require further research to optimise media formulations. However, the feasibility of *in-vitro* multiplication of valuable seed from progeny-tested parents has been demonstrated. Further research will be necessary before the methods can be applied to field-grown *Acacia melanoxylon.*

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BIOLOGICAL CONTROL: DOES IT HAVE A PLACE IN PLANT PROPAGATION?

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Before the question posed in the title of this paper can be answered it is necessary to pose, and attempt to answer, two others:

(1) What is biological control? and (2) what can it achieve?

What is biological control? The term biological control can mean rather different things to different people. Like many well worked (or over-worked) terms it has been adapted and modified by various authors to suit their own particular view points. The way in which the term will be used in the present paper should be clear from the following discussion.

The basic ideas, concepts and early applications of biological control were developed primarily by entomologists who, at least 100 years ago, recognised the importance of natural enemies in regulating populations of pest species. To a large extent it is only during the past few decades that such concepts have been extended to organisms other than insects and mites. I will first discuss biological control with respect to pest insects, then consider briefly if and how it may be applied to other "pest organisms" in the broader sense.

A much quoted definition of biological control is that of DeBach (1), an entomologist: "*Biological Control* is the regulation by natural enemies of another organism's population density at a lower average level than would otherwise occur."

To understand this definition properly we need to consider how insect populations change with time and the factors that influence such changes. Figure 1 summarizes the essential features. Insects (like most living organisms) have the potential for continued rapid increase in numbers under optimum conditions but in practice never achieve this except for short periods of time. Instead, their numbers tend to fluctuate around a mean which remains relatively constant. The shorter term fluctuations about the mean are determined by fluctuations in environmental conditions which include both abiotic and biotic factors. Among the latter, natural enemies are the most important.

