STERILE-MALE TECHNIQUE FOR ERADICATION OR CONTROL OF HARMFUL INSECTS

PROCEEDINGS OF A PANEL
ON APPLICATION OF THE STERILE-MALE TECHNIQUE FOR THE
ERADICATION OR CONTROL OF HARMFUL SPECIES OF INSECTS,
ORGANIZED BY THE
JOINT FAO/IAEA DIVISION OF ATOMIC ENERGY
IN FOOD AND AGRICULTURE
AND HELD IN VIENNA, 27 - 31 MAY 1968

PANEL PROCEEDINGS SERIES

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

A Panel on the Application of the Sterile-Male Technique for the Eradication or Control of Harmful Species of Insects was organized by the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture and held in Vienna, 27 - 31 May 1968. Previous panels on this and related subjects resulted in the publication by the Agency of the following books in the Technical Reports Series (TRS) and the Panel Proceedings Series (PPS):

TRS 21: "Insect population control by the sterile-male technique"
TRS 44: "Advances in insect population control by the sterile-male technique"
PPS: "Radiation, radiosiotopes and rearing methods in the control of insect pests" (1968)
PPS: "Control of livestock insect pests by the sterile-male technique" (1968)
PPS: "Insect ecology and the sterile-male technique" (1969)

The sterile-male concept of insect control is based on the use of sexually sterilized males to seek out and mate with normal females in a field environment. No offspring will result from such matings, and if the number of sterilized males present is higher than the number of native males for successive generations, the target species will be eradicated or suppressed.

Although the sterile-male concept sounds simple it is not simple to implement and involves a vast amount of research on basic biology, field ecology, numbers of the species in the field on a seasonal basis, effective methods of trapping or of sampling a population before, during and after sterile insects are introduced, radiation dose to cause sterility, competitiveness of irradiated males, economical mass-rearing methods, release methodology, dispersion and mating behaviour of released specimens, and organization of men and materials for field trials. These are some of the important areas of research and it is obvious that much time and effort will be expended on them before completely satisfactory results are obtained.

Good progress has been made in basic laboratory research on various facets of the sterile-insect methods of insect control such as mass rearing, release procedures, and the biology of numerous insects in various parts of the world for possible use in sterility programs. Small-scale field experiments to test the applicability of the methods and to identify problems that need further investigation have not kept pace with the basic work. This is due almost entirely to lack of funds. Small-scale field trials require extra funds which are usually not available to laboratory research organizations.

This publication contains the summary of the meeting and the recommendations of the Panel, which are intended to serve as a guide to the Joint FAO/IAEA Division and to others engaged in this work. Included is a list of insects that appear to be suitable as candidates for investigations on the applicability of the sterile-male method to their control, and a further list of insects that have been studied in the laboratory, in field cage tests or small field trials and require further testing on a larger scale in the field. The papers presented by panel members are also included.

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SUMMARY OF THE PANEL

SUMMARY OF THE PANEL

1. GENERAL

Insects are among man's most important enemies, attacking and destroying food, fibres and forest commodities and, in addition, carrying and transmitting diseases of plants, humans and animals. The losses of food crops total many hundreds of million dollars annually.

Chemical control of harmful insects fails in many instances because these pests become resistant to chemicals, thus making effective control impossible. Of greater importance is the persistence of insecticide residues in food chains following use of these chemicals on plants and anima Although the chemical residues are in most cases exceedingly minute, they are viewed with concern by health authorities because of possible harmful effects on man. In addition, the use of pesticides on a wide scale may be harmful to beneficial forms of life such as fish, wild mammals and birds.

In view of this, the Panel feels strongly that there is an urgent need to expand research on the use of the sterile-male technique for insect control and recommends that the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture encourage and support such research.

2. INSECTS ON WHICH RESEARCH INFORMATION IS AVAILABLE AND WHICH ARE READY FOR FIELD TESTING

Research on some of the insects in this list is in an advanced stage while on others it will still entail much work. However, all these insects appear to be ready for further evaluation in either small- or large-scale field trials to determine the feasibility of the sterile-insect method of control and to identify problems that need more investigation. The list does not include all insects that are ready for field trials, but rather those that are known to the members of the Panel.

Anastrepha ludens (Loew) - Mexican fruit fly

Sterile Mexican fruit flies are currently being used in a localized area on the Southern California border as a caretaker population to prevent movement of wild flies into the citrus-growing areas of California.

Ceratitis capitata (Wied) - Mediterranean fruit fly

Although eradication trials are under way on Capri and in Central America, there seems to be a need for further field tests in different areas, for further studies on producing more vigorous flies and for more field ecological investigations.

