1998

Entomology in the Developing World

Elvis A. Heinrichs

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E. A. Heinrichs

Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803

The global population continues to increase at an alarming rate, with 90% of the added population, or 85 million per year, occurring in the developing nations of the world. From 1950 to 1980, world food production doubled, with increases in the developing countries exceeding that of the developed countries. However, food production was not able to keep pace with the population in the developing world, where population increases were twice the rate of those in the developed world. Increases in per capita food production since the 1950s have been only one-third of the developed world because increased food production has been offset by the high rate of population growth (Brown 1981). Even if birthrates decrease and the world population does not reach the level predicted, there will be significant pressure on a limited land resource.

Most of the world's land is not suitable for agriculture. Only about 10%, or 1.4 billion hectares, out of 14.7 billion hectares of land in the world is good cropland (Dudal 1976). Good cropland is being lost at an alarming rate due to waterlogging, salinization, deforestation, and subsequent erosion, flooding, and desertification. Ethiopia has been described as "literally going down the river" because more than one billion tons of topsoil

are lost annually from denuded highlands where trees are cut for much needed firewood (Brown 1981). Transformation of arable land to desert is occurring at the rate of six million hectares per year. Because of the continuing loss of arable land the demand for food and fiber must be met by more intensive use of existing land. With modern technology, the potential for significant increases in food production on existing land is great.

Importance of Insects

Among the technology components required to meet the increasing demand for food, effective insect control is playing a major role. In 1971, a U.S. National Academy of Science study (NAS 1977) estimated that only a 20% reduction in losses from pests attacking major food crops would provide a savings sufficient to feed almost 500 million people per year. Insects destroy structures and crops, and they transmit diseases to humans and livestock. Human and livestock diseases vectored by insects sap the strength and take the lives of countless millions of developing world citizens each year. Losses of field crops caused by insects are estimated at 14% worldwide. Higher losses generally occur in the tropical countries of the developing world. Insect-caused rice yield losses were estimated at 35% in Southeast Asia, 14% in Africa, and only 2% in Japan (Cramer 1967). Even when grain is harvested and placed in storage, it continues to be threatened by insect attack. Because of primitive and inadequate storage conditions, high temperature, and humidity, insect-caused storage losses are by far the greatest in tropical countries.

Because of the tremendous need to minimize insect-caused losses of food, fiber, livestock, and humans, many agencies have contributed personnel and finances to develop effective insect control systems. Among the international agencies involved in the development of insect management systems are the Food and Agriculture Organization (FAO), World Health Organization (WHO), United Nations Development Program (UNDP), World Bank, and the International Agricultural Centers (IARCs). U.S. agencies include universities, U.S. Agency for International Development (USAID), religious organizations, National Institutes of Health (NIH), USDA, Peace Corps, private consulting firms, Rockefeller Foundation, and Ford Foundation. U.S. agencies have primarily been involved in university development and agricultural development projects. These agencies have been instrumental in enhancing the profession of entomology in the developing world. In Asia, where the green revolution has had a significant impact on agricultural production, the various aid agencies have played a major role in training entomologists in the art of teaching, research, and extension. Their expertise has been used in the development and implementation of insect management strategies for the high-yielding varieties.

Many of the entomologists who have played major roles in the development of insect management strategies are U.S. citizens working overseas, or foreign nationals trained in U.S. universities, and are members of the Entomological Society of America. Of our society's total membership of 8,350, 908 or 11% are located in foreign countries. Many of these members have played pivotal roles in outstanding success stories in agricultural development. A few of these will be presented in this paper.

Insect control in the third World has evolved from the use of primitive or traditional control methods, many of which were dropped when insecticides became readily available. By giving farmers a product they could apply, commercial insecticides in the early 20th century revolutionized insect control (Hansen 1987). Later, because of the social and direct costs of using insecticides as a sole control tactic, the concept of integrated pest management (IPM) was implemented in varying degrees throughout much of the developing world. The term IPM denotes the intelligent selection and use of pest control actions that will ensure favorable economic, ecological, and social consequences (Rabb 1972).

