PROC. V INT. SYMP. BIOL. CONTR. WEEDS, BRISBANE, AUSTRALIA, 1980: 3–9

LESSONS FROM EARLY ATTEMPTS AT BIOLOGICAL CONTROL OF WEEDS IN QUEENSLAND

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ABSTRACT

Four long-standing weed biocontrol programs in Australia are discussed: Prickly pears, *Opuntia* spp., *Lantana camara, Xanthium pungens* and *Eupatorium adenophorum*. Importation lessons include: Biological control programs are long-term. The pest taxonomy and identity must be clear. Short-lived annuals dependent on uncertain rainfall have poor biocontrol prospects. A complex of organisms and perhaps biotypes may be necessary. Native parasites may nullify a potentially effective agent. Careful screening of imported material is necessary to exclude the accidental introduction of pathogens. Plant pathogens can give significant control of weeds. Assessment of the results of weed biocontrol is complex.

INTRODUCTION

The principle of biological control is now widely, probably universally, accepted as an ideal method of controlling pests. Unfortunately not as widely accepted is the almost invariable requirement that some level of input of other control methods will be necessary if a satisfactory reduction in the importance of the pest in all situations is to be achieved. It is frequently not possible to predict what effects biological control organisms will have on existing problems and control methods, or in what way land management (pest management systems) will have to be modified to optimise efficiency.

In the past, in Australia at least, weed biological control programs have been initiated in response to primary industry and political pressures following the massive invasion of regions, mainly rangeland, by a pest species which was not amenable to more conventional methods of control (Haseler 1979).

Australia has been in the forefront in biological control attempts and investigations since this principle was first recognized. It is useful to review some of the major projects undertaken in this country not only to determine their success or otherwise, but also to see how seemingly straight-forward projects have evolved into more complex systems.

I have discussed four long-term biological control projects in Australia and what lessons can be learned from their progress.

PRICKLY PEAR

Prickly pear (*Opuntia* spp.) is still a by-word when biological control is considered and the spectacular success which attended this program is still much discussed. But what is not generally realized is that the prickly pear campaign involved several members of this genus, and the much publicized success was only in some of the environments colonized by this plant.

The pest prickly pears (*O. inermis* [DC] DC. and *O. stricta* [Haw.] Haw.) in 1925 infested an estimated 60 million acres and this area was extending at the rate of a million acres each year (Dodd 1940). This spread has continued although at a slower rate but population densities are generally below any economic threshold. Completely satisfactory control of the pest pears is exerted

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over most of the infested environments by the moth *Cactoblastis cactorum* Berg. (Lepidoptera:Phycitidae) augmented by the cochineal *Dactylopius opuntiae* Licht. (Hemiptera:Dactylopiidae) (Mann 1970). However, control is not satisfactory in central and southern New South Wales due probably to the shorter summer period (V.C. Gray, pers. comm.), or in coastal areas of Queensland due probably to abnormal host plant growth (G.G. White, pers. comm.).

Tiger pear, *O. aurantiaca* Lindt., and Drooping tree pear, *O. monacantha* (Willd.) Haw., are controlled in Queensland by cochineal insect species, *Dactylopius* spp., but at the expense of continued manual distribution of these organisms. In New South Wales the tiger pear cochineal insect is of limited value due to a much shorter active period in summer. Three other species of *Opuntia* are under effective biological control by different species of *Dactylopius* (Mann 1970), chemical or other methods of control is only necessary where eradication is desired.

The prickly pear campaign began in 1911. Consignments of *C. cactorum* (amongst other insect species) were received from South America in 1914 (but did not survive), and again in 1925. Field releases of eggs were first made in 1926 and by 1929 these had reached a massive scale involving 2 100 000 000 eggs between 1929 and 1932. By 1933 all major areas of *O. inermis* and *O. stricta* had collapsed (Mann 1970).

The prickly pear campaign did not happen overnight; it involved 22 years of continuous research. Further, research into chemical and mechanical control methods proceeded concurrently with the biological control investigations, and legislation was enacted by State governments to enforce land management conditions on affected landholders (Mann 1970).

The prickly pear campaign showed that:

(a) biological control of weeds can be spectacularly effective. Paradoxically, the degree of success achieved by the single insect *C. cactorum* in fact created what could be called an unfortunate precedent for all weed biological control. Probably too much is now expected.

(b) the creation of regional bodies (Commonwealth Prickly Pear Board) to investigate all aspects of the pest problem can allow systematic planning and co-ordination of effort in research, legislation and land use both at regional and farm level.

(c) biological control programs are long-term.

(d) insect enemies of related host species can give effective biological control of plants; *O. inermis* is from North America and *C. cactorum* from South America (Dodd 1940).

