ASSESSMENT OF AGRICULTURAL PEST STATUS AND AVAILABLE CONTROL METHODS IN THE GUINEA NATURAL RESOURCES MANAGEMENT PROJECT

APPROACHES TO INTEGRATED PEST MANAGEMENT

Contract No. 624-0219-C-00-2094-00
Guinea Natural Resources Management Project

CHEMONICS

Submitted to:
United States Agency for
International Development/Guinea
Conakry, Guinea

Submitted by:
CHEMONICS INTERNATIONAL

July 20, 1994

ASSESSMENT OF AGRICULTURAL PEST STATUS AND AVAILABLE CONTROL METHODS IN THE GUINEA NATURAL RESOURCES MANAGEMENT PROJECT

APPROACHES TO INTEGRATED PEST MANAGEMENT

Contract No. 624-0219-C-00-2094-00
Guinea Natural Resources Management Project

Submitted to:
United States Agency for
International Development/Guinea
Conakry, Guinea

Submitted by:
CHEMONICS INTERNATIONAL

Authors: Doudou D. Faye, Ph.D.
Senior Entomologist/ITM/R&D/NRM
Sphere Corporation, Georgetown, Texas

Walter Knausenberger, Ph.D.
USAID Africa Bureau
Washington, D.C.

July 20, 1994

/

ACKNOWLEDGMENTS

The authors wish to thank Chemonics International for giving us the opportunity to meet and work with the Guinea Natural Resources Management (NRM) project, especially Dr. Bob Chase, who, in addition to his availability and encouragement, reviewed Dr. Faye's first draft; Dr. K.B. Paul for his suggestions and guidance; Saidou Baldé, Labé plant protection station chief; the project staff in Labé, and the three watershed teams. Their support was appreciated. Dr. Faye expresses his appreciation for Mrs. Ann Chase's hospitality and welcome.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

ACRONYMS

BRP	Bassin Representatif Pilote
CA	Chef d'Antenne (Branch chief)
CAPV	Chef d'Antenne Protection des Végétaux (station chief, plant protection)
CE	Concentrée Emulsifiable
CFR	(U.S.) Code of Federal Regulations
CR	Conseiller Rural
DGA	Direction Générale de l'Agriculture
DNFC	Direction Nationale de Forêt et Chasse
DPV	Division de la Protection des Végétaux
EC	Emulsifiable Concentrate
EPA	(U.S.) Evironmental Protection Agency
FAO	(United Nations) Food and Agriculture Organization
g	gram
G	granular
GNRM	Guinea Natural Resources Management project
ha	hectare
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IPM	Integrated Pest Management
kg	kilogram
km2	square kilometer
l	liter
LD50	Lethal Dose 50
L(N)PV	Laboratoire (National) de la Protection des Végétaux
m	meter
MARA	Ministère de l'Agriculture et des Ressources Animales
ml	milliliter
mg	milligram
néré	local name for the tree *Parkia biglobosa*
OP	organophosphate insecticide
P	poudre, powder
PNUD	Programme des Nations Unies pour le Développement
tapades	fields located near dwellings
teli	local name for the tree *Erythrophyleum guiniensis*
UNDP	United Nations Development Program
USAID	United States Agency for International Development
WMU	Watershed Management Unit

EXECUTIVE SUMMARY

The 21-day mission in the GNRM project area of Dissa, Koundou, and Diaforé watersheds was for the purpose of evaluating the incidence of pests, present control strategies, the relevance of chemical pesticide use, and a proposition for an integrated pest management program. We primarily targeted termites and pests of stored products, since they were reported as the most serious problems. Visits in the project area allowed us to document the severity of pests, availability of technical support, pesticide distributors, and relevant laws and regulations.

Distribution and severity of pests. The types of pests are similar in all three watersheds but differ in their virulence. In Dissa and Koundou, termites, though found in *tapades* and dwellings, are not the worst problem; rather, the most damage is caused by grasshoppers on vegetable gardens, and by pests that infest stored products—the maize weevil, larger and lesser grain beetle, angoumois moth, cowpea weevil, *tribolium spp.*, etc. Secondary pests or nuisances were weaver ants on orange and mango trees, fruit flies on vegetables, cotton stainers on rice, bollworms on orange fruit, and mealybugs on cassava.

Control measures. The rare times that chemical control is used, application is usually through a wide-range operation under foreign sponsorship and the local services of plant protection, supervision, and monitoring. Local control measures are often restricted to mechanical, physical actions, supplemented with suggested botanical or traditional plant treatment; this is mainly practiced in the case of termite control. The same was true with efforts to protect stored products.

Pesticide registration, availability, and management. Updated information on pesticide registration, use, and management is available, but not easily obtained; it remains unknown to most pesticide users, including government agents. This can be a serious handicap. Furthermore, there is no landfill pesticide disposal. Pesticide storage facilities need to be improved (aeration, sanitation, water supply, material safety data sheets for each chemical, warning signs, fences, removal of non-related items, etc.). One pesticide company representative supplies approved pesticides as well as protective equipment, but its storage facility should be moved out of the middle of the city, and away from offices. Landfill or disposal strategies should be developed by each approved pesticides sales company.

Integrated Pest Management (IPM) approach. With the approval of pesticide use under USAID/EPA 22 CRF, Section 216, a systematic approach to pest control should be followed. This will lead to the obligation to sound pest and pesticide management under IMP principles calling for minimizing hazards, through a combination of practical and proven control measures proposed or already available under good technical guidance. These measures include the use of least-toxic pesticides, sustainability, safety, training, monitoring, pesticide resistance avoidance, sensitization, a no-action option, use of botanical and other local control measures, demonstration and applied research with farmer involvement, etc.

SECTION I
TRIP PURPOSE AND ORGANIZATION

A. Purpose of Trip

Two main insect pest problems are recognized in the Guinea Natural Resources Management (GNRM) project. Termites attacking crops, agroforestry nurseries and dwellings, and an array of insect storage pests (weevils, bruchids, bostrichids etc.) were reported. In the case of the Diaforé watershed, the situation is severe. It has the lowest average annual rainfall (1,230 mm), compared to 1,415 mm in Koundou and 1,855 mm in Dissa. With the smallest area of 65 km^2, and the second highest population density (31/km^2), concentrated on the lowlands, land availability is limited. This factor has induced land overuse through reducing the fallow period from seven to three years, heavy deforestation activities, and decreasing productivity. With low levels of organic matter combined with extensive uncontrolled burning, termite activity has markedly increased. Postharvest losses of up to 60 percent before or during storage due to pest infestation, coupled with other poor conservation techniques, have led to severe food shortages. Farmers, confronted with such a situation, usually try to alleviate the problem by attempting additional agricultural activities such as vegetable gardening, beekeeping, and other small business enterprises. The severity of the agroecolgy in the lateritic and eroded land, called *bowal*, exacerbates the problem.

In its previous evaluation of the watersheds, the GNRM project recognized several development constraints, including termites and stored product pests frequently mentioned in the rapid rural appraisal studies (GNRM Annual Work Plan 1993). Consequently, the project is seeking approval to use synthetic chemical pesticides to control these pests in the watersheds. This analysis will deal not only with termites but will include a review of other potential key pests of vegetable gardens, field crops, and fruit trees, as well as possible control measures.

The project proposes to use, for termite control, either one or a combination of:

- Basudine (Diazinon) 60 EC and/or 10 G
- Dursban (Chlorpyrifos) 5G and/or 10 G

For storage pests:

- Actellic (Pirimiphos-methyl)

The use of these chemicals has been requested, pending careful evaluation of several factors pertaining to their use, including but not limited to pesticide availability, minimal environmental impact, sustainability, effectiveness, low level hazard, and as a potentially valuable component of an integrated pest management (IPM) program.

A mission of 21 days was initiated to ascertain the appropriateness of the proposed action, to assess existing pests and potential pest control methods, and finally to provide inputs geared toward creating an IPM program (if lacking) in the watershed(s) concerned. The result of such a study could be used as a reference or starting block for the country and its neighbors where similar problems prevail.

B. Persons Contacted

USAID/Conakry

Wilbur Thomas	Mission director
Thomas Park	Deputy mission director
Dan Jenkins	Regional development officer
S. K. Reddy	Regional development officer
Kalo Lascine	Assistant NRM project manager

Chemonics, Guinea NRM project

K.B. Paul	Chief of party
Bob Chase	Soil scientist
Tom Aversa	Agroforestry specialist
Mouctar Diallo	Administrative assistant

Government of the Republic of Guinea, Conakry

Sagnah Tatenin	Interim director, DNFC
Mathias R. Haba	National watersheds coordinator, DNFC, Fouta Djallon Highlands Integrated Rural Development project
Mamadi Camara	Director, National Plant Protection Service

Laboratory of Plant Protection, Foulaye

M. Sidibe	Deputy director/entomologist
Lamouré Sidibe	Phytopathologist, National Institute for Agronomic Research
Kalabane	Head, entomology section
Saidou Baldé	Station manager, Province of Seyni

Labé

Alkali Touré	Head of agricultural extension office
Mariama O. Baldé	Local extension agent
Moussa Camara	Director of rural development
Pepe P. Guilavogui	Head of the agricultural promotion office
Siba Camara	Assistant station chief, plant protection office
Camara S. Diouma	Plant protection agent
Keita C. Mouhamed	Plant protection agent

Dissa Watershed

Pe Vincent Gamy	Director of Dissa Watershed
Missan Maomy	Contractor
Morlaye Keita	Agroforestry specialist, watershed management unit
Rabiatou Camara Diallo	Local extension agent
Abdoulaye Touré	Small enterprises technical assistant

Koundou Watershed

Bacar Alpha Ba	Director of Koundou Watershed
Bocar Sow	Small community enterprises
Mamadou Y. Sow	Agroforestry specialist

Diaforé Watershed

Idrissa Keita	Warehouse keeper/entomologist

Food and Agriculture Organization

Gerard J. Bernard	Resident representative
Marc Moens	Program leader

Natural Resource Institute

Stephen Russel-Smith
Tom G. Wood

Other

Minoru Tamashiro	Tropical entomologist, Univ. of Hawaii, Minoe
Nan-Yao Su	Associate professor of entomology, University of Florida Research and Education Center
Aref Aboukhalil	SAREF International, Conakry

C. Trip Schedule

Visits were made to the three watersheds from April 8-20, 1994, with the project team and Laboratory of Plant Protection (Laboratoire de la Protection des Végétaux) (LPV) of Labé. Meetings were held with farmers, local agricultural officials, in the plant protection laboratory at Foulaya, the Division of Crop Protection (Division de la Protection des Végétaux) (DPV), the National Office of Wildlife and Forest (DNFC), the pesticide storage facility in Labé, funding and international agencies (USAID and FAO), and Aref Talal from SAREF, the representative of the chemical company ALM International S.A. in Conakry.

The consultants visited the Dissa watershed on April 8 and 9. The villages visited were Hafia, Foulaya, Fotongbé, and Marema. Specific sites were dwellings, storage buildings, vegetable gardens, and termite mounds. The project team included the chief of party, the agroforestry agent, the community enterprise specialist, and the animatrices.

The Koundou watershed was visited from April 12-14 with Bob Chase, the soil and water conservation specialist of the project, Mr. Saidou Baldé, the Labé Province station plant protection chief (chef d'antenne), and the Koundou watershed team composed of the watershed director Bocar A. Ba; Bocar Sow, small enterprise community specialist; Mariama O. Baldé, local extension agent, and Mamadou Y. Sow, agroforestry specialist.

Villages and other sites visited include the plant protection station in Labé, the prefectoral plant protection service in Labé and its pesticide storage building; the villages of Linsan Saré (and its weekly market), Kokolou, Dongol, Thiankoye, and Guéwé (agroforestry nursery).

In the Diaforé watershed, visits and meetings were made with Dr. Chase, the Labé plant protection station chief, Mr. Baldé, and the watershed team composed of Mamadou Saliou Diallo, Souare M. Aliou, soil and water management specialist; and Mohamadou Malal Baldé, small community enterprise specialist. Villages and sites visited were Kouné (where the mosque had been infested with termites), Diaforé, and Guonkou (and its weekly market). In the village of Guonkou, a mound destruction and queen removal demonstration was made.

In Conakry, the writers visited and interviewed the FAO staff, the ALM International chemical company country representative SAREF, and personnel at the Division of Plant Protection (DPV). Debriefing was conducted in the National Headquarters of Forest and Wildlife and with the USAID/Guinea NRM project staff on April 22.

SECTION II
COUNTRY SITUATION AND AFFECTED ENVIRONMENT

This section discusses the conditions under which the pesticides are to be used, including climate, flora, fauna, geography, hydrology, and soils. The project will conduct pilot pest control activities in the three watershed sites of the Fouta Djallon Highlands of Middle Guinea. The following synopsis of the Koundou and Diaforé watersheds was taken from a report by Stephen Kelleher, a consultant for the World Resources Institute (Kelleher 1990).

The Fouta Djallon mountains and plateaus in Middle Guinea cover more than 60,000 km^2, approximately one-quarter the land area of Guinea. Nearly the entire region is mountainous, and a quarter of the area (13,000 km^2) lies more than 900 m above sea level. The mountains traverse the region in a north-south direction, rising steeply from the west and gently from the east. Approximately one-third of the population of Guinea lives in the Fouta Djallon, two thirds of whom are Peul.

A. General Agroecology of the Project Area

Numerous land and soil types exist in the Fouta Djallon Highlands. Farmers have independently classified the soil types by a catena concept, which describes interlocking soils on a landscape from the hill crests to valleys. These are **bowal, hansangéré, dantari, dunkiré, hollande and suntuuré.**

Bowal. Bowal is a name given to broken, lateritic, ironstone crusts. Bowal is found on hill tops, plateaus, and slopes. Bowals are the primary grazing lands for cattle, and are considered a common property resource.

Hansangéré. Hansangéré lands are generally found on hillcrests and slopes. They are characteristically a mix of soil and rock derived from either adjacent bowal or from adjacent basalt, granite, or metamorphosed sandstone parent materials. The stony nature of these areas allows for good water infiltration.

Dantari. Dantari soils are also found on slopes but are not confined to them. These are finer, more compact, and more homogenous than hansangéré soils and generally do not have as high a water infiltration rate. These soils are considered workable, but exhausted, and are often acidified. In contrast with hansangéré soils, animal traction is a possibility on dantari soils.

Dunkiré. In the valleys of watersheds, alluvial flood plains are found. Many of these areas receive annual deposits of fine clays and sand, and soil has built up over time through these deposits. These are locally called dunkire and are cultivated regularly.

Hollande. In lower areas of the alluvial plain fine-textured, heavy clay hydromorphic soils are found. The local name for these areas is hollande. These soils are used for grazing cultivation and some gardening.

Suntuuré. The Fouta Djallon is an area of high plant species diversity and an important center of endemism. Vegetation is classified as a combination of woodland, open savanna woodland, bush woodland, light forests, and lightly wooded savanna bush. However, most natural forests have been replaced by cultivation, secondary growth, fallow, and grassland.

Gallery forests are traditional buffers of natural forest left around springs and along watercourses. This buffer helps maintain water quantity as evaporation is reduced, water infiltration is increased, and erosion and stream sedimentation is lessened. The tradition of leaving galleries intact is not always respected, and some farmers now clear land up to the stream banks. The gallery forests are likely high in floral and faunal biodiversity and provide non-timber artisanal and medicinal products. Isolated forest "islands" are found on various land types. These usually indicate a water source, a "sacred wood," or a cemetery.

B. Presentation of the Watersheds

B1. Koundou Watershed

The Koundou watershed is located between latitudes of 11 degrees 39'N and 11 degrees 52'N, and between longitudes of 12 degrees 32'W and 12 degrees 47'W. Total land area is 107 km^2. The watershed receives 1,600 to 2,000 mm rainfall per year, and has a six-month annual dry season.

This watershed is characterized by five physiographic types broken down as follows: laterite crust plateau; doleritic, granitic and schist escarpments; undulating plain; hilly plateau; and irregular plains. Susceptibility of the area to erosion is classified as susceptible, average, and insignificant. Elevation ranges from 200-300 m above sea level along water courses, to 800-900 m along hill crests and slopes. The mesa Mount Kokolou is a dominant feature on the landscape.

The principal watercourses are the Kansouma and the Koundou that are fed by numerous streams and springs. These two come together as the Koundou, which flows into the Komba River. The Komba River eventually joins the Kolibu, which passes through Guinea Bissau, where it empties into the Atlantic Ocean.

Vegetation varies according to land type. Overall there exist savanna, shrub savanna, and open forest, as well as dry mountain forest and islands of closed forest where species such as *Pterocarpus erinaceous*, *Terminalia spp.*, *Afzelia africana*, *Coryla pinnata*, *Burkea africana*, and *Exynanthea abyssinica* are found. Gallery forests are also found along water courses and around springs.

The watershed is arranged as a cul-de-sac. Villages are located mostly along hillcrests and slopes, away from the alluvial plain. No roads cross the watershed.

Bowal is not as visually dominant in the Koundou watershed as in Diaforé, but more greatly affects production, since most villages and many suntuurés and fields are located on hillcrests and slopes composed of, or evolved from, bowal. Many soils have a high content of ferruginous gravel that varies in depth from 30 to 100 cm. Due to the cultivation of slopes, erosion is more of a potential problem here than in Diaforé, although some people use rock and dead wood barriers against it.

Slightly evolved hansangéré soils, close to bowal, and dantari soils are cultivated. In some areas, dantari soils benefit from proximity to doleritic and basaltic escarpments, factors that contribute locally to a richer nutrient base. Average fallow periods of five to ten years are generally followed by two to three years of cultivation in a rice/*fonio*/peanut/manioc rotation. Animal traction is used in Koundou on those soils that are not too steep or rocky.

Soils along floodplains are deep alluvial deposits (dunkiré) with some hydromorphic (hollande) areas that experience seasonal variations in saturation. In some areas fruit orchards and dry season gardens are installed, although the majority of the floodplain seems under some secondary vegetative cover. Dense communities of bamboo and Ronier palms are found here.

Part of the classified forest of Nialama is located within the watershed. This forest covers an area of approximately 10,000 ha, of which approximately 5,000 fall within watershed boundaries. The forest was classified in 1942. Nialama is classified as a dry secondary forest, although it is possible that remnants of primary forest exist.

B2. Diaforé Watershed

The Diaforé watershed is located in the prefecture of Tougué and the sub-prefecture of Kouratongo, between the latitudes of 11 degrees 27'N and 11 degrees 39'N and the longitudes of 11 degrees 23'W and 11 degrees 34'W. The land area of the Diaforé watershed is 60 km^2, or 6,000 ha.

The Diaforé watershed receives 1,200 to 1,600 mm of rain per year. mostly between April and November. Heaviest rainfall occurs from June-September. The dry season is considered six months long, between November and April, as early and late rains are not significant.

The principal watercourse in the watershed is the Diaforé, which flows southeasterly. The Kouratongo branch from the northeast flows in a southerly direction and joins the Diaforé near the village of Foreya. The Koumbama and Fulasso flow from the north between the Diaforé and the Kouratongo streams, join to become the Fulasso, and flow into the Kouratongo. The third major branch of the Diaforé is the Kouné, which flows in a northeasterly direction and joins the Diaforé near the terminus of the watershed. After

Typical landscape of termite presence, Diaforé

leaving the watershed, the Diaforé flows in an easterly direction and eventually empties into the Bafing, which later joins the Senegal River.

None of these watercourses has a continual flow all year round, although certain springs are permanent. During the dry season the Diaforé breaks up into a series of stagnant ponds within the stream bed where banks are up to 10 m high. The length, width, and depth of these seasonal swamps varies.

Estimates derived from aerial photos (1 to 30 thousand) subdivide the land into the following three broad physiographic types:

-50 percent bowal (3,000 ha)
-30 percent varied slopes, soil types, fallow, small forest areas (1,800 ha)
-20 percent alluvial plain, watercourses, and gallery forests (1,200 ha)

Further analysis of the aerial photos, 1985 Landsat imagery, and topographic maps from 1953 show a 48 percent increase in suntuurés and a 500 percent increase in exterior fields between 1953 and 1989. (This information considers not only the Diaforé watershed, but the adjacent Kabari watershed as well). This information was gathered during a study sponsored by NASA and undertaken at the University of Arizona with Guinean participation and support. The study did not include the Koundou watershed.

The watershed is characterized by extensive bowal (50 percent) that gives a very barren impression to the landscape. Closer inspection reveals small forest islands on these areas, wide swaths of mature gallery forest, and fallow lands in various states of regeneration. Species found include *Parkia biglobosa*, *Holarrhena africana*, *Parinari exelsa*, *Erythrophleum guineensis*, *Butyrospermum parkii*, and *Prosopis africana*. The area, generally considered a transitional savanna zone, is seasonally drier than areas of the Fouta Djallon to the south and west, and has more Sahelian tree species such as baobab.

The classified forest of Bakoun is approximately 20 km east of Kouratongo, outside of the Diaforé watershed boundaries. This 28,000 ha forest was legally classified in 1953. This forest constitutes a separate watershed basin.

The following, on the Dissa watershed, was taken from a 1992 report by Peace Corps volunteer Trevor Taylor.

B3. Dissa Watershed

The Dissa watershed is located between 12 degrees 25'N and 12 degrees 30'N longitude and 10 degrees 13'W and 10 degrees 20'W latitude, in the district of Wolia in the sub-prefecture of Souguéta.

Average rainfall is 1,900 to 2,000 mm annually. Average temperatures for the hottest months (March and April) are 26° to 35° C, whereas averages for the coldest months (December and January) fall between 14° and 19° C.

The vegetation of the Dissa watershed can be classified as a combination of open savanna woodland, bush woodland, light forests, and lightly wooded savanna bush. Much of the uncultivated land remains wooded, perhaps more so than the more densely populated regions of the Fouta. Similarly, in general, farmers leave land fallow for longer periods of time, allowing secondary grasslands and bush and wooded savanna to return.

Gallery forests are found along waterways and around springs. Dense forest stands are also maintained in certain areas for cultural reasons. There are a number of large rocky bowals, which are highly eroded and maintain only hardy grasses and bushes. Burning practices and grazing retard growth in these areas.

Two principal watercourses with numerous smaller courses are found. The Dissa branch flows southerly through the eastern edge of the watershed, where a complex network of streams feeds the Sangaran watercourse on the western edge of the watershed. The Sangaran flows easterly to the Dissa that continues southeasterly to the Kora, and the Kora flows west to the Kolente, which flows into the Atlantic. The majority of the villages in the watershed are located around the Sangaran branch and its feeders. Most of these watercourses dry up completely or break up into stagnant ponds, including the Dissa. Residents in Amaraya, where the Dissa meets the Kora, have noted greater than a one-m drop in the Kora during the rainy season over the past seven years. There are numerous springs throughout the watershed.

The Souti Yanfou classified forest is located just outside the watershed boundaries, 500 m to the west of Souguéta. It was classified in 1943, and is approximately 11,000 hectares. The flora and fauna of the forest seems to be quite varied. Locals claim that there are chimpanzees, monkeys, leopards, wild boars, and other wild animals inhabiting the forest. However, forest encroachment is restricting these animals to smaller and smaller areas.

SECTION III
LITERATURE REVIEW OF CURRENT TERMITE AND STORED PRODUCT PEST CONTROL STRATEGIES

A. Termites

Of nearly 2,500 species of termite species identified worldwide, some 300 are considered pests. Most are controlled via long residual pesticides, among them the organochlorines (Cowie et al, 1989). Even though their efficacy has been proven, danger of poisoning (applicators, and non-targeted animals), lack of skilled workers (Gray and Butcher, 1969), and their effect on the environment (persistence and leaching to the water table, etc.) present major drawbacks.

Cowie et al (1989) have reviewed common termite control in Africa and Indo-Malaysia. Wardell (1987) reviewed several control methods and also pointed out beneficial functions of the termite. Over and above the damage termites cause, there are many advantages to their presence and action in the environment:

- soil enrichment due to the biological wastes associated with their large colonies and varied source of nutrients derived from a wide range of foraging habitats
- soil aeration due to their tunneling, which facilitates water infiltration and cycles micronutrients from the sub soils, mainly in clayey, hard-pan soil
- modification of the soil texture
- food source for several predators, and man as well
- source of income—in the Diaforé watershed, alates (winged adults) were collected, fried, and sold in the market (50 FG/pile)
- their association with fungi and other micro-organisms represents a significant link in the food chain

The species in the genera *Macrotermes*, *Microtermes*, *Odontotermes*, and *Ancistrotermes* are the most damaging in Africa (Logan and al, 1990). Control of these pests is difficult due to their different biology. *Macrotermes* spp. build large epigeal termitaria (mounds) and forage underneath the soil through tunnels up to 50 m long (Logan and al, 1990), and attack plants at the base, ring-barking or cutting them (Cowie & Wood, 1989). *Macrotermes* and *Ancistrotermes* spp. build diffuse subterranean nests and attack plants from the root system to the stem. The hollowing from the feeding is usually filled with soil (Cowie & Wood, 1989). *Microtermes* live farther underground than *Macrotermes*. *Odontermes* spp. can have either subterranean or epigeal mounds. They attack plants when foraging under soil sheeting on the outer surface of the plants, and can cause important damage to the stem. Control measures are furthermore difficult to implement without specific knowledge of the species involved due to differences between species in a single genus in mode of attack.

Control has generally been through chemical methods, although the high risk involved is recognized. Alternative control methods include:

Mechanical/physical. Destroying the mounds, removing and killing the queen, installing physical barriers.

Cultural practices. Planting appropriate tree species; planting healthy and vigorous stocks; adequate watering prior to planting to reduce post-planting stress period; mulching; planting at higher density than required, then thinning; using susceptible plants to attract and trap the pest; burning and using wood ash; discouraging monoculture; using botanical derived extracts; etc.

Biological control. Not very popular, but promising in forestry: introducing or managing predatory ants; encouraging inter-specific competition by other insects, micro-organisms, and termites with the key pest; using *Bacillus thuringiensis*, *Beauveria bassiana* and nematodes; using termites as a food source, etc.

Chemical control. This method relies heavily on the cyclodienes' persistence. Several other pesticides, such as the organo-phosphates (OP's) chlorpyrifos, isofenphos, and pyrethroids, such as permethrin, are used. Bait formulations with Mirex, fungicides, or IGRs such Amdro and Logic are also available. For some, their application in forestry is not fully evaluated (Wood and Kambal, 1989). Research on the use of fungicides in agroforestry to cut the food supply of the subterranean termite by controlling the symbiotic fungi such as *Termitomyces* spp. has been documented (Wardell, 1987). The use of slow, controlled-release pesticide is attracting more attention (Canty, nd; Tamashiro, pers. comm.; Russel-Smith, pers. comm.; and Logan et al., 1990).

B. Stored Product Pests

In addition to the termites, stored products pests are of importance in Africa. Ezueh (1981) recognized the difficulty of quantifying the losses because of extremely variable and complex traditions influencing storage practices. The world annual storage loss for grains was estimated at 10 percent of annual production (more than 100 million tons). Losses up to 30 percent or more are reported (Ezueh, 1981). The maize weevil (*Sitophilus zeamais, Curculionidae*) has been reported in several African countries, attacking a wide range of stored products. Other pests such as the cowpea bruchid (*Callosobruchus maculatus*, Bruchidae), the flat grain beetle (*Tribolium* spp., Tenebrionidae), the lesser grain borer (*Rhizopertha dominica*), the larger grain borer (*Prostephanus truncatus*, Bostrichidae), and the angoumois grain moth (*Sitotroga cereallela*, Gelechiidae) are a few of those encountered.

Whitten (1992) recognized that control of storage pests is usually oriented toward physical and chemical techniques (Whitten, 1992). Farmers' attempts to control pests are usually limited to bulk storage, in clay pots, gourds, and basket storage. Crib building is common. Whitten (1992) reported that controlling insect pests in storage facilities has dealt mostly with physical and chemical techniques and that biological approaches are not a dominant intervention strategy. It is likely that bulk and bag storage will rely heavily in the future on sealed storage, controlled atmospheres, solarization, and sanitation.

Alternative non-synthetic chemical control methods are usually less emphasized. The use of botanical extracts is common. This approach, while promising, should be closely investigated due to the unknown toxicity class of most plant toxicants used. Also, no action is suggested in areas where termites are present but do not constitute a threat.

Damage to bananas caused by termites, Dissa

Further information on alternative control methods is found in publications such as *The IPM Practitioner*, *Common Sense Pest Control*, etc., which are good and valuable references. The review of Logan et al. (1990) is an excellent review of alternative and non-chemical control methods.

SECTION IV
CURRENT STATUS OF PESTS AND CONTROL MEASURES IN THE WATERSHEDS

Documentation on the watersheds' ethnography, geography, natural resources, and other pertinent information is provided in the baseline studies and other mission reports cited in the list of references (MARA/DNFC/USAID, 1993). Information on the current status of pests and pest management in the project area is lacking. To better address the problem at hand, a brief review of the status of pests, control strategies, and agroecology is necessary.

Three main agricultural activities prevail in the watersheds: field crop cultivation, gardening, and beekeeping. The field crops are mainly corn, rice, cassava, and *fonio* in outside fields, and in the fields located near or in the dwellings (*tapades*), vegetables, sweet potatoes, taro, cassava, cotton, corn, oranges, bananas, and mangos.

A multi-cropping system in the *tapades* is possible, due to the richness of the soil maintained by women through composting, deposit of any discarded organic matter, a protective enclosure against animals, and the ability of the women to invest time and effort. Usually, the younger the women, the richer the soil. The diversity of the terrain, richness of the soil, gender, and ecological zones determine the cropping system or pattern. The consultant's visit in the gardens and discussion with the women have resulted in several observations, and raise several issues.

Family and collective vegetable gardens are cultivated in the *tapades* near the improved water sources provided by the project. This is a new activity for most women, since they had not practiced gardening previously. Their interest is illustrated by their eagerness to learn and their receptiveness toward external technical input. In other villages, wherever water is not a constraint, the same apparently held true.

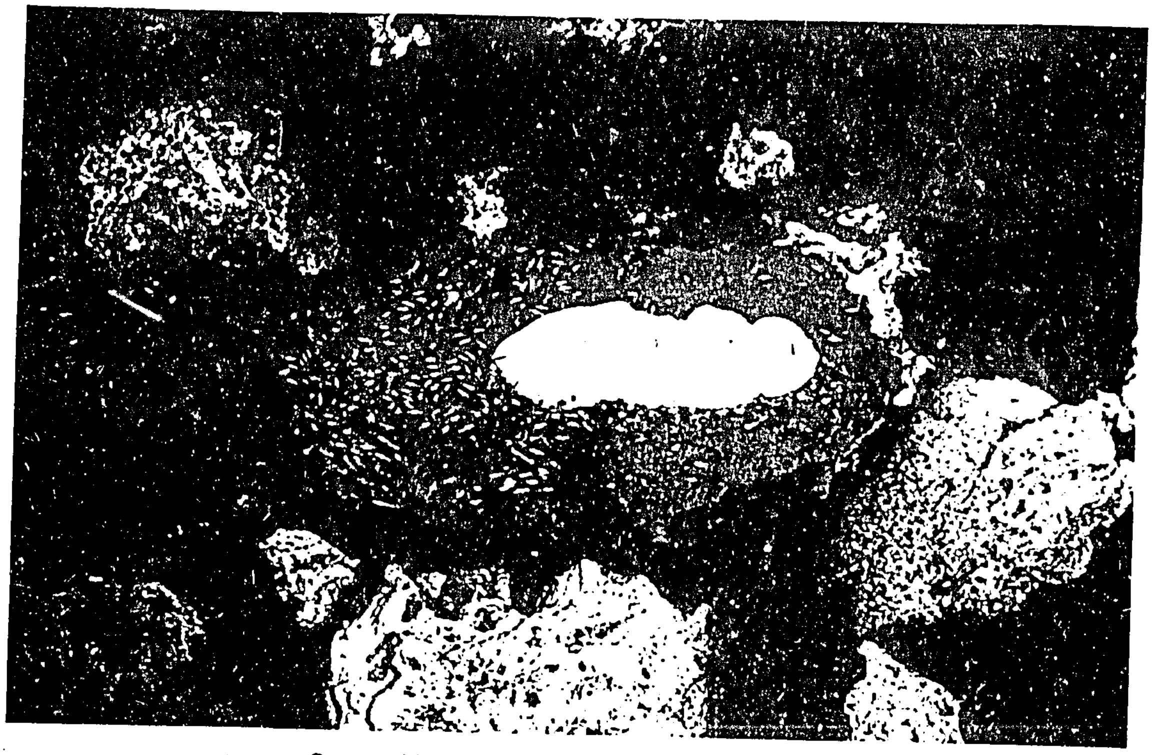
A. Termites

Termites have often been reported as among the most important pest problems in the watersheds. Based on observations of this writer, the termites are most severe in Diaforé. They cause damage on seedlings of corn, rice, peanuts, manioc, vegetables, wooden fences around orchards and nurseries or *tapades*, stored goods, wooden fences, and dwellings. Even though 33 species have been suspected (K.B. Paul, pers. comm.), no written source describing or indicating the species involved was located. Of these species, only one is theoretically causing the most serious damage; genera from the Termitidae family—*Macrotermes* sp., *Odontotermes*, *Microtermes* and *Nasutitermes*—seem to be prevalent. *Bellicositermes natalensis* was the only species identified in the plant protection laboratory at Foulaya, Kindia. Samples have been collected for further identification.

In the field, termites build conspicuous mounds of different shapes, ranging from dome-like structures of the *Macrotermes* spp. to umbrella-like mounds of the *Cubitermes* spp. (Wildlife Cons. Dept.; no date). The latter seem to be more frequent and in large number in the lateritic slopes of the bowal and in some open plains.

A1. Local Experience with Termite Control

Termite control is usually limited to physical destruction of the mound and removal and killing of the queen(s). If this operation is performed by the plant protection laboratory staff, chemical pesticide is applied copiously in the mound prior to closing it. This method was reported to be very efficient by the plant protection laboratory at Foulaya (Kalabane and Camara, 1989). Of 1,364 mounds treated in the prefectures of Labé, Pita, Dalaba, and



Queen with soldiers, workers, and guards, Diaforé

Mamou with either Basudine 10G, 60 EC, or Folidol E 605 (Parathion) formulation, 1,318 were completely inactivated, a 97 percent success rate. Farmers may either open the mound, kill the queen(s) if found and expose the colony to the sun to desiccate, to predation by chicken, birds, and ants, or pour some Néré (*Parkia biglobosa*) concoction from bark, leaves and pods inside the open nest before closing. Others will use ashes of the same species of Néré or Teli (*Erythrophyleum guiniensis*), known for its toxicant properties, especially in Ghana and Cameroon. Some farmers collect cow urine to drench the open mound. Kerosene ("*gasoil*") and the black powder found in batteries are also used. In some cases, incantations or talismans are made and deposited on the mounds or in the areas for protection; monkey skulls or chameleons may also be buried in the mound. The "flooding" method is also used: water from rainfall is channeled into the open mound to drown the colony.

According to villagers in Hafia (Dissa watershed, Souguéta), termite excavations around house walls constitute a refuge and entry hole for snakes and rodents into the houses. For them, this is a serious issue. Farmers reported instances where trying to cope with the termite resulted in so much damage that it became intolerable; consequently, the land or dwelling is surrendered to the pest.

A2. Report on a Large-scale Termite Control Program

For almost 30 years, the Republic of Guinea has been somewhat isolated from the rest of the world, resulting in an introspective way of thinking and communicating with the scientific community. This has resulted in lack of scientific progress, as evidenced by rudimentary plant protection activities compared with the work and documentation found in neighboring countries. Among the crucial issues, termite and storage pest problems have been identified and action toward their control recognized as a priority.

In 1989, the plant protection laboratory, during its termite control campaign in cooperation with the UNDP project funded by FAO (PNUD/FAO/GUINEA/86/004) in the *tapades* (home gardens), identified and treated 1,364 termite mounds with Basudine 10G, 60 EC at 200, 250, 300 and 350 ml or grams of the two formulations, and with Folidol E.605 at 100, 150, and 200 ml in the Prefectures of Labé, Mamou, Pita, and Dalaba. Additional 50 ml or 50 g of each formulation was made in the prefectures of Labé and Pita due to the abundance of rainfall during the treatment period. According to the report (Kalabane and Camara, 1989), 1,318 mounds were completely eradicated, resulting in 97 percent control. On a per-prefecture basis, Mamou had the highest mound count (426), followed by Pita (341), Labé (313), and Dalaba (284). In each prefecture, 411, 337, 290, and 280 mounds were destroyed respectively. The laboratory concluded that the pesticides used were efficient termiticides at any dose used. They recommended a second treatment at the beginning of the rainy season in areas that received only one application. Furthermore, the laboratory suggested that for more successful control, the extension agents (Conseillers Ruraux, CR) should educate the farmers on mound-opening techniques prior to the chemical application (Kalabane and Camara, 1989). Note that the laboratory agents have received, through USAID, a pest management training course from the Centre de la Protection des Végétaux, Dakar, Senegal.

In 1992, the International Fund for Agricultural Development (IFAD) sponsored a termite control program in the prefectures covered by the project: Lelouma, Tougué, Koubia, Mali, and Labé. Diaforé was not included in the project. A report was not available, but according to Mr. Baldé, results were satisfactory.

B. Weevils and Other Stored Product Pests

Storage of foodstuffs is handled several ways. In the case of maize (the main product stored), it is left on the cob and placed in bags, on top of wooden cribs inside the house, or hung from the ceiling frame. It can also be separated from the cob and kept in sealed bags, bowls, or clay jars. The container is either placed on top of the crib, set on a pedestal (wood, rock, other container) or simply left in contact with the soil. Cribs inside the house are usually built of bamboo above the fireplace, which provides heat and smoke to repel pests, but the maize grains will usually have a black coloration from the smoke and their germinating ability may be affected.

Several insect pests were noticed, ranging from the maize weevil, *Sitophilus zeamais* (Curculionidae: coleoptera), grain beetles such as *Tribolium* spp. (Tenebrionidae: coleoptere), and bruchids, (Bruchidae: coleoptere) mostly in the same commodity.

