SUPPORTING THE INTRODUCTION OF EXOTIC BIOLOGICAL CONTROL AGENTS FOR UK HORTICULTURE

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ABSTRACT

Horticulture occupies 2% of the cropped land in the UK but it accounts for 30% of the value of all crops. Crops are therefore of high value and require protection from pests. The internationalisation of the industry has resulted in considerable movement of pests as well as produce across national frontiers. Some of these pests can be controlled by biological methods, which is encouraged by government policies of pesticide minimisation and environmental protection. A sophisticated industry has developed to service this need, and some biological control agents available commercially are exotic to the UK. The release of exotic arthropods is regulated by the Wildlife and Countryside Act (1981) which is aimed at protecting the environment. In contrast, the release of exotic micro-organisms is not limited specifically other than as plant protection products. These are regulated by the Plant Protection Products Regulations (1995) which implement Directive 91/414/EEC, and are aimed primarily at safety. This legislation provides the regulatory framework within which the development of biological control as an effective pest control option can be achieved for the benefit of the horticultural industry in the UK. Further scientific advances and clarification of regulations are required before the use of exotic species for biological control in outdoor crops can reach its full potential.

INTRODUCTION

The United Kingdom is located on the northwest seaboard of Europe and therefore experiences a cool temperate climate. As an island it has a relatively impoverished native fauna and flora. The variability in climate from winter and summer is not great, as compared to continental regions, but winters are sufficiently cool that plant development ceases or is very limited, unless crops are grown under protection. The diversity of crops grown in agriculture and horticulture are also relatively small as compared to many regions at lower latitudes; the exception again being under protection. These crops are damaged by many insect and mite pests and their control is dependent on a combination of approaches, including biological control. It is necessary to examine briefly the UK horticulture industry, and associated driving forces, to understand the needs for the use of exotic biological control agents before examining the regulations associated with their introduction and release.

Horticulture in the UK

UK horticulture is a highly sophisticated industry relying heavily on technological advances to remain competitive. Frequently growers are highly specialised producing a very limited

range of high quality produce. The area of the UK devoted to horticulture is small at only 187,000 ha, equivalent to 2% of the cropped area (Anon., 1996a). However, these figures conceal the value of this output which at £1,969M is equivalent to 29.6% of the farm gate value of all crops (Anon., 1996a). Horticultural crops are therefore of relatively high value and growers are prepared to make a greater financial investment in protecting them from damage by pests and diseases than on arable crops.

The horticulture industry in the UK comprises a diversity of commodity sectors but, when considering insect control, these can be grouped into three contrasting 'ecological' environments; protected crops with varying degrees of environmental control, annual field-grown crops which are in the ground for periods ranging from a few weeks to many months with subsequent plantings frequently being in different fields, and finally perennial crops which persist in the same land for anything from two years to a few decades.

A large proportion of the produce from these different environments is sold fresh directly through the multiple retailers and processors who demand a very high quality product and an ever increasing diversity of produce the year around. This is not satisfied by UK production alone as some commodities, such as citrus, cannot be grown in the UK climate, while others are not produced in sufficient quantity. The consequence is that the value of imports of horticultural produce to the UK is £2,517M as compared with the farm gate value of home produced produce at £1,951M (Anon., 1996b). Though these figures are calculated by different methods, they do illustrate the scale of the importation of horticultural produce to the UK, a significant proportion of which is fresh. The implications of this are explored below.

An international industry

The internationalisation of horticulture has presented the consumer with an ever greater variety of high quality produce irrespective of season. This has driven producers to extend the period over which crops are grown by exploiting protected environments and by the use of varieties with different harvest dates. In addition, some growers are investing in production overseas so they can import fresh produce to the UK out of season. For some commodities different stages of the crop production process are done in different countries or even continents. For example, chrysanthemum cuttings may be produced in Kenya, South Africa, Brazil, Costa Rica or the Canary Islands and then air freighted to the UK where they are grown in manipulated and protected environments to produce a flower crop throughout the year. It is interesting to note that the movements of fresh plant material are between different zoogeographical regions with very different faunas.

