Israel Journal of Entomology, Vol. VI, 1971

THE ROLE OF THE STERILITY TECHNIQUE IN PEST CONTROL

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A B S T R A C T

One of the new methods for controlling or eradicating harmful insects is the sterility technique. The principle of this technique is simple a population will decrease or die out if a certain proportion of its members becomes sterile. The appropriate ratio between sterile and fertile insects in an isolated population can be brought about directly by chemo- sterilants or indirectly by releasing artificially reared and sterilized insects. In actual practice, a number of sometimes complex problems have to be solved before the potential merits of the sterility technique can be evaluated. Because this technique is entirely specific and because it does not provide an immediate relief of infestations it is not as generally as the use of insecticides. On the other hand, the possibility of eradicating certain insects from large areas without seriously contaminating the environment may far outweigh any disadvantages. Radiation, chemosterilants, or one of the genetic techniques can be employed in the sterility method but usually the choice is limited because many of the problems of reproduction and its regulation remain unsolved. Chemosterilants are the most flexible means that can be used in the sterility method and their potential must not be overlooked. The recent developments in the research on insect hormones and the discovery of their sterilizing properties may open up new possibilities in the application of chemosterilants.

Metabolism and reproduction are the two basic processes associated with life. When certain forms of life become undesirable, man uses his ingenuity and tries to destroy them as effectively as he can. Until fairly recently, the target was metabolism and the result was rapid death. Because of its simplicity and rapidity, this concept is far from being obsolete, and in insect control, physical and chemical insecticides will probably never lose their role and appeal. But simple solutions are seldom without problems and the problems of insecticides are too well known to require restatement and repetition. Alternatives are needed and, fortunately, some are available. Without attempting to review all such alternatives that include many concerned with reproduction, I will address myself to only one of them: the sterility control method. The principle of this method is simple: if some members of a population of sexually reproducing organisms are rendered sterile, the reproductive potential of the population will decrease; if the ratio of sterile to fertile members remains sufficiently large, the population will die out. Elaborate and detailed mathematical models supporting this proposition have been constructed (Knipling 1968, Lawson 1967) and, what is more convincing, the validity of the principle has been demonstrated in practice (Knipling 1966). Granted, that the sterility method is an effective tool for controlling and eliminating pest insects; why then is it being used only sporadically in a few countries against a few species ?

Certainly one reason is a lack of understanding and appreciation of the power of the method but there are a number of other practical reasons that I shall try to analyze here. First requirement, however is the realization that the sterility method involves two different techniques for achieving the required ratio between sterile and fertile insects in a population: either a part of the existing population is sterilized, or artificially reared and sterilized insects are released into an existing population. Knipling, the main proponent and initiator of the sterility method, has repeatedly emphasized the differences between the two techniques in terms of feasibility and practicality. The sterilization of an existing population, most probably by chemosterilants, is most effective and economical when the population density is high - a concept similar to that for a proper use of insecticides. But when the population density is low, the release method gains advantage because it becomes possible to achieve the high ratio of sterile to fertile insects by releasing realistic numbers of artificially reared insects. It makes little difference which sterilization method is used as long as the insects are competitive, compatible with those in nature, and their cost is not prohibitive.

Unquestionably, the sterilization of existing populations is the simpler of the two methods and its use appears to be more relevant to the most common problems in pest control. Usually, the need for control is strongest when the pest population is high and threatens to become even higher. Also, the technique for applying chemicals is familiar: insecticides, herbicides, and fertilizers are being used daily by millions and chemosterilants could in theory be applied in the same way. Unfortunately, there are serious and difficult problems connected with this seemingly simple proposition. After the initial wave of interest and enthusiasm in the early 1960's, the inherent complexity of research in chemical regulation of fertility discouraged many who expected if not a panacea then at least a rapid success. But the problems proved to be just as real as the potential. Some skeptics postulated a fundamental impossibility of developing safe chemosterilants because, presumably, any compound that interfered with reproduction in insects would similarly endanger other organisms including man. Others, however, whose enthusiasm was cautious but more durable remained optimistic about the specificity of chemical reactions. The bits of information available in 1960 increased only slowly but the prospects for the direct use of chemosterilants can now be evaluated on a firmer basis.

