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EVALUATION OF INSECTICIDES FOR GRASSHOPPER CONTROL

Sahel Regional

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INTEGRATED PEST MANAGEMENT AND ENVIRONMENTAL PROTECTION PROJECT

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EXECUTIVE SUMMARY

Grasshoppers and locusts are becoming an increasing threat to much of the semi-arid region of Africa including all of the Sahel. Four locust species and one migratory grasshopper are of major concern.

The migratory grasshopper Oedaleus senegalensis has already caused extensive damage to millet and sorghum crops in Mali, Senegal and Burkina Faso. Many farmers have had to replant their crops, some for the third and fourth time. Yet the worst is still to come. Most crop damage can be expected to occur in late August, September and early October as adult O.senegalensis return south associated with the southerly retreat of the Intertropical Convergence.

To be most effective, control operations must be directed against the nymphal stages. Two opportunities exist: shortly after the beginning of the summer rains in May and June; and late summer at the terminus of the grasshopper's migration in southern Mauritania and northern Mali. The first opportunity has already passed for this year, and the second opportunity is rapidly approaching.

To prevent outbreaks of the African Migratory Locust, surveillance must be maintained continually on the outbreak areas of the Niger River flood plain of central Mali and the Lake Chad basin. Until its demise, OICMA was successful in preventing swarm formation. In 1986 swarms invaded southern Sudan and Uganda. During its last major outbreak in the late 1930's and early 1940's, this locust spread throughout much of Africa south of the Sahara.

The Desert Locust, the most feared of the world's locusts, escaped control on the Red Sea coast in large numbers during the spring of 1986. Swarms were recorded as far north as Egypt and Jordan. A new generation is now developing in the summer breeding area of Sudan and northern Saudi Arabia. This locust has the potential of spreading to India on the east and the Atlantic Ocean on the west. It may add to the problems of West Africa. The last Desert Locust plague occurred in the 1950's.

The Brown Locust has already reached plague status in southern Africa.

The Red Locust has begun to spread within its historic outbreak area of Tanzania and Zambia. If not suppressed quickly, it could spread throughout most of eastern Africa.

Altogether, the consequences of continued population increase and spread of these grasshoppers could be enormous. They pose a threat to the food supply of a vast area of Africa and the Middle East. The peoples of this vast area are unable to tolerate not only the threat of devastating infestations of these insects but also the continued use of the chlorinated hydrocarbon insecticides for their control.

Tests were conducted in Mali during the summer of 1986 using Carbaryl and Malathion, environmentally acceptable pesticides that are registered for grasshopper control in the United States, and Fenitrothion, a Japanese manufactured pesticide not yet registered for grasshopper control in the U.S. All three performed well as controls for African grasshoppers under African conditions. They should be chosen as acceptable alternatives to those pesticides that are presently the most widely utilized.

RECOMMENDATIONS

1. When purchasing or providing funding for the purchase of insecticides for use against grasshoppers and locusts, except in unusual circumstances, AID should consider only those insecticides that are registered for use against grasshoppers in the United States. Both carbaryl and malathion are registered for use in grasshopper control in the United States and have shown by the Mali test results to be efficacious under arid African conditions.

2. AID should support additional testing of malathion and carbaryl in Ultra Low Volume aerial application against mixed grasshopper and/or locust species including their use in drift spraying.

3. AID should continue to discourage the use of long lasting chlorinated hydrocarbon insecticides for locust and grasshopper control in Africa, and should encourage the use of the least hazardous application techniques consistent with efficacious pesticides of U.S. manufacture, registered for this use in the United States.

4. The grasshopper and locust problem is building rapidly towards plague status, and there are no quick fix methods of control. With recognition of the many political and economic constraints among the affected nations, AID should begin the development of a long range plan for U.S. participation taking full cognizance of FAO's established role. AID's support should include access to modern technological advances including weather monitoring and remote sensing.

5. AID should build a cadre of knowledgeable scientists, capable of withstanding the rigors of the desert and bush, who are readily available on call to provide technical assistance to affected nations and provide guidance to AID for both short and relatively long-term assignments.

ACKNOWLEDGEMENTS

Without the assistance of a rather large group of interested people, this assignment would have been even more difficult to accomplish.

Particular appreciation must be extended to Abdul Diallo and Mammadou Fofani, Agricultural Development Office, USAID/Mali for their almost daily assistance in dealing with the banks on financial matters: contractual arrangements for vehicular equipment and aircraft; negotiations with the Ministry of Agriculture and its Crop Protection Service, Researche Agronomique and Integrated Pest Management Project; and general translation assistance.

The knowledge of Dr. Nick Jago, Tropical Development Research Institute, United Kingdom, of the biology and habits of Oedaleus senegalensis and Locusta migratoria and the numerous sedentary species of grasshoppers in Mali was extremely valuable in determining test site location and timing of treatments. The hospitality afforded us at his camp in Mourdiah was a welcome relief to the rigors of life in the bush.

Though the report of this assignment is the responsibility of the Consortium for International Crop Protection,the representatives of our partners in the tests, Ing. Moussa Keita, OPSR, Bamako; Cheick Oumar Daffe, SRCVO, Bamako; Ing. Mathia Kamissoko, OPSR, Mopti, must rightly be recognized as co-authors of the insecticide testing portion of this report.