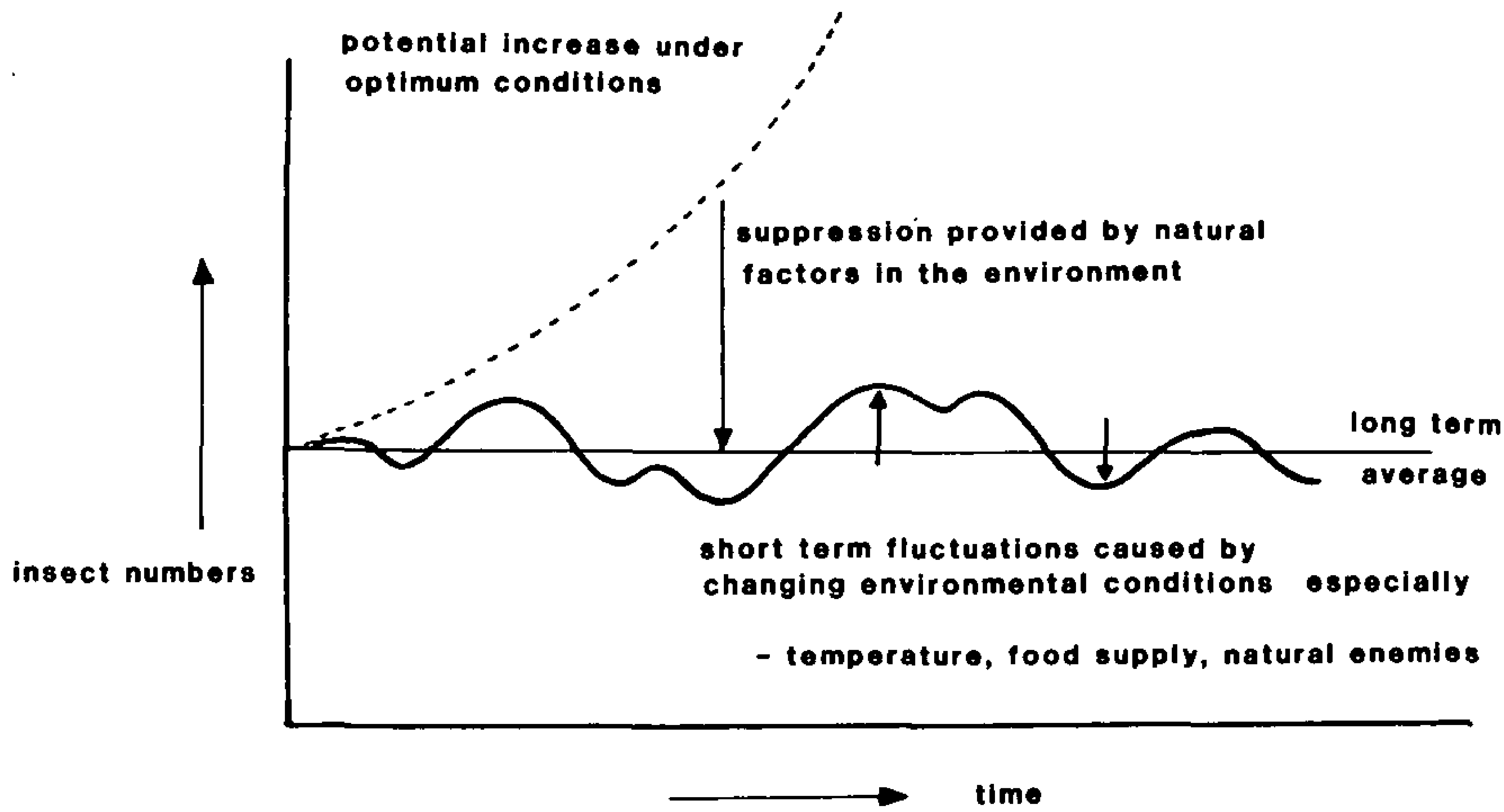

Figure 1. Natural regulation of insect numbers.

Note that in DeBach's definition of biological control, natural enemies may be an entirely *natural* element of the environment without any human manipulation. In my view it is better to refer to this simply as *natural control* (or regulation) and to reserve the term *biological control* for situations where the natural enemy component has been (or is being) manipulated by human agency. I would therefore like to offer you another (and simpler) definition of biological control.

"the use of natural enemies to suppress pest species"

This definition emphasises the element of human interaction (use) and the fact that the target species is of economic importance (pest).

Let us now consider briefly what natural enemies are. They fall under three headings: (a) parasites, (b) predators, (c) pathogens.

Parasites of insects are mostly other insects from the orders

Hymenoptera (wasps) and Diptera (flies). The larval stage of the parasite lives on or in the body of the attacked (host) insect and invariably kills it before the parasite completes its own development. All juvenile stages of insects (eggs, larvae, pupae) are subject to parasite attack but adult insects are rarely affected. All insect species without exception (including parasites) are subject to such parasitism.

Predators, on the other hand, capture and consume insects as a source of food and a predator may eat many individual insects during its lifetime. Many important insect predators are also other insects. Ladybirds are common examples, but many birds, mammals, and other vertebrates also utilise insects as part or most of their diet. Predators are usually less specialised than parasites as to their prey but this is not always the case. Some ladybirds for example confine their feeding strictly to a few species of scale insects or aphids. Among mites, predatory mites are important natural enemies of some plant-feeding mites.

Insect pathogens are micro-organisms which induce disease conditions (often fatal) in insects. Almost all groups of micro-organisms include some insect pathogenic species. Fungi, bacteria, and viruses are the most important groups. Some nematodes, although not strictly micro-organisms, also affect insects and are usually considered along with true pathogens.

What can biological control achieve? Biological control, as now defined, involves some degree of human intervention. This can take one of three forms:

(a) Introduction (or inoculation)
(b) Augmentation (inundation, or mass rearing and release)
(c) Conservation and encouragement.

