sider what steps should be taken to protect agricultural interests against any adverse effects. Referring to the record of safety achieved so far, Mr. Wortley concluded that agriculture had little to fear and much to gain from the successful development of an atomic energy industry if the well-laid plans of the present continued to be followed.

In a paper on the waste management implications of nuclear site selection, J. F. Honstead and J. Beranek (IAEA) said that while in general site selection would ultimately be guided by criteria other than waste management, the decision could have considerable influence on the waste problem, including the cost of waste management operations. "The concern for keeping the cost of waste handling problems to a minimum", they said, "requires that one maintains an awareness of how site characteristics affect the budget." Each of the three main approaches to the waste problem - absolute containment, delay storage to permit radioactive decay and dispersion of low-level waste in the environment - was affected to some degree by site characteristics, and the appropriate waste management system must be based on a study of these characteristics.

At the final session Mr. Balligand, in a closing speech, said that the meeting had confirmed the impression that the security of nuclear sites from the point of view of public health was extremely well supervised all over the world. The symposium had provided an opportunity not only for the pooling of information on past experience and current practice but also for an exchange of ideas for the formulation of more widely applicable criteria than existed at present. After the proceedings had been carefully studied it would be possible for IAEA to formulate recommendations, which would be submitted to a small working group of experts and later published as an Agency document. Mr. Balligand emphasized, however, that before universal rules could be framed the main task was to collect the maximum possible information and study individual cases with the help of small groups of experts. The Agency, he pointed out, had already provided such expert groups to advise on specific problems at the request of Member States.

NUCLEAR ENERGY AGAINST INSECT PESTS

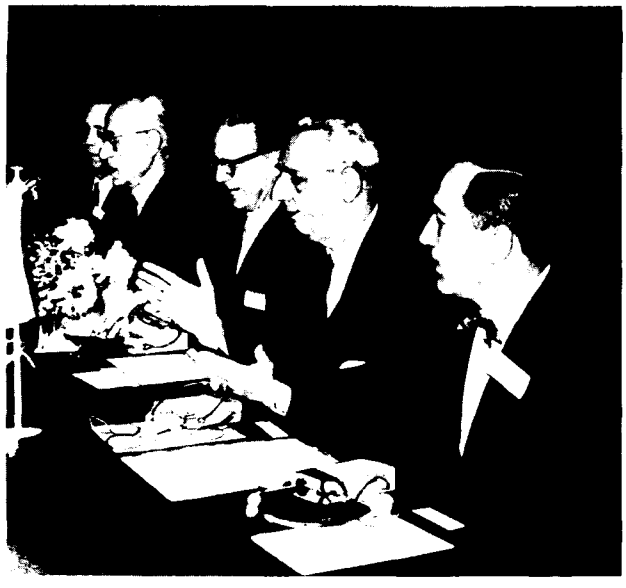
Twice within just over two and a half years, the International Atomic Energy Agency has convened scientific symposia on the use of nuclear energy to combat insect pests. The second of these - on the Use and Application of Radioisotopes and Radiation in the Control of Plant and Animal Insect Pests, held in Athens last April and jointly organized by IAEA and FAO with the co-operation of the Greek Government - confirmed even more clearly than the first meeting (Bombay, December 1960) that nuclear energy is a fully established tool in the struggle for the protection of human food resources.

In this struggle, nuclear energy in the form of radioisotopes is fulfilling a number of different, but altogether complementary, roles.

A prerequisite for any effective control, or possibly eradication, of harmful insects is knowledge of their ecology, of their breeding and feeding habits, their dispersal and migration, and of insect-plant relationships. Radioisotope techniques, in particular tagging, have provided an effective means for these studies.

Among striking illustrations of the usefulness of tagging given during the symposium in Athens were those described by C. Courtois and J. Lecomte

At the opening session of the Athens symposium: (left to right) Dr. C. Logothetis (FAO); Mr. D. Vourdoubas, Greek Minister of Agriculture; Prof. A.N. Rylov, IAEA Deputy Director General in charge of Training and Technical Information; Prof. G. Pantazis, Vice-President of the Greek Atomic Energy Commission; and Dr. M. Fried (IAEA)



(France). They stated that thanks to the food exchange habits of bees, it had been possible to mark with the short-lived radioisotope gold-198 the entire 40 000 inhabitants of a beehive within less than 48 hours. For four to five days after the start of the tagging it was then possible to observe the movement of the marked bees.

