Chapter 11

Improved Systems to Reduce Losses

CONTENTS

Boxes

Figure

Table

Chapter 11

Improved Systems To Reduce Losses

This chapter examines various technologies available to reduce pre- and post-harvest losses in African farming systems. The first section deals with the various elements of integrated pest management—a strategy that aims at integrating the best mix of available methods to control losses of crops due to pests. The second section examines technologies to improve animal health in low-resource agriculture, both grazing and mixed crop/livestock systems. Improved animal health has the potential to reduce direct losses due to mortality, as well as improve productivity of livestock. Veterinary support and improved animal nutrition are the major areas examined. The final section looks at a host of technologies that fall under the general category of post-harvest technologies. Although many technologies specifically address themselves to reducing post-harvest losses, such as improved preservation and processing, others are more important for their ability to reduce drudgery and increase efficiency of post-harvest activities.

INTEORATED PEST MANAGEMENT[1]

Summary

A wide range of insects, mites, fungi, bacteria, viruses, weeds, vertebrates, and other pests plague Africa's resource-poor farmers and herders. In fact, an estimated 30 percent of the production from some crops is lost in the field or in storage (1,13,56). Although only certain crops suffer such severe pest damage and some experts find that typical losses are lower, the problem is still one with significant implications for food security. The vulnerability of farmers to pest-induced crop loss is likely to increase as more land is planted with genetically uniform monocultures and as the genetic base of crops narrows.

Pests also present problems for public health and livestock. Malaria persists as the most important infectious disease in Sub-Saharan Africa despite attempts to control the vector mosquitoes with insecticides and massive programs to distribute antimalarial drugs (51). The two major arthropod-born diseases of livestock, trypanosomiasis (transmitted by tsetse flies) and East Coast fever (transmitted by ticks), prevent livestock production in large areas of Africa (25,64).

Pest control methods include: quarantines to prevent entry of new pests into new areas; pest-resistant varieties of crops and livestock; cultural controls, such as crop rotations and intercropping; biological controls; and a variety of biological and chemical pesticides.[2] Integrated Pest Management (IPM) is a pest control system that draws on these various pest control methods to provide the most effective mix of available techniques (68). Criteria for determining the optimal methods for resource-poor farmers and herders include (3,39,43,71):

- **Technical-effectiveness:** pest damage is kept to an acceptable level.
- **Cost-effectiveness:** methods are affordable and economically advantageous.

[1]This material is based primarily on the OTA contractor report prepared by Dale Bottrell, University of Maryland, (app. A).

[2]"Biological" pesticides refer to those derived from plants, bacteria and viruses, and fungi. "Chemical" pesticides refer to all other pesticides (i.e., the synthetics).

- **Sustainability:** system is designed for long-term effectiveness, and required inputs are accessible and reliable.
- **Safety:** human and environmental health are ensured.

Developing IPM packages is expensive because they are information-intensive and require trained scientists to research the basic biology of the pests, their natural enemies, and how both interact with the host. Using the packages does not have to be expensive, however. Resource-poor farmers and herders already practice pest control methods that can be improved by scientific knowledge, and the tasks of maintaining the systems—timing of planting, cultivation practices, scouting the field for pests, and so forth—are well within the reach of most African farmers, if they are given training and support (23). IPM may also help reduce problems associated with uncontrolled chemical pesticide use in developing countries. These include human and environmental contamination arising from misapplication of pesticides and the high cost of imports when foreign exchange is scarce.

Development assistance to Africa's resource-poor farmers and herders could benefit from a longer term, sustainable approach that calls for increased emphasis on IPM. Using chemical pesticides alone is a common short-term approach, but a more diversified approach that draws on various pest control methods will be more effective over the long term. Chemical pesticides can be expensive and access to them is unreliable for many resource-poor Africans. Subsidies shift the economic burden to governments, but still drain national economies. Furthermore, free pesticides discourage farmers and herders from exploring sustainable alternatives (58).

IPM is a concept of pest control that combines different aspects of available pest control methods. Central to IPM are efforts to maintain pest levels at non-injurious levels, rather than trying to eradicate all pests. It is an information-intensive technology that requires biological and ecological knowledge about the pest, its habitat, and the pest's natural enemies—e.g., their population dynamics, physiology—and constant monitoring of pest levels to keep them below predetermined economic thresholds, beyond which levels of damage are not affordable (50,72).

IPM usually contains a variety of components. Quarantines offer the first line of defense against the introduction of new pests to an area. Pest-resistant varieties of crops are used to minimize damage and increase crop survival. Cultural controls include agricultural practices that deter build up of pest populations and/or encourage predators, and parasites and pathogens that act as biological controls on pests. Biological pesticides, which tend to be more target-specific and less damaging to the environment, are generally preferred to chemical pesticides. Chemical pesticides, especially insecticides that kill pests and beneficial insects alike, are used conservatively; this better enables natural enemies to "track" changes in the population size of the pests—increasing or decreasing in number in response to the status of the pests.

Options for Managing Pests

Quarantines

Quarantines are regulatory techniques to prevent the entry and establishment of new plant and animal pests in a country or area. For example, the cassava mealybug *Phenacoccus manihoti)* and the cassava green mite (Mononychellus *tanajoa* complex) were accidentally introduced into Africa from South America in the 1970s. These exotic pests now infest at least 60 percent of the cassava-growing area of Africa and cause annual losses estimated at nearly $2 billion (22). The possibilities for introduction of exotic pests into new areas of Africa can be expected to increase as the frequency of contact among nations increases.

Quarantines require a high degree of coordination at a national or regional level. A dilemma common to almost all Sub-Saharan countries is the inability to enforce quarantine regulations at ports of entry. While most countries have some form of quarantine regulations, few are effective (3). A study by the Food and Agriculture Organization (FAO) of quarantine programs in West and Central Africa showed that the quarantine personnel were not technically qualified because of inadequate training (60). Further, regional mechanisms for cooperation, so important in regulating the spread of pests, are not fully used because of political tensions and poor communications. Their cost-effectiveness in Africa cannot be addressed because data—e.g., on the origin, volume, and economic worth of the produce—are lacking (3). Quarantine experts concur, however, that although quarantine programs do not guarantee complete protection, if properly implemented they greatly reduce the risk of costly accidental introductions,

Pest Resistance

pest resistance refers to the use of varieties of plants and animals which are resistant, tolerant, or unattractive to the pest. In recent years, plant breeders have bred resistance into, or identified resistance sources for, a range of basic African food crops, including sweet potato, yam, cocoyam, cowpea, sorghum, maize, rice, millet, and cassava. Recent significant accomplishments in pest resistance include the development of cassava varieties that are genetically resistant to mealybug and green spider mite (21). Resistant cassava clones are being distributed to Nigerian farmers, and seeds are being dispatched to national programs throughout Africa. Improved lines of cassava with resistance to the African cassava bacterial blight (caused by *Xanthomonas campestris pv. manihotis)* also have been developed. Several improved lines give yields up to 30 tons per hectare (40) and have out-yielded local standard varieties by 2 to 18 fold primarily due to their disease resistance (32,33).

Cultural Controls

Cultural controls involve manipulating farming practices to alter the environment so it is less favorable for the pest or more favorable for the pest's natural enemies. Virtually all resource-poor farmers use cultural controls. Intercropping, for example, is a widespread practice which helps reduce pest problems. Different crop species can also be grown on a rotation basis, thereby disrupting the lifecycle of many pests. For example, groundnuts or other nematode-resistant crops are used to disrupt the populations of this pest, which, if left untreated, can devastate cassava yields (22). Other traditional African cultural practices known to reduce pest populations include burning undesirable vegetation, planting crops during pest-free times of year, and cultivating to control weeds (43). For example, Kenyan farmers, recognizing the link between low soil fertility and *Striga* weed, use crop rotations and fertili-

Photo credit: Donald Plucknett/Consultative Group on **International Agricultural Research**

Pest resistance has been identified for a number of important African crops including sweet potatoes like those being planted by this Rwandan woman.

zation with manure to control this parasitic plant which, if untreated, can virtually eliminate yields of cereal grains (11). These techniques are often the least expensive and most effective methods for suppressing insects, disease agents, and weeds (3,17).

Biological Control

Biological control involves either the propagation and release of new natural enemies—predators, pathogens, and parasites—against target pests or the encouragement of practices that preserve and increase the effectiveness of existing natural enemies. It is a process of reinforcing nature's own system of checks and balances that can be used by the individual farmer. Traditional agricultural practices, especially intercropping, encourage natural biological control of pests, and unless disrupted by pesticides or other means, natural predators and parasites keep many potential native insect and mite pests in check. No one must purchase this form of crop protection and it continues to benefit farmers as it has for as long as traditional agriculture has existed.

Classical biological control, which involves propagation and release of new natural enemies, has been applied in Africa to a relatively small number of foreign insect, mite, and weed species. Whereas naturally occurring biological control involves no cost and requires no institutional support to maintain, classical biological control involves costs to find, import, rear, and distribute the new natural enemies and requires institutional support to maintain the program.

The Africa-wide Biological Control Project of Cassava Pests, set up by the International Institute of Tropical Agriculture (IITA) in 1980, is the largest organized effort in biological control in the region. This project is responsible for successfully introducing a parasite for control of cassava mealybug *(Phenacoccus manihoti).* Since 1982, a parasitic wasp *Epidinocarsis lopezi,* imported from South America, has been released at 54 different sites. The parasite has successfully established itself at most of the release sites, covering roughly 9 percent of the total land planted with cassava in Africa, and is spreading to other areas. In Nigeria, where it has been studied most intensively, mealybug populations have been reduced to non-injurious levels wherever the parasite has become established. The parasite will now be released in other mealybug areas as part of a $20 million biological control program (9,15, 26,33). Worldwide, economic returns from classical biological control programs are estimated at $30 for every $1 invested (49).

Pesticides

Pesticides include a variety of chemical substances that can be divided into biological (plant, bacterial and viral, and fungal-derived) and chemical (synthetic)[3] pesticides. Pyrethrin, derived from chrysanthemum plants, is a biological pesticide that was used in traditional agricultural systems in Africa, and is now produced commercially in Kenya (74). In general, biological pesticides are a fairly recent area of research, and although they are currently a minor component of pesticide use, their importance is expected to increase. Some new pesticides will blur the area further between biological and chemical forms. Future pesticides are likely to be based on insect pheromones, microbial products, naturally occurring insect growth regulators, etc. (74).