Long before the biblical plagues of locusts, insects have been a scourge to agriculture and at times have been the cause of widespread famine. Over the years, farmers developed novel methods of controlling insect pests. Many of these traditional methods have proven scientifically sound. An example of controlling certain rice pests in China is to herd ducklings through the rice paddies where they eat insects and weeds.

But pesticides have, on many farms, replaced these traditional methods, including the herding of ducks in China. Pesticide technology used in the United States and Europe was exported to countries with cultures and social structures that were not prepared to adopt new technology. Insecticides considered to be too dangerous for use in the Western world were exported to the developing countries. In the 1960s insecticide use in Third World countries increased rapidly. Insecticide use in rice in the Philippines began increasing in the 1950s, 10 years before the release of the high yielding variety IR8. By 1980, 95% of the farmers in the "rice bowl" of Nueva Ecija province were using insecticides. Insecticide use was encouraged through subsidies granted to farmers and

the credit provided in development loans. However, farmers' decisions to use insecticides do not consider environmental effects and social costs. Therefore, use of insecticides as a sole tactic to control insects has had severe repercussions. The most obvious are human-poisoning cases. In addition, a common occurrence is the resurgence of so-called "secondary pests" from a status of minor to major importance, when their natural control agents are killed by insecticide.

Farmers in the developing world often are not aware of the dangers of insecticides and therefore do not protect themselves from exposure when spraying. Based on a survey of 19 countries, WHO estimated that there were 500,000 poisoning incidents and 5,000 deaths per year (Copplestone 1977). More recent reports double that number (Gupta 1986). Additional chronic effects on the health and vigor of farmers are difficult to monitor. As a result, the USAID has changed its policy on pesticides and now requires a risk-benefit evaluation for insecticides used in assistance programs (Bottrell 1984). In implementing this policy USAID received the assistance of the Consortium for International Crop Protection (CICP), housed in College Park, M. CICP furnishes entomological expertise to USAID missions in the design of agricultural projects.

However, it was not the adverse effects of insecticides on human health that caused entomologists in developing countries to seek alternative control tactics. Instead, it was the increasing failure of chemicals to provide satisfactory control of insect pests. In fact, from 1940 to 1975, the period of greatest growth in pesticide use, preharvest losses to insects worldwide almost doubled from 7 to 13% (Pimentel et al. 1978).

Rice IPM

One cause of increased crop losses, in spite of increased insecticide use, is the development of insect strains that are resistant to insecticides. However, an even more important factor is resurgence where insect populations, after insecticide treatment, rebound to higher levels than before treatment. This has been a common occurrence in rice where the brown planthopper, Nilaparvata lugens (Stål), once considered a pest of only minor importance, has become one of the most devastating rice pests throughout Asia (Heinrichs and Mochida 1984). Our studies in the Philippines have shown that many of the commonly recommended insecticides were much more toxic to the brown planthopper's natural enemies, such as spiders, than they were to the brown planthopper. In addition, sublethal rates stimulated the brown planthopper to increase its reproductive rate and feed more (Chelliah and Heinrichs 1980).

In studies conducted on the International Rice Research Institute (IRRI) farm in the Philippines, insecticide-treated plots had as many as 2,000 brown planthoppers per plant while there were only about 2 hoppers on the untreated plants (Heinrichs et al. 1982). This response to insecticide has been common from China to India.

In Indonesia, the evidence that certain insecticides were the major cause of brown planthopper outbreaks was so overwhelming that President Soeharto met with rice entomologists to seek a solution. Based on the advice of Indonesian entomologists and entomologists from IRRI, the Tropical Agricultural Research Center in Japan, the Overseas Development National Research Institute in Great Britain, and FAO, President Soeharto issued Presidential Decree No. 3 on November 3, 1986. The decree restricted the use of 57 heavily subsidized insecticides. Three rice insecticides were retained for

brown planthopper control; buprofezin, an insect growth regulator that is safe to humans and natural enemies of the brown planthopper (Heinrichs et al. 1984), mipcin and bassa. Carbofuran was retained for control of stem borers and leafhoppers. The decree also declared IPM as the national pest control strategy for rice. This is the first case of a nationally mandated pest management program.