Dr. Jerome Onsager, U.S. Department of Agriculture, ARS, Director, Rangeland

Insects Laboratory, Bozeman, Montana and Dr. Larry Turner, Wildlife Biologist, Environmental Protection Agency, Washington, D.C., were only able to remain in Mali for two weeks. Although they missed the actual treatments, their knowledge of the pesticides to be used on the target insects and their effect on the total environment, and their suggestions as to dosages and rates of application which should prove the most efficacious with the least environmental hazard, precautions necessary to protect both humans and wildlife guided the conduct of the tests.

Carroll Collier, S&T, Agriculture whose persistence and insistence for the needs of the test, was instrumental in bringing it about.

Ms. Emmy Simmons, USAID, Bamako, must be recognized for her continuing interest in the outcome of the tests, the general grasshopper problem in Mali, and her assistance in the analysis of the test results.

Credit must also be extended to Deputy USAID Director Wilbur Thomas, ADO James Jackson, Comptroller George Jenkins, the staff of the USAID Drought Relief Office and the many officials of the Crop Protection Service (OPSR), The Integrated Pest Management Program (IPM), and FAO that provided financial and/or logistical assistance and participated in the planning and conduct of the test.

INTRODUCTION

Locusts and grasshoppers once again pose a threat to African agriculture. The situation today is mindful of conditions that existed in the early 1950's: a plague condition that lasted nearly 10 years and was never really brought under control but rather through the vagaries of nature died a natural death.

Since the 1950's there have been sporadic outbreaks of grasshopper and locusts of varied intensity in Africa. In the late 1960's and mid-1970's infestation buildups were brought under control before they had an opportunity to spread over a vast area and reach plague status. Though unsuccessful in the 1950's to bring the infestation under complete control, the lessons learned and the people trained enabled the successful conclusion of the campaigns of the 1960's and 1970's.

In general, the present locust and grasshopper upsurge is vastly different from the one that occurred in the 1950's. At that time principal concern was with only one grasshopper, the Desert Locust. The area of concern was large, extending to India on the east, the Atlantic Ocean on the west, south to Tanzania in east Africa and as far north as Turkey in the Middle East. Concern by the outside world did not surface until plague status had been reached.

The present upsurge involves several grasshopper species. First and foremost are the locusts because of their ability to reap complete devastation on the agriculture of a region or even a nation.

The Brown Locust of South Africa has already reached plague status. In spite of extensive control efforts, cropland damage has been severe.

The Red Locust of east Africa is spreading throughout much of its historic outbreak area; and if only partially controlled, as is the present case, it can soon be expected to invade neighboring nations within its invasion area.

African Migratory Locusts have already escaped the bounds of their historic outbreak areas in the Niger River flood plain of Mali, the Lake Chad Basin, and the flood plains of rivers flowing into Lake Chad. In eastern Sudan, in the sugarcane fields near Kassala, the gregarious form of this locust has developed. Although an historic holdover area for the African Migratory Locust, gregarization has seldom occurred there and then only in association with major outbreaks, the source of which was Mali and/or the Lake Chad basin. Swarms of this locust were observed in Gao, Mali in 1985. In 1986 swarms are reported to have invaded northern Uganda and are reported to be widespread in southern Sudan.

The Desert Locust, the most feared of all the world's locusts and the one of biblical record, in 1986 migrated out of its winter breeding area along the Red Sea coast of Ethiopia, Sudan, Saudi Arabia and Yemen in numbers that have not been seen in nearly 35 years. Swarms have reached both Egypt and Jordan, countries that have not been invaded by Desert Locusts since the early 1950's. The principal gregarious concentrations of the Desert Locust are now in the summer breeding area in the deserts of northern and western Sudan and the Nafud of northern Saudi Arabia where they are essentially immune to effective control measures. So, the numbers of these gregarious

Desert Locusts should continue to multiply. Solitary Desert Locusts are also on the rise at the extreme ends of the outbreak area. They are being reported as increasing and at population levels not seen in years in Pakistan at the eastern end of the outbreak area and in northern Mali and southern Mauritania at the western end.

The migratory grasshopper, Oedaleus senegalensis, and numerous other more sedentary species of grasshoppers of the Sahel in Senegal, Mali, Mauritania, Burkina Faso and Chad have reached such high population levels over such a vast area that they threaten to devastate much of the millet and sorghum production in the area of less than 1000mm of rainfall. In 1985, in spite of control efforts, losses to these crops in the infested area of northwestern Mali approached 35% to 50% (Mathys, 1985). The prospect of even higher populations of grasshoppers over an even more extensive area in 1986, has prompted FAO to make a world wide appeal for assistance. This pessimistic outlook is also being voiced by other groups who are acutely aware of the situation. Many farmers have already had to replant their millet three and even four times. Yet the main problem period has not yet been reached. The crisis period will occur in September when adult O. senegalensis begin their southerly migration associated with the southerly retreat of the Intertropical Convergence.

In the 1950's both the British and French were still quite active in locust and grasshopper control. The French principally confined their activities to the former French West African nations, Djibouti in east Africa, and Morocco, Algeria and Tunisia in north Africa. British action was primarily aimed at protection of their former colonies in Africa and throughout the

Middle East. Their participation was even greater than that of the French. The United States and other donor nations, along with FAO and the UNDP, were active in the control operations and institution building with emphasis on the establishment of regional control organizations and the strengthening of national crop protection services manned by skilled local technicians and financially supported by the affected nations. New control techniques, developed as a result of extensive grasshopper infestations in the grasslands of the mid-western and western United States, were introduced and became the mainstay of control operations as they are known today.