The primary benefit of pesticides is they can be marshaled quickly to give rapid control of a threatening pest. For example, minimal applications of the insecticide permethrin to cowpea in Nigeria reduced the major insect pest populations 50 to 85 percent and increased yield sevenfold (42). The dramatic impact that pesticides can have was also illustrated by their role in controlling the 1986 locust and grasshopper outbreaks. As late as August, these insects were expected to destroy the crops of tens of millions of Africans. Reuter News Agency warned of an invasion of "biblical proportions." However, by the end of October, 1986, cooperation and technology had been generally suc-

[3]Biological pesticides can be modified and, thin, also considered "synthetics" but the term refers more often to pesticides without biological bases.

cessful in protecting crops in the affected region (3). In Senegal, for example, crop losses were kept to about 5 percent (7’3). Pesticides provide short-term control, however, and grasshoppers and locusts are recurrent African pests. For instance, desert locust outbreaks are occurring in 1988 and control is likely to be more difficult than in 1986.

Chemical pesticide use in Africa varies considerably among crops, pests to be controlled, and geographical region. Large areas of cash crops (cotton, coffee, banana, cocoa, etc.), usually planted as monoculture, generally receive the greatest quantities of pesticides, but the chemicals are also used on some food crops, especially the high-yielding varieties of cereal grains and vegetables.

Concerns exist that use of chemical pesticides has been promoted more quickly in Africa than has the capability to ensure their effective and safe use (3). In particular, critics point to the export by industrialized countries of pesticides that are restricted or banned for sale in their domestic markets. For example, about 25 percent of U.S. pesticide exports were chemicals that have been heavily restricted, suspended, or prohibited in domestic markets (6,67). Many Sub-Saharan countries lack the infrastructure to govern the importation, domestic use, and disposal of pesticides. Of 15 West and Central African countries included in a 1985 survey, 5 had no laws to govern the importation or use of the materials. Even with pesticide laws, most governments lack the infrastructure required to enforce them. Farmers are seldom prepared to handle pesticides. Often they cannot read or understand pesticide labels, or they use pesticides from unlabeled containers. They rarely possess (or wear) protective clothing or safety devices, and may carelessly dispose of the leftover materials. African countries seldom have medical personnel and facilities trained to diagnose and treat cases of pesticide poisoning, and extension efforts to train farmers on correct use of pesticides are often minimal (6,44). Consequently, developing countries account for up to 50 percent of pesticide applicators’ acute poisoning and 73 to 90 percent of fatalities, even though they use only 10 to 25 percent of the world’s pesticides (2,6,12,19,37).

Apart from the concern over health and environmental impacts in Africa, increased pesticide use is being challenged by growing genetic resistance in pest organisms. In 1984, 638 pest species worldwide (428 arthropods, 50 weeds, 150 plant pathogens, and 10 small mammal pests and plant-attacking nematodes) were known to possess strains resistant to one or more previously effective pesticides (54). Resistance has appeared in many serious pests affecting agriculture, livestock, and public health in Africa (3).

Potential

1PM is a strategy designed to provide the best mix of available pest control methods and thus it is a responsible approach to pest management. In a sense, virtually all resource-poor farmers and herders in Africa practice a form of “integrated pest management. ” They depend on a combination of traditional practices such as intercropping, using pest-resistant local varieties when possible, and enhancing naturally occurring biological controls over certain pests, However, 1PM programs are just beginning to benefit from scientific advances in understanding of the ecology of pests and are beginning to be implemented in a way consistent with local agricultural and socioeconomic conditions, Management information is the primary input required for 1PM. The potential of the technology will depend, in large part, on how successfully traditional and modern knowledge on pest control can be merged. Farmers are an important source of information on local pest resistant varieties, many of which can be further improved by scientific research.

Implementing effective 1PM programs throughout Africa will take many years, but because 1PM represents an effective approach to pest management, benefits will accrue as countries move in the direction of using this method. Some countries (e.g., Central African Republic, Somalia, or Guinea) have little government infrastructure and few pesticide laws, delivery systems, personnel, facilities, or cooperative links with neighboring countries and international centers (table 11-1). In these countries, a minimum of 10 years would probably be required just to create an organizational structure necessary to develop and sustain an effective long-term effort in pest and pesticide management (3).

Quicker results could be expected in countries (e.g., Nigeria, Kenya, Cameroon, Ivory Coast) with more developed pest management infrastructure, assuming pest management is given a higher priority and increased attention is given to an integrated approach rather than simply relying on pesticides alone. Greater attention should also be directed to assessing what influence pesticide subsidies may have on adopting the best mix of pest management technologies. Nigeria, for example, has substantial government and scientific resources. Pesticide enforcement procedures and improved quarantine programs could be in place in a few years. Work toward developing 1PM programs for selected crops could begin immediately, drawing from existing scientific knowledge and farmers' experience and practices. Within 5 years, 10 to 20 percent of farmers of specific crops such *as* rice (where a rich knowledge base already exists) could be using partial 1PM packages. Within 10 years, an estimated 50 percent of the farmers could be using 1PM technology (3).

As biological pesticides become better researched, they are likely to become a more important tool in the 1PM arsenal. For example, Neem trees *(Azadirachta indica)* produce repellents and feeding deterrents for a broad spectrum of economic agricultural and household pests. Neem is being grown commercially in several African countries (69). Ended *(Phytolacca dodecandra)* is a plant that has proven effective as a molluscicide. This plant, which can be grown in much of Africa, holds promise as a control agent for schistosomiasis, a snail-transmitted disease (69). Several viral-based pesticides are important in 1PM systems, for example, in soybean production in Brazil

Table 11-1.—Effectiveness of Plant Protection in 15 West and Central African Countries[1]

	Percent of countries in category			
Area of plant protection	Good	Moderate	Poor	No information
Plant protection personnel	7	40	46	7
Pest control equipment	0	47	47	6
Support facilities	0	13	80	7
Plant protection laboratories	0	47	47	6
Pest diagnostic laboratories	0	47	47	6
Plant quarantine buildings, equipment	7	40	40	13
Pesticides available locally	0	43	20	27
Plant protection service	7	20	40	33
Agricultural schools, training facility	7	66	**20**	**7**
Specialized plant protection curriculum	7	33	53	
Institutionalized research	7	53	20	20
On-farm, applied research,	0	13	74	13
Pest lists	13	47	33	7
Pest distribution knowledge	0	47	40	13
Pest biology knowledge	7	7	13	73
Economic loss knowledge	0	27	40	33
Pest control knowledge	0	20	80	0
Overall strength				
Extension	7	40	40	13
Research	20	54	13	13
Training	7	46	40	7

[1] Countries in survey were Benin, Cameroon, Central African Republic, Congo, Gabon, The Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Nigeria Sierra Leone, Togo, and Zaire.

SOURCE: P.S. Teng, "Plant Protection Systems in West and Central Africa: A Situation Analysis," unpublished report to the U.N. Food and Agriculture Organization Plant Protection Service, August 1985.

and ‘coconut production in the South Pacific (23),

Problems and Approaches

Interdisciplinary Approach to Filling Information Gaps

The development and implementation of technically effective and socioeconomically and environmentally sound pest control policies and programs is a major challenge facing Africa. Meeting this challenge will require a new approach, where experts accustomed to working in isolation in their own disciplines learn to work with others in an interdisciplinary team. Teams composed of traditional pest management disciplines (e. g, entomologists, plant pathologists, weed scientists); basic biologists (e.g., ecologists, taxonomists, geneticists); economists; and other social scientists are required.

1PM requires much greater understanding of the ecology of the pest/natural enemies/host complex than does the use of chemical pesticides. Gathering this information can be a slow process, but it can be facilitated by taking advantage of farmer and herder knowledge. Studying local pest control practices and how these fit into other agricultural activities can allow research and extension personnel to improve their effectiveness. Tapping the knowledge base of African pastoralists, such as how the Fulanis keep trypanosomiasis, ticks, and tick-borne diseases to low levels, may also provide researchers with methods to reduce livestock losses (16). 1PM research personnel could use farmers’ fields for much of their experimentation; extension personnel could organize demonstrations of new practices in these same fields and extend the demonstrations to other areas where conditions are similar.

The International Agricultural Research Centers and a few national institutions possess the interdisciplinary expertise required to foster this approach. Their efforts in breeding crops with pest resistance and developing cultural controls have already had a favorable impact, Universities in the United States have experience in the development of 1PM systems and could serve as an important technical resource,

Improved Infrastructure and Management

A number of countries are hindered in their attempts to control pests by their lack of basic infrastructure, resources, and personnel (44, 60). In spite of the obvious economic impact of crop losses due to pests, governments generally have not emphasized improving plant protection as a means of increasing and ensuring adequate food security. A general trend exists of under-investment in plant protection extension, research, and training relative to other disciplines of agriculture (3).

To date, the largest efforts to develop 1PM systems for crop pests have been through the CILSS (The Permanent Interstate Committee for Drought Control in nine West African Countries of the Sahel) Integrated Pest Management Project and U.S. Agency for International Development’s (AID) Regional Food Crop Protection Project (RFCP). Both focused on pest problems of basic crops in the Sahel (the RFCP Project also included Cameroon and Guinea Bissau). Also, both projects served to increase attention to crop protection issues and improved Sahelian institutional capabilities in 1PM (70). However, the CILSS 1PM Project was unsuccessful in developing 1PM packages for the RFCP Project to extend because the projects suffered management problems that reduced their effectiveness (70).

Improving the Use of Chemical Pesticides

Development assistance often has relied on chemical pesticides for quick “solutions” to pest problems but often has ignored long-term impacts (3). In some respects, pesticide problems in Africa and in other developing areas have come about because of an error in the transfer of technology. Modern pesticide technology developed by and for use in the developed world has been exported to developing countries without adequate attention to whether the institutional capacity existed to handle it

(2). These problems are exacerbated by industrialized nations' policies allowing export of unregistered and highly hazardous pesticides. Although some people have advocated banning export of such pesticides, this does not have the support of many exporting countries nor importing countries who desire to retain sovereignty over their choice of imports.

pesticide use is encouraged also by subsidies that serve as incentives for farmers to use more than may actually be needed, discourage farmers from using alternative methods, and impede institutional efforts in 1PM (58). In Senegal, 90 percent of all agricultural pesticides are distributed to growers free of charge by crop marketing boards and other agricultural agencies. The rate of pesticide subsidy in Ghana is nearly 70 percent (3).