B1. The Maize Weevil

This pest (*Sitophilus zeamais* Curculionidae: Coleoptera) was the most abundant and most frequently found or reported. These pests damage grain by boring inside, feeding, reproducing, and excreting, leaving a powdery frass. In severe cases, 100 percent loss is possible. Nevertheless, women try to salvage as much grain as possible by sifting prior to cooking. The insects can be found outside the food source when infestation is severe, which makes their control difficult. Infestation can start from the field prior to harvesting. Adults mate and females deposit eggs on the maize at milky and dough stage. After harvest, larvae feed on the stored grain. Several generations are possible per year. The weevil can move in and out the cob, and can also be found in cracks and other hard-to-reach spaces (e.g. inside the bamboo sticks used for cribs). It was also found in cassava where its boring and feeding activity resulted in exit holes and powdery matter when the cassava was split open.

B2. Other Stored Product Pests

Other beetle species—the larger grain borer, *Prostephanus truncatus* (Bostrichidae: Coleoptera), the lesser grain borer, *Rhizopertha dominica* (Bostrichidae: Coleoptera), and the Angoumois moth *Sitotroga cereallela* (Gelechiidae: Lepidoptera)—were also mentioned by Saidou Baldé, the CAPV in the province of Labé, their damage being similar to the others.

The host range for these pests is broad, ranging from cowpeas, mainly attacked by the cowpea weevil, *Callosobruchus maculatus* (Bruchidae: Coleoptera), peanut, cassava, and rice. Samples of cassava and maize taken from a weekly market in Linsan Saran were infested or damaged by these insects.

B3. Local Experience with Stored Product Pest Control

At the farmer level, action is seldom taken, although sometimes ash or powdered hot pepper is mixed with the grain prior to storage. Cassava is sometimes cured by boiling and drying before storage. Chemical control by the plant protection laboratory is performed using Actellic Dust at 2 percent a.i. or Actellic 50 EC. Sidibé (1989) reported a large-scale treatment in 1989.

B4. Report on a Large-scale Stored Product Pest Control Program

In October-November 1989, the same team was also involved in a project on stored product pest treatment PNUD/FAO/GUI/86/004 (Sidibe, 1989). The areas of intervention were identified by the *conseillers ruraux* (CR)—extension agents—in the four prefectures mentioned above. Overall, 420 farmers were identified, but only 59 benefited from the treatment. In all, 122 kg of Actellic 2 percent P and 44 l of Actellic 50 EC were used to treat 200 tons of stored commodity (maize, cassava, peanuts, cowpeas, and rice). The report mentioned only the main pests found on maize (*Prostephanus truncatus*, *Sitophilus zeamais*, and *Sitotroga cereallela*). Maize was the commodity mostly found in the storage premises or the only one in adequate condition for treatment. Results obtained were satisfactory. K.B. Paul (1988) reported the efficient use of Actellic 1 percent in Rwanda at a rate of 1g/kg of grain, the equivalent of 10g/20kg of grain using the Actellic 2 percent.

Problems mentioned during the campaign included:

- Lack of earlier acknowledgement of the farmers receiving the demonstration treatment
- The timing of the operation conflicting with the farmer's schedule (field weeding, harvesting, surveillance, etc.)
- Insufficient numbers of bags to contain the commodity to treat in certain households
- Some reluctance by the farmers to implement the measures recommended
- Incompatibility of the technique with traditional control methods

The plant protection team planned to address these constraints in future operations.

C. Other Pests Found in the *Tapades* and Their Control

Grasshoppers. Their attacks are confined to the edges of vegetable gardens. The most frequent species was the *criquet puant* ("smelly grasshopper"), *Zonocerus variegatus*, (Acrididae: Orthoptera). The Senegalese grasshopper *Oedaleus senegalensis* (Acrididae: Orthoptera) was not observed but reported. Feeding was observed on eggplant leaves and cassava. Grasshoppers are usually in clumps or randomly distributed along the field edge, migrating from the weeds or neighboring mature crops. Control is usually not implemented except by planting bitter cassava; the latter was observed being chewed by grasshoppers.

Fruit flies. *Ceratitis capitata* (Tephritidae: Diptera) was reported on orange and mango fruits and on vegetables. Adults lay eggs in the fruit that will constitute the food source of the larvae and suffer a secondary attack by micro-organisms. Damaged fruits were shed on the ground and rotted, an important economic loss. No chemical control is reported by the farmer; destruction of the attacked fruit is the only method used.

Cassava mealybug. *Phenococcus manihotis* (Coccidae: Homoptera). The fixed forms of the mealybug cause severe damage to cassava plants. When the attack is severe, leaves and stems are covered with white powdery matter. Mealybugs feed by sucking and covering the stomates of the leaves, weakening the plant that subsequently wilts and dies. Similar damage by scale insects was observed on mango and citrus plants. No chemical control is undertaken by the farmer. IITA has been working on mealybug-resistant varieties and the release of natural enemies such as the parasitic wasp, *Epidinocarsis lopezi*, already in effect in 24 African countries (IITA, 1990).

Cotton stainer *Dysdercus volkeri* (Lygeidae: Hemiptera) was reported by the Koundou watershed team. They damage rice during grain filling by piercing and sucking the milky grain, leaving an empty paddy. Their presence was probably related to the existing cotton crop, where it attacks the boll prior to maturation. This results in discoloration of the lint, and consequently alters its quality. No chemical control was reported on rice.

A bollworm *Cleptophlebia leucotreta* (Tortricidae: Lepidoptera). The CA of Labé reported that the damage caused by the adult moth starts when the female oviposits on the orange fruit during its early development. When hatched, the larvae bore into the fruit to feed and grow. At the last stage, larvae exit the fruit and pupate in the soil near the trunk. The damaged fruit is shed by the plant. Important losses have been reported. Identification was done through the LPV at Foulaya, Kindia, and research is being carried out regarding its monitoring and control. Its presence could also be related to cotton, being an endocarpic feeder of the boll. At present, control is by manually dislodging the worm from the fruit and destroying it.

Weaver Ants. (Formicidae) on mango and citrus trees. Reported and observed in Lisan Saran, red ants (Formicidae) are more of a nuisance than an economic pest. Their territorialistic behavior is expressed by attacking intruders, sometimes to the point that farmers are unable to climb their fruit trees. Their nests are made of curled leaves, surrounded by silky webs, produced by the larvae from their silk glands. They tend scale insects inside the nest and feed on the honey dew secreted by the scale insects (Holldobler, 1990). No control method was mentioned.

The species found seem to be *Oecophylla longinoda*, the African weaver ant (Formicidae) already reported in the Old World; *O. smaragdina* is another species found in India, Queensland, Australia, and the Solomon Islands (Holldobler, 1990). These ants have been used for more than 1,600 years in China (The IPM Practitioner, 1992) to control pests found in citrus, mango, and several other tropical and subtropical fruit trees. They are known for being "violent, skilled attackers, moving from tree to tree in search of insect prey." In China, farmers use bamboo poles as bridges to make it easy for ants to move from tree to tree. This might be an applied research topic for controlling *Clebtophlebia leucotreta* on citrus trees. They have been tested in Ghana and proven to reduce incidence of most serious viral and fungal diseases of cacao, by controlling the mirid leaf bug vector of the pathogens and other tissue and sap feeding insects.

The plant protection team pointed out difficulties, such as lack of early identification of farmers to receive the demonstration treatment; bad timing of the operation (the farmers being busy with weeding, field surveillance, harvest, etc.); lack of storage bags prior to treatment for most farmers; and reluctance of some to abandon traditional methods or try the chemical method suggested. The team recognized these limiting factors and planned to consider them when organizing other similar operations.

SECTION V
REVIEW OF PEST MANAGEMENT STRATEGY AND PESTICIDE LEGISLATION

Information provided in this section is a synthesis of visits and interviews with national and prefectoral crop protection services, farmers, Guinea NRM project personnel, and documentation from various relevant sources.

A. Organization and Function of the Division of Crop Protection (DPV)

The Division of Plant Protection (DPV) is under the General Department of Agriculture (DGA), in the Ministry of Agriculture and Animal Resources (MARA). It is headed by a national director based in Conakry. The director is responsible for implementing pesticide regulation and control, as well as keeping agents up to date on usage techniques. It is equipped with a National Laboratory of Plant Protection located at Foulaya, Kindia, where fundamental and applied research are conducted. The staff of the laboratory work with farmers, chemical companies that have produced pesticides in the past, and project donors. They provide training and technical support to the best of their capacity. Visits to the Labé station, the plant protection service there, and the Foulaya Entomology Research Center reveal that the agents could definitely benefit from long- or short-term training and a minimum of logistic support; their performance would certainly improve. The station chief *(chef d'antenne)* of Labé, Saidou Baldé, could be a good candidate, considering his 10-year experience in termite control and his strong drive and interest in pest management. The laboratory in Foulaya also conducts pesticide screening tests and proposes recommendations from test results. The Division of Plant Protection is represented in each of the five provinces by a station chief and his assistant. In the 35 prefectures, there are three crop protection agents (agents de la protection des végétaux, APV). In the 336 sub-prefectures, agents of MARA (extension agents) act as liaison between the prefecture PV service and the farmers in their area of action.

The station chief is usually a university graduate from the Department of Agronomy, University of Guinea, and his assistant may have the same academic background or be from a vocational agriculture school. Both have a general background in crop protection from field experience, documentation, farmers, or short seminars. The station chief and his assistant monitor and coordinate all the prefectures in a province, and report to the laboratory at Foulaya. The station chief is also in contact with the projects that operate in his domain. He/she acts as an advisor or consultant, and sometimes gets involved in activities related to pest management in a given project program. In Labé, the station chief's means of transportation is limited to a motorcycle used to cover the whole province. Since 1989, no funds have been allocated for supervising activities (monitoring, scouting, etc.).

At the prefecture level, one plant protection agent and two assistants are responsible for pest management activities. They report to the station chief of their province. According to the agents, each prefecture has a storage unit where the pesticides and application equipment are kept. During one visit to a prefecture, the consultants noted a limited level of understanding of pest management of the two agents contacted.

The consultant did not visit any sub-prefecture agricultural service, but it was reported that crop protection activities are carried out by extension agents who report to the prefecture supervisor. These are the ones more in touch with the farmer. But due to the lack of transportation and incentives, periodic pest monitoring information is not well documented.

The chart below shows the structure of the DPV in Guinea.

Ministry of Agriculture and Animal Resources (MARA)
(Ministère de l'Agriculture et Ressources Animales)

Department of Agriculture (Direction Générale de l'Agriculture—DGA)

Division of Plant Protection (Division de la Protection des Végétaux—DPV)
Control and Phytosanitary Legislation
Crop Protection and Registration Procedures
Crop Pest Inventory and Monitoring
Postharvest and Storage Loss Assessment

Province (Regional Level)
Crop Protection and Stored product Laboratory at Foulaya, Kindia.
Five Laboratory PV Stations (Antennes): Labé, Boke, Kankan, Nzérékoré and Kissidougou

Prefectures (Total of 35)
Labé, Boke, Kankan, Nzérékoré, Kissidougou, Conakry I, Conakry II, Conakry III, Tougué, Koubia, Dalaba, Mamou, Koundara, Pita, Coyah, Gacul, Forecariah, Faranah, Lelouma, Boffa, Dabola, Mali, Kouroussa, Gueckedou, Dubreka, Siguiri, Macenta, Fria, Kindia, Mandiana, Lola, Telimele, Kerouane, Yomou, and Beyla.

B. Pesticide Registration Process

Law L/92/028/CTRN of August 6, 1992, regulates Pesticide Registration Procedures, PRP (see Annex B). Presidential decree D/94/044/PRG/SGG of March 22, 1994, ratifies and implements the Pesticide Registration Law (Annex C).

The PRP law is composed of four titles:

Title I contains two subtitles, and deals with general background information (definition of terms of reference).

Title II has 11 subtitles, describing and specifying the policy of pesticide management in the country. Provisions are made regarding importating; processing; storage; screening trials; sales; creation of a registration committee; chemical, physical or biological alterations of pesticide formulations; intended use; restricted use; packaging; proper management of the pesticides by licensed sales representatives, etc.

Title III with seven subtitles deals with fines and other related penalties for misuse and mismanagement.

Title IV with two subtitles reiterates the general provisions and establishes this document as a national law.

Certain pesticides are no longer allowed to enter the country, and their use is either restricted or banned. The FAO program officer in Conakry provided the list of six pesticides Guinea has included as Prior Informed Consent pesticides under the International Code of Conduct for the Distribution and Use of Pesticides (MARA #2653/MARA/CAB; 1993):

- Chlordane
- Chlordimeform
- Cyhexatin
- Ethylene dibromide (EDB)
- Heptachlor
- Mercury-containing compounds

Therefore, these should not be used in the GNRM project areas.

Demonstration with farmer participation, Diaforé

Law L/92/027/CTRN of August 6, 1992 (Annex A), regulates the quarantine on import/export of plant materials. The law requires mandatory declaration and a legal phytosanitary certificate stating that the product (plant, fruit, by-product) has been treated and/or is free from any potential infestation. This certification should be carried out by the phytosanitary inspectors selected by the Department of Plant Protection. The control is theoretically implemented at all harbors, airports, and main roads at borders, but at the time of the consultant's visit to the department there was as yet no decree to implement the law.

C. Pesticides Used or In Stock

According to the station chief in Labé, the pesticides mentioned below represent those most frequently used in Guinea. They are authorized by the laboratory.

Pesticides are categorized according to their toxicity, which is usually expressed as the amount of pesticide (in mg) for each kg of body weight that a given population tested should be exposed to (oral, dermal, inhalation) to have a 50 percent mortality. The lower the amount of pesticide needed, the more toxic the compound, and the lower the category rank (Category I, II, III, IV). Wording on the label is also function of the category assigned to the pesticide (i.e., danger, warning, caution).

Table 1. Classification of Pesticide Toxicity by Category and LD50 (mg/kg)

Cat.	Description	Oral LD50 (mg/kg)		Dermal LD50 (mg/kg	
		Solid	Liquid	Solid	Liquid
Ia	Extremely dangerous	>5	<20	10	<40
Ib	Very dangerous	5-50	20-200	10-100	40-400
II	Warning	50-500	200-2000	100-1000	400-4000
III	Caution	>500	>2000	>1000	>4000

Source: Wilma Arendse et al. Agrodok-series no. 29. Agromisa. CTA. 1989.

Table 2. Lethal Dose Estimated for Humans, as Function of LD50 Values

Oral LD50 (mg/kg)	Estimated Lethal Dose
<50	Few drops or the tip of a knife
5-50	From a knife tip to teaspoonful (5 ml)
50-500	From one teaspoonful to 2 tablespoonsful (5-30 ml)
500-5000	From 30 ml to 0.5 l

Source: Wilma Arendse et al. Agrodok-series no. 29. Agromisa. CTA. 1989.

In the prefecture of Labé, a visit to the storage unit and discussion with the crop protection agents showed an inventory of the following pesticides:

Sumithion 50 EC (Fenitrothion): Broad-spectrum OP insecticide used on field crop pests, locusts, grasshoppers, and termites.

Ofunack 40 EC (Pyridaphenthion): Broad-spectrum OP insecticide with low mammalian toxicity registered for rice, cotton, beans, potato, maize, fruits, and gardens. It is compatible with most insecticides and fungicides. Donated by Japan. Made by Mitsui Toatsu Chem. Inc. It is not for sale in the U.S., and is not featured in the "Rainbow Report" (EPA 1992) on the status of registered pesticides and special review. Therefore, its use should not be considered by the Guinea NRM project.

Oftanol 5G (Isofenphos): Highly toxic (Category I). Broad-spectrum OP insecticide. Not recommended for use.

Basudine 60 EC and 10G (Diazinon): A broad-spectrum OP Category II (oral rat), III (dermal and inhalation), IV (irritation). It is hazardous to fish and wildlife. However, the "Rainbow Report" (March 1992) supported its use, awaiting more data. It is used in termite control by LPV at the rate of 200-350 ml/mound for the 60 EC formulation, and 200-350g/mound for the 10 G with equal success. The amount used was a function of mound size.

Folidol E. 605. Parathion. *Not to be considered by the GNRM project.*

Dursban (Chlorpyrifos and Chlorpyrifos-methyl): Broad-spectrum OP insecticide registered for use on grain crops, storage, empty storage, domestic dwellings, earthen structures, direct application to stagnant water, poultry, sheep and dogs, beef cattle, fruits and vegetables, etc. The methyl form is less toxic: acute oral 1,530 mg/kg, and acute dermal of more than 2,000 mg/kg (Category III). It comes in EC or dust formulation. For termite split-open mound and closing after treatment, use the granular formulation if available at 200-400g/mound, depending on mound size. Dust formulation is preferable to the liquid formulation.

Actellic 2 percent (Pirimiphos-methyl: A widely used OP insecticide for storage pests with an oral acute toxicity of 2,050 mg/kg (Category III) and an acute dermal of 1,505mg/kg (Category II), and irritation (Category III). It is toxic to fish and other wildlife. Registered for stored maize, rice, wheat, and sorghum. It has demonstrated adverse chronic effects and does not have any domestic tolerance; the latter is proposed to support consumption of treated grain. It is widely used in several countries in West Africa, including Guinea.

Super Homai 70 percent WP (Kitazin): This is a fungicide and insecticide composed of 35 percent methylthiophanate, 20 percent Thiram, and 15 percent Diazinon. Additional information was not available; however, it looks promising in seed treatment but not for food items. It was a gift from the Nippon Soda Co. Ltd., Tokyo. Japan. Its use could be recommended, as it is registered and in good standing with EPA.

Other pesticides include:

Diphacinone 0.005 percent (Yasodion): Anticoagulant rodenticide. Gift from Japan, from Ohtsuka Chemical Industrial Co. Ltd.

Dithane M.45 80 percent (Mancozeb): Fungicide. From Rohm & Haas Corporation

Jet VP 30 percent (Dichlorvos): Fumigant. From Nippon Soda Co. Ltd.

Cyalothrin 100 G/L EC (Cyhalone 10EC): Pyrethroid insecticide.

Cyfluthrine EC 050: Pyrethroid insecticide.

D. Other Pesticides or Nonchemical Control Methods

Under "other pesticides and methods" the following should be considered: botanical insecticides, biorational pesticides, lower rates of synthetic pesticides, innovative methods for pesticide application, and pesticide rotation to prevent buildup of resistance.

Botanical insecticides are insecticides derived from plant materials. Farmers have been using them with some success for centuries, and modern scientists are rediscovering them as a way to avoid synthetic pesticides. Another advantage is that they can be produced at low cost on small farms from flowers, leaves, stems and roots, etc., or industrially. As of mid-1993 in the U.S., the following natural insecticides are registered by the EPA and most are available commercially: **azadirachtin** (the primary insecticidal ingredient from the neem tree), **capsaicin** (from hot chili peppers), **garlic**, **sesame oil**, **rotenone**, **pyrethrum**, **ryania**, and **sabadilla**. Some of their registrations (by the U.S. EPA), derivation, EPA toxicity category and acute oral and dermal LD50 values are summarized in Table 3 below. They are all of relatively low toxicity, which makes them worth considering further for use in Guinea, but only after sufficient testing. *Plant-derived pesticides not registered with the USEPA cannot be extended to farmers or promoted commercially where U.S. funds are involved. Experimental use on less than 4.0 ha (10 acres) is permissible.*

Table 3 presents botanical products presently registered with the USEPA.

Reduced rates of application. Sometimes lower than recommended rates of certain synthetic pesticides can still satisfactorily control pests. For example, the FAO-funded termite control trials in the Labé region determined that there was no difference in efficacy for termite control between 200 g and 400 g of Basudine per mound. Thus, one should choose the lower amount.

Biorational pesticides include viruses, bacteria, fungi, and protozoa, and chemical analogs of naturally occurring biochemicals, such as avermectin. The most plausible biorational pesticides with immediate potential in Guinea, are the fungi *Beauveria* and *Metarhizium*. These pathogens are showing great promise as grasshopper control agents.

Other Methods for Insect Management:

- Biological control: conservation, augmentation, inoculation, and habitat manipulation with parasites, predators and pathogens
- Plant resistance (natural, and through breeding programs)
- Environmental manipulations: plant spacing, intercropping, timing of planting and harvesting, crop rotation, water management, fertilizer management, soil preparation, sanitation, trap crops
- Physical and mechanical control: screens, traps, protective packaging, barriers, flaming and burning, hand picking
- Attraction and repellency: attractants, repellents

Table 3. Characteristics of EPA-Registered Botanical Insecticides

Insecticide Name	Derivation	Registration	Toxicity Category	LD50 Oral/Dermal (mg/kg)
Azadirachtin	*Azadirachta indica*	'Align' on fruits/vegs roots, tubers	IV	>5000/>2000
Capsaicin	*Capsicum frutescens*	'Hot sauce' animal repellant	III	- / -
Garlic	*Allium sativum*	'Garlic barrier' vegs, citrus	-	- / -
Sesame oil	*Sesamum indicum*	'Sesamex' a pyrethrum synergist	III	2000-2270/ -
Pyrethrum	*Chrysanthemum cinerariaefolium*	Many products stored food grains, pets	III	1500/>1800
Ryania	*Ryania speciosa*	Many products citrus thrips, Eur. corn borer, codling moth	III	1200/ -
Sabadilla	*Schoenocaulon* sp.	- -	III	- / -

Insecticide Name	Derivation	Registration	Toxicity Category	LD50 Oral/Dermal (mg/kg)
Rotenone	*Derris, Tephrosia, Lonchocarpus*	Many products garden dusts, animal ticks	III I	132-1500/ - (EC formulation)

Note: Hyphens indicate data are not available. The label of 'Garlic Barrier' insect repellent has the signal word "CAUTION" with the admonition to avoid contact with the eyes, and if in them to flush with plenty of water. The empty, thoroughly rinsed container can be disposed of in household trash.

E. Pesticide Manufacturing Company or Representation and Handling

At present, Guinea does not have any pesticide manufacturing or reformulating/ packaging plants. According to the Labé station chief, most of the pesticides in the country are gifts from donors such as Japan. All the pesticide stocks are located in the national headquarters or at the prefectures' warehouses. Pesticide is issued upon a plant protection agent's request and approval by his superior.

Manufacturers such as ALM International (in more than 26 African countries) are represented in Guinea by SAREF International, Conakry. According to Aref Talal, the chemical product manager, SAREF provides phytosanitary, veterinary, and pharmaceutical products from several related companies (Bayer, Sanoufi, ICI, Marubeni, 30 percent of Dow-Elanco). Actellic is also sold by the company, as well as protective equipment (applicators, clothing, gloves, goggles, masks, etc.). SAREF sells both to the government and to private users (homeowners, farmers), and provides technical assistance through its support system headed by an agronomist/ pesticide specialist. Records of the different products were available.

SAREF's storage facilities could not be visited since it was the week-end, but Mr. Talal told us the pesticides are stored in warehouses adjacent to the main office building. Since the company is located in the center of Conakry, this presents a serious hazard that should be avoided. When asked about disposal of expired pesticide, he said that the company does not have this problem, since it avoids overstocking by ordering any authorized product requested and receiving delivery within two weeks. From this, the authors concluded that the company lacked a disposal or landfill site and contingency waste management strategy.

Other companies, such as Ciba Geigy and Rhone-Poulenc, were said to be represented in Guinea, but could not be located and verified.

F. Visit to the Pesticide Storage Building of the Labé Prefecture

The storage building in the Labé prefecture is of concrete block, with sturdy locks. Ventilation is insufficient. Pesticides were stored in 200 l or 20 l barrels for the liquid formulation, and in their original boxes and paper or plastic bags for the dust and granular formulations. Two 20 l vegetable oil plastic containers were used to store Ofunack 40 EC left from previous use. Fumigants were kept in their original cans. A new large size sprayer was still in its original box. There was no water source in or around the building for emergency showers.

The building is big enough to be an improved storage facility. There are no shelves to hold the pesticides, and other materials such plywood, cement, and non-related items share the same building, which could favor poisoning. The cement floor needs to be cleaned of dust since traffic inside may stir it up and cause it to be inhaled. No warning sign was on the door or around the building, but the entry to the building was well secured. A conspicuous sign should be provided (Attention! Danger!). The storage unit also needs to be fenced to keep wandering livestock and children away.

It was reported that some products had expired, but could not be discarded; therefore, they were left in the warehouse. When asked about landfill and disposal, agents said there was no functional pesticide waste disposal policy or facility. This is a problem not unique to Guinea, and should be addressed by an environmental management activity or project that will at the same time provide pesticide training courses for local technicians.

NB: During a two-to-three-hour meeting with the Labé prefecture team, it became obvious that two of the three agents (the head of the PV service was absent) did not have adequate knowledge of pests and pesticide management. This is a serious issue that should be addressed before giving them supervisory functions on large-scale pesticide application campaigns. They did in fact request better training and to be equipped with protective gear (not found in either the province or the prefecture offices).

SECTION VI
DISCUSSION AND RECOMMENDATIONS

A. Discussion

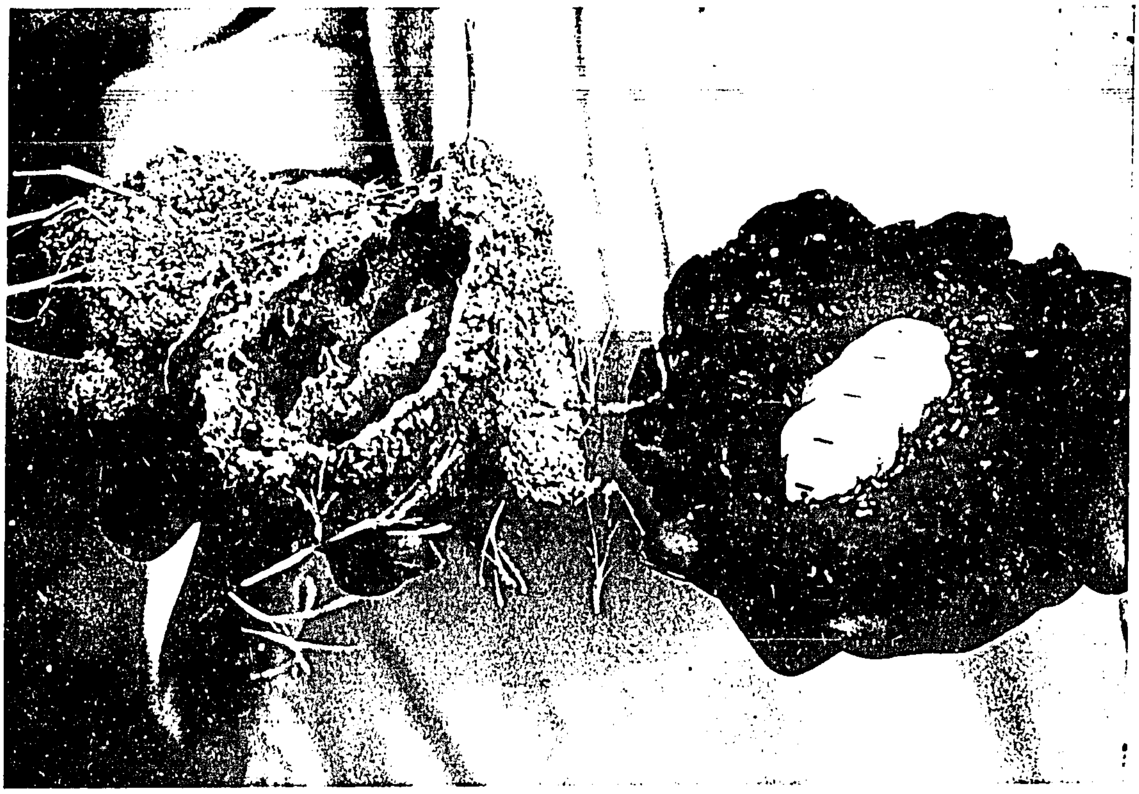
In general, farmers were at first reluctant to mention any means of controlling the pests they reported. This was not at all surprising, since they had heard rumors of possible help by use of chemical control. What became clear was that the gravity of the pest situation in the three watersheds varies according to the ecology of the area, land availability, and land and pest management practiced.

The Dissa watershed seems the least affected by termites, even though their presence was obvious. Farmers were far more concerned about sporadic attacks of grasshoppers in the vegetable gardens and cassava nurseries, and weevils in stored maize and cassava. Immature grasshoppers could be controlled by trapping those already at the edge of the field with rows of plants to keep them from progressing farther. Bait formulation of Diazinon or Fenitrothion would be safer to use than emulsion concentrate formulation. The farmer can also break the soil to disturb oviposition and destroy the grasshopper eggcases, which requires knowledge of the grasshoppers' egg-laying habits. In dwellings, physical and mechanical controls can be used against the termites. The approaches are described below.

Storage techniques could be improved by using a few simple precautionary measures. Most of the goods in the houses were stored directly on the mud floor or in cribs (*miradors*) made of bamboo, themselves exhibiting exit holes of wood-boring beetles. The premises should be checked for infestation prior to storing. Selection of seeds and food grain to store should be made in the field.

In the Koundou watershed, weevil, fruit worm, and ant activity on citrus and mangos was more noticeable. Termites were present but did not seem to be a serious problem. The collective gardens could be an ideal on-farm training site. The women are very involved and most are new to vegetable gardening. Composting, ash broadcasting, and observation of more frequent pests and beneficial insects in the garden constitute a good practice. There was not enough gardening activity to fully assess the pest problem, since it was the dry season, but seeing ants attacking termites and several parasitic tachinid flies was an occasion to introduce the concept of biocontrol to the women.

In the Diaforé watershed, termites—as well as a shortage of water—were major issues. The lack of arable land and overuse (reduced fallow) of the external fields has forced man and pest into direct competition for crops. The villages of this area are already very poor. They had relied in the past on orange sales to Senegal for income, while using cassava, maize, rice, peanuts, and vegetables for food. With the severity of termite and *Cleptophlebia leucotreta* (moth larva attacking orange fruits) attacks, both income and available food supplies have decreased drastically.



Termite queen chambers, Diaforé

A cost/benefit analysis for pesticide use in the treatment of subsistence crops is not appropriate, since one cannot put a dollar value on action pertaining to non-lucrative activity. Infestation of the area is not sufficiently serious to justify resorting to chemical control of the whole zone; however, spot treatment of crucial selected mounds is indeed advisable. This will also help prior measures undertaken by other projects (PNUD/FAO, 1989). The large-scale termite control campaign funded by IFAD in 1992 did not cover the Diaforé watershed, except for part of Tougué Prefecture. No additional information was available in this regard.

Overall, each watershed could make seed stocks more secure by using improved storage techniques that are already available. Furthermore, the use of seed treatments:

- Actellic 1 percent or 2 percent at label rate for food stored products,
- A binary (fungicide and insecticide combination) such as Super Homai (readily available and in stock)

on non-food products (seed) would enhance storage life and stability.

B. Recommendations for an Integrated Pest Management Program

B1. Termite Management

Synthetic chemical pesticides, persistent chlorinated hydrocarbons, were the most prevalent means of controlling termites. However, their hazardous effects constitute a major drawback and alternative approaches should be explored. In African countries, pesticides are not well regulated, and not always available on a timely basis or used appropriately. They are usually still donated by foreign assistance. Application is often undertaken by local government agents with little participation by the assisted farmer. Yet local practices and less toxic measures have been developed by farmers and in certain instances have shown surprisingly satisfactory results.

B1a. Control in Fields and *Tapades*

B1a(1). Mechanical Destruction and Chemical Treatment of Mound

The mound will be inspected to see if it is live by monitoring activity in or around it. Indications could be workers, guards, and soldier termites near fresh excavations, foraging activity during early morning or late at night, and the presence of insect predators around the mounds (dragonflies, ants, birds, small reptiles, etc.). Once the presence of the termites is confirmed, opening the mound is carried out by splitting it from the top third and digging a trench toward the center to reach the queen's chamber(s). After removal of the queen, 200 g/mound of a Diazinon 10G formulation or Chlorpyrifos in this case is sprinkled on the nest to reach the tunnels. If this chemical is not available, botanical extracts of Néré or Teli or other known toxicants are deposited (in the form of liquid solution, ash, or ground material) in the nest before closing it back up. The project's agroforestry activities should encourage the introduction and/or wider planting of plants such as Neem (*Azadirachta indica*, *Cassia siamea*, several *Euphorbia*, *Acacia*, and *Terminalia spp.*, known for their ability to resist, repel, or tolerate termite attacks. These plants, in addition to native species such as Néré (*Parkia biglobosa*) and Teli (*Erythrophleum suaveolens*), could be used to reforest and treat mounds. The treated mound should be marked using signs, branches, or other devices to keep people and animals away. It should also be regularly monitored for any occurrence related to the treatment applied and to evaluate the treatment's effectiveness.

B1a(2). Use as a Food Source

Once the active mound has been split open and the queen removed and killed, it is left exposed to the elements and predators. Some termites are also collected by children or adults and are considered a delicacy in some areas. Fried alates, for example, were sold in a Diaforé weekly market at 50 FG per serving. This could be a good source of protein supplement in areas with severe food shortages prior to harvest ("*période de soudure*," usually July-August). Death of exposed termites can also be achieved via desiccation by the sun.

B1a(3). Protection of Seeds and Seedlings

In the *tapades*, several preventive measures could be implemented:

- Treat potting soil with a binary formulation of a fungicide and insecticide (such as Super Homai) prior to potting to minimize termite attack, since termites could be already in the soil prior to potting. The use of the product is of course subject to EPA approval and should not be considered as endorsed by the writers.

- Select vigorous, resistant stocks as live fences. Several plants have been known for their rapid propagation. Most Euphorbiacae, Hypericacae such as Kiidi (*Jatropha curcas*), and Fabacae such as indigo plant (*Indigofera tinctoria*) are readily available.

- Avoid unnecessary root pruning and allow sufficient time after the operation for recovery. This will allow the young plant to repair damaged tissue and reduce its vulnerability to termite attack.

- Seed treatment could be made with ashes from the botanicals mentioned above, although any ashes may be useful. Diazinon or other seed treatment product could be added as supplement.

- Water nursery stock prior to planting, which will reduce stress associated with transplanting.

- Observe proper timing for planting seedlings. Begin planting soon after the first annual crop is sown and when the soil registers a good field capacity to a depth of 20-30 cm.

- Plant an excess ("overplant") to anticipate possible loss due to termites. Thinning the excess could be performed later if necessary.

- Use plastic potting containers filled with treated soil. During planting out, the soil dug should be mixed with ash or a recommended chemical. The plastic sleeve should be kept to hold the potting soil and allow 3-5 cm of the tubing above the ground.

- Construct a pedestal or elevated wooden or concrete support for placing the seedlings. In areas where palm trees are available, the Ronier (*Borassus ethiopium*, Palmae) plant is recommended as termite-resistant.

- Provide an alternative food source to termites to lure them away from seedlings. This is done by refraining from completely clearing soil litter or uprooting weeds, but rather trimming them around the seedlings. Alternatively, a row of cut banana pseudostems (if available) cold be planted around the perimeter of the nursery. Some pitfalls are to be considered, however, such as the possibility of termite buildup.

- No action: learn to live with termites if their presence is not a threat; this is achieved by setting a threshold for action if they become a problem.

B1b. Control in Dwellings

New non-chemical approaches—from mechanical/ physical to biological methods—are gaining attention for subterranean termite control in infested areas. Due to conditions in the watersheds, the emphasis will be on mechanical and physical measures. Physical barriers may be used to exclude termites from dwellings. The approach described below could be sustainable in the watersheds.

Termite damage to mango roots, Diaforé

B1b(1). Sand Barriers

The Ebeling technique (Daar, 1990) consists of building a sand barrier around the house to protect it. This has been field tested on buildings in developed countries since the 1950s and found very effective under certain circumstances. The principle is simple. Sand barriers act as a physical shield to termites. A 50 cm-wide continuous pile of sand or grit small enough to sift through a 16-mesh screen is placed along foundation walls on the soil surface or in a trench. The technique calls for a 5 cm-deep barrier adjacent to the wall, feathering out to a 1.30 cm- depth at the outer edge. **This could be a topic for applied research prior to adoption.** Recommended: a deeper trench (20-50 cm) owing to the severity of the problem.

Sand mining is a common activity in the watershed areas. Most sand is composed of sharp crystals of silica and other hard rock. When termites try to bore through the barrier, abrasion of the cuticle of the head capsule will lead to desiccation or micro-organism invasion and death. In areas where the availability of sand is limited, an alternative could be fine lateritic gravel, found almost everywhere in the watersheds. Monitoring will be by frequent check and destruction of any tunneling or termite presence. Sound building materials should be used to enhance the success of any control method.

B1b(2). Use of Used Engine/Transmission Oil to Treat Fence Posts and Building Materials

Used engine or transmission oil can be collected from urban areas or in the villages. Fence posts can be dipped in the oil before installing them, and a coat of oil painted along the fence up to 20-40 cm high. The oil in the wood may be a good termite deterrent. If the fence is permanent, oil can even be mixed with the soil below. Building materials could also be treated this way. Oil may also be applied to the house roof; this will at the same time reduce the disposal of used oil. Another topic of applied research that could be tested.

B1b(3). Cow Manure as a Wall and Fence Coating

Cow manure can be collected and diluted to a slurry. Ash of various botanical deterrents can be mixed in the slurry and painted on the wall. This practice is common in some rural areas of Senegal; it is yet another topic of applied research to be tested.

B1b(4). Use of Concrete Walls and Floors

Houses visited made of concrete block walls and cement floors were not attacked by termites, or much less so.

B1b(5). Néré Pods on Hut Roof

Néré and/or teli pods can be collected and placed on thatched roofs. The exudate gradually released from leaching by the rain will give a brownish color to the straw, and the toxicity or repellent property of the extract will keep termites away. The pods can also be tied on main branches of mango trees or other trees as protection. Ash can be broadcast on roofs or along fences where it is also reported to control snakes. Botanical-rich rotenone (*Derris*, *Lonchocaprus*, etc.) could also be considered wherever available. These could be additional topics of applied research to be tested.

B2. Storage Pest Management

It is through a combination of sound storage practices that satisfactory results will be attained. The use of Actellic 2 percent at a rate of 10.0 g/20 kg of grain is recommended, but only after sound storage measures have been put into practice:

- **Carefully select good quality seed** by removing cracked, immature, and infested seeds. Look for frass or foreign bodies (dead insects, etc.).

- **Avoid excess humidity prior to storage.** More than 12 percent will favor seed deterioration.