In the long term this cooperative approach paid off handsomely. The modernistically equipped organizations with their well trained personnel were able to take over the work, no longer reliant on donor nation technical expertise. Within two years they were able to suppress the Desert Locust upsurge of the late 1960's, the first time for such an accomplishment in the recorded history of locust control. Prior efforts, at best, had only been able to partially limit crop damage until the plague had run its course.

Years passed without a major locust or grasshopper outbreak in Africa and the Middle East, a credit to the ability of the FAO sponsored Control Organizations and Independent Regional Control organizations and vitalized National Crop Protection Services to recognize and suppress population buildups quickly, before they got out of hand. But this success also led to adversity. Without the threat of serious locust or grasshopper damage, the memory of the people became short. Funding sources dried up or were seriously reduced. Equipment grew old and deteriorated. Many of the highly trained personnel gravitated to higher paying, more secure jobs. The

Organization for the Control of the African Migratory Locust (OICMA) has been dissolved. The Desert Locust Control Organization for West Africa (OCLALAV) can barely sustain the salaries of its personnel and is incapable of mounting any effective control effort. Thus the entire system that took so long to build is now almost in total disarray.

This deterioration has forced these locust and grasshopper control organizations out of the mainstream of new technological development. Pesticides that were once the only effective control materials available are still utilized, although many new, more environmentally acceptable materials are now available. A lack of testing for efficacy and demonstrations to provide evidence of this efficacy to government officials responsible for making control decisions, extension agents and farmers, perpetuates the use of less desirable controls.

The Agency for International Development, bound by the provisions of the U.S. Environmental Protection Act, has been hampered in its effort to provide assistance in this crisis situation by the continued use in many of the affected nations of the long residual chlorinated hydrocarbon insecticides that are no longer registered for this use in the United States. For some of them, all use has been banned in the United States and many other developed nations. Yet, these materials are still available for purchase by the locust and grasshopper affected nations or are donated to them with little thought as to the long-term consequences. Price still appears to be the primary consideration, although the normal justification used is that there are no effective replacements or that it poses little environmental hazard at low dosage in desert areas and without repeat

applications. Others suggest that it is less hazardous to use the existing stocks of these materials rather than to dispose of them by other means.

The purpose of this cooperative study by AID and FAO was to determine the efficacy of ultra low volume formulations of two U.S. manufactured insecticides, Carbaryl and Malathion, against African grasshoppers under African conditions. Both of these insecticides are far more environmentally acceptable than many of the insecticides presently being used in Africa. They have a proven record of efficacy against grasshoppers in the United States in the formulations tested and are registered for this use in the United States.

A third insecticide, Fenitrothion, a Japanese manufactured product, was added to the test at the request of FAO. Though not registered for use on grasshoppers in the United States, it has gained some popularity for locust and grasshopper control in other parts of the world and is more environmentally acceptable than the presently widely-used chlorinated hydrocarbons.

By agreement between AID and FAO, insecticide testing was to be conducted by both aerial application and ground application and include ULV sprays, dusts and baits. AID felt that testing should be limited to Carbaryl and Malathion, since they were registered for grasshopper control in the United States. FAO proposed that the tests be expanded to include Fenitrothion, Pydrin and Dursban among others. In the end AID prevailed and only Fenitrothion was added. The agreement provided that AID would furnish the technical personnel and their support costs and pay for the costs of

application. Insecticides were provided free of charge by the manufacturers including air freight costs to Mali. FAO was to pay local support costs.

To fulfill its part of the agreement, AID contracted with the Consortium for International Crop Protection (CICP) to organize and direct the test and evaluate and report the results. The United States Department of Agriculture, Agricultural Research Service provided Dr. Jerome Onsager to collaborate on the test design, test location, insecticide dosage levels, population assessment, calibration of equipment and analysis of results. The Environmental Protection Agency provided Wildlife Biologist Dr. Larry Turner to evaluate the test area from the standpoint of possible environmental hazard, provide guidance in minimizing environmental hazard, and to the extent possible within a short time-frame, make a general assessment of the known grasshopper infested area within Mali and the probable effects on the overall ecology of a widespread air and ground control program using the pesticides to be tested versus the pesticides used in Mali in 1985. Travel funds for Drs. Onsager and Turner were provided by AID.

Mali was selected as the nation in which the testing would be conducted. Extensive damage to sorghum and millet by grasshoppers occurred in 1985 although controls had been undertaken. The study by Mathys (Oct.-Dec. 1985) projected that grasshoppers would again be widespread and numerous in 1986. Samples of soil and vegetation collected by Mathys several weeks after treatment and analyzed in Switzerland revealed significant residue levels of some of the insecticides used in the grasshopper control campaign. The Mali government, concerned with the relatively high pesticide residue levels and

the prognosis of a severe grasshopper problem in 1986, welcomed the proposal that the tests be conducted in Mali.