Let us briefly review each in turn:

Introduction. *This is the "classical" form of biological control* that has been practised for many years. It involves the artificial introduction into a country or an area of a species of natural enemy that was not previously present. Once the natural enemy has been introduced it is left to fend for itself, to establish or not, to suppress the target species or not (see Figure 2). A considerable number of successes have been recorded around the world but many more failures. A relatively recent success in New Zealand is that of effective suppression of armyworm (*Leucania separata*) with introduced parasites. Similar efforts against grass grub (*Costelytra zealandica*) have been unsuccessful. Success is most likely against pests that have themselves been introduced—but there are no guarantees. What constitutes successful control? It depends very much on the circumstances. Any reduction in the population density of some pests (particularly indirect pests of plants, such as root feeders on ornamental plants) may be considered worthwhile but for direct pests (for example caterpillars damaging cut flowers), even 80 or 90% control would be considered inadequate.

A big advantage of this method of biological control is that once established it should be permanent, provided the action of the natural enemy(ies) is not disrupted by, for example, the careless use of insecticides. Insect pathogens may also be considered for introduction under certain circumstances. This form of biological control is essentially the function of a research organization and, because of quarantine implications and the need to exclude hyperparasites, decisions are usually taken at a national level. There is little that the individual grower can do other than press for adequate research funding.