These are some of the results obtained by the French scientists. Working bees do not, as a rule, fly further afield from their hives than one km; the majority of the tagged bees were, in fact, caught within a 600-metre radius. They do not search for honey in a haphazard way, but follow specific routes determined by topography, vegetation and other factors. Returning with food, the working bees tend to deliver it at the centre of the hive where queen bees usually stay. From there the food is distributed to other inhabitants of the hive nearer the periphery. Investigations carried out with radioactive phosphorus-32 have established the fact that male bees, while able to nourish themselves to a certain extent, prefer to be fed by worker bees whenever these are present. Queen bees pass on food to worker bees, but only to a very small number of some two dozen specialized workers.

Gold-198 was used also in research work on the habits of ants. The most interesting finding of an early study quoted at Athens was that an exchange of food takes place between nests more than 50 metres apart and belonging to different species of ants. A subsequent study revealed a division of responsibility within the ants' nests: the tagged ants were found invariably to explore the same run and to have little contact with other individuals of the same colony. In the same experiment abnormal radioactivity was noted in the ants prior to any labelling. This would, it was stated, seem to point to accumulation of radioactive fall-out in ants' nests.

Phosphorus-32 and iodine-131 have been used also by a group of German scientists to study the feeding habits of ants and termites. According to a report presented by W. Kloft (Fed. Rep. of Germany) ants transmit food from one nest to another within certain limited areas, and it appears that insects living in well-organized groups are able to make better use of their food and consequently live longer than isolated individuals. Another discovery is that during winter ants store food reserves in the bodies of a number of specially fattened individuals.

Another experiment carried out with phosphorus-32 by M.S. Quraishi (Iran) has shown that the female of a species of mosquitoes mates more than once and that the insect disperses from a point of release to distances of up to 4.5 km. Indications as to the length of the life of mosquitoes have also been obtained. Mr. Quraishi further described results obtained with the same labelling method in studying the behaviour of a wheat pest which causes serious grain losses in Pakistan and the Middle East.

Sterile Male Technique

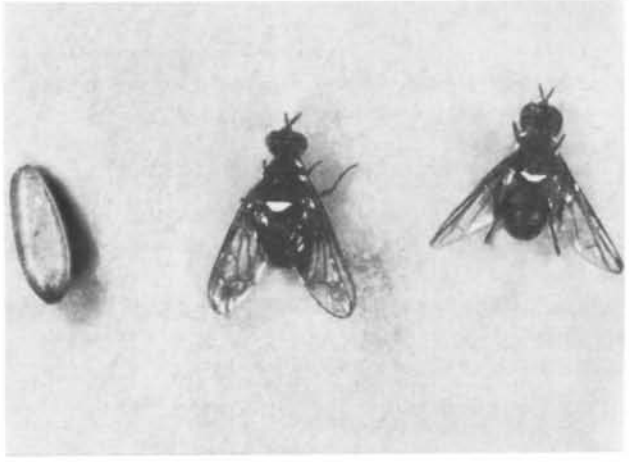
The eradication of the screw-worm, an insect which causes severe losses of livestock and deer, from the island of Curaçao by the release of flies sterilized with gamma rays has prompted world-wide studies to explore other uses of the so-called "sterile male technique". The most important requirements for its successful application are the ability to mass-produce and sterilize the pest without seriously impairing the mating competitiveness of the irradiated insects, and sustained releases of males reared and sterilized in the laboratory in quantities so large that they can nullify the reproductive potential of the wild population.

W. E. Stone (USA) reviewed the progress in radiation-sterilization research, now under way at laboratories of the US Department of Agriculture and at a few other places. He described in particular experiments with fruit flies, a species of mosquitoes, and various other insects.