Development assistance could take a longer term view that encourages sustainable, safer solutions to predictable problems. For instance, the Food and Agriculture Organization of the United Nations (FAO) and various locust control agencies could contribute by placing increased emphasis on early-warning systems for locusts and other migrant pests, thereby encouraging a preventative—rather than crisis-reaction—approach to controlling major pest outbreaks.

Recently developed guidelines within FAO, the World Bank, and AID hold promise for improving the safety of pesticide use in developing countries. The FAO Code provides voluntary guidelines for governments of exporting and importing nations on distribution and use of pesticides. The World Bank Guidelines prohibit use of highly toxic pesticides and unsafe pesticide practices in Bank-financed projects. AID's policy on pesticide assistance requires a risk-benefit evacuation of agricultural pesticides proposed for use in AID's development assistance projects. However, AID could strengthen its policy of encouraging the use of non-chemical methods and 1PM systems. AID's present funding of pesticides in development projects could be reduced or eliminated in countries that lack proper infrastructure for handling the materials. It is too early to determine the impact of the FAO, World Bank, and AID guidelines, but they represent a step toward preventing pesticide abuse and should serve as an important reference for other donors and pesticide enforcement agencies in Africa.

IMPROVING ANIMAL HEALTH

Summary

Poor animal health is the most serious obstacle to improving livestock production in Sub-Saharan Afric. ThRee principal mechanisms are available to overcome constraints to animal health (75):

1. **improve control of** endemic **diseases and parasites,**
2. **enhance nutritiim to reduce susceptibility to disease and parasitism, and**
3. **use disease-resistant breeds and study the mechanisms and inheritance of disease resistance.** .

Progress in improving animal health necessarily involves all three approaches since nutritional status, exposure to disease, and genetic make-up all interact to determine how well an animal is able to function in a given environment. This section examines the role of veterinary support and improving animal nutrition in grazing and mixed crop/livestock systems. Disease resistance is covered in chapter 9.

Improved understanding and appreciation of traditional livestock systems have provided important insights for livestock development in Africa. Increasingly, research illustrates the value of indigenous livestock breeds and local practices. Development agencies are more cognizant of the multiple values African agriculturalists derive from livestock, and are more aware of the need to consider these various uses when promoting livestock development. Western livestock specialists are facing the fact that livestock development in Africa needs to be viewed from a perspective quite different from that to which they are accustomed:

> Because of the major focus (in industrialized countries) on meat or milk production, we look upon the thin, boney looking cattle arriving at slaughter markets in (developing countries) as having undergone gross mismanagement. However, when we recognize that the major strategy is to utilize animals for human subsistence, the emaciated animals entering the market can be viewed as having rendered valuable services rather well. The challenge for the developing countries is not one of shifting livestock to a meat/milk economy but rather working within traditional systems to increase overall efficiency of the total services rendered by the animals through such programs as health services (46, p. 13).

Veterinary Support

Veterinary medicine has made great advances over the last several decades. Mass drug production techniques have greatly reduced drug costs and many side effects have been reduced or eliminated (14), As the value of livestock relative to the cost of veterinary care continues to increase, the economic viability of investing in animal care has become increasingly attractive, even to low-resource farmers and herders. For the most part, however, veterinary services are highly subsidized by African governments in order to capitalize on economies of scale in mass immunization programs (14). Subsidies also help to increase national meat and milk production and therefore to lower consumer prices.

Veterinary support services were among the first livestock projects promoted in Sub-Saharan Africa some 60 years ago, and these types of projects still predominate. One problem caused by this heavy emphasis on veterinary work is that while most epidemic diseases are now largely controllable and livestock populations have increased as a result, other needed areas of technology (e.g., range management and animal husbandry) and institutional backup have lagged behind (14). Lack of effective disease surveillance and disease reporting systems, as well as a lack of adequate diagnostic laboratories also hamper progress in disease control (16).

Development assistance agencies to date have focused their animal disease control efforts on trypanosomiasis (48). Trypanosomiasis, transmitted by the tsetse fly, afflicts humans (sleeping sickness) and animals (Nagana). The tsetse fly is present in 37 African countries, infesting some 9 million hectares or 42 percent of the total land area. Thirteen countries[4] are almost completely infested (62). Altogether, some 45 million people are estimated to inhabit infested land. The U.N. Food and Agriculture Organization (FAO) estimates that presently infected areas might eventually support up to 120 million head of cattle (or the equivalent of other stock) if the disease were controlled (48).

Controlling trypanosomiasis by animal immunization is at present impossible and treatments have in many cases produced drug-resistant trypanosomes. Thus, for now the control of tsetse and trypanosomiasis will rely on a combination of other methods including ground and aerial spraying of insecticides, changing the tsetse's habitat through bush-clearing, disrupting the tsetse's reproductive

[4] Benin, Central African Republic, Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Sierra Leone, Togo, and Zaire.

cycles through the release of sterilized flies, and the use of baited traps to reduce populations (48,76). Increased attention is also being directed toward improved husbandry and management of animals that display some tolerance to typanosomiasis such as the N'Dama, Maturu, and Keteku breeds of cattle (16) (see ch. 10). This extremely dynamic and constantly changing livestock disease creates unique difficulties in efforts to implement and monitor elaborate control and eradication programs.

Some people are concerned, however, that an inordinate proportion of resources and funding have been focused on trypanosomiasis (16). while researchers generally agree that controlling trypanosomiasis would have major impacts on the potential for livestock development, many argue that development of a general vaccine to deal with this variation seems unlikely for some time because of the large number of strains present among the three African trypanosome species and their characteristic of changing forms in the bloodstream (16,59).

In the meantime, a number of other diseases that may be more easily controlled have received considerably less attention. Two such diseases are rinderpest and contagious bovine pleuro-pneumonia (CBPP). Vaccines for both exist, the former with a once-in-a-lifetime inoculation, the later providing one year immunity (so research on longer term protection is desirable). Other relatively neglected livestock diseases in Africa include East Coast Fever and other tick-borne diseases, foot-and-mouth disease, streptothricosis, African swine fever, and various diseases caused by internal parasites. Box 11-1 identifies major livestock diseases in Africa and the availability of control methods.

Breakthroughs in preventing and treating animal health problems have outpaced the ability to distribute the veterinary technology in Africa. African extension systems face numerous problems including a lack of adequate funds to get trained staff into the field to address clients' needs and a general lack of proven technologies that do not disrupt the delicate equilibrium of interacting environmental, economic, and social factors in African livestock systems (14). A further problem is how the lack of interaction between veterinarians and other livestock scientists has created a narrow focus for extension agents. Most agents are trained in veterinary sciences and are seldom able to provide support on improved range management or animal husbandry. The benefits of veterinary support could be enhanced if promoted in conjunction with improved nutrition and management (14,16).

Access to vaccine is fundamental to disease campaigns. A recent review of vaccine-producing facilities in Africa found that relatively minor investment in these facilities and rehabilitating their equipment could result in adequate production levels of rinderpest and CBPP vaccine for the region (30). Problems of inefficiency and improved quality control need to be addressed, however. Vaccine for poultry (e.g., Newcastle vaccination), can be more efficiently and cheaply obtained in international markets (14).

Animal Nutrition

Livestock malnutrition is considered by many to be the single most serious limitation to improved livestock production in Africa. Nutritional stress, compounded by intestinal parasites, is largely responsible for the high mortality (17 to 45 percent) recorded for calves, kids, and lambs in their first 3 months (14,45). Improving animal feed has thus become a major focus for African livestock development. This emphasis is reflected in staffing at the International Livestock Center for Africa (ILCA), where plant agronomists significantly outnumber animal scientists and veterinarians combined (46). Investigation of forage species, treatment of crop residues to increase digestibility, and improved storage qualities in forage are important areas being studied. Another promising avenue of investigation is providing supplemental fodder for small ruminants in mixed production systems (see ch. 10).

Improving animal nutrition in Africa confronts the same serious problems as in cropping systems—resource-poor farmers and herders' severe constraints on access to exter-

Box 11-1.—State of the Art: Control of Major Livestock Diseases in Sub-Saharan Africa

Rinderpest: A virus affecting ruminants and occasionally swine. It has a high mortality and spreads rapidly. A reliable, once-in-a-lifetime, vaccine is available but could be improved by making it thermostable, thereby reducing cost and reliability problems associated with current cold storage requirements.

CBPP (Contagious bovine pleuro-pneumonia): A cattle disease caused by parasitic micro-organisms called mycoplasma. Immunity can be maintained for one year with vaccination but longer term protection is desirable. Treatment is also possible but generally not practical,

PPR (Peste des petits *ruminants):* A viral disease affecting small ruminants that can result in high mortality and is increasing in prevalence, A once-a-year inoculation with rinderpest vaccine has good results.

Anthrax, Blackleg, Pateurellosis: Available vaccines are adequate.

African swine fever: A complex disease precluding intensive swine production in many areas. No effective control exists except slaughter, Research on control methods is needed urgently,

Trypanosomiasis: No complete control exists. Because of the complexity of the pathogen, development of a vaccine has low probability in the next 10 to 20 years. Control of the vector (tsetse fly) through use of traps or vaccine-impregnated screens is most promising. Aerial spraying is expensive, clearance is seldom permanent, and may be environmentally harmful. Research on fly attractants, use of sterile male flies, and the search for tolerant cattle breeds deserves high priority.

Dermatophilosis (Cutaneous streptotrichosis): As yet this is an under-researched constraint to cattle production in the West African humid to sub-humid zone, and a major impediment to use of Zebu type cattle in infected areas. More investigation on control is needed.

Gastro-Intestinal Parasites: They probably cause the greatest losses among livestock in the region, especially in morbidity. Drugs for control are available but additional research is needed on integration into existing management systems.

Tick-borne Diseases: The International Laboratory for Research on Animal Diseases and the International Center for Insect physiology and Ecology (both located in Kenya) have had promising results in vector control for East Coast Fever. Research is needed to see if this initial success can be extended to control vectors of piroplasmosis and heartwater in West Africa.

SOURCES: World Bank, Western African Projects Department, West ***Africa Agricultural Research Review*** (Washington, DC: The World Bank, February 1987); William M. Moulton, “Major Disease Deterrents to Improving the Sub-Saharan African Livestock Industry, ” J.R. Simpson and P. Evangelou (eds.), ***Livestock Development in Sub-Saharan Africa: Constraints, Prospects, and Policy*** (Boulder, CO: Westview Press, 1984), pp. 79-90.

nal inputs. The need to depend on resources internal to the system may be even more pronounced in animal agriculture, however. The greater isolation of grazing systems, particularly among pastoralists, necessitates a higher level of self-sufficiency. In mixed crop/livestock systems, animal rearing is undertaken as a secondary activity to crop farming, so resource-poor farmers are generally less willing to divert meager resources to animal improvements. Understanding these constraints has important lessons for research and development assistance.