With only four insecticides available for rice insect control in Indonesia, there has been concern that the insects will develop resistance to these insecticides. In response, Michigan State University entomologists have established a USAID-funded program to develop insecticide resistance management strategies for use on the thousands of small rice farms throughout Indonesia.

The bold move by President Soeharto has proven to be successful because of the management program developed by Indonesian scientists in close collaboration with scientists from several international agencies. A major component of the Indonesian rice IPM program is the planting of insect-resistant varieties and conservation of biological-control agents. In cases where resistant varieties and biological agents fail to provide satisfactory control, farmers apply insecticides that have low toxicity to the biological-control agents.

Indonesian entomologists and plant breeders are part of an international network and work in collaboration with counterparts in IRRI and national rice research programs throughout the world. The Indonesian scientists have developed a series of insect-resistant rice varieties for use in their IPM program. Key scientists in the rice varietal development program have been trained in U.S. universities. Dr. I. N. Oka received his entomology training at Cornell; plant breeders Dr. B. H. Siwi and Dr. Harahap received

their training at Texas A&M and North Carolina State University, and Louisiana State University, respectively.

The success of the Indonesian program in breeding for insect resistance has been possible because of the tremendous amount of genetic diversity in the world collection of rice maintained at IRRI. Of the 80,000 rice (Oryza sativa) accessions stored in the IRRI International Rice Germplasm Center, many have resistance to the various insect pests (Heinrichs et al. 1985).

The IRRI collection also contains 2,000 accessions of wild rice Oryza spp. Some of these accessions possess resistance to rice insects for which no resistance has been found in O. sativa (Romena & Heinrichs 1990). Recent developments in biotechnology make it possible to use wild rices as donors for insect resistance when crossing with O. sativa.

The Rockefeller Foundation program on Rice Biotechnology, established in 1984, consists of a coordinated effort by research institutions in the United States and other countries including the IRRI, all of which are at the forefront of molecular biology. A principal goal of the program is to genetically transform rice through the introduction of alien genes. Genetic engineering will make it possible to incorporate any gene, from any source, into rice. Current efforts aim at incorporating into rice the toxin gene from a bacterium, Bacillus thuringiensis, an insect pathogen. One target pest, found throughout Asia, is the yellow stem borer, Scirpophaga incertulas (Walker). Only low levels of resistance to it have been found in rice. Indeed, genetic engineering offers exciting possibilities for developing rice plants with resistance to the major insects and pathogens and with the potential for increasing grain yield and enhancing the nutritional value of

the grain.

Insect resistant rice varieties have saved virtually billions of dollars by reducing insecticide requirements and preventing grain yield losses. Insect-resistant varieties are grown throughout South America, Central America, and Asia. Most of the seven million hectares of hybrid rice grown in China is resistant to the brown planthopper and is exceptionally high yielding.

Although effective and economical rice insect management systems have been developed by research entomologists, transfer of the developed technology to farmers, who are often illiterate and steeped in superstition, has proven to be a challenge. However, a successful example is the FAO Intercountry Program on Integrated Pest Control in Rice, that is working in cooperation with the IRRI, Gesellchaft für technische Zusammenarbeit, and seven national programs. This program has developed technology transfer techniques that are being used to train farmers in the practical aspects of pest management (Zelazny et al. 1985).

The program was established initially in the Philippines and has expanded to Bangladesh, India, Indonesia, Malaysia, Sri Lanka, and Thailand. Training under the program has concentrated on demonstrating that by using insecticide only when necessary, farmers can increase their profit margin. Most of the training is done in rice fields where farmers are taught to monitor fields once a week, to distinguish harmful insects from beneficial insects, to ignore small pest populations, and to apply insecticides when the threshold level for a given insect is reached. Repeated visits to farmers, practical demonstrations, and public recognition of their achievements in adopting IPM have been shown to be the most successful training methods (Zelazny et al. 1985).