Describing the efforts made in the USA to eliminate the screw-worm fly by the sterile male technique, Mr. Stone reported that under a co-operative programme initiated in 1958 an average of 50 million screw-worm flies were reared, sterilized, and released per week, resulting in the eradication of the pest in the southern United States, east of the Mississippi River, in less than two years, with an estimater saving to farmers of 20 million dollars per year.

A similar programme, started in early 1962, is intended to eradicate the screw-worm fly from the

A puparium, a female and a male of the Dacus fly. This and the next two pictures were taken in the course of an IAEA expert's investigations in Greece aimed at developing a method of mass breeding of the fly

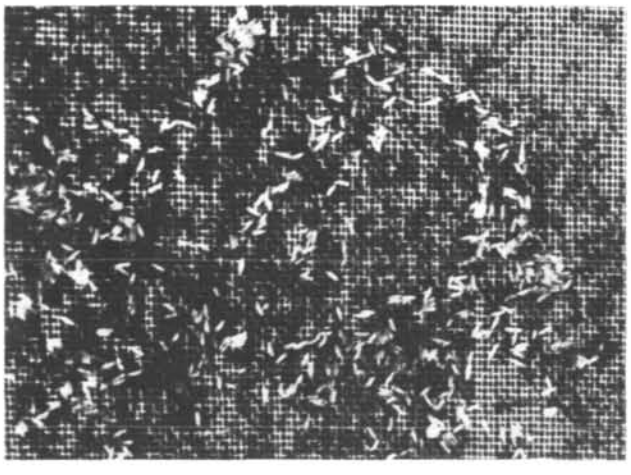


Upper surface of paraffin dome showing the Dacus fly laying eggs. Thin paraffin domes are used to obtain eggs in a form suitable for measurement

south-western part of the USA and to maintain a barrier against re-infestation from Mexico. By early February 1963, the rate of release of sterile flies had reached 113 million per week in certain areas of Texas.

Discussing the effects of irradiation on various insects and at different stages of their life cycles, Mr. Stone pointed out that the radiation doses needed to induce sterility are subject to considerable variations. In some cases damage was caused to certain insects, which excluded the application of the method in combating these pests. Also, some insects appeared so abundant that the use of the sterile male technique might not be feasible without first reducing

Dacus fly eggs on nylon organdy. The cloth is used to collect the eggs after passing them through a funnel



the pest population with chemical insecticides. Despite these difficulties, in Mr. Stone's view, when conditions are favourable few other approaches to the control of pests are so potentially rewarding.

Another instance where the sterile male technique is expected to yield positive results in the not too distant future is a project to eradicate the Dacus or olive fly, now under way in Greece with the assistance of IAEA. K. S. Hagen, an expert provided by the Agency for this project, described in detail the difficulties encountered in breeding this insect, which causes serious damage to olive crops in the Mediterranean countries. He said special food, the control of potentially harmful micro-organisms and, possibly, the presence of other organisms were necessary for the mass rearing of Dacus flies. In recent experiments streptomycin had been added to the food of adult flies to control bacterial infection of the eggs.

Closely connected with these experiments, carried out at the Agricultural College of Athens, is research under way at the Democritus Nuclear Research Centre of the Greek Atomic Energy Commission and at the Benaki Phytopathological Institute, both at Athens. Studies on the doses of gamma radiation required to sterilize olive flies were described by H. Thomou. According to her, sensitivity to radiation differs between insects from different parts of the country. Preliminary studies carried out by C. E. D. Palekassis, with phosphorus-32 as a marker, on the flight habits and migration of olive flies, have shown that the flies do not fly beyond a maximum of some 4.3 km. Microscopic studies, some of them carried out with the electron microscope, on the damage caused by gamma radiation to the ovaric structures of Dacus flies were the subject of a paper presented by B. Baccetti and R. De Dominicis (Italy).

Another report on research undertaken with the support of IAEA was delivered by F. Soria (Tunisia). He described investigations, carried out with radioactive phosphorus as a label, into the distribution of the Mediterranean fruit fly which, in his country, prevents the growing of summer fruit and requires costly pest control measures. These investigations are preliminary to an intended application of the sterile male technique in Tunisia.