Dacus cucurbitae Coq. - Melon fly
and
Dacus dorsalis (Hendel) - Oriental fruit fly

These two species have been used in sterile-insect release trials on South Pacific islands. Large-scale eradication attempts should be considered.

Anastrepha suspensa - Carribean fruit fly

Successful mass rearing and sterilization studies warrant the initiation of field trials in the near future.

Anastrepha fraterculus Wied. - South American fruit fly

Mass rearing of this insect is being perfected. Determination of sterilizing dose and studies of competitiveness have been performed. The insect occurs in isolated coastal valleys of Peru which offer ideal locations for carrying out small-scale experiments.

Dacus tryoni (Froyg.) - Queensland fruit fly

The sterile-male technique has been successfully tested with this species in small isolated populations in Australia. Suppression of outbreaks appears to be possible but complete eradication seems to be more costly than could be justified by the problem.

Drosophila spp. - Vinegar flies

Information is available on the ecology, radiobiology and mass rearing of these insects. Results of small field tests in tomato fields and packing plants suggest larger field trials for the near future.

Dacus oleae (Gmelin) - Olive fly

The main obstacle is the lack of economical mass rearing. The implementation of the production through improvement of the diet is under consideration at various laboratories, and relatively expensive mass rearing may be envisaged in a few years. The production may be supplemented with rearings on olive fruits. A field test should be carried out in a sufficiently isolated small area, preferably an island, to determine the feasibility of the sterile-insect release method.

Glossina morsitans (Westwood)
and
Glossina austeni (Newstead) - Tsetse fly

Self-supporting laboratory colonies of these two species of tsetse fly exist. The feasibility of using the sterile-insect release method against G. morsitans is being studied. Sterilization by irradiation and chemosterilants is being evaluated for both species. A primary consideration should be to produce competitive insects in the laboratory on economical artificial diets.

Hylemya antiqua (Meig) - Onion fly

Semi-artificial rearing and the effects of radiation on the reproductive potential have been investigated. Basic biological studies such as dispersal and mating behaviour have been completed. Field tests are desirable.

Aedes aegypti - Yellow fever mosquito

Only one field test, in which gamma-ray sterilization was used, has been carried out with this species and it was unsuccessful, probably because of too high a radiation dose and the fact that the treated males were not competing satisfactorily with wild males. Several genetic mechanisms are available and might be preferable to gamma irradiation. Mass rearing of this species is simple, efficient and economical. WHO is contemplating more research on the species (see WHO/VBC/ 67.47).

Aedes scutellaris - Vector of filariasis

Mass production techniques are available. Cytoplasmic incompatibility appears promising.

Culex pipiens fatigans Wied. - Vector of filariasis

A partially successful field test with insects sterilized by gamma radiation was conducted in India. Mass rearing is possible and ecological information is available. A successful test with cytoplasmic incompatible males has been conducted (see WHO/VBC/67.47).

Anopheles gambiae - Vector of malaria

Genetic mechanisms appear to offer promise. Ecological studies and current rearing procedures appear to make small-scale field experiments feasible (see WHO/VBC/67.47).

Dermatobia hominis (Linnaeus) - Torsalo, human bot fly

A fair amount of research on this species has been done in Central America. Work on ecology and behaviour was published. Progress was made on rearing larvae in an artificial medium but more research is needed. However, a small field test could be done by using larvae reared in living animals.

Haematobia irritans (Linnaeus) - Hornfly

Mass-rearing techniques have been developed which are usable for small-scale tests. Considerable biological information is available as well as data on radiation.

Musca domestica (Linnaeus) - House fly

Radiation and chemosterilant data were obtained. Ecological data and mass-rearing techniques are available. Several field trials were fairly successful, indicating a need for larger control programs.

Authonomus grandis (B[illegible] Boll weevil

Rearing methods are nearing perfection. Current sterility methods, although resulting in reduction of mating competitiveness and longevity, have enabled small-scale field tests to be carried out. Large-scale field tests are desirable.

Oryctes rhinoceros L. - Rhinoceros beetle

Damage is caused to coconut palms only by adults. Conventional ecological studies were conducted in South-East Asia and the South-Pacific region. Data on mass-production techniques and on sterilizing radiation doses are now known for this and related dinastid species. Adults were trapped for sterilization and release studies. In view of the advanced stage of these investigations, which are supported by a UNDP(SF)/FAO/SPC project, a preliminary field test on a small infested South-Pacific island is encouraged.

