RADIATION ENTOMOLOGY: AN ESSENTIAL COMPONENT OF INTEGRATED CONTROL OF INSECT PESTS FOR INCREASED FOOD PRODUCTION

C. E. ANNOH AND D. A. ADABIE-GOMEZ
Biotechnology and Nuclear Agriculture Research Institute, Ghana Atomic Energy Commission
P.O. Box 80, Legon - Ghana

Summary

The application of nuclear technique for research and control programmes in insect science has been found to be one of the safest and environmentally friendly tools in food and agricultural research programmes. This paper discusses the role of Radiation Entomology in insect pests and vector management programmes for improved agriculture in some developed and developing countries. It highlights on the prospects of its application in the areas of Sterile Insect Technique (SIT) and Insect Disinfestation of stored products, with emphasis on research programmes going on at the Biotechnology and Nuclear Agriculture Research Institute (BNARI) of Ghana Atomic Energy Commission at Kwabenya.

Introduction

For several decades now, mankind has been battling with incessant threats caused by insect pests to crops, livestock and human health. Various methods have therefore been used to control these pests in order to improve upon health and ensure sustainable agricultural produce to feed the expanding population (Batra, 1982; Hill, 1983; Kumar, 1984; Stiling, 1985).

The use of insecticides has been one of the most effective methods to control insect pests and over 95% of the pests are controlled in this way. However, the misuse and overuse of insecticides has eventually created more problems among which are environmental pollution and insecticide-resistance.

In modern entomology, integrated method of control has been found to be one of the most effective approaches for pests and vector management (Barfield and Stimac, 1980; Flint and Vanden Bosch, 1981; Metcalf and Luckman, 1982; Youdeowei and Service, 1983). This involves the use of two or more methods of control strategies that are environmentally friendly, more target-specific, and relatively cost-effective.

The advancement of the peaceful uses of nuclear energy for research in agriculture has resulted in the use of radiation techniques on insects known as RADIATION ENTOMOLOGY. Ionizing radiation for pest control can be used in two ways:

i. Low to medium doses of radiations are applied to insects to induce sterility effect in their reproductive functions and this process is known as RADIOSTERILIZATION.
ii. In IRRADIATION DISINFESTATION technique, higher doses of radiation are applied to kill the insects of stored products.

This paper briefly reviews the role of Radiation Entomology in pests and disease vector control programmes in some developed and developing countries. It also discusses the prospects of its application in integrated pest management programme in Ghana to increase food production for the expanding population.

Evolution of Radio-sterilization

The idea of using sterile male insects in a natural population control, was first conceived by E.F. Knipling in 1938 for the possible control of the New World Screwworm (NWS) fly, *Cochliomyia hominivorax* (Coq.) a destructive livestock pest in the United States of America (IAEA Report, 1962). In the first attempts which were unsuccessful, a long time associate of Knipling read an article by J.J. Muller on genetic effects of radiation (Muller, 1950.). It was then that the method to sterilize insects finally became apparent.

Research activities began immediately on radiation in insects in Kerrville, Texas and by

1951, Bushland and Hopkins published their first scientific paper on induced sterility in insects (Bushland & Hopkins, 1951).

What Is Sterile Insect Technique (SIT)?

The Sterile Insect Technique (SIT) which is also known as sterile male technique (SMT) consists essentially in the rearing and releases of male insects, made sexually sterile by exposure to a gamma radiation source, in large numbers greater than those existing in the natural habitat. Continued releases of the sterile males increase the ratio of sterile to normals so that eventually suppression or eradication of the species results.

