https://doi.org/10.29321/MAJ.10.A01440

THE PRINCIPLES OF BIOLOGICAL CONTROL

BY

J. G. MYERS, SC. D., F.E.S., *Imperial Bureau of Entomology*

Probably ninety-nine out of every hundred people, when they think of the contributions of science to human welfare, recall the physical, chemical and mechanical inventions which produced the industrial revolution and are now engaged in the mechanisation of the world, and in the evolution of its new master, the centaur of the new civilization—that half-man, half-automobile, envisaged by that brilliant recent writer, Woodruff, in *Platos American Republic*. We are not accustomed to think of *biological* inventions; by which we mean, with Haldane, 'the establishment of a new relationship between man and other animals or plants, or between different human beings, provided that such relationship is one which comes primarily under the domain of biology, rather than physics, psychology, or ethics.' The application of biology to the solution of human problems has as yet hardly begun. Haldane has shown that the number of great biological inventions can be counted on the fingers of one hand, and most of these were made before the dawn of history.

When mankind was at the hunting stage of culture, living only on animals and perhaps a few plants, secured with the aid of primitive tools, a Malthusian prophet might justly have envisaged, concurrently with improvement in weapons and in hunting technique, a gradual decrease and final extinction of the game, and with it the annihilation of the human race dependent thereon. It is improbable that he would have predicted the innovation—the first great biological invention, namely, the domestication of animals and plants—which was to save the future and ensure the continued evolution of man.

It is interesting to realise that until recent years there had not been, during the whole historic period, any noteworthy addition to the list of man's domestic animals. All had been the servants of man from the dawn of history, they had accompanied him out of the mists of antiquity and had materially assisted his emergence.

The principle of biological control involves a tremendous increase in the numbers of man's animal auxiliaries—it is, in fact, an extension of the first great biological invention—the domestication of animals. It is true that the animals thus utilized are usually not domestic animals in the strict sense of the term, but there exists every gradation between these and such closely-domesticated organisms as dairy cows. Moreover, in what were in all probability among the first attempts at biological control—the destruction of rats and mice by dogs and cats—animals probably already domesticated were the agents. Ferrets, however, used against rats and rabbits, are very much less domesticated than dogs or cats and form a transition to natural enemies which are utilized without true domestication. It is these latter which are the chief agents in the biological control of insect pests.

The term 'biological control' covers at the same time, a multitude of sins and a number of man's newest and most promising weapons in his struggle with the organic environment. We must carefully examine these, for with the increasing popularity of natural control methods it becomes more and more necessary to define clearly what reputable workers understand by 'biological control,' and to distinguish between what should be actually attempted in this sphere, and what must still remain the subject of cautious experimentation. The need is the more urgent from the fact that, as Thompson has recently emphasised, 'economic entomology, though it finds in science its principles and its tools, is itself not so much a science as an art, like medicine. As in medicine, the practice of the art is always to some degree in advance of the written recipes and rules, which hardly do more than catalogue what experience has taught. One consequence of this is that while certain general methods gradually develop, there is a considerable period during which they can be learned only from the practitioners of the trade; another is that their general value remains uncertain until their scientific basis is critically examined. Such is at present the situation in regard to the biological control of insect pests . . . '

How then shall we define 'biological control? In a sense any method of combating a pest by means other than direct chemical or physical ones, is biological. The breeding of immune varieties of plants is one such, very promising, means. We would, however, limit the term to the utilisation of one kind of organism for the limitation or destruction of another. The theoretical possibilities of such a method are, of course, extremely numerous but we shall confine the following analysis to those cases in which attempts have been actually made or suggested. Even for these the accompanying table is not complete, but it will serve as a basis for discussion:

I. Control of injurious animals.

A—By other animals.

1. Control of nematodes by predacious nematodes (Steiner and Heinly, suggestion only, 1922).
2. Control of molluscs by vertebrates (slugs and snails by birds, hedgehogs, etc.)
3. Control of insects and other anthropods by
    - (a) mites.
    - (b) other insects.
    - (c) birds.
    - (d) other vertebrates (e.g., fish and newts against mosquito larvae, toads against nocturnal insects, bats against mosquitoes).
4. Control of vertebrates by other vertebrates (e g., fish by fish, snakes and rats by mongoose, rabbits by weasels, mice and rats by birds of prey).