This enormous international trade of both planting material and fresh harvested produce means that there is a huge movement of plant material across international boundaries. Many of these plant species are exotic to the country in which they are finally grown or marketed. Despite the considerable efforts of the plant health services world wide, the sheer volume of produce transported means there is inevitably a small 'international trade' in exotic pests and disease associated with this plant material. One consequence of this is that exotic pest species are from time-to-time introduced into the UK where they may become established on horticultural crops and a control solution is required; the western flower thrips (*Frankliniella occidentalis*) is a good example (Helyer, Baker and Saynor, 1987). Initially these exotic pest species may not have a natural enemy complex associated with them and control will rely on

insecticides. With time the native natural enemies may become associated with an exotic herbivore and limit its populations (Schönrogge, Stone and Crawley, 1996), but this is only likely in the outdoor environment. If a biological control option is to be developed for such exotic pest species, it may become necessary to import natural enemies from the area of origin of the pest if a satisfactory native natural enemy cannot be identified.

Limited availability of agrochemicals

The markets and consumers require blemish free horticultural produce, and therefore much pest and disease control is directed at the production of *quality* produce that is of good appearance, has long shelf life and good storability. This differs markedly from the arable sector where much agrochemical usage is directed primarily at maintaining yields.

Agrochemicals can play an important rôle as a component of crop protection strategies directed at producing quality horticultural produce, and they are often the first choice for growers due to their simplicity of use and low cost. There is, however, increasing concern within the horticulture industry over the decreasing number of active ingredients available to them. The agrochemical industry has to remain profitable and to achieve this it needs to obtain a sufficient share of a large enough market to recoup its development and registration costs and then make a profit. As new registration regulations require that each active ingredient is reviewed periodically, manufacturers are not looking favourably on the small area, and therefore relatively small market for them, that horticulture provides. Even when horticulture as a whole is considered a large enough market, individual crop-pest sectors may be too small for the industry to consider targeting (Fraser, 1993).

In addition to the commercial reasons that have resulted in a decline in the availability of agrochemicals, there are a number of biological 'forces' that have driven the development of biological control options. Some formulations of agrochemicals are phytotoxic, the expanding ornamental sector being particularly sensitive. A good example is the control of *F. occidentalis* in protected cucumbers where the only formulation of dichlorvos available killed the thrips and damaged the plants severely (Jacobson, pers. comm.).

Resistance to pesticides is an ever increasing consideration, with some species having strains that are so resistant that chemical control is either no longer an option or has to be used with great care. There are a number of examples in UK horticulture where resistance to pesticides is a particular concern including *Phorodon humuli* on hop (Muir, 1979; Furk and Baxter, 1988), *Panonychus ulmi* on apple (Cranham and Helle, 1985) and *Aphis gossypii* on cucumber (Furk and Hines, 1993) and biological alternatives to insecticides are being sought and deployed.

A final biological consideration is the introduction of biological agents, particularly bumble bees and honey bees, for the pollination of crops. This technology has been adopted very widely in protected crops in the UK over the last five years. Commercially-produced colonies of bumble bees are now used to pollinate virtually all long-season tomato and sweet pepper crops. Elsewhere in the world such methods are being applied to crops outdoors, and the use of honey bees in orchards is a well established practice. In protected crops this method of pollination is so effective that it is a major driving factor in determining the pest control strategy; many insecticides are incompatible with bumblebees, leaving biological control as the only viable alternative.

Policies and demands to reduce pesticide usage

Simultaneous with the reduction in the availability of active ingredients for insect and mite control are the demands for a reduction in the use of insecticides. This is being driven by government policy, market pressure and consumer demand.