The nationally mandated rice IPM program in Indonesia has significantly reduced insecticide inputs and increased yields and profits (FAO 1988). Insecticide applications per crop dropped from 4.5 in 1986, to 2.0 in 1987, and 0.5 in 1988. Insecticide costs decreased from 7,500 rupiah per hectare in 1986 to 2,200 rupiah per hectare in 1988, in spite of the two-fold increase in cost per unit of insecticide due to a decrease in the subsidy. Yields increased by one metric ton per hectare after the establishment of the IPM program.

There are approximately 10 million food crop farmers throughout the thousands of Indonesian islands. Although it is a formidable task to have an effect on such a large population of farmers, the IPM program leaders have set high goals. A training model has been established wherein 700,000 farmers per year are to be trained in IPM by 1994.

Cassava IPM

The rice example is not the only success story for pest management in the developing world. Let's leave Asia and rice, and move to Africa and South America where exciting things are happening in cassava. Cassava is the third largest tropical food crop and a significant source of calories for 500 million people in the developing world. Cassava originated in Latin America and was introduced into Africa by the Portuguese in the 16th century (Wodageneh 1985). It is generally referred to as manioc or tapioca but is known by more than 30 different names. Cassava is a basic source of carbohydrates for 200 million people living south of the Sahara. In Africa, cassava covers 10 million km^2 and the total area devoted to the crop is 6.6 million hectares.

The edible portion of cassava, the roots, can remain in the soil for up to four years. Therefore, cassava roots are available when other crops fail due to drought or locust plagues. Because of these properties, cassava is considered a famine crop. Cassava is threatened by a host of insect pests. Increased international trade in agricultural products and the mobility made possible by modern transportation has greatly increased the threat of foreign pest introduction. The chances for the entry of foreign species is greatest in developing countries, where quarantine procedures are often inadequate. Two extremely serious cassava pests that have entered Africa are the mealybug Phenacoccus manihoti Mat-Ferr, and the green mite Mononychellus tanajoa Bondar. The cassava mealybug was discovered in the Congo in 1973, and by 1982 it had spread thoughout the cassava belt of Central Africa from Senegal in the west to Malawi in the east. Entomologists were perplexed by the seriousness of the damage caused by this insect. It was not known to cause damage in other parts of the world where it occurs, including Latin America, where it apparently originated. The obvious answer was that the mealybugs were brought into Africa without the complex of natural enemies that serve to control them in the American tropics (Glass 1988).

Mealybugs pierce the leaves with their needle-like beaks, remove plant sap and kill the plants. Mealybug damage can cause total loss of root development. The mealybug causes yield losses ranging from 30 to 80% in more than 30 African countries (Herren 1981).

What was the response to this serious threat? Insecticides were not considered practical on the small farms in Africa. Resistance to the mealybug in the germplasm collection was not adequate. Cultural controls offered little promise. Classical biological

control, the introduction of natural enemies, offered the best hope for finding a solution.

Hans Herren, a Swiss entomologist with training in biological control and IPM in California was appointed to lead the biological control effort. The cassava biological control project, covering vast areas of Latin America and Africa, is the largest biological control effort ever undertaken. A cooperative agreement between the International Institute of Tropical Agriculture in Nigeria, and Centro Internacional de Agricultura Topical (CIAT) in Colombia, and the Commonwealth Institute of Biological Control in London was signed in 1981. Generous donor support enabled the development of cooperative regional projects encompassing four continents and 22 institutes.

In a worldwide search for parasites that could control the mealybug, a CIAT scientist found a tiny wasp, Epidinocarsis lopezi, in Paraguay. This parasite lays eggs in the mealybug and the larvae devour the internal organs of the insect. It was introduced into Africa and it spread rapidly throughout the cassava belt. It has drastically reduced mealybug populations where it has been released. In Nigeria, damage symptoms declined from 88% of the plants at the end of the first dry season, after E. lopezi was released, to 23% the next year (Glass 1988).

Cassava farmers in Africa now have hope of producing a healthy cassava crop. It is estimated that biological control of the mealybug in Africa will provide an annual saving of 50 million tons of cassava roots. An economist estimated that the benefit/cost ratio of the cassava project would be 149:1 in 20 years.