> The principles underlying (the efficient use of crop residues and pastures in Africa) center on maximizing their utilization rather than on achieving an optimal nutritional status for each animal. The difference between these two contrasting concepts is important. The . . . key task is to use what is available in African smallholdings, rather than to seek the ideal feeds for African animals (4).

Problems of animal nutrition are quantitative and qualitative. Quantitative improvements can be achieved through proper stocking of rangelands, establishing improved pastures as complementary forage to native pastures, planting forage crops, promoting soil and water conservation practices, and through timely harvest and storage of crop residues (75). Improvements in quality involves ensuring nutritional adequacy of pastures, forages, and feed supplements and correcting deficiencies through pasture management, germplasm selection, and residue enhancement (75).

Seasonal fluctuations in the availability and nutritional adequacy of feed supplies are among the most serious nutritional problems for African livestock in pastoral and mixed crop/livestock systems. Shortfalls are most pronounced in the dry seasons in arid and semi-arid zones. It is during this period when competition for animal milk between calves and people becomes most pronounced. The consequence of this is low weaning weights and high morbidity for calves. Improving feed resources for calves and calving mothers can bring major improvements in calf survival rates. Finding ways to supplement feed during this period is critical to improving productivity and thus deserves high research priority.

Domestic ruminants such as cattle, camels, goats, and sheep must be able to obtain some minimum level of energy from the plant material they eat. These animals are not able to compensate for nutritionally poor forage by eating more, so access to quality forage is essential. The level of plant material or dry matter that an animal is able to mobilize for energy is called its digestibility or DIG—a function of the total digestible nutrients of the plant (46). For domestic ruminants, the required DIG value is approximately 45 percent. Only about 5 percent of the feed available on low-resource farms is typically of high nutritional content, i.e, with a DIG value of 55 percent or greater (46). Of the remainder about half has adequate nutritional range (DIG 40 to 45 percent) and half is less than adequate. Research to increase the feeding value of plants and byproducts by 5 to 10 percent thus could prove significant (46).

The principal mechanism for increasing digestibility is to provide the microbial organisms in the animal's digestive rumen track with an improved supply of nitrogen and other critical growth factors. This can be achieved by chemically treating crop residues (e.g., with anhydrous ammonia or urea), supplementing crop residues with more nitrogen-rich forage (e. g., *Trifolium)* or both (4,46). Although these approaches appear promising, more on-farm testing is needed to better assess socioeconomic feasibility under resource-poor conditions (76).

Low nitrogen levels in many African soils hinder both plant and animal productivity, so researchers have begun to focus attention on using forage legumes to enhance soil fertility and provide a protein supplement for livestock simultaneously. Some efforts are being directed to improving protein sources within grazing regions such as by planting nitrogen-fixing trees in conduction with reforestation campaigns. Others are aimed at better extracting leaf protein from legumes (69]. The major focus, however, is on more intensive agroforestry systems, such as using leguminous forage species as links between crop and livestock production (see ch. 10).

Various forms of animal confinement, such as maintaining animals in stalls or tethering them, are becoming increasingly prevalent in more populated, land-scarce regions of Africa. Stall feeding historically has not been a part of African agricultural systems, except in small enclaves such as the Mandara Mountain region of Northern Cameroon, on the slopes of Kilimanjaro in Tanzania, on the island of Ukaru in Lake Victoria, and on mixed-cropping dairy farms in Kenya and Rwanda. Another exception is the common rearing of small livestock in and around many urban areas throughout Africa (29). The primary constraint to animal confinement is that it is labor-intensive and thus it competes for labor also needed for growing crops. Confinement also tends to increase the incidence of animal health problems and mortality in the absence of adequate veterinary care.

Confinement offers some significant advantages, however. First, it is possible to regulate nutritional needs more carefully, assuming that sufficient fodder and feed-supplements are available. Second, manure can be collected, allowing it to be used more efficiently for fertilizer. Third, veterinary care is easier because the animals are contained (vaccinations and

Photo credit: Kay Muldoon/The World Bank

Inadequate animal nutrition is the most serious limitation to improved livestock production in Africa. Livestock's fitness for animal traction is most important during the dry season when high quality food is in short supply.

many other veterinary services are made easier, but containment actually aggravates other problems, such as ticks). Fourth, animal feeding efficiency is increased due to reduction of energy expended for grazing. And last, confinement generally produces higher quality meat.

Potential Gains From Improved Animal Health

Improvements in animal health offer direct and indirect benefits for agricultural productivity (14). One direct benefit is reduced mortality. Given the high mortality rates common for African livestock (25 to 40 percent for young stock and 3 to 15 percent for older stock), the potential for significant improvement seems great. To illustrate, vaccination and dipping campaigns in two Nigerian villages recorded a 75-percent reduction in death rates of sheep and goats (35). In another case, veterinary packages for goat care brought economic returns of at least 20 percent (76). High returns are also reported for the rinderpest campaigns and efforts to combat foot-and-mouth disease (14). Although these returns on investment appear attractive, research is still needed on the ability and willingness of resource-poor agriculturalists to take advantage of these services.

Improved animal health care also brings indirect benefits. As noted above, shortfalls in feed during parts of the year and competition between humans and calves for milk supplies causes high levels of pre-weaning mortality in African livestock. By improving calf nutrition during this period, not only is mortality reduced, but indirect benefits are achieved such as earlier sexual maturity of livestock, increased mature body weight, and increased efficiency in overall feed use (5,14).

The prospect of controlling tsetse fly or at least expanding stock of trypano-tolerant livestock could have major impact on crop and livestock production in Africa. Many currently infested areas are among the most arable and they potentially could support sizable human populations. Increasing population densities in these regions can, in turn, help control reinfestation. Some researchers note, for example, that as land is converted to cultivation, shade cover is decreased and the habitat becomes less suitable for tsetse flies, which require shade (57).

Problems and Approaches

Much of Africa maybe witnessing a deterioration in animal health services at a time when greater—not less—support is needed. It is unlikely that governments will be able to provide significant increase in funding for livestock development. The challenge for development efforts, therefore, must focus on making more effective use of existing resources.

Incorporating Sustainability in Eradication Program Planning

Considerable resources and energy have been directed to livestock disease eradication programs in Africa, particularly rinderpest and trypanosomiasis. In both cases, however, the area of infestation has actually increased in recent years. Headway has been made in particular regions, only to be lost because necessary provisions to contain the disease could not be sustained.

Serious concerns exist over the ability of African governments to sustain disease eradication programs after donor-supported mass inoculation campaigns are completed and the responsibilities, including costs, are transfered to national governments. The recent resurgence of rinderpest in Africa illustrates the problem: after a successful disease control campaign in the 1960s and 1970s, a serious resurgence has occurred because poorer African countries were unable to continue to vaccinate young stock once donor funding was discontinued (figure 11-1) (48). This suggests that criteria regarding sustainability must be incorporated in program planning, especially in light of mounting interest in another major rinderpest eradication program.

It is also evident that efforts to clear areas of tsetse fly infestation will continue as a major focus of livestock development work (66). Here too, provisions should be made to ensure greater sustainability. Attention to long-term land-use planning is essential if success is to be achieved and funds not wasted (57). Land should be capable of supporting intensive land use, since establishing permanent agriculture in an area is a first line of defense against reinfestation. This may require establishing adequate support services and infrastructure, as well as policy interventions. Further, the ability of farmers to invest in animal husbandry and management—particularly in animals that display some trypano-tolerance—may be as important as those technologies for directly controlling tsetse flies (e.g., traps and spraying) or trypanosomes (e.g., trypanocidal drugs) (16).

Large-scale efforts to control trypanosomiasis in a region must also address their sustainability, for example, by making an assessment of potential adverse impacts. The FAO commission on African Animal Trypanosomiasis recommends, for example, that tsetse fly control or eradication be supported only in conduction with land-use planning that accounts for increases in the spontaneous settlement that would undoubtedly follow a successful campaign (48).

Promoting a More integrated Approach to Livestock Development

Livestock development work has been approached, for the most part, as single sector/single technology interventions. Interventions have generally failed to be examined for their impacts on the broader production system, potential adverse effects have been discounted and possible complementarily of coordinating activities among sectors has not been investigated. In looking at the various obstacles to

Figure 11-1.—The Resurgence of Rindepest in Africa and the Near East

The situation between 1976-79
(after termination of the JP 15 Campaign)

The situation after 1979 to date

Countries reporting rinderpest

SOURCE: Della McMillan, "Government Assisted Land Settlement: Status and Potential in African Low-Resource Agriculture," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

livestock development, what at first may seem an obvious solution, may in fact exacerbate problems (18). For example, solving livestock watering problems in arid and semi-arid regions by drilling boreholes seemed an obvious solution, but experience has shown otherwise because severe overgrazing occurred near wells. Similarly, veterinary interventions to address problems of high mortality in pastoralist herds have also tended to lead to serious overgrazing and, in many cases, have worsened existing problems.

> Programs are initiated without coordination. They are in the hands of technical experts, each of whom is concerned only with his or her own area of expertise. There is no effort to relate the actions taken to the full cycle of activities necessarily involved ., . What is needed is a coordinated approach. This means that such technical matters as disease control, land improvement, and marketing operations are to be developed in a concerted, integrated fashion. It also means that the legitimate interests and aims of the pastoralists, including their use of livestock as factors in their social relations, are taken into account (18).

A number of technologies able to enhance animal health under low-resource conditions have been identified. In humid and subhumid regions, cut-and-carry fodder operations seems particularly promising for more intensive systems, such as livestock/agroforestry systems and intensive forage gardens. In more arid regions, access to dry-season fodder supplements could significantly improve calf survival rates. Various forms of pasture and fodder improvements or improved conservation of crop residues could meet these needs (31, 38). Cultivating the potential of these various technologies, however, will require greater collaborative work than currently exists among plant and animal scientists, as well as other social scientists,

The importance of crop residues as supplemental feed has particular implications for crop breeders who, often divorced from the needs of the livestock subsector, tend to ignore the importance of crop residues to resource-poor farmers. Considerable variation exists in the digestibility of crop residues. Technology to supplement or treat crop residues for increased digestibility is an important area for collaborative research. Increased attention should now be directed to on-farm research and testing; this will also require supportive socioeconomic analysis to evaluate technologies' impacts and adoption under farmers and herders' conditions.