Government policy is driven by both the Ministry of Agriculture Fisheries and Food (MAFF) and the Department of the Environment (DoE). MAFF wishes to reduce pesticide usage as part of its policy to reduce overall farm inputs to retain profitability, as well as its policy to protect the environment. Policies on the environment from MAFF and DoE are similar and recently they jointly published the Rural White Paper, *Rural England - A Nation committed to a living countryside* (1995), in which they identified an action plan for the responsible use of pesticides.

The consumer is becoming increasingly informed about environmental issues and is demanding food with fewer pesticides, and the multiple retailers are becoming increasingly pre-eminent in limiting the use of pesticides while retaining high product quality. Quality now applies not only to the produce itself, but also to the way in which it was produced. This is being achieved through the development of protocols that document how crops are to be grown. These protocols have now been developed for more than 30 horticultural commodities in the UK and are coordinated by the National Farmers Union with the cooperation and participation of the majority of the multiple retailers (Anon, 1994; 1995). In some commodities biological control of pests is of paramount importance. Failure to comply with these protocols may mean that that market outlet is no longer available to a producer.

The biological control industry

The implication from what has gone before is that biological control in UK horticulture is considered already as a viable alternative to insecticides in some commodities, particularly where there are biological 'driving forces' whereby insecticides do not provide effective control to produce a quality crop. The development of an industry around the supply of biological control agents is driven by very similar commercial considerations to an agrochemical business in that it needs a sufficiently large and continuing market to make that industry profitable. Therefore the biological control industry requires biological control to be used in a similar way to insecticides; repeated inundative release is the preferred approach as classical biological control, whereby permanent equilibria between pest and natural enemy are established, does not provide the continuing market needed for profitability. In addition, classical biological control is not thought possible in the majority of horticultural commodities, particularly where crops have a very short growing period, or are grown in protected environments as control may be achieved too late to secure a quality crop. However, there are instances where introductions are made once in a season, after which an equilibrium is established exerting control for the whole season.

A strong and competitive biological control industry has developed in the UK. The different companies, and there are currently three major players in the UK, mass produce and distribute a diversity of natural enemies of a consistent quality to the horticulture industry. In addition, they work closely with growers providing considerable technical support to ensure the effective use of the biological control agents within integrated pest management

systems. The development and maintenance of a competitive and profitable biological control industry requires that production facilities and technical expertise are used effectively throughout the year. To achieve this the biological control industry, like the industry it serves, is becoming increasingly international, to take advantage of different growing seasons in different countries, in both the production and the distribution of products.

Competition between biological control companies has resulted in each trying to obtain a competitive advantage over the others. As it is not possible to patent biological control agents, an advantage can be obtained while another company is unable to mass produce a 'new' species. As a consequence details of production processes are guarded carefully, but it does not take long before a competitor is also able to produce and market a 'new' biological control agent. The consequence of this was that for a period there was a continuing search for novelty of product in an attempt to capture a greater market share. However, on occasions it appeared that the principal criteria as to whether to market a new product was that it could be produced economically rather than it was an improvement over the products that were available already; the complementary research to determine efficacy and other benefits were often superficial.

The biological control industry is very aware of the regulations that control the release and use of biological control agents and highly responsible over the potential dangers of introducing exotic species into the UK. After the introduction of the Wildlife and Countryside Act in 1981 the industry focused on indigenous species for use in the UK, partly because it was unclear what was required to obtain a licence for the introduction of an exotic species. However, as procedures have become clearer, the biological control industry is applying for licences for the introduction and release of exotic species to the UK. There are currently 27 species of arthropod for use as biological control agents on the product lists of the different companies operating within the UK, of which nearly half may be considered exotic to the UK, though it is unclear whether they are all for sale in this country.

In summary, the highly competitive horticulture industry is producing products of the highest quality to satisfy the demands of retailers, processors and consumers. In some commodities this is only possible through the use of biological control as a diversity of factors make the use of insecticides unsuitable. A biological control industry has developed to service this demand which markets both indigenous and exotic species. There is a range of legislation and regulations to which the biological control industry works which is outlined below.

