Atoms for pest control

by D.A. Lindquist* and co-workers

Insects cause losses estimated at between 8% and 20% of total production of crops and livestock throughout the world.

With the aim of developing technologies which can reduce such losses, the Insect and Pest Control Section of the Joint FAO/IAEA Division actively sponsors projects and conducts research through the Entomology Section of the Agricultural Biotechnology Laboratory at Seibersdorf. In its work, the Section has placed considerable emphasis on the Sterile Insect Technique (SIT). This technique involves the sterilization and release of large numbers of insects of the target species into the area where control is to be achieved. There, the sterile insects mate with the fertile wild insects, which produce no progeny: the technique is thus a highly specific form of "birth control". It is being used against a number of pest species in several countries.

An important requirement is that insects of the target species be produced in large numbers. Thus, one of the main activities of the laboratory is to develop methods of mass-rearing insects that are to be controlled using the SIT. Most research during the past two decades has been carried out on the tsetse fly and the Mediterranean fruit fly.

A second aspect of the Section's work is the use of radioisotopes and stable isotopes, which are valuable tools in the study of insect ecology and behaviour. Immigration and migration of insects are readily studied using isotope techniques. Isotopes also play a very important rôle in determining the efficacy of various parasites and predators.

The tsetse fly

The tsetse fly is the sole vector of animal and human trypanosomiasis (sleeping sickness), a disease which has had a devastating effect for many years on the development of human and agricultural resources in Africa. For more than 15 years, the Insect and Pest Control Section has been active in developing the Sterile Insect Technique (SIT) to eradicate tsetse flies. Research has been conducted both at the Seibersdorf Laboratory and by research contractors in Member States including Nigeria, where an Agency-sponsored tsetse eradication programme is currently in progress.

Mass-rearing of two economically most important species of tsetse flies (*Glossina morsitans* and *Glossina palpalis*) has been conducted in two phases. First, relevant equipment was designed, methods were developed, and the reproductive biology of insects was studied under standardized environmental conditions using living animals as a blood source – a procedure often referred to as *in vivo* feeding. A very efficient *in vivo* system has been available since 1979.

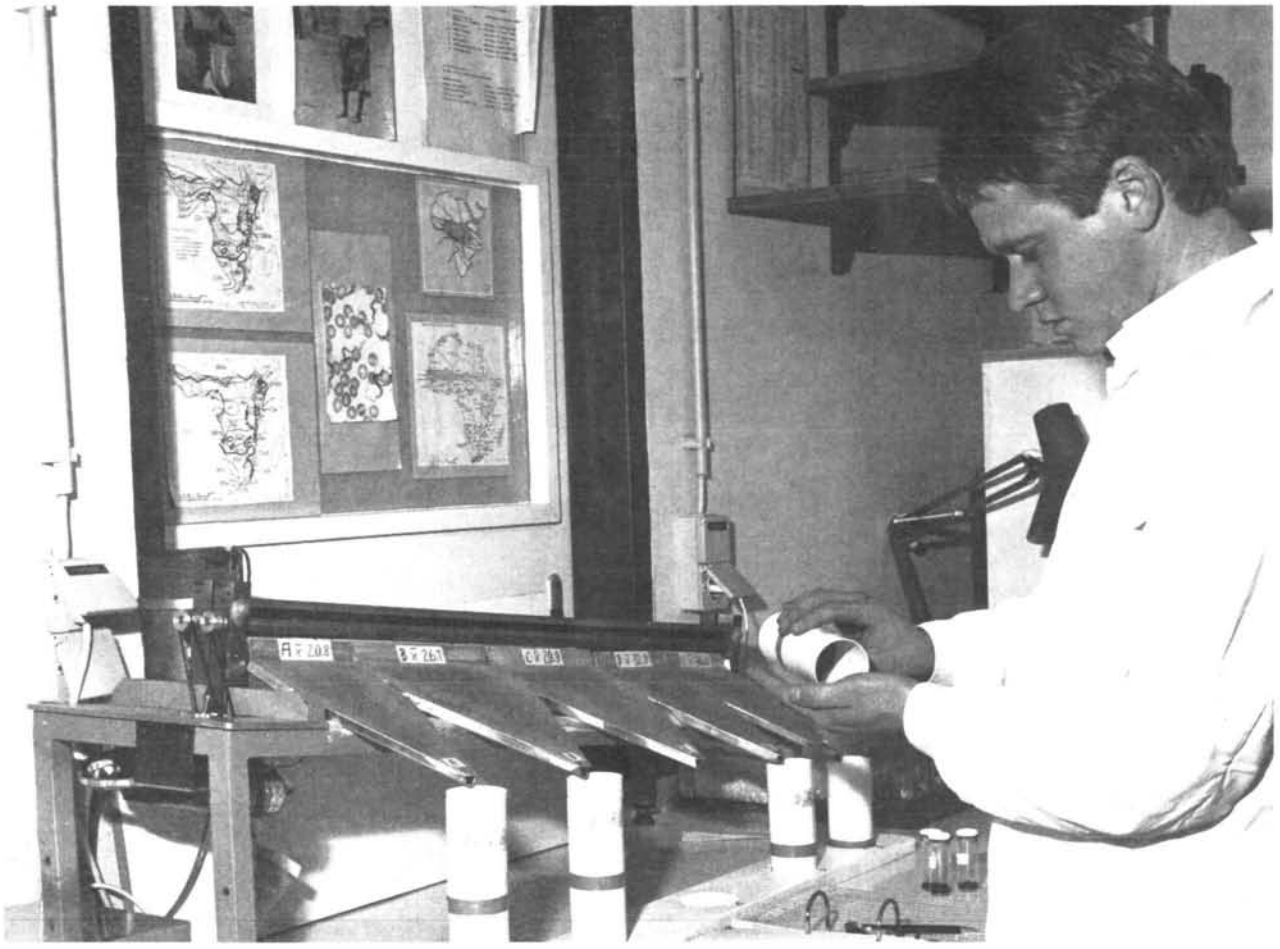
During the second phase of the rearing programme, emphasis was placed on the development of an *in vitro* feeding system to replace living animals. This uses silicone membranes to simulate the skin of the host animal, covering defibrinated whole blood taken from cows and pigs. Systematic improvements in diet preparation and membrane feeding procedures, coupled with strict application of criteria to determine the suitability of blood preserved in different ways, has made possible the mass-rearing, *in vitro*, of several tsetse species with efficiency and performance comparable to *in vivo* rearing.