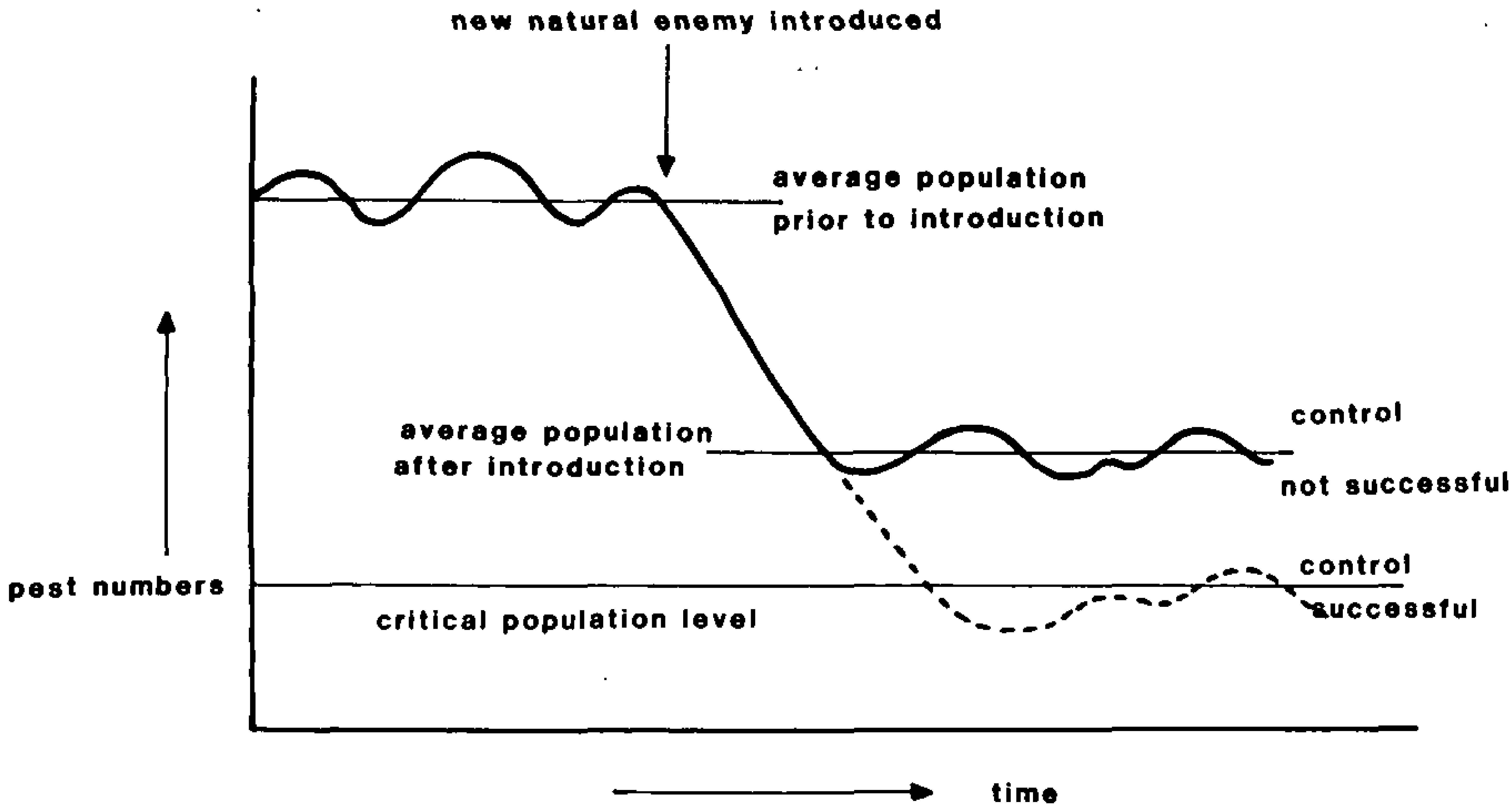

Figure 2. "Classical" biological control by introduction of a new natural enemy.

Augmentation. Augmentation involves the release into selected areas of suitable natural enemies to provide short term local control—a procedure sometimes referred to as inundation. Such natural enemies normally already exist in some form in the environment. The process is thus very much in the nature of using a "living insecticide". Figure 3 depicts the process graphically. Note that the effect wears off and the pest population recovers after a period of time.

Augmentation is obviously dependent on the ready supply of the right sorts of natural enemies which, in turn, is dependent on the development of suitable culture techniques. This has been achieved for a number of predators, parasites, and pathogens. In North America and some European countries certain commercial companies are prepared to meet the demand for these organisms and a grower can place a seasonal order but so far this has not happened in

New Zealand (the potential market here may be too small). Similarly, some insect pathogens in spore form or similar can be formulated into products for spray application to plants. *Bacillus thuringiensis* is an example.