Adjusting Imbalances in Technical Support Services

A number of imbalances in African technical support services have been identified that, if corrected, could provide more effective use of scarce resources devoted to improving animal health—especially among resource-poor farmers and herders. These include excesses in funds devoted to veterinary support v. other areas of animal health; in research and extension budgets devoted to salaries v. operations; and in soliciting students for livestock extension services from farming and urban backgrounds v. from pastoralist communities.

Veterinarians comprise an estimated 70 percent of all African professional livestock workers and have been successful in setting research priorities for African livestock development. Major advances have been made in controlling most epidemic livestock diseases as a result. Research for other animal health areas, such as animal nutrition, as well as related disciplines of range management and animal husbandry have suffered relative neglect. Advances in these neglected areas are essential for resolving the most important constraints now confronting sustainable livestock development in Africa. This suggests that a more balanced allocation of research activities could be promoted.

Concerns also exist over the increasing proportion of livestock services budgets being directed toward staff salaries. Although a general underinvestment in scientific staff is widely recognized, more specific concerns are expressed due to the relative emphasis on staff v. operating funds, and the ineffectual services that can result. One reason for this is that in many African countries vocational school graduates are basically guaranteed a civil service position. Because operating budgets are stagnant or declining, the increasing number of personnel have little money to support research or buy equipment (14). For the most part, staff are underemployed except for the few months during vaccination campaigns. Also, staff are heavily restricted in their ability to engage in field work and research, perhaps reflecting a more serious problem.

Another imbalance in livestock support services stems from the relatively few pastoralists in such technical support positions. Students from pastoral communities are less likely to be solicited to become veterinary agents than students from farm or urban backgrounds (14). Important benefits may be derived from increasing training among members of pastoral communities because of their greater familiarity with livestock problems and management practices. Also, greater confidence may emerge between veterinary agents and the people they serve when veterinarians' backgrounds reflect their clients'.

Providing pastoralists with veterinary support still presents unique challenges. These include accommodating the needs of a transient people and finding trained veterinarians willing to live and practice in those conditions. One solution currently being investigated is providing veterinary support via a pastoralist with some basic training and access to supplies, but who will live and operate within the pastoral community. Experience with grassroots veterinarians—or paravets, as they are sometimes called—is still too new to judge their effectiveness, but initial results are promising. Experience in Niger and the Central African Republic suggests that frequent contact with government services and the existence of supportive institutional structures (e.g., pastoralist associations) tend to increase their effectiveness (14).

Supporting Regional Cooperation

Increased cooperation in research seems essential in a region where a critical mass of qualified researchers per country is often lacking. Establishing research networks thus becomes very important. In addition to being able to link individual scientists, networks represent a resource for national program development through coordination, technical backstopping, training and printing facilities, and information dissemination (4). The proliferation of research networks dealing with livestock and crop/livestock issues and the increased funding being devoted to these groups is a promising development.

Production of animal vaccine is another area where significant benefits may be derived from regional cooperation. For example, benefits may be derived from designating particular facilities for primary responsibility for particular vaccines. This would reduce the need for individual facilities to produce smaller amounts of many different products.

POST-HARVEST TECHNOLOGIES[5]

Summary

Post-harvest crop losses significantly reduce the food and income available to resource-poor agriculturalists in Africa. It is difficult to estimate food losses with precision; they are location- and season-specific to a degree that makes the concept of "average levels of loss" almost meaningless (53). Previous high estimates for overall food losses (e.g., at least 20 percent) are no longer accepted by most scientists, although losses can exceed this level in specific cases (20).

Post-harvest processing typically demands long, tedious hours of labor. While African women are active in field production of crops and livestock—responsible for 50 to 70 percent of planting, weeding, hoeing, and harvesting of crops, as well as domestic animal care–post-harvest activities are almost entirely their domain. African women are typically responsible for 80 to 90 percent of the transport of crop from the fields and their subsequent storage and processing, as well 60 percent of the marketing. These activities are balanced around other responsibilities for collecting water and fuel, cooking, and family care for which they are almost entirely responsible. Efforts to enhance post-harvest technology thus should primarily benefit, and specifically evaluate impacts on, African women. More efficient technologies can contribute to free time that can be spent on farming or family activities, or other enterprises (61).

Numerous post-harvest technologies exist for each of the dozen or so major African crops, livestock, and fish. Socioeconomic and technical factors influence the selection of a particular technology, including the size of the farming enterprise, the reliability of the harvest, labor availability, food needs, and income-generation potential (61). OTA has only dealt with a small illustrative subset of promising post-harvest technologies for drying, storing, and processing foods, and in the cases of rice and maize, threshing or shelling for separating the grain from the rest of the plant.

No single machine or new practice will drastically improve the post-harvest operations of African farmers, but a large number of relatively simple technologies do exist that have the potential to improve the various post-harvest processes. Several of these improved technologies have been successful in reducing labor demands and in making operations more efficient. These improvements face the best likelihood of success if they are adapted from

[5]This material is based primarily on the OTA contractor report prepared by the Tropical Development and Research Institute, London, U. K., (app. A).

proven, traditional techniques and if they take into consideration the primary role women play in African agriculture.

Development assistance to improve post-harvest technologies can be most effective by using an integrated approach that considers the entire production system and the interactions of various farming activities. Assistance can then be directed to the greatest problems, which will differ among farming systems. Such a location-specific approach also will enable assistance to change, as necessary, to match the changes that accompany development.

Opportunities for Improvement

Threshing and Shelling

Rice, an important crop in humid regions, is still harvested by hand on most low-resource farms and threshing is done by trampling or hitting the rice-bearing straw against a hard surface—both inexpensive techniques, but labor-intensive and wasteful. Small, pedal-operated rotary threshers are in use in West Africa. This technique is faster, reduces waste because stalks can be refed to separate more grain, and allows the hands to remain free to feed the thresher. But to illustrate the importance of considering local conditions, these threshers may prove unsuitable in certain areas of West Africa where custom forbids women to sit astride. Where draft animals are available they can be used to power a simple thresher that increases output considerably compared with traditional methods and has the advantage of not requiring the rice stalks to be collected into bundles (61).

Small quantities of maize, another African staple, are traditionally shelled by hand—a process that is laborious, tedious, but efficient because little grain is damaged. Larger quantities are shelled by placing the cobs in a sack and beating this with a stick. However, some hand-held shellers are now available such as a wooden one developed by the Tropical Development and Research Institute (TDRI) (61). This tool is simple, inexpensive, and made from local materials, but it is tiring to use extensively and only shells cobs of a standard size. Small rotary shellers seem suitable for resource-poor farmers and are being introduced into rural areas of Kenya by the United Nations International Children's Emergency Fund (UNICEF). Surveys show, however, that unless they have large amounts of maize to shell, farmers prefer traditional methods because few kernels are crushed. Simple machines to speed threshing and shelling would seem opportune, but the social consequences (e.g., reduced employment for women) must also be considered (61).

Drying and Storage

Food must be dried properly before storage to prevent deterioration, inhibit grain germination, limit the growth of fungi and bacteria, and reduce insect infestations. Over-dried crops are subject to breakage, discoloration, scorching, and reduced nutritional value. Many drying methods are available and the choice of method depends on several factors such as climate, quantity, intended final use of the food product, and the availability of fuel. For most staple foods, the basic methods available to resource-poor farmers are sun and air drying. Some artificial drying is necessary when crops are harvested during the wet season.

Traditionally, grains such as rice, millet, and shelled maize are simply spread on the ground and left to dry in the sun. One straight-forward way to speed this process is to place the grain on a black plastic sheet to increase the air temperature. This process also is effective for root crops such as cassava; in fact, cassava drying time can be reduced 25 percent by using a black plastic base. Where maize matures during wet periods, such as in the humid areas of West Africa, rapid drying is necessary to prevent spoilage. Drying cribs provide shelter from the rain and allow ventilation through open sides (61).

As farmers grow more improved, high-yielding varieties of maize that mature when the conditions for air and sun drying are inadequate, some artificial drying becomes essential. One simple dryer consists of a cylindrical clay structure with a thatched roof and a raised floor. Fuel is burned beneath in a firing chamber; air is drawn in, heated, and rises through the grain. Farmers' acceptance of this technology has been slow, however, because the dryer is hard to install and use. Other alternatives are in use, but a need still exists for low-cost dryers that can be built from locally available materials. Solar dryers are another option. The National Council for Science and Technology in Kenya has developed an improved solar dryer that provides equal drying on all sides without overdying. The dryer is made locally of black-painted wood, covered with polyethylene, and has a metal drying chamber. Although solar dryers are inexpensive to operate, they do not operate effectively during the rainy season (61).

Once a crop has been dried to a suitable moisture level, it must be stored. Storage must protect crops from rain, theft, and attack by fungi, insects, and rodents. Cassava presents particular storage problems because it deteriorates within a few days of being dug from the ground. Traditional cassava storage methods include reburial, coating with mud, placing under water, or the daily watering of heaps of cassava roots. An improved approach is packing freshly harvested roots in boxes of damp sawdust, which can be effective for 1 to 2 months.

Traditional approaches for storing grains in Africa are often ingenious in their design and use of local materials (27,41,55,63). Generally, storage areas are built from mud, plant material, stones, or some combination of these. They commonly have thatched roofs and are raised off the ground. In humid areas where the structures combine drying and storage functions, they are more open to allow ventilation (e.g., open-sided cribs). Since rainfall patterns and harvests tend to be more reliable in Africa's humid regions than in its drier regions, storage facilities tend to be smaller, holding perhaps a l-year supply of food. By contrast, in semiarid areas where harvests are far less reliable, storage granaries are commonly large, substantial mud structures capable of holding 2 or more tons of grain for up to 5 years. Sealed, underground pits are sometimes used. Because dried grain is vulnerable to insects and rodents, farmers sometimes mix sand, limestone, or other abrasive minerals with the grain. This traditional method provides a relatively effective barrier because it affects the insect's surface in such a way as to cause subsequent desiccation of the pest. Mixing selected ashes, herbs, or dried animal dung also can protect stored produce against insect attack. Seeds of the Neem tree, which act as natural insecticides, have also been added to stored grain to repel insects (61).

Traditional methods of insect control in storage are rarely as effective as modern synthetic insecticides and fumigants, although they are less expensive and safer. Insecticides are now widely available in most countries and in some cases represent a cost-effective means of protecting stored produce. Training farmers to use these products safely and arranging for reliable supplies presents a challenge to extension services, however (61).