For controlling certain insects, the method is indeed effective and desirable but its application requires safer compounds than those now available. A clear sign of progress is the development of chemosterilants far less toxic and dangerous to handle than were the alkylating agents known 10 years ago (Borkovec 1966). The variety of classes of new chemosterilants indicates that the reproductive system can be attacked in many different ways and some of them, e.g., the sterilizing activity of insect hormones and similar compounds, are extremely specific. It is true, nevertheless, that no chemosterilant that could be safely applied in nature in a manner similar to the use of insecticides is now available for economically important insects. The task of finding such a compound will be difficult but it is sufficiently important to merit a far greater support than it is receiving now.

The release technique, though much more complicated and demanding than the sterilization of existing populations, has been already put into practice with radiation and also with chemicals. It is perhaps an advantage that the universally used insecticidal method usually stops at the point where the release method needs to start, i.e., at low densities of pest populations. But reducing the population is only one of many conditions required for success of the release method. Knipling (1968), in his analysis of the potential role of this method, listed the following nine basic requirements most of which may require extensive research and experimentation:

1. Availability of a method of inducing sterility without serious adverse effects on the mating behavior and competitiveness of the male insects.

2. A pratical method of rearing the insect in large numbers.

3. Quantitative information on the natural population density, especially at the lowest level in the population density cycle.

4. A practical way of further reducing natural populations to levels manageable with sterile insects if this is necessary or economically advantageous.

5. Information on rate of population increase as a guide for determining the necessary rate of overflooding with sterile insects.

6. The cost of reducing the natural population plus the cost for rearing and releasing the required number of sterile insects should be favorable in relation to costs of other methods of control plus the losses that occur in spite of control.

7. If complete elimination cannot be achieved because of reinfestations by migrating insects or because of new introductions, the cost of maintaining complete control by continuing sterile-insect releases must be favorable in relation to the costs for other available methods and the additional losses caused by the insect.

8. There could be justification for employing the sterile-insect release method, even if the method is more costly than current ways to control or eradicate insect populations, if hazards to man and his environment are an important consideration when other methods of control are employed.

9. Sterile insects to be released must not cause undue damage to crops or livestock, or create hazards for man and animals that outweigh the benefits of achieving or maintaining population control.

These points deserve close scrutiny by anyone interested in the application of the release method but most of them have been adequately discussed before and it may be appropriate here to consider in some detail only the three methods of sterilization: radiation, chemosterilants, and genetic techniques.

A. Radiation.

Providing that a safe and controlable source of radiation is available the method has much to offer: millions or even billions of insects can be rapidly treated and the sterile insects carry no harmful residues when they are released. The limiting factor, however, is the susceptibility of the insects to radiation. In general, if at some stage of development the reproductive system is substantially more susceptible to radiation damage than the rest of the organism then there are good chances that competitive sterile insects can be produced. If the reverse is true or if the differences in sensitivity of the various systems to radiation are very small, radiation sterilization becomes usually impossible. Because the susceptibility of tissues to radiation damage is an inherent characteristic and the attempts for modifying it have met with little success there are only few variables that could affect the results of irradiation. It seems that only a fraction of important insect species can be sterilized by this technique without losing appreciable competitiveness. Whether such only partially effective insects can still be used in a control operation may depend on economic and logistical factors.

