STATUS OF THE STERILE-INSECT RELEASE METHOD IN THE WORLD

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Abstract

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The suppression of insect pests in the field by the sterile-insect release method (SIRM) is summarized. Some of the obstacles to the application of this method are reviewed. A number of misconceptions about the SIRM are analysed and refuted. The screwworm program in the Southwestern United States of America and Mexico is examined.

When I learned a few days ago that I had been assigned this ambitious title for discussion at this Panel, I was somewhat dismayed. It is difficult to keep up with research and field trials on the sterile-insect release method in my country and certainly impossible to know all that is going on in the rest of the world. I cannot hope to do justice to this topic, but I will endeavour to present a status report that summarizes my observations and personal opinions in this area. I sincerely hope that you will forgive me for any sins of omission.

I believe there is one thing upon which we all agree: As entomologists we have reached the crossroads in our endeavours in controlling insects that affect human and animal health and agricultural production. Our former reliance on pesticides is gradually being curtailed, not only by those sincerely concerned about adverse effects on the environment, but just as much by the problem of resistance. It is unlikely that this trend will be reversed in the future. In fact, a more realistic view would be to accept the idea that our reliance on pesticides will become even more restricted. Therefore, we find ourselves, to an increasing degree, seeking alternative methods of pest control. The sterile-insect release method (SIRM) has for some years been regarded as a promising alternative.

Critics of this technique can justifiably chastise us by pointing out that the only successful large-scale application of the sterile-male technique has been restricted to a single species of insect, the screwworm fly. Seventeen years have elapsed since eradication of this species from the island of Curaçao and 13 years since the species was eradicated from the Southeastern United States of America. The species was reported eradicated from the USA and British Virgin Islands in 1972 as a result of a program conducted by the Animal and Health Inspection Service (APHIS), USDA, in co-operation with the US Air Force, Special Operations Force. These agencies are at present conducting a similar screwworm program in Puerto Rico. The screwworm program in the Southwestern United States and Mexico, initiated in 1962, has been extremely successful. How much longer will it be before

TABLE I. DEMONSTRATION OF INSECT POPULATION SUPPRESSION FOLLOWING RELEASE OF STERILE INSECTS

Species	Test sites
Ceratitis capitata (Wiedemann) (Mediterranean fruit fly)	Hawaii, USA Capri, Italy Procida, Italy Tenerife, Spain Murcia, Spain Grenada, Spain Puntarenas, Costa Rica Carazo, Nicaragua Tacna, Peru
Dacus dorsalis Hendel (Oriental fruit fly)	Guam, Southern Marianas Saipan, Tinian and Agiguan, Southern Marianas
Dacus curcubitae Coquillet (Melon fly)	Rota and Guam, Southern Marianas
Anastrepha ludens (Loew) (Mexican fruit fly)	Tijuana, Mexico
Dacus tryoni (Froggatt) (Queensland fruit fly)	Warren, Australia
Glossina morsitans Westwood (Tsetse fly)	Lake Kariba, Rhodesia
Hylemya antigua (Meigen) (Onion maggot)	Wageningen, The Netherlands
Culex fatigans Wiedemann	New Delhi, India
Anopheles albimanus Wiedemann	Lake Apastepeque, San Salvador
Haematobia irritans (L.) (Horn fly)	Kerrville, Texas, USA
Stomoxys calcitrans (L.) (Stable fly)	Hague, Florida, USA
Musca domestica (L.) (House fly)	Latium, Italy Grand Turk, Bahama Islands
Anthonomus grandis Boheman (Boll weevil)	South-east USA
Melolontha vulgaris F. (Cockchafer)	Vendlincourt, Switzerland
Laspeyresia pomonella (L.) (Codling moth)	Summerland, B.C., Canada Yakima, Washington, USA
Heliothis virescens (F.) (Tobacco budworm)	St. Croix, US Virgin Islands

TABLE I. (cont.)

Species	Test sites
Heliothis zea (Boddie) (Corn earworm)	St. Croix, US Virgin Islands
Manduca sexta (L.) (Tobacco hornworm)	St. Croix, US Virgin Islands
Pectinophora gossypiella (Saunders) (Pink bollworm)	San Joachim, California, USA[a]

[a] Sterile insects used to prevent establishment of species in area but not to suppress an established population.

similar success on another species is available? I will not endeavour to review all research contributions and field tests demonstrating the efficiency of the SIRM. All of us are familiar with these programs and most of them have been adequately documented in former panels and symposia published by the IAEA.

Table I briefly summarizes these field programs. The list is impressive and demonstrates that the release of sterilized insects has been repeatedly shown to be effective in suppressing insect populations in small and medium-sized field tests. Now we must determine whether the SIRM will be applicable for the suppression and possible eradication over larger areas, for what species it will be most useful, and when we can realistically begin its application.