Acanthoscelides obtectus Say - Bean weevil

Mass-rearing techniques and ecological and gamma-radiation studies have indicated that small field trials should be considered for this insect.

Melolontha vulgaris F. - Cockchafer

Methods of estimating population density in treated and control areas are known. Ecology, behaviour, population dynamics and other biological information suggest the feasibility of the sterile-male technique either alone or in combination with other control methods. Sterile-insect control methods would contribute decisively to long-term population regulation as a unique and efficient method. Areas of several hundreds or thousands of hectares of farmland might be protected, but technological improvements in collecting and irradiating several million adults (tons) in a few days are necessary.

Carpocapsa pomonella L. - Codling moth

Small-scale field tests indicate the feasibility of the sterile-male method. Large-scale tests are necessary to demonstrate the success of this technique on an economical basis for commercial application. Mass rearing is possible and the radiation sterilizing dose has been determined.

Diatraea saccharalis (F.) - Sugar cane borer

Many data on the biology, sterilizing radiation doses, seasonal population fluctuations and alternate host plants, such as Zea maize, are known for the sugar cane borer. The principal obstacle now is mass rearing; however, a field test might be possible with trapped wild insects.

Leucoptera coffeella - Coffee leaf miner

Mass-rearing methods and the sterilizing dose are known together with the habits of this insect. Field tests are foreseen for the near future.

Heliothio virescens (F.) - Tobacco budworm
and
Heliothio zeae (Boddie) - Cotton bollworm

Rearing and testing of sterilized insects of these two species have progressed to the point that large isolated areas should be utilized.

Chilo suppressalis Walker - Rice-stem borer

The moth can be sterilized by irradiation without substantial alteration of behaviour. Economical rearing methods are under way. Small-scale field tests are necessary.

Pectinophera gonypiella (Saunders) - Pink bollworm

Rearing, although not yet perfected, has enabled field cage tests to be performed with sterilized insects and large-scale experiments are warranted.

Dysdercus peruvianus C. - Cotton red stainer

This species infests cotton in the coastal valleys of Peru. Since sterile insects cause damage, they should be released away from the crop area in spring before migration of the natural population to cotton. The natural history of this insect has been studied, mass rearing techniques have been developed and the radiation biology is currently being investigated. The natural habitat (isolated coastal valleys) offers an excellent opportunity for a pilot study to control a migratory insect.

Popillia japonica (Newm.) - Japanese beetle

Preliminary radiation and ecological information is available. There is a possibility that collected beetles can be used in small field tests.

Protoparce sexta (Ich.) - Hornworm

Information on ecology, mass rearing and radiation dose is available. The research is promising and field trials are planned.

Trichoplusia ni - Cabbage looper

Radiation data and ecological information are available. Mass-rearing techniques are progressing satisfactorily. A powerful attractant has facilitated field work and should be very useful in pilot tests with sterile insects.

See Panel Recommendation No. 1 in the Appendix.

3. NEED FOR A RESEARCH DEVELOPMENT AND EVALUATION FUND

The information necessary for application of the sterile-insect release method to a specific pest is by no means complete after basic research on an insect has shown that the method is likely to be feasible as a means of control. It is essential to conduct pilot experiments to demonstrate the effectiveness of the technique before the method can be applied in a practical project to control any given pest. Such tests must be conducted on a scale adequate to demonstrate the feasibility and practicability of mass rearing the insect. Efficient methods must be developed to reduce costs of materials and labour. Cost analyses must be made that can be used for practical application. Suitable test sites must be selected and basic data obtained on the population ecology of the insect in the test area. To demonstrate the feasibility of eradication, a test area must be found that provides complete isolation, such as an island or an isolated valley. If suppression of a population in a non-isolated area is the goal, the test site must be large enough to demonstrate effective suppression. The effectiveness of the released insect must be demonstrated by showing the rate of overflooding of native insects and by showing a suppression in insect populations in relation to previous history and/or in comparison with a comparable untreated area.

Facilities, funds, manpower and technical competence which suffice for basic and small-scale applied research are totally inadequate for the research development and evaluation required for the pilot stage of the sterile-insect release technique. Generally, the development of pesticides has been supported by the chemical industries that undertake this development themselves, but public funds must be provided for these phases in perfecting the sterile-insect release method. The funds needed to complete the research development and evaluation phases will vary with the insect and the location. However, experience with insects for which these phases have been completed indicates that such costs will probably range from about $50 000 to $500 000 per annum for each insect over a period of two to three years.