- **Sanitation is a must.** The premises should be clean and disinfected. Actellic can be used before storing.

- **Combine several suggested techniques** to minimize pesticide usage and exposure. Some examples:

  - Solarization: expose seeds to sunlight to force any insect out or to kill them by desiccation. This also will reduce excessive seed moisture content.

  - Vegetable oil: the addition of a small quantity of oil in the product to store, and on bags (Raqib et al, no date; Dunkel, 1992) can protect the grain from attack by several stored product pests

  - Ash: mix the grain with wood ash prior to storage

  - Mix hot pepper or garlic powder (Rodale, 1992) with the grain

  - Boil grain/tuber: curing grain and cassava tubers can improve their resistance to pest attack

  - Sand: the abrasive effect of the silica and other sharp-edged particles reduces insect movement in the stored product

  - Disturbance: periodically overturning the barrel, jug, or other sealed container will prevent the insect from feeding or laying eggs

  - Hermetic seal: air-tight closures will lead to depletion of the oxygen inside the container, and will result in the insects' asphyxiation and death

  - Harvest on time: shortly after physiological maturation

  - Biocontrol: use of *Beauveria bassiana* and *Bacillus thuringiensis*

  - Erection of rat/insect proof cribs

  - Knowledge of pests and beneficial insects

  - Careful use of botanical extracts: neem oil, néré, etc.

For any agricultural activity to be successful, *education and sensitization* of farmers and extension agents on insect biology, recognition, and control, (e.g., organizing a termite awareness week or month) is a must. Training, sensitization, and demonstration are effective means of communication. Furthermore, farmer involvement through a participatory approach is a good vehicle. This will necessitate good training of the plant protection agents. Mr. Baldé, for example, could benefit from a short-term visit to a termite research center such as the Natural Research Institute in England, or elsewhere in Europe or Africa. He has ten years of experience in termite control and could be very valuable when well trained. He seems to have satisfactory training in pest control and is eager to learn more, and could be highly effective as a termite specialist, being from the area and readily available.

SECTION VII
MANAGEMENT OF PESTICIDES UNDER THE GNRM PROJECT IN RELATION TO USAID ENVIRONMENT AND PESTICIDE PROCEDURES AND THE SCOPE OF WORK

Recommendations of pesticides used are made to ensure the Guinea NRM project's full compliance with EPA guidelines. The pesticides proposed are justified below.

A. EPA Registration Status

The revised list of chemicals proposed by the Guinea NRM project—Diazinon, Chlorpyrifos, Pirimiphos-methyl—and those also proposed by this assessment—malathion, Bacillus thurengiensis, the three-compound product of methylthiophanate + thiram + Diazinon—are all registered and approved by the EPA.

B. Availability and Effectiveness of Other Products or Non-chemical Control Measures

At the farmer level, pest control is limited to empirical measures applied inconsistently. None of them have been fully and conclusively tested although some seem promising (botanical control measures, for instance) and merit further research. Pesticides other than those supervised by crop protection services are purchased in the marketplace or illegally imported from neighboring countries. Such products are either adulterated or not used properly (wrong crop and pest). When control is carried out or supervised by crop protection services, more success was reported. The pesticides proposed are also available to the plant protection staff.

C. Extent To Which Proper Pesticide Use is a Part of an Integrated Pest Management Program

The use of the recommended pesticides will be part of a systematic approach. Existing practices and other relevant control measures (cultural, mechanical, physical, biological) will be fully exploited. The amount and formulation type to use will be wisely selected to minimize misuse, exposure, and contamination without hindering efficient control. Precautionary measures will be respected to the fullest extent (label instructions, etc.).

D. Proposed Methods of Pesticide Application

Whenever possible, granular formulations will be used, mainly in mound treatment, with all preventive measures implemented. These include but are not limited to use of protective clothing, goggles, masks, gloves, abundant supply of water to use in case of spills, antidotes such as atropine, and choice of proper time for treatment (early morning or late afternoon) to minimize exposure of non-target organisms such as livestock, bees, and children.

E. Acute and Long-term Hazards

Respecting the measures mentioned above will minimize human and environmental hazards. The chemicals to be used are relatively safe when handled properly; most of them belong to Categories III and IV (see table of classification on page 26).

F. Compatibility of Proposed Pesticides with Target and Non-targeted Organisms

In the case of mound treatment, placing the chemical inside the open mound and then closing it will keep the pesticide in the treated area and on the target. For treating seeds, drift will be minimized since all application will be handled and supervised by trained plant protection personnel.

G. Provision for Training Users and Applicators

All operations will be handled by trained plant protection laboratory agents. They will be given refresher training on good application practices through seminars and workshops. Pesticide safety data sheets will be provided. Farmers receiving the service should also be trained on pesticide management and pest/beneficial insect awareness.

H. Provisions for Monitoring Pesticide Use and Effectiveness

Periodic visits will be scheduled for post-treatment evaluation. This will include recording any unusual happenings around the treated area or commodity, visit to farmers to evaluate the impact of training and acceptability of methods used, inventory and test of alternatives control measures. For this to be possible, providing logistical support (transportation and incentives) should be considered.

Table 4. General Employer Responsibilities When Using Pesticides

General Employer Responsibilities found in EPA's Worker Protection Standard (WPS)	User	GNRMP
1. PPE—Use of Personal Protective Equipment (PPE) when handling and applying pesticides. The pesticide label will specify when PPE is worn to protect	X	X
* Body	X	X
* Hands	X	X
* Eyes and face	X	X
* Respiratory system	X	X
Cleaning and maintaining PPE	X	X
Ensuring that PPE does not cause heat stress	X	X
2. REI—Ensuring that Restricted-Entry Interval (REIs) are observed as required by the label. The REI will be a minimum of 12 hours and as high as 72 hours for highly toxic pesticides in certain climates	X	X
3. NOTIFICATION—Notifying employees of pesticide applications that might affect them		X
Includes posting signs and notice of applications done by commercial applicators		X
4. DECONTAMINATION—Making field decontamination sites available to employees for at least 30 days after last pesticide application		X
5. MEDICAL EMERGENCIES—In the event of a suspected pesticide poisoning, the employer provides transportation to a medical facility for employees		X
6. TRAINING—Employers must have a training program on pesticide safety		X
7. CENTRAL INFORMATION—At a central place for all employees, certain information must be maintained		X

Source: Texas Agriculture, Texas Farm Bureau, South Edition, April 15, 1994.

BIBLIOGRAPHY

Anonymous, "La Guinée va-t-elle continuer à négliger son agriculture?" *Politique Africaine*, No. 25:120-126., 1987.

Beal, H. Raymond, "Trip Report on foreign travel to Africa (Senegal, Guinea-Bissau and Niger) on termite problems," USDA Forest Service, Southern Forest Experiment Station. Gulfport, Mississippi, 8 pp., 1983.

Canty, C., "Transfer of controlled release insecticide technology for protection of forest seedlings from termite attack," source not found.

Cowie, H.R., J.W.M. Logan, and T.G. Wood, "Termite (Isoptera) damage and control in tropical forestry with special reference to Africa and Indo-Malaysia: A review," *Bull. Entomol.* Vol. 19:173-84, 1990.

Daar, Sheila, "IPM for Termites: A new direction in structural pest control services," *The IPM Practioner*. Vol. 12. #11/12. Nov.-Dec., 1990.

Faye, D.D., M.L. Bocoum, and O.T. Touré, "Aperçu sur quelques pratiques d'innovations et de technonologies en milieu paysan au Sud du Bassin Arachidier et en Gambie," West Africa Rural Foundation (WARF) Publ., 182 pp., Dakar, Senegal, 1993.

Fischer, J., M.S. Diallo, and B. Thiam, "Rapport préliminaire sur les pratiques de gestion des resources naturelles: Les avantages et les inconvénients des régimes fonciers dans le bassin versant de Diaforé, Fouta Djallon, Guinée," 71 pp., 1993.

Gandreau, M., P. Gilruth, G.E. Karch, K.L. McKay and Burton Sensenig, "Guinea Natural Resources Assessment," 43 pp., 1990.

Holldobler, B., and E.O. Wilson, *The Ants*, The Belknapc Press, Harward Univ. Press, Massachusetts, 732 pp., 1990.

International Institute of Tropical Agriculture, "Report and Budget Proposal," Biological Control Program, Cotonou, Benin, 11 pp., 1990.

IPM Practioner: Monitoring the Field of Pest Management, Bio-Integral Resource Center (BIRC), Berkeley, California.

Kelleher, S., "Observations on farmer practices in two watersheds in the Fouta Djallon," Draft, 23 pp., 1990.

Ladipo, D.O., and H.D. Onyeachusim, "Crop seed protection and soil enrichment using Erythrophleum suaveolens," *Agroforestry Today*, Jan/Mar 1993.

Logan, J.W.M., R.H. Cowie, and T.G. Wood, "Termite (Isoptera) control in agriculture and forestry by non-chemical methods: A review," *Bull. Entomol.* Res. Vol. 80:309-330, 1990.

______, "Termites (Isoptera): a pest or resource for small farmers in Africa," *Trop. Sci.*, Vol. 32:71-79, 1992.

______, D. Rajagopal, J.A. Wightman, and M.J. Pearce, "Control of termites and other soil pests of groundnuts with special reference to control release formulations of no-persistent insecticides in India an Sudan," *Bull. of Entomo. Research*, Vol. 82:57-66, 1992.

MacDonald, W., draft "Initial Environmental Examination or Categorical Exclusion for Guinea Natural Resources Management Project 675-0219," Oct. 1993.

Malaret, L. and N.F. Ngoru, "Ethno-ecology for community based pest management knowledge of termites in Machakos District, Kenya," 1988.

MARA/Institut de Recherches Agronomiques de Guinée, "Bilan des Activités 1986-1992," 10 pp., 1992.

MARA MARA/CAB, "Programme conjoint FAO/PNUE sur le fonctionement de la Procédure d'Information et de Consentement Préalable (ICP)," PL 32/21, #2653, December 7, 1993.

MARA/DNFC/USAID/Chemonics International, GNRM Project No. 675-0219, "Rapport des études des BRP et leurs plans de travail, et propositions des recherches," Labé, 1993.

MARA/DNFC/USAID, GNRM Project No. 675-0219, Annual Workplan for 1993, Report No. WKP93, 67 pp., May, 1993.

Paul, K.B., "Protection des denrées stockées chez les paysans: Résultats des recherches faites par FSRP et les recommandations," Farming Systems Research Program ISAR/Rwerere, Rwanda. 5 pp., 1988.

Seny, K., and I. Camara, "Rapport de Mission sur la Lutte Chimique contre les Termites au Fouta Djallon," LVP, Foulaya, Kindia, 1989.

______, "Rapport de Mission d'Evaluation de la Micro-Réalisation portant sur la lutte chimique contre les termites au Fouta Djallon," MARA/DPV/LNPV, Foulaya, Kindia, 6 pp., 1989.

Sidibé, Moussa, "Rapport de Mission," Laboratoire National de Protection des Végétaux et des Denrées Stockées, Foulaya, 6 pp. & Annex, 1989.

Tamura, T., Sakaida, K., and Shimada S. S., "Some data on geomorphology of termite mounds in Tropical Africa," *The Science Report of the Tohoku University*, 7th series, Vol. 40 #1:212-36, 1990.

Thomson, W.T., *Agricultural Chemicals: Book I, Insecticides*, Thomson Publications, 302 pp., 1992.

VITA/Africare, Central African Republic, Postharvest Food systems Project, Phase I reports, 21 pp, USAID Coop Agreement # 616-0016-A OO-404600.

Wilma, A., K. den Braber, I. van Halder, M. Kramer, and H. van der Valk, "Pesticides: composition, utilisation et risques," Agrodok-series N° 29, Agromisa, CTA, 53 pp & annex, 1989.

Wardell, A.D., "The African Termite. Peaceful coexistence or total war," a revised version of "Control of termites in nursery and young plantations in Africa: established practices and alternative courses of action," *Commonwealth Forestry Review*, Vol. 66:77-89, 1989.

Whitten, M.J. "Pest Management in 2000: What we might learn from the twentieth century," *Pest Management and the Environment in 2000*, C.A.B. International, A.A.S.A. Kadir & H.S. Barlow, eds, 1992.

Wildlife Conservation Dept. (Education Office), "The Hidden World of the Termite," Conservation Fact Sheet No. 7, 2 pp. source unknown, no date.

ANNEX A

LAW L/92/027/CTRN INSTITUTING PHYTOSANITARY CONTROL OF IMPORTED AND EXPORTED PLANTS

LOI

L/92/ 027 /CTRN

INSTITUANT LE CONTROLE PHYTOSANITAIRE DES VEGETAUX A L'IMPORTATION ET A L'EXPORTATION.

LE CONSEIL TRANSITOIRE DE REDRESSEMENT NATIONAL A DELIBERE ET ADOPTE ;

LE PRESIDENT DE LA REPUBLIQUE DE GUINEE PROMULGUE LA LOI DONT LA TENEUR SUIT :

CHAPITRE I /- DEFINITION

ARTICLE 1ER / - Le terme " Végétaux " désigne les plantes et parties de plantes vivantes (y compris les semences) dont l'État juge nécessaire de contrôler l'importation ou de certifier l'état phytosanitaire.

ARTICLE 2 / - Le terme " Produits végétaux " désigne les produits non manufacturés d'origine végétale (y compris les semences non visées par la définition du terme végétaux) ainsi que les produits manufacturés qui, étant donné leur nature ou celle de leur transformation, peuvent constituer un risque de diffusion des ennemis des végétaux et produits végétaux.

ARTICLE 3 / - Le terme "ennemis" désigne toute forme de vie végétale ou animale, ainsi que tout agent pathogène, nuisible ou potentiellement nuisible aux végétaux ou aux produits végétaux.

CHAPITRE II / - OBJET ET OBLIGATIONS

ARTICLE 4 / - Il est institué en République de Guinée le Contrôle phytosanitaire obligatoire des végétaux et produits végétaux à l'importation à l'exportation.

ARTICLE 5 / - Le contrôle phytosanitaire est assuré par les Inspecteurs phytosanitaires du service de la Protection des Végétaux.

ARTICLE 6 / - Il est crée au niveau des Ports, Aéports Internationaux et des principales frontières terrestres des Postes de Contrôle Phytosanitaire ayant pour tâche essentielle d'éviter l'introduction et la dissémination à l'intérieur du Territoire National d'organismes dangereux pour les végétaux et produits végétaux.

ARTICLE 7 / - L'introduction en République de Guinée des produits végétaux, parties de végétaux, terre, fumier, compost et tous les emballages, véhicules et conteneurs servant à leur transport est subordonnée à la présentation d'un certificat phytosanitaire délivré par le service de la Protection des végétaux du pays d'origine.

ARTICLE 8 / - Les végétaux et les produits végétaux à l'exportation doivent obligatoirement être accompagnés d'un certificat phytosanitaire attestant que l'envoi est estimé conforme aux reglementations phytosanitaires en vigueur dans les pays importateurs.

ARTICLE 9 / - Les personnes physiques ou morales exportatrices seront tenues de soumettre au contrôle des Inspecteurs phytosanitaires, leurs produits et matières ; un certificat phytosanitaire leur sera délivré pour attester l'origine et l'état sanitaire de leurs produits matières.

ARTICLE 10 / - L'Inspecteur Phytosanitaire pourra effectuer pour examen, les prélèvements d'échantillons qu'il jugera nécessaires suivant les modalités de prélèvement définis par un Arrêté du Ministère de l'Agriculture et des Ressources Animales.

ARTICLE 11 / - Le Contrôle s'effectuera au choix de l'Inspecteur phytosanitaire :

* Pour l'importation à bord des navires ou sur les quais et entrepôts immédiatement après déchargement au port ; à l'Aéroport ou aux différents postes frontaliers.
* Pour l'exportation en entrepôt ou dans les véhicules avant ou après déchargement, au port, à l'Aéroport ou aux différents postes frontaliers.

ARTICLE 12 / - Les végétaux et les produits végétaux déjà inspectés dans leur pays d'origine, accompagnés d'un certificat phytosanitaire, sont également contrôlés aux différents postes frontaliers de la République de Guinée avant d'être introduits à l'interieur du Territoire National.

ARTICLE 13 / - Le contrôle par les Inspecteurs phytosanitaires, des végétaux ou produits végétaux importés doit s'effectuer dans un délai maximum de 72 heures tenant compte de la nature périssable de ces derniers après leur arrivée.

ARTICLE 14 / - L'Inspecteur phytosanitaire est le seul mandaté pour décider de l'admission, du refoulement, de la mise en quarantaine, de la destruction ou de la désinfection des produits et matières importés ou destinés à l'exportation.

ARTICLE 15 / - Il sera effectué le traitement de tous les produits contaminés et un certificat de désinfection sera délivré aux importateurs et aux exportateurs pour tous les produits qui auront été désinfectés.

ARTICLE 16 / - Si des végétaux ou produits végétaux à l'importation sont reconnus non conformes, ou s'ils doivent être détruits en totalité ou en partie, un procès-verbal officiel devra être transmis sans delai à l'Organisation de la Protection des végétaux du pays exportateur.

ARTICLE 17 / - Les mesures de refoulement, ou de destruction ordonnées par les Inspecteurs phytosanitaires sont exécutées en présence d'un ou de plusieurs agents de l'Administration des Douanes.

ARTICLE 18 / - Le traitement ou la destruction des végétaux ou produits végétaux non conformes est à la charge des importateurs ou des exportateurs qui seuls sont responsables de l'Etat sanitaire de leurs produits.

ARTICLE 19 / - La matière de reproduction importée doit faire l'objet de mésures particulières et ne doit être mise à la disposition des utilisateurs pour vulgarisation que si son immunité est reconnue.

ARTICLE 20 / - Cependant le matériel destiné aux travaux de Recherche sera exceptionnellement exempté des mésures envisagées à l'Article 19, à condition que leur utilisation soit strictement limitée dans l'espace.

CHAPITRE III/- INFRACTIONS ET PENALITES

ARTICLE 21 / - Les agents assermentés du service de la Protection des végétaux visés à l'article 5 sont autorisés à effectuer tout contrôle aux Ports, dans les magasins et entrepots aux postes frontaliers et aux Aéroports internationaux.

Tous ceux qui feront obstacles à l'exercice de leurs fonctions sont passibles de peines prévues par les lois et règlements en vigueur en République de Guinée.

ARTICLE 22 / - Sont passibles d'une amende de 200.000 à 500.000 FG toutes les infractions aux dispositions des articles 7 et 8 Ci-dessus.

CHAPITRE IV / - DISPOSITIONS FINALES

ARTICLE 23 / - Le Ministre de l'Agriculture et des Ressources Animales, en collaboration avec tous les Départements concernés, est chargé de l'exécution de la présente Loi.

ARTICLE 24 / - La présente Loi qui abroge toutes dispositions contraires sera enregistrée et publiée au Journal Officiel de la République de Guinée et exécutée comme Loi de l'Etat.

CONAKRY, LE 6 AOUT

- GENERAL LANSANA CONTE -

ANNEX B

LAW L/92/028/CTRN INSTITUTING LEGISLATION ON PESTICIDES

REPUBLIQUE DE GUINEE

CONSEIL TRANSITOIRE DE REDRESSEMENT NATIONAL

TRAVAIL - JUSTICE-SOLIDARITE

LOI

L/92/028/CTRN

INSTITUANT LA LEGISLATION SUR LES PESTICIDES

LE CONSEIL TRANSITOIRE DE REDRESSEMENT NATIONAL A DELIBERE ET ADOPTE ;

LE PRESIDENT DE LA REPUBLIQUE PROMULGUE LA LOI, DONT LA TENEUR SUIT :

TITRE I - DES GENERALITES

ARTICLE Ier/. La présente LOI a pour objet la mise en oeuvre d'une politique nationale à l'égard des Pesticides et, notamment, le contrôle de l'importation, de la mise sur le marché, de l'étiquetage, de l'utilisation, de l'expérimentation, du stockage et de l'élimination des produits périmés ainsi que de la fabrication, de la formulation du conditionnement ou du reconditionnement et du transport desdits pesticides.

Ne sont pas concernés par cette présente LOI les produits destinés exclusivement à l'exportation et ont été préparés et conditionnés conformément aux spécifications et instructions de l'acheteur.

ARTICLE 2 /.- Au sens de la présente LOI, on entend par :

PESTICIDES : Les substances actives et les préparations contenant une ou plusieurs substances actives qui sont destinées à :

* Combatre les organismes nuisibles aux végétaux et produits végétaux ou à prévenir leur action ;
* exercer une action sur les processus vitaux des végétaux pour autant qu'il ne s'agit de substances nutritives ;
* assurer la conservation des produits végétaux stockés ;

* détruire les végétaux indésirables ;
* prévenir une croissance indésirable des végétaux.

VEGETAUX : Les plantes vivantes et parties vivantes de plantes Y compris les semences au sens botanique du terme destinées à être plantées.

PRODUITS VEGETAUX : Les produits d'origine végétale non transformés ou ayant fait l'objet d'une préparation simple telle qu mouture, séchage, décorticage ou pression, pour autant qu'il ne s'agit de végétaux tels q"ils sont définis à la rubrique précédente, y compris les graines destinées à la consommation non visées par la définition du terme "VEGETAUX".

MISE SUR LE MARCHE : Toute distribution à titre onéreux ou grat

ORGANISME NUISIBLE : Les ennemis des végétaux ou des parties des végétaux appartenant au règne animal ou végétal ou se présentant sous forme de virus, mycoplasme ou autre agent pathogèn

AUTORISATION D'EXPERIMENTATION : L'autorisation délivrée par les autorités Nationales d'utiliser un pesticide dans certaines conditions déterminées dans le but de recueillir les renseignements necessaires pour envisager l'homologation.

AUTORISATION PROVISOIRE DE VENTE : Autorisation délivrée par les autorités Nationales pour les produits ne présentant pas de risque excessifs pour la santé humaine, animale et pour l'environnement et pour lesquels la plupart des données biologiques requises ont pu être fournies.

HOMOLOGATION : Processus par lequel les Autorités Nationales approuvent la mise sur le marché d'un pesticide après examen des données scientifiques complètes montrant que le produit est efficace pour les usages prévus et ne présente pas de risqu excessifs pour la santé humaine, animale ou pour l'environnement.

TITRE II - DE LA GESTION DES PESTICIDES

ARTICLE 3/.- Il est interdit d'importer, de fabriquer, de formuler, de conditionner ou de reconditionner, de stocker, d'expérimenter, d'utiliser ou de mettre sur le marché tout pesticide non homologué ou autorisé.

ARTICLE 4/.- Le Ministre de l'Agriculture et des Ressources Animales sur avis du Comité des pesticides, ci-après dénommé le "Comité," procède à l'homologation des pesticides.

La composition, les attributions et le fonctionnement du Comité sont fixés par Décret.

ARTICLE 5/.- La procédure d'homologation, dont les modalités sont fixées par Décret prévoit :

* Le refus ou l'ajournement de la Décision pour complément d'information,
* L'autorisation d'expérimentation,
* L'autorisation provisoire de vente,
* L'homologation,

Les autorisations et l'homologation peuvent être modifiées ou retirées sur Décision de l'Autorité Ministérielle chargée de l'Agriculture et des Ressources Animales après avis du Comité.

ARTICLE 6/.- Toute modification de la composition Chimique, biologique ou physique du produit, ainsi que tout changement dans la destination pour laquelle le produit a été autorisé ou homologué doit être soumis à l'examen de l'Autorité Ministérielle chargée de l'Agriculture et des Ressources Animales qui, sur avis du Comité, décide si une nouvelle d'autorisation ou d'homogation doit être présentée.

ARTICLE 7/.- Les règles d'emballage, d'étiquetage, d'utilisation, d'expérimentation, de stockage et d'élimination des pesticides, ainsi que la procédure pour l'analyse des produits saisis, sont fixées par voie D'Arrêtés.

ARTICLE 8/.- Toute publicité pour un pesticide est interdite sauf s'il bénéficie d'une autorisation provisoire de vente ou d'une homologation.

La publicité ne peut mentionner que les indications contenues dans l'autorisation ou l'homologation et doit être conform aux lois et Réglements en vigueur.

ARTICLE 9/.- Des dérogations aux dispositions relatives à la procédure d'homologation peuvent être accordées par l'autorité Ministérielle chargée de l'Agriculture et des Ressources Animales et sous son contrôle, pour les besoins de la Recherche et de l'expérimentation..

ARTICLE 10 /.- Toute activité de fabrication, de formation, de conditionnement ou de reconditionnement des pesticides est soumi au respect des dispositions du Code de l'Environnement et des textes pris pour son application.

Une licence est requise par l'Autorité Ministérielle chargée de l'Agriculture et des Ressources Animales, sur proposition du comité, pour toute personne qui procède à la mise sur le marché de pesticides.

Un Décret fixe les conditions de délivrance des Licences.

ARTICLE 11/.- Les titulaires d'autorisation et d'homologation doivent tenir unregistre de gestion des pesticides. Ce régistre doit :

* Etre tenu pendant trois ans à compter de la date d'échéance des autorisations ou d'homologation
* Etre à la disposition des autorités chargées des contrôl

ARTICLE 12/.- Le Ministère chargé de l'Agriculture et des Ressources Animales édicte les conditions et les modalités d'utilisation des pesticides

ARTICLE 13/.- Les personnes physiques ayant accès, dans le cadre de leur fonction aux dossiers d'homologation sont tenues au secrét professionnel sauf à l'égard des Autorités Judiciaires.

.../...

T I T R E III - DES INFRACTIONS ET DES PENALITES

ARTICLE 14/.- Les agents assermentés de l'Autorité Ministérielle chargée de l'Agriculture et de l'autorité Ministérielle chargée de la Santé, les Agents du Service de l'Environnement, ainsi que les agents habilités en matière de repression des fraudes (ci-après dénommés "les agents"), recherchent et constatent par procès-verbal les infractions à la présente Ordonnance et aux textes pris pour son application.

ARTICLE 15/.- Les agents peuvent s'introduire à toute heure raisonnable, accompagnés au besoin d'un representant de la force Publique et à l'exception des locaux à usage d'habitation dans tout bien immeuble, fond, local, quai, véhicule, gare et aérog are où est exercée toute activité d'importation, de fabrication, de formulation, de conditionnement ou de reconditionnement, de stockage, de transport ou de mise sur le marché de pesticides.

Les Agents peuvent :

* examiner toute licence, agrément ou registre
* prélever des échantillons de pesticides à des fins de contrôle
* saisir tout pesticide reconnu non conforme aux conditions d'autorisation ou d'homologation.

ARTICLE 16/.- Tout produit saisi aux termes de l'Article 15 de la présente LOI sera élimité par les agents des Services de l'Environnement et de la Protection des végétaux aux frais de l'auteur de l'infraction.

ARTICLE 17/.- Les complices des auteurs des infractions visées au présent titre seront punis dans les conditons prévues par le Code Pénal.

ARTICLE 18/.- Quiconque, ayant été condamné pour avoir commis des infractions visées au présent titre, commettrait la même infraction dans un delai de Douze mois à compter de la première est passible de peines d'amendes et d'emprisonnement pouvant atteindre le double du maximum fixé aux articles précédents pour cette infraction.

ARTICLE 19/.- Les taux des amendes visées au présent titre sont révisés par une LOI.

ARTICLE 20/.- Les agents peuvent transiger avant ou après jugement définitif sur les infractions à la présente LOI et à ses textes d'application ;

* Avant jugement la transaction éteint l'action publique
* Après jugement la transaction n'a d'effet que sur les peines pécuniaires.

Le montant des transactions consenties doit être acquitté dans un délai fixé dans l'acte de transaction, faute de quoi, il est procédé à la poursuite.
Le barême de transaction est fixé par voie réglementaire.

TITRE IV - DES DISPOSITIONS GENERALES

ARTICLE 21/.- Les conditions d'application des dispositions de la présente LOI sont fixées par des textes d'application du Ministre de l'Agriculture et des Ressources Animales pris en tant que de besoin, conjointement avec les Ministres intéressés.

ARTICLE 22/.- La présente Loi qui abroge toutes dispositions contraires sera enregistrée et publiée au Journal Officiel de la République de Guinée et exécutée comme LOI de l'Etat.

CONAKRY, LE 6 AOUT 1992

GENERAL LANSANA CONTE

ANNEX C

DECRE D/94/044/PRG/SGG IMPLEMENTING LAW L/92/028/CTRN

REPUBLIQUE DE GUINEE

TRAVAIL - JUSTICE - SOLIDARITE

PRESIDENCE DE LA REPUBLIQUE

CRETARIAT GENERAL DU GOUVERNEMENT

DECRET

D/94/ 044 /PRG/SGG

PORTANT APPLICATION DE LA LOI L/92/028/CTRN DU 6 AOUT 1992 PORTANT LEGISLATION SUR LES PESTICIDES.

LE PRESIDENT DE LA REPUBLIQUE ,

VU La Loi Fondamentale,

VU La Loi L/93/028/CTRN du 6 Août 1992 portant Législation sur les Pesticides;

VU Le Décret D/92/036/PRG/SGG du 6 Février 1992 portant nomination des Membres du Gouvernement ;

VU Le Décret D/92/213/PRG/SGG du 3 Septembre 1992 portant attributions et organisation du Ministère de l'Agriculture et des Ressources Animales ;

Le Conseil des Ministres entendu en sa Séance Ordinaire du [illegible]

DECRETE -"-

BEST AVAILABLE DOCUMENT

DU SERVICE DE LA PROTECTION DES VEGETAUX

ARTICLE 1ER.- Le service de la Protection des Végétaux, en collaboration avec l'Autorité Ministérielle chargée de la Santé, la Direction Nationale de l'Environnement et le service de la Repression des Fraudes, est chargé du contrôle des Pesticides sur toute l'étendue du territoire de la République de Guinée.

- DE L'AGREMENT DES PESTICIDES

ARTICLE 2.- Tout Pesticide doit faire l'objet d'un agrément ou bénéficier d'une Autorisation Provisoire de vente préalablement à son importation ou à sa fabrication en République de Guinée.

ARTICLE 3.- L'Agrément et l'Autorisation Provisoire de vente ne sont accordés que par le Ministre chargé de l'Agriculture sur proposition d'un Comité dit " Comité des pesticides ".
Cependant, pour les pesticides destinés à des fins de recherches, une autorisation peut être délivrée par le Directeur du service chargé de la protection des végétaux.

ARTICLE 4.- LE COMITE DES PESTICIDES

1 - Propose les principes et les orientations générales de la réglementation des Produits ;

2 - Examine les risques de toxicité à l'égard de l'homme, des animaux et de l'environnement des produits visés à l'Article 2 de la loi n°L/92/028/CTRN du 6 Août 1992 ;

3 - Propose Eventuellement au Ministre chargé de l'Agriculture une liste de Pesticides d'emploi interdit ou limité compte tenu des risques évoqués à l'alinéa précédent ;

4 - Propose au Ministre chargé de l'Agriculture toutes les mesures susceptibles de contribuer à la normalisation, à la définition et à l'établissement des conditions et modalités d'emploi des Pesticides concernés par la Loi n°L/92/028/CTRN du 6 Août 1992 en égard à leur efficacité et à leurs inconvénients de tous ordres.

5 - Définit les méthodes de contrôle de la composition et de la qualité des produits soumis autorisation ou à homologation et procède à leur évaluation.

6 - Reçoit, examine et tient les demandes d'autorisation et d'homologation

7 - Emet un avis sur les demandes de licences mentionnés à l'Article 10 de la Loi n°L/92/028/CTRN du 6 Août 1992 ;

8 - Recourt le cas échéant, à des expertises réalisées par des laboratoires agréés par le Ministre chargé de l'Agriculture.

9 - Donne son avis sur toutes les questions que lui soumettent les Ministres intéressés ;

ARTICLE 5.- LE COMITE DES PESTICIDES COMPREND :

- Le Représentant du Ministre chargé de l'Agriculture et des Ressources Animales - Président

- Un Représentant de la Direction Nationale de l'Environnement - Vice-Président.

M E M B R E S :

- Le Chef Service de la Protection des végétaux Responsable de l'instruction des Dossiers - Secrétaire Permanent

- Un Représentant de la Direction Nationale des Forêts et Chasse ;

- Un Représentant de la Direction de l'Institut de Recherche Agronomique de Guinée.

- Un Représentant de la Direction Nationale de l'Elevage ;

- Un Représentant du Ministère de la Santé -

- Un Représentant du Ministère de l'Industrie/Petite et Moyenne Entreprise.

- Un Représentant du Ministère de la Justice ;

- Un Représentant du Ministère du Plan et des Finances

- Un Représentant du Ministère du Commerce - Transport et Tourisme

- Un Représentant du Ministère de l'Enseignement Supérieur et de la Recherche Scientifique ;

En cas de nécessité, les membres du Comité peuvent se faire remplacer par un représentant compétent en la matière. Des Experts ayant ou non la qualité d'agent public, peuvent, en raison de leur compétence, être appelés par le Président du Comité à participer aux travaux du Comité avec voix consultative.

ARTICLE 6.- Le Comité peut, chaque fois qu'il estime nécessaire solliciter le Concours des organismes Officiels de Recherches.des services compétents des Ministères membres du comité et des laboratoires Etrangers, pour effectuer tout travail d'expérimentation et de contrôle nécessaire à l'appréciation des dossiers présentés et ultérieusement, au suivi des Produits agréés. Ce travail d'expérimentation ou de contrôle est effectué aux frais du bénéficiaire de l'Agrément.

ARTICLE 7.- Le Comité se réunit à la demande de son Président ou d'un tiers de ses membres.

Les réunions du Comité requièrent la présence de la majorité des membres.

L'avis du Comité est pris à la majorité des présents. En cas de partage des voix, la voix du Président est Prépondérante.

ARTICLE 8.- Tout dossier de demande d'Agrément ou d'Autorisation provisoire de vente d'un Pesticide est adressé au Ministre chargé de l'Agriculture qui le transmet au comité des Pesticides pour avis.

ARTICLE 9.- Sans préjudice des articles précédents, le comité fixe sa propre procédure.

DE LA PROCEDURE D'HOMOLOGATION

ARTICLE 10.- Le Dossier d'homologation adressé au Ministre de l'Agriculture sera accompagné d'une demande d'homologation établie sur un formulaire simple comportant les rubriques suivantes :

- Numéro et date d'enregistrement
- Nom et Adresse du requérant
- Nom et Adresse du formulateur
- Nom et Adresse du propriétaire de la Marque
- Nom Commercial
- Usage (organismes nuisibles visés, modes d'emploi, doses d'emploi et contre indication).

ARTICLE 11.- La demande établie en deux (2) exemplaires comprend

a) - Un formulaire prévu à cet effet et délivré par le Ministre de l'Agriculture ;

b) - Un dossier concernant l'homologation proprement dit et comprenant toutes les informations sur l'identification et les propriétés physico - chimiques du produit et de la matière active, la toxicologie, les effets sur l'environnement, les résidus ainsi que tout ce qui concerne la sécurité d'emploi du produit ;

c) - un dossier concernant l'effet biologique du produit ; l'efficacité, la phytotoxicité etc... et comprenant les données sur les essais faits localement et/ou dans les pays ayant des conditions climatiques et agronomiques similaires ;

d) - Un Spécimen de l'étiquetage ;

e) - Une note sur la description des méthodes d'analyse permettant le contrôle de la matière active.

Le contenu des pièces à joindre à la demande d'homologation est fixé par Arrêté du Ministre de l'Agriculture.

Des échantillons de la spécialité, destinés à l'étude des propriétés physiques, biologiques ou chimiques du produit sont, en tant que de besoins, exigés après enregistrement de la demande.

BEST AVAILABLE DOCUMENT

ARTICLE 12.- Après examen du Dossier de demande d'autorisation ou d'Agrément, le comité des Pesticides propose au Ministre de l'Agriculture et des Ressources Animales l'une des mesures suivantes :

1 - Un avis favorable d'Autorisation d'expérimentation, d'Autorisation provisoire de vente (A. P. V.) ou d'homologation, assorti le cas échéant, de conditions particulières.

2 - Un refus d'agrément (impliquant obligatoirement le retrait d'une éventuelle autorisation provisoire de vente préalablement accordée).

La décision du Comité est transmise au Ministre de l'Agriculture qui prend la Décision finale et la notifie au demandeur.

ARTICLE 13.- L'Autorisation d'expérimentation est accordée pour une durée d'un an renouvelable sous réserve que le demandeur fournisse les justifications nécessaires.

L'Autorisation provisoire de vente est accordée pour une durée de quatre (4) ans, sauf reconduction exceptionnelle pour un délai maximum de deux (2) ans.

L'Homologation est accordée pour une durée de dix (10) ans, renouvelable, une seule fois, pour une période de même durée.
Pour certains pesticides à usage limité et d'utilisation dangereuse l'agrément ou l'A.P.V peut être assorti de la désignation limitative des utilisateurs.
Les Arrêtés d'agrément ou d'Autorisation Provisoire de vente, (A.P.V.) sont susceptibles, à tout moment, de modification, suspension ou retrait si le comité l'estime nécessaire.
Mais la décision doit toujours être motivée.

ARTICLE 14.- L'[illegible] des frais d'expérimentation de Pesticides non encore agréés et n'ayant pas fait l'objet d'une A.P.V. est réservé aux Instituts de Recherche ou au laboratoire du Ministère de l'Agriculture et des Ressources Animales. Le comité des Pesticides pourra éventuellement ordonner la destruction des cultures ayant servi de champs d'expérimentation.

BEST AVAILABLE DOCUMENT

L'importation à des fins d'expérimentation de pesticides non agréés ou autorisés provisoirement est soumise à autorisation préalable du Ministre chargé de l'Agriculture sur proposition du Comité des Pesticides.

DES OBLIGATIONS

ARTICLE 15.- L'autorisation d'expérimentation est assortie des conditions suivantes :

1 - Programme d'essais placé sous la surveillance et le contrôle conjoint du Ministère chargé de l'Agriculture, du Ministère chargé de la santé et du Ministère chargé de l'Environnement, chacun en ce qui le concerne.

2 - Interdiction de toute publicité ;

3 - Etiquetage conforme au modèle type défini par arrêté du Ministre chargé de l'Agriculture.