LANTANA

Lantana, *Lantana camara* L., is a vigorous thorny shrub introduced into Australia last century as an ornamental plant (Everist 1959). Although native to North and South America, most Australian cultivars probably came from Europe where plant breeders produced a multitude of flower colour and growth forms. In Australia, numerous distinct and self-perpetuating taxa are known from the field (Everist 1974); these taxa vary significantly in their habit, vigour, toxicity to stock, environmental limits, susceptibility to herbicides and acceptability as food for insects.

Lantana is mainly a pest of forests, reserves and pastures, and a nuisance on roadsides and rights-of-way. Although the poisonous nature of some taxa can cause serious stock losses, its main significance in grazing situations is as an indicator of incorrect land use and management. However, it is also regarded by a section of the community as beneficial because of its value in erosion control and the aesthetic appeal of flowering plants. A weed by definition is any plant which interferes with man's interests. Few, if any, plants are weeds in every situation and conflicts of interest between community groups can develop over the desirability of controlling them. In Australia no weed biological control program can now proceed without federal approval following a national survey of agricultural and other interests.

Biological control investigations commenced in 1902 in Hawaii (Perkins and Swezey 1924) and in 1914 in Australia. Four species of insects were introduced into Australia in 1914/16, and another in 1935 (Wilson 1960). Since 1956 16 further insect species have been introduced and released in the field in Queensland and New South Wales (Haseler 1977). Overseas investigations in South America are continuing and the introduction and release of additional insect species and plant pathogens into Australia are anticipated (K.L.S. Harley, pers. comm.).

The degree of control exerted by those insect species already established in Australia varies enormously with environment and with host species taxonomy. Success ranges from virtually complete in well watered (>900 mm) tropical and sub-tropical, open environments to insignificant in drier, cooler or shaded situations (B.W. Willson, pers. comm.).

Several important principles can be learned from the lantana investigations.

(a) The pest problem must be defined. Until the complexity of the taxonomy of *L. camara* was recognized the pest was regarded as a simple although widespread one. It is certainly not simple.

(b) Biological control can seldom be achieved by a single organism where several different environments are invaded by the pest. A complex of organisms and perhaps a complex of biotypes of the same species may be required. Continuity of assessment, review and the strategic release of additional material will be necessary.

(c) A time lapse of many years can be anticipated in virtually all biological control programs against weed pests.

(d) A priority of investigations can be related to those situations most threatened by the pest. Lantana organisms adapted to dry, cool and shaded situations are now most in demand.

(e) It is seldom that a general assessment of a biological control project can be made, particularly when the whole problem is considered. Depending upon where you happen to be standing, the lantana program is both a success and a failure.

(f) Land management strategies can augment the effects of the lantana organisms to the point where effective control is gained. The planting or encouragement of competing beneficial pasture species combined with rigid control of grazing pressures can suppress and eventually eliminate lantana provided its vigour is reduced by insect attack. The tactical use of fire is useful, again provided that it is timed to allow rapid reinvasion by biological control organisms.

(g) The status of a weedy plant in the economy of a country must be clear before biological control is attempted.

NOOGOORA BURR

The *Xanthium* species known as noogoora burr in Queensland is provisionally identified as *X. pungens* Widder; it is one of the *strumarium* group, the taxonomy of which is not clear (Everist 1974). The origin of the Queensland taxon is not known although it is thought to be North American, perhaps only from a limited locality of that continent (McMillan 1971). The genus is now cosmopolitan.

Following the accidental introduction of noogoora burr into Queensland about 1879 (E.H. Marks, pers. comm.) the plant spread widely and despite large scale and expensive government directed containment campaigns (Anon. 1960-1975), it is now present throughout the State. Serious infestations are present in New South Wales, but other States have limited establishment by enforced chemical and other control measures (Australian Weeds Committee, pers. comms.).

Noogoora burr is a short-lived, annual herb which germinates in response to soil saturation and high temperatures. A delaying mechanism in one of the two seeds in each fruit results in a series of germinations following each heavy rainfall; seeds are long-lived. Further, while flowering is mainly controlled by photoperiod, in tropical Queensland fruit may set in any season (Wapshere 1974).

Noxiousness is due to contamination of wool by the spiny seed pods, to loss of pasture which is suppressed by rapid vegetative growth following rain, and to stock poisoning after ingestion of newly emerged cotyledons (Everist 1974).

Comprehensive surveys between 1929 and 1940 of the insect fauna of *Xanthium* in North and South America and India found widespread attack but almost invariably the organisms had alternate or alternative plant hosts (Wilson 1960). Two oligophagous stem-borers, although shown under cage tests to accept related Compositae (including sunflower, *Helianthus annuus* L.) as food material, were approved for release only after a cost/benefit consideration of the importance of the weed against possible crop damage was made (Haseler 1977). Neither species has subsequently attacked crop plants, particularly sunflower, in the field in Australia.