THE GRASSHOPPER AND LOCUST PROBLEM

Mali is ill-prepared to face the hordes of grasshoppers predicted to infest the nation in 1986. Lack of operational funds prevented the Crop Protection Service of Mali from staffing more than half their field operational bases. Those that are staffed are hampered by a lack of vehicles and control equipment and funds for fuel and travel. The demise of OICMA has made matters worse. Although FAO has provided funds to Mali to pay the salaries of the former OICMA employees under supervision of the Mali Crop Protection Service, a decision on the disposition of its assets has not yet been made; so Mali has only limited use of OICMA's vehicular and other equipment. OICMA's only aircraft was still inoperable in early August 1986, although FAO had provided funds for its repair and maintenance.

Likewise OCLALAV is in the doldrums. Though apparently still financially capable of paying the salaries of its employees, operationally it is dead. The two aircraft of OCLALAV in Senegal have not flown in more than one year and require extensive maintenance prior to use. Other equipment of OCLALAV is in a similar state of disrepair.

Mali, a member of both OICMA and OCLALAV and one of the few nations that has maintained current in payment of its assessments, cannot expect to receive much assistance during this current crisis from either source.

In early 1986, the FAO issued a worldwide appeal for grasshopper control assistance for Mali and other West African nations. Tunisia responded by offering Dieldrin and HCH. Objections were voiced by AID citing the FAO code of conduct for pesticide use. FAO rejected the Tunisian offer to Mali but provided 200 tons of 2% propoxur dust (8,000 lbs. a.i..); France provided 50 tons additional (2,000 lbs. a.i.). Several other nations made commitments to assist, and FAO declared that the grasshopper problem in West Africa was being adequately addressed. Yet, at the end of July 1986, with more than 250,000 has. of infestation in northwest Mali alone, the insecticide stock had dwindled to an amount sufficient to treat a mere 8,000 has.

The Norwegian Stromme Foundation liaison officer, Dr. Hans Indrebo, concerned with the disastrous effects the grasshoppers could have on their northwest Mali project area, decided that it was time to act. A survey of the Keyes and Yelimane circles by entomologist Ian MacKay and Crop Protection Service specialist Sekou Coulibaly between July 4 and 14 confirmed the threat. The CICP consultant assisted Dr. Indrebo in the development of the plan of action.

The Stromme Foundation expects to spend up to $1.5 million in this control effort. It will be aimed at adult grasshoppers migrating south from Mauritania in late August, September and early October. Aircraft will be positioned at Keyes and Yelimane. Spraying will be confined to pre-selected valleys where the wind currents should channel and concentrate the grasshoppers, providing suitable control targets. Insecticides and support equipment will be air-lifted to the worksites by the Norwegian Air Force.

The technique to be used by the Norwegians is suitable for northwest Mali but inappropriate for much of the remainder of the nation. Grasshoppers returning from the north to the Sahel of Mali, unlike the towering concentrated swarms of most locusts, usually migrate in at low level and thin density, arriving continuously over several days. Although some larger more concentrated swarms do occasionally form, concentration mostly occurs as they stop to feed on the maturing crops. To limit crop loss, quick acting contact insecticides must be applied immediately. Repeat applications may be required on an almost daily basis until migrations cease.

Villagers are ill equipped to protect themselves under these conditions. They lack the skills in calculating proper insecticide dosage levels and the equipment to apply quick acting liquid pesticides. They must resort to the use of hand applied, low concentration, slower acting insecticidal dusts. Thus crop damage is usually severe before grasshopper mortality occurs.

Even the more technologically advanced approaches are often doomed to failure when reliance must be placed solely on ground application. Dr. Nick Jago, entomologist with the British Tropical Development Research Institute and renowned as a grasshopper specialist, while studying the biology of the insects of millet in Mourdiah, Mali, had hoped to protect his study area from grasshopper attack through the use of four truck mounted power mist blowers. However, his units were overwhelmed. On July 31, Dr. Jago reported that in spite of his team's effort the entire millet crop in the Mourdiah area had been destroyed.

To assure an efficient and effective operation, control measures must be taken before migration occurs. This necessitates control while the grasshoppers are still in the nymphal stage. Hatching occurs within about 15 days of the onset of the summer rains. The area of rainfall slowly moves from south to north so the hatch is not uniform. By the time the first general hatch has occurred in northern Mali and Senegal, earlier hatchlings from father south are adults and beginning their migration north, laying a new batch of eggs along the way. Eventually the bulk of all O. senegalensis grasshoppers reach southern Mauritania and northern Mali where the Intertropical Convergence terminates its northward movement. Here in these moist sands, eggs are laid and a new generation of grasshoppers soon emerges. Upon becoming adults this new generation begin the migration south associated with the southerly retreat of the Intertropical Convergence.

To be successful, control must be carried out on nymphs of the initial hatch or on nymphs of the new generation which develops at the northern terminus of migration. The use of aircraft is a must. The area of infestation is vast with few roads, and those roads that exist often become impassable with the rains. The window of opportunity for control is small. Personnel, equipment and insecticides must be in place well in advance of its initiation. With even minimal delay, the opportunity for effective control may be lost until the coming year.

O. senegalensis grasshoppers moving north to Mauritania and northern Mali can be expected to produce one and perhaps two additional generations prior to returning south. Since migratory insects can usually outrun the bulk of their natural enemies at least for a time if adequate rainfall occurs, the

survival rate of the young of these new generations should be high. Without adequate controls at the northern terminus of migration, a several fold increase in the number of grasshoppers returning south over the number migrating north is not beyond reason.