4 - Possession d'un matériel approprié et suffisant pour la protection du personnel contre l'exposition aux pesticides lors de leur dilution, de leur application de leur transport et de leur stockage ;

5 - Présentation d'une note à usage médical sur les traitements en cas d'intoxication ;

6 - Engagement à faire subir des examens médicaux périodiques au personnel ;

7 - Interdiction d'utiliser les produits récoltés pour la consommation humaine ou animale sauf dérogation ministérielle.

ARTICLE 16.- Après toute application de Pesticides :
- Les emballages vides sont rendus inaptes à tout usage ;
- Les reliquats des pesticides doivent être détruits avec toutes les précautions d'usage.

ARTICLE 17.- L'autorisation provisoire de vente et d'homologation sont assorties des conditions suivantes :

1 - Engagement à respecter la Réglementation phytosanitaire en vigueur et, notamment, à ne faire usage que de produits régulièrement autorisés à la commercialisation.

2 - Elimination de tout risque de contamination par les Pesticides destinés à la Commercialisation pendant le transport de ces derniers.

3 - Engagement de se mettre sur le marché, sous le nom Commercial indiqué, qu'une spécialité définie par :

- son nom Commercial
- Le nom du détenteur de la marque
- Le numéro d'autorisation ou d'homologation délivré par le Comité
- La composition de la spécialité.

<u>ARTICLE 18.-</u> Lorsqu'un produit fait l'objet d'un retrait ou d'un refus de renouvellement d'autorisation Provisoire de vente ou d'homologation pour des considérations autres que celles de Santé Publique ou animale, d'environnement ou de toxicité à l'égard des cultures, la mise sur le marché de ce produit et sa distribution doivent cesser deux (2) ans après la date de notification de retrait ou du refus de renouvellement.

Si le retrait ou le refus de renouvellement d'un produit est justifié par des considérations de Santé Publique ou Animale, d'environnement ou de toxicité à l'égard des cultures, la mise sur le marché ainsi que toute distribution doivent cesser immédiatement après la notification de la décision.

<u>DES INFRACTIONS ET DES PENALITES</u>

<u>ARTICLE 19.-</u> En application de l'article 14 de la loi n°L/92/028/CTRN du 6 Août 1992, les Agents chargés de l'application de ladite Loi et de ses textes d'application sont munis d'une carte de service qu'ils doivent présenter dans le cadre de l'exercice de leur fonction de contrôle.
La carte doit être restituée à la cessation de Fonction.

ARTICLE 20.- En application de l'Article 14 de la Loi L/92/028/CTRN du 6 Août 1992, toute infraction aux dispositions de la Loi et à ses textes d'application est constatés par un procès verbal redigé en trois (3) exemplaires.

ARTICLE 21.- En application de l'article 15 de la loi L/92/028/CTRN du 6 Août 1992, les Agents remettent un recépissé en cas de saisie ou de prélèvement d'échantillon.

ARTICLE 22.- Toute infraction aux articles 13 et 15, notamment la vente ou la distribution de produits non homologués ou non autorisés, en vrac, périmés, falsifiés et l'usage d'emballage ou d'étiquettes non conformes aux modèles autorisés entraine la saisi immédiate des stocks en cause sans préjudice des autres sanctions prévues par le code pénale.

ARTICLE 23.- Toute infraction aux articles 16, 17 et 18 constatée entraine la fermeture de l'établissement ou la saisie des véhicules concernés sans préjudice des autres sanctions administratives et pénales prévues par les textes en vigueur.

ARTICLE 24.- Toute autre infraction au présent Décret est passible des peines prévues par la réglementation en vigueur.

DISPOSITIONS FINALES

ARTICLE 25.- Le Ministre de l'Agriculture et des Ressources Animales en collaboration avec tous les Départements concernés est chargés de l'exécution du présent Décret.

ARTICLE 26.- Le présent Décret qui abroge toutes dispositions contraire sera enregistré et publié au Journal Officiel de la République de Guinée./.-

CONAKRY, le 22 MARS 1994

LANSANA CONTE -

BEST AVAILABLE DOCUMENT

ANNEX D

TERMITE (ISOPTERA) CONTROL IN AGRICULTURE AND FORESTRY BY NON-CHEMICAL METHODS: A REVIEW

Bulletin of Entomological Research (1990) 80, 309-330

33 0 E
30 8
3/22

Termite (Isoptera) control in agriculture and forestry by non-chemical methods: a review

James W.M. Logan, Robert H. Cowie and T.G. Wood
Natural Resources Institute, Chatham Maritime, Kent, UK

Abstract

Non-chemical control of termites in agriculture and forestry is attracting renewed interest following increasing restrictions on the use of persistent organochlorine (cyclodiene) insecticides. Non-chemical control involves methods which attempt, without using commercial pesticides, to (i) prevent termite access to the plants, (ii) reduce termite numbers in the vicinity of the plants or (iii) reduce susceptibility/increase resistance of the plants themselves. There have been few adequate trials of any of these methods. Numerous cultural procedures have been suggested, including measures to enhance plant vigour, to manipulate termite numbers and behaviour, and others whose mode of action is unclear. Many are simply part of good agricultural/silvicultural practice and to be recommended. Biological control by predators or pathogens is unlikely to be successful due to the termites' social structure and behavioural responses to infected individuals and to loss of individuals to predators. The use of 'natural' insecticides from locally available plant products may be effective in some cases but, as they are not subject to the same rigorous safety and environmental evaluation as commercial pesticides, their use cannot be sanctioned unconditionally. Other locally available products, e.g. wood ash, have not been adequately evaluated. Removal of reproductives from the nest and construction of physical barriers may have limited applications, but resistant species and varieties, combined with appropriate cultural methods and, perhaps, minimal use of modern pesticides in an integrated approach, offer the greatest potential for a long term solution. The lack of critical scientific evaluation of non-chemical control makes it a field wide open for research.

Introduction

Termite attack on field and tree crops and on forestry trees, especially in the semi-arid and sub-humid tropics, causes significant yield losses (Harris, 1971; Johnson *et al.*, 1981; Wood *et al.*, 1980a) and is often a major constraint on reforestation (Cowie *et al.*, 1989). Control in agriculture and forestry has relied almost exclusively on persistent organochlorine (cyclodiene) insecticides since their development in the 1940's (Harris, 1971; Sands, 1973a, 1977; Sen-Sarma, 1986). These chemicals, when placed as a barrier in the soil (e.g. seed dressing, planting hole or furrow treatments), can provide protection throughout the growing season for annual crops or longer for perennial and tree crops and forestry. Prior to the use of cyclodienes, highly toxic chemicals such as Paris Green and arsenates were used (Beeson, 1941; Harris 1971). Increasing concern over damage to human health and the environment has now resulted in the banning or severe restriction of cyclodienes in many countries. Research to develop alternative chemical methods has centered on newer, less persistent insecticides (Wood *et al.*, 1987), controlled release formulations of non-persistent insecticides (May, 1986) and baiting

Correspondence: Mr J.W.M. Logan, Natural Resources Institute, Central Avenue, Chatham Maritime, Chatham, Kent ME4 4TB, UK.

techniques (El Bakri *et al.*, 1989; Logan & Abood,1990). Only controlled release formulations have so far shown significant potential in the field but they are not yet widely registered and their current high cost would be prohibitive for small scale rural farmers in developing countries. Consequently, and because of increased environmental awareness demanding reduction in the use of commercial pesticides (Hansen, 1987), there is renewed interest in non-chemical control of termites. In this review we include the use of locally produced plant derivatives, defining non-chemical control as those measures which do not use commercially produced pesticides.

Published information on non-chemical control is widely scattered in the literature, much of it anecdotal. There have been few adequate trials and there are conflicting views on the efficacy of the various techniques, which are often based on long established local practice (Cowie *et al.*, 1989; Epila & Ruyooka, 1988; Malaka, 1972; Malaret & Ngoru, 1989; Stoll, 1986; Wardell, 1987). This review brings together much of this information and assesses the potential of the various methods.

Termite diversity

Of the approximately 2500 species in the order Isoptera, about 300, spread across all families, have been recorded as pests (including those damaging buildings). However, measures to control them frequently ignore the diversity in ecology and behaviour manifested by the group. It would be unthinkable to consider control of, say, all Lepidoptera in such a way, yet 'termite control' is often considered by non termite specialists as if a single pest were to be dealt with. A basic understanding of termite diversity and biology is a prerequisiste for adequate pest management. Appropriate background is available in a number of general texts (Grassé, 1982, 1984, 1986; Harris, 1971; Krishna & Weesner, 1969, 1970; Lee & Wood, 1971), but the essential relevant information is summarised here.

Termites are social insects living in colonies usually comprising a reproductive pair (king and queen) and numerous sterile workers and soldiers whose tasks include foraging, nest building and maintenance, care of eggs and young, and defence. All species maintain symbiotic relationships with micro-organisms which are essential to digestion (see below). Few species build the often spectacular mounds for which these insects are renowned. There are major differences in distribution, biology and pest status among the seven conventionally recognized families; these are outlined below. The seven families are subdivided to include 15 subfamilies as follows:

Mastotermitidae

Kalotermitidae

Termopsidae
- Termopsinae
- Porotermitinae
- Stolotermitinae

Hodotermitidae
- Cretatermitinae (fossil)
- Hodotermitinae

Rhinotermitidae
- Psammotermitinae
- Heterotermitinae
- Stylotermitinae
- Coptotermitinae
- Termitogetoninae
- Rhinotermitinae

Serritermitidae

Termitidae
- Termitinae
- Apicotermitinae
- Nasutitermitinae
- Macrotermitinae

The Mastotermitidae contain only a single extant species, *Mastotermes darwiniensis* Froggatt, confined to northern Australia and New Guinea. It lives in subterranean colonies, often associated with wood, and is locally a pest in sugarcane and forestry (Sands, 1973b). More seriously, it can cause dramatic damage to buildings.

The Kalotermitidae, commonly known as dry-wood termites, are generally scarce but widely distributed especially in coastal and other humid regions in the tropics. They live in small colonies of a few hundred to a few thousand individuals, which excavate in wood (usually dead), generally maintaining no contact with the soil as a moisture source or dispersal medium. Some species, notably *Cryptotermes brevis* (Walker), cause serious damage to buildings, but in agriculture and forestry they are relatively minor pests, with significant damage confined, in general, to the humid tropics and to certain tree and bush crops (e.g. tea), in which excavations in dead branches may extend into living wood (Sands, 1973a, 1973b).

The Termopsidae, a small family of termites living in damp, rotten wood, partially or wholly buried underground, have a scattered, essentially temperate distribution and are rarely pests.

The Hodotermitidae (harvester termites) are locally distributed in dry and semi-desert parts of the Old World. They build subterranean nests and forage in the open, predominantly on grass and grass litter. They damage pasture (Coaton, 1954; Nel & Hewitt, 1969) but may only be serious pests where there is excessive grazing by stock (Lee & Wood, 1971; Sands, 1977). They may occasionally damage crops (Sands, 1973a, 1973b).

The Rhinotermitidae include some widespread and frequently common termites. They generally nest underground, often associated with dead wood. Some species build mounds. Two genera, *Reticulitermes* and *Coptotermes*, include important building-damaging species. *Coptotermes* spp. are major pests of mature forestry trees and tree crops, particularly in Australia and south-east Asia, often attacking trees through the roots deep in the ground and eventually excavating the trunk (Cowie, *et al.*, 1989).

The Serritermitidae contains a single South American species which is not a pest.

The above six families, known as 'lower termites', are largely wood-feeders and their symbiotic intestinal microbiota is dominated by cellulolytic protozoa (comprising up to one third of the total body weight) and considerable numbers of facultative and obligate anaerobic bacteria. The remaining family, Termitidae, known as 'higher termites', lack the cellulolytic protozoa and, with the exception of the Macrotermitinae, bacteria are the dominant gut microbes, with the addition of actinomycetes in some soil-feeding Termitinae and Apicotermitinae. The Termitidae include about 75% of termite species, divided among four subfamilies.

Termitinae are the most diverse and widespread subfamily of the Termitidae. Most have subterranean nests or nest in wood and are either dead wood or soil and/or dung feeders; some construct small mounds. Although many species cause minor damage to trees or buildings, a few, e.g. *Amitermes evuncifer* Silvestri which attacks yams in west Africa (Wood *et al.*, 1980b), are economically important.

The Apicotermitinae build diffuse subterranean nests and are often found in the mounds of other species. They are frequently encountered around crop roots but, since they are almost exclusively soil feeders, do not cause any damage.

The Nasutitermitinae have characteristic soldiers with heads extended anteriorly into a tube which secretes or squirts a sticky defensive repellent. They feed on dead grass, leaves or woody material, and some build mounds (Araujo, 1970; Sands, 1961, 1965). With some exceptions, particularly in South America, they are of minor economic importance (Sands, 1973a, 1973b).

The Macrotermitinae, fungus-growers, are widely distributed throughout the Old World except at high altitudes and in desert areas. They maintain an obligate exosymbiosis with the fungus *Termitomyces* spp. which they cultivate within the nest on fungus 'combs' constructed from faecal material (Martin, 1987; Wood & Thomas, 1989). The fungus is cellulolytic and is responsible for external 'digestion', while there are also bacteria and protozoa in the gut which may or may not be symbiotic. They are the commonest termites of Africa and a major component of the Asian and Oriental faunas. Most feed on dead plant material but some also feed on living plants, causing serious and widespread damage, particularly in semi-arid Africa and India. They attack a wide range of crops (Sands, 1973a, 1973b, 1977) and are major pests of exotic forestry (Cowie *et al.*, 1989). Those most frequently causing damage belong to the genera *Macrotermes*, *Microtermes* and to a lesser extent *Odontotermes* and *Ancistrotermes* in Africa, and predominantly to *Microtermes* and *Odontotermes* in the Indian subcontinent. These genera differ characteristically in their biology and mode of attack. *Macrotermes* spp. build large epigeal nests (mounds) from which they forage outwards for distances up to 50 m in galleries/runways either just below or on the soil surface (Darlington, 1982a). They attack plants at the base of the stem, ring-barking or cutting them through completely (Cowie & Wood, 1989; Sands, 1973a). *Odontotermes* spp. build both subterranean and, especially in India, epigeal nests. Damage is due to either foraging under soil sheeting on the outer surface of the plants, sometimes leading to severence of the stem (Cowie & Wood, 1989; Sands, 1973a), or attack on the roots (Mitchell *et al.*, 1987; Nair & Varma, 1985). *Microtermes* spp. and *Ancistrotermes* spp. have diffuse subterranean nests (Wood & Johnson, 1978) and attack plants from below ground by entering the root system and tunnelling up into the stem, hollowing it out and frequently filling it with soil (Cowie & Wood, 1989; Sands, 1973a, 1973b; Wood *et al.*, 1987). These characteristic modes of attack grade into each other and one genus may adopt more than one of them. Within a genus, different species may be more or less important as pests.

Principles of Damage and Control

A number of generalizations can be made about severity of attack. In general, attack is more severe on introduced or exotic plant species or varieties than on indigenous or local ones, presumably because the latter have evolved some level of resistance. Attack is more severe on stressed than unstressed plants, stress being due to disease, physical damage, lack of or too much water, etc. Crops planted in lowland areas are more likely to be attacked than those in highland areas, simply because termite distributions are often limited by altitude. In general, with some notable exceptions, termites cause more severe damage in drier savanna than in wet forest agriculture. These generalisations apply to considerations of potential ways of reducing plant susceptibility or of manipulating termite numbers and behaviour without resort to commercial pesticides.

The first principle of control is to decide whether control is both desirable and economically feasible (Cowie *et al.*, 1989; Horn, 1988). For the latter, yield loss estimates are essential but have been assessed in detail only rarely (Johnson *et al.*, 1981; Wood *et al.*, 1980a); damage levels may be only poor indicators of ultimate yield loss (Wood & Cowie, 1988). For instance, in maize, compensatory growth by surviving plants following early season attack, harvest of cobs on the ground from plants lodged late in the season, and damage to vegetative parts occurring after cob formation will result collectively in over-estimates of yield loss if they are based only on attack or damage scores.

Control measures differ depending on the type of termites involved. Conventionally, damage to plants by subterranean termites has been prevented by persistent insecticidal barriers in the soil around the roots, preventing termite access to the crop/tree; mound-building termites can be controlled to a limited extent by destroying or poisoning the mound and/or queen; and dry-wood termites, although considerably less important, have proved extremely difficult to control chemically but a combination of cultural and chemical control may be effective against them in some instances (Cowie *et al.*, 1989; Sands, 1973a, 1973b, 1977). Control measures can be divided broadly into those which attempt to (i) prevent termites gaining access to the plants, (ii) reduce termite numbers in the vicinity of the plants, and (iii) render the plants themselves less susceptible to attack by the termites. Non-chemical techniques include a range of cultural procedures, biological control, queen removal, use of resistant crops/trees and a number of other measures and fall into all three categories.

Cultural methods

Healthy plants may sometimes be damaged by termites, but unhealthy, stressed plants are generally more susceptible (Cowie *et al.*, 1989; Sands, 1973a, 1973b, 1977; Sen-Sarma, 1986). Drought, disease, weeds, lack of fertilizer, transplant shock, mechanical and fire damage and general neglect may all increase the likelihood of attack (Abd el Nour, 1975; Brown, 1962; Coaton, 1950; Harris, 1971; Kashyap *et al.*, 1984; Logan & El Bakri, 1990; Mercer, 1978; Misari & Raheja, 1976; Nair & Varma, 1985; Ripper & George, 1965). Crops and trees are increasingly planted on marginal land, resulting in greater stress and hence liability to attack (Sands, 1977; Wessels, 1984). Cultural control therefore includes those procedures which help to maintain or enhance plant vigour and which generally are good agricultural/silvicultural practice. Other cultural procedures aim to reduce termite numbers or modify their behaviour. In some cases, these are also part of good standard practice. Various other techniques and procedures have been noticed as influencing termite attack but the underlying reasons can only be guessed at.

Maintenance of plant vigour

Good quality seed, healthy seedlings, appropriate transplanting procedure. Good quality seed is more likely to produce healthy plants. Sound nursery practice followed by selection of vigorously growing seedlings should ensure that only healthy stock is planted out; careful handling and planting may also be important (Beeson, 1941; Brown, 1962; Harris, 1971; Snyder, 1926; Wardell, 1987). In Uganda, for instance, tea seedlings planted with the tap root bent suffered greater damage than those planted correctly (Harris, 1971). The use in forestry of polythene planting tubes, which keep the root ball together and moist until planting out, reduced planting shock and consequent susceptibility to termites (Harris, 1971).

Water stress. Levels of rainfall and irrigation may be related to termite attack on plants because (i) levels of termite foraging activity are frequently related to soil moisture levels, and, more importantly, (ii) deficiency or excess of water may stress plants and encourage attack.

In India, termite attack on tea is greater during the rainy season (Srivastava & Butani, 1987) and attack on maize and groundnuts was greater in parts of experimental fields with higher soil moisture levels where termite foraging activity was greater (Reddy & Sammaiah, 1988). Fuller (1912) found that 'mild' watering of fruit trees in the dry season in South Africa stimulated foraging and led to increased termite attack. Limiting the water supply may be of value in specific cases but an adequate supply to maintain plant vigour is nevertheless essential. Termite attack on *Eucalyptus* spp. has been shown, in Senegal, to be negatively correlated with sap pressure (Gueye & Lepage, 1988). In general, attack on crops and trees, e.g. *Eucalyptus* spp., cotton and groundnuts in Africa, is greater in drier areas and during dry periods. Overall annual rainfall is important but the temporal distribution of rainfall through the growing season may be more significant (Abd el Nour, 1975; Brown, 1962; Johnson *et al.*, 1981; Pearson, 1958; Ripper & George, 1965). However, attack on *Eucalyptus* spp. was considered by Nair & Varma (1981; 1985) to be unrelated to rainfall. Other factors, for instance differences among termite species in moisture-related foraging patterns (Roonwal, 1979, p. 29), may be more significant in some regions.

Various measures may reduce attack in circumstances where plants are subject to water stress. Watering of nursery stock just prior to planting out provides an immediate supply of water in the event of an unexpected dry period and ensures cohesion of the soil-root ball. Planting at the correct time so that crops/trees are not subject to drought also helps to ensure plant vigour (Harris, 1971; Wardell, 1987). In rainfed crops and forestry, small-scale water trapping techniques to channel and retain water (Greenfield, 1989; Moldenhauer & Hudson, 1988) may help reduce attack. Burying water-filled earthenware pitchers alongside trees has also been suggested (Wardell, 1987). In Nigeria, Johnson *et al.* (1981) suggested the use of short season varieties of groundnuts and early planting to avoid lack of rain towards harvest.

In irrigated areas regular irrigation will limit periods of water stress. Frequent irrigation may therefore reduce attack (Fuller, 1912; Kumarasinghe & Ranasinghe, 1988), for example, irrigated wheat in Ethiopia suffered greater damage the longer the intervals between irrigation (Cowie & Wood, 1989), and more frequent irrigation reduced attack by *Microtermes obesi* Holmgren in experiments on wheat in India (Verma, 1980). Lack of irrigation has been suggested as one of a number of possible factors influencing levels of termite attack on date palms in Sudan (Logan & El Bakri, 1990) and sugar cane in Sri Lanka (Kumarasinghe & Ranasinghe, 1988). The timing and amount of irrigation may be important. Heavy irrigation three months before cotton sowing in Sudan stimulated termite activity and resulted in increased root damage but irrigation at or just after sowing had no effect on termite attack (Crowther & Barlow, 1943). Waterlogging may weaken plants, enhancing their susceptibility. Even distribution of irrigation throughout a crop to ensure no areas remain dry or waterlogged is clearly also important and may necessitate careful levelling of fields prior to planting (Kakde, 1985; Krishnamoorthy & Ramasubbiah, 1962).

Crop rotation. Intensive cropping, especially monocropping, for long periods reduces soil fertility and structure. Under such conditions crops will be less vigorous and therefore more susceptible to attack. This has been suggested as a factor influencing *Hodotermes mossambicus* (Hagen) attack on cotton in southern Africa (Pearson, 1958) and may be a contributing factor to the high levels of termite (Macrotermitinae) damage to maize in western Ethiopia (Cowie & Wood, 1989). Crop rotation, especially including fallow periods, to reduce detrimental effects on soil fertility and structure is, in principle, to be recommended. However, under long-term cultivation the build up of some termite species and the decrease of others may well be more important; negative effects of rotation (e.g. Crowther & Barlow, 1943) are probably not related to effects on plant vigour but to fundamental changes in the make-up of the termite fauna (see below).

Damage to plants. Both dry-wood and subterranean termites frequently gain access to living plant tissue in plantation crops and forestry trees through wounds or fire damage (Browne, 1968; Harris, 1969, 1971; Kashyap *et al.*, 1984; McCaw, 1984; Perry *et al.*, 1985; Sands, 1977). In plantation crops many authors have recommended that dead wood be removed and cut back to the living tissue and pruning be carried out carefully with clean cuts and in a manner to avoid dieback (Harris, 1971; Sands, 1977; Sivapalan *et al.*, 1977). Pruning cuts and accidental wounds should be treated with paint or tar (Kashyap *et al.*, 1984) or perhaps with various plant gums (Beeson, 1941). Such procedures are labour-intensive; they may be cost-effective in plantation crops such as tea but not in forestry (Sen-Sarma, 1986).

Chamsama & Hall (1987) showed that root pruning of forestry seedlings in Tanzania, prior to transplanting reduced planting shock, enhanced drought hardiness and improved post-transplanting survival. Such treatment may therefore lead to healthier plants more capable of withstanding termite attack. However, poor root pruning, leading to breaks, splits and bruises, may encourage attack (Beeson, 1941), particularly if insufficient time is allowed for healing before planting out (Wardell, 1987).

In Sudan, and elsewhere in Africa, cotton suffers heavier termite attack if the roots are damaged by careless thinning, cultivation (including hoeing) or fungal disease (Pearson, 1958; Ripper & George, 1965). Similar damage to tea also leads to increased attack (Harris, 1971). Often, termite attack and microbial infection are seen together (Perry *et al.*, 1985; Ripper & George, 1965) but it is rarely clear which came first.

Weeding. Weeds competing with crops/trees, especially young ones, for nutrients, light and water may lead to stress and hence increased susceptibility to termite attack. As suggested for forestry trees in Sudan by Abd el Nour (1975), Abbas & Ahmad (1984) indicated high levels of damage in neglected fields of various crops in Pakistan; Ripper & George (1965) noted higher incidence of termite attack on cotton in Sudan in areas where the sedge *Cyperus rotundus* was abundant. Hoeing or hand weeding may then be recommended although other factors, both positive and negative, such as potential damage to root systems (see above), effects on termite numbers and activity (see below) and effects on soil water evaporation and erosion may be more important. Parry (1959) indicated that clear-weeding of *Eucalyptus* spp. led to increased termite attack during the first six months but to subsequent heightened resistance. The explanation for this was not clear.

Inorganic fertilizer. Fertilizers enhance plant vigour and should therefore reduce susceptibility to termite attack. Fuller (1912) reported that fertilizer (kainite) gave good protection from termite attack on trees in Australia, but there have been few subsequent studies specifically addressing this question and the little information available indicates only minor effects or none at all (Barnett, 1986; Brown, 1962; Crowther & Barlow, 1943). However, Sivapalan *et al.* (1977) showed that excessive use of nitrogenous fertilizer in tea encouraged fast growing soft tissue particularly susceptible to attack by the dry-wood termite *Glyptotermes dilatatus* (Bugnion & Popoff).

Manipulating termite numbers and behaviour

Crop rotation. When natural vegetation is cleared and the land cultivated, the nests of mound-building termite species and those with shallow subterranean nests are destroyed; and species dependent on trees and woody litter eventually disappear. Species with deep subterranean nests, and with the ability to survive on particular living crops and crop residues, remain and increase (Black & Wood, 1989; Kooyman & Onck, 1987; Wood *et al.*, 1977). Crop rotation, and fallow periods, should prevent the rapid build up of these species to high levels. Tree crops (e.g. rubber) may not be seriously attacked by termites dependent on wood for nests and food (e.g. *Coptotermes* spp.) if planted on land previously used for several years for annual non-woody crops (Harris, 1971; Snyder, 1926). However, in a number of cases, rotation seems to have led to greater levels of attack. Short-term rotations led to higher attack than longer rotations in cotton in Sudan (Tarr, 1960). Cotton in rotation following lubia (hyacinth bean) or dura (sorghum) in Sudan suffered heavier tap root damage than when it followed fallow, but this was considered probably due to the remaining crop residues from the previous year allowing build up of pest termites (see below) rather than due to the direct effects of the rotation (Crowther & Barlow, 1943). Support for this suggestion came from the observation that there was less damage in continuous cotton since residues, including roots (which were pulled up), were burnt after harvest.

Inter-cropping. In some cases establishment of monoculture forestry plantations can lead to a similar build up of numbers of certain termite species (e.g. *Coptotermes* spp. in south-east Asia) capable of surviving on the particular tree, while less adaptable termite species disappear (Sands, 1977; Tho, 1974). Under-planting with other tree species has been suggested as a means of retaining the range of termite species naturally present (Tho, 1974). However, in single species stands of *Eucalyptus* spp., attack by *Macrotermes* sp. ceases after canopy closure; and seedlings planted in an area in which *Eucalyptus* spp. have been grown previously are not attacked (ICFR, 1986). These facts suggest that the damaging *Macrotermes* populations disappear under mature monoculture *Eucalyptus* plantations. In Australia, *Nasutitermes exitiosus* (Hill) disappears when *Pinus* spp. are planted either as a monoculture or mixed with *Eucalyptus* spp. although *Coptotermes lacteus* (Froggatt) is unaffected (Lee & Wood, 1971).

Certain grasses are grown in West Africa to repel termites (see below) (Malaka, 1972; Sands, 1961) but otherwise the effects of inter-cropping on termite damage in field crops are unknown.

Crop residues and other organic matter. The addition or removal of organic matter from the field have both been suggested as methods of reducing levels of attack. Essentially, the conflicting principles are (i) that removal of residues and other debris from the field will reduce potential termite food supplies and hence lead to a reduction in termite numbers and subsequent attack; and (ii) that leaving residues in the field or adding further organic matter will provide alternative food to which the termites will be attracted, thereby reducing levels of attack. The respective counter-arguments are (i) that removal of alternative food sources will concentrate termite activity on the crops/trees, leading to increased damage; and (ii) that leaving residues and other food sources in the field will provide extra resources and allow termite populations to build up, again leading to increased damage. This conflict of ideas has been recognized for some time (Brown, 1962; Pearson, 1958). There is evidence supporting both views and a generalization may not be possible, different methods being appropriate in different places with different termite species and different crops/trees.

Many authors have recommended clearing and destruction of woody debris from new land before planting forest or plantation crops in order to reduce subsequent termite damage (Beeson, 1941; Harris, 1971; Sands, 1977; Snyder, 1926; Srivastava & Butani, 1987; Tho, 1974; Wood, 1968). In established plantations, the removal and destruction of dead wood and, particularly, termite infested trees is recommended as a control measure (K. W. Dammerman, quoted by Kashyap *et al.*, 1984; Harris, 1971; Srivastava & Butani, 1987) and should be done before the next rainy season to prevent release of large numbers of alates (Kalshoven, 1954). These practices should be effective for the control of dry-wood termites (Kalotermitidae) and others such as *Coptotermes* spp., but may be less successful for control of Macrotermitinae. The former use the wood both as nest sites and as food so clearing debris will remove existing colonies and most potential nest sites. Leaving it allows the build up of populations and encourages alate pairs to settle and establish further colonies; when these food sources are exhausted, which can coincide with the maturation of the plantation, heavy attack by an enhanced population occurs (Sands, 1977). Macrotermitinae, on the other hand, build their nests in the soil and are not dependent on wood for nest sites. Existing colonies and nest sites are not then directly affected by removal of debris and, since the termites can survive on the food stored in their fungus combs when other food is not available (Wood & Johnson, 1978), they may be able to persist for some time following land clearance. Consequently, removal of debris, e.g. by burning (Sudheendrakumar & Chacko, 1986), may not have a significant effect. In fact, Coaton (1950) found that termite attack in fruit and forestry plantations was reduced to negligible levels, even in areas with normally high levels of damage, by leaving organic debris from land clearance and by cutting but not removing weeds. Experience in forestry plantations in Tanzania prompted Wardell (1987) to recommend leaving as much debris as possible on the site after clearing, to ring-weed rather than clear-weed young stands and to use dried out stoloniferous and rhizomatous material from planting holes as a mulch. Similarly, mulching crops with various items including hay, manure, wood shavings or threshed maize cobs was said to dramatically reduce attack by small species of Macrotermitinae (*Microtermes* spp., *Ancistrotermes* spp., *Allodontermes* spp.) in South Africa, although it had much less effect on attack by larger species (*Macrotermes* spp., *Odontotermes* spp.) (Coaton, 1950). In Uganda, Dawkins (1949) found that repeated mulching of tree nurseries with grass, over a period of a year, greatly reduced termite, probably Macrotermitinae, foraging. Tree trunks, branches and woody remnants are used in rice fields in the Philippines and Sierra Leone to reduce termite attack (Litsinger *et al.*, 1978; Raymundo, 1986) and cuttings of the savanna tree *Vitex doniana*, buried alongside cassava cuttings in Uganda, attracted termites away from the cassava, reduced termite attack on it and led to increased sprouting (Epila & Ruyooka, 1988). Other authors, however, suggest that thinnings and other debris left in the field in areas where Macrotermitinae are the pest problem lead to increased termite numbers and subsequent attack (Beeson, 1941; Ripper & George, 1965). Clearly, the type of debris may be important; not all debris will be similarly palatable to all termite species. The different seasonal patterns of foraging of different termite species may also be important. Furthermore, mulches have significant effects on soil physical and chemical properties (Lal, 1987), especially moisture availability, which may influence both termite activity and plant growth.

Maintenance of high levels of organic matter in the soil, as well as on the soil surface, may also have significant effects on damage. Undecomposed organic matter in the soil, including ploughed in weeds, green manure and crop residues, has been considered a cause of attack on cotton in Malawi and Sudan (Agricultural Research Council of Malawi, 1971; Matthews, 1989; Ripper & George, 1965) and maize in the USA (Snyder, 1926), although Coaton (1950) considered ploughing in green manure or crop residues alleviated even severe attack in South Africa. Wardell (1987) recommended use of organic manures in planting holes. Timing of manuring may be critical: organic matter or green manures applied immediately before sowing protected young cotton plants in Sudan, possibly by providing an alternative food source for the termites, but if applied earlier (up to 2 years before sowing) resulted in increased damage by allowing termite numbers to build up (Crowther & Barlow, 1943). Again, the type of manure/mulch/debris will be important, depending on the preferences of the local termite species, but the effects on plant vigour (see above), resulting in heightened resistance to attack, may be more significant.

Adjacent plants. An extension of the idea of providing alternative food sources within the crop is to use other plants as trap hosts for infesting termites. Thus Sivapalan *et al.* (1977, 1980) found that the presence of shade trees around highly susceptible clones of tea in Sri Lanka was correlated with reduced attack by the dry-wood termite *Glyptotermes dilatatus*, which initiated colonies in the shade trees but could not survive subsequently (see also Sands, 1977). However, an analogous counter-argument to that presented above for retaining organic debris suggests that surrounding plants may instead act as a further source of food or nest sites and lead to increased termite populations and higher levels of attack, as implied by Smith (1985) in cocoa surrounded by shade trees and attacked by *Neotermes* sp. in Papua New Guinea.

Weeding. Ripper & George (1965) indicated greater damage to cotton in Sudan in fields in which *Cyperus rotundus* was abundant (see above). Whether this was a result of the weed attracting termites and/or providing a plentiful source of food and allowing termite numbers to build up, or a result of competition with the weed reducing cotton plant vigour (above), was unknown. In an analogous way to the clearing or otherwise of debris, etc. (see above), the results of weeding would depend on the balance between these factors. Hoe-weeding would also destroy some termite galleries (see below).

Breaking up termite galleries. Termite damage is not generally a problem in crops planted on deep cracking soils because the frequent cracking prevents adequate building and maintenance of mounds, runways and galleries (Lee & Wood, 1971). Artificial breaking up of the soil may have a similar effect, reducing termite foraging activity. Deep ploughing is common practice in India, at least in part for this reason (Kakde, 1985), and a similar practice has been recommended in South Africa (Otto, 1951) and the USA (Snyder, 1926). Beeson (1941) suggested that repeated digging of forest nursery soil beds would reduce termite attack. Regular cultivation around plants to break up termite passages in the soil is effective against shallow-nesting species (Fuller, 1912) but may only have a temporary effect (Coaton, 1950).

Other practices

High density sowing. Many farmers sow seed at a higher rate than recommended in order to offset anticipated losses due to termites; surviving plants may then be thinned to the appropriate number (Crowther & Barlow, 1943; Harris, 1971; Matthews *et al.*, 1972; Pearson, 1958; Wardell, 1987; Wood & Cowie, 1988). Small gaps may be filled by compensatory growth of unattacked plants (Matthews *et al.*, 1972; Wood & Cowie, 1988) but the frequently patchy nature of termite attack may still lead to some large areas losing all plants, and unless thinning is carried out rigorously, yield may be reduced by interplant competition (Cowie *et al.*, 1989; Pearson, 1958; Wood & Cowie, 1988).

Spacing. Widely-spaced cotton (Crowther & Barlow, 1943) and groundnuts (Mercer, 1978) are more liable to attack but the reasons are not clear.

Time of harvesting. Crops are often more seriously damaged towards harvest than earlier in the season (Sands, 1977) although this depends on the species of termite involved (Wood & Cowie, 1988). Prompt harvest may therefore reduce yield loss (Amin *et al.*, 1985; Harris, 1971). Delays in harvesting can also lead to yield loss through lodging (e.g. in maize and sunflower) or pod/peg damage in groundnuts (El Amin *et al.*, 1983; Harris, 1971; Wood *et al.*, 1980a).

Biological control

Biological control aims to manipulate other organisms (predators and pathogens/parasites) in an attempt to reduce pest numbers to economically acceptable levels (Horn, 1988). Termites are eaten by a wide range of vertebrate and invertebrate predators whose natural influence on termite numbers and population dynamics is partially understood in a small number of cases (Wood & Johnson, 1986). However, the natural role of their pathogens and other associated non-symbiotic microorganisms is largely obscure (Grassé, 1986; Wood & Sands, 1978).

Biological control can be effected in three ways: (i) by introducing exotic natural enemies/pathogens to pests of exotic origin—this is not applicable here as almost all termite pests of agriculture and forestry are indigenous; (ii) by enhancing the effects of natural predators or pathogens by habitat modification or mass release; and (iii) by the release of particular strains, for instance of insecticide resistant predators or specifically toxic pathogens.

Predators

The predation hazards confronting termites are enormous. They are preyed upon by a wide range of predators, specialist or opportunistic. Attack is mainly upon individuals outside the nest, foraging neuter casts or alate reproductives leaving the nest to found new colonies. Reviews are included in Araujo (1970), Deligne *et al.* (1981), Grassé (1986), Hegh (1922), Krishna & Weesner (1970), Snyder (1956, 1961, 1968) and Wood & Sands (1978).

Predation of alate reproductive colony-founding swarms. This is entirely opportunistic since the alate flights are seasonal and short-lived and cannot provide a regular food supply. Arthropod predators include scorpions, solpugids, spiders, centipedes, dragonflies, cockroaches, mantids, crickets, beetles, flies, ants and wasps (Wood & Sands, 1978). It is likely that ants account for a significant proportion of the probable near-100% mortality of swarming alates. Even when pairs have successfully dug into the soil they are liable to predation by several specialist predators (see below). Vertebrate predators of alate swarms include fish, reptiles, amphibia, birds and mammals including man (Hegh, 1922; Nutting, 1969; Snyder, 1956, 1961, 1968). Of these, birds are the best documented. De Bont (1964) believed that survival of insectivorous Palaearctic migrants may depend on flights of alate termites; some birds take 10–30% of some swarms (Thiollay, 1970). High production of alates (30–170% of standing crop biomass—Wood & Sands, 1978) is anticipatory of large losses to predators and it is inconceivable that predation on alates could be enhanced artificially to influence levels of subsequent termite populations.