B—By plants.

1. Control of insects and other anthropods by
   (a) bacterial diseases.
   (b) parasitic fungi.
   (c) algae (e.g., mosquito larvae by *Chara* spp.).
   (d) phanerogams, e.g., scale-insects on lime trees diminished by allowing Bengal Beans to climb over trees. Montserrat, Ballon. (*Melinis* grass against flies and ticks).
2. Control of injurious vertebrates by bacterial diseases, (e.g., rabbit in Australia, rats).

II. Control of injurious plants (Weeds) by

1. insects (e.g., against prickly pear and *Lantana*).
2. mites (e.g., against prickly pear).
3. fungi (e.g., against prickly pear, blackberry, Californian thistle).
4. bacteria (e.g., against prickly pear).

In addition there are such border-line cases as that of d'Herelle's bacteriophage; and such indirect control as that of cattle flies by the utilization of dung beetles, which render the manure unsuitable for their breeding.

Most of these cases represent actual attempt; a few are only suggestions. *As to their relative practicability, it cannot be too strongly emphasised that all are either in the experimental stage or may be dismissed as valueless, save the control of insects and other anthropods by insects.* It is far too frequently forgotten that this and this alone is the only sound general practice in biological control. To this must be credited every one of the sweeping successful applications of the principle. Only when this method has failed after years of trial, should the introduction of natural enemies other than insects (or other anthropods) be contemplated. The introduction and acclimatisation of predacious birds and mammals as a measure against pests (whether insect or vertebrate) has led to such disasters in the past, that it should be universally condemned. I need only mention the introduction of the mongoose into the West Indies, of the stoat and weasel into New Zealand, and of the English Sparrow into North America and other parts of the world. So far as insect-eating birds are concerned, we should carefully distinguish, of course between the importation of foreign species and the encouragement of native ones which have been found useful to agriculture. As McAtee (1926) has recently shown, the local birds may be looked upon 'as an ever-present force which automatically tends to check outbreaks large or small, among the organisms available to them as food. It is a force which should be kept at maximum efficiency by protective measures and which should be taken into consideration and used whenever possible.'

Bird protection then, both passive, by restriction of killing, and active by establishment of sanctuaries and perches, and checking of ground vermin, may be looked upon as a general insurance against insect outbreaks. It can rarely be considered as a measure against individual pests.

Save that in their case, protection is less practicable, the same remarks apply to insectivorous mammals, lizards and amphibians, the two latter being especially important in the tropics.

The control of weeds by means of their insect enemies is still entirely in the experimental stage. The best known attempt—that directed against *Lantana camara* in the Hawaiian Islands—has been successful in that the plant has been largely prevented from seeding by insects introduced from Mexico. By this means its re-infestation of cleared land and its further spread are greatly checked. The prickly-pear (*Opuntia* spp.) in Australia—the most spectacular weed in the world—is also, according to latest reports, gradually succumbing to the attacks of insects and mites imported, on a very large scale, from America.

Numerous observers, in many parts of the world, have been greatly impressed with the tremendous mortality among certain insect pests, under certain conditions, through the attack of fungous parasites and bacterial diseases. And just as numerous attempts have been made to reproduce these conditions artificially, and to control outbreaks by propagating the disease. In particular instances, sweeping successes have been claimed, notably by Le Moult and by d'Herelle, but later observers have usually failed to obtain similar results. One of the most thorough and careful workers in this field, Paillot (1916) came to the conclusion that 'la creation d'epidemies artificielles comparables, en intensite et en etendue, aux epidemies naturelles, soit a peu pres impossible dans l'etat actuel de nos connaissances; trop de ces facteurs interviennent, en effet, dans la propagation de ces epidemies, qui echappent plus on moins completement a l'influence de l'homme.' Petch (1921) a mycologist who is perhaps the foremost authority on entomogenous fungi expressed the same conclusion even more strongly when he said:

> 'At the present day, after thirty years' trial, there is no instance of the successful control of any insect by means of fungous parasites. If entomogenous fungi already exist in a given area, practically no artificial method of increasing their efficiency is possible. If they are not present, good may result from their introduction if local conditions are favourable to their growth; but, on the other hand, their absence would appear to indicate unfavourable conditions.'