Processing

Processed grains and other staple foods make up one of the most important parts of the diet of most low-resource farmers. Processing is the essential step of readying crops and other foods for consumption, and it usually involves several slow, laborious steps. Food processing in almost all cases is the responsibility of women. Many opportunities to improve processing exist, with most focusing on reducing the labor involved. The following discussion gives examples of these opportunities for different crops and commodities.

Cereals.-Traditional milling of sorghum, for instance, involves soaking the grain to loosen the bran and then pounding it in a mortar to remove the bran. Sorghum grain is usually processed into a porridge or partially fermented flat bread. These traditional foods take a long time to prepare and they are losing popularity with urban populations. Sorghum, however, grows

Photo credit: S. Imevbore/U.N. Food and Agriculture Organization

Low-resource farmers use a variety of inexpensive and simple methods to store harvested grain. Traditional granaries, such as these made in Nigeria from reed or mud, are relatively effective but can be improved.

well in semi-arid regions and is drought resistant so new processing techniques that could produce more marketable foods and encourage wider acceptance could relieve some dependency on imported food. TDRI, together with the Kenya Industrial Research and Development Institute (KIRDI), is developing "instant" foods from sorghum and promoting these as substitutes for rice. Also, a mechanized milling method known as dry abrasion has been introduced into villages in Botswana by the Canadian International Development Research Center (IDRC). Once trained to use this mill, a farmer can save several hours of labor each week.

Maize is traditionally milled with a pestle and mortar, sometimes after soaking a few days so fermentation can occur. The equipment used is inexpensive, but the process is time and labor consuming. Various types of hand mills are available, but rural women are increasingly making use of community mills.

Small amounts of rice can be processed for daily use, but the bulk of the crop is stored in an unprocessed form so that it is less vulnerable to insects. Processing involves several stages, including soaking, parboiling, drying, hulling, and winnowing. Each step is time-consuming and has potential to be made more efficient through new techniques and equipment. For instance, parboiling is done to make hulling easier and it reduces the number of broken grains because the husk is split during heating and the kernel is strengthened. However, three tedious steps are involved: soaking the grain, heating it until it cracks, then drying it in the sun. In addition, rice prepared this way commonly has an unpleasant odor. The traditional method of winnowing is to toss the rice kernels and separated husks into the air from a flat wooden tray. The kernels fall back to the tray first while the lighter husks catch in the breeze and fall to the ground. Improved methods are being developed for both parboiling and winnowing. For example, hand-operated winnowers—such as one that consists of a vertical drum with a fan at one end—can be inexpensive and easy to build. A new method of parboiling is also being developed which is faster and does not result in the unpleasant smell (61).

Legumes.—Legume processing can be particularly demanding. The traditional method of hulling is to soak the legumes or mix them with oil, sun-dry them, and pound them in a pestle and mortar. The husks are then winnowed off. Small hand or power-operated hullers are available, but these often split the bean. Legumes are usually soaked overnight and then cooked for 1 to 4 hours, a process that is slow and results in the loss of valuable nutrients. Some precooked legumes—legumes that have been flaked, pressure cooked, and dehydrated–are being developed but the level of technology may be beyond the reach and access of resource-poor farmers.

One particularly important cash crop for resource-poor farmers is the groundnut—or peanut. Unlike other legumes, they do not have a hard husk. A wooden, hand-operated decorticator, developed by UNICEF in Kenya, is claimed to be three times more efficient than traditional hand methods for removing groundnut shells.

Cassava.—Cassava is a root crop and important staple that is processed into a variety of products according to local traditions and needs. Processing cassava is one of the most time-consuming and strenuous tasks faced by African women, and traditional methods can take several days to complete. The main products are chips, flour, and gari. Gari is becoming increasingly popular in some West African countries (e.g., Ghana) because of shortages of other foods.

To prepare cassava, it is first soaked a few days to reduce the cyanide content of the roots. Then the root is peeled, chopped into small pieces, and sun-dried. Chips are produced after drying for 3 to 10 days. The chips are pounded in a mortar to make flour. Gari preparation is also lengthy but, once prepared, it is easy to cook and keeps well for several months. Peeled root is washed and grated, then allowed to ferment. Simultaneously, water is extracted either by placing the mixture in bags under heavy weights or some other pressure system. Next, the fermented cassava mixture is sieved and roasted.

Techniques are being developed to speed and ease these various steps. Hand or pedal-operated graters are available now. Improved presses, too, are under development. Any modification to traditional methods, however, must be careful to result in a comparable cyanide reduction.

Oil Seeds.—Vegetable oils are an important commodity and are often in short supply. palm oil, in particular, is a major income source for rural women in the humid areas. While palm fruits are harvested by men, oil processing is a woman's task. First, the fruits are boiled for 5 to 10 hours in an iron pot. The oily fibers are then separated from the rest of the seed by either pounding in a mortar or trampling in a pit. These methods are slow and laborious. In traditional processing, water is added during fiber separation and the oil is scooped and sieved from the mixture of fibers, kernels, and water. Then the oil is boiled in drums and left to cool, where any remaining vegetable debris sinks while the oil floats and can be skimmed off.

Several advances have been made in oil processing. Sterilizers, small boilers for steaming larger quantities of seeds in shorter time, have been developed. A palm-pounding machine also exists. Several types of screw and hydraulic presses have been designed to make the final stage of oil extraction easier and less time-consuming, but again, such techniques are not in widespread use.

Coconut oil, sunflower oil, and other seed oils are also important in various regions and are similarly difficult to process. Simple improvements in graters and presses can increase output. For example, shea nuts are a locally important source of shea-nut butter, an edible fat that provides income for rural women. Traditional methods of producing the butter result in about 25 percent fat. A hand press developed by the German Appropriate Technology Exchange (GATE) results in high-fat butter, reduces the time involved, and cuts fuel requirements. Although it is expensive to buy initially, the press is estimated to pay for itself in 2 years because of the extra income it generates.

Milk.–Milk products are highly valued by herders and farmers. Herders use milk and milk products as barter for food grain. Surveys have revealed many traditional systems of milk preservation, principally in the form of butter, ghee, or other fermented products (47).

The InternationaI Livestock Centre for Africa (ILCA) recently organized a dairy technology unit, whose focus is to research low-cost means of milk preservation (36). working in the highlands of Ethiopia, the ILCA group has developed an internal agitator fitted to the traditional regional clay milk churn that cuts churning time in half and has increased butter recovery from 75 to 92 percent. The program is also promoting the use of a locally producible wooden press for making cheese, including Queso Blanco, Halloumi, and cottage cheese (36). More efficient cheesemaking is also resulting from improved locally constructed evaporation coolers. As a result of these promising technologies, 13 countries have begun to direct attention to promoting similar improvements in milk preservation (47).

Fisheries.-Other particularly important food sources in many countries are derived from marine and inland fisheries. Major coastal fisheries are found in West Africa, Mozambique, and Tanzania, and inland fisheries are important around Lakes Chad, Victoria, and Malawi. The inland delta of the Niger River in Mali is also important because seasonal flooding supports a large population of migrant fishers.

Fish is a highly perishable commodity and heavy losses occur at every stage of the post-harvest chain. Losses occur during handling on boats and after landing; from blowflies during drying and beetles during storage; and during smoking, packaging, and transport because of crumbling and spoilage. Much of the fish caught is sold immediately, but a significant portion is dried or otherwise preserved, especially where it is transported long distances. For migrant fishermen in Mali, for instance, 3 to 4 months elapse between the fish catch and consumption. As much as 50 percent of the fish processed can be lost.

The most common methods of fish processing are air and sun drying, salting, and smoke drying. The traditional approach to drying is simply to spread the fish on straw on the beach and leave them in the sun. One improvement is the use of simple racks that raise the fish off the ground and improve airflow around the fish. Racks can be built from local materials that are cheap and effective. Another potential improvement underway is the development of solar driers.

Salt drying, on the other hand, has the advantage of not only drying the fish, but preventing microbiological spoilage. It is usually carried out simply by sprinkling dry salt between stacked layers of split fish or immersing the fish in brine.

Smoke drying is widely used in West Africa and is traditionally carried out over a grid of fire or in mud, wood, or oil drum ovens. The heat not only dries the fish, but reduces blowfly attack. Blowflies are a serious threat to fisheries, particularly in the wet season when drying is slow. In Senegal in 1984, one-third of the fish catch was lost to blowfly infestation. Phenolic compounds in the smoke that inhibit bacterial action may also be deposited on the surface of the fish. while this approach is cheap, it requires large amounts of firewood, an increasingly scarce resource. Many different improved ovens are being introduced, such as the Chorker fish smoker that FAO introduced in

Ghana. This smoker has a large capacity, is easy to operate, reduces smoking time, and is inexpensive to build, although the design requires skilled workers (box 11-2).

Energy Sources.—One of the critical needs of the resource-poor farmer is fuelwood and other sources of energy for processing food. Fuelwood is becoming scarce in many parts of Africa. Reforestation efforts such as the country-wide tree planting initiative carried out by the Kenyan National Council of Women in 1977 are long-term solutions. Ways to meet needs more immediately include:

- Briquetting, where cellulosic residues such as rice husks or groundnut shells can be pressed into briquettes and burned. However, any development of this type of alternative energy source should be careful not to create problems with soil productivity and conservation due to removal of residues that otherwise would contribute to soil organic matter.
- Solar energy, too, offers an alternative although its role may be small. Solar cookers have proven relatively unsuccessful, in part because of the conflict with the local custom of cooking in the evening after the sun has gone down, and in part because they require direct sunlight and must be constantly adjusted as the sun moves. Solar driers, although not yet used on any significant scale, may prove more efficient.
- Improved cook stoves and post-harvest technologies that use fuelwood more efficiently (box 11-3) (8,10,28).

Potential

No single machine or new practice will drastically improve the post-harvest operations of African farmers, herders, and fishers, but a large number of relatively simple techniques do have the potential to make myriad small improvements. The impact of technologies can be enhanced if their development is based on an understanding of the entire production cycle. Fishing illustrates this point. As the capacit y for fish processing is increased by improved ovens, more fish have to be supplied regularly to make the ovens economically efficient. Thus, improved fish catches are required, which requires improvements in boats, nets, and other gear. Boats could be fitted with engines, but their high fuel consumption and need for maintenance sometimes is not suitable for resource-poor agriculturalists. At the other end of the post-harvest chain, improved methods of packaging and marketing would similarly be needed.