Opportunistic predation of foraging sterile castes. These predators include all those groups which attack alates, although the relative importance differs, birds being much less important than ants. In Zambia, the main opportunist ant predators of surface foraging species of *Hodotermes*, *Trinervitermes* and Macrotermitinae were *Myrmicaria eumenoides* Gerstaecker and *Pheidole megacephala* Fabricius (Sheppe, 1970). Bouillon (1970) noted that in South Africa the grass-harvesting *Hodotermes* spp. and *Microhodotermes* spp. are attacked by *Anoplolepis custodiens* (F. Smith) and *Iridomyrmex humilis* (Mayr), respectively to such effect that foraging is limited to an hour or two in any one location. Ohiagu & Wood (1976) observed surface predation by *Crematogaster* sp. on grass-harvesting *Trinervitermes* spp. Among vertebrate opportunists, birds and mammals are best documented. Milstein (1964) recorded the bird, korhaans (*Afrotis* spp.) with 1500-1900 *Hodotermes* workers in their stomachs and Steyn (1967) found 5100 in one Guinea fowl. Smithers (1971) found termites in the guts of over 15 species of mammals in Botswana; over half the individuals of some species had eaten termites.

Clearly, surface-foraging termites, such as harvester termites which feed in the open, or those Macrotermitinae which feed under thin surface sheets of soil or occasionally in the open, suffer most from opportunistic predation, whether this is by ants, birds or mammals. There are no quantitative estimates of consumption on which to base attempts to enhance predation, although Beeson (1941) claimed that transplanting *Solenopsis* sp. to nurseries of tree seedlings in India controlled termites. Burying 'gur' (unrefined sugar) near trees to attract ants which prey on termites has also been suggested (Anon., 1898).

Specialized predation on foraging sterile castes. The more constantly available food supply, represented by the non-reproductive castes has led to the evolution of behavioural and morphological adaptations of predators which exploit the two main concentrations of termite activity, foraging parties and the brood centre ('hive'). The latter involves the need for excavation of protective nest walls and both require resistance to defence mechanisms of the termites. Hive predators tend to be nomadic since their feeding is commonly destructive, whereas predators on foraging parties need the ability to harvest rapidly a sufficient amount of food before the rest flees underground, or aggressive or distasteful soldiers become too numerous.

Specialized invertebrate predators of foraging termites seem to be confined to a few species of ponerine and myrmicine ants. Emerson (1945) recorded raids by *Termitopone commutata* (Roger) on foraging columns of *Syntermes* spp. in south America where parties of over 100 ants carried off one or two termites each. The African ponerine *Megaponera foetens* (Fabricius) exclusively preyed on foraging Macrotermitinae in Nigeria (Longhurst *et al.*, 1978), the main prey species being *Macrotermes bellicosus* (Smeathman) (141 termites m^{-2}/yr) and other species (52 m^{-2}/yr). Predation on *M. bellicosus* was equivalent to the standing crop population and 1/7th of the total annual production (Collins, 1981). *Decamorium uelense* (Santschi) preys on small termites which feed inside their food sources of roots and plant debris (Longhurst *et al.*, 1979); *Microtermes* spp. comprised 99.5% and were consumed at the rate of 632 termites m^{-2}/yr) which is equivalent to 74% of the standing population and approximately one-eighth of the total annual production.

The aardwolf (*Proteles cristatus*) preys almost entirely on *Trinervitermes* spp. (Kruuk & Sands, 1972). Wood & Sands (1978) estimated that a modest *Trinervitermes* population would supply 20-50 times the annual metabolic needs of a single aardwolf; enhancing aardwolf, and indeed other vertebrate populations, to a level capable of controlling termite numbers is, therefore, inconceivable.

Habitat modification in perennial crops (Majer, 1986) has, in a few instances, effectively reduced pest ant populations by increasing the favourability of the habitat for predatory ants. A similar approach, or transplanting ant nests to specific locations, could have two effects on termites: (i) reduction in numbers—this is unlikely as loss of neuter castes is rapidly countered by increased egg laying and social regulation of caste ratios; and (ii) reduction in foraging activity due to interference (see Bouillon, 1970), a possibility perhaps worth exploring.

Specialized predation on colony brood centres. Specialized predation by invertebrates on the hive has only been perfected on a large scale by the burrowing doryline ants. These have subterranean raiding columns and appear to bivouac in the nest systems of the termites on which they prey. The reaction of termite colonies invaded by *Dorylus* spp. varies: *Macrotermes* spp. and *Cubitermes* spp. seem to remain and fight to a finish, while *Trinervitermes* spp., *Pseudacanthotermes* spp. and some soldierless genera such as *Alyscotermes* may leave and migrate to the surface where the ants rarely follow. Bodot (1961, 1967) noted that approximately 26% of *M. bellicosus* nests were attacked each year by dorylines in the Ivory Coast. In environments disturbed by clearing for cultivation, these attacks resulted in extinction, which could reflect the lowered vitality of the termite colonies resulting from food shortage. In contrast, in a stable environment in East Africa where most colonies of *Macrotermes michaelseni* (Sjöstedt) were mature, although 80% of colony mortality was caused by dorylines, it only amounted to a few per cent annually. Recolonization of areas artificially cleared of mounds, or following natural high mortality, is rapid (Darlington, 1982b; Pomeroy, 1983).

Specialized vertebrate predators of the hive are all mammalian, with typical 'ant-eater' adaptations. They include pangolins in Africa and India, the aardvark of Africa, the armadillo in Texas, ant-eaters in South America, the sloth bear in India and the numbat and echidna in Australia (Wood & Sands, 1978).

There are no quantitative data on the consumption of termites by colony-raiding predators on which to base attempts to enhance predation.

Pathogens

The distinction between naturally occurring microbial symbionts, commensals, parasites and pathogens, including bacteria, fungi, protozoans, viruses and nematodes, is difficult without knowledge of the ecology of the termites. Many of the micro-organisms that have been found in association with termites (Grassé, 1986; Johnson & Gumel, 1981) are not significant pathogens and hence not potentially useful as biological control agents; some are obligate symbionts (Breznak, 1982; O'Brien & Slaytor, 1982). Few proven pathogens have been isolated from termites. Nevertheless, termites have been considered as good candidates for pathogenic control because they live in a conducive environment—humid, crowded and intimate (Burges & Hussey, 1971, p. 708). But despite the laboratory testing of hundreds of known insect pathogens against termites (Lund, 1971), few have been tested in the field and none has proved effective. Successful control may be unlikely in general because of the well-known termite behaviour of isolating infected colony members in walled off parts of the nest (Logan & Abood, 1990; Pearce, 1987; Reese, 1971; Su *et al.*, 1982; Wood & Sands, 1978), thus preventing spread of the pathogen through the colony. However, in some cases, termites may consume dead and diseased individuals and hence spread the disease through the colony (Page, 1967), although in others they do not (Grassé, 1986). Considerable problems in developing formulations and application methods are likely (Sands, 1973b) and decisions about appropriate strategies to adopt, either stimulation of the endemic tendencies of natural pathogens or introduction of artificial inocula (Ferron, 1978; Nickle, 1984), would be premature. Much background information is available in Burges (1981), Burges & Hussey (1971) and Ferron (1978).

Viruses. Pathogenic virus-like particles have been isolated from termites (Gibbs *et al.*, 1970) and the pathogenicity to termites of nuclear polyhedrosis virus from the moth *Spodoptera littoralis* Boisduval and of an iridovirus from the mole cricket *Scapteriscus borellii* Giglio-Tos have been experimentally demonstrated (Al Fazairy & Hassan, 1988; Fowler, 1989). However, the potential of viruses as control agents has not been further evaluated.

Bacteria. The mutualistic association between termites and their dense and diverse bacterial gut flora (e.g. Yara *et al.*, 1989) is well-known (see above) but only rarely have pathogenic bacteria been isolated from termites. Khan *et al.*, (1977a) isolated a naturally occurring termite strain of *Bacillus thuringiensis* Berliner (Bt) from *Bifiditermes beesoni* (Gardner) and demonstrated its pathogenicity to other termite species. Other studies of Bt have demonstrated the pathogenicity to various termites of commercially produced strains not derived from termites (Farghal *et al.*, 1987; Khan *et al.*, 1978, 1985; Smythe & Coppel, 1965). It can be passed between individual termites by trophallaxis (Khan *et al.*, 1981) and live termites can pick up infection from treated cadavers (Farghal *et al.*, 1987). There are differences in susceptibility among termite species (Farghal *et al.*, 1987). However, only Kakaliyev & Saparliyev (1975) have assessed its efficacy in the field, concluding that it held little promise as a control agent. In general, Bt may not be a good candidate for soil insect control because of its poor survival in the soil (Burges, 1981).

Various other bacteria, notably *Serratia marcescens*, are pathogenic to a number of termite species and can be transferred by trophallaxis (Khan *et al.*, 1977b; Khan *et al.*, 1981; Lund, 1971). Page (1967) combined both *B. thuringiensis* and other bacteria with fungi, suggesting a synergistic effect, but presented no field results.

Fungi. Biological control of insects with fungi has been broadly reviewed by Ferron (1978) although with few specific references to termites. Termites are natural hosts for at least 20 species of obligate ectoparasitic fungi (Blackwell & Rossi, 1986), while many other fungal species are associated more generally with them (Grassé, 1986; Johnson & Gumel, 1981; Sands, 1969; Thomas, 1987a). The infectivity and pathogenicity of some of these and other fungi has been demonstrated in the laboratory (Bao & Yendol, 1971; Sands, 1969; Smythe & Coppel, 1966; Yendol & Rosario, 1972) but their ecological significance remains unknown (Grassé, 1986); they are probably rarely encountered in the field at the laboratory concentrations tested. However, Hanel & Watson (1983 and references therein) have attempted to control *Nasutitermes exitiosus* (Hill), which damages forest trees in Australia, by dusting/spraying individual termites with *Metarhizium anisopliae*. Although the fungus spread through the colony and survived for up to 15 weeks in some cases, the results for colony mortality were unconvincing. It is possible that either other micro-organisms in the colony inhibit the fungus or the termites themselves produce a fungistatic secretion. Inhibition of fungi, other than the obligate symbiont *Termitomyces* spp. in colonies of Macrotermitinae (fungus-growing termites), is well established, although the mechanism is not clear (Thomas, 1987b; Wood & Thomas, 1989).

Protozoa. Protozoa are important symbionts of lower termites (Honigberg, 1970; Yamin, 1980) but reports of protozoan pathogens infecting termites are few (Jafri *et al.*, 1976). They have not been considered as biological control agents.

Nematodes. Nickle (1984) gives much general information on nematode infection of insects and Poinar (1979) gives basic data on species with potential as pest control agents, but neither author specifically mentions biological control of termites. Poinar (1975) listed the termite species (13) in which natural nematode infections, frequently due to *Rhabditis* spp., had been recorded. Nematodes enter their insect hosts both via natural openings (mouth, anus, spiracles) and by active penetration of the cuticle and intersegmental membranes (Bedding & Molyneux, 1982). Their pathogenic action is at least partly due to infection of the insect by bacteria associated with the nematodes (Danthanarayana & Vitarana, 1987; Fujii, 1975; Georgis *et al.*, 1982). They have been tested against a number of soil pests in the field but the results have not been consistent (Georgis & Poinar, 1983; Poinar, 1979); and although they have been commercially marketed in the USA for prevention of subterranean termite damage to buildings (Weidner, 1983), rigorous field trials involving application of high concentrations of nematodes to the soil to act as a barrier to termites have not convincingly demonstrated their efficacy (Mix, 1985, 1986). Mix (1985) indicated that termites were able to move through treated soil, while Epsky & Capinera (1988) suggested that they could detect and avoid the treated area, readily circumvent or find gaps in it and that protection only lasted for two to three weeks. Efficacy probably depends on precise temperature and humidity requirements and on protection from sunlight (Gaugler & Boush, 1979; Georgis & Hague, 1981; Mix, 1986; Schmiege, 1963). These may be the main reasons why control of subterranean termites with nematodes has not yet met with successs despite the pathogenicity of the nematodes to the termites.

In contrast, application of a suspension of *Heterorhabditis* sp. to individual branches of tea bushes, infested with the dry-wood termite *Glyptotermes dilatatus* in Sri Lanka, suggested that infection could spread through the colony and give effective and economic control (Danthanarayana & Vitarana, 1987). However, control of dry-wood termites in less valuable crops or in forestry trees, by this time-consuming and labour-intensive method, is unlikely to be appropriate or cost-effective.

Queen removal

Removal of the queen and/or destruction of the nest have been advocated frequently for the control of mound-building termites, especially the fungus-growing Macrotermitinae (e.g. Dawkins, 1949; Kakde, 1985; MacGregor, 1950; Rajagopal, 1982). The nest is readily identified and the royal chamber easy to locate. However, if nymphs or alates are present at the time of de-queening, replacement reproductives may develop (Coaton, 1949; Darlington, 1985; Fuller, 1912; Sieber, 1985; Wilkinson, 1940), although this is frequently not appreciated with regard to the Termitidae. However, Wilkinson (1940) considered that, if the fungus combs as well as the queen were removed, the colony did not recover. Dawkins (1949) advised lighting a fire in the mound after queen removal. Consequently, success of the technique varies. However, foraging activity may be reduced even if de-queened colonies do not die since they remain inactive for 12-18 months until new queens become established (Coaton, 1949). In addition, termite colonies are totally subterranean for their first few years and so, even if mature colonies are killed, immature colonies are overlooked and may spread to take over the area previously foraged by the de-queened colony (Cowie *et al.*, 1989). Nevertheless, reduction in foraging activity may be for a sufficient period to allow young trees to become established or offer short term protection to crops, but only in the rare cases where mound-building species are the only serious termite pests.

Control of *Coptotermes curvignathus* Holmgren by queen removal has been attempted, but reproductives of lower termites are replaced even more readily than those of higher termites (Wood, 1968); and in forestry it is mature trees which are attacked, which would necessitate continuous destruction as mounds appear (Cowie *et al.*, 1989).

Plant insecticides, wood ash and other toxic/repellant materials

Locally available parts of plants, plant extracts and other substances have frequently been claimed to be effective in termite control, although they have received little rigorous assessment in the field.

Plant insecticides

A wide range of plants is toxic or repellent to insects or have antifeedant properties (Harborne, 1988). Many have been considered for use as insecticides (Gerits & van Latum, 1988; Stoll, 1986). Ideally, plant insecticides should come from readily available local plants or those which are easy to grow, preferably on poor quality land so that they do not compete with food or cash crops. The active ingredient should be available with little or no preparation and the plants should not develop into weeds or act as hosts for crop pests. In addition they should have low toxicity to non-target organisms, especially beneficial insects and humans.

Laboratory studies have identified a number of plants containing material toxic to termites. Most research has concentrated on chemicals in timber which confer resistance to attack (see below). Many timbers contain chemicals or complex mixtures of chemicals that repel or kill termites or interfere with their gut fauna (Adams *et al.*, 1988; Beal *et al*, 1974; Carter & Mauldin, 1981; Lin & Wang, 1988; Rudman & Gay, 1967) but these chemicals are difficult to extract (Carter & de Camargo, 1983). Consequently, they are unlikely to be useful as insecticides in their own right, particularly as most of the toxic chemicals in timber are avoided by termites except in no-choice tests (Carter & de Camargo, 1983; Carter & Smythe, 1974). However, waste sawdust or wood chips from trees containing repellant chemicals may provide some protection if incorporated into soil or used as a mulch round crops or trees, but this has yet to be tested.

Herbaceous plants or the leaves and fruit of trees are more likely to be effective; they are easily crushed and usually can be used without complex extraction procedures. Laboratory experiments have found numerous materials repellant or toxic to termites in such plant material (Table 1) but in very few of these studies was their effectiveness tested in the field.

Nevertheless, there are many reports of plant materials or extracts being used in the field (Table 1). Some authors make recommendations on the basis of personal experience; others report local practices which may or may not be effective. The simplest method of application is as a mulch. Several mulches using leaves or berries of the plant or oil cake (the residue after oil such as neem or castor has been extracted) are reported to be effective. Whether this was due to toxic effects or to effects of the mulch *per se* on soil physical and chemical properties (Lal, 1987), which in turn affected plant vigour and susceptibility to termite attack, is unknown. Water extracts of plants have been mixed with irrigation water, sprayed on to plants or mixed with the soil to protect trees and crops. Further details and references are given in Table 1.

Beeson (1941) gave recipes for mixtures of plant extracts which prevented termite foraging on trees and attack on wound or fire damage in India. As the original paper is difficult to obtain these are described here. 'Gambir mixture' made from the leaves of *Uncaria gambir* (Naucleaceae) or the dried aqueous extract of *Acacia catechu* (Leguminosae) mixed with oil from *Canarium strictum* (Burseraceae), *Hopea* sp. (Diptocarpaceae) or *Shorea* sp. painted on wounds or fire damage to trees prevents invasion by termites. 'Gondal fluid' (castor oil cake mixed with plant extracts from *Gardenia gummifera* (or *G. lucidia*) (Rubiaceae), *Ferula jaeschukeana* (Umbelliferae) and aloes (Agavaceae) (*Agave vera*, *A. cantela* or *A. angustifolia*) and soaked for two weeks) painted round the base of a tree gives protection against termite foraging for about eight months. Giridhar *et al.* (1988) showed that *Calotropis* (Asclepiadaceae) latex protected wooden pegs for four months.

Some grasses are actively avoided by termites (Sands, 1961) and are planted by farmers to keep termites from farms and gardens in Nigeria (Malaka, 1972).

Wood ash and other materials

Wood ash heaped around the base of the trunk has been recorded as preventing termite infestation of coffee bushes (Khashyap *et al.*, 1984) and is said to repel them from date palms (Popenoe, 1973). It is said also to be effective in protecting tree seedlings if mixed into forestry nursery beds or applied as a layer below polythene planting tubes (Beeson, 1941; C. Holding (CARE, Sudan) pers. comm.) and to protect stored yams, wooden posts and stacks of hay and maize straw (Jack, 1913; Malaka,

Table 1. Plant species* reported to be toxic or repellent to termites.

Plant	Method/Use	Country	Author
ACANTHACEAE			
Adhatoda vasica	infusion used against termites	India	Secoy & Smith, 1983(A)
AGAVACEAE			
Agave americana	water extract (leaves) to protect paper	India	Dastur, 1954(TA)
Agave angustifolia (aloe)[1]	water extract as paint for tree wounds	India	Beeson, 1941(TB)
Agave vera (aloe)[1]	water extract as paint for tree wounds	India	Beeson, 1941(TB)
Agave cantela (aloe)[1]	water extract as paint for tree wounds	India	Beeson, 1941(TB)
Sansevieria libericum	water extract to protect crops	Nigeria	Malaka, 1972(TA)
ANACARDIACEAE			
Anacardium occidentale (cashew)	seed oil/stem gum to protect timber	?	Usher, 1974(TA)
ARALIACEAE			
Hedera helix	saponins in leaves inhibit feeding	–	Tschesche *et al.*, 197
ASCLEPIADACEAE			
Calotropis procera	latex from stem to protect timber	India	Giridhar *et al.*, 1988(
Sarcostemma acidum	decoction with salt as termite repellent	India	Secoy & Smith 1983(
Sarcostemma brevistigma	plants/salt bag hung in irrigation water	India	McIndoo, 1945(A)
	decoction with salt as termite repellent	India	Secoy & Smith, 1983(A)
BURSERACEAE			
Boswellia dalzielli	gum to protect wood	?	Jacobson, 1975(TA)
Canarium strictum[2]	gum from leaves to paint for tree wounds	India	Beeson, 1941(TB)
Commiphora africana	water extract in tree nursery irrigation	Malawi	Wardell, 1987(A)
	resin used as termite repellent	W. Africa	Jacobson, 1975(T)
CARICACEAE			
Carica papaya (papaya)	immature fruit juice toxic		Yaga, 1973(L)
CARYOPHYLLACEAE			
Gypsophila paniculata	saponins in roots inhibit feeding		Tschesche *et al.*, 1970(L)
COMPOSITAE			
Chrysocoma tenuifolia	oil from leaves/flowers toxic/repellent		Hewitt & Nel, 1969(L)
Parthenium hysterophorus	extract of leaves toxic		Tilak, 1977(L)
Tagetes minuta	water extract in tree nursery irrigation	Malawi	Wardell, 1987(A)
Tagetes sp.	water extract in tree nursery irrigation	Zimbabwe	S. Page, pers. comm.(A)
CONVOLVULACEAE			
Ipomoea fistulosa	mulch to protect drying groundnuts	India	C.S. Gold, pers. comm.(E)
CUPRESSACEAE			
Chamaecyparis formosensis	?	?	Grainge & Ahmed, 1988(?)
Juniperus sp.	extract of leaves toxic	–	Adams *et al.*, 1988(L)
DIPTOCARPACEAE			
Hopea sp.[2]	oil used as paint for tree wounds	India	Beeson, 1941(TB)
Shorea sp.[2]	oil used as paint for tree wounds	India	Beeson, 1941(TB)
EUPHORBIACEAE			
Euphorbia tirucalli	planting hole to protect *Eucalyptus*	Tanzania	Wardell, 1987(B)
Euphorbia continifolia	planted as repellent	Africa	Secoy & Smith, 1983(?)
Ricinus communis (castor)	oil cake mulch in tree nursery	India	Beeson, 1941(TB)
	oil cake as paint for tree wounds	India	Beeson, 1941(TB)
	oil cake mulch in sugar cane fields	India	Anon., 1898(B)
FABACEAE			
Daniellia oliveri		Africa	Secoy & Smith, 1983(?)
GRAMINEAE			
Cymbopogon citratus		?	Sands, 1961(TA)
Cymbopogon schoenanthus		Nigeria	Malaka, 1972(TA)
Digitaria sp		Nigeria	Malaka, 1972(TA)
Pennisetum purpureum		Nigeria	Malaka, 1972(TA)

Table 1. *Continued*

Plant	Method/Use	Country	Author
HIPPOCASTANACE.			
Aesculus hippocastanun	saponins in fruit toxic; inhibit feeding	–	Tschesche *et al.*, 1970(L)
LABIATEAE			
Hyptis spicigera	whole plant laid below stored millet	W. Africa	Dalziel, 1937(T)
Ocimum basilicum (basi	water extract as seed dressing for yam	Nigeria	Malaka, 1972(TA)
Ocimum canum	water extract in tree nursery irrigation	Malawi	Wardell, 1987(A)
Ocimum urticifolium	water extract in tree nursery irrigation	Malawi	Wardell, 1987(A)
LEGUMINOSAE			
Acacia catechu[2]	leaves/gum as paint for tree wounds	India	Beeson, 1941(TB)
Albizzia anthelmintica	saponins in roots toxic, inhibit feeding	–	Tschesche *et al.*, 1970(L)
Cassia siamea	leaf mulch in tree nursery	Kenya	Wardell, 1987(A)
Glycyrrhiza glabra	saponins in roots toxic, inhibit feeding	–	Tschesche *et al.*, 1970(L)
Hardwickia manii	stem and branches toxic	?	Grainge & Ah[illegible], 1988(A)
Leucaena leucocephala	leaf mulch in tree nursery	Kenya	Wardell, 1987(A)
Parkia clappertoniana	water extract to protect crops	Nigeria	Malaka, 1972(TA)
Pterocarpus erinaceus	leaves used to protect millet granaries	?	Booth & Wickens, 1988(A)
Robinia pseudacacia	wood shavings repellent	?	Jacobson, 1975(L)
Swartzia madagascariensis	powdered fruit toxic	?	Jacobson, 1975(TA)
	powdered pods to protect stored grain	Africa	Drummond & Palgrave, 1973(TA)
LILIACEAE			
Aloe graminicola	water extract for *Eucalyptus* irrigation	Tanzania	Wardell, 1987(B)
MELIACEAE			
Azadirachta indica (neem)	oil cake mulch in *Eucalyptus* nursery	India	Beeson, 1941(TB)
	leaf mulch in tree nursery	Kenya	Wardell, 1987(A)
	mulch to protect drying groundnuts	India	C.S. Gold, pers. comm.(E)
Melia azedarach	seed extract (methanol)	–	Jacobson, 1982(L)
	leaf/berry mulch/extract in tree nursery	Kenya	Wardell, 1987(A)
	soil treatment with leaves protects wheat	India	McIndoo, 1945(E)
	bark, seed, leaf and fruit extracts	–	Lin & Wang, 1988(L)
MORACEAE			
Ficus carica	sap used to destroy termite mounds	Africa	Secoy & Smith, 1983(A)
NAUCLEACEAE			
Uncaria gambir[2]	leaves/gum as paint for tree wounds	India	Beeson, 1941(TB)
PALMAE			
Elaeis guineensis (oil palm)	oil from fruit as seed dressing, yam	Nigeria	Malaka, 1972(TA)
PAPAVERACEAE			
Argemone mexicana	oil from seed	Nigeria	Dalziel, 1937(T); McIndoo, 1945(T)
	juice from plant	Nigeria	Dalziel, 1937(T)
PINACEAE			
Pinus roxburgii	needle extract repellent		Zaheer *et al.*, 1987(L)
PRIMULACEAE			
Cyclamen europaeum	saponins in tuber toxic, inhibit feeding		Tschesche *et al.*, 1970(L)
Primula elatior	saponins in roots toxic, inhibit feeding		Tschesche *et al.*, 1970(L)
ROSACEAE			
Quillaja saponaria	saponins in bark inhibit feeding		Tschesche *et al.*, 1970(L)
RUBIACEAE			
Gardenia gummifera[1]	water extract to protect trees	India	Tryon, 1903(T); Beeson, 1941(T
Gardenia lucidia[1]	water extract as paint for tree wounds	India	Beeson, 1941(TB)
SAPOTACEAE			
Butyrospermum parkii	water extract of kernels repellant	W. Africa	Dalziel, 1937(TA)
Chrysophyllum albidum	fruit exocarp to protect crops	Nigeria	Malaka, 1972(TA)

Table 1. *Continued*

Plant	Method/Use	Country	Author
SCROPHULARIACEAE			
Digitalis purpurea	saponins in seeds toxic, inhibit feeding	-	Tschesche *et al.*, 1970(L)
Digitalis lanata	saponins in seeds toxic	-	Tschesche *et al.*, 1970(L)
SIMAROUBACEAE			
Quassia indica	water extract of leaves	Indonesia	Usher, 1974(TA)
SMILACACEAE			
Smilax aristolochiaefolia	saponins in roots toxic, inhibit feeding	-	Tschesche *et al.*, 1970(L)
SOLANACEAE			
Nicotiana tabacum (tobacco)	water extract in tree nursery irrigation	India	Beeson, 1941(TB)
	water extract in crop irrigation	India	Roonwal, 1979(TB)
	water extract in tree irrigation	Zimbabwe	Jack, 1913(B)
	dust to protect trees	Zimbabwe	Jack, 1913(B)
Solanum spp.	saponins inhibit feeding, some toxicity	-	Tschesche *et al.*, 1970(L)
THEACEAE			
Thea sinesis (tea)	saponins in fruit toxic	-	Tschesche *et al.*, 1970(L)
UMBELLIFERAE			
Ferula laeschukeana[1]	water extract—tree band	India	Beeson, 1941(TB)
Ferula assafoetida	reduced attack on wheat	India	McIndoo, 1945(A)
VERBENACEAE			
Lippia javanica	water extract in tree nursery	Malawi	Wardell, 1987(A)
Acorus calamus	water extract to protect crops	India	Roonwal, 1979(B)
	water extract to dip sugar cane setts	India	Butani, 1967(TE); Roonwal, 1979(B)
VITIDACEAE			
Cissus quadrangularis	planted as termite repellent	Africa	Dalziel, 1937(T)

*Plant names are those given by authors; family names from Willis (1973).
[1] mixed together to give Gondal fluid; [2] mixed together to make Gambir mixture.
?—information not given; T—traditional; L—laboratory study; E—formal experimental field trials;
A—reported to the author as effective, hearsay; B—reported by the author as effective, first hand knowledge.

1972). Use of wood ash is a common practice which demands proper evaluation.

Nigerian farmers bury dead animals or fish viscera to reduce termite attack but the rationale behind this is not clear (Malaka, 1972). In India, water containing decomposed fish, tobacco and salt, or the washings from a bear skin (!) were reputed to keep termites from mango trees (Anon., 1898). Kerosene, diesel and crude oil have been recommended to prevent attack on timber and on tree bark (Beeson 1941; Giridhar *et al.*, 1988; Logan & El Bakri, 1990; Malaka, 1972). The addition of crude, fuel or fish oil emulsion to irrigation water is reputed to reduce damage to tree seedlings and sugar cane (Beeson, 1941; Butani, 1967; Rao, 1951; Roonwal, 1979). Snyder (1926) recommended an emulsion of kerosene and fish oil soap applied to a layer of sand or ashes under pots in horticultural nurseries in the USA. Coal tar, traditionally used to protect the cut ends of sugar cane setts in India is ineffective as termites attack unprotected buds (Butani, 1967; Rao, 1951) but, painted round the trunks of fruit trees, it can prevent foraging on bark and subsequent ring-barking (Giridhar *et al.*, 1988; Jack, 1913) and applied to pruning cuts prevents termite access (Snyder, 1926). Swathing the base of young trees in sheep dung or a mixture of cow dung and aloe juice, or burying soap near the roots, have been suggested (Fuller, 1912).

Plant resistance

Resistance functions either by inhibition of pest attack or by the ability of plants to produce normal yields despite attack (Horn, 1988). Generally, however, the possibility of using termite resistant varieties or species of crops and trees has been ignored. The ready availability and high efficacy of organochlorine insecticides has, until recently, obviated the need for research on resistance. Even now, with the widespread concern over the environmental effects of these compounds, most research focuses on the use of new and safer insecticides rather than on the use of resistant species or varieties.

Resistant crops

In general crops showing resistance or tolerance are indigenous while the susceptible crops are exotic. For instance, in Africa sorghum and millet are more resistant to termites than maize (Cowie & Wood, 1989); and cowpea and bambara nuts are not attacked while

84

groundnuts suffer serious damage (Johnson *et al.*, 1981). Presumably indigenous crops have evolved defence mechanisms against the local termite species. Nevertheless, some exotic plants, such as mango, avocado and citrus in South Africa, are resistant to termites (Fuller, 1912). Where there are major losses to termites, resistant crops could provide options by way of rotations or inter-cropping but the over-riding factors are likely to be socio-economic. Grafting susceptible fruit trees on to root stocks of resistant species has been practiced successfully (Fuller, 1912).

Cultivars of a particular crop may also differ in susceptibility (Amin *et al.*, 1985; Johnson *et al.*, 1981; Kumarasinghe & Ranasinghe, 1988; Mercer, 1978; Parihar, 1985; Singla *et al.*, 1988). Amin *et al.* (1985) screened over 500 groundnut cultivars and found a wide range of resistance to pod scarification by termites (0 to 44% pods scarified). Mortality of groundnuts due to termites also varies among cultivars (Mercer, 1978; Sithanantham, in press). Variation in susceptibility between cultivars has also been recorded for tea and sugarcane (Kumarasinghe & Ranasinghe, 1988; Sands, 1976; Singla *et al.*, 1988; Sivapalan *et al.*, 1977). Local varieties of groundnuts in Nigeria and castor and cotton in India, presumably selected by farmers over many years, knowingly or otherwise, are more resistant to termite attack than introduced cultivars (Johnson *et al.*, 1981; Parihar, 1985; Roonwal, 1979). Poorer quality, hybrid date palms in northern Sudan are reported to be more resistant to termite attack than named varieties (Logan & El Bakri, 1990). Variation in susceptibility between cultivars has also been recorded for tea (Sands, 1976; Sivapalan *et al.*, 1977) and sugar cane (Kumarasinghe & Ranasinghe, 1988; Singla *et al.*, 1988).

Resistant forestry trees

There is far more information on resistance of trees to termites, although few trials have been established specifically to identify resistant species. Exceptions are the trials on a range of species by Mitchell *et al.* (1986, 1987) in Zimbabwe and Midgley & Weerawardane (1986) in Sri Lanka and trials on *Eucalyptus* spp. and *Leucaena* cultivars in India by Rajagopal (1982) and Chander *et al.* (1984), respectively. Much of the information on tree resistance is based on casual observation and is scattered through the literature, often as minor comments in reports and papers. In some cases neither the termite species nor the country are given and the information therefore has only limited usefulness (e.g. Webb *et al.*, 1984).

On the other hand, there is a vast amount of information on resistance of timber to attack by termites (e.g. Bampton *et al.*, 1966, Harris, 1971; Wigg, 1946). Although this has some relevance to the susceptibility of the living tree, changes in chemistry due to seasoning, drying and ageing after felling may alter the timber's palatability to termites (Jones, 1985; Ratcliffe & Cummins, 1939; Wigg, 1946).

The degree of resistance depends on tree species, tree provenance (the source of the seed), termite species and the tree's age and condition. In Africa, most indigenous trees are resistant to termite attack and, although they may be covered in soil sheeting laid down by foraging termites, attack is limited to feeding on dead bark (Cowie *et al.*, 1989; Harris, 1955; Lee & Wood, 1971). Generally, this is the case elsewhere, although *Coptotermes* spp., especially, cause substantial damage to indigenous trees in Malaysia and several Australian termites attack native *Eucalyptus* spp. (Cowie *et al.*, 1989; Fox, 1974; Greaves, *et al.*, 1967; Tho, 1982).

It is seldom possible to define a tree species as resistant. Trees resistant to one termite species may be susceptible to others. In Australia, *Eucalyptus marginata* is resistant to a range of termite species but is attacked by *Nasutitermes exitiosus* (Hill), while *Pinus* spp., susceptible to many Australian termites, and *Araucaria cunninghamii*, attacked by *Coptotermes* sp., are both resistant to *Nasutitermes* (Lee & Wood, 1971; Wood, 1978). Similarly, trees recorded as resistant in one country may be susceptible in another. *Pinus* spp. tend to be relatively resistant to African termites (FAO, 1985; Wardell, 1987) but are extremely susceptible to those in Malaysia (Tho, 1974).

Some *Eucalyptus* and other exotic tree species in Africa and India develop resistance to attack by Macrotermitinae two to five years after transplanting to the field (Cowie *et al.*, 1989 and other references therein). Conversely, many *Eucalyptus* spp. in Australia suffer no attack from termites as saplings but are heavily attacked when mature; they also become more susceptible at the onset of senescence (Fox, 1974; Harris, 1971).

Mechanisms of resistance

Plant resistance has been classified as non-preference (the insect does not feed on the plant); antibiosis (the plant possesses physical or chemical characters that exert a negative effect on pest survivorship; or tolerance (the ability of the plant to withstand insect damage and to continue to yield at productive levels). In addition, plants may exhibit pseudo-resistance (the plant passes through susceptible stages quickly or while the pest populations are low) or induced resistance (when resistance is due to environmental conditions, rainfall, soil fertility etc., (Painter, 1951)). Although there has been little research into the mechanisms of plant resistance to termites in crops or trees there are indications that they are very varied and involve all of the above categories.

Non-preference. Termites appear to prefer soft material to hard. Chemical analysis of pods of 21 groundnut cultivars showed that resistance was inversely related to their crude fibre, lignin and manganese contents. Resistance was probably related to shell hardness (Rasheedunisa, 1986). The degree of attack by *Glyptotermes dilatatus* on different tea varieties was inversely related to the hardness of the wood. Hardwood tea varieties are also less susceptible to pruning damage and die-back than softwood varieties, resulting in more potential entry sites for termites (Sands, 1976; Sivapalan *et al.*, 1977). In trees, resistance may be due to the hardness of the timber or, more commonly, to chemicals in the wood which may be repellent to the termites (e.g. Rudman & Gay, 1967; Saeki *et al.*, 1973; Sivapalan *et al.*, 1977; Williams, 1965). For instance, resistance of *Pinus* sp. to *Nasutitermes exitiosus* in Australia may be due to pinenes in the timber, which are major constituents of the termites' alarm pheromones (Moore, 1965).

Antibiosis. Bald cypress contains chemicals toxic to the gut protozoa of *Coptotermes formosanus* Shiraki (Waller & La Fage, 1987).

Tolerance. Resistance of some *Eucalyptus* seedlings was believed to be due to an ability to tolerate considerable termite damage to the roots rather than having mechanisms to prevent attack. Similarly, increased resistance of *Eucalyptus* to termite attack in Africa with age may be due to tolerance induced by the greater volume of root available (Brown, 1962).

Pseudo-resistance. In sugarcane (Singla *et al.*, 1988), where termite attack was confined to the cuttings before sprouting, resistance was associated with rapid germination which reduced the time available for attack.

Induced resistance. Resistance, in relation to tree health and vigour have been discussed above (see Cultural control); the healthier the tree or crop the more likely it will be that it can withstand attack. Drought stress, in particular, reduces the resistance of plants to termites.

Physical barriers

Ebeling & Pence (1957) suggested the use of fine mineral particles (sand or crushed volcanic cinders) as a barrier to subterranean termites (*Reticulitermes hesperus* Spencer). Limited testing suggests that it has some potential (Ebeling & Forbes, 1988). Tamashiro *et al.* (1987a, 1987b) have further developed the technique using basaltic particles against *Coptotermes formosanus*. The barrier is impenetrable because the particles are too large and heavy for the termites to carry away yet are small enough so that in packing they create no continuous passages through which the termites can move. Particle size is the crucial factor and must be between about 1.7 and 2.4 mm. The particles are also too hard for the termites to chew through.

The technique may have potential as a preventive measure in control of subterranean termites in buildings but its applications in agriculture and forestry are clearly limited. A layer of sand under forestry or tree crop nursery beds, for instance, might provide some protection. Germinating coconuts are said to be protected by this method or by covering them with sand rather than soil (Harris, 1971; C. M. John quoted by Kashyap *et al.*, 1984). However, wider applications in the field are unlikely, particularly if a range of termite species of widely differing sizes (e.g. *Macrotermes* spp. and *Microtermes* spp.) are involved.

Wardell (1987) suggested that the plastic bag in which seedling trees are grown in the nursery be retained on transplanting to the field to act as a physical barrier but this was felt unlikely to be effective by Cowie *et al.* (1989), especially in view of the fact that termites are capable of destroying much more durable plastic (Edwards & Mill, 1986). The plastic may also restrict lateral root growth, reducing tree stability (Brown, 1962).