There exists the distinct possibility that swarms of both the African Migratory Locust and the Desert Locust will invade the Sahel during late 1986 or early 1987 and add to the problems of Mali and other West African nations.

Desert Locusts that escaped control on the Red Sea Coast of Saudi Arabia, Yemen, Ethiopia and Sudan entered the summer breeding area of northern and western Sudan and northern Saudi Arabia with the advent of the summer rains in late June and July. Control is difficult in these areas, and escapes often occur if breeding is extensive. Swarms that develop in the Sudan can move back to Ethiopia or west to the Sahel in the fall or early winter. Swarms that develop in Saudi Arabia can move east towards Iran, Pakistan and India or south to the northern coast of Somalia. Escapes from Sudan to the west and from Saudi Arabia to the east could spark the beginning of a general locust upsurge throughout the whole of the invasion area. If the general Desert Locust movement is back to the Red Sea coast and to the northern coast of Somalia, effective control measures must be taken in these areas during the winter of 1986-87. Successful control on the Red Sea coast and the coast of northern Somalia is critical for the prevention of a plague, since as many as eight generations of the Desert Locust can develop in this area in any one year.

In Mali numerous small hopper bands and groups of gregarious African Migratory Locusts will develop in 1986 with the advent of the summer rains. Some swarming will likely occur. Swarming could easily spread beyond the outbreak area. Extensive localized damage to crops planted in the Niger River flood plain is likely to occur. Swarms originating in the flood plain of Mali could join up with swarms from the Lake Chad Basin adding to the problems of southern Sudan. During outbreak conditions, gregarious breeding is also likely to occur in the Awash Valley of Ethiopia, in central Somalia, and in the irrigated fields near Kassala, Sudan.

The last major outbreak of this locust occurred in the 1930's and early 1940's. It lasted more than 10 years and spread throughout most of southern Africa. It was during the outbreak that OICMA was formed.

Insecticide Spray Test

The rains in Mali began in early May, but these early rains were widely scattered and of short duration. Some areas received enough rain to allow grasshoppers to hatch but an insufficient amount for the production of new vegetation; so these newly hatched grasshoppers quickly dispersed widely in search of food. A few locations in northwestern Mali received sufficient rain for both a grasshopper hatch and production of new vegetative growth, and no dispersion occurred. The area surrounding the village of Guire, about 120 kms. southeast of Nara (the location of the nearest airstrip) was one of these areas. Rainfall exceeding 25mm occurred over a two-day period. Farmers quickly took advantage of the rainfall and planted their millet crop.

Within two weeks following this rain, large numbers of Oedaleus senegalensis hatched on the savanna to the southwest of Guire. About 3,000 hectares of this infestation were selected as the test site.

By the end of June the grasshoppers were becoming adults, but spraying was delayed pending release of the FAO funds. By the time word was received that the FAO funds had been released, the grasshoppers had denuded the savanna, destroyed the village's millet crop, and begun their northward migration (Photograph 1).

Since no additional rain had fallen in northwest Mali, any new hatch in that area was at least two weeks away. The search for a new test site shifted to central Mali, where there had been substantial rainfall and grasshoppers were reported to be numerous. A suitable site was located near the village of Songho, about 50 kms. east of Mopti and 35 kms. from the airstrip at Severe. Grasshoppers were just hatching. The dominant species, making up 80% of the population, was the African Migratory, Locusta migratoria. The remaining 20% was comprised of a number of grasshopper species foremost of which was O. senegalensis. By completion of the hatch, the population had reached levels of an estimated 300 to 500 per m^2, far above the level at which they could be counted accurately.

Initiation of spraying was scheduled for July 23, by which time the grasshoppers were expected to be mid-third to early fourth instar. By that time it could be expected that the hatch would be complete.

I

II

III

I. Guire Village millet crop after grasshopper attack.

II. View of area of liquid insecticide spray plots, Koti-Maude, Mali.

III. View of area of carbaryl-rice bran bait application.

Crowding, as the young hoppers grew older and larger, would force them to disperse somewhat, making it easier to assess the population density. Still, the grasshoppers would be young enough that there was little chance that they would begin to band up and start to migrate. The window of opportunity for conducting the test was estimated to be about 10 days.