B. Chemosterilants.

Though chemical sterilization is a much more flexible procedure than irradiation the very nature of the almost unlimited variables poses a problem in experimental design. Hundreds of chemosterilants are known and new structural types are being discovered every year. As with radiation, the susceptibility of insects varies in an, as yet, unpredictable way not only with the structure of the chemosterilant but also with its mode and time of application, and with the developmental stage of the insect. The differences in effects of the many known classes of chemosterilants (Borkovec 1966) indicate that there are few basic limitations of the method; the principal problem is to decide how much effort can be reasonably devoted to devising a satisfactory procedure for chemosterilization. In distinction to the limitations of chemosterilants for sterilizing natural populations, in the release method the possible toxicity and non-specifity of the compound can be dealt with because the chemosterilant is not directly introduced into the infested area. The rearing and sterilization of insects to be released is usually conducted under strictly controlled conditions and even highly toxic and potentially hazardous chemicals can be applied without danger to the environment. The timing of the chemosterilization may be of crucial importance. For this reason the sterilization of immature insects that would be released several days or possibly weeks after being treated is of particular interest. It is obvious, however, that the lower the acute and chronic toxicity of the chemosterilant the better are its chances for a practical utilization. Like radiation, chemosterilants may also produce incompletely sterile or only partially competitive insects. Whether such insects would still be usable in the release method will again depend primarily on economic and logistical factors.

C. Genetic Techniques

The distinction between the two methods mentioned previously and the genetic techniques is somewhat questionable. It is well recognized that radiation and chemosterilants usually induce changes in the genetic make-up of the treated insects. In this sense both methods are genetic and no fundamental differences exist between radiation and chemical sterilization. There are exceptions, primarily in chemosterilization, in which the mechanism does not involve the hereditary characteristics of the insect gametes but they are unimportant in a classification by sterilizing agents rather than by the mode of action. The genetic techniques, on the other hand, refer to the way in which sterility could be transmitted rather than to how it was induced. Actually, it would be less confusing and more appropriate to classify these techniques as miscellaneous or simply different from those mentioned before.

The oldest of these techniques (Serebrovsky 1940) utilizes the effect of chromosomal translocations on zygotic mortality. Insects possessing this mutant are only partially sterile but the survivors among their progeny will further disseminate the genetic abnormality into the population and thus reduce the reproductive potential without additional releases. The initial mutation in the released insects may be spontaneous but the selection of such mutants is extremely laborious. A much more desirable method is inducing the original mutation by radiation or chemicals - and so we return in a circle to the already mentioned two methods. Other techniques, that again employ insects that are not sterile, are based on the incompatibility of two closely related species or strain. The progeny of such crosses may be sterile, semisterile, or it will not survive. Whether the incompatibility is cytoplasmic or truly genetic is immaterial as long as the population suppression is sufficiently large and the introduced males are fully competitive with the natural males. Although 30 years have passed since the first and surprisingly detailed theoretical elaboration of the genetic technique (Serebrovsky in his 1940 paper actually stated that experimental work has been started with Musca domestica and Calandra granaria) few field studies have been described in the literature and only the one (Laven 1967) employing cytoplasmic incompatibility appeared to be successful.

In conclusion, one important aspect of the sterility control method requires discussion, i.e., its absolute specificity. As the principle of the method indicates, each species of pest insects has to be treated separately and, whenever possible, on a regional, continental, or even global scale. Exceptional situations may arise, e.g., pest control in greenhouses and in other isolated facilities, but for free-living insects much more extensive operational concepts must be developed. The two current large-scale applications of the sterility method, one in the U.S.A. and Mexico for the eradication of the screw-worm fly and the other in Central America for the control of the Mediterranean fruit fly, are conducted under international cooperation and the cost of operating them is very high. Several years of research preceded each project and though much information and experience of a general nature was gained, every new application of the method will require extensive and specific experimental effort. Some specific experimentation will always have to be done but basic research can provide a broad and universally applicable foundation on which the superstructures dealing with individual species can be built. Thus far, the basic research relating to the induction of sterility has been entirely inadequate despite of the fact that the problems of regulating fertility are considered by many as the most important dilemma of our time. It may be a coincidence that the population explosion, a phenomenon so familiar in the world of insects, became a household word in the last few years. Nevertheless, insects and people have been interconnected in many different ways and, with a passing reference to the genetics of Drosophila, it would not be the first time that basic research involving insects would bring benefit to mankind.

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