaryl	0064	Grass	E1	0	2.13
Carbaryl	0067	Grass	E4	0	2.16
Carbaryl	0070	Grass	W7	0	0.713
Carbaryl	0074	Grass	E1	1	0.955
Carbaryl	0077	Grass	E4	1	0.515
Carbaryl	0080	Grass	W7	1	0.507
Carbaryl	0113	Grass	E1	7	0.881
Carbaryl	0116	Grass	E4	7	1.64
Carbaryl	0119	Grass	W7	7	0.305
Carbaryl	0145	Sorghum	E1	14	0.081
Carbaryl	0146	Sorghum	E4	14	0.145
Carbaryl	0147	Millet	W7	14	0.278
Carbaryl	0122	Water	W7	7	0.0001
Carbaryl	0065	SoilF	E1	0	0.301
Carbaryl	0066	SoilC	E1	0	0.244
Carbaryl	0068	SoilF	E4	0	0.148
Carbaryl	0069	SoilC	E4	0	0.303
Carbaryl	0071	SoilF	E4	0	0.304

APPENDIX Z. (continued)

CHEMICAL	SAMPLE#	MEDIUM	PLOT	DAYSPOST	RESIDUE (PPM)
Carbaryl	0072	SoilC	W7	0	0.571
Carbaryl	0075	SoilF	E1	1	0.056
Carbaryl	0076	SoilC	E1	1	0.117
Malathion	2005	Birdw	E6	3	0.030
Malathion	2006	Birdw	E6	3	0.001
Malathion	2007	Birdw	E6	3	0.016
Malathion	2008	Birdw	E6	3	0.005
Karate	2022	Birdw	W3	3	0.001
Karate	2023	Birdw	W3	3	0.001
Karate	2024	Birds	W3	3	0.045
Karate	2025	Birdc	W3	3	0.001
Karate	6006	Millet	B5	23	0.001

*Note

ND = Not detectable residue at given level
SoilC = Soil sampled from cropland
SoilF = Soil sampled from rangeland
Bird# = Denotes species of bird