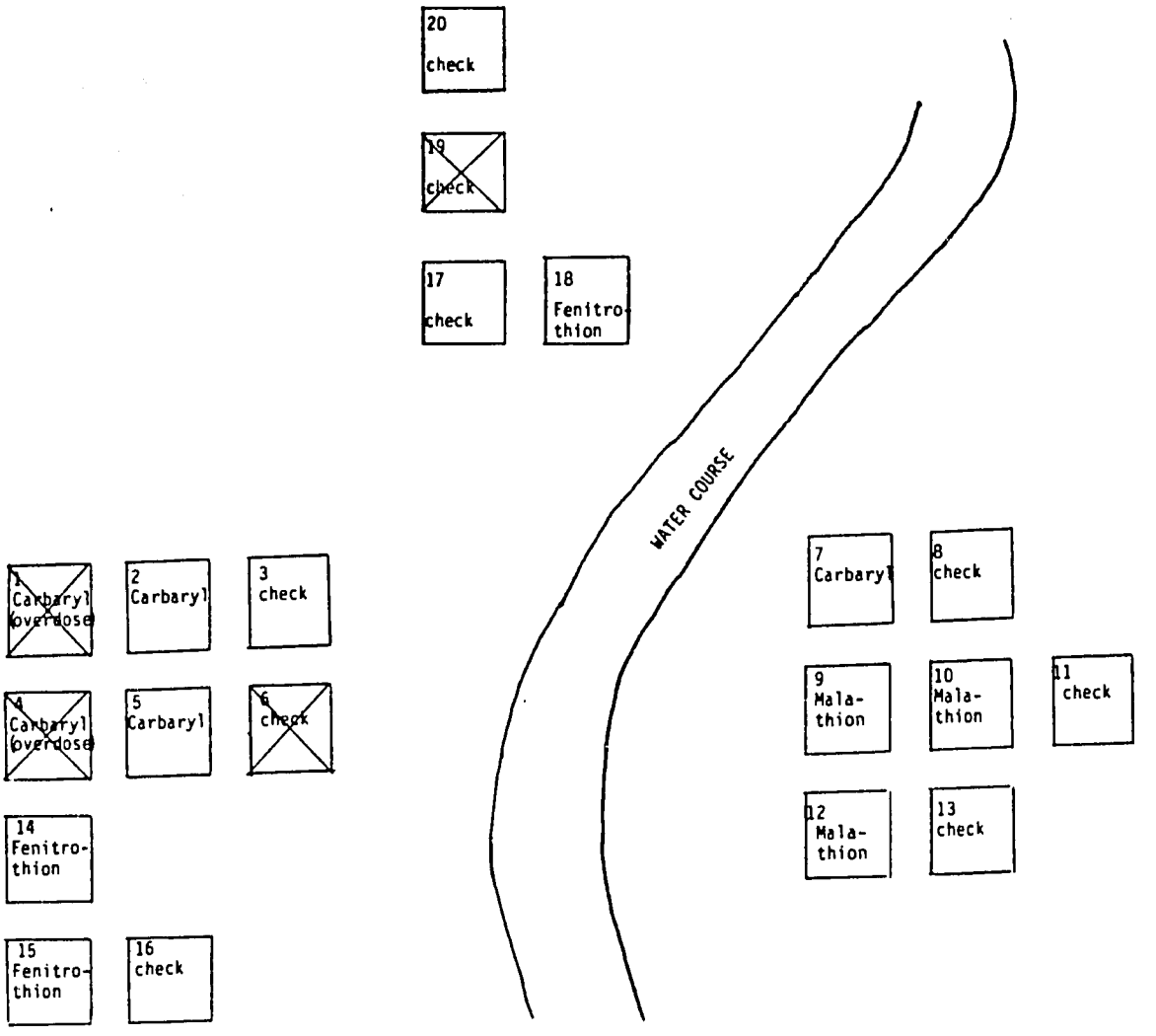
On July 20, word was received that the aerial applicator company (with which a contract for spraying had been let) would default on the contract unless an extension of a week to 10 days could be granted on the reporting date for work. The window of opportunity for the test would not allow such a lengthy extension. Since this aerial applicator company had the only spray aircraft in Mali, the aerial spray portion of the test was cancelled.

Since only the ground application portion of the test was to be undertaken, another, smaller area was selected as it provided for easier access. Located near the village of Koti-Maude, in a direct line it was only a short distance from Songho but was several miles closer to Mopti by road. The change in location also resulted in a change in grasshopper species dominance. At Koti-Maude, the migratory grasshopper O. senegalensis made up more that 70% of the population as determined in sweep nets, while the African Migratory Locust was rare.

Nineteen 1/4-ha. plots were established: 12 were reserved for the treatments and seven for untreated checks. Plot 6 was later discarded as being too close to an intermittent water course. Plot 19 was discarded due to insufficient population. Plots 1 and 4 were discarded due to insecticide overdose (Table I - Plot Layout). Principal vegetation in all plots was

TABLE I

Plot Layout



millet. Plant spacing varied greatly (Photograph 2). Except for Plot 7, the millet plants were 10 to 12 inches in height with foliage covering no more than 25% of the surface area of the plot. In the southern half of Plot 7, millet was 2 ft. or more in height and the foliage completely covered the soil surface. In all plots except 13 there was a heavy growth of weeds. A 25 meter wide untreated strip surrounded each plot.

Pre treatment population counts were made in the treated plots, and untreated checks were made immediately in advance of treatment. Counts were made on the basis of $1/10m^2$ rings as described by Onsager and Henry (1977). At least 50, but not more than 100, grasshoppers were counted on each plot along a diagonal transect. Rings were spaced two meters apart.

Post treatment population counts were made 24 and 48 hours after treatment, except that only a 24-hour post treatment count was made on the Fenitrothion-treated plots. Heavy rains on July 27 and 28 washed out the road to the treatment area preventing further evaluation. Post treatment evaluation was made on the basis of counts of a minimum of five grasshoppers and a maximum of 10.

The dosage rates for aircraft application as proposed by Dr. Onsager (1 lb. a.i. per acre (1.12Kgs per ha.) for carbaryl Sevin-4-Oil and 8 fluid oz. per acre (19.76 oz./ha.) with ULV malathion 95%) were retained in the ground application tests. The dosage established for Fenitrothion, 1/2 liter of 50% per ha., is the recommended dosage of OCLALAV and was used at that rate in Mali in 1985.