The report of the Panel shows that research on the pilot testing phase is needed for a dozen or more insect species and this number can be expected to increase each year as adequate basic information is obtained on other insects under investigation.

To proceed with the development of the technique with the wide range of insects for which the method shows promise, it is essential that a special research development fund first be established by international agencies to finance the pilot testing phase of the technique. It would be essential for such tests to be financed with international funds, since developing countries cannot be expected to finance such test programs. Furthermore, many insect pests cover large areas and are not limited by international boundaries. Money from such funds should be used only for development of the technique and not for practical suppression or eradication programs. As pilot tests for different insects are completed, which will probably require a minimum of two to three years for each test, the funds should revert back to the development fund and be employed for pilot testing of the method with other insects.

See Panel Recommendation No. 2 in the Appendix.

4. LIST OF INSECTS ON WHICH BASIC AND APPLIED RESEARCH IS NEEDED

Listed below are species of insects on which research should be encouraged with the goal of utilizing the sterile-male technique for eradication or control of these species. This inventory, suggested by the Panel, does not include all insects deserving further investigation. Some of these insects have been investigated to a limited extent, others have been used successfully in field trials while others have not been studied at all. All of them, regardless of stage of development, need research in certain areas to reduce costs or increase efficiency.

This list of pests of economic importance is proposed with priority for:

(1) species which transmit diseases;
(2) species which already have developed or are building up resistance to insecticides;
(3) species which have a very low tolerance level of infestation on their host animals, host plants or on commodities;

(4) species requiring chemical control that would result in intolerably high residue levels;
(5) species for which no alternative control methods are available.

Order	Species	Common name
Diptera	Aedes aegypti (Linnaeus)	Yellow fever mosquito
	Anastrepha fraterculus (Wied)	South American fruit fly
	Anastrepha ludens (Loew)	Mexican fruit fly
	Anastrepha scutellaris (Walker)	Fruit fly
	Anastrepha suspensa (Loew)	Caribbean fruit fly
	Anopheles gambiae (Giles)	Mosquito
	Ceratitis capitata (Wied)	Mediterranean fruit fly
	Ceratitis rosae	Natal fruit fly
	Cochliomyia hominivorax (Coquerel)	Screw-worm fly
	Culex fatigans (Wied)	House mosquito
	Dacus cucurbitae (Coquerel)	Melon fly
	Dacus dorsalis (Hendel)	Oriental fruit fly
	Dacus oleae (Gmelin)	Olive fly
	Dacus tryoni (Frogg)	Queensland fruit fly
	Dermatobia hominis (Linnaeus)	Human bot fly, Torsalo
	Drosophila spp.	Vinegar flies
	Glossina spp.	Tsetse flies
	Leptolylemyia coarctata (Fallen)	Wheat bulb fly
	Lucilia (Phaenicia) spp.	Blowfly
	Musca autumnalis (Degue)	Face fly
	Musca spp.	House flies
	Myiopardalis pardalina (Big)	Asian fruit fly
	Pegomya hyoscyami (Panzer)	Paug. beet fly
	Phorbia antiqua (Neigen)	Onion maggot
	Phorbia brassicae (Bouché)	Cabbage maggot
	Phorbia cilicrura (Rondani)	Seed corn maggot
	Phorbia floralis	Turnip maggot
	Psila rosae (Fabricius)	Carrot fly
	Rhagoletis cerasi (Linnaeus)	Cherry fruit fly
	Rhagoletis cingulata (Loew)	Cherry fruit fly
	Simulium spp.	Black flies
	Stomoxys calitrans (Linnaeus)	Stable fly
Coleoptera	Acanthoscelides obtectus (Say)	Bean weevil
	Amphimallon majalis (Razoumowsky)	European chafer
	Amphimallon solstitiales	European chafer
	Anthonomus grandis (Boheman)	Boll weevil
	Anthonomus vestitus	Cotton square weevil
	Bothynoderes punctioentris (Germ)	Sugar beet weevil
	Bruchus pisorum (Linnaeus)	Tea weevil
	Costelytra zealandica	Grass grub
	Diabrotica spp.	Root worms
	Dynastid beetles (Oryctes spp.)	Rhinoceros beetles
	Epilachna spp.	Leaf beetles
	Hylotrupes bajulus	Old house borer