The contribution of improved post-harvest technologies can be enhanced by focusing increased attention on African women (7,34,52). Most development programs in the past were directed toward men. Donor agencies and African governments are recognizing the necessity of assisting women because if the technology does not fit with women's many duties, it stands little chance of success.

Problems and Approaches

One of the obstacles that has hindered the development of post-harvest technologies for resource-poor agriculturalists is the low priority that this subject has received from development assistance agencies. Assistance typically has emphasized improvements in production; and the female-dominated post-production side of agriculture has lacked a vocal constituency. Furthermore, food losses at the farm level, as compared to commercial level, most likely are not as high as previously believed, and may actually be acceptable to the farmer or fisher. Development agencies may find it more rewarding to measure success in terms of reducing women's drudgery, rather than quantitatively measuring reductions in lost food.

The growing awareness in the development community and among African leaders of the need to find more effective ways of ensuring that assistance reaches women, offers hope that priorities are becoming more balanced. However, women still are underrepresented in extension service positions and at higher levels in the development assistance community.

A common feature of development failures has been the inappropriateness of introduced technologies. Not surprisingly, traditional

Box n-2.-Women Invent New Technology for Smoking Fish

In Africa, as in other hot, humid zones, it is difficult to preserve fish products since fresh fish deteriorates rapidly and cannot be transported immediately to centers of consumption. This causes significant losses and reduces the amount of animal protein, already scarce, that reaches the local population. Hence, the importance of the chorkor, an oven for smoking fish named for the Ghanian village where it was invented in 1970. It was developed by local women with the assistance of a small project directed by the U.N. Food and Agriculture Organization (FAO) and the Food Research Institute in Accra, Ghana.

The chorkor is an improved version of the traditional cylindrical clay ovens that African women use for smoking fish. Although the traditional ovens still predominate, they are not very efficient. The women who use them work an average of 5 hours a day to obtain only 10 to 20 kilos of poor-quality smoked fish and they breathe in a large quantity of smoke in the process. Furthermore, the traditional ovens use enormous amounts of firewood, which is expensive in many African countries.

The women of Chorkor, aware of these problems, decided to modify the traditional cylindrical oven. A modified rectangular oven can be built of clay (which can be coated with a layer of cement to keep off rain), with sundried bricks, or with cement blocks mortared, like the bricks, with a mixture of sand and cement, It uses grills made of inexpensive wire netting and wood frames. The wooden frames allow 15 layers of fish to be dried at once (compared to 2 to 3 layers in the traditional ovens), and can be arranged to form a chimney to facilitate circulation of heat and smoke, The oven has two parts, divided by a partition, which can be used together or separately. This permits smoking fewer fish, if desired, and storing already-smoked fish in the section not in use.

The advantages of this oven over the traditional ones are great. It can be built in 5 days fairly inexpensively; it lasts longer (if the trays are built well and oiled regularly, and the frames kept from burning and protected from the elements, they can last up to 3 years, and a well-made oven can last up to 8 years); it can dry 240 kg of fish at one time (as compared to only 20 kg with the old system); and it gives a much more uniform and better-quality product. Moreover, it uses one-tenth the amount of wood that traditional ovens use, does not fill the eyes and lungs of the workers with smoke, and takes much less time and effort to use.

It is not surprising that the chorkor has been enthusiastically received, especially considering that the inhabitants of the West Coast of Africa prefer smoked fish to fish dried in the sun or salted, Smoked fish has a milder flavor, but since it has a higher moisture content, it spoils more easily if it has not been preserved properly as happens frequently with traditional ovens. With the chorkor system, the smoked fish lasts up to 9 months because the chimney formed by the trays allows more uniform penetration of smoke and heat. The chorkor is, consequently, not only an efficient innovation but also a socially useful technology, as much for the women who use the ovens as for the consumers.

Although it is still not well-known outside its region of origin, the chorkor oven is spreading with the help of FAO and UNICEF to Guinea, Togo, Benin, and Guinea-Bissau. In Guinea, for example, 300 women are forming a cooperative for preserving fish with the chorkor and for marketing what they produce. Togo will install 10 chorkors in strategic locations on the coast, teach the Togolese women how to take advantage of the new method, and give them technical advice on construction of the ovens; some Togolese women will go to Ghana to learn how it works, Guinea-Bissau hopes to spread the use of the chorkor to all the islands of the Bijagoz archipelago.

It is clear that the local costs of the raw materials for the construction of the chorkor oven will vary from country to country. The same is true of customs, tastes, and climatic conditions, needs of the local rural and urban populations, traditions regarding the use of fish, and the fish species that can be smoked. Obviously care must be taken in spreading use of the chorkor oven. But it is equally evident that the women of Ghana have made an important contribution to the development of appropriate technologies.

SOURCE: Guillermo Almeyra, "Women Invent New Technology for Smoking Fish, " Ceres, vol. 20, No. 1, January/February 1987, pp. 5-7.

Box 11-3.-Improved Charcoal Stoves

Most stove programs in Africa have had little success, distributing at best 5,000 to 8,000 stoves. Many of the designs were too expensive, ill-adapted to traditional cooking or heating requirements, or required materials and skills that often were unavailable. An important breakthrough in fuel-efficient stoves came with the U.S. AID-funded Kenya Renewable Energy Development Project, launched in 1982. By the end of 1985 the project had given birth to a new industry whose main producers alone had sold 110,000 improved charcoal stoves at a profit.

The new stove is a modification of an existing one called a "jiko." In contrast to the jiko, the improved stove is about 50 percent more fuel efficient; it costs 65 to 100 Kenyan shillings, but lasts longer than the old one which costs 60 shillings. For the average Nairobi family spending 170 shillings a month on charcoal, the new stove pays for itself within 8 weeks.

There was a high level of local participation in the design. Scrap metal artisans were consulted to make manufacturing easy. The stove is constructed of scrap metal, with an insulating ceramic liner, a built-in grate in the top half, and an ash chamber in the bottom. Prototypes were test marketed in 600 households to make sure they were acceptable.

The Kenyan approach has potential in countries where fuelwood is marketed and is expensive. For the poor and scattered rural populations that comprise much of Africa, a different approach is needed. The improved stove developed by the Burkina Energy Institute, for example, is basically a shielded version of the traditional three-stone stove. The improvement is a circular shield built of clay, dung, millet chaff, and water that goes around three-stones that act as pot rests. The stove can be built in half a day to fit any desired pot size, and requires little, if any, cash. Fuel savings range between 35 and 70 percent, Most women recoup the investment of a day's labor within 1 or 2 weeks. The low-cost, high benefit, and rapid-dissemination method have brought some 85,000 improved three-stone stoves into use.

SOURCE: Paul Harrison. The Greening of Africa: Breakng Through *the Battle for Land andFood (Toronto:* Paladin Grafton Books, 1979), pp. 205-220.

methods have not been abandoned by farmers, herders, and fishers until an improved technology has clearly been shown to be an effective improvement and has few consequent disadvantages. The most successful technologies have been those based on, or improvements of, traditional practices. This recognizes that traditional practices are often well-adapted to existing conditions and are already proven to be appropriate and acceptable to the adopters.

CHAPTER 1 1 REFERENCES

1. Barr, B. A., Koehler, C. S., and Smith, R. F., "Crop Losses, Rice: Field Losses to Insects, Diseases, Weeds, and Other Pests," *UC/AID Pest Management and Related Environmental Protection Project* (Berkeley: University of California, 1975).
2. Bottrell, Dale, "Social Problems in Pest Management in the Tropics, *Insect Science Applications,* vol. 4, No. 1/2, 1983, pp. 179-184.
3. Bottrell, Dale G., "Pest Control," contractor report to the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).
4. Brumby, Peter, *ILCA—Its Approach and Work, A Presentation for International Centres' Week 1986, Washington, D.C.* (Addis Ababa, Ethiopia: International Livestock Centre for Africa, 1986),
5. Brumby, P.J. and Trail, J. C. M., "Animal Breeding and Productivity Studies in Africa, " *ILCA Bulletin, No. 23,* January 1986, pp. 23-27.
6. Bull, David, *A Growing Problem: Pesticides and the Third World Poor* (Oxford: Oxfam, 1982).
7. Carr, M., "Appropriate Technology for Women," *Appropriate Technology,* vol. 5, No. 1,1978, pp. 4-6.
8, Clarke, T. A., "Small-Scale Briquetting by Hand," *Appropriate Technology,* vol. *13, No. 2, 1986,* p. 9.

9 Commonwealth Agricultural Bureaux International (CAB I), *CAB International News*, London, October 1986, pp. 6-7.

10 Commonwealth Science Council, *Solar Dryers, Their Role in Post-Harvest Processing* (London: The Commonwealth Secretariat, 1985).

11. Conelly, W. T., "Perception and Management of Crop Pests Among Subsistence Farmers in South Nyanza, Kenya," manuscript submitted to Perception and Management of Pests and Pesticides Work Group, 1985.

12. Conservation Foundation, "Report Urges Better Chemical Controls Abroad," *Cons& vation Foundation Letter, No. 2, 1988,* pp. 1-7.

13 Cramer, H. H., "Plant Protection and World Crop Production," *Pflanzenschutz-Nachrichten,* vol. 20, 1967, pp. 1-524.

14 De Haan, C. and Nissen, N. J., *Animal Health Services in Sub-Saharan Africa: Alternative Approaches,* World Bank Technical Paper Number 44, World Bank, Washington, DC, 1985.

15. Development International, "Mastering the Mealybug—A Beneficial Approach," Development International (prototype issue], 1986, p. 19.

16. Dipeoulu, (former) Dean, Faculty of Veterinary Medicine, University of Ibadan, Nigeria, personal communication, Oct. 8, 1987

17. Glass, E.H. and Thurston, H. D., "Traditional and Modern Crop Protection in Perspective, " *BioScience*, vol. 28, 1978, pp. 109-115.

18. Goldschmidt, W., "The Failure of Pastoral Economic Development Programs in Africa, " J.G. Galaty, et al. (eds.), *The Future of Pastoral Peoples* (Ottowa: International Development Research Center, 1981), pp. 101-118.

19. Goodman, L.W. and Portilla, B., "Foreign Toxins: Multinational Corporations and Pesticides in Mexican Agriculture," paper prepared for World Resources Institute conference, 1985.

20. Greeley, Martin, "Pinpointing Post-harvest Food Losses," *Ceres*, vol. 15, No. 1, 1982, pp. 30-37.

21. Hahn, S.K. and Howland, A. K., "Breeding for Resistance to Cassava Mosaic, " *Proceedings Cassava Mosaic Workshop* (Ibadan, Nigeria: International Institute of Tropical Agriculture, 1982), pp. 37-39,

22. Hahn, S.K. and Keyser, J., "Cassava: A Basic Food of Africa," *Outlook on Agriculture,* vol. 14, No. 2, 1985, pp. 95-99.