E. Horber (Switzerland) reported that the sterile male technique had been successfully applied to eliminate white grubs in a farming area of north-western Switzerland. He showed that this method is also applicable to an area which is not strictly isolated geographically and to an insect whose artificial breeding in large quantities is not feasible.

Other Applications

A considerable part of the discussions at Athens centred on experiments carried out with the help of radioisotope tracers to determine the absorption, translocation, metabolism and excretion of insecti-

cides by animals, insects and plants, and the quantity of residues which might present special hazards. A number of experiments with various well-known insecticides, labelled with a suitable radioisotope, were described by different authors. Thanks to the introduction of radioisotope techniques, it has been possible to determine the effects of these insecticides both quantitatively and qualitatively.

A particularly sensitive method of studying these processes - radioautography - was described in detail by David L. Joftes (USA). By putting insects or plants, or parts of them, which have taken up radioactive tracers, on photographic film and letting the radiation emanating from the tracer darken the film it has been possible to detect those parts of an insect or plant where a specific insecticide accumulates.

S. Andreev (USSR) gave a survey of the use of radioisotopes in the Soviet Union for the control of plant pests. Enumerating the main fields of application, he stated that radioisotopes had been used for the tracing of certain crop pests and of their parasites, and to determine the spreading of potato bugs. With the help of radioactive baits the size of the feeding areas of field rodents had been determined.

Mr. Andreev also reported on the use of tracers for establishing optimal rates of chemical insecticide spraying. Further, he stated that irradiation could increase the virulence of certain micro-organisms and thus their effectiveness as a means of controlling insect pests.

The Soviet scientist described an experiment for the disinfestation of grain, in which 30 tons of grain per hour were moved past a cobalt-60 rod. He said that if carried out at a certain speed the pests present in the grain would be destroyed by this strong radiation source.

The treatment of agricultural commodities by participants. W. E. Stone (USA) said that this technique might offer a means of quarantine treatment, more effective and less undesirable than fumigation and other procedures.

C. B. Papadopoudou (Greece) presented preliminary results showing that radiation treatment of dried figs could kill insects without appreciable damage to the fruit. Much more work would, however, be needed before this could be put into practical use.

H. Huque (Pakistan) stated that about ten major insect pests destroyed at least three to five per cent of his country's much needed staple grains. On a conservative estimate, annual insect damage to grains in State storage alone was of the order of one million rupees.

G. V. Viado (Philippines) said that insect pests had been undermining the economy of his country for decades. A case in point was that of the pests infesting stored grains and copra. Corn, the staple food in some regions of the Philippines, could not be stored for more than two to three months without extensive damage by insect pests, and the poor quality of Philippine copra on the world market was due to the damage inflicted by the copra beetle to the stored produce.

Progress and Outlook

The symposium in Athens revealed not only considerable progress since the Bombay meeting in 1960, but also an increased interest in the use of the new nuclear techniques for entomological research and insect pest control in both the advanced and many developing countries. But as Professor A. N. Rylov, IAEA Deputy Director General in charge of Training and Technical Information, said in his opening speech at Athens, nuclear energy is not a panacea. "Only by the judicious use of all available techniques", he said, "can man hope to succeed in the relentless struggle against his insidious insect enemies."

This idea was also brought out by D. A. Crossley, Jr. (USA), who declared that "in modern insect control practices, an integration of chemical, biological, cultural and other manipulative procedures is increasingly visualized as the ideal means for minimizing the depredations of pest insects and mites". He said: "Recent concepts transcend the older ideas of biological control, in that pest insects are considered as members of more extensive ecological systems." Mr. Crossley stated the following principles for an integrated control concept: (1) crops, pest insects, and other organisms and environment should be considered as a functional unit - the ecosystem; (2) control measures should aim at keeping pests below economic levels, rather than attempt complete eradication; and (3) disruption of other parts of the ecosystem must be considered in the evaluation of control procedures.