Order	Species	Common name
	Leptinotarsa decemlineata (Say)	Colorado potato beetle
	Melolontha hippocastani (Fabricius)	Cockchafer
	Melolontha vulgaris (Fabricius)	Cockchafer
	Phyllopertha horticola	Garden chafer
	Popilla japonica (Newm.)	Japanese beetle
	Phyndites cupreus var. auratus	Weevil
	Sitophilus granaria (Linnaeus)	Granary weevil
	Tremuotrypes solani (Pierce)	Andean weevil
	Scotytidae spp.	
Lepidoptera	Cacoecia promulana	Daisy tortrix
Hemiptera	Carpocapsa pomonella (Linnaeus)	Codling moth
	Cenrygaster integriceps	Grape phylloxera
	Chilo suppressalis (Walker)	Rice stem borer
	Dactylosphera vitifolii (Shimer)	Grape phylloxera
	Dendrolimus spectabilis (Butler)	Korean pine caterpillar
	Diatraea saccharalis (Fabricius)	Sugar cane borer
	Distantiellia theobroma (Distant)	Cacao capsid
	Dysdercus peruvianus C.	Cotton red stainer
	Grapholita tunebrana Tr.	Plum fruit moth
	Heliothis spp.	Fruit worms
	Hyphantrea cunea (Drury)	Western fall webworm
	Nezara viridula (Linnaeus)	Southern green streak bey
	Ostrinia nubilalis (Hübner)	European corn,borer
	Pectinophora gossypiella (Saunders)	Pink bollworm
	Pectinophora malvella (Hübner)	Mallow moth
	Phylloxera vastatrix (Planel.)	
	Porthetria dispar (Linnaeus)	Gypsy moth
	Prodenia litura (Fabricius)	Cotton leaf worm
	Protoparce sexta (Johansen)	Tobacco hornworm
	Spodoptera spp.	Army worms
	Spodoptera exigua (Hübner)	Cutworm moth
	Trichoplusia spp.	Loopers
	Zeuzera pyrina (Linnaeus)	Leopard moth
Other Phyla	Nematodes	Eelworms
	Vertebrateae	Rodents, birds
	Acari: Ornithodoros tholozani	Laboulleum and ticks

See Panel Recommendation No. 3 in the Appendix.

5. PRIOR REDUCTION OF INSECT POPULATIONS TO LEVELS MANAGEABLE BY THE RELEASE OF STERILE INSECTS

In view of the high natural densities of many major insects, the application of the sterile-insect release method alone is not likely to be economically feasible in most areas. An important part of research on the development of the sterile-male method should therefore involve investigations on ways to reduce high natural populations drastically before contemplating the use of sterile-insect releases. A high level of suppression by chemical, biological, cultural or other means may be possible in a well co-ordinated program and thus reduce populations well within the range of practical management with sterile insects. Complete suppression of the populations below the economic threshold levels might then be achieved and maintained indefinitely in large areas by the release of sterile insects at a cost less than that of the usual methods employed for control.

The initial investment for such a program might be very high, but in the long run it could represent a temporary investment and result in the maintenance of sub-economic-threshold regional populations which would otherwise cause high losses in spite of conventional control methods.

See Panel Recommendation No. 4 in the Appendix.

6. BASIC RESEARCH ON THE POPULATION ECOLOGY OF MIGRATORY INSECTS CONSIDERED AS PROMISING CANDIDATES FOR APPLICATION OF THE STERILE-INSECT RELEASE METHOD

A number of lepidopterous insects of major importance as pests of cereals, other basic food crops and cotton in various parts of the world are known or suspected to disperse widely from their source of origin each season. The Heliothis species complex is of particular importance among the migratory insects.

In view of the high losses caused by these insects and the difficulties and high costs generally experienced in their control by conventional means, there is an urgent need to develop more effective, less costly and more selective means for their suppression on a regional basis.

The feasibility of employing sterile-insect releases as a means of population suppression on a regional, national or international basis cannot now be determined because of a lack of information in areas where the insects overwinter, their distance and rate of dispersion, and their density, especially during periods of scarcity and restricted distribution. Support for research on the population ecology of such insects will be essential before an intelligent approach to their control by the sterile-insect technique or by any other method can be formulated. Close co-operation by investigators in various contiguous countries may be necessary and should be facilitated wherever possible.

See Panel Recommendation No. 5 in the Appendix.

7. SUB-STERILIZING DOSES OF RADIATION

The Panel members discussed recent work on the effectiveness of sub-sterilizing doses of radiation on lepidopterous insects. It has been found that sub-sterilizing doses of radiation or chemicals can lead to a level of sterility in surviving F_1 progeny that is higher than the sterility level in the parent generation. Other work indicates that a sub-sterilizing dose may carry over into the F_2, F_3 or F_4 generation. Obviously, sub-sterilizing