23. Hansen, Michael, *Escape from the Pesticide Treadmill: Alternatives to Pesticides in Developing Countries,* Preliminary Report (Mount Vernon, NY: Institute for Consumer Policy Research, Consumers Union, May 1986).

24. Harrison, P., *The Greening of Africa: Breaking Through the Battle for Land and Food* (Toronto: Paladin Grafton Books, 1987),

25. Harwood, R.F. and James, M. T., *Entomology in Human and Animal Health,* 7th ed. (New York, NY: Macmillan, 1979).

26. Herren, H. R., Neuenschwander, R. D,. Hennessey, R. D., and Hammond, W. N: O., "Introduction and Dispersal of *Epidinocarsis lopezi* (Hym., Encyrtidae), and Exotic Parasitoid of the Cassava Mealybug, *Phenacoccus manihoti* (Horn., Pseudococcidae), in Africa," *Agriculture, Ecosystems and Environment, vol. 19, 1987,* pp. 131-144.

27 Hindmarsh, P. S., Tyler, P.S. and Webley, D, J., "Conserving Grain on the Small Farm in the Tropics, *Tropical Science,* vol. *20,* pp. 117-128.

28 Hislop, D., "Residue Briquetting in The Gambia," *Appropriate Technology, vol.* 13, *No. 2, 1986,* pp. *22-23.*

29 Holtzman, John, *Stall Feeding of Cattle in the Mandara Mountains of Northern Cameroon,* Pastoral Development Network Paper Number 24a, (London: Overseas Development Institute, August 1987).

30. Institut d'Elevage et de Medecine Veterinaire de Pays Tropicaux (IEMVT), *Survey on the Potentialities of the African Laboratories for Rinderpest and Pleuropneumonia Vaccine Production,* Maisons Alfort, France, 1983.

31. International Board for Plant Genetic Resources (IBPGR) and the Royal Botanic Gardens, Kew, *Forage and Browse Plants for Arid and Semi-Arid Africa,* IBPCR, Rome, 1984,

32. International Institute of Tropical Agriculture, *1975 Annual Report* (Ibadan, Nigeria: International Institute of Tropical Agriculture, 1976),

33, International Institute of Tropical Agriculture, *IITA Research Highlights* (Ibadan, Nigeria: International Institute of Tropical Agriculture, 1984).

34, International Labor Office (ILO), *Improved Village Technology for Women's Activities,* ILO, Geneva, 1984.

35. International Livestock Centre for Africa (ILCA), "Veterinary Package Boosts Nigerian Sheep and Goat Production," *ILCA Newsletter,* vol. 3, No. 3, 1984, pp. 1, 3.

36. International Livestock Centre for Africa (ILCA), *ILCA Annual Report, 1986/87,* ILCA, Addis Ababa, Ethiopica, 1987, pp. 45-46.

37, Jejyaratnam, Jeyarajah, "1984 Occupational Health in Developing Countries," *Scandinavian Journal of Work, Environment, and Health, vol. 11, 1985,* pp. *229-234.*

38. Kategile, J. A., "Discussion, Summary, and Rec-

ommendations, " J.A. Kategile, *Pasture Improvement Research in Eastern and Southern Africa* (Ottowa, Canada: International Development Research Center, 1985) pp. 499-508.

39. Kenmore, P. E., Heong, K. L., and Putter, C. A., "Political, Social, and Perceptual Aspects of Integrated Pest Management Programmed, " B.S. Lee, W.H. Loke, and K.L. Heong (eds.), *Proceedings of Seminar on Integrated Pest Management in Malaysia,* Malaysian Plant Protection Society, Kuala Lumpur, 1985, pp. 47-66.
40. Leuschner, K., "Whiteflies: Biology and Transmission of African Mosaic Disease, " T. Brekelbaum, A. Bellottii, and J.C. Lozano (eds.), *Proceedings of Cassava Protection Workshop,* International Development Research Centre Series CE-14, Centro International de Agricultural Tropical, Cali, Columbia, 1978, pp. 5-58.
41. Lindblad, C. and Druben, L., "Small Farm Grain Storage," *United States Action/Peace Corps Program and Training Journal, Manual Series, No. 2, VITA Publications Manual Series, No. 35E* (Mount Rainier, MD: Volunteers in Technical Assistance, 1976).
42. Matteson, P. C., "The Effects of Intercropping with Cereals and Minimal Permethrin Applications on Insect Pests of Cowpea and their Natural Enemies in Nigeria, " *Tropical Pest Management,* vol. 28, 1982, pp. 372-380.
43. Matteson, P. C., Altieri, M., and Gagne, W. C., "Modification of Small Farmer Practices for Better Pest Management," *Annual Review of Entomology,* vol. 29, 1984, pp. 383-402.
44. M'Boob, S. S., "Some Observations on the Status of Plant Protection Infrastructures in Central and West Africa, " unpublished report to U.N. Food and Agriculture Organization, AGPP, October 1984.
45 McDowell, R. E., "Livestock Nutrition in Subsaharan Africa: An Overview, " J.R. Simpson and P. Evangelou (eds.), *Livestock Development in Sub-Saharan Africa: Constraints, Prospects, Policy* (Boulder, CO: Westview Press, 1984), pp. 43-59.
46. McDowell, R. E., "An Animal Science Perspective on Crop Breeding and Selection Programs for Warm Climates," Cornell International Agriculture Mimeograph 110, Department of Animal Science, Cornell University, Ithaca, NY, April 1986,
47. McDowell, Robert E., Visiting professor, Department of Animal Science, North Carolina State University, personal communication to the Office of Technology Assessment, 1987.
48. McMillan, Della E., "Government Assisted Land Settlement: Status and Potential in African Low-Resource Agriculture," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December, 1987).
49. Messenger, P. S., Biliotti, E., and van den Bosch, R., "The Importance of Natural Enemies in Integrated Control," C.B. Huffaker and P.S. Messenger (eds.), *Theory and Practice of Biological Control (New* York, NY: Academic Press, 1976), pp. 543-563.
50 Metcalf, Robert L. and Luckmann, William H., *Introduction to Pest Management (New* York, NY: John Wiley and Sons, 1982).
51 Molineuax, L. and Gramiccia, G., *The Garki Project,* World Health Organization, Geneva, 1980.
52 Muntemba, S. (cd.), *Rural Development and Women: Lessons from the Field. Volumes 1 and 2* (Geneva: International Labour Office, 1985).
53. National Academy of Sciences/National Research Council, Board on Science and Technology for International Development, *Postharvest Food Losses in Developing Countries* (Washington, DC: National Academy of Sciences, 1978).
54. National Academy of Sciences/National Research Council, *Pesticide Resistance-Strategies and Tactics for Management* (Washington, DC: National Academy Press, 1986).
55. O'Kelly, E. and Forster, R. H., "Processing and Storage of Foodgrains by Rural Families, " *FAO Agricultural Services Bulletin 53* (Rome: U.N. Food and Agriculture Organization, 1983).
56. Pimental, David, *World Food, Pest Losses, and the Environment* (Boulder, CO: Westview Press, 1978).
57. Pingali, P. L., Bigot, Y., and Binswanger, H. P., *Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa,* Report No. ARU 40, Agriculture and Rural Development Department (Washington, DC: World Bank, May 15, 1985; rev. February 1986).
58. Reppetto, R., *Paying the Price: Pesticide Subsidies in Developing Countries* (Washington, DC: World Resources Institute, 1985).
59. Stewart, R., "Prospects for Livestock Production in Tsetse-Infested Africa, " *Impact of Science on Society,* Unesco No. *142,* pp. 17-125, 1986.
60, Teng, P. S., "Plant Protection Systems in West and Central Africa - A Situation Analysis, " report to U.N. Food and Agriculture Organization, Plant Protection Service, August 1985.
61. Tropical Development and Research Institute (TDRI), "Post-harvest Technology," contractor

report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

62. U.N. Food and Agriculture Organization (FAO), "African Trypanosomiasis," Information Sheet, FAO, Rome, 1981.
63. U.N. Food and Agriculture Organization (FAO), *Processing and Storage of Foodgrains by Rural Families* (Rome: FAO, 1983).
64. U.N. Food and Agriculture Organization, *African Agriculture: The Next 25 Years—Atlas of African Agriculture,* (Rome: FAO, 1986).
65. U.N. Food and Agriculture Organization (FAO), Emergency Center for Locust Operations, *African Locust Bulletin, No. 1-11, 1986.*
66. U.N. Food and Agriculture Organization (FAO), *FAO in Africa* (Rome: FAO, 1986).
67. U.S. Congress, General Accounting Office, "Better Regulations of Pesticide Exports and Pesticide Residues in Imported Foods is Essential, " Rep. No. CED-79-43 (June 22) (Washington, DC: U.S. General Accounting Office, 1979).
68. U.S. Congress, Office of Technology Assessment, *Pest Management Strategies in Crop Protection,* vol. I, OTA-F-98 (Washington, DC: U.S. Government Printing Office, October 1979).
69. U.S. Congress, Office of Technology Assessment, *Plants: The Potential for Extracting Protein, Medicines, and Other Useful Chemicals,* OTA BP-F-23 (Washington, D. C.: U.S. Government Printing Office, September 1983).
70. U.S. Congress, Office of Technology Assessment (OTA), *Continuing the Commitment: Agricultural Development in the Sahel,* OTA-F-308 (Washington, DC: U.S. Government Printing Office, August 1986).
71. Usenbo, E. I., "Approaches to Integrated Control of Cotton Pests in the Midwestern State of Nigeria," PhD. thesis, University of London, 1976.
72, Van den Bosch, R., Messenger, P. S., and Gutierrez, A. P., *An Introduction to Biological Control (New* York and London: Plenum Press, 1982).
73. Walsh, J., "Return of the Locust: A Cloud Over Africa," *Science,* vol. 234, 1986, pp. 17-19, pp. 815-816.
74. Ware, George W., "The Pesticide Book," (New York, NY: W.H. Freeman and Co., 1978).
75, Winrock International, *Sheep and Goats in Developing Countries: Their Present and Potential Role,* World Bank Technical Paper (Washington, DC: The World Bank, 1983).
76. World Bank, *West Africa Agricultural Research Review* (Washington, DC: The World Bank, February 1987).