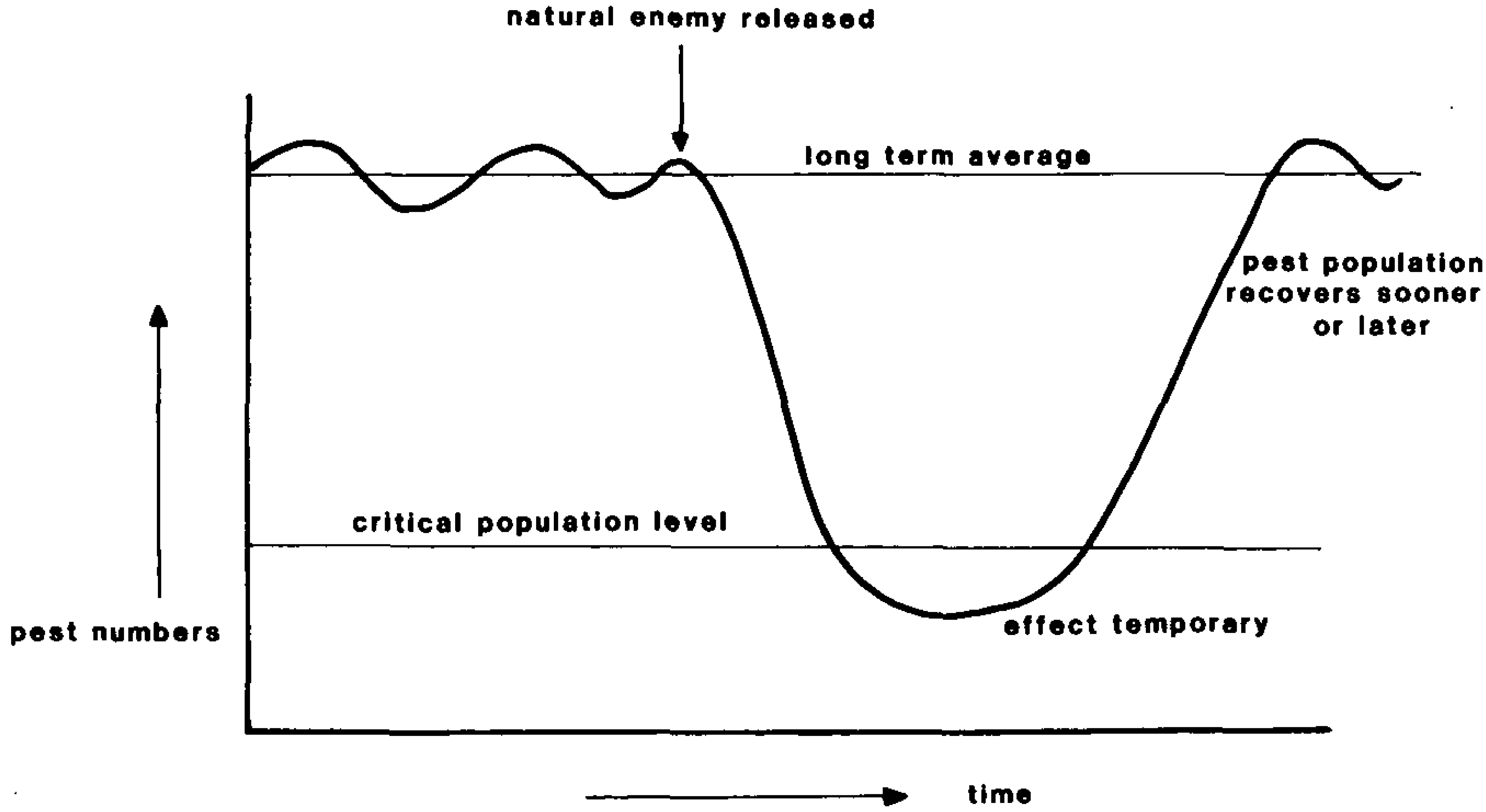

Figure 3. The effect of an inundative release of a natural enemy.

Biological control of pests of glasshouse ornamental plants by regular augmentation with natural enemies (predatory mites and whitefly parasite in particular) is now being recommended in England (3) where they are readily available at set prices. Unless the supply problem can be overcome there seems little prospect for general adoption of such methods in New Zealand.

In utilising this type of biological control procedure for a pest or pests it commonly happens that other pests (and diseases) still require chemical control. The choice of pesticides for this purpose must be carefully made to avoid harmful effects on the introduced natural enemies. Detailed information is available from such publications as those produced by the Glasshouse Crops Research Institute in England (2).

This now leads us to consider the third form of biological control; that of conservation and encouragement.

Conservation and encouragement. It is clearly important to conserve natural enemies that have been introduced, either on a once only basis or where regular augmentation is practised, but the same consideration may also be important with respect to natural enemies that occur quite naturally. Careless use of pesticides in particular can make pest situations worse in the long run or release potential pests from natural control (Figure 4). Apart from conservation, there is also the possibility of positively encouraging the development of natural enemies by such measures as providing nectar sources for adult parasites or using pheromones to manipulate insect behaviour. However, progress in this direction is so far limited by inadequate knowledge and techniques.