Until a few years ago the major obstacle to the successful application of the SIRM to most insect species was the problem of mass-rearing. When the book, Insect Colonization and Mass Production [1], appeared, only three species of insects could be reared "by the millions". At present there are at least six laboratories capable of producing over 10 million medflies, Ceratitis capitata (Wiedemann), per week and the majority of these are in developing countries. Even previously difficult-to-rear species are being produced in large numbers. In laboratories of the US Department of Agriculture the production of boll weevils, Anthonomus grandis Boheman, is at present 1 million per week in a plant with a 15-million per week capacity. Production of pink bollworm, Pectinophora gossypiella (Saunders), exceeds 1.3 million per day, codling moths, Laspeyresia pomonella (L.), are produced at a rate of 3 million per year, and the production of the tobacco budworm, Heliothis virescens (F.) is 70 000 per day. The "Screwworm Plant", located at Mission, Texas, has a 200 million per week capability. The Canada Department of Agriculture laboratories can produce 2 million codling moths per month, and WHO laboratories in New Delhi are at present producing nearly 5 million Culex fatigans per week. Even the tsetse fly, Glossina morsitans Westwood, is being produced today in numbers that were undreamed of only a few years ago [2]. As the mass-rearing techniques have improved, rearing costs have decreased. For many species the inability to mass-rear per se is no longer the major obstacle to launching autocidal programs.

In spite of these advances, there is a great need to improve the quality of the insects produced, to make sure they are free of disease and fully competitive once released in nature. The fitness of the released insects should approach that of the native insects with which they will compete for mates. This may be very difficult to accomplish. In the process of colonization of an insect species certain characteristics important for survival in the wild are either selected against or at least lose their selective advantage under laboratory conditions. In either case deterioration of the laboratory colony over an extended period of time is expected.

Actually, we know very little about the components of fitness in nature. The relative importance of longevity, sexual vigour, ability to disperse, response to stimuli, or ability to locate food is difficult to assess. We do know that the genotypes present in nature are the most fit since they are the result of continued selection for all fitness components. Therefore, it appears reasonable that we should endeavour to release insects that genetically resemble the wild ones.

Loss of competitiveness can also be attributed to the irradiation treatment used to sterilize the insects. Except for a few well-documented problems, for example, the boll weevil cannot be sterilized with ionizing irradiation without drastic effects on longevity, much progress has been made in minimizing the detrimental effects of the sterilizing treatment [3-6].

One of the greatest achievements in recent years has been progress in dispelling some of the misconceptions about the SIRM. Perhaps, taken individually, these are not particularly impressive, but collectively they present some real progress in theory and planning for insect control. A few of these are enumerated below:

1. That the released insects must be completely sterile

It was formerly thought that the released insects must be completely sterile. This is not necessarily true. If the fully sterilizing treatment severely lowers the competitiveness of the released insects, serious consideration should be given to the possibility of utilizing substerilizing doses in order to increase competitiveness and to maximize the impact of the released insects. For certain species a slight residual fertility would be desirable in control programs (as opposed to eradication programs) if it significantly increased the competitiveness of the released males. The residual fertility in the males cannot have any adverse effect on the size of the next generation, provided that the females released simultaneously are sterile. Released insects can only increase the size of the next generation if the females are capable of producing viable eggs. When the adult stage is not damaging to crops, the release of males that are only semisterile but whose progeny are fully sterile may be more advantageous than the release of fully sterile males. Applications of this principle to Lepidoptera have been previously discussed [4,7].

2. That the SIRM is applicable only on islands or in special ecological situations

Eradication of the screwworm fly from the Southeastern United States of America should disprove this idea. However, we are just beginning to appreciate that in many areas a species is often relatively or completely isolated by ecological factors. For example, many agricultural pests are one-host species whose distribution is limited to areas where the crop is grown. Other species that cause damage over vast areas during some seasons are restricted to much smaller areas during other seasons. Many other examples of ecological isolation are known.

3. That the SIRM is feasible only in large-scale programs where total eradication is the objective

It is probable that long-term suppression of a species below economically important levels will be the goal in many future programs. Actually, many agricultural situations exist in which the SIRM could achieve extremely economical control by preventing build-up of the insect population to damaging levels without the use of pesticides. The overall impact of continued effective control over several years may provide a level of control that becomes increasingly more economical.

4. That the SIRM will be effective as the sole control technique

In most situations integration of the sterility approach with other chemical and biological methods would be preferable to any method used alone. Numerous possibilities for integration exist: Use of pesticides to lower the insect population before release of sterile insects; programs in which the sterile males produce the usual suppressive effects on the populations and the females produce inviable eggs that can support the growth of beneficial parasites; use of cultural methods to reduce density to relatively few per acre; use of attractants (male annihilation), pheromones, hormones, light traps, sound and many other suppressive measures. These diverse approaches could all be integrated into a pest-management system utilizing the best features of each method at the proper time.