Basic studies on the nutritional requirements of tsetse have indicated that flies do not require intact cells and hemolysed blood. These findings have given impetus to the development of diets prepared from freeze-dried blood. Improvements in producing, testing and storing freeze-dried blood have made it possible to prepare blood quite cheaply, store it for at least a year before use and to ship the material anywhere in the world.

The technology and equipment developed at Seibersdorf for both *in vitro* and *in vivo* rearing of tsetse flies have been transferred to the BICOT facility in Nigeria, where they are being used as part of an on-going SIT programme.

Attempts have also been made to circumvent the economic and logistic problems associated with currently available methods of feeding tsetse. To this end, alternatives to the use of whole blood for the feeding of tsetse flies are being sought. Research at the Seibersdorf laboratory has already resulted in the development of a semi-defined synthetic diet which has been shown to be satisfactory for the rearing of a number of species of tsetse. The diet, which is composed of commercially available ingredients, is the first synthetic diet of its type anywhere for a blood-sucking insect. Work is continuing to reduce the complexity of the dietary ingredients, and to make the diet as inexpensive as possible. The aim is to develop a cheap diet, composed of simple ingredients, which can be easily sterilized, stored and handled.

* Mr Lindquist is Head of the Insect and Pest Control Section of the Joint FAO/IAEA Division.



A technician at the Seibersdorf laboratory operates a machine which sorts the puparia of the tsetse fly according to their size.

A practical artificial diet for tsetse flies would find application not only in the mass-rearing of tsetse but also in studying the nutrition and metabolism of the fly, in testing the physiological effects of various compounds, in investigating the development of trypanosomes in the fly and in rearing other haematophagous insects.

BICOT

On 3 June 1977 the Federal Nigerian Government and the IAEA signed an agreement which gave birth to a project for the Biological Control of Tsetse by the Sterile Insect Technique, popularly known as BICOT. Headquartered in Vom, in Plateau State, Nigeria, BICOT became operational in January 1979. By that date, basic amenities had been provided for colonizing *Glossina palpalis palpalis*, the target species of tsetse. A number of staff were seconded to the project by the Federal Department of Pest Control Services, and by the Nigerian Institute for Trypanosomiasis Research. Financial support has since been provided by the Federal Nigerian Government and contributions have been made by Belgium, Italy, the Federal Republic of Germany, Sweden, and the United Kingdom. These generous contributions have made it possible to purchase needed equipment, supplies and vehicles, and to hire expert services.