REGULATIONS

The agreements and legislation that controls the introduction and release of exotic biological control agents into the UK fall into three categories. Firstly, international conventions and codes of conduct are aimed primarily at the protection of endangered species and habitats, or at ensuring that the biodiversity of countries is not exploited solely for the benefit of a second country. Secondly, national environmental regulations are directed at minimizing risk to the environment and are administered by the DoE. Finally, the regulations that relate to the registration of crop protection products and organisms are the responsibility of MAFF and are directed primarily at the safety of the user, consumer and the environment. The groups of organisms covered differs between regulations and therefore the information required to introduce any exotic species for biological control have to be examined

individually. Some of this legislation applies to the UK alone while others implement EC regulations within the UK. The regulations are complex and the interpretation given is that of the author. Legislation applicable to genetically-modified organisms is specifically excluded from this discussion.

International Conventions

The two articles of international legislation that impact on the release of exotic species into Britain are *The Convention on the Conservation of European Wildlife and Natural Habitats* (the "Bern Convention"), which was adopted by the Council of Europe on 19 September 1979, and the *Convention on Biological Diversity*, which was signed by contracting parties at the Earth Summit at Rio de Janeiro in 1992. The Bern Convention requires that the introduction of exotic species should be carefully controlled, and that the possible consequences of the introduction should be assessed beforehand. The Convention on Biological Diversity aims to prevent introductions which will threaten ecosystems, habitats or species. Neither of these conventions specify the organisms with which they are concerned, but they are assumed to be all encompassing.

Recently the *FAO Code of Conduct for the Import and Release of Exotic Biological Control Agents* (1995) has drawn together a procedure that could be adopted internationally which involves representatives of governments, exporters and importers.

Environmental Regulations

The starting point for the introduction of exotic biological control agents into Great Britain is the *Wildlife and Countryside Act* (1981) which is directed primarily at the protection of the environment. The Act states that it is an offence "to release into the wild any animal which is of a kind which is not normally resident in and is not a regular visitor to Great Britain in a wild state" without a licence.

This Act contains a number of potentially ambiguous terms which require interpretation in relation to biological control; the DoE are in the process of producing a guide to clarify requirements and so aid the introduction of exotic biological control agents (DoE, pers. comm.). 'Any animal' is taken to include arthropods and nematodes, but excludes fungi, bacteria, viruses and protozoa. Species that are 'ordinarily resident' are those that occur in Great Britain and have self sustaining and viable populations, breeding and producing young which reach maturity without the deliberate assistance of man. Sub-species and strains that originate from a geographical location outside of Great Britain are considered to be exotic and cannot be released without a licence. 'Releases' into the 'wild' includes anywhere from which animals might escape and include any semi-confined situation such as gardens and glasshouses.

Applications for a licence to release exotic species are handled by the Chemicals and Biotechnology Division of the DoE that act as the secretariat to the Advisory Committee on Releases to the Environment (ACRE). The information required to be submitted in a dossier is given in Table 1, and is aimed at establishing whether a species poses a risk to the environment, in particular whether the species will become established in the Great Britain. The dossier is assessed by ACRE and is commented on by the statutory conservation bodies e.g. English Nature.

Table 1. Summary of the information required by the Department of the Environment to support applications for licences to release exotic biological control agents in England.