Beeson (1941) suggested digging a deep trench around tree nurseries. This may provide some protection from species with large colonies and long surface or near-surface foraging galleries (e.g. *Macrotermes* spp.) but will not affect attack by species foraging from deep in the soil below the nursery beds (e.g. *Microtermes*).

Quarantine

A number of termite species have been introduced accidentally to various countries where they have subsequently become pests. Notable examples are mainly species damaging buildings such as *Cryptotermes brevis* and *Coptotermes formosanus* but there are a few instances (e.g. Brown, 1981) in which introduced termites have caused major problems in agriculture or forestry. Legislation (Anon., 1957) and strict quarantine procedures (Wylie & Peters, 1987) have been implemented in order to prevent further introductions or restrict spread of infestations.

Discussion

Agronomists, field workers and other non-specialists involved in 'termite control' are often not aware of the major distinctions between dry-wood termites, subterranean termites, mound-building termites, harvester termites, soil-feeding termites, surface-foraging termites, etc., etc., despite such basic knowledge being crucial to the design and success of control measures and even to the initial evaluation of the need for control. Clearly, it may not always be necessary to distinguish individual species. For instance, the conventional but now unacceptable application of broad spectrum persistent organochlorine insecticides as barriers in the soil preventing termite access to crops, trees or buildings, is in general equally effective against all subterranean termites. Non-chemical control, however, will often demand greater understanding of the biology of particular genera and species. Resolving the debate over removal of debris, crop residues, etc. or the addition of extra organic material in fields of crops and in tree plantations depends on basic knowledge of the termites' population dynamics, foraging patterns, preferred food sources and nest sites. Use of resistant species and varieties of crops and trees depends crucially on the match between the plant's resistance mechanisms and the local termites' ability to circumvent them, both of which have evolved differently in different regions.

The lack of careful scientific evaluation of the many suggested methods of non-chemical termite control makes assessment of their relative potential difficult. Only rarely has a link between plant physiology and termite damage been explicitly demonstrated (Gueye & Lepage, 1988), although the frequently described correlations between termite damage and factors presumed to lead to plant stress are strongly suggestive. Many of the cultural measures discussed in this review are aimed at reducing plant stress; they are therefore part of good agricultural/silvicultural practice and so are always to be recommended. Other cultural measures depend on greater knowledge of the local situation, including the biology of the local termite species, and general recommendations cannot be made. While the most widely applied conventional techniques involving persistent insecticide barriers in the soil can often give almost complete protection, cultural techniques seem unlikely to achieve this level of success. Nevertheless, they generally cost little and if they achieve some reduction in damage, particularly in regions where more sophisticated measures are unavailable or too expensive, they should be implemented.

Biological control has received little attention and seems unlikely to be generally successful. Manipulation of predators, either local or introduced, will have little effect if only foraging worker termites are killed, while the possibility of manipulating predators which seek out the king and queen seems remote. Many micro-organisms are pathogenic to termites, but few have received more than cursory attention. This, combined with the termites' behavioural mechanisms for combatting infection of the colony, means that successful and widely applicable microbial control is a long way off.

It is widely believed that 'natural' plant-based pesticides are invariably safer to humans, livestock and beneficial insects and less environmentally damaging than synthetic pesticides (Stoll, 1986). This may be so in some cases but many of these substances (e.g. nicotine) are highly toxic to Man and other non-target species. Pyrethrum and derris are highly toxic to fish and should not be used near water. Locally-produced plant based pesticides seldom undergo the rigorous testing for toxic, sub-lethal and environmental hazards which are required for synthetic commercial pesticides. Consequently great care is required in their use until these properties have been assessed.

Most plant based insecticides break down rapidly in the soil and so should not present long term environmental problems. For the same reason, they do not give the prolonged protection to crops and trees required to control termite attack. Possible exceptions are *Calotropis procera* latex and Gondal fluid (see above). Research into the use of plant extracts for termite control so far suggests that they may have considerable potential in providing a cheap locally available method of control. However, much more requires to be done.

Queen removal and construction of physical barriers may be worthwhile in specific cases. However, the use of resistant species and varieties, now a well established concept in tropical agriculture and forestry, almost certainly offers the most widely appropriate, non-chemical, possibility of reducing losses due to termites. Termite resistant crop species are often already known and should be promoted if other social and economic constraints allow, but development or identification of varieties resistant to termites has not received the attention it deserves. More is known of resistance of tree species but insufficient acknowledgement of local and regional differences has meant that much of the literature is of little specific value. Identification of appropriate resistant species/varieties demands that field trials be carried out in the area to be planted to ensure that the trees are resistant to the local termites, prior to large scale planting. Use of resistant plants requires no development or implementation of new techniques once the appropriate species/variety is identified and seems especially suitable in developing countries where other methods are difficult to justify economically (Horn, 1988).

Recommendations to use any control measure must take into account local socio-economic needs. For instance, the increased labour involved in some simple cultural measures, such as careful manual pruning of tea (Sivapalan *et al.*, 1977) and removal of debris from forestry plantations (Wood, 1968) may not be cost-effective or may take the initial cost beyond the reach of local people. The timing of appropriate measures may coincide with other demands for labour, preventing adequate implementation of termite control.

Implementation of control measures must also be environmentally sound. Techniques which reduce termite numbers may well have detrimental effects on soil aeration and water infiltration, with concomitant influences on soil fertility, plant community structure and in some cases may lead to increased rates of soil erosion (McMahan, 1986). But almost nothing is known of the inter-relationships of these phenomena. If biological control ever becomes possible, its implementation must depend on the results of stringent assessments of its wider effects. The use of locally available substances as control agents must be carefully monitored since some may be more dangerous than many commercial products.

Non-chemical control of termites is in its infancy but is a field ripe for rigorous evaluation. The virtually complete protection provided, at least from subterranean termite attack, by the persistent organochlorines may well be beyond our grasp. Current research on other insecticides and formulations may provide a partial solution to the problem in specific cases, but in the long term, and with an aim to reduce dependency on insecticides and to provide cheap, locally available alternatives for small farmers/foresters, appropriate cultural methods, combined with the harnessing of resistance and the minimal use of modern or plant based insecticides and formulations in an integrated approach, will provide the best answer.

Acknowledgements

We thank Mr H. Khader Khan for identifying the plants mentioned only by common names in Beeson (1941).

References

Abbas, H.M. & Ahmad, F.U. (1984) Insect pests of pulses in Pakistan. pp. 184-207. *In* Ahmad, F.U. (*Ed.*) *Insect Pests of Important Crops in Pakistan*. Karachi, Pakistan Ministry of Food, Agriculture and Cooperatives.

Abd el Nour, H.O. (1975) Drought and termites: a threat to *Cupressus lusitanica* plantations in Jebel Marra—Sudan. *Sudan Silva* 3(20), 12–17.

Adams, R.P., McDaniel, C.A. & Carter, F.L. (1988) Termiticidal activities in the heartwood, bark/sapwood and leaves of *Juniperus* species from the United States. *Biochemical Systematics and Ecology* 16, 453–456.

Agricultural Research Council of Malawi (1971) *Cotton handbook of Malawi*. 82 pp. Zomba, Malawi, Ministry of Agriculture and Natural Resources.

Al Fazairy, A.A. & Hassan, F.A. (1988) Infection of termites by *Spodoptera littoralis* nuclear polyhedrosis virus. *Insect Science and its Application* 9, 37–39.

Amin, P.W., Singh, K.N., Dwivedi, S.L. & Rao, V.R. (1985) Sources of resistance to the jassid (*Empoasca kerri* Pruthi), thrips (*Frankliniella schultzei* (Trybom)) and termites (*Odontotermes* sp.) in groundnut (*Arachis hypogaea* L.). *Peanut Science* 12, 58–60.

Anon. (1898) White ants as a pest of agriculture—a note by the Settlement Officer of Balaghat, Central Provinces, prefixed by certain passages reprinted from the Indian Museum

Notes on termites in relation to crops etc. *Entomological series No. 7. The Agricultural Ledger 1897* No. 18, 434. Calcutta, Office of the Superintendant, Government Printing.

Anon. (1957) An ordinance for the control of the spread of infestation by termites or white ants. *St. Helena Ordinance* No. 3 of 1957, 4 pp.

Araujo, R.L. (1970) Termites of the Neotropical Region. pp. 527–576 *in* Krishna, K. & Weesner, F.M. (*Eds.*) *Biology of termites, Volume II.* London, Academic Press.

Bampton, S.S., Butterworth, D. & MacNulty, B.J. (1966) Testing materials for resistance to termite attack. Part 2. The resistance of some Nigerian timbers to attack by subterranean termites. *Material und Organismen* 1, 185–199.

Bao, L.-L. & Yendol, W.G. (1971) Infection of the Eastern Subterranean Termite, *Reticulitermes flavipes* (Kollar) with the fungus *Beauveria bassiana* (Balsamo) Vuill. *Entomophaga* 16, 343–352.

Barnett, D.W. (1986) Summary of results from termite control trials 1972–1985. FRIM Report 86003. 9pp, Forestry Research Institute of Malawi; Zomba, Malawi.

Beal, R.H., Carter, F.L. & Southwell, C.R. (1974) Survival and feeding of subterranean termites on tropical woods. *Forest Products Journal* 24(8), 44–48.

Bedding, R.A. & Molyneux, A.S. (1982) Penetration of insect cuticle by infective juveniles of *Heterorhabditis* spp. (Heterorhabditidae: Nematoda). *Nematologica* 28, 354–359.

Beeson, C.F.C. (1941) A guide to the control of termites for forest officers. *Indian Forest Records (New Series), Entomology* 4, 44–90.

Black, H.I.J. & Wood, T.G. (1989) The effects of cultivation on the vertical distribution of *Microtermes* spp. (Isoptera: Termitidae: Macrotermitinae) in soil at Mokwa, Nigeria. *Sociobiology* 15, 133–138.

Blackwell, M. & Rossi, W. (1986) Biogeography of fungal ectoparasites of termites. *Mycotaxon* 25, 581–601.

Bodot, P. (1961) La destruction des termitières de *Bellicositermes natalensis* par une fourmi: *Dorylus (Typhlopone) dentifrons* (Wasmann). *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Paris* 253, 3053.

Bodot, P. (1967) Etude écologique des termites des savanes de basse Cote-d'Ivoire. *Insectes Sociaux* 14, 229–258.

Booth, F.E.M. & Wickens, G.E. (1988) Non-timber uses of selected arid zone trees and shrubs in Africa. *FAO Conservation Guide* No. 19, 176 pp.

Bouillon, A. (1970) Termites of the Ethiopian region. pp. 153–280 *in* Krishna, K. & Weesner, F.M. (*Eds.*) *Biology of termites, Volume II.* London, Academic Press.

Breznak, J.A. (1982) Intestinal microbiota of termites and other xylophagous insects. *Annual Review of Microbiology* 36, 323–343.

Brown, K.W. (1962) *Termite control research in Uganda with particular reference to control of attacks in* Eucalyptus *plantations.* 9 pp. Eighth British Commonwealth Forestry Conference. Entebbe, Government publication, Uganda Protectorate.

Brown, L.C. (1981) *Land resources and agro-forestal development of St Helena. Volume 2. The resources.* 204 pp. Surbiton, UK, Land Resources Development Centre.

Browne, F.G. (1968) *Pests and diseases of forest plantation trees.* 1330 pp. Oxford, Clarendon Press.

Burges, H.D. (1981) *Microbial control of pests and plant diseases 1970–1980.* 949 pp. London, Academic Press.

Burges, H.D. & Hussey, N.W. (1971) *Microbial control of insects and mites.* 861 pp. London, Academic Press.

Butani, D.K. (1967) Sugarcane termites—a resumé. *Indian Sugar* 17, 543–549.

Carter, F.L. & de Camargo, C.R. (1983) Testing antitermitic properties of Brazilian woods and their extracts. *Wood and Fiber Science* 15, 350–357.

Carter, F.C. & Mauldin, J.K. (1981) Responses of *Reticulitermes flavipes* to extracts from nine antitermitic hardwoods. *Material und Organismen* 16, 175–188.

Carter, F.L. & Smythe, R.V. (1974) Feeding and survival responses of *Reticulitermes flavipes* (Kollar) to extractives of wood from 11 coniferous genera. *Holzforschung* 28, 41–45.

Chamsama, S.A.O. & Hall, J.B. (1987) Effects of nursery treatments on *Eucalyptus camaldulensis* field establishment and early growth at Mafiga, Morogoro, Tanzania. *Forest Ecology and Management* 21, 91–108.

Chander, S., Brar, D.S., Shamet, G.S. & Chandi, K.S. (1984) Growth performance of *Leucaena leucocephala* (Lam.) de Wit in relation to termite damage in Kandi Area. *Journal of Tree Science* 3, 129–130.

Coaton, W.G.H. (1949) Queen removal in termite control. *Farming in South Africa* 24, 335–344.

Coaton, W.G.H. (1950) Termites and their control in cultivated areas in South Africa. *Bulletin of the Department of Agriculture, Union of South Africa*, No. 305, 28 pp.

Coaton, W.G.H. (1954) Veld reclamation and harvester termite control. *Farming in South Africa* 29, 243–248.

Collins, N.M. (1981) Populations, age structure and survivorship of colonies of *Macrotermes bellicosus* (Isoptera: Macrotermitinae). *Journal of Animal Ecology* 50, 293–311.

Cowie, R.H., Logan, J.W.M. & Wood, T.G. (1989) Termite (Isoptera) damage and control in tropical forestry with special reference to Africa and Indo-Malaysia: a review. *Bulletin of Entomological Research* 79, 173–184.

Cowie, R.H. & Wood, T.G. (1989) Damage to crops, forestry and rangeland by fungus-growing termites (Termitidae: Macrotermitinae) in Ethiopia. *Sociobiology* 15, 139–153.

Crowther, F. & Barlow, H.W.B. (1943) Tap-root damage of cotton, ascribed to termites, in the Sudan Gezira. *Empire Journal of Experimental Agriculture* 11, 99–112.

Dalziel, J.M. (1937) *The useful plants of west tropical Africa being an appendix to the flora of west tropical Africa.* 612 pp. London, Crown Agents for the Colonies.

Danthanarayana, W. & Vitarana, S.I. (1987) Control of the live-wood tea termite *Glyptotermes dilatatus* using *Heterorhabditis* sp. (Nemat.). *Agriculture, Ecosystems and Environment* 19, 333–342.

Darlington, J.P.E.C. (1982a) The underground passages and storage pits used in foraging by a nest of the termite *Macrotermes michaelseni* in Kajiado, Kenya. *Journal of Zoology* 198, 237–247.

Darlington, J.P.E.C. (1982b) Population dynamics in an African fungus-growing termite. pp. 54–58 *in* Breed, M.D., Michener, C.D. & Evans, H.E. (*Eds*) *The biology of social insects.* Boulder, Westview Press.

Darlington, J.P.E.C. (1985) Multiple primary reproductives in the termite *Macrotermes michaelseni* (Sjöstedt). pp. 187–200 *in* Watson, J.A.L., Okot-Kotber, B.M. & Noirot, C. (*Eds*) *Caste differentiation in social insects.* Oxford, Pergamon Press.

Dastur, J.F. (1954) *Useful plants of India and Pakistan.* 260 pp. Bombay, Taraporevala Sons and Co. Ltd.

Dawkins, H.C. (1949) Timber planting in the *Terminalia* woodland of northern Uganda. *Empire Forestry Review* 28, 226–247.

De Bont, A.-F. (1964) Termites et densité d'oiseaux. pp. 273–283 in Bouillon, A. (Ed.) *Etudes sur les termites Africains*. Léopoldville, Editions de l'Université.

Deligne, J., Quennedy, A. & Blum, M.S. (1981) The enemies and defense mechanisms of termites. pp. 1–76 in Hermann, H.R. (Ed.) *Social Insects. Volume II*. London, Academic Press.

Drummond, R.B. & Palgrave, K.C. (1973) *Common trees of the highveld*. Harare, Longman Zimbabwe. 99pp.

Ebeling, W. & Forbes, C.F. (1988) Sand barriers for subterranean termite control. *The IPM Practitioner* 10(5), 1–6.

Ebeling, W. & Pence, R.J. (1957) Relation of particle size to the penetration of subterranean termites through barriers of sand or cinders. *Journal of Economic Entomology* 50, 690–692.

Edwards, R. & Mill, A.E. (1986) *Termites in Buildings*. 261 pp. East Grinstead, Rentokil.

El Amin, E.M., Ishag, H.M. & Burhan, H.O. (1983) Important factors affecting the yield of groundnuts (*Arachis hypogaea* L.) in the Sudan. *Zeitschrift für Angewandte Zoologie* 70, 39–55.

El Bakri, A., Eldein, N., Kambal, M.A., Thomas, R.J. & Wood, T.G. (1989) Effect of fungicide-impregnated food on the viability of fungus combs and colonies of *Microtermes* sp. nr. *albopartitus* (Isoptera: Macrotermitinae). *Sociobiology* 15, 175–180.

Emerson, A.E. (1945) The neotropical genus *Syntermes* (Isoptera: Termitidae) *Bulletin of the American Museum of Natural History* 83, 427–471.

Epila, J.S.O. & Ruyooka, D.B.A. (1988) Cultural method of controlling termite attacks on cassava (*Manihot esculenta*) with *Vitex doniana*: a preliminary study. *Sociobiology* 14, 291–297.

Epsky, N.D. & Capinera, J.L. (1988) Efficacy of the entomogenous nematode *Steinernema feltiae* against a subterranean termite, *Reticulitermes tibialis* (Isoptera: Rhinotermitidae). *Journal of Economic Entomology* 81, 1313–1317.

FAO (Food and Agriculture Organization of the United Nations) (1985) Methods of termite control in exotic forestry plantations on the Fouta Djallon, Guinea Republic. 15pp. *FAO Technical Report* FO:DP/GUI/82/003.

Farghal, A.I., Darwish, Y.A. & Abdel Galil, F.A. (1987) Relative susceptibility of four insect species to some bacterial insecticides. *Assiut Journal of Agricultural Sciences* 18, 21–30.

Ferron, P. (1978) Biological control of insect pests by entomogenous fungi. *Annual Review of Entomology* 23, 409–442.

Fowler, H.G. (1989) An epizootic iridovirus of Orthoptera (Gryllotalpidae: *Scapteriscus borellii*) and its pathogenicity to termites (Isoptera: *Cryptotermes*). *Revista de Microbiologia* 20, 115–120.

Fox, R.E. (1974) Check list of tree species of known susceptibility to termite attack in the Darwin region of the Northern Territory. *Technical Note, Forestry & Timber Bureau; Canberra*. No. 9, 21 pp.

Fuller, C. (1912) *White ants in Natal*. 13 pp. Pretoria, Union of South Africa Department of Agriculture.

Fujii, J.K. (1975) Effects of an entomogenous nematode, *Neoaplectana carpocapsae* Weiser, on the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, with ecological and biological studies on *C. formosanus*. 179 pp. PhD Thesis, University of Hawaii.

Gaugler, R. & Boush, G.M. (1979) Laboratory tests on ultraviolet protectants of an entomogenous nematode. *Environmental Entomology* 8, 810–813.

Georgis, R. & Hague, N.G.M. (1981) A neoaplectanid nematode in the larch sawfly *Cephalia lariciphila* (Hymenoptera: Pamphiliidae). *Annals of Applied Biology* 99, 171–177.

Georgis, R. & Poinar, G.O. (1983) Effect of soil texture on the distribution and infectivity of *Neoaplectana glaseri* (Nematoda: Steinernematidae). *Journal of Nematology* 15, 329–332.

Georgis, R., Poinar, G.O. & Wilson, A.P. (1982) Susceptibility of damp-wood termites and soil and wood-dwelling termites to the entomogenous nematode *Neoaplectana carpocapsae*. *IRCS Medical Science: Biochemistry; Biomedical Technology; Environmental Biology and Medicine; Experimental Animals; Microbiology, Parasitology and Infectious Diseases* 10, 563.

Gerrits, R. & van Latum, E.B.J. (1988) *Plant-derived pesticides in developing countries—possibilities and research needs*. 104 pp. The Hague, Netherlands' Ministry of Housing, Physical Planning and Environment.

Giridhar, G., Vasudevan, S. & Vasudevan, P. (1988) Antitermites properties of *Calotropis* latex. *Pesticides* 22(1), 31–33.

Gibbs, A.J., Gay, F.J. & Wetherly, A.H. (1970) A possible paralysis virus of termites. *Virology* 40, 1063–1065.

Grainge, M. & Ahmed, S. (1988) *Handbook of plants with pest-control properties*. 470 pp. New York, Wiley.

Grassé, P.-P. 1982. *Termitologia, Volume I*. 676 pp. Paris, Masson.

Grassé, P.-P. 1984. *Termitologia, Volume II*. 613 pp. Paris, Masson.

Grassé, P.-P. 1986. *Termitologia, Volume III*. 715 pp. Paris, Masson.

Greaves, T., Armstrong, G.F., McInnes, R.S. & Dowse, J.E. (1967) Timber losses caused by termites, decay, and fire in two coastal forests in New South Wales. *Technical Paper Division of Entomology, C.S.I.R.O., Australia* No. 7, 4–18.

Greenfield, J.C. (1989) Moisture conservation in rainfed agriculture in developing countries. *Rural Development in Practice* 1, 5–6.

Gueye, N. & Lepage, M. (1988) Role des termites dans de jeunes plantations d'*Eucalyptus* du Cap-Vert (Senegal). *Actes des Colloques Insectes Sociaux* 4, 345–352.

Hanel, H. & Watson, J.A.L. (1983) Preliminary field tests on the use of *Metarhizium anisopliae* for the control of *Nasutitermes exitiosus* (Hill) (Isoptera: Termitidae). *Bulletin of Entomological Research* 73, 305–313.

Hansen, M. (1987) *Escape from the pesticidal treadmill: alternatives to pesticides in developing countries*. 185pp. New York, Institute for Consumer Policy.

Harborne, J.B. (1988) *Introduction to ecological biochemistry*. Third edition. 356 pp. London, Academic Press.

Harris, W.V. (1955) Termites and forestry. *Empire Forestry Review* 34, 160–166.

Harris, W.V. (1969) *Termites as pests of crops and trees*. London, 41 pp. Commonwealth Institute of Entomology.

Harris, W.V. (1971) *Termites. Their recognition and control*. Second Edition. 186 pp. London, Longmans.

Hegh, E. (1922) *Les Termites*. 756 pp. Brussels, Imprimerie Industrielle et Financiére.

Hewitt, P.H. & Nel, J.J.C. (1969) Toxicity and repellancy of *Chrysocoma tenuifolia* (Berg) (Compositae) to the harvester termite *Hodotermes mossambicus* (Hagen) (Hodotermitidae). *Journal of the Entomological Society of Southern Africa* 32, 133–136.

Honigberg, B.M. (1970) Protozoa associated with termites and their role in digestion. pp. 1–36 in Krishna, K. & Weesner, F.M. (Eds) *Biology of Termites, Volume II*. London, Academic Press.

Horn, D.J. (1988) *Ecological approach to pest management*. 285 pp. London, Elsevier.

ICFR (Institute of Commercial Forestry Research) (1986) Studies on the incidence and control of termites in plantations. pp. 72–74 in, *Forest Protection, the 1986 Annual Report of the Insti-*

tute of Commercial Forestry Research. Pretoria, Institute of Commercial Forestry Research;

Jack, R.W. (1913) Termites or "white ants". *Bulletin of the Rhodesia Department of Agriculture*; No. 139, 16 pp.

Jacobson, M. (1975) *Insecticides from plants. A review of the literature, 1954–1971*. 138pp. Handbook of the United States Department of Agriculture No. 461, 138 pp.

Jacobson, M. (1982) Neem research in the US Department of Agriculture: chemical, biological and cultural aspects. pp. 33–42 *in* Schmutterer, H., Ascher, K.R.S. & Rembold, H. (*Eds*) *Natural pesticides from the neem tree* (Azadirachta indica *A. Juss*). Eschborn, Gesellschaft für Technische Zusammenarbeit.

Jafri, R.H., Ahmad, M. & Idrees, K. (1976) Microsporidian infection in the workers of termite, *Microcerotermes championi*. *Pakistan Journal of Zoology* 8, 234–236.

Johnson, R.A. & Gumel, M.H. (1981) Termite damage and crop loss studies in Nigeria—the incidence of termite-scarified groundnut pods and resulting kernel contamination of field and market samples. *Tropical Pest Management* 27, 343–350.

Johnson, R.A., Lamb, R.W. & Wood, T.G. (1981) Termite damage and crop loss studies in Nigeria—a survey of damage to groundnuts. *Tropical Pest Management* 27, 325–342.

Jones, T. (1985) Forest pests and diseases. pp. 249-272 *in* Haskell, P.T. (Ed.) *Pesticide application: principles and practice*. Oxford, Clarendon press.

Kakaliyev, K. & Saparliyev, K. (1975) [Research in pathogenicity of entobacterine for controlling termites in nature.] *Izvestiya Akademii Nauk Turkmenskoi SSR (Seriya Biologicheskikh Nauk)* 6, 39–41. (in Russian).

Kakde, J.R. (1985) *Sugarcane production*. 384 pp. New Delhi, Metropolitan.

Kalshoven, L.G.E. (1954) Survival of *Neotermes* colonies in infested teak trunks after girdling or felling of the trees (second communication). *Tectona* 43, 59–74.

Kashyap, R.K., Verma, A.N. & Bhanot, J.P. (1984) Termites of plantation crops, their damage and control. *Journal of Plantation Crops* 12, 1–10.

Khan, K.I., Fazal, Q. & Jafri, R.H. (1977a) Pathogenicity of locally discovered *Bacillus thuringiensis* strain to the termites: *Heterotermes indicola* (Wassman) and *Microcerotermes championi* (Snyder). *Pakistan Journal of Scientific Research* 29, 12–13.

Khan, K.I., Fazal, Q., Jafri, R.H. & Ahmad, M. (1977b) Susceptibility of various species of termites to a pathogen, *Serratia marcescens*. *Pakistan Journal of Scientific Research* 29, 46–47.

Khan, K.I., Fazal, Q. & Jafri, R.H. (1978) Development of *Bacillus thuringiensis* in a termite, *Heterotermes indicola* (Wassman). *Pakistan Journal of Science* 30, 117–119.

Khan, K.I., Jafri, R.H. & Ahmad, M. (1981) Role of trophallaxis in the dispersal of radioactive I131 and of bacterial infections in the termite, *Bifiditermes beesoni*. *Material und Organismen* 16, 189–197.

Khan, K.I., Jafri, R.H. & Ahmad, M. (1985) The pathogenicity and development of *Bacillus thuringiensis* in termites. *Pakistan Journal of Zoology* 17, 201–209.

Kooyman, C. & Onck, R.F.M. (1987) Distribution of termite (Isoptera) species in southwestern Kenya in relation to land use and the morphology of their galleries. *Biology and Fertility of Soils* 3, 69–73.

Krishna, K. & Weesner, F.M. (1969) *Biology of termites. Volume I*. 598 pp. London, Academic Press;

Krishna, K. & Weesner, F.M. (1970) *Biology of termites. Volume II*. 643 pp. London, Academic Press.

Krishnamoorthy, C. & Ramasubbiah, K. (1962) Termites affecting cultivated crops in Andhra Pradesh and their control: retrospect and prospect. pp. 243–245 *in*, *Termites in the humid tropics*. Paris, UNESCO.

Kruuk, H. & Sands, W.A. (1972) The aardwolf (*Proteles cristatus* Sparrman, 1783) as predator of termites. *East African Wildlife Journal* 10, 211–227.

Kumarasinghe, N.C. & Ranasinghe, M.A.S.K. (1988) Incidence of termite damage in sugar cane grown in Sri Lanka. *Beiträge zur Tropischen Landwirtschaft und Veterinärmedizin* 26, 303–307.

Lal, R. (1987) *Tropical ecology and physical edaphology*. 732 pp. Chichester, Wiley.

Lee, K.E. & Wood, T.G. (1971) *Termites and soils*. 251 pp. London, Academic Press.

Lin, T.-S. & Wang, C.-L. (1988) The anti-termite properties of extracts from *Melia azedarach* Linn. *Bulletin of the Taiwan Forestry Research Institute, New Series* 3, 255–261.

Litsinger, J.A., Price, E.C. & Herrera, R.T. (1978) Filipino farmer use of plant parts to control rice insect pests. *International Rice Research Newsletter* 3(5), 15–16.

Logan, J.W.M. & Abood, F. (1990) Laboratory trials on the toxicity of hydramethylnon (Amdro; AC 217,300) to *Reticulitermes santonensis* Feytaud (Isoptera: Rhinotermitidae) and *Microtermes lepidus* Sjöstedt (Isoptera: Termitidae). *Bulletin of Entomological Research* 80, 19–26.

Logan, J.W.M. & El Bakri, A. (1990) Termite damage to date palms (*Phoenix dactylifera* L.) in northern Sudan with particular reference to the Dongola district. *Tropical Science* 30, 95–108.

Longhurst, C., Johnson, R.A. & Wood, T.G. (1978) Predation by *Megaponera foetens* (Fabr.) (Hymenoptera: Formicidae) on termites in the Nigerian southern Guinea savanna. *Oecologia* 32, 101–107.

Longhurst, C., Johnson, R.A. & Wood, T.G. (1979) Foraging, recruitment and predation by *Decamorium uelense* (Sanstchi) (Formicidae: Myrmicinae) on termites in southern Guinea savanna, Nigeria. *Oecologia* 38, 83–91.

Lund, A.E. (1971) Microbial control of termites. pp. 385–386 *in* Burges, H.D. & Hussey, N.W. (*Eds*) *Microbial control of insects and mites*. London, Academic Press.

McCaw, W.L. (1984) Wood defect associated with fire scars on jarrah *Eucalyptus marginata*. *Ausralian Forest Research* 13, 2[illegible]–266.

MacGregor, W.D. (1950) Termites, soil and vegetation. *Forestry Abstracts* 12, 1–6.

Majer, J.D. (1986) Utilizing economically beneficial ants. pp. 1–68 *in* Vinson, S.B. (*Ed.*) *Economic impact and control of social insects*. New York, Praeger.

McIndoo, N.E. (1945) *Plants of possible insecticidal value. A review of the literature up to 1941*. 286 pp. Washington, United States Department of Agriculture.

McMahan, E.A. (1986) Beneficial aspects of termites. pp. 144–164 *in* Vinson, S.B. (*Ed.*) *Economic impact and control of social insects*. New York, Praeger.

Malaka, S.L.O. (1972) Some measures applied in the control of termites in parts of Nigeria. *Nigerian Entomologists' Magazine* 2, 137–141.

Malaret, L. & Ngoru, F.N. (1989) Ethno-ecology: a tool for community based pest management. Farmer knowledge of termites in Machakos District, Kenya. *Sociobiology* 15, 197–211.

Martin, M.M. (1987) *Invertebrate-microbial interactions*. 148 pp. Ithaca, Cornell University Press.

Matthews, G.A. (1989) *Cotton insect pests and their management*. 199 pp. Longman; Harlow, UK.

Matthews, G.A., Rowell, J.G. & Beeden, P. (1972) Yield and plant development of reduced cotton stands in Malawi. *Experimental Agriculture* 8, 33–48.

May, P.D. (1986) Controlled release pesticides control termites. *Australian Centre for International Agricultural Research, Forestry Newsletter* 2, 4.

Mercer, P.C. (1978) Pests and diseases of groundnuts in Malawi. III. Wilts, post-harvest, physiological and minor disorders. *Oléagineux* 33, 619–624.

Midgley, S.J. & Weerawardane, N.D.R. (1986) Termite control in Sri Lanka. *Australian Centre for International Agricultural Research, Forestry Newsletter* 2, 3–4.

Milstein, P. Le G. (1964) Birds and agriculture. *Lantern* 14, 40–44.

Misari, S.M. & Raheja, A.K. (1976) Notes on field pests of groundnuts in Northern Nigeria. pp. 57–69 in *Minutes of the International Symposium on Field Pests of Groundnut and Millet*. Kaolack, Senegal 21–23 April 1976. Lagos, African Groundnut Council.

Mitchell, M.R., Gwaze, D.P. & Stewart, H.T.L. (1986) Termite susceptibility of Australian trees in Zimbabwe. *Australian Centre for International Agricultural Research, Forestry Newsletter* 2, 2.

Mitchell, M.R., Gwaze, D.P. & Stewart, H.T.L. (1987) Survival and early growth of Australian tree species planted at a termite-infested site in Zimbabwe. *East African Agricultural and Forestry Journal* 54, 251–259.

Mix, J. (1985) Beal's research shows nematodes don't control subterranean termites. *Pest Control* 53(2), 22–23.

Mix, J. (1986) Nematodes flunk again. *Pest Control* 54(3), 48–54.

Moldenhauer, W.C. & Hudson, N.W. (1988) *Conservation farming on steep lands*. 296 pp. Ankeny, Iowa, Soil and Water Conservation Society.

Moore, B.P. (1965) Pheromones and insect control. *Australian Journal of Science* 28, 243–245.

Nair, K.S.S. & Varma, R.V. (1981) Termite control in eucalypt plantations. *Kerala Forest Research Institute. Research Report* No. 6, 48 pp.

Nair, K.S.S. & Varma, R.V. (1985) Some ecological aspects of the termite problem in young eucalypt plantations in Kerala, India. *Forest Ecology and Management* 12, 287–303.

Nel, J.C.C. & Hewitt, P.H. (1969) A study of the food eaten by a field population of the harvester termite, *Hodotermes mossambicus* (Hagen) (Isoptera, Hodotermitidae), and its relation to population density. *Journal of the Entomological Society of Southern Africa* 32, 123–131.

Nickle, W.R. (1984) *Plant and insect nematodes*. 925 pp. New York, Marcel Dekker.

Nutting, W.L. (1969) Flight and colony foundation. pp. 233–282 in Krishna, K. & Weesner, F.M. (*Eds*) *Biology of termites, Volume I*. London, Academic Press.

O'Brien, R.W. & Slaytor, M. (1982) Role of microorganisms in the metabolism of termites. *Australian Journal of Biological Science* 35, 239–262.

Ohiagu, C.E. & Wood, T.G. (1976) a method for measuring rate of grass-harvesting by *Trinervitermes geminatus* (Wasmann) (Isoptera, Nasutitermitinae) and observation on its foraging behaviour in southern Guinea savanna, Nigeria. *Journal of applied Ecology* 13, 705–713.

Otto, H. (1951) Harvester ants don't like water. [illegible] method discovered on Free State farm. *The Farmer's Weekly* April 25, 1951, 10–13.

Page, R.Z. (1967) Termite control by induced epizootics of entomophagous microorganisms. *United States Patent Office Number* 3, 337, 395. 3 pp.

Painter, R.H. (1951) *Insect resistance in crop plants*. 520 pp. New York, Macmillan.

Parihar, D.R. (1985) Crop termite damage in Indian desert and its control in castor. *Zeitschrift für Angewandte Zoologie* 72, 309–315.

Parry, M.S. (1959) Control of termites in *Eucalyptus* plantations. *Empire Forestry Review* 38, 287–292.

Pearce, M.J. (1987) Seals, tombs, mummies, and tunnelling in the drywood termite *Cryptotermes* (Isoptera: Kalotermitidae). *Sociobiology* 13, 217–226.

Pearson, E.O. (1958) *The insect pests of cotton in tropical Africa*. 355 pp. London, Empire Cotton Growing Corporation and Commonwealth Insititute of Entomology.

Perry, D.H., Lenz, M. & Watson, J.A.L. (1985) Relationships between fire, fungal rots and termite damage in Australian forest trees. *Australian Forestry* 48, 46–53.

Poinar, G.O. (1975) Entomogenous nematodes. 317 pp. Leiden, Brill.

Poinar, G.O. (1979) *Nematodes for biological control of insects*. 277 pp. Boca Raton, Florida, CRC press.

Pomeroy, D.E. (1983) A striking increase in a population of termite mounds in eastern Kenya. *Kenya Journal of Science and Technology Series B* 4, 89–96.

Popenoe, P. (1973) *The date palm*. 247 pp. Miami, Field Research Projects.

Rajagopal, D. (1982) Relative incidence of termites on exotic species of *Eucalyptus* in Karnataka. *Myforest* 18, 9–13.

Rao, G.N. (1951) Control of termites in sugarcane. *Current Science* 20, 330–331.

Rasheedunisa (1986) Preliminary investigations on some chemical constituents of pod shell in relation to resistance of groundnut cultivars against termites. *Journal of Oilseeds Research* 3, 195–200.

Ratcliffe, F.N. & Cummins, J.E. (1939) Termite (white ant) research in Australia. *Empire Forestry Journal* 18, 221–228.

Raymundo, S.A. (1986) Traditional pest control practices in West Africa. *IRRI Newsletter*, 11(1), 24.

Reddy, M.V. & Sammaiah, C. (1988) *Odontotermes brunneus* (Hagen) (Termitidae: Isoptera) as a new pest of maize and groundnut. *Entomon* 13, 47–50.

Reese, K.M. (1971) Navy fights Formosan termite in Hawaii. *Chemical and Engineering News* 49, 52.

Ripper, E.E. & George, L. (1965) *Cotton pests of the Sudan*. 345 pp. Oxford, Blackwell.

Roonwal, M.L. (1979) Termite life and termite control in tropical south Asia. 177 pp. Jodhpur, Scientific Publishers.

Rudman, P. & Gay, F.J. (1967) The causes of natural durability in timber. Pt. XXI The anti-termitic activity of some fatty acids, esters and alcohols. *Holzforschung* 21, 24–26.

Saeki, I., Sumimato, M. & Kondo, T. (1973) The termiticidal substances from the wood of *Chamaecyparis pisifera* D. Don. *Holzforschung* 27, 93–96.

Sands, W.A. (1961) Foraging behaviour and feeding habits in five species of *Trinervitermes* in West Africa. *Entomologia Experimentalis et Applicata* 4, 277–288.

Sands, W.A. (1965) A revision of the termite subfamily Nasutitermitinae (Isoptera, Termitidae) from the Ethiopian region. *Bulletin of the British Museum (Natural History) Entomology*. Supplement 4, 172 pp.

Sands, W.A. (1969) The association of termites and fungi. pp. 495–524. in Krishna, K. & Weesner, F.M. (Eds) *Biology of termites. Volume I.* London, Academic Press.