Although the mealybug does occur, it is not an important pest in South America, but cassava farmers there are confronted with other pests and different control strategies are used. The burrowing bug, Cyrtomenus bergi Froeschner, feeds on cassava roots.

Insect feeding combined with soil pathogens induce the appearance of dark spots on the fleshy white roots, rendering them commercially unacceptable (Belloti et al. 1988).

To manage this pest, a cultural control, the intercropping of Crotalaria or Sunne Hemp, is an economical and sustainable means of insect control developed by CIAT entomologists. Crotalaria possesses insecticidal activity and acts as a repellent to the burrowing bug. In addition, Crotalaria, a legume, acts as a green manure.

Tsetse Fly

In addition to contending with crop-destroying insects, citizens of the developing world come face-to-face with death and debilitation caused by insect-vectored diseases. The tsetse fly, known as the fly of the deadly sleep, is a vector for microscopic parasites that cause sleeping sickness in humans and nagana in livestock. Fossil records show that the tsetse fly lived in subtropical Colorado 35 million years ago. Today they are only found in Africa. In the forest and savanna, south of the Sahara, 50 million Africans in 38 tsetse-infested countries, from Senegal in the west to Mozambique in the east, live with the tsetse threat, as do 40 million cattle and countless goats, sheep, camels, pigs, and horses (Gerster 1986).

The tsetse strongly influenced the history of Africa and will shape its future. Twenty thousand Africans fall victim to sleeping sickness every year, and many cases go unreported. Nagana kills three million cattle and other livestock annually depriving subsistence farmers of food, draft power, and manure for crop fertilizer.

To control the tsetse, insecticides are sprayed from the air. Ground teams spray the lower branches of bushes to prevent invasion of areas treated from the air. Ground

teams spray DDT, an insecticide banned in developed countries.

Teams of scientists from international agencies, including the International Laboratory for Research on Animal Diseases and the International Center for Insect Physiology and Ecology in Nairobi, WHO, and Walter Reed Army Medical Center, and national scientists are searching for more effective means of preventing sleeping sickness and nagana. Alternatives to insecticides are being developed to control the tsetse fly. One approach is to trap the insect. Trapping is more cost-effective than chemical control, and safer for humans and the environment. After 16 years of studying the odors that can be used to attract flies to the traps, where they are killed by insecticides, a Zimbabwe entomologist, Dr. Glynn Vale, discovered that ox breath was most effective. Chemical analysis of ox breath in England indicated that the active components were CO_2, acetone, and octenol. These chemicals can attract flies from several kilometers. Use of these traps can eliminate sleeping sickness in an entire village. Scientists are indeed tightening the noose on the elusive tsetse by investigating other approaches: releasing biological-control agents such as predators, releasing sterile male flies, and breeding disease-resistant cattle.

Migratory Locusts

Migratory insects continue to threaten crops in the developing world, and their control requires close collaboration among nations and the international aid agencies. For many thousands of years, locust plagues have threatened agricultural production in a vast belt extending from western Africa through the Middle East to India. Migratory locust control provides a good example of controlling destructive pests of multinational

importance. The latest locust outbreak of 1985 to the present has required the service of entomologists from many nations and international agencies. The office of Foreign Disaster Assistance of USAID and CICP are two agencies providing technical assistance to countries involved in the current locust outbreak (A. Showler, Office of Foreign Disaster Assistance, USAID, personal communication) The main activity of USAID and CICP entomologists has been to develop locust control programs, coordinate donor country efforts, mitigate the adverse effects of the aerial application of insecticides, and improve locust forecasting.

In spite of significant improvements, locusts continue to threaten vast areas where farm families cannot afford losses. The migratory locust problem will continue to require a spirit of international cooperation among entomologists from international and national programs.

Russian Wheat Aphid

As illustrated in the previous discussion, entomologists from the United States have contributed significantly to the development of insect control strategies in the developing world. However, international cooperation is a two-way street, and it is extremely important to emphasize our continuing dependence on other nations for our U.S.-based agricultural research program. This is illustrated by the case of the Russian wheat aphid.