Scientific and common names of organism
Description of organism
Description of purpose of proposed release
Description of sites where release will take place
Description of intended conditions of release
Origin of organism or strain to be released
Details of culture conditions, location of cultures and disease control measures
Description of the geographical distribution and of the natural habitat of the species
Life cycle of the organism in its native habitat
Interactions with other organisms
Environmental parameters for survival of the organism
Physiological and other characteristics of relevance in assessing survival of the organism
Potentially significant interactions with the environment
Details of receiving environment
Information on monitoring and control

Licences are issued for a species and a particular purpose i.e. the release of a defined number of individuals to one crop type. If the licence applicant is a company supplying biological control agents, two types of licences are issued; firstly the "supplier's licence" for research and development and for the distribution of the species, and secondly, a "grower's licence" should accompany each consignment of the exotic species purchased which allows him to release that species. In the first instance licences are issued for one year during which time the introductions are monitored and the results reported to the DoE. Subsequent licences may be issued for three years.

Although this Act has been in place for 15 years, it is comparatively recently that licences have been issued. As a consequence there was a period when no releases of exotic species for biological control occurred. Prior to the Act, introductions were unregulated and include the spectacularly successful use of *Phytoseiulus persimilis* and *Encarsia formosa*. The DoE are currently considering species released prior to the adoption of the regulations to determine whether they pose any threat to the environment and, if not, whether they can be covered by a generic licence.

To date licences have only been issued for the release of five exotic species for biological control purposes in glasshouses, and one for release in the wider environment. There is currently no charge for a licence as the DoE wish to encourage biological control.

Pesticide Regulations

The *European Commission Directive 91/414/EEC* "concerning the placing of plant protection products on the market" is now the key legislation for new products where the active ingredient has not been registered previously in any member state. Its main objective is to harmonise the registration procedures for plant protection products throughout the European Union (EU) and the prime considerations are safety to users, consumers and the environment.

This directive is aimed at all plant protection products which are defined as 'active substances' which are 'substances or micro-organisms including viruses, having general or specific action against harmful organisms'. The term micro-organisms has no clear biological meaning but discussion documents within the EU propose that this should include bacteria, fungi, protozoa, mycoplasma, viruses, viroids and nematodes. It is vital that the definition of micro-organisms is clarified without delay.

Directive 91/414/EEC is implemented in the UK through *The Plant Protection Products Regulations* (1995). This legislation supersedes *The Control of Pesticides Regulations* (1986) which implemented the *Food and Environment Protection Act* (1985) which now applies only to the registration in the UK of active ingredients and micro-organism that were registered in another member state prior to 1993. Directive 91/414/EEC specifically includes the use of micro-organisms as biological control agents. In the UK applications for registration of micro-organisms are made to the Pesticides Safety Directorate (PSD), an Executive Agency of MAFF. The information required for registration of micro-organisms as pesticides is summarised in Table 2.

Table 2. Summary of data required by PSD for the registration of a micro-organism as a pesticide under EC Directive 91/414/EEC

Identity and information on the proprietary product
Identity of the active agent
Biological properties of the active agent, including target for control
Manufacture and formulation
Application
Experimental data on efficacy
Experimental data on infectivity, allergenicity and toxicity, including carcinogenicity and teratogenicity
Effects on humans
Residues
Information on environmental and wildlife hazards
Labelling

Information provided by PSD indicates that a different amount of information will be required where an agent is an introduced species or strain as compared with a naturally occurring indigenous species. This is to ensure that an adequate assessment of risk to the user, consumer and the environment can be made. As yet no organisms have been registered through this new procedure; the three micro-organisms currently registered for use in the UK received approval through the Control of Pesticides Regulations (1986). It is recognised that the costs of assessing a dossier for a micro-organism are less than those for handling one for a chemical insecticide, and MAFF wish to encourage the use of biological agents for control purposes. However, PSD currently charge £4,400 as an initial "sift fee" to ensure all the information is provided and then a further £13,000 to process the full dossier. The benefit of the harmonisation of registration through Directive 91/414/EEC is that once a micro-organism has been registered in one country and the product has been placed on Annex I, registration can be achieved in other EU countries through mutual recognition at a reduced price rather than having to go through the full registration procedure in each member state.