So far as insect pests are concerned—and these are the worst of our troubles—we are thus left with control by means of their insect enemies. But even here, further analysis is necessary before we arrive at what is practicable and promising and what is not. With insectivorous vertebrates we have just seen that importations have usually proved more or less disastrous mistakes while encouragement of local species is recommended as a measure of general insurance. Precisely the opposite has been the case with insect enemies of insects, for here, as noticed above, all the most sweeping successes have been won with introduced parasites, while the attempted encouragement of native ones has usually proved futile. A consideration of these successes, and notably of those achieved in Hawaii, shows that the most favourable circumstances may be summed up under four heads;

(1) the pests to be controlled are immigrants, accidentally introduced without their natural enemies;

(2) the indigenous fauna is of a limited and peculiar kind, so that the chances of the immigrants finding new enemies in it are very small;

(3) the climate is warm and equable, allowing introduced parasites to multiply without seasonal checks;

(4) there are only a few main crops, so that high organisation and centralisation are possible, and a small improvement is rendered important by the large scale of operations.

Probably no other part of the world is quite so favourably situated as Hawaii in reference to all four of these conditions. But it is safe to say that any country possessing these four qualities in some degree, is favourably situated for biological control. One would expect that once suitable natural enemies were discovered, imported and established, the task would in most such cases be accomplished. Probably the most unfavourable regions in which to attempt control of this nature lie in continental areas, with a rich and varied fauna, and a 'temperate' climate, with a cold winter. In such areas it might be necessary to breed the parasites continuously in the laboratory and distribute them periodically, so as to force them into a condition of permanent dominance, to use the term of H. S. Smith. Such is the method used with the Australian ladybird, *Cryptolaemus montrouzieri*, in California, against the citrus mealy-bug. It is, of course, considerably more expensive than mere introduction and establishment accomplished once and for all, but at least in the citrus industry, it remains less costly than chemical measures of control.

This principle of assisting, as it were, the work of parasites already established, may theoretically be extended to indigenous natural enemies of pests either native or imported. In fact, the large scale utilisation of parasites already present, notably those of the codlin moth in California and of the sugarcane borer (*Diatraea*) in Louisiana, is one of the latest developments of applied entomology. But such extension, whether on a large or on a small scale, has nowhere yet met with any striking success, and biological control as a whole should not be judged by the trial of it alone. The corollary is that the best results in biological control are to be expected in the future, as they have been obtained in the past, from the introduction and establishment of parasites from other regions.

When we come to the tropics it is often a matter of the greatest difficulty to decide whether a given pest is an introduced or an indigenous insect, and provided the entomologist ascertains exactly what parasites are attacking it in the various regions of its range, this becomes largely an academic question. The sugarcane froghopper in Trinidad, evidently an indigenous insect, has very thoroughly adapted itself to cane-field, *i.e.*, essentially exotic conditions, while its local enemies have very largely failed to do so. The position thus simulates that of an insect introduced into a new country, without its natural enemies, and the way is open for the importation and establishment of foreign parasites which are as well adapted to cane-field conditions as the froghopper itself. The same principle applies to a number of other tropical pests.

A most essential part of the work consists in freeing the imported parasite from its own natural enemies (hyperparasites) before it is liberated. Mistakes of this kind are usually irrevocable.

The controversy as to the necessity for a sequence of parasites to attack various stages of the pests insect, with the dangerous tendency to the opposite extreme of super and co-parasitism, or the injurious competition of several parasites for the same individual hosts, seems now to have been resolved in the policy of sending one or two judiciously selected species at the beginning and observing their effect, before introducing others. The choice of species to introduce must, in the present state of our knowledge, be left in each case to the judgment of the specialised investigator who can study the pest and its enemies in the different parts of its range.

The emphasis on foreign parasites implies, of course that the task is not one for the local entomologist to perform single-handed. Biological control offers an extremely promising field for co-operative research, and with the foundation by the Empire Marketing Board of a special laboratory for this work under the Imperial Bureau of Entomology, its rapid further development along these lines, throughout the Empire, seems assured. The mission of the present writer to the extremely promising field of the West Indies is the latest extension of the same organisation. *Fiji Agricultural Journal*, 1929, Vol. II. No. 3.