The only insect known to be specific to *Xanthium, Euaresta aequalis* Loew (Diptera:Trypetidae), is established in restricted areas but causes no significant control of its host (Wilson 1960). Of the two stem-boring beetles, *Mecas saturnina* Le.C. (Coleoptera:Prionidae) has survived at one site but shows little potential as a control factor. *Nupserha antennata* Gahan (Coleoptera:Prionidae) is established widely at several sites in diverse environments, but although large populations are very destructive in mid-summer, the short oviposition period is not synchronized with the much longer noogoora burr germination and the plant persists as a major weed. Further, rainfall in Queensland is very variable in time, space and volume and annual host population fluctuations may be so extreme as to severely limit the efficiency of biological control factors. A 'rust' fungus, *Puccinia xanthii* Schw. was recorded from noogoora burr in Queensland for the first time in 1975 (Alcorn 1975) and dispersal is now widespread. Although reservations are held about its specificity (Alcorn 1976), this pathogen gives considerable promise as a control factor and major damage is reported to dense stands of the host.

Probable reasons for the lack of success with this program are:

(a) Short-lived annual plants are poor candidates for biocontrol.

(b) Plants with wide environmental limits make poor biocontrol candidates as a variety of enemies is usually necessary in terms of both locality and of season.

(c) Opportunistic plants in environments with a variable climate, particularly rainfall, are poor biocontrol candidates.

(d) The taxonomy of the host plant is important and must be understood.

(e) Host specificity testing in cages gives indications only and should not be proposed or accepted as definitive.

CROFTON WEED

Crofton weed, *Eupatorium adenophorum* Sprang., is a Mexican shrub which was first reported from Queensland in 1930 and which spread aggressively between 1940 and 1950 in the south-eastern districts of that State (Dodd 1961).

A trypetid gall-forming fly, *Procecidochares utilis* Stone (Diptera:Trypetidae), was introduced from Mexico to Hawaii in 1945, and thence in 1952 to Australia. Within two years dense populations of the gall-fly developed, but these were almost as quickly suppressed by a subsequent explosion of native parasites which attacked this exotic insect. Apparently concurrently with the establishment of the gall-fly a fungus disease of crofton weed, *Cercospora eupatorii* Peck., appeared, possibly arriving as a contaminant of a consignment of gall-flies from Hawaii (Dodd 1961). This wind-borne and very specific disease attacked all parts of the plant but was especially damaging to seedlings (Haseler 1963). A native crown-boring beetle, *Dihammus argentatus* Auriv. (Coleoptera:Cerambycidae), causes major damage to the roots of mature plants (Haseler 1963).

Crofton weed still infests the areas originally invaded but is only dominant in cool, shaded and wet environments. Attack by the gall-fly is generally light and probably is significant only for limited periods of the year. Seedling growth is heavily attacked by the fungus disease and it is probable that this is a major factor controlling further spread. Attack by the crown borer weakens plants to the point where pasture species can compete successfully in all but shaded, wet situations (Haseler 1963).

The failure of *P. utilis* to give effective biocontrol of crofton weed is due to suppression of populations by native parasites, but this suppression is seasonal due to non-synchronization of the life periods of the host and its parasites. This results in enormous fluctuations of the host populations which periodically reach high levels. It is possible that mass release strategies timed to take advantage of this non-synchronization could achieve complete suppression of the weed (Haseler 1963). The native host range of the principal parasite is not known but from evidence available it would seem that these host insects are gall-forming Hymenoptera and not Diptera (Haseler 1963).

From consideration of this program it is apparent that:

(a) Native parasites can significantly limit an otherwise effective biocontrol agent.

(b) Advance prediction of the effect of native parasites on an exotic species is difficult except in very general terms; e.g., gall-forming insects may be prone to parasite attack in an environment where other gall forming insects are common.

(c) A knowledge of the ecology of an exotic insect in its new environment may allow manipulation of populations to give effective control where this is otherwise not achieved.

(d) A plant pathogen can offer a significant and cumulative increment in the biocontrol of a weed.

(e) Care must be taken to exclude the introduction of other exotic organisms with beneficial species. The fact that the crofton weed disease is both specific and effective is completely fortuitous. All exotic insects introduced into Australia must now have federal clearance which includes a condition that a complete generation has been completed under quarantine before release in the field.

DISCUSSION

It can be stated that weed biological control programs tend to evolve rather than follow firm directions, and the evolution continues for many years until the environment stabilizes. In an environment of a changing nature like Queensland this may take several decades. To maximize the effects of biological control it is necessary to constantly review and assess the effects of the exotic organisms and if necessary to augment them by other activities particularly at the farm level. Land management is vitally important and the manipulation of biological factors should be considered as an integral part of weed control. The operative words in this field are 'constant review'.

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