DISCUSSION

Horticulture in the UK is a complex industry with many driving forces with the retailer, processors and consumer being particularly dominant. The structure of the industry, and those that service it, has resulted in biological control playing an important role in the control of pests in some commodities. The approach, however, is to use biological control agents as if they were insecticides and release them inundatively. This is probably the only practical solution in annual crops grown either outdoors or under protection where production of quality crops is the objective, and if a biological control supply industry is to survive to service the industry. Classical biological control has been adopted in perennial crops, and includes the use and movement between orchards of insecticides resistant predatory mites (Solomon, 1989). However, at present this use of classical biological control is based upon native rather than exotic species.

There is a very clear division between the regulations that limit the release of exotic arthropods as compared to micro-organisms. Those for the first group are directed at protecting the environment, and licences required for release are free, while the latter group relate more to safety and the steps to approval for use are expensive. The cost of the different licensing and approval systems are the key to the potential successful uptake of biological control in UK horticulture. It is not only the visible costs of obtaining a licence or approval, but more importantly the costs of obtaining the data for inclusion in the dossier. The toxicity data, and to a lesser extent the efficacy data, necessary for approval of micro-organisms by PSD are particularly costly. The small market to the suppliers of micro-organisms mean that many horticultural commodities do not provide a sufficient return on their investment to warrant development and exploitation in an individual country. The consequence is that at present on the basis of cost alone micro-organisms, be they indigenous or exotic, are less likely to be commercialised for use than arthropod biological control agents. Conversely, the licensing of an exotic arthropod biological control agent for use on a commodity with a relatively small areas would be economically viable. However, the mutual recognition of registration of plant protection products should in future increase greatly the financial attractiveness of developing and commercialising micro-organisms as biological control agents in the EU.

It is the exotic arthropods as biological control agents that generate the greatest excitement to both growers and suppliers. The development of the regulations that control their release has brought a more rational approach to their exploitation; it is no longer sufficient to sell a product if it can be reared. In addition, the biological control industry is increasingly aware of the need for a consistently high quality product and is going to considerable lengths to ensure this (van Lenteren, 1996). To date emphasis has been on the use of exotic species in protected crops. There is, however, tremendous potential for the exploitation of biological control in outdoor environments; the large areas for release would be particularly attractive commercially to the biological control industry. To achieve this with exotic species will require the development of robust criteria that enable the risk of release, and the potential for a species to establish, to be assessed accurately.

There does remain one topic that requires clarification and further research, namely what is considered exotic as compared to indigenous. The Wildlife and Countryside Act (1981) defines a resident species as one that has self sustaining and viable populations able to reproduce and reach maturity without the assistance of man. This still seems to be open to

different interpretations. For example, are limited records of occurrence of a species from many years ago sufficient to indicate that a species is indigenous? Following on from this, should strains from different geographical areas be defined as exotic? The Wildlife and Countryside Act (1981) considers species or strains originating from outside the UK to be exotic and requiring a licence before release. The relevance of a geographical as opposed to an ecological description requires consideration. The genetic variability of many species has been little studied, let alone the spatial scale over which the different 'strains' move and interact. Therefore for the majority of species it is very difficult to define a strain other than by its geographical origin. However, the regulations as developed and implemented to date are a pragmatic approach which enable limited introductions of exotic species to take place so that horticulture in the UK can remain competitive. At the same time scientific advances will enable the outstanding questions to be addressed and, in future, the regulations developed.

ACKNOWLEDGEMENTS

I am grateful to Dr Bill Parrish of the Biotechnology Unit of the Department of the Environment (Secretariat to the ACRE Committee) for valuable discussion on the interpretation of the Wildlife and Countryside Act 1981, and Dr Alison Hamer of the New Substances Branch of the Pesticides Safety Directorate for clarifying the pesticide regulations. In addition, I thank Phil Walker and Richard Greatorex of Biological Crop Protection Ltd and Ciba Bunting, respectively, for comments on an industry perspective, and to colleagues within HRI valuable discussion.

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