Application of Radio-Sterilization in Insect Pest Control Programmes

The New-World Screwworm (NWS) Eradication Programme

The best known and most successful SIT programme is the NWS eradication programme, which has been operational for over four decades now (Baumhover, 1958). The Screwworm fly, *Cochliomyia hominivorax* is an obligate dipterous; the principal host being cattle, sheep, goats and hog/pigs. Rabbits, squirrels, deers and even chicken also serve as hosts. Man is often attacked and death occurs in about 10% of human cases (Snow, 1988). A severe human case of myiasis - an infestation of animal wounds by the larvae of the fly is shown in Plate 1. The fly itself is harmless, but the larvae are destructive and deadly. They depend totally on the living tissue of host animals for survival. Its dispersal is usually caused by both migration and shipment of infested animals to market.

Plate 1.

In the Americas

Countries that have experienced complete eradication of screwworm fly include Curacao 1958, South Western USA 1959, Puerto Rico 1962, South Western USA 1963 and Mexico 1985. It is recorded that countries in the Americas alone made an estimated saving of about US $ 4,000 million as a result of the eradication programme (Krafsur *et al.*, 1987).

In North Africa (The Libyan Arab Jamahiriya)

Severe cases of myiasis were found in livestock in the Libyan Arab Jamahiriya in the spring of 1988. The larvae causing the myiasis were identified as the NWS, *Cochliomyia hominivorax*. The eradication programme was effected through shipment of already packaged sterile flies imported from Mexico. Release of sterile male flies began in mid-December 1990 and by early February 1991, 28 million flies were released weekly over the entire infested area of 28,000 square kilometres. Sterile fly releases ended on 18th October 1991 after a total of 1300 million sterile male flies had been released (Linquist and Abusowa, 1992).

The economic impact of this programme was very significant. Originally estimated to cost US $ 117.5 million in 1990, the actual eradication programme was completed in one instead of 2 years at the cost of US $ 66.6 million. This put the annual sub-regional benefit of the eradication programme at more that US $ 300 million.

SIT for Control of Fruit Flies: e.g., Mediterranean Fruit Fly, Ceratitis capitata (Wiedman)

The Mediterranean fruit fly (Medfly) is one of the most destructive insects affecting fruits in the world. It is wide spread and an important pest of tropical fruits in the Mediterranean area. The application of insecticides and parasites

have been used to control this pest but have not been very satisfactory. Insecticides have created problems of residues in food and even killed beneficial parasites and predators (IAEA Report, 1962). The use of SIT has however yielded very good results and led to complete control of the medfly in several countries including Tunisia (Cheikh *et al.*, 1975) Spain, Italy, Greece, (Louis *et al.*, 1987) and Israel (Nitzan *et al.*, 1992).

SIT for Tsetse Fly Control in Africa

Integrated control programmes using SIT component to control tsetsefly species have been successful in some African countries. These included the United Republic of Tanzania (Williamson *et al.*, 1983), Burkina Faso (Van der Vloedt *et al.*, 1980; Kabore and Bauer, 1987) and Nigeria (Takken *et al.*, 1986; Oladunmade *et al.*, 1990).

In The United Republic of Tanzania

The first large scale SIT field project involving the use of laboratory reared radiation sterilized tsetse flies was started at the later part of 1971 in the United Republic of Tanzania. The target species, was *Glossina morsitans morsitans*, colonized in the laboratory by using flies from pupae collected in the field. The fly colony was fed *in vivo* daily on goats and rabbits and the target area for the SIT test, was estimated at about 195 km^2 in size (Williamson *et al.*, 1983). Between November 1977 and January 1979, about 1.3 million puparia of *G morsitans morsitans* were produced in support of the SIT field experiment. The natural tsetse fly population was suppressed by aerial application of insecticide, endosulfan, before the release of sterile males. During the 15 months of fly release, a total of 510,000 papae were used at a cost of US $ 0.22 per pupa. The overall expenses in this operation was expected to reduce in future rearing programmes by converting to ***in vitro*** mebrance feeding system of colony flies (Williamson *et al.*, 1983).