The primary objective of the project is to investigate the advantages, efficacy and economics of the SIT for eradicating *G.p.palpalis*, and to work out a protocol for incorporating the technique into overall tsetse and trypanosomiasis control programmes in Nigerian and other African countries which are affected.

The area selected for fly release lies some 200 km south of Vom, within a major agricultural development project area, and covers approximately 1500 km^2 traversed by complex river systems. Intensive farming on the southern and western boundaries of the area provides a barrier against possible infiltration of flies from outside, once the area is freed of tsetse.

Since the inception of the project, considerable effort has been expended to mass-rear the target species, to undertake an extensive survey of the project area, to strengthen the near-natural barriers through the use of biconical traps, judicious and limited spraying of insecticides on the periphery, and the placement of

insecticide-impregnated screens at vantage points on the numerous tributaries of the two major river systems feeding the project area.

Both *in vivo* and *in vitro* rearing systems are used to maintain the colony of *G.p.palpalis*, which now contains about 70 000 females. This number of females yields approximately 5000 surplus males every week for irradiation and release in the field. Most of the research in support of BICOT is carried out at the laboratory in Seibersdorf, where a colony of about 50 000 females is also maintained as "back-up" for BICOT. Every fortnight, flies (as pupae) from the Seibersdorf colony are made available to BICOT, partly to boost the producing colony and partly to supply additional surplus males for release in the field. Most of the southern and central portions of the project area, constituting more than 50% of the "hot spots", have now been subjected to releases of sterile males, with excellent results: complete eradication has been achieved in some isolated forest patches. By the end of 1984, the entire 1500 km^2 area will have been covered.

The achievements of BICOT to date, coupled with the results of similar experiments in Upper Volta, have demonstrated beyond question the technical feasibility of eradicating riverine species of tsetse using the SIT, when it is combined with trapping devices and the limited use of insecticides presented on screens. The cost-competitiveness of the BICOT operations with traditional tsetse control methods has yet to be determined; however, preliminary data from a similar project in Upper Volta show that the technique is economically competitive with insecticides in eradicating *Glossina palpalis gambiensis*.

Of the 55-man BICOT staff, only two are international experts provided by the IAEA. To date, eight of the Nigerian staff have received training at Seibersdorf in tsetse mass-rearing and irradiation techniques.

What does the future hold for BICOT? Success in eradicating the target tsetse species from an area of 1500 km^2 must not be considered the end, but only the beginning of a larger programme. That the project is located within the 9400 km^2 Lafia Agricultural Development Area, and close to potential cattle grazing and pasture land, is sufficient reason for considering extending BICOT activities beyond the target date of December 1984. The potential gains from such an extension are obvious. Secondly, BICOT could serve the vital rôle of becoming the main training ground for nationals from the ever-increasing number of African countries desirous of applying the SIT as a component of their national and regional tsetse control programmes. Should this latter expectation be realized, BICOT would have fulfilled more than was conceived under the original objective.

The Mediterranean fruit fly

The Mediterranean fruit fly (*Ceratitis capitata*, more commonly known as the Medfly) is one of the most devastating insect pests of citrus, stone fruit and many other fruits and some vegetables in the world. Some countries where this insect pest does not exist refuse to import fruits and vegetables from countries where it does. Quarantine rules are strictly enforced, and thus can have a significant effect on exports.

The development of the SIT for use against the Medly has been actively supported by the Insect and Pest Control Section for many years. Field tests have been sponsored in Italy, Spain and other Mediterranean countries. When the Medfly invaded Mexico and neighbouring Guatemala, the Agency was requested to assist in transferring the SIT technology to Mexico. This was accomplished, in co-operation with the USA; the Medfly Eradication Programme successfully eliminated the pest from Mexico, preventing losses estimated at more than US$ 500 million a year. The Mexican programme is continuing, with the objective of eliminating the pest from Guatemala. A similar, but smaller-scale, programme supported by Italy was begun in Peru in 1982, the primary aim being to eradicate the Medfly from two major fruit-growing valleys in southern Peru.

MISR-MED

Following the success of the Medfly Eradication Programme in Mexico, a similar programme has been initiated in Egypt. On 16 October 1983 the IAEA signed an agreement with the Government of Egypt, with the express purpose of eradicating the Medfly from Egypt. An Integrated Pest Management (IPM) approach involving the use of bait sprays, suitable quarantine procedures, and the release of sterile Medflies is being used. The programme, named MISR-MED, has its headquarters in Alexandria, Egypt. Because of its economic feasibility, environmental acceptability and effectiveness for eradication, the SIT is an ideal system for the core of the IPM programme. The programme is being supported by Austria and Italy.