Carbaryl-Rice bran bait was mixed at the rate of 1 lb. of Carbaryl a.i. to 100 kgms. of bran and applied in strips by hand from a pickup truck at the rate of 50 kgms. per ha. (Photograph 3). The texture of the bran was flaky but fine, though not approaching the consistency of flour. The bait was mixed by pouring the bran on reed mats and spraying on the carbaryl, diluted with diesel fuel, using a hand operated knapsack sprayer. The bran was turned and mixed constantly as the carbaryl was applied. Mixing took place 48 hours in advance of treatment.

Liquid sprays were applied with Holder back pack mist blowers using a no. 1.2 nozzle. Output was calculated by spraying at maximum engine speed into a calibrated container for one minute and measuring the effluent. Effective swath width was measured under calm air conditions with the use of dye cards. Repeated timings were taken of the spray operator spraying along a 50 meter length strip until a uniform rate of application was established. Following calibration, diesel fuel was added as a diluent and carrier for the insecticide in the quantities necessary for uniform coverage at the desired dosage level. Three replications were made for each treatment.

At the suggestion of Dr. Turner, dye cards were to be used to evaluate the spray deposit and calculate the residue at time of application. As the numbers of dye cards available was limited, it was decided to use them only on the first and second carbaryl plots to be treated. Unfortunately, a mistake was made in the application on these two plots and an overdose occurred; so these plots and the dye cards were discarded.

On day 3 of the treatment schedule, plots were established for the application of Carbaryl 5% dust to be applied with a back pack duster at an application rate of 12 kgms. per ha. (0.6 Kgms. carbaryl a.i./ha.). However, the elements again prevailed. A sudden desert sandstorm, shortly after treatment began, forced a work stoppage. The following day heavy rain began to fall and this portion of the test had to be cancelled.

Tables II, III, and IV summarize the results of the test.

Many of the damaging species of grasshoppers of West Africa are rather sedentary and cause damage only locally. Both larval and adult stages can be successfully attacked. However, to prevent a repeat infestation the following year, controls should be undertaken prior to adult egg laying in the late summer or early fall.

The principal species, Oedaleus senegalensis, being migratory can generally be successfully controlled only in the nymphal stage. Control should be initiated on the first generation in early summer shortly after hatch. O. senegalensis develops rapidly on the advent of the summer rains. Hatch usually occurs within 15 days. Development is rapid, only four to five days between instars. From hatch to egg laying adult is as short as 35 to 45 days. The window of opportunity for effective control is very limited.

A second opportunity for control of this grasshopper is provided at the northern terminus of migration in southern Mauritania and northern Mali on nymphs of the second or third generation.

TABLE II

					Effectiveness Measures							
					After 24 Hours				After 48 Hours			
Plot No.	No. of 0.1 M2 Samples	No. of Hoppers	No. per M2	Treatment Number*	No. of Samples	No. of Hoppers	No. per M2	% Reduction	No. of Samples	No. of Hoppers	No. per M2	% Reduction or Increase
2	19	58	31	1	50	5	1	96.77	50	2	0.4	98.71
3	50	52	10.4	10					23	54	23.5	+125.96
5	10	65	43.3	1	27	7	2.6	94.00	30	7	2.3	94.69
7	20	59	29.5	1	11	9	8.2	72.20	16	6	3.8	87.12
8	38	50	13.2	10					32	50	15.6	+ 18.18
9	30	54	18	2	34	7	2	88.89	26	7	2.7	85.00
10	10	62	62	2	31	6	1.9	96.94	25	7	2.8	95.48
11	15	53	35.3	10					13	51	39.1	+ 10.76
12	15	55	36.7	2	20	9	4.5	87.74	28	10	3.6	90.19
13	40	52	13	10					39	53	13.6	+ 4.62
14	30	72	24	3	12	9	7.5	68.75				100.00
15	30	61	20.3	10					20	51	25.5	+ 25.62
16	20	79	35.9	3	10	7	7	80.50				100.00
17	40	60	15	10					25	53	21.5	+ 43.33
18	20	69	34.5	3	20	6	3	91.30				100.00
20	50	68	13.6	10					26	52	20	+ 47.06
21**	25	58	23.2	4					25	9	3.6	84.5

Source: G. Cavin Field Trials, July 1986
Filename: Hoppers

* Treatments are: 1 = carbaryl at 1 lb./acre; 2 = malathion at 8 fl. oz./acre; 3 = fenitrothion at 250 gms/ha.; 4 = carbaryl at 1 lb./100 Kgms ricebran applied at the rate of 50 Kgms per hectare; 10 = check