For years we have heard that the Russians are coming and we have feared the possibility of their invasion. However, we never expected them to have three pairs of legs, antennae, and a long beak that can penetrate a wheat plant and suck it dry. Feeding damage can cause up to 90% yield loss. The aphid also has potential for

transmitting several viral diseases of small grains.

The Russian wheat aphid entered the Texas panhandle in 1986 and moved through the midwest and western states into Canada (Webster et al. 1987). Damage to wheat was estimated at more than $200 million from 1986 to 1988. Like the cassava mealybug in Africa, this insect also left its natural enemies at home, somewhere in west Asia.

University and USDA scientists throughout the West are collaborating to develop an integrated management system combining the use of resistant cultivars, biological agents, and pesticides. Evaluation of U.S. cultivars of wheat and barley for resistance to the aphid at the USDA-ARS laboratory at Stillwater, Okla. did not identify any resistant germplasm. However, wheat from South Africa, Russia, and Iran did have resistance to this pest and will be used in breeding cultivars with genetic resistance to the aphids. The search for predators and parasites to control this pest will be done in the home range of the aphid in Pakistan, Iran, and Afganistan (Halbert 1989). It is obvious that it is in the best interests of U.S. agriculture to foster close ties with foreign countries, so that we can continue to obtain plant germplasm and beneficial insects needed to develop integrated insect management systems for crops in the United States.

Conclusions

Nations of the world are being drawn into a global economic, political, and technological web. Environmental issues are major concerns of all nations, developed and developing. Climatic change (greenhouse effect), desertification, ozone depletion, loss of biological diversity, and environmental degradation provide evidence that the biosphere is under great, and ever-increasing stress. Human war on nature, unlike a

nuclear war, is one of attrition over decades, rather than an immediate catastrophe.

This article has indicated some of the roles that entomolgists are playing in the development of sustainable agricultural systems in the developing world. These roles contribute to solving some of the environmental problems that seriously threaten the quality of life for humans on planet earth.

I have reported only a few examples of success in sustainable pest management systems in the developing world. There are others that have made major contributions toward alleviating disease, hunger, and malnutrition.

However, there is still much to be done. The future of sustainable systems of insect management in the world depends on an even greater level of international cooperation and a reversal in the current trend of decreasing financial support to international agriculture. It also depends on strong professional societies, many of which in recent years have formed under the guidance and encouragement of the Entomological Society of America. Indeed, members of the Entomological Society of America have had a strong influence on the development of entomology as a profession in the developing world.

References Cited

Belloti, A. C., O. Vargas H., B. Arias, O. Castano & C. Garcia. 1988. Cyrtomenus bergi Froeschner, a new pest of cassava: biology, ecology, and control. In 7th symposium of the International Society for Tropical Root Crops, Gosier (Guadeloupe), July 1-6, 1985. [ed.], Institut National de la Recherche Agronomique, Paris.

Bottrell, D. G. 1984. Government influence on pesticide use in developing countries. Insect Sci. Applic. 5: 151-155.

Brown, L. R. 1981. The worldwide loss of cropland, pp. 57-96. In R. G. Woods [ed.], Future dimensions of world food and population. Westview, Boulder, Colo.

Chelliah, S. & E. A. Heinrichs. 1980. Factors affecting insecticide-induced resurgence of the brown planthopper, Nilaparvata lugens on rice. Environ. Entomol. 9: 773-777.

Copplestone, J. F. 1977. A global view of pesticide safety, pp. 147-157. In D. L. Watson and A.W.A. Brown [eds.], Pesticide management and insecticide resistance. Academic, New York.

Cramer, H. H. 1967. Plant protection and world crop production. Pflanzenschutz-Nachr. Bayer 20: 3-254.

Dudal, R. 1976. Inventory of the major soils of the world with special reference to mineral stress hazards, pp. 3-13. In M. J. Wright [ed.], Plant adaptation to mineral stress in problem soils. A special publication of Cornell University Agriculture Experiment Station, Ithaca

Food and Agriculture Organization (FAO). 1988. Integrated pest management in rice in Indonesia. FAO. Jakarta.