On the Island of Zanzibar, in the United Republic of Tanzania, a major SIT programme had been initiated in 1993 to eradicate *G. austeni,* the only tsetse species on the island (Offori, 1993). The laboratory rearing facility in Tanga on the mainland, was being used to produce sterile flies for release in Zanzibar. Pilot releases using steriles male flies fed *in vitro* from the Tanga mass rearing facility have been started. Results to date indicated that the sterile male flies adapted and dispersed well within the target area in the Jozani forest. Eradication of *G. austeri* was expected to be completed within 2 years (Offori, 1993).

In Burkina Faso

Experimental studies were carried out in Burkina Faso between 1976 and 1984 aimed at testing and applying SIT for eradication of riverine and savannah tsetse flies. In a 5-year research programme, *Glossina palpalis gambiensis* was eradicated in a-100 km^2 area of a riverine forest. It was a combined application of a non-persistent insecticide, thiodan and release of laboratory reared sterile males of the target species (Politzar & Cuisance, 1982).

A large scale programme initiated in 1981 was directed against two riverine species of tsetse, *G.p. gambiensis* and *G. tachinoids* and one savannah species *G.m. submorsitans*. This was the first large scale tsetse SIT project directed against eradication of more than one species at the same time (Kabore and Bauer, 1987). The project covered 3500 km^2 of agropastoral land, including about 500 linear kilometers of riverine forest. The flies were fed *in vivo*(rabbits) and *in vitro* (on defibrinated bovine blood collected from the local abattoir). Releases of sterile male flies were done during the rainy seasons, first on a weekly basis but later fortnightly.

In all more than 900,000 sterile males (713,000 *G.p. gambiensis,* 225,000 *G. tachinoides*) were released. Complete eradication was achieved within 4 months.

In Nigeria

The project Biological Control of Tsetse Using the Sterile Insect Technique (BICOT) was started in 1979, and successfully completed in 1986. The main objective was to demonstrate the use of SIT in eradicating *Glossina palpalis palpalis* and to investigate ways of integrating the technology into the regular tsetse control operations in Nigeria (Offori, 1993) The target species, *G.p. palpalis*, was mass-reared using

both *in vivo* (guinea-pigs) and *in vitro* (fresh bovine and freeze dried porcine blood) feeding techniques. The target area of about 1500 km^2 in size was characterized by three major river systems. The natural population was suppressed using biconical traps and deltamethrin impregnated screens. This approach, already demonstrated in Burkina Faso, proved effective in reducing the population to as low as 5% of the original. Sterile male flies were then released at weekly intervals from predetermined points 2 km apart. Using the release ratio of 10:1 sterile males to nature males, eradication was achieved in 8-12 months by the end of 1986, in the target areas (Oladunmade *et al.*, 1990).

There are several other insects of economic importance on which ionizing radiation has been used or being studied extensively to suppress or eradicate their population. These are listed in Table 1.

The Biotechnology and Nuclear Agriculture Research Institute (BNARI) of Ghana Atomic Energy Commission (GAEC) in collaboration with Animal Research Institute (ARI) of Council

TABLE 1

Some insects against which radiation has been used or is being considered for their Control

Common Names/Scientific Names	*Country Controlled/Trials*	*References*
Australian Sheep blow fly *Lucilia cuprina (Wied) and Lucilia sericata*	Australia	IAEA Technical, Report 21 Insect Population control by the Sterile-Male Technique Vienna, 16-19 October 1962
New Guinea Screwworm *Chrysomyia bezziana Villen*	New Guinea and New Britain	- do -
Tropical OX. Warble or Tropical Warbe fly *Dermatobia hominis*	Central America and South America	- do -
Sugar-cane borer *Diatraca saccharalis* (Fab)	U.S.A.	- do -
Corn earworm *Heliothis zea*	U.S.A.	- do -
Fall armyworm *Laphygma frugiperda* (Smith)	U.S.A.	- do -
Queensland fruit fly *Dacus tyroni* (Frogg)	Eastern Australia	- do -
Olive fly *Dacus oleae* (Gmelin)	Greece, Italy and Israel	Hagen *et al.*, 1963
Codling moth *Carpocapea pomonella* (L.)	British Columbia All apple growing areas	Proverbs and Newton, 1962
European Corn borer *Ostrinia nubilalis* (Habn)	Europe	Walker and Brindley, 1963
Pink boll worm *Pectinophora gossypiella* (Saunders)	U.S.A.	Ouye *et al.*, 1964
Mexico fruit fly *Anastrepha ludens* (Loew)	Mexico	Christenson, 1962
Oriental fruit fly *Dacus dorsalis* (Hendel)	Rota Island near Guan	- do -
Melon fly *Dacus curcurbitae*(Coq)	Rota Island near Guan	- do -
Malaria Mosquito *Anopheles quadrimaculatus*	U.S.A	Weidhass *et al.*, 1962

for Scientific and Industrial Research (CSIR) and the Veterinary Services of the Ministry of Food and Agriculture are progressively developing the use of SIT as a component of integrated control of riverine tsetse fly populations in Ghana.

With the assistance of the International Atomic Energy Agency (IAEA) Technical Cooperation Programme, well-equipped laboratory rearing facilities have been established at BNARI and ARI. Colonies of two species of tsetse fly, *Glossina palpalis palpalis* and *G. tachinoides* have been established in the laboratories. Radiation studies on the flies in relation to their longevity, mating competitiveness, reproductive performance and their developmental process are being conducted. It is expected that with the installation of a new multi-purpose Gamma Irradiation Facility (GIF), the SIT programme will begin mass production of flies and subsequently perform trial releases of sterile male flies in the target sites in the Northern and Upper Regions of the country by the end of 1994.

It is hoped that in the near future the Institute would extend the SIT control programme to cover insects, such as, stem-borers, armyworm, mosquitoes and other insects of economic importance to enhance food production to feed the population.

Irradiation Disinfestation Studies in Ghana

Another significant role of Radiation Entomology is in food irradiation for disinfesting insects. Records on post harvest losses of food and stored-products in Ghana are very high and insect infestation is a major cause of post-harvest food loss. It is gratifying therefore to note that lethal doses of gamma radiation (up to about 0.5 kilo. Gray) can be applied to well-packaged food and agricultural stored products to disinfest insects without causing any undesirable residues in the food for human consumption(IAEA Report, 1991).

The development of suitable packaging materials for controlling re-infestation of irradiated products is very necessary. Some packaging materials found to be very effective to prevent post-irradiation infestation are polyvinyl chloride (PVC) bags and polythene (PE) lined jute bags (Bhuiya *et al.*, 1991).

At BNARI, Kwabenya, studies have been conducted on insects disinfestation of cowpeas, smoked fish and other stored products in different packaging materials to preserve these food items (Amoako Atta, 1979; Montford, unpublished; Appiah *et al.*, unpublished). A pilot study on the "Transfer of food Irradiation Technology to Industry" showed that no live larvae exited in holes on irradiated samples of fruits of egg-plant, that had been irradiated with a minimum dose of 0.5 kGy of gamma radiation in small polyethylene pouches (Appiah *et al.*, unpublished). It was further observed that smoke - dried herrings in low density polyethylene bags and irradiated at 1 kGy were without live insects. Further research studies are ongoing for conclusive results on both suitable packaging materials and acceptable radiation doses for different insects of stored products. There are prospects of embarking on irradiation disinfestation of stored products in commercial quantities at the Institute when the multi-purpose GIF begins full operation in the near future.

Conclusion

Radiation Entomology for integrated insect pest control is a good nuclear technology for mankind to exploit for increase food production and to improve his standard of living. The technique is simple and applicable in both developed and developing countries. Its application in the areas of radio-sterilization and insect disinfestation programmes is target-specific, no resistance is developed by the insects, it leaves no undesirable residues in foods, and it is, above all, environmentally safe.

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