Within the first 18 months of the project a facility capable of mass-rearing 1000 million Medflies per week will be constructed, methods of sterilizing, packaging, and releasing flies will be developed, a pre-eradication field survey will be completed, and an appropriate infrastructure to carry out the eradication programme will be developed. A programme for training staff in SIT procedures has been initiated.

Following eradication of the Medfly in Egypt, MISR-MED expertise and production will be available to countries of the Mediterranean basin and Middle East.

The Seibersdorf Medfly programme

The Medfly programme at Seibersdorf involves several lines of research designed to define the rearing conditions to be implemented in the programme in Egypt. Investigations are in progress to determine the suitability of

ingredients from Egypt, such as bran, yeast and molasses, for developing diets for fly larvae. Given a nutritionally acceptable larval diet, factors such as texture, water content and depth of medium need to be determined accurately, as these affect the rate of larval development and dissipation of heat in the medium. Control of temperature in the larval diet is of critical importance. Progress has been made during the last few months in defining a diet in which temperature is kept to an acceptable level, and from which a high production of good pupae is obtainable.

Two different systems of recovering mature larvae from the diet are currently used in Medfly mass-production facilities. In one, mature larvae are mechanically separated from the diet, while in the other mature larvae are recovered as they leave the diet voluntarily by jumping. These two systems will be compared to determine which yields better quality pupae, and which is most suitable under Egyptian conditions.

A major activity concerns the development of a "starter diet". In this system, mature eggs are placed for two days on a small amount of a highly nutritious diet, and the young larvae which emerge are then transferred to the normal bran-based diet. Successful development of a starter diet would save a significant amount of space in the Egyptian factory, and may also be essential for the implementation of a genetic sexing system which is currently being developed. Progress has been more than encouraging, indicating that a successful starter diet will soon become available for use in Egypt.

Only the sterile males are important in the reduction of the breeding potential of the native population in a sterile insect release programme. The release of sterile Medfly females may actually be detrimental, since the sterile females "sting" fruits in attempting to lay eggs in them, even though these females do not produce eggs. Therefore, it is advantageous to release sterile males only. Secondly, if it were possible to rear and release only males there would be substantial savings in rearing costs.

For these reasons, a programme was initiated at the laboratory in April 1983 to develop a genetic sexing mechanism for the Medfly. One approach involves the determination of the temperature tolerance of strains of Medfly, the idea being that a sex-discriminating temperature might be used to eliminate the females.

When the temperature-sensitive factors have been isolated, the next stage will consist in transferring these factors onto the male-determining chromosome, and testing the new strain through mass-rearing.

Application of isotopes in pest management

The Insect and Pest Control Section has been actively involved since 1982 in a United Nations Development Programme (UNDP)/IAEA project in Indonesia aimed at using isotopes and radiation techniques to increase agricultural production. An expert assigned to the project during the past 12 months has established a functional radioisotope laboratory at the project headquarters in BATAN, Jakarta, for studying the ecology and feeding behaviour of rice insects and other crop pests. During this period, considerable progress has also been achieved both in training Indonesian entomologists in the design, execution, and interpretation of results of experiments involving the use of isotopes, and in developing and testing new labelling techniques suited to the local conditions in Indonesia. For example, experiments have been designed aimed at facilitating the labelling of paddy rice through the ^{32}P labelling of corn oil. Using autoradiography techniques, the feeding patterns of both the brown planthopper and the green leafhopper have been determined. The aim is to establish the cause of resistance of rice varieties to these pests. The indication is that resistance in both cases is caused by inhibition of feeding.

One significant achievement in this context has been the development of a new dry vial/scintillation counting system, which has proved superior to the standard GM counting system in counting efficiency. When finally refined, the method could be recommended for universal application: the local entomologists and the expert involved in the project would thus have made a major contribution.

Training

A major activity of the Insect and Pest Control Section during the past 20 years has been the training of a cadre of entomologists, from developing Member States, with the aim of increasing their competence in applying nuclear techniques for insect pest management. To date, more than 150 scientists from 42 countries have benefited from the Agency's regular training programme in entomology; and since 1963, when the Joint FAO/IAEA biennial, eight-week training course was initiated in collaboration with the University of Florida, and the US Department of Energy and Agriculture, 179 entomologists from 67 countries have participated in the programme. In addition, more than 40 scientists involved in SIT-related programmes have benefited from short-term training provided by the Entomology Laboratory at Seibersdorf.