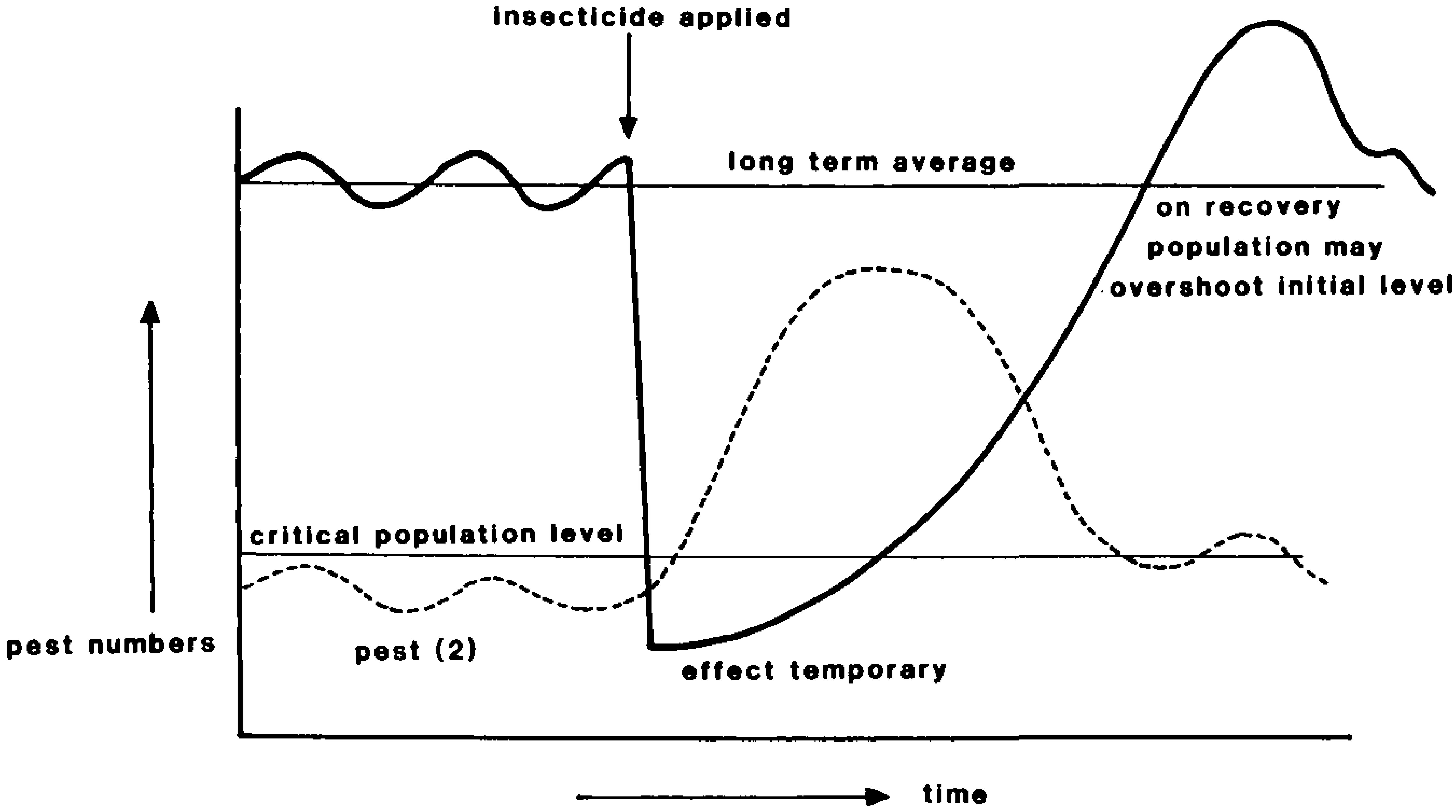

Figure 4. The effect of insecticide application on a pest population.

DISCUSSION AND CONCLUSIONS

Where does this leave us with respect to nursery plants and the plant propagator?

First, there may be a few pests that in the long term prove to be less troublesome because of improved biological control in the general environment. (The potential for this for many pests in New Zealand is still probably considerable.) However, biological control in this form rarely provides the very high level of suppression required in nursery situations so that one should not be too optimistic.