THE SCREWWORM PROGRAM IN THE SOUTHWESTERN UNITED STATES AND MEXICO

The campaign to suppress the screwworm fly in Southwestern United States of America and Northern Mexico was inaugurated in 1962. This campaign represents the major application of the SIRM in the world in scope and duration. A brief examination of the program may provide us with useful guidelines for our future programs.

Table II shows the incidence of screwworm cases reported in the Southwest during the past 10 years. During the period 1963-71 there was little doubt that an immensely successful operation was underway. Ten years of success in the control and near eradication of a major pest certainly constitutes ample proof that the sterile-male technique does work on an area-wide basis. From 1964-1971 it was generally agreed that self-sustaining populations of screwworm flies had been eradicated from the Southwestern United States and that most of the cases each year were attributable to immigrating flies from Northern Mexico. This year (1972) there has been the worst epidemic of screwworm cases since records have

TABLE II. INCIDENCE OF SCREWWORM CASES REPORTED IN THE US SOUTHWEST[a]

Year	Texas	Oklahoma	New Mexico	Arizona	California	Arkansas
1962	49 484	444	1133	231	-	-
1963	4 916	20	1447	728	-	-
1964	223	0	14	158	-	0
1965	446	0	122	465	7	0
1966	1 203	0	93	509	70	0
1967	835	0	0	23	14	0
1968	9 268	0	70	405	135	0
1969	161	0	18	32	8	0
1970	92	0	33	23	5	0
1971	444	0	0	4	0	25
1972	90 980	1035	1254	2317	27	6

1972: Kansas 3; Florida 2; Louisiana 1.

[a] These data are based on larvae identified and records compiled at Mission, Texas, by the Field Operations Section, Screwworm Eradication Program, Veterinary Sciences, Animal and Plant Health Inspection Service, US Dept. of Agriculture.

been kept. No one knows the exact reasons for this sudden reversal in a successful program. Several explanations are possible, and these are currently being investigated:

(1) Weather: The winter of 1971-72 was perhaps one of the mildest ever in the Southwestern USA. Conditions for continuous screwworm breeding were favourable much farther north than could be expected during average winter seasons; therefore, screwworm populations were much higher in Northern Mexico than during average years. Areas in Northern Mexico and Southern Texas that are normally semi-arid had unusually heavy rainfall and therefore supported abnormally high screwworm populations. Simultaneously, the number of flies released per unit area had to be reduced because of budgetary limitations.

(2) Changes in competitiveness of the released flies: Although there have have been several attempts to maintain genetic variability and vigour in the release strain, it is possible that there was a significant deterioration of the laboratory colony.

(3) Genetic changes in the native population: Since the native population on the USA-Mexico border has been subjected to the pressure of sterilized flies for the past 10 years, there is, of course, the possibility that the native population could have evolved differences that would place the released flies at a serious disadvantage. If, for example, there was selection for earlier mating, changes in mating behaviour, location of mating, or other behavioural changes, the released insects could be isolated from the random mating pool to some degree.

I hasten to point out that despite a rather disappointing record during the past year the program is not doomed. There is no apparent reason why the success achieved in the years 1964-71 cannot again be attained. Loss of competitiveness of released flies because of laboratory adaptations can, of course, be reversed by substituting field-collected strains into the laboratory mass-rearing facility. If any genetic changes in the native population have taken place, the flies collected for the new laboratory colony would possess the same genotypes as the wild population and, therefore, would possess similar behavioural patterns. Loss of vigour because of changes in larval diet introduced several times during the course of the program can be resolved by reverting to the original successful production methods that originally produced effective, competitive flies. All these possibilities are currently being studied. However, it is premature to consider further changes or modifications in the program until recently inaugurated field and laboratory studies have produced additional data. Recently an agreement was signed between the Governments of Mexico and the United States of America for an extended program in Mexico to begin during the next year and on 7 February 1973 the joint Mexico-US Commission for Eradication of Screwworms was organized.

In closing, I am very optimistic that the SIRM will play a central role in the control, suppression and possible eradication of other species of insects. It appears that for the near future dipteran species may be the best candidates, although it should not be too long before Lepidoptera can be effectively controlled by this technique. Relatively clear-cut and easy successes similar to those achieved in early screwworm programs may be difficult to repeat. Further developments, particularly in the areas of insect colonization, field ecology, population dynamics and sterilization techniques, are required. The obstacles that must be surmounted in the application of this approach to the control of insect populations are certainly no greater than the obstacles present in other alternative methods of insect control.

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