** Plot 21 refers to rice bran carbaryl bait test.

TABLE III

					Effectiveness Measures							
					After 24 Hours				After 48 Hours			
Plot No.	No. of 0.1 M2 Samples	No. of Hoppers	No. per M2	Treatment Number*	No. of Samples	No. of Hoppers	No. per M2	% Reduction	No. of Samples	No. of Hoppers	No. per M2	% Reduction or Increase
Without Treatment												
3	50	52	10.4	10					23	54	23.5	125.96
20	50	68	13.6	10					26	52	20	47.06
17	40	60	15.0	10					25	53	21.5	43.33
15	30	61	20.3	10					20	51	25.5	25.62
8	38	50	13.2	10					32	50	15.6	18.18
11	15	53	35.3	10					13	51	39.1	10.76
13	40	52	13.0	10					39	53	13.6	4.62
Averages:			17.3									39.36
Standard Dev.:			7.9									38.24
With Treatments:												
14	30	72	24.0	3	12	9	7.5	68.75				
7	20	59	29.5	1	11	9	8.2	72.20	16	6	3.8	87.12
16	20	79	35.9	3	10	7	7	80.50				
12	15	55	36.7	2	20	9	4.5	87.74	28	10	3.6	90.19
9	30	54	18.0	2	34	7	2	88.89	26	7	2.7	85.00
18	20	69	34.5	3	20	6	3	91.30				
5	10	65	43.3	1	27	7	2.6	94.00	30	7	2.3	94.69
2	19	58	31.0	1	50	5	1	96.77	50	2	0.4	98.71
10	10	62	62.0	2	31	6	1.9	96.94			2.8	95.48
Averages:			35.0				4.2	86.34			2.6	91.87
Standard Dev.:			11.8					9.75				

Source: G. Cavin Field Trials, July 1986
Filename: Hop3

* Treatments are: 1 = carbaryl at 1 lb./acre; 2 = malathion at 8 fl. oz./acre; 3 = fenitrothion at 250 gms/ha.; 10 = check

TABLE IV

					Effectiveness Measures							
					After 24 Hours				After 48 Hours			
Plot No.	No. of 0.1 M2 Samples	No. of Hoppers	No. per M2	Treatment Number*	No. of Samples	No. of Hoppers	No. per M2	% Reduction	No. of Samples	No. of Hoppers	No. per M2	% Reduction or Increase
Carbaryl Results												
7	20	59	29.5	1	11	9	8.2	72.20	16	6	3.8	87.12
2	19	58	31.0	1	50	5	1.0	96.77	50	2	0.4	98.71
5	10	65	43.3	1	27	7	2.6	94.00	30	7	2.3	94.69
Averages:			34.6				3.9	87.7			2.2	93.5
Malathion Results												
9	30	54	18.0	2	34	7	2.0	88.89	26	7	2.7	85.00
12	15	55	36.7	2	20	9	4.5	87.74	28	10	3.6	90.19
10	10	62	62.0	2	31	6	1.9	96.94	25	7	2.8	95.48
Averages:			38.9				2.8	91.2			3.0	90.2
Fenitrothion Results												
14	30	72	24.0	3	12	9	7.5	68.75				
18	20	69	34.5	3	20	6	3.0	91.30				
16	20	79	35.9	3	10	7	7.0	80.50				
Averages:			31.5				5.8	80.2				
Check Results												
3	50	52	10.4	10					23	54	23.5	+125.96
13	40	52	13.0	10					39	53	13.6	+ 4.62
8	38	50	13.2	10					32	50	15.6	+ 18.18
20	50	68	13.6	10					26	52	20	+ 47.06
17	40	60	15.0	10					25	53	21.5	+ 43.33
15	30	61	20.3	10					20	51	25.5	+ 25.62
11	15	53	35.3	10					13	51	39.1	+ 10.76
			17.3				0.0	0.0			22.7	+ 39.4

Source: G. Cavin Field Trials, July 1986
Filename: Hop2

* Treatments are: 1 = carbaryl at 1 lb./acre; 2 = malathion at 8 fl. oz./acre; 3 = fenitrothion at 250 gms/ha.; 10 = check

Control of adult O. senegalensis during their northward migration or return southerly migration has been largely unsuccessful. Hand application by farmers is generally too late to prevent substantial crop damage. Aerial application using quick acting contact insecticides applied immediately after grasshopper invasion has in some instances successfully minimized crop damage. However, several repeat applications may be necessary as migrating grasshoppers can continue to arrive for several days. Often, a lack of rapid communication prevents reporting invasions until too late to prevent serious crop damage.

All three of the insecticides tested should provide effective control against the nymphal stages of most species of African grasshoppers and locusts. A few species, such as Aiolopus simulator which hides in cracks under the soil surface and Hieroglyphus daganensis which lives partly underwater are difficult to control by most environmentally acceptable methods.

The extended residual activity of Carbaryl Seven-4-Oil, up to 21 days* makes it a candidate to replace the chlorinated hydrocarbons as a barrier spray to migrating hopper bands.

Malathion at 30 fluid oz. per ha. proved effective in controlling settled swarms of Desert Locusts in Ethiopia in 1968, 1969 (DLCO-EA unpublished reports).

* Onsager, Jerome A., "Efficacy of Carbaryl Applied to Different Life Stages of Rangeland Grasshoppers," Journal of Economic Entomology, pp. 269-273, April 1978.

The effectiveness of carbaryl at 1.12 kgms. per ha. on newly arrived adults of O. senegalensis within the treated plots should make it a good candidate for settled locust swarm control.

Both carbaryl and malathion at the dosages tested should provide quick mortality of migrating adult O.senegalensis. The dosage of Fenitrothion used, as recommended by OCLALAV, may be insufficient for the most effective control of adult locusts and grasshoppers and needs further evaluation.