Second, there seem to be good prospects for further application of inundative techniques utilizing both parasites and predators and also insect disease organisms. The latter in particular lend themselves to the development of commercial products that can be applied in spray form and we are likely to see other types of pathogens appearing beyond the familiar *Bacillus thuringiensis*. There is for example a commercial product (Mycotal) now available in Europe based on the fungal pathogen *Cephalosporium (Verticillium) lecanii*. It requires high humidity but is effective against aphids, whitefly, and thrips (in suitable strains for each). A big advantage of such products is that they are highly compatible with parasites and predators. The critical question is whether such techniques can provide the very high level of control of pest problems that the plant propagator requires in order to produce essentially pest (and disease) free plants. Only experience will tell. Another development that is taking place is research into genetic modification of insect pathogens to render them more virulent or in other ways to modify their action. In Canada, for example, a major cooperative programme has been established recently to work on *Bacillus thuringiensis* in this way. The potential for such developments seems almost limitless.

For the time being at least there will continue to be a need for fairly intensive use of chemicals. If these can be integrated with the biological controls that are available so much the better.

Finally, may I indulge in some speculation? Biological control of plant disease organisms is an area in which I am not competent but which clearly presents prospects for further development. Antagonism between different microorganisms has been well established since the discovery of the first antibiotics in the 1940's. Only rather limited use has followed of antibiotic substances for plant disease control in contrast to animal diseases. However, there are encouraging developments involving the use of antagonistic microorganisms for suppression of some plant pathogens. The most successful has probably been the development of the product Dygall (based on *Agrobacterium radiobacter*) for the control of crown gall (*Agrobacterium tumefaciens*). A considerable amount of work has been (and still is being) done on the potential of various *Trichoderma* species (a fungus) for control of diseases such as silver leaf caused by *Chondostereum purpureum*. Also much recent interest has focussed on soil inhabiting fluorescent *Pseudomonas* bacteria which are antagnostic to a number of fungal pathogens. Although such phenomena are easy to demonstrate in the laboratory it is another matter to utilize such organisms in a complex environment such as the soil where antagonists of the the antagonists may prevent their successful establishment. Nevertheless, there must be further potential for the expansion of this concept to other plant diseases.

Such use of living microorganisms to counter plant pathogens falls clearly within the scope of biological control but other developments are starting to blur the boundaries between different control options. Supposing, for example, we are able to isolate and chemically characterise the active substances involved in such associations, then to synthesize them and perhaps modify them chemically for greater activity. Is this still biological control? Similar considerations apply to insect pheromones which may be produced synthetically. One further example: some workers have suggested that "organic" methods of crop culture may stimulate the growth in the soil of pre-existing microorganisms antagonistic to some plant pathogens resulting in more disease-free plants. If substantiated, is such a practice cultural control or biological control? Such questions become rather meaningless but do perhaps remind us that a virtual revolution in the discipline of plant protection is a distinct possibility in the near future and that we are probably just starting to see the beginning of this.

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THE MAINTENANCE OF STOCK PLANTS

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At Lyndale Nurseries we are of the opinion that the production of good plants from cuttings begins with the maintenance of stock plants that will produce the cutting material.

By growing the majority of our stock plants on the nursery property we can be sure that:

1. The history and identity of each stock plant is known.
2. Material produced by the stock plants is free of pests and diseases.
3. Cutting material can be collected with ease at the optimum time to ensure best possible results.

As well as our regular stock beds we have employed the available space between areas on banks, etc. to grow plants suited to particular conditions. For example, on a sunny north-facing bank grevilleas thrive in very sandy soil built up from used propagating mix. Banks are also filled with leptospermums and smaller growing conifer cultivars.

In the laying out of stock beds thought should be given to accessibility when collecting cuttings. Plants need a certain amount of room to grow and we need room to be able to remove the maximum amount of cuttings from each plant. Obviously a happy medium must be struck so as not to waste valuable nursery land.