# Preface

The Pre-Conference Symposium of the 1992 BCPC Conference, the proceedings of which comprise this monograph, had its genesis in the ECLAIR programme of the European Community. This acronym stands for "European Collaborative Linkage of Agriculture and Industry through Research" and the objective of this important programme is to bring together agriculturalists, industrialists and research workers in programmes designed to make European agriculture more environmentally friendly and efficient.

Crop protection is clearly a crucial area, in which the benefits of agrochemicals have to be weighed against the possible environmental problems consequent on their continued widespread use; it is also an area in which considerable progress has been made in resolving this dilemma, based on the concept of pest management. It is therefore not surprising that the ECLAIR programme supported several crop protection projects, all of which had as their objective the reduction of pesticide use and/or the development of environmentally friendly control techniques. One of the largest of these projects was ECLAIR 209, entitled "The Development of Environmentally Safe Pest Control for European Olives" and it is the work of this project which is reported in this volume.

Why olives? The olive tree, *Olea europaea* L., is grown all over the world for its fruit and the oil obtained from the latter. The trees are extremely long lived, 100 years or more, with an associated agroecosystem, which although fragile, is stable and has facilitated the co-evolution of pests and natural enemies so that generally speaking, and certainly in Europe, there is a small, well defined pest complex with effective natural enemy control, a useful prerequisite for an IPM programme.

In Europe, Spain, Greece and Italy produce between them about 64% of the world production of olive oil and 50% of the fruit, but this production is threatened by an insect pest complex which causes losses of some 15%, equivalent to about £450 million a year. European growers spend about £55 million a year on pest control, half of which relates to pesticide use. The damage caused by these pests and their control by chemicals results in a reduction in yield and quality of oil and fruits. The use of expensive chemicals and application machinery increases production costs and the agrochemicals produce safety problems for growers and consumers, and problems of pesticide resistance and environmental pollution.

The ECLAIR 209 project was developed to address these problems; some of the participants had previously been involved in collaborative research in some of the above areas and the EC programme offered an important opportunity to develop a larger multi-disciplinary project. A preliminary meeting was held in the School of Biology of the University of Wales, Cardiff in 1989 as a result of which it was agreed to put in a proposal to the EC, with Cardiff as the co-ordinator.

The participants in the project are the following:

| | *Participants* | *Type of Organisation* | *Country* | *Function* |
|---|---|---|---|---|
| 1. | University of Wales, Cardiff | University | UK | Coordinator; and basic research in entomology, chemistry, biochemistry |
| 2. | Consejo Regulador Sierra de Segura | Oil producing co-operative | Spain | Experimental sites for field work |
| