Insects, isotopes and radiation

Wider use of nuclear techniques is expected in controlling harmful insects

by Donald A. Lindquist

Over 1 million species of insects inhabit the world, more than the total number of species of all other animals and plants combined. Fortunately for mankind, the vast majority of these insects are either beneficial or harmless. The relatively few species (15 000 or less) that are detrimental result in losses of 15-20% of the world's agricultural (plant and animal) production. These losses are from direct damage to plants and animals, as well as from diseases of plants and animals transmitted by insects. Very significant additional losses are caused by insects during storage of agricultural products. Other losses occur from human diseases, such as malaria, yellow fever, dengue, and onchocerciasis, that are transmitted by insects.

When there were few people in the world, the loss of food caused by insects was less important than today because the amount of available food was adequate for the population. Factors other than insects, of course, limited food availability. However, insects became much more important as the human population increased and plants and animals were domesticated to feed this increased human population. When animals or plants are produced in concentrated areas (monocultures) they provide a culinary feast for insects and result in a great increase in insect pest numbers. Food must be produced in this manner to feed the number of people in the world; thus agricultural products, both during production and storage, must be protected from insect attack (along with other pests, such as diseases, weeds, nematodes, rats, and birds). The total land in agricultural production used today to feed the world's approximately 5 billion people is considerably less than 1 hectare per person.

Modern insecticides were rapidly developed after World War II and provided plant and animal producers with an extremely powerful tool for use against insects. Insecticides provide the primary method of insect control; however, they are not completely satisfactory. Thus, alternative methods of insect control are required; these include host resistance, insect attractants, traps, inundative release of parasites and predators, biological insecticides, and the sterile insect technique, which will be discussed later.

Setting up tsetse traps in Nigeria. The project to control the tsetse fly in Nigeria, known as BICOT, has shown encouraging results. (Credit: E. Offori)

Integrated pest management

Integrated pest management (IPM) involving more than one control tactic has been developed and implemented in many parts of the world to more effectively utilize various insect control methods in an integrated fashion and to reduce over-dependence on insecticides. Utilizing natural control agents as much as possible, IPM depends to a large extent on observations of the number of damaging insects present; insect control (almost always insecticides) is only applied when these numbers reach a critical level (the economic threshold). IPM usually is applied on an individual field or farm basis, a procedure that frequently reduces the amount of insecticides used and the rate at which insects become resistant to them.

Area-wide control

While IPM emphasizes insect control on an individual field or farm basis, insects can be controlled over large areas, regardless of land ownership or

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whether crops are produced. The objective of "area-wide insect control" under most situations is preventative control, in that the pest insects are controlled at their source before they move into farmers' fields. Certain insects, such as locusts, tsetse flies, mosquitoes, and some pest *Lepidoptera* (which attack many food grains) are more amenable to area-wide control at less cost than field-by-field control. In some cases, the insect pests are present in a very small area and frequently on wild host plants before they move to farmers' fields. Applying control technologies when insects are concentrated in small areas is very effective in reducing control costs later in the season. Unfortunately, preventative insect control has not received the attention that it should have.

Eradication of an insect species from a defined area is always approached from an area-wide basis. While eradication is applicable in relatively few situations, its economics are very favourable. The sterile insect technique (SIT), which uses radiation to sexually sterilize insects and prevent reproduction, is particularly effective in eradication programmes.

Research scientists are developing a number of new or alternative methods of insect control. Most of these are applicable only on an area-wide basis. These include the SIT; the use of insect pheromones (sex attractants) to prevent mating by confusing insects so that males and females cannot get together; other types of chemical attractants; traps; and inundative release of parasites and predators. Host plant resistance is also most effective when applied on an area-wide basis.

Farmers or producers with very small holdings have much more difficulty in controlling insects than those with large holdings. The small producer frequently lacks resources for insect control and is also to a great extent at the mercy of insect control measures taken by neighbours. If they do not use effective ones, the small producer will suffer a serious insect problem.

Isotopes and radiation

The Joint Division of the IAEA and Food and Agriculture Organization (FAO) has been involved in the use of isotopes and radiation in insect control since 1964. Isotopes are used as tags or markers, for instance, of chemical molecules, insects, or plants. For example, with these tags one can follow the fate of insecticides within insects and the environment; the incorporation of nutrients into the insect; and the movements of insects under field conditions. They also can mark plants on which insects feed so that the quantity of consumed food can be measured and directly correlated with plant resistance. They can be used as well to follow parasites and predators of insects — for example, their movements, numbers, and ability to help control insect pests.

In a SIT operation, radiation is used to sexually sterilize insects. The SIT is the largest part of the programme of the Insect and Pest Control Section of the Joint FAO/IAEA Division. Radiation is also used in insect studies including genetics, genetic engineering, microbial control, quarantine treatments of agricultural commodities, and induction of mutants in plants to breed resistant varieties.

The sterile insect technique

The discovery that X-rays or gamma radiation could cause sufficient genetic damage to insect reproductive systems to induce sterility resulted from work conducted by H.J. Muller starting in the 1920s. Muller won a Nobel Prize for his work on the genetic effects of irradiation in insects. The sterilizing effect of radiation was noted by scientists of the US Department of Agriculture who had been seeking a method to sterilize insects for many years. These scientists had theorized that if large numbers of the target insect species were reared, sterilized, and released into the field, the sterile insects would mate with the wild insects. These matings would result in no offspring and thus a decline in the population would be obtained. They calculated that if sufficient numbers of sterile insects were released, the reproductive rate for the wild population would rapidly decline and reach zero. In simple language, birth control of insects. Radiation sterilization was the answer.

The first demonstration of this technology was the eradication of the screwworm from the Dutch island of Curaçao in 1954. The programme was conducted by scientists of the US Department of Agriculture in co-operation with the Dutch Government. Thus, the initial SIT project was international, and to a large extent, operational SIT projects since then have remained international in scope.

At the present time, there are approximately 10 species of insect pests being attacked by the SIT. Research and development is being conducted on other insect species and it is anticipated that the technology will be more widely used in the future. It is applicable for area-wide insect eradication, quarantine, and, in some cases, control. It is not applicable on an individual field or farm

FAO/IAEA Symposium, November 1987

In November 1987, the IAEA and FAO are jointly sponsoring a major scientific gathering — the International Symposium on Modern Insect Control: Nuclear Techniques and Biotechnology. It is anticipated that participants will present data on emerging new insect control technologies, as well as important information about changing insect problems in developing countries. The exchange of views and scientific information is expected to help identify new problems, potential solutions, and opportunities for technology transfer — all towards the goal of less expensive, sustainable agricultural production.

The symposium is being held in Vienna, Austria, from 16-20 November. Further information may be obtained from IAEA Conference Services, or by writing the Insect and Pest Control Section of the Joint FAO/IAEA Division, A-1400 Vienna, Austria.

basis. Therefore, SIT programmes tend to be large and, as a result, are considered expensive when viewed from the programme's total cost. However, when applied against very damaging and widely dispersed insects the cost per unit area of land or production area is frequently less than the cost of each individual field being treated separately by other technologies. Further, economics favour eradication in many situations.

Since the SIT is species specific, the selection of the insect pest or group of pests on which to work is of primary importance. It must be very destructive and its control or eradication (of the single species or group of species) must put money into the farmer's pocket. When more than one species is attacked at the same time, they are usually closely related and the mass-rearing procedures are quite similar.

More use of the SIT will result from increased efficacy and improvement in economics. This continues to show that when applied against an appropriate insect or insects, the technique is more cost efficient than other technologies. Additional factors favouring its use include the growing problem of insect populations that become resistant to insecticides, and concerns about environmental damage caused by continuous annual use of insecticides to control the same insect species.

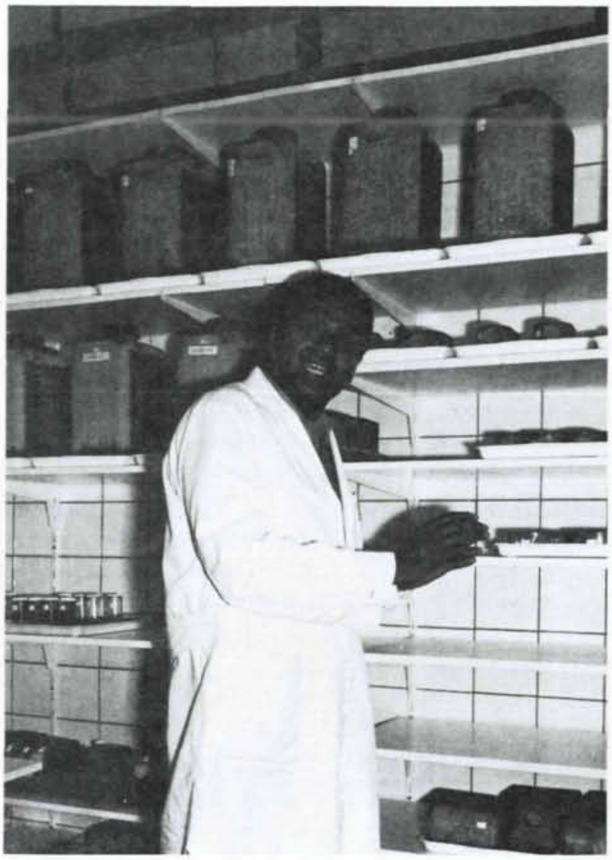
The Joint FAO/IAEA insect pest programme

The selection of the species (the problem) for applying the SIT is of primary importance. This selection process, and subsequent actions by the IAEA and FAO, are based on the many tools available within the agencies to assist Member States. A technical section is the only organizational unit where *all* the tools can be brought together and co-ordinated for the purpose of technology transfer to solve a specific problem in a Member State. In addition to the technical expertise available within a section, the tools range from advisory bodies to training support programmes to research contracts.*

The Joint FAO/IAEA Division also has access to some tools from FAO, including its associate professional officer programme and technical co-operation projects. In addition, access to expertise in, and co-operation with, FAO technical divisions is very valuable.

Very few of all these tools are under the direct control of a technical section. Consequently, the section must plan several years in advance and keep many people informed about progress, needs, and problems of individual projects. In the case of the Joint Division, this planning and information flow involves both the IAEA and FAO.

* A detailed list of available tools in this case would include individual consultants; consultant groups; advisory groups; sabbatical leave personnel; training (fellowships for individual specialized training); training courses; study tours; scientific visits; research contracts; research agreements; technical contracts; research co-ordination meetings; symposia; seminars; technical co-operation projects (expert services; consultants; equipment); cost-free experts; and support by the Agency's Laboratory at Seibersdorf, Austria.



The IAEA's entomology laboratory at Seibersdorf is supporting research and development of the sterile insect technique for the eradication of insect pests. Here, a visiting scientist from Zambia checks on tsetse flies used in experiments.

Project in Nigeria

A co-operative project betweent the IAEA, FAO, and Nigeria — known as BICOT — seeks to develop the SIT for use against *Glossina palpalis palpalis*, one of the tsetse fly vectors of animal trypanosomiasis. Nagana, or animal trypanosomiasis, is a major deterrent to agricultural development in much of Africa. Tsetse eradication is an excellent method of controlling the disease. Through this large-scale research and development effort, the target species has been eradicated from the 1500 square kilometres that constitute the project area in north-central Nigeria.

All the tools referred to earlier, including those made available by FAO, have been utilized in developing and implementing BICOT. Training has played a major role in the project. At least partially because of this training, and the confidence that the Government of Nigeria has in trained Nigerian personnel associated with the project, the Nigerian Government has requested that the project be expanded to include all of the agricultural development and livestock grazing project in Plateau State, a total of 12 000 square kilometres. This expansion, BICOT-II, again will require the use of tools available from the Agency and FAO for successful implementation.

Support of IAEA's Seibersdorf Laboratory

The entomology unit of the Agency's Seibersdorf Laboratory provides invaluable research and development support for field projects and co-ordinated research programmes. In addition, essential training, which cannot be obtained at other locations, is continuously provided by this unit, through facilities made available by the IAEA and FAO to support SIT projects and isotope applications in entomology.

In the case of BICOT, seven Nigerians have received training at Seibersdorf and several others were trained elsewhere. Specialized equipment has been developed and fabricated at Seibersdorf and sent to Nigeria. Greatly improved tsetse rearing methods that were developed at Seibersdorf and transferred to Nigeria have significantly reduced the cost of tsetse rearing. A biological evaluation system to measure the progress of eradication also has been developed at Seibersdorf and is currently being used in BICOT and other field projects. A back-up colony of tsetse flies has been maintained at Seibersdorf and several hundred thousand surplus insects have been sent to Nigeria as an adjunct to the locally produced tsetse flies.

The entomology unit also actively supports SIT field programmes for eradication of the Mediterranean fruit fly (medfly). Action programmes require the mass-rearing of this insect in huge numbers. A mass-rearing factory at Tapachula, Mexico, produces 500 million or more medflies per week. About half of these are males. The SIT was used to eradicate the medfly from Mexico, and now sterile flies are being released in Guatemala to eradicate the pest from that country. Rearing costs (diet ingredients, materials, salaries) are about US $100 per million flies.

At Seibersdorf, major emphasis is placed on developing a genetically altered medfly strain in which the females can be selectively killed in the egg or very early larval stage. Medfly females add little or nothing to the efficacy of the SIT. With the genetic sexing strain, 500 million males could be reared at Tapachula for about the same cost as the 250 million males presently being reared. Thus, a significant savings (about 40%) in medfly mass-rearing can be achieved with a genetic sexing strain. In addition, the release of only sterile males, instead of both sexes as is now done, will increase the efficacy of the technology. Reduced costs of aerial release of sterile flies also will be achieved.

Development research for additional savings involves re-using the medfly larval rearing diet (which appears possible without loss of quantity or quality of the reared insects). The cost of the larval diet to rear medflies at Tapachula is approximately US $25 per million. Re-using the larval diet once would save about 40% of this, or US $260 000 per year.

When the SIT is used for medfly eradication, reducing the wild medfly population before the release of the sterile flies is frequently required for economic reasons. The current method is one or two aerial applications of an insecticide bait spray. Although the insecticide, malathion, is very safe, it does have mild transitory environmental effects. When very large areas are sprayed, it causes some concern which, on occasion, results in serious problems in programme operation. A project at Seibersdorf is to determine whether a strain of the biocontrol agent, *Bacillus thuringiensis (B.t.)*, can replace malathion in bait sprays. Laboratory data are very positive. There is a reasonable chance that an effective *B.t.* strain can be developed to replace malathion in bait sprays against the medfly before release of sterile insects.

Results and challenges

Efforts by the IAEA and FAO to transfer the SIT technology to developing countries have been reasonably successful. The technical results have been excellent. One major benefit of projects such as BICOT is the increased capability of local organizations and staff to handle area-wide insect control programmes. This capability is becoming much more important, not only for insect control within a country but also for quarantine problems relating to export of agricultural commodities. Insects frequently prevent export because of quarantines against them in receiving countries. The elimination of newly introduced insect pests is becoming much more important as agricultural trade increases. The experience gained by local organizations in SIT projects is directly applicable to solving this problem.

One area needing significant improvement in this process of technology transfer is management. Experience and training opportunities in management of the type required for SIT programmes is scarce or nonexistent in developing countries. Yet management is as important as technical expertise in operation of SIT projects.

Another area which needs improvement is refresher courses for some individuals who have already received Agency training. Training should be viewed as a continuous process. The cost may appear high, but the cost of not subscribing to refresher training is higher.