Sands, W.A. (1973a) Termites as pests of tropical food crops. *Pest Articles and News Summaries* 19, 167–177.

Sands, W.A. (1973b) Termites as tree and crop pests. *Mededelingen Fakulteit Landbouwwetenschappen, Gent* 38, 817–830.

Sands, W.A. (1976) Visit to Sri Lanka to study termite (Kalotermitidae) damage to tea 12–18 October 1975. *Report No. CVR/76/1.* 27 pp. London, Centre for Overseas Pest Research.

Sands, W.A. (1977) The role of termites in tropical agriculture. *Outlook on Agriculture* 9, 136–143.

Schmiege, D.C. (1963) The feasibility of using a neoplectanid nematode for control of some forest insect pests. *Journal of Economic Entomology* 56, 427–431.

Secoy, D.M. & Smith, A.E. (1983) Use of plants in control of agricultural and domestic pests. *Economic Botany* 37, 28–57.

Sen-Sarma, P.K. (1986) Economically important termites and their management in the Oriental region. pp. 69–102 *in* Vinson, S.B. (*Ed.*) *Economic impact and control of social insects.* New York, Praeger.

Sheppe, W. (1970) Invertebrate predation on termites of the African savanna. *Insectes Sociaux* 17, 205–218.

Sieber, R. (1985) Replacement of reproductives in Macrotermitinae (Isoptera, Termitidae). pp. 201–207 *in* Watson, J.A.L., Okot-Kotber, B.M. & Noirot, C. (*Eds*) *Caste differentiation in social insects.* Oxford, Pergamon Press.

Singla, M.L., Duhra, M.S. & Aulakh, M.S. (1988) Varietal resistance in sugarcane to *Scirpophaga excerptalis* Wlk. and *Odontotermes* spp. *Journal of Insect Science* 1, 99–101.

Sithanantham, S. (in press) Studies on soil pests associated with groundnuts in Zambia. *Proceedings of the 10th International Soil Zoology Colloquium, Bangalore, 7–13 August, 1988.*

Sivapalan, P., Senaratne, K.A.D.W. & Karunaratne, A.A.C. (1977) Observations on the occurrence and behaviour of live-wood termites (*Glyptotermes dilatatus*) in low-country tea fields. *Pest Articles and News Summaries* 23, 5–8.

Sivapalan, P., Karunaratne, A.A.C. & Jayatilleke, D.G.S. (1980) Clonal susceptibility and the influence of shade trees on the incidence of *Glyptotermes dilatatus* (Bugnion & Popoff) (Isoptera: Kalotermitidae) in tea. *Bulletin of Entomological Research* 70, 145–149.

Smith, E.S.C. (1985) A review of relationships between shade types and cocoa pest and disease problems in Papua New Guinea. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries* 33, 79–88.

Smithers, R.H.N. (1971) *The mammals of Botswana.* Museum memoir No. 4. 340 pp. National Museums of Rhodesia; Salisbury.

Smythe, R.V. & Coppel, H.C. (1965) The susceptibility of *Reticulitermes flavipes* (Kollar) and other termite species to an experimental preparation of *Bacillus thuringiensis* Berliner. *Journal of Invertebrate Pathology* 7, 423–426.

Smythe, R.V. & Coppel, H.C. (1966) Pathogenicity of externally occurring fungi to *Reticulitermes flavipes. Journal of Invertebrate Pathology* 8, 266–267.

Snyder, T.E. (1926) *Preventing damage by termites or white ants.* Farmers' Bulletin No. 1472. 22 pp. United States Department of Agriculture, Washington.

Snyder, T.E. (1956) Annotated, subject-heading bibliography of termites 1350 B.C. to A.D. 1954. *Smithsonian Miscellaneous Collections* 130, 1–305.

Snyder, T.E. (1961) Supplement to the annotated, subject-heading bibliography of termites 1955 to 1960. *Smithsonian Miscellaneous Collections* 143(3), 1–137.

Snyder, T.E. (1968) Second supplement to the annotated, subject-heading bibliography of termites 1961 to 1965. *Smithsonian Miscellaneous Collections* 152(3), 1–188.

Srivastava, K.P. & Butani, D.K. (1987) Insect pests of tea in India and their control. *Pesticides* 21(2), 16–21.

Steyn, P. (1967) Crop content of crowned Guinea-fowl *Numida meleagris. Ostrich* 38, 286.

Stoll, G. (1986) Natural crop protection. 188 pp. Langen, West Germany, Josef Margraf.

Su, N.-Y., Tamashiro, M., Yates, J.R. & Haverty, M.I. (1982) Effect of behaviour on the evaluation of insecticides for prevention of or remedial control of the formosan subterranean termite. *Journal of Economic Entomology* 75, 188–193.

Sudheendrakumar, V.V. & Chacko, K.C. (1986) Effect of site preparation on incidence of termites in *Eucalyptus* plantations. pp. 364–366 *in* Sharma, J.K., Nair, C.T.S., Kedharnath, S. & Kondas, S. (*Eds*) *Eucalypts in India: past, present and future.* Peechi, India, Kerala Forest Research Insititute.

Tamashiro, M., Yates, J.R. & Ebesu, R.H. (1987a) The Formosan subterranean termite in Hawaii: problems and control. pp. 15–22 in Tamashiro, M. & Su, N.-Y. (*Eds*) *Biology and control of the Formosan subterranean termite.* Honolulu, Hawaii Institute of Tropical Agriculture and Human Resources.

Tamashiro, M., Yates, J.R., Ebesu, R.H. & Yamamoto, R.T. (1987b) The Formosan termite: Hawaii's most damaging insect. *Hawaii Architect* 16(12), 12–14, 40.

Tarr, S.A.J. (1960) The effects of fungicide-insecticide seed treatments on emergence, growth and yield of irrigated cotton in the Sudan Gezira. *Annals of Applied Biology* 48, 591–600.

Thiollay, J.-M. (1970) L'exploitation par les oiseaux des essaimages de fourmis et termites dans une zone de contact savane-foret en Côte-d'Ivoire. *Alauda* 38, [illegible].

Tho, Y.P. (1974) The termite problem in plantation forestry in Peninsular Malaysia. *Malaysian Forester* 37, 278–283.

Tho, Y.P. (1982) Gap formation by the termite *Microcerotermes dubius* in lowland forests of Peninsular Malaysia. *Malaysian Forester* 45, 184–192.

Thomas, R.J. (1987a) Distribution of *Termitomyces* and other fungi in the nests and major workers of several Nigerian Macrotermitinae. *Soil Biology and Biochemistry* 19, 335–341.

Thomas, R.J. (1987b) Factors affecting the distribution and activity of fungi in the nests of Macrotermitinae (Isoptera). *Soil Biology and Biochemistry* 19, 343–349.

Tilak, B.D. (1977) Pest control strategy in India. pp. 99–109 *in* McFarlane, N.R. (*Ed.*) *Crop protection agents—their biological evaluation.* London, Academic Press.

Tryon, H. (1903) White ants. *Queensland Agricultural Journal* 13, 284–285.

Tschesche, R., Wulff, G., Weber, A. & Schmidt, H. (1970) Frasshemmende Wirkung von Saponinen auf Termiten (Isoptera, *Reticulitermes*). *Zeitschrift für Naturforschung* 25, 999–1001.

Usher, G. (1974) *A dictionary of plants used by man.* 619 pp. London, Constable.

Verma, A.N. (1980) Effect of number of irrigations on termite damage in wheat crop. *Haryana Agricultural University Journal of Research* 10, 564–565.

Waller, D.A. & LaFage, J.P. (1987) Food quality and foraging response by the subterranean termite *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae). *Bulletin of Entomological Research* 77, 417–424.

Wardell, D.A. (1987) Control of termites in nurseries and young plantations in Africa: established practices and alternative courses of action. *Commonwealth Forestry Review* 66, 77–89.

Webb, D.B., Wood, P.J., Smith, J.P. & Henman, G.S. (1984) *A guide to species selection for tropical and sub tropical plantations.* Tropical Forest Papers Number 15 (2nd edition). 256 pp. Oxford, Commonwealth Forestry Institute.

Weidner, T. (1983) Spear termiticide: a new era in biological warfare. *Pest Control* 51(11), 72–80.

Wessels, N.O. (1984) Afforestation of marginal land for commercial timber production in South Africa. *South African Forestry Journal* 130, 54–58.

Wigg, L.T. (1946) Durability of some East African timbers. *East African Agricultural Journal* 12, 90–100.

Wilkinson, H. (1940) Termites in East Africa. II. The biology and control of termites damaging grassland. *East African Agricultural Journal* 6, 67–72.

Williams, R.M.C. (1965) Infestation of *Pinus caribaea* by the termite *Coptotermes niger* Snyder. *12th International Congress of Entomology, London, 8–16 July, 1964.* 675–676.

Willis, J.C. (1973) A dictionary of the flowering plants and ferns. Eighth edition. 1245 pp. Cambridge, Cambridge University Press.

Wood, B.J. (1968) *Pests of oil palms in Malaysia and their control.* 204 pp. Kuala Lumpur, The Incorporated Society of Planters.

Wood, T.G. (1978) Food and feeding habits of termites. pp. 55–80 *in* Brian, M.V. (*Ed.*) *Production ecology of ants and termites.* Cambridge, Cambridge University Press.

Wood, T.G., Bednarzik, M. & Aden, H. (1987) Damage to crops by *Microtermes najdensis* (Isoptera, Macrotermitinae) in irrigated semi-desert areas of the Red Sea coast. 1. The Tihama region of the Yemen Arab Republic. *Tropical Pest Management* 33, 142–150.

Wood, T.G. & Cowie, R.H. (1988) Assessment of on-farm losses in cereals in Africa due to soil insects. *Insect Science and its Application* 9, 709–716.

Wood, T.G. & Johnson, R.A. (1978) Abundance and vertical distribution in soil of *Microtermes* (Isoptera, Termitidae) in savanna woodland and agricultural ecosystems at Mokwa, Nigeria. *Memorabilia Zoologica* 29, 201–213.

Wood, T.G. & Johnson, R.A. (1986) The biology, physiology, and ecology of termites. pp 1–68. *in* Vinson, S.B. (Ed.) *Economic impact and control of social insects.* New York, Praeger.

Wood, T.G. & Sands, W.A. (1978) The role of termites in ecosystems. pp. 245–292 *in* Brian, M.V. (*Ed.*) *Production ecology of ants and termites.* Cambridge, Cambridge University Press.

Wood, T.G. & Thomas, R.J. (1989) The mutualistic association between Macrotermitinae and *Termitomyces.* pp. 69–92 *in* Wilding, N., Collins, N.M., Hammond, P.M. & Webber, J.F. (*Eds*) *Insect-fungus interactions.* London, Academic Press.

Wood, T.G., Johnson, R.A. & Ohiagu, C.E. (1977) Populations of termites (Isoptera) in natural and agricultural ecosystems in southern Guinea savanna near Mokwa, Nigeria. *Geo-Eco-Trop* 1, 139–148.

Wood, T.G., Johnson, R.A. & Ohiagu, C.E. (1980a) Termite damage and crop loss studies in Nigeria—a review of termite (Isoptera) damage to maize and estimation of damage, loss in yield and termite (*Microtermes*) abundance at Mokwa. *Tropical Pest Management* 26, 241–253.

Wood, T.G., Smith, R.W., Johnson, R.A. & Komolafe, P.O. (1980b) Termite damage and crop loss studies in Nigeria—pre-harvest losses to yams due to termites and other soil pests. *Tropical Pest Management* 26, 355–370.

Wylie, F.R. & Peters, B.C. (1987) Development of contingency plans for use against exotic pests and diseases of trees and timber. 2. Problems with the detection and identification of pest insect introductions into Australia, with special reference to Queensland. *Australian Forestry* 50, 16–23.

Yamin, M.A. (1980) Cellulose metabolism by the termite flagellate *Trichomitopsis termopsidis. Applied and Environmental Microbiology* 39, 859–863.

Yaga, S. (1973) Termiticidal activity of immature fruit juice from papaya. *Mokuzai Gakkaishi* 19, 349–350.

Yara, K., Jahana, K. & Hayashi, H. (1989) In situ morphology of the gut microbiota of the fungus-growing termite *Odontotermes formosanus* (Termitidae Macrotermitinae). *Sociobiology* 15, 247–260.

Yendol, W.G. & Rosario, S.B. (1972) Laboratory evaluation of methods for inoculating termites with entomophthoraceous fungi. *Journal of Economic Entomology* 65, 1027–1029.

Zaheer, K., Iqbal, H. & Rehman, L. (1987) Isolation and characterisation of termite repellents from the needle of *Pinus roxburgii. International Pest Control* 29(4), 87–89.

ANNEX E

INITIAL ENVIRONMENTAL EXAMINATION OR CATEGORICAL EXCLUSION

INITIAL ENVIRONMENTAL EXAMINATION
or
CATEGORICAL EXCLUSION

PROJECT COUNTRY: The Republic of Guinea (Conakry)

PROJECT & ACTIVITY TITLE: Natural Resources Management Project (675-0219): Pesticide Use and Pest Management Interventions

DURATION & FUNDING: FY(s) 1991 - 1995 US $ est. 50,000 max. (parent project $ 12 million)

IEE PREPARED BY: Walter I. Knausenberger, USAID/AFR/ARTS/FARA and Wayne McDonald, USAID/REDSO/WCA

ENVIRONMENTAL ACTION RECOMMENDED:

Positive Determination	
Negative Determination	X
Categorical Exclusion	
Deferral	X

REVIEW OF PRECEDING IEE'S:

The Guinea Natural Resource Management Project (GNRMP) is an integrated rural development activity designed to improve management of the natural resources for profitable and sustainable agricultural production in three watersheds in the Fouta Djallon Highlands of central Guinea. It is complementary to the multi-donor Fouta Djallon Highlands Integrated Rural Development Project.

The original Initial Environmental Examination for the GNRMP recommended a deferral for the project's technology transfer and applied research component until specific activities had been identified. A categorical exclusion was approved for the project's technical assistance, training, monitoring and management components.

Based on the project's first year workplan, which identified 26 interventions under three technology transfer components, a second IEE was completed for the technology transfer and applied research component, which included all proposed interventions except pest management. The present (third) Initial Environmental Examination is for the proposed pest management interventions.

SUMMARY OF FINDINGS:

In accordance with USAID Pesticide Procedures (22 CFR 216.3(b)), a risk-benefit evaluation of the planned pesticide use under this project was conducted. This IEE indicates that no potentially unreasonable risks arise from the limited scale of pesticide use aniticpated. Thus, a Negative Determination with conditions is recommended for pesticide use in pilot pest management projects for the following four site/pest combinations:

-- **Termites in and around fields/gardens and in tree nurseries:**
    -- diazinon (e.g., Basudine 60% EC, and/or Basudine 10% G Granular formulation)
    -- chlorpyriphos (e.g., Dursban 5% G and 10% G)
-- **Stored product insects in consumption grains:**
    -- pirimiphos-methyl (e.g. Actellic 2% G or 50% EC)
    -- chlorpyriphos (e.g., Dursban ECs)
Seed treatment (destined for planting only):
    -- thiophanate-methyl + thiram + diazinon (Super Homai 70% WP)
Variegated grasshopper (*Zonocerus variegatus*) in irrigated and rain-fed horticultural plots:
    -- diazinon (e.g., Basudine 60% EC)
    -- chlorpyriphos (e.g., Dursban EC)

The conditions which apply to this negative determination are that:

-- only national crop protection service and laboratory agents, and trained GNRM project agents, are to store, handle and use the pesticides provided;

-- the LPV staff will develop and follow treatment protocols which build in a maximum practical range of alternative techniques aimed at minimizing the need for pesticides;

-- LPV and GNRM staff will establish a simple but robust monitoring process to keep track of the efficacy of the treatments and to identify and mitigate any unexpected negative impacts (on non-target organisms and people) which may be linked to the treatments.

-- USAID will encourage the development of appropriate applied IPM research trials through its technology development grants;

-- no pesticide product will be made available directly to villagers;

-- the storage facilities in Labe be upgraded as described above, if they are to be used for project chemicals; likewise, the storage facilities in the *cités* should be brought up to the minimum standards; and

-- independent evaluation of the project activities' implementation be periodically assessed by a knowledgeable person(s) on no less than an annual basis.

A negative determination is recommended for applied research activities designed to integrate chemical pesticides with non-chemical and other methods, provided that the aggregate size of the trial plots remains under 4 hectares, and all due precautions are taken to prevent untoward impacts of the pesticides.

A deferral is recommended for any treatment strategies involving pesticides against:

-- **Orange fruitworm:** too little is known about this species to recommend particular control approaches.

-- **Termite control in and around homes:** The risks associated with pesticide use around homes are much greater than in the case of the control of mounds in external fields.

-- Any **other host/pest combinations** where the need may exist.

A deferral is also recommended for any activities relating to systematic training of villagers in pesticide use.

CLEARANCE:

Mission Director:
Wilbur Thomas ______________________ DATE: ________

Mission Environmental Officer:
S.K. Reddy ______________________ DATE: ________

Regional Environmental Officer:
W. McDonald ______________________ DATE: ________

CONCURRENCE:

Bureau Environmental Officer
John G. Gaudet, AFR/ARTS/FARA

APPROVED ____________________
DISAPPROVED ____________________
DATE ____________________

CLEARANCE:

General Counsel
Africa Bureau:
Mary Alice Kleinjan

DATE ____________________

96

INITIAL ENVIRONMENTAL EXAMINATION

Guinea Natural Resources Management Project (675-0219): Pesticide Use and Pest Management Interventions

RISK-BENEFIT ASSESSMENT

This document presents the risk-benefit assessment pertinent to the Guinea Natural Resources Management Project's proposed pest management interventions, pursuant to the requirements of USAID pesticide procedures (22 CFR 216.3(b)). It is based in part upon an environmental assessment carried out of the pest management situation in the project area (Faye and Knausenberger 1994).

Table of Contents

1.0 BACKGROUND AND PROJECT DESCRIPTION

The Guinea Natural Resource Management Project (GNRMP) is an integrated rural development activity designed to improve management of the natural resources for profitable and sustainable agricultural production in three watersheds in the Fouta Djailon Highlands of Middle Guinea. It is complementary to the multi-donor Fouta Djallon Highlands Integrated Rural Development Project.

1.1. Preceding GNRMP Initial Environmental Examinations

The present IEE was needed because the original IEE (dated 9/3/91) for the NRMP's Project Paper recommended a deferral for the project's technology transfer and applied research component, until the research activities had been further defined. This same approved IEE included a Categorical Exclusion for the project's technical assistance, monitoring, training and management components.

Then, based on the first GNRMP Annual Workplan (1993), a subsequent IEE (the second) was prepared in October 1993, concurred in by the RLA, and approved by the USAID/Conakry Mission Director 12/1/93. This IEE recommended 25 of the technology transfer interventions for a Negative Determination, and one for a Categorical Exclusion. A deferral was recommended for one set of technology transfer and applied research activities, i.e., the proposed pest management interventions. The recommendation was based upon the fact that the procedures as required in 22 CFR 216.3 (b), pesticide procedures, regarding pesticides had not been completed at the time the individual technology transfer interventions were identified.

Thus, the present Initial Environmental Examination (third in a series for the GNRMP) is for the pest management interventions under the applied research component of the project. Many of the elements of this component are funded by local currency generated through PL 480, but the mission has been maintaining close budgetary control over the funds. It is also appropriate to adhere to the principles of U.S. environmental procedures in this instance.

1.2. Pertinence of Pesticide Use and Pest Management to NRM Project

The participatory nature of the project's planning process required that the applied research and technology transfer activities be identified only after project beneficiaries were consulted with respect to needed interventions. Based upon this consultative process the project has developed a first year work plan identifying the particular field level interventions and applied research activities to be implemented under the research and technology transfer component. No project interventions, nor advance of funds for project interventions, supporting pest management have been undertaken subject to approval of this Initial Environmental Examination and concurrence by Africa Bureau Environmental Officer and General Counsel.

Project activities are being implemented in three watersheds of 12 identified in the multi-donor Fouta Djallon Highlands Integrated Rural Development (FDHIRD) Project. The three watershed management units targeted by the NRMP, geographically more-or-less centered on Labé, are:

- Koundou: 16 villages, ca. 4,000 inhabitants, ca. 95 sq.km.;
- Diaforé: 12 villages, ca 2,000 inhabitants, ca.60 sq.km.;
- Dissa: 8 villages, ca. 2,000 inhabitants, ca. 50 sq.km..

The overall project and project area has been adequately described in the Project Paper and the Work Plan, and summarized in the previous IEEs. This section will be limited to a description of the proposed pest management activities.

The NRMP Rapid Rural Appraisal of the Representative Pilot Watersheds (MARA/DNFC/USAID 1993) determined that both men and women in all three watersheds consider insects pests to be among the three most frequently cited problems in agricultural production. This was confirmed by the Guinea Plant Protection Service (SPV, LPV). The Project therefore is treating this as a principal constraint to sustainable agricultural production in the project area of intervention, and as an aspect for which early impact should be achievable.

1.3. Proposed GNRMP Pest Management Interventions

Based on observations by the Project staff, and confirmed by an independent pest management and environmental assessment of the watersheds (Faye and Knausenberger 1994), the following pest insects were identified as significant, which are to be targeted as priorities for control measures. The GNRM project plans to collaborate with specialists of the National Laboratory of Plant Protection (LPV) to establish limited field evaluations, including the use of insecticides, to address these problems:

- at least one species of termite (prob. *Macrotermes* sp.) (dozens of species in several genera are thought to be present in the area, but little specific information was obtainable) which consumes crops in the field[1];

- weevils and other stored product pests (beetle and moth larvae) which attack stored grains, roots and seeds;

- Variegated grasshopper in gardens and external fields;

- a fruitworm which attacks oranges; and

- a range of pests on a variety fruit and vegetable crops, cotton and other potential and actual cash crops.

Other pest problems are more or less significant factors detracting from agricultural productivity in the watersheds, notably weeds, a range of insect and disease pests of horticultural and industrial crops (e.g., cotton), as well as rodents and granivorous birds. In light of the USAID/Guinea emphasis on agricultural marketing promotion, it may well occur that other pests will need to be addressed as part of the GNRMP interventions. However, these are not covered by the present IEE.

Of particular concern to the project zone is the termite species which attacks food crops. In addition, they cause severe damage to village housing, including floors, where termite nests can become established, walls which include elements made of wood, and most roofing, which consists of wood lattice and straw. This problem is particularly prevalent in the Diafore watershed. Plant protection officials and farmers estimate that crop losses reach 60 percent. Farmers have stopped planting root crops, orange and other nursery tree seedlings can not reliably survive, and traditional practices of mulching to promote soil fertility and water efficiency is becoming problematic due to the increasing presence of termites. Food crop damage from termites alone is a key contributor to malnutrition and hunger between the time that the food stocks of the last harvest are finished and the first harvest from the following season begins, about two months.

The Guinea Plant Protection Service, supported by the Food and Agriculture Organization, UNDP and IFAD, has conducted several controlled studies on termite control in the project zone (the prefecture of Labe) from 1988 to 1991. Results from these trials of mechanical and chemical control have been successful. Termites have been virtually eliminated from treated areas. Following the first treatments in 1989 termites have been absent from the

[1] Note: termites affecting housing would <u>not</u> be a primary target for the project's management interventions, but the available options for control of termite damage to structures should nevertheless be enhanced by the interventions in the fields.

treated areas for as long as three years.

The project proposes to initiate with local farmers pilot integrated pest management activities which combine mechanical control methods with limited and site specific applications of chemical pesticides.

These pilot activities will consist of (1) the establishment of a protocol with the Guinea Plant Protection Service to furnish technical assistance and training; (2) training of Plant Protection Service agents and selected farmers in pest control measures and the safe handling, storage and application of pesticides; (3) controlled farm level applications of pesticides and mechanical control methods to reduce food crop damage from termites and weevils; and (4) an extension campaign to sensitize farmers to the concept and adoption of methods for integrated pest management.

The total investment for this pilot phase of the pest management interventions is estimated to be approximately $50,000 over the remaining project life. This includes staff time, training, support to applied research and all materials and equipment required.

2.0 COUNTRY AND ENVIRONMENTAL INFORMATION

Following is a brief review of the environmental conditions under which the pesticides are to be used. The Project will conduct pilot pest management activities in the three watershed sites of the Fouta Djallon highlands area of Middle Guinea.

The Fouta Djallon mountains and plateaus in Middle Guinea cover more than 60,000 km2, approximately one-quarter the land area of Guinea. Nearly the entire region is mountainous, and a quarter of the area (13,000 km2) lies over 900 meters above sea level. The mountains traverse the region in a north south direction, rising steeply from the west and gently from the east. Approximately one third of the population of Guinea lives in the Fouta Djallon, two thirds of whom are Peuhl.

There are numerous land and soil types in the Fouta Djallon. Farmers have independently classified the soil types by a catena concept, which describes interlocking soils on a landscape from the hill crests to valleys.

In the valleys of watersheds, alluvial flood plains are found. Many of these areas receive annual deposits of fine clays and sand, and soil has built up over time through these deposits. These are locally called dunkire and are cultivated regularly. In lower areas of the alluvial plain fine textured, heavy clay hydromorphic soils are found. The local name for these areas is hollande. These soils are used for grazing cultivation and some gardening.

The Fouta Djallon is an area of high plant species diversity and an important center of endemism. Vegetation is classified as a combination of woodland, open savanna woodland, bush woodland and light forests and lightly wooded savanna bush. However, most natural forests have been replaced by cultivation, secondary growth, fallow, and grassland.

Gallery forests are traditional buffers of natural forest left around springs and along water courses. This buffer helps maintain water quantity as evaporation is reduced, water infiltration is increased and erosion and stream sedimentation is lessened. The tradition of leaving galleries intact is not always respected, and some farmers now clear land up to the stream banks. The gallery forests are likely high in floral and faunal biodiversity and provide non timber artisanal and medicinal products. Isolated forest "islands" are found on various land types. These usually indicate a water source, a "sacred wood" or a cemetery.

3.0 EVALUATION OF PESTICIDE USE WITH RESPECT TO ENVIRONMENTAL IMPACT POTENTIAL

USAID's pesticide procedures[2] are applicable to all proposed projects or activities which "include assistance for procurement or use or both of pesticides registered for the same or similar uses by U.S. EPA without restriction." In this case, the Initial Environmental Examination for the project shall include a separate section evaluating the economic, social and environmental risks and benefits of the planned pesticide use to determine whether the use may result in significant environmental impact. The below discussion shall address the factors to be considered in such an evaluation.

3.1. USEPA Registration Status of the Requested Pesticides

The following problem insects are considered to be priorities for control requiring pesticides. The pesticides proposed to be used by the project are:

For termites in and around fields/gardens:

-- diazinon (e.g., Basudine 60% EC, and/or Basudine 10% G Granular formulation)
-- chlorpyriphos (e.g., Dursban 5% G and 10% G)

For stored product insects in consumption grains:

-- pirimiphos-methyl (e.g. Actellic 2% G or 50% EC)
-- chlorpyriphos (e.g., Dursban ECs)

For seed treatment (destined for planting only):

-- thiophanate-methyl + thiram + diazinon (Super Homai 70% WP)

For Variegated grasshopper (Zonocerus variegatus):

-- diazinon (e.g., Basudine 60% EC)
-- chlorpyriphos (e.g., Dursban EC)
-- fenitrothion (e.g., Sumithion 50 EC)

For orange fruitworm:

The "orange fruitworm" is said in recent years to have caused major yield reductions and abandonment of citrus plantations. Though identified as a priority problem needing attention (Balde 1990, Faye & Knausenberger 1994), control strategies have not been worked out locally; too little is known about this species to recommend particular control approaches. The species involved in this problem is thought to be the larva of the moth genus Cryptophlebia. If pupation occurs in the soil as suspected, this may offer useful approaches to control. Further investigation is required. Baits treated with malathion may be worth considering.

When pesticides are to be used in USAID projects, USAID policy promotes, whenever possible, the use of pesticides that the U.S. Environmental Protection Agency (USEPA) has registered as "general use". In the U.S., general use pesticides (GUPs) can be purchased and used without restriction because the EPA has determined that they present minimal risk to people and the environment, if used according to label instructions. On the other hand, restricted use pesticides (RUPs) can be purchased and utilized only by certified, licensed applicators, or persons directly supervised by them. RUPs generally are very toxic and/or their normal use is considered too hazardous for persons who have not received special training in their correct use. RUPs are usually unsuitable for use by farmers in USAID projects, and will not be used by LPV staff either in the GNRM project.

22 CFR 216.3(b)(1)(i)

Tables 1-3 show pesticides that are being recommended for approval for use in the GNRM Project for the specific purposes presented. All are registered by USEPA, and have no notice of Special Review or intent to suspend or cancel. Diazinon, malathion, pirimiphos-methyl, thiophanate-methyl and thiram are general use pesticides. Chlorpyriphos and fenitrothion are restricted use pesticides, and subject to more stringent usage requirements (as described below).

Table 1. **Pesticides Acceptable for Use in the USAID/Guinea GNRM Project on Cereal Grains, Roots and Tubers**. An "X" in a crop column signifies EPA registration for that crop. The crop names are: MAI = maize, SOR = sorghum, MIL = millet, RIC = rice, CAS = cassava, SWP =sweet potato, and POT = white potato.

Pesticide common name	EPA Registration Status on Selected Crops						
	MAI	SOR	MIL	RIC	CAS	SWP	POT
INSECTICIDES:							
Chlorpyriphos[1/]	X	X					X
Diazinon	X	X		X[4,5/]	X	X	X
Malathion	X	X[2/]	X	X[2/]		X	X
Pirimiphos-methyl	X[3/]	X[3/]					
FUNGICIDES:							
Thiophanate-methyl	X						X
Thiram		X	X	X	X		

Footnotes for Table 1:

1/ Some formulations Restricted Use
2/ Pre- and post-harvest application.
3/ Post-harvest application.
4/ Tolerance obtained from FAO Codex Alimentarius - Pesticide Residues in Food, Second Edition, 1993.
5/ Tolerance is for polished rice (i.e., post-harvest)

Table 2. **Insecticides Acceptable for Use in the USAID/Guinea GNRM Project on Selected Vegetable and Fruit Crops**. An "X" in a crop column signifies EPA registration for that crop. The crop names are: TOM = tomato, EGG = eggplant, OKR = okra, MEL = melon, CUC = cucumber, SQU = squash, CIT = citrus, and MAN = mangoes.

Registration Status - Some Vegetable & Fruit Crops

Pesticide common names	TOM	EGG	OKR	MEL	CUC	SQU	CIT	MAN
INSECTICIDES:								
Chlorpyrifos1/	X			X	X			
Diazinon	X		X	X	X	X		
Malathion	X	X	X	X	X	X	X	X
FUNGICIDES:								
Thiophanate-methyl	X2/							
Thiram	X	X	X	X	X	X		

1/ Some formulations Restricted Use
2/ Tolerance obtained from FAO Codex Alimentarius - Pesticide Residues in Food, Second Edition, 1993.

Table 3. Insecticides Acceptable for Use against Subterranean Termites in Field and Agroforestry Situations, Stored Product Pests and Variegated Grasshoppers in the USAID/Guinea GNRM Project. Selection decision dependent upon formulation and target insect combination.

Insecticide common name	EPA Registration Status on Selected Target Insects: Termites in field/ garden	Stored Product Pests	Grasshoppers
Chlorpyrifos1/	X	X	X
Diazinon	X	X	X
Fenitrothion1/			X
Malathion	X	X	X
Pirimiphos-methyl		X	

1/ Restricted Use Pesticide

3.2 Basis for Selection of the Proposed Pesticides

The pesticides proposed for use were selected because they: 1) have been shown to be effective for use against termite, stored product pests (weevils, other beetles, and cereal moth larvae) and Variegated grasshoppers, respectively, in several trials carried out by the Laboratoire de Protection des Végétaux, supported since 1986 by FAO, UNDP and IFAD (Faye and Knausenberger 1994); 2) are available at LPV in the Labé Prefecture of Middle Guinea; 3) have been shown to be safe and effective when used according to label instructions in other nations with pest/crop/agroecosystem conditions similar to those of Guinea (e.g. in Mali and Senegal); and 4) with the exception of fenitrothion and some formulations of diazinon, are EPA general-use pesticides and therefore of relatively low toxicity.

3.2.1 The Effectiveness of the Requested Pesticides for the Proposed Uses

Effectiveness entails applying the pesticide at the correct time, at the proper rate, with proper application equipment and technique, and only when and where needed. Thus, effectiveness results in large part from correct, rational use.

Termites. Effective mechanico-chemical control of termites has been demonstrated in Middle Guinea by a combination of physical excavation (up to 1.5 m down) of the mounds and removal and killing of the queen(s), in combination with chemical treatment. Mechanical control can be fairly effective if the queen is located and destroyed. However, available evidence indicates that mounds will be reconstituted even after the queen is destroyed. Often two queens are in the same mound, and hand digging to locate the queen will frequently miss the second queen. Also, some species of termites will be able to generate a new queen from pre-royal nymphs, depending upon the population structure of the mound at the time of intervention. Mechanical control on younger termite mounds can be effective before termite numbers have had a chance to develop. When combined with chemical control on older mounds, the two actions can effectively eliminate termite pests for a long period of time, at least three years.

The FAO-supported studies in Middle Guinea have demonstrated that convincing long-lasting control for termites requires the use of chemicals. Experimental control operations have been performed by the LPV staff in Labe during the past several years, and are reported to be very effective (LPV Annual Report 1988-90). In 1988, 1364 mounds were treated in the prefectures of Labe, Pita, Dalaba, and Mamou with either Basudine 10G or 60 EC formulations. Of these, 1318 were completely inactivated, a 97% control rate (Seni & Camra 1989). Similar results are said to have been achieved in other control campaigns carried out in Middle Guinea by LPV staff with FAO and IFAD support.

Stored Product Pests. With respect to stored product (mainly maize and cassava) pest control at the farmer's level, action is seldom taken, for lack of options. Steps taken, if any, involved ash or powdered hot pepper mixed with the grain prior to storage. Cassava is sometimes cured by boiling and drying before storage. Chemical control measures have been successfully tried by the LPV, using Actellic Dust at 2% a.i. or Actellic 50 EC. In 1989, 200 tons of maize, cassava, peanuts, cowpeas and rice were treated for 420 farmers, using 122 kg of Actellic 2% P, and 44 liters of Actellic 50 EC. The treatments occurred in the prefectures of Labe, Pita, Dalaba and Mamou. The report indicated satisfactory control of *Sitophilus zeamais, S. cereallela* and *Prostephanus truncatus*.

Seed Treatment. Seed treatment is a highly desirable and effective means of protecting seeds destined for sowing, both while in storage and after sowing. Often, combination formulations are used, providing protection against fungal attack as well as against insects. At least one such combination product is presently in use by the Labé plant protection staff: Super Homoi, consisting of 15% diazinon, 20% thiram, and 35% thiophanate-methyl. It is made by the Japanese firm Nippon Soda. Thiram and thiophanate-methyl (e.g., Fungo, Topsin-M) have many approved food uses, and are common seed treatment products.

Grasshoppers. The Labé LPV staff has had considerable experience in control of Variegated grasshoppers, mainly using products made available during the 1988/89 Desert locust invasion of Guinea. According to the 1990 Labe LPV Annual Report, treatment of fenitrothion (Sumithion 33 EC) at 1 ml/ha in 1 l of water gave good results. In some areas, treatment at monthly intervals was required.

Chlorpyriphos and fenitrothion are the only products presently available for grasshopper control in Labé. They are both USEPA restricted use pesticides, and are among nine insecticides[3] approved by USAID in the 1989 Programmatic Environmental Assessment (PEA) for locust/grasshopper control in Africa and Asia. Great caution should be taken to ensure that these RUPs are not used except under the conditions consistent with those described in this section above (i.e., utilized only by a trained and experienced LPV applicator). Malathion is a non-RUP which is recommended as an alternative to the above two, if and when additional pesticide purchases were to be considered. The use conditions and precautions for the grasshopper control situation is described in detail in the PEA (TAMS 1989).

3.2.2 Pesticides Not Acceptable for Use in USAID GNRM Project

Apart from the products listed and discussed above, no other pesticides are recommended for approval under this IEE. Many of the pesticides presently available in Labé (Faye & Knausenberger 1994) are Restricted Use Pesticides, and in any case shall not be provided to farmers. In particular, two pesticides initially considered by GNRMP staff for inclusion under this IEE cannot be supported: Oftanol (isofenphos) and Ofunack (pyridaphenthion). Oftanol, because it is a particularly toxic Restricted Use pesticide, and Ofunack because it is not registered, neither in Guinea nor in the U.S. Another pesticide which has seen use in termite control operations in the Labé area but which must not be supported by the GNRM is Folidol (parathion). This is one of the most highly toxic pesticides known, but has no comparative advantage over the alternatives provided for above.

However, with trained GRG and GNRM project staff, some other pesticides might in the future be utilizable on a very limited basis in research and demonstration plots, in seed multiplication plots, in the teaching of safe pesticide use, or in small-scale pest control programs. Such future use would be strictly within and under the direct control of the LPV and, eventually when trained, appropriate GNRMP and PVO and Peace Corps staffs. Or, in certain emergency situations in which approved pesticides were deemed ineffective, or significant crop losses would occur if a restricted use were not used, then USAID/Guinea and the GRG, acting together, could make an exception to save the crop. This restricted use must include adequate training, described below, and not result in illegal pesticide residues.

3.2.3 Availability and Effectiveness of Other Pesticides or Nonchemical Control Methods

Under "other pesticides and methods" the following should be considered: botanical insecticides, biorational pesticides, lower rates of synthetic pesticides, innovative methods for pesticide application, and pesticide rotation to prevent buildup of resistance.