Gerster, G. 1986. Tsetse--the deadly fly. National Geographic 170(6): 814-833.

Glass, E. 1988. Biological control of cassava pests in Africa, pp. 23-38. In Annual Report of the Consultative Group on International Agricultural Research, Washington, D.C.

Gupta, Y. P. 1986. Pesticide misuse in India. Ecologist 16: 36-39.

Halbert, S. 1989. Minutes of the Western Regional Coordinating Committee 66 on Biological Control Meeting held at Bozeman, Mont,, March 1. Cooperative States Research Service, USDA, and Montana State University. Minutes on file in the office of the Director, Idaho Agricultural Experiment Station, University of Idaho,

Moscow.

Hansen, M. 1987. Escape from the pesticide treadmill: alternatives to pesticides in developing countries. Institute for Consumer Policy Research, Mount Vernon, N.Y.

Heinrichs, E. A. & O. Mochida. 1984. From secondary to major pest status. The case of insecticide-induced rice brown planthopper, Nilaparvata lugens resurgence. Prot. Ecol. 7: 201-218.

Heinrichs, E. A., R. P. Basilio, & S. L. Valencia. 1984. Buprofezin, a selective insecticide for the management of rice planthoppers and leafhoppers. Environ. Entomol. 13: 515-521.

Heinrichs, E. A., F. G. Medrano, & H. R. Rapusas. 1985. Genetic evaluation for insect resistance in rice. International Rice Research Institute, Los Banos, Philippines.

Heinrichs, E. A., G. B. Aquino, S. Chelliah, S. L. Valencia, & W. H. Reissig. 1982. Resurgence of Nilaparvata lugens (Stål) populations as influenced by method and timing of insecticide applications in lowland rice. Environ. Entomol. 11: 78-84.

Herren, H. R. 1981. International Institute of Tropical Agriculture research brief 2: 4. Ibadan, Nigeria.

National Academy of Science (NAS). 1977. Supporting papers: World food and nutrition study. 1: 102-105.

Pimentel, D., J. Krummel, D. Gallahan, J. Hough, A. Merrill, I. Schreiner, P. Vittum, F. Koziol, E. Back, O. Yen & S. Fiance. 1978. Benefits and costs of pesticide use in U.S. food production. BioScience 28: 778-784.

Rabb, R. L. 1972. Principles and concepts of pest management, pp. 6-29. In Implementing practical pest management strategies. Proceedings of a national pest-management workshop. Purdue University, Lafayette, Indiana.

Romena, A. M. & E. A. Heinrichs. 1990. Wild rices Oryza spp. as sources of resistance to rice insects. Journal of Plant Protection in the Tropics. 6 :13-21.

Webster, J. A., K. J. Starks & R. L. Burton. 1987. Plant resistance studies with Diuraphis noxia (Mordvilko) (Homoptera: Aphididae), a new United States wheat pest. J. Econ. Entomol. 80: 944-949.

Wodageneh, A. 1985. Cassava and cassava pests in Africa. FAO Plant Prot. Bull. 33(3): 101-108.

Zelazny, B., L. Chiarappa & P. Kenmore. 1985. Integrated pest control in developing countries. FAO Plant Prot. Bull. 33(4): 147-157.

Acknowledgements

I thank the following colleagues who so generously provided me with literature and personal communication: A. C. Belloti, C. Delp, E. H. Glass, P. Matteson, D. Reed, A. Showler, and J. Webster.

E. A. Heinrichs. 1998. Entomology in the Developing World. Unpublished manuscript, 23 pages

Keywords: importance of insect pests, international agencies, FAO, WHO, UNDP, USDA, USAID, Rockefeller Foundation, Ford Foundation, farmers choose insecticides over more labor demanding control methods, pesticides and human health, rice insect pest management (IPM), International Rice Research Institute, cassava IPM, tsetse fly vector of sleeping sickness, migratory locusts, Russian wheat aphid