Botanical insecticides are insecticides derived from plant materials. They have been used successfully for centuries in traditional farming systems, and today they are increasingly important in modern agriculture as many growers begin to turn away from synthetic pesticides. "Botanicals" can be concocted on the small farm from flowers, leaves, stems and roots, etc., or produced by industry from more refined extracts. As of mid-1993 in the U.S., the following natural insecticides are registered by the EPA and most of them are on the market as commercial products: **azadirachtin** (the primary insecticidal ingredient from the neem tree), **capsaicin** (from hot chili peppers), **garlic, sesame oil, rotenone, pyrethrum, ryania, and sabadilla**. Some of their registrations (by the U.S. EPA), derivation, EPA toxicity category and acute oral and dermal LD50 values are summarized in Table ...* below. Note that these are all of relatively low toxicity and thus worth considering further for use in Guinea, but only after

[3] The other seven products are: acephate, bendiocarb, carbaryl, diazinon, lambda-cyhalothrin, malathion and tralomethrin. All of these chemicals are currently registered by the U.S. EPA or its equivalent in other countries. Six of these l/g insecticides are **restricted use pesticides** in the U.S.: bendiocarb, chlorpyrifos, fenitrothion, lambda-cyhalothrin and tralomethrin.

sufficient testing. *Plant-derived pesticides not registered with the USEPA cannot be extended to farmers or promoted commercially where U.S. funds are involved. Experimental use on less than 4.0 ha (10 acres) is permissible.*

Annex 2 presents botanical products presently registered with the USEPA.

Reduced rates of application. It is sometimes possible to utilize lower than recommended rates of certain synthetic pesticides and still attain satisfactory pest control. For example, the FAO-funded termite control trials in the Labé region determined that there was no difference in efficacy for termite control between 200 g and 400 g of Basudine per mound. Thus, one should choose the lower amount.

Biorational pesticides include viruses, bacteria, fungi, and protozoa, and chemical analogs of naturally occurring biochemicals, such as avermectin. The most plausible candidate biorational pesticides with immediate potential in Guinea, are the fungi *Beauveria* and *Metarhizium*. These fungal pathogens are showing great promise as grasshopper control agents.

Other Methods for Insect Management.

- Biological control: conservation, augmentation, inoculation, and habitat manipulation with parasites, predators and pathogens
- Plant resistance (natural, and through breeding programs
- Environmental manipulations: plant spacing, intercropping, timing of planting and harvesting, crop rotation, water management, fertilizer management, soil preparation, sanitation, trap crops
- Physical and mechanical control: screens, traps, protective packaging, barriers, flaming and burning, hand picking
- Attraction and repellency: attractants, repellents

3.3 Extent to Which the Proposed Pesticide Use is Part of an Integrated Pest Management (IPM) Program

The GNRM project will encourage a commitment to IPM as a component of appropriate, sustainable natural resources and crop management. Thus, the LPV's work involving pesticides should follow basic IPM principles: employing ecological (non-chemical) crop protection methods as far as possible, and minimizing chemical inputs by using them only if economically justified, and only on an "as-needed" basis. In addition the project will provide farmer training and demonstration in appropriate sanitary, cultural and mechanical techniques known to reduce insect presence. The demonstrations should emphasize complementarities between prudent NATURAL RESOURCES and crop management strategies (e.g., organic matter and wee cover management) with pest management objectives.

The integrated pest management approach to be adopted as appropriate by the project will emphasize, with respect to pesticide usage, site specific application and minimum dosage. This will help control exposure to non-target species.

In the case of termites this will involve the digging and removal of the queen. This will help reduce termite presence, particularly in areas where termites mounds are newly established. The project will also conduct an exhaustive survey of traditional control methods and test the most promising ones.

For weevils and other stored product insects, the project will assess food storage techniques, and determine if more appropriate storage facilities can be constructed that are more resistant to insect attack. This may involve suc actions as treating the base of traditional storage sheds with neem leaves contain a naturally occurring property for repelling insects. Other actions may involved the construction of clay based storage shed, which provide some resistance to insect penetration. Also, seed storage in vessels which can be hermetically sealed could be encouraged.

Specific suggestions for an IPM program under the GNRM project are provided in the assessment by Faye and Knausenberger (1994).

The following general technical and economic guidelines apply:

-- Least-toxic, maximally pest-specific pesticides should always be preferred.

-- No pesticide use should be recommended to farmers unless the use pattern has been tested and shown to be economic under local conditions.

-- LPV should recommend pesticide use to farmers only as a last resort when a significant pest infestation has been signalled through field inspection, non-chemical pest control methods have proven inadequate, and the use pattern in question has been shown to be economic. Pesticide use would thus be restricted to a minimum, on an "as-needed" basis only.

-- To safeguard applicators and minimize nontarget effects, GRG and NGOs should concentrate on the least-toxic, most pest-specific pesticides. It should be remembered that USAID regulations prohibit funding of extension of local botanical compounds that have never undergone safety testing for U.S. registration.

-- No insecticide use should be recommended on a "preventative" or "calendar schedule" basis.

-- To ensure that pesticide use is sustainable and that farmers develop habits and attitudes that take the real economic costs of pesticide application into account, no free pesticides should be provided to farmers, or any form of pesticide or application subsidy, except for farmer's field adaptive research and for very limited extension demonstration purposes. In all other cases, when farmers wish to use pesticides they should be required to purchase them from commercial suppliers and pay full market price. Exceptions for emergencies could be allowed for.

3.4 Proposed Methods of Application and Safety Measures

3.4.1 Availability of Application and Safety Equipment

The Project must require that adequate personal protective equipment (PPE) be used in all pest control activities in which pesticides will be used. To "use" pesticides mean to purchase, transport, store, measure/mix/load, apply, and dispose of pesticides and containers, as well as clean application equipment. And, as far as USAID is concerned, "use" of pesticides includes the provision of fuel for pesticide transport and application vehicles. The Project must require the LPV to adhere to safety standards which will avoid, or reduce to a minimum, all environmental or human health hazards during each and every pesticide use. Approved contracts or grant budgets must allocate funds for protective gear if any pesticide use is proposed. LPV technical personnel must be adequately trained to ensure that pesticides are used safely.

READING AND HEEDING THE LABEL INSTRUCTIONS, AND USING COMMON SENSE, SHOULD ALLOW FOR SAFE AND EFFECTIVE PESTICIDE USE.

Guinea NRM project personnel and LPV should have on hand guidance on safe and rational pesticide application, such as the following USAID documents: 1) Pesticide User's Guide (Overholt and Castleton 1989), 2) Guide pour l'Usage des Pesticides (Overholt and Castleton, 1989) and 3) Environmental Guidelines for PVO/NGO Field Use in Africa (USAID 1993).

Table 4. Toxicity of Selected Insecticides/Fungicides Available in the Labe Prefecture, Guinea.

Common Name 1/	Activity 2/	Toxicity Acute LD50 (mg/kg) Oral	Dermal	Category	EPA Signal Word
Carbaryl	I	850	-	I,II,III	D,W,C 3/
Chlorpyrifos	I	96-270	2,000	II III	WARNING/ CAUTION 3/
Diazinon	I	300-400	3,600	II III	WARNING/ CAUTION 3/
Malathion	I	1,000-2,800	4,100	III	CAUTION
Pirimiphos-methyl	I	>2,000	>4,592	III	CAUTION
Thiophanate-methyl	F	>15,000	>15,000	IV	CAUTION
Thiram	F	>5,000	>5,000	IV	CAUTION

Footnotes:

1/ Accepted common (or generic) names, for which some have many trade names.
2/ I = insecticide, A = acaricide, F = fungicide, N = nematicide and H = herbicide.
3/ Toxicity (and corresponding signal word) depends on the formulation. Liquids generally more toxic than dry products.

3.4.2. Safe Application and Disposal Procedures

Termites. Termite mounds will be dug out to a depth of approximately 1.5 meters, or until the queen's nest is located. The nest is readily located by the presence of a large number of white colored larvae. If possible the queen will be removed and destroyed before application of the pesticide.

The insecticide Basudine, preferably the 10% Granular formulation, will be applied at a dose of 200 grams per average mound (but no more than 350 grams for any size mound). Large-scale trials supported by UNDP/FAO showed that all dosages were effective.

In some instances it may be deemed appropriate to apply Basudine in the emulsifiable concentrate formulation (60% EC), at effective (active ingredient) rates of 350 to 560 ml of 60% product per 10 l water per average mound (i.e., 200 resp. 350 ml active ingredient. More or less water may be required depending on the size of the mound. The formulation will take place only after the termite mound has been opened and the queen removed. This will keep the pesticide in its original container until the moment it is needed. The material will be poured from the container strategically into the mound. No sprayer will be required.

However, if a sprayer is used, the mixed dosage will be placed in a hand-held pump sprayer, and a full ten liters of formulated product at the above dosages sprayed thoroughly and as uniformly as possible on the interior and exterior surfaces of the termite mound, particularly in and around the principal passage tunnels. The dosage applied to each termite mound will vary according to the size of the mound, but normally will not exceed 10 liters of formulated product using no more than 350 ml active ingredients in all.

Following the spray operation the excavated soil will be crushed and used to seal off the termite mound. The termite mound will be fenced off for a period of at least four days to prevent animals from disturbing the site.

All used equipment and materials, including the pesticide container, will be placed in a specially marked container and returned to the Plant Protection Service office. There the spray equipment will be properly rinsed and cleaned. The used container will be pierced, crushed and buried at least 50 cm deep in soil well removed from water. The project will assist in developing appropriate and safe disposal sites.

The application of the pesticide will only be done by a trained Plant Protection Service agent, who will utilize appropriate protective equipment (mask, gloves and boots) when preparing and applying the dosage.

Stored product insects. All products to be used are well-established to be safe for use on stored grains for human consumption. Once proper preparation of the storage site has occurred, Actellic 2% P (powder) or 50% EC liquid will be formulated/applied according to standard procedures to the premises and stored products to be protected.

Super Omoi (or Homai) is binary product (fungicidie and insecticide combination) registered with the USEPA, and is applied only to seed grain intended for storage until the next growing season. It will be applied according to label directions.

3.5 Avoidance of Acute and Long-term Human Toxicological Hazards

The hazard of using a pesticide results from a combination of inherent toxicity and likely bodily exposure. Some pesticides, even of low toxicity, present potential exposure problems such as acute inhalation toxicity, serious eye or skin irritation. However, none of the products suggested for the pest management interventions are in USEPA Toxicity Category I, and most are in Category III or IV. With the standard safety precautions to be taken in connection with the proposed interventions involving pesticides, no or very minor hazards are to be expected.

The proposed general use pesticides (Tables 1-3) are considered safe to use by an applicator who has received sufficient training and who also heeds the use instructions provided on the pesticide label (that include advice on using the proper protective equipment and clothing). The greatest exposure during pesticide use is usually experienced by those who measure, mix, load, apply, clean equipment, and enter a treated area without protective gear. Precautions must be taken at all times during these operations. Users must also be trained what to do in cases of emergency situations such as pesticide spills, leakage or sudden spray from faulty equipment (such as when a hose or coupling fails, etc.).

No short- or long-term effects of human exposure to pesticides are anticipated. The pesticide applicator therefore, must always be conscious of and attentive to prevention of bodily contamination.

Besides the safe application measures to be taken as specified in Section 3.4, the following "prudent pesticide use principles" will be adhered to:

- Protective measures: Appropriate protective clothing, gloves and goggles will be used for all mixing and application operations. An abundant supply of water to use in the event of spills, and atropine (epinephrine) will be available as an antidote. Treatment is preferable during early morning hours to minimize contact with non-target organisms.

- Storage: any pesticide to be used in this project will be stored in the "Cité's" (Watershed Management Units' headquarters compound) storage area with other agronomic equipment in a separate locked cabinet.

- Avoidance of excess stocks: No more pesticide will be acquired than is needed for a specific operation as worked out by protocols established with the LPV; thus, no surplus stock will accumulate.

- Disposal: No excess chemicals are expected to result from the treatments to be undertaken. Used containers will be rinsed, pierced, crushed and buried as described above.

- Limited scale of operations: two fields or external gardens per village for every village in two of the watersheds (Koundou, with 16 villages, and Diaforé, with 12). The control activity will be extended to the third watershed at a later date.

3.6 Compatibility of the Proposed Pesticide with Target and Non-target Ecosystems

The General Use Pesticides proposed for the GNRM Project are mostly non-persistent and should not cause long-lasting harm to the environment. The ENVIRONMENTAL GUIDELINES on the pesticide label should always be followed.

3.6.1 Possible Adverse Effects on the Environment

Use of the proposed pesticides in LPV activities (according to instructions on the pesticide label, and assuming properly trained applicators) should cause no significant harmful effects to the environment. Nevertheless, there may be times when pesticides might be misused unintentionally by LPV personnel, or they might observe incorrect use by others. Therefore, knowledge of some possible harmful effects to the environment is useful.

Many insecticides are very toxic to bees and other pollinators. If spraying cannot be avoided during the flowering period of desired plants, then it should be done early in the morning or late in the afternoon, or when cool, when bees are not as active (at less than 19 degrees C or 65 F). The relative toxicities of some pesticides available in Guinea to bees are:

Highly toxic: diazinon and fenitrothion.

Moderately toxic: malathion.

Other pesticides found in Guinea that are toxic to bees include the following: carbaryl and pirimiphos-methyl.

Pesticides proposed for the GNRM that are considered toxic to fish are diazinon, malathion, pirimiphos-methyl.

One of the pesticides is toxic to birds: chlorpyrifos.

Carbaryl is toxic to animals that eat fish.

Although Guinea has a great diversity of flora and fauna, it is not anticipated that adverse impacts are likely to occur to the environment by use of pesticides by LPVs in their agricultural development programs. That is because pesticide use by LPV personnel will be coupled with training (Section 3.8) and monitoring (Section 6.0). Also, use will not be in forested, wildlife and protected areas, but in sites that already have a history of agriculture use. Thus biodiversity is not expected to be affected by limited and strictly controlled LPV use of pesticides in their internal research and demonstration, seed multiplication, teaching of safe pesticide use, and vegetable production.

No synthetic pesticides will be extended to the villagers and farmers under this project.

3.6.2 Protected and ecologically sensitive areas

Protected and sensitive habitats (e.g. bodies of water with vulnerable aquatic life) within or closely bordering crop and livestock production areas may be at risk from pesticide use. The present human population distribution and movements need to be considered examined with respect to proximity to national protected areas.

When pesticides are used by LPV staff, great care will be taken to avoid pesticide drift and possible groundwater and surface water contamination. Proper procedures for disposal of unused and obsolete pesticides, and empty pesticide containers will be followed.

Project and LPV staff should be familiar with protected and ecologically sensitive areas, and if any control activities are nearby they should avoid any pesticide spraying within 100 m of the protected area.

3.7 Guinea's Ability to Regulate or Control the Distribution, Storage, Use and Disposal of the Requested Pesticides

The Government of Guinea has just passed legislation governing the use and distribution & importation of pesticides. The applicable Guinean legislation includes:

-- a law instituting pesticide registration procedures (Loi L/92/028/CTRN), signed 6 August 1992, and

-- a Decree of Application (D/94/044/PRG/SGG) approved by the Council of Ministers on 12 Oct. 1993 and signed into law 22 March 1994.

While applicable Guinean legislation has recently been passed, and provides for a pesticide registration process, a formal list of registered products has not yet been promulgated. Six pesticides have been banned from importation into the country (chlordane, chlordimeform, cytexatin, ethylene dibromide, heptachlor and mercury-containing compourds). Given the recent date of this legislation, the fact that the registration process is not yet instituted, and that resources for effective application and enforcement are lacking in Guinea, the standards of U.S. law as applied to pesticide use and disposal will govern the practices followed under GNRM project.

Within the project zone (Labé) the Guinea Plant Protection service has an adequate number of trained personnel to provide technical assistance with respect to use and disposal of the pesticides in question.

3.8 Provisions Made for Training of Users and Applicators

For the proposed pilot actions to be initiated by the project, pesticide application will be done only by trained agents of the Guinea Plant Protection Service based in Labé. In addition, in villages where pest management activities will be undertaken, the project will train selected villagers in the methodology of application and effective treatment of termite mounds and grain storage areas. Training will also be provided in general principles of crop protection and sound crop management. Emphasis should be placed upon recognition of natural enemies of pest organisms and monitoring for early recognition of problems.

4.0 BASELINE ASSESSMENT AND INFORMATION AVAILABLE

USAID/Guinea sponsored a study in April 1994 entitled "Assessment of Agricultural Pest Status and Available Control Methods in the Guinea Natural Resources Management Project: Approaches to Integrated Pest Management," which focusses on the key pest problems in the central highlands area. It provides the basis for the information in this IEE.

This assessment highlighted the fact that surprisingly little is known among local crop protectionists about the biology and specific make-up of the species involved. Likewise, little applied research into alternative control measures has been conducted in Guinea on these problems. This presents an opportunity which the GNRMP is ideally situated to address through its technology transfer and applied research component: facilitating the evaluation for IPM measures which are locally sustainable and effective.

5.0 ISSUES, MITIGATION OF IMPACTS EXPECTED AND RECOMMENDATIONS FOR GNRM PROJECT ACTIONS

Issue: Minimal Human and environmental health risks.

Based on the analysis and measures described in Section 3 above, no significant impacts or risks for either environmental or human health are likely to ensue from the pesticide use to be supported under this activity. Key points in support of this conclusion are:

- The scale of the activity will be very limited, initially involving no more than perhaps 120 discrete treatment sites (termite, stored product pests and grasshoppers) in 28 villages. The total amount of pesticide product to be used will be well under 50 kg or liters.
- The approved pesticides are among the least toxic, yet effective, available.
- Termite control measures will combine pesticides with mechanical control, and will rarely need to be repeated.
- Only Crop Protection Service staff will carry out the treatments.
- All pesticide materials, used equipment and empty containers will be stored at the central "Cité" sites or at LPV headquarters
- All appropriate safety measures as outlined above will be taken to protect human health, non-target organisms and other environmental assets.

Issue: Likely growing demand for pesticides and pest management technologies

Experience in other developing countries shows that pesticide demand and supply increases as subsistence agriculturists emerge into a market economy. Likewise, it is apparent that with the demonstrations proposed for the pest management interventions, success will create an increasing demand as cash becomes available. There are at present no systematic plans for addressing the medium-term implications of investments in demonstration of this pest management technology. This will be tempered in the case of termite control because it is likely that a single successful treatment will solve the problem at a given site for several years. Nevertheless, consideration should be given for systematically addressing the likely eventuality of an increasing trend towards pesticide use.

Recommendation: USAID should consider having a Programmatic Environmental Assessment for pest management and pesticide use prepared within the GNRMP. This will provide the legal context and technical rationale for a series of adaptive responses, which are socially and economically compatible and consistent with good natural resources management practices. A key point in favor of this approach is that a PEA gives the Mission and project personnel greater flexibility, and will eliminate the need for further review, in USAID/Washington, of sub-activities which address situations and problems as they arise. This will also usually require some provision of appropriate for training of villagers in safe use of pesticides and alternative technologies.

Concern: Pesticide Storage Facility Improvements Needed in Labé Prefecture.

As described in Faye and Knausenberger (1994), the LPV storage building in Labé, where the pest management campaign will be based, has significant deficiencies. While it is a sturdy, well-locked concrete block facility, it has poor ventilation, and storage shelves are lacking; there is no water source for mixing, clean-up and emergency use; likewise, non-pesticide goods were being stored with pesticides, which is not appropriate. Also, there are no warning signs, nor fences, and the floors were very dusty, so that persons entering kick up pesticide-laden dust.

Recommendation: Means should be found to upgrade the facility to address the above deficiencies, if it is to be used in connection with the GNRMP pest management activities. Storage of the materials in the GNRMP pilot watershed headquarters (*Cité*) would also need to meet minimum standards, but the opportunity to assist in the upgrading of the Labé LPV storage facility should be considered.

Concern: **Insufficient pest management knowledge and skills among Guinean crop protection staff (LPV) in Labé.**

The assessment determined that the apparent level of knowledge of some of those to whom this program is to be entrusted is not up to the professional level desirable. Fortunately, the supervisory staff appeared to be quite competent. This limited staff depth and expertise could be a significant constraint to the effective implementation of the pest management interventions, given the focus on IPM options and the challenges that presents, especially in light of the diversity of target hosts and sites involved, and the need to develop training events for the villagers.

Recommendations:

-- Staff interviewed requested training to refresh and upgrade their skills. As soon as possible, this should be facilitated in crop protection training centers such as in Senegal, Niger, Cameroon or Benin.

-- USAID might consider support to a national- and/or regional-level workshop on termite management experiences and approaches, bringing together African, FAO and other international centers of IPM and agroforestry expertise, as well as local NGOs.

Finding: **Many opportunities exist to promote alternatives pest management strategies minimizing the use of synthetic chemical pesticides in a fashion optimally compatible with natural resources management objectives.**

A range of options for promoting alternative and nonchemical pest management strategies was presented above (esp. Sect. 3.2.3). Possible approaches to IPM including traditional technologies were reviewed in the GNRMP context by Faye and Knausenberger (1994). A strategic approach to promoting such options is presented below.

Recommendations:

-- USAID/Guinea's NRMP should formulate a policy pertaining to pesticide use and IPM approaches.

-- LPV and SPV should develop IPM demonstration protocols separately addressing termites, stored product insects, and grasshoppers. These protocols should be vetted outside the project. USAID AFR/W is prepared to review and comment on such protocols.

-- LPV needs to take the sorts of IPM options presented in the Pest Management Assessment (Faye & Knausenberger 1994) into account in developing the protocols referred to.

-- GRG itself could be encouraged to formulate and adopt a national IPM policy.

-- LPV could be encouraged to consider experimenting with botanical insecticides, if they are not already doing so, but ONLY IN SMALL SCALE TRIALS. However, under U.S. Law, unregistered active ingredients of plant-derived pesticides may not be extended to farmers or used commercially.

the LPV and other agents should select both the least toxic pesticides, AND the least toxic formulations (e.g., granular) of those pesticides.

-- LPV could approach IITA Plant Health Management Center in Cotonou, Benin, about collaborating on the evaluation of the fungi *Beauveria* and *Metarhizium*. The products could be considered now for trials against the Variegated grasshopper (Fr.: Criquet puent, *Zonocerus variegatus*). A major *Zonocerus* biological program is being planned in the central West African region. Contact: Jeffrey Waage, c/o LUBILOSA, International Institute of Biological Control, Ascot, Berks SL5 7TA, United Kingdom. Tel.: 44-344-872999, fax: 44-344-875007).

6.0 MONITORING

6.1 Provisions Made for Monitoring the Use and Effectiveness of the Treatments

The Project in collaboration with the Guinea Plant Protection Service will develop and implement a monitoring and evaluation plan for pest control activities.

All treated sites will be mapped, marked and surveyed twice a month for a period of two months, followed by monthly observations for a period of two years to observe the results of pesticide application. At sites where applications are made villagers will be trained to observe any unusual effects from the application of the pesticide.

6.2 Provisions for Monitoring the Human Health and Environmental Impact of the Treatment

The small scale of the activities and the very limited nature of likely adverse impacts does not justify a specific monitoring program. However, the GNRMP M&E and general staff, LPV staff, and villagers will be sensitized to the sorts of impacts to be alert to. Under certain circumstances, if opportunities present themselves, LPV staff exposed to pesticides consistently should be tested for blood cholinesterase inhibition, an indicator of exposure to pesticides.

7.0 ENVIRONMENTAL DETERMINATIONS

The pest management assessment, and the risk-benefit analysis in this IEE, demonstrate that the immediate, direct and indirect risks are minimal, and that significant benefit will be derived from the interventions. Also, adequate provision for preventive and mitigative measures is made in this project. Thus, prudent use of pesticides is acceptable, and a Negative Determination with conditions is recommended for pesticide use in pilot pest management projects for the following four site/pest combinations:

-- **Termites in and around fields/gardens and in tree nurseries:**

  - diazinon (e.g., Basudine 60% EC, and/or Basudine 10% G Granular formulation)
  - chlorpyriphos (e.g., Dursban 5% G and 10% G)

It is estimated that demonstrations will be carried out by LPV staff (only) in about 30 villages, in no more than two tapades per village, and no more than four termite mounds per tapade. Treatment will entail combined mechanical and chemical measures as outlined above. Alternative approaches will be investigated through applied research grants. It is estimated that about 10 kg of pesticide product will suffice for this aspect.

-- **Stored product insects in consumption grains:**

pirimiphos-methyl (e.g. Actellic 2% G or 50% EC)
chlorpyriphos (e.g., Dursban ECs

Only demonstration sites will be treated, and only by the LPV and GNRMP agents. An estimated range per family for treatment is 200 - 500 kilograms of grains stored for consumption.

-- **Seed treatment (destined for planting only):**

-- thiophanate-methyl + thiram + diazinon (Super Homai 70% WP)

On the order of 20 kg of grain stored for planting will be treated per family on a demonstration basis only. Mixing and application will occur by the LPV agents.

-- **Variegated grasshopper (*Zonocerus variegatus*) in irrigated and rain-fed horticultural plots:**

- -- diazinon (e.g., Basudine 60% EC)
- -- chlorpyriphos (e.g., Dursban EC)
- -- fenitrothion (e.g., Sumithion 50 EC)

While this will also be on a pilot scale, here it is especially important that treatment only occur by the LPV and trained GRNMP staff, because application will normally take place by spray applicator, and because the pesticides involved are among the most toxic. Use of baits is preferable if the knowledge in their effective use is accessible.

USAID and LPV/SPV are referred to the *Programmatic Environmental Assessment for Locust/Grasshopper Control in Africa and Asia*, and in particular the Supplemental Environmental Assessments in many of the nations surrounding Guinea (Mali, Senegal, Cameroon).

The <u>conditions</u> which apply to this negative determination are that:

-- <u>only</u> national crop protection service and laboratory agents, and trained GNRM project agents, are to store, handle and use the pesticides provided;

-- the LPV staff will develop and follow treatment protocols which build in a maximum practical range of alternative techniques aimed at minimizing the need for pesticides;

-- LPV and GNRM staff will establish a simple but robust monitoring process to keep track of the efficacy of the treatments and to identify and mitigate any unexpected negative impacts (on non-target organisms and people) which may be linked to the treatments.

-- USAID will encourage the development of appropriate applied IPM research trials through its technology development grants;

-- no pesticide product will be made available directly to villagers;

-- the storage facilities in Labe be upgraded as described above, if they are to be used for project chemicals; likewise, the storage facilities in the *cités* should be brought up to the minimum standards; and

-- independent evaluation of the project activities' implementation be periodically assessed by a knowledgeable person(s) on no less than an annual basis.

A <u>negative determination</u> is recommended for applied research activities designed to integrate chemical pesticides with non-chemical and other methods, provided that the aggregate size of the trial plots remains under 4 hectares, and all due precautions are taken to prevent untoward impacts of the pesticides.

A <u>deferral</u> is recommended for any treatment strategies involving pesticides against:

115

-- **Orange fruitworm:** too little is known about this species to recommend particular control approaches.

-- **Termite control in and around homes:** The risks associated with pesticide use around homes are much greater than in the case of the control of mounds in external fields.

-- **Any other host/pest combinations** where the need may exist.

A deferral is also recommended for any activities relating to systematic training of villagers in pesticide use.

Concluding Recommendations:

1. **Agent Training/Skills Upgrading.** In line with the concern raised in Section 5.0, USAID/Guinea should consider ways to upgrade the skills of key LPV staff in the Fouta Djallon region of the GNRMP by sending them to francophone crop protection training in West Africa (see above). This could be considered, for example, through the use of HRDA training resources, for example. USAID/AFR/W is in a position to make recommendations of specific training sites in the region.

2. **Seize the opportunity to implement biological control using biopesticides.** The International Collaborative Grasshopper/Locust Biological Control Programme (LUBILOSA) based at the Plant Health Management Center of the International Institute of Biological Control in Cotonou, Benin, is beginning a regional program to control the *Zonocerus* variegated grasshopper, with CIDA support. They are looking actively for collaborators. Contacts should be taken up promptly with Dr. Christopher Lomer in Cotonou: BP 08-0932, Cotonou, Benin (tel.: 229-30-19-94, x-36-01-88; fax: 229-30-14-66) or Dr. Waage at the address given above (end of Section 5.0).

3. **Consider the option of a Programmatic Environmental Assessment (PEA):** As stated in Section 5.0, USAID should consider having a Programmatic Environmental Assessment for pest management and pesticide use prepared within the GNRMP. This will provide the legal context and technical rationale for a series of adaptive responses, which are socially and economically compatible and consistent with good natural resources management practices. A key point in favor of this approach is that a PEA gives the Mission and project personnel greater flexibility, and will eliminate the need for further review, in USAID/Washington, of sub-activities which address situations and problems as they arise. This will also usually require some provision of appropriate for training of villagers in safe use of pesticides and alternative technologies.

4. **Consider ways of influencing the formulation of a national IPM policy.** By focussing attention on a broader range of policy and technology adoption issues which arise when considering IPM as opposed to simple pesticide-based control options, one could facilitate a new "paradigm" about how to go about pest management in the country. An opportunity top put it on the table may be presented through the NEAP dialogue. USAID/AFR/W could be supportive in making the case, if this is deemed worth pursing.

ANNEX F

SCOPE OF WORK

SCOPE OF WORK FOR TERMITE AND STORED PEST CONTROL
Guinean Natural Resources Management Project
(675-0129)

The Guinea NRM Project recently completed a survey of agricultural production constraints in the Fouta Djallon Highlands. This scope of work will address two biological constraints to agricultural production in the region caused by insects.

Termites and stored product pests are identified as two of the main problems in all three watersheds surveyed. These pests destroy crop land, crop storage facilities, and wooden fences protecting fields for domestic animals which substantially increases deforestation. In the Diafore watershed the problem is the most severe.

The people in the Diafore watershed in Guinea are extremely poor. Termite activity in the area has increased insignificantly over the past eight years. People report that approximately 60 percent of their field crops are lost to termites and as a result, they have stopped planting root crop. Termite control at present in this region consists mostly of digging out the queens from the mound, as soon as termite mounds begin to appear. The species builds large mounds which simplifies the location of the nest but increases the labor required to locate the queen. Most of the men have left the villages to look for paying jobs so only women and children are available to excavate the existing mounds.

The Guinea NRM project plans to collaborate with the services of specialists from the National Laboratoire de Protection des Vegeteaux (LPV) to establish a limited field evaluation of the use of BASUDINE (diazinon) and DURSBAN (chlorpyrifos), to be used in combination with a mechanical control method (locating and killing the queen) for controlling termites. LPV agents have worked with termite control in some of the project area.

These experts will work with the villagers to control termites in two house gardens in each of two villages in the Diafore watershed. This extension work will be expanded to a third village at a later date. The technicians will ask the farmers to dig up selected termite mounds to a depth of at least 50 cm and attempt to locate the queen. The technicians will then chemically treat the mound. Local farmers will be instructed to keep animals away from the treated mounds for at least four days. As always, the technicians will explain how mechanical control could be effected by the farmers themselves in the event that termites return.

In addition, as a parallel field research activity, project staff will introduce 'bitter' manioc to the most heavily infested areas to see if the natural arsenic contained in these plants will deter termite activity and infested areas. Project staff are already in communication with the International Institute for Tropical Agriculture (IITA) in this regard.

Damage of stored grains and seeds by weevils is another major problem in the target watersheds. Therefore, what little the people produce from their harvests, a significant amount is lost in storage. In addition to several sound grain storage methods, the project staff would like use, on a limited basis, ACTELLIC (pirimiphos-methyl) to reduce storage loss.

The project staff are anxious to be able to demonstrate that, if they can control the activity of the pests, using simple practical techniques, the people can begin again to produce productive root crops and once again obtain normal yields from their traditional crops, as well as maintain a secure food storage facility as were possible before the termite problems became so bad. Should these techniques prove effective will be available for use as models for replication throughout the project area as well as throughout Guinea and the Sahel.

II. Scope of Work

A. Scope and Make-up of Team

The chemical products that have been proposed for use in addressing the two problems identified above (termites and stored grain pest) are reasonable choices in terms of chemical control, if properly used. Also, the problems do appear to be serious and current, and for expediencies sake, the chemical approach as defined, should be cost-effective, efficient, relatively safe for the environment, and should go a long way in resolving the problems. Normally, the next step in the process would be to carry out a straight forward Cost-Benefit Analysis for the pesticides to be used as required under Reg. 16, and outlined below. However, because this project is dealing in basic area of natural resource management, and because the Bureau, the Agency (and recently the US Congress) are now much more conscious of "Sustainable Development and Environment", the project staff should make an extra effort to explore Integrated Pest Management (IPM) options, as described above.

It is therefore recommended that a short-term specialist have the expertise in the field area or the practical application of IPM and entomology, that is, a termite management specialist with research and extensions background. The specialist will work directly with Dr. Walter Knausenberger, AID/AFR/ARTS/FARA Environmental Analyst and Advisor, during his last six days of his assignment in Guinea. This complementary approach would be more productive and would serve the mission by not only allowing the project to conform to the Agency's general environmental procedures, but would also promote environmentally superior technologies for sustainable development.

As stated, the results of this assignment could be replicated throughout the country and in neighboring countries which have similar pest problems. The specialists will visit the at least two project watersheds with the Guinea NRM personnel to inspect severely infested sites, targeted for intervention.

B. Satisfying A.I.D. Pesticide Procedures

When assistance involves procurement of use, or both, of pesticides registered for the same of similar uses by U.S. EPA without restriction, there must be an evaluation of the economic, social and environmental risks and benefits of the planned pesticide use to determine whether the use may result in significant environmental impact. Note that "use" is understood broadly to include, for example, facilitating storage of pesticides, or the application of pesticides by provision of fuel for transport of pesticides. In accordance with USAID's environmental procedures which require an Initial Environmental Examination (IEE) and USAID pest management guidelines, a cost-benefit analysis will be performed.

1. Cost-Benefit Analysis

A. Cost-benefit analysis should be drawn up which will include, but not be limited to, the following:

- The U.S. EPA registration status of the requested pesticides (s);
- The basis for selection of the requested pesticide (s);
- The extent to which the proposed pesticide use is part of an integrated pest management program;
- The proposed method or methods of application, including availability of appropriate application and safe equipment;
- Any acute and long-term toxicological hazards, either Human or environmental, associated with the proposed use and measures available to minimize such hazards;
- The effectiveness of the requested pesticides (s) for the proposed use;
- Compatibility of the proposed pesticide (s) with target and non-target ecosystems;
- The conditions under which the pesticide (s) are to be used, including climate, flora, fauna, geography, hydrology, and soils;
- The availability and effectiveness of other pesticides or non-chemical control methods;
- The requesting country's ability to regulate or control the distribution, storage, use and disposal of the requested pesticide (s);
- The provisions made for training of users and applicators; and,
- The provisions made for monitoring the use and effectiveness of the pesticide(s), especially here would be an assessment of pesticide management capacities in Guinea.

2. Additional List of Elements to be considered by the Team

The following need to be elucidated:

- Registration and Development of Pesticides. Product registration and licensing define the conditions of market access for individual products;
- Procurement and supply system;
- Product Stewardship (training and infrastructure to support product and technology dissemination to the user, including follow-up);
- Pesticide Registration Process;
- Pesticide Distributor Licensing.

3. Extending Integrated Pest Management (IPM)

The Guinea NRM project provides an ideal opportunity to promote the adoption of appropriate pesticide management practices and the introduction of alternative pest management technologies. How this would be best supported would need to be elaborated, but one approach could be to encourage the programmatic adoption by the GOG, and/or by PVOs, of IPM polices and principles in their extension and corp production improvement strategies. This could also involve introducing the USAID "Africa Bureau Environmental Guidelines for PVO/NGO Field Use", in which pesticide use is featured as part of PVO/NGO programs and interventions at field level. The short-term specialist should obtain a copy of the latest draft of these guidelines from AID/AFR/ARTS/FARA (Walter Knausenberger).

In any case, AID's present IPM policy stresses the use of "least toxic" pesticides, if any are needed at all. The short-term specialist, after preliminary discussions with all concerned in this activities, will provide (either at community-level meetings, or on-on-one with farm families or the LPV extension staff) information good, low-tech, least-toxic practical approaches which might be considered both of the above problems identified by the Mission. One example would be the technologies developed under the Bean-Cowpea CRSP for post-harvest control. Also, he should present and discuss local adaptation of any techniques available from IITA, and should provide suggestions on the use of techniques already identified by LPV researchers in country. The TA team will also work with the villagers to develop a sustainable practice to reducing storage loss of agricultural products.

4. Monitoring, Extension and Next Steps

Given the fact that termites are among the three most important problems in all target watersheds in the Guinea NRM project, the T.A. team should provide some recommendations for the project staff on how the information and technical trials can be extended to other project areas which have similar pest problems. They should also take this as an opportunity to illustrate for project staff how this can be linked with the core purposes of the Guinea NRM project, while flagging issues related to sectors of importance to USAID, such as, Agricultural Marketing.

The short-term specialist will therefore visit at least two watersheds sites with the Guinea NRM personnel to inspect infested sites, targeted for intervention. Lastly, the specialist will work with Dr. Knausenberger to address monitoring as an issue, especially in relation to the overall NRM project.

III. Duration of Assignment

The short-term specialist will provide his services beginning approximately the 1st week of April for approximately 21 work-days including three days in the United States for research, two days in Chatham, England for research on tropical termite and storage product pest management at the Natural Resources Institute (NRI), and two weeks in Guinea. A six-day work week is requested. The specialist will need a day at the beginning of his assignment in-country assignment in Conakry for orientation and six days at the end to work with Dr. Knausenberger to combine and present their findings on termite and storage product pest management and environmental procedures required in accordance with the IEE. Three days back is the United States are requested for the short-term specialist to finalize the report and the IEE is requested.

IV. Reports

The short-term specialist will report to Dr. K.B. Paul, the Guinea NRM Chief of Party. A draft report will be submitted to the project COP and USAID/Conakry at least two days prior to departure with an oral presentation at least one day prior to departure from Guinea. The report will be finalized in the U.S., incorporating input from USAID/Conakry and AID/Washington. It will be translated into French. Ten copies of the report in French and English will be sent to USAID/Conakry by Chemonics.

V. Qualifications

A. IPM Specialist

Minimal qualifications:

M.S. entomology or environmental related science
FSI 3/3 Level in French language
Field experience
Research and extension experience.

VI. Logistical Support

The short-term specialist will report to the Chief of Party who will coordinate his logistical support with the Project Management Unit (PMU). The PMU will make provisions for lodging, in-country transportation, office space and any other logistical support needed. The specialist must bring laptop computer. Printing and photocopying support will be available through the PMU. Final report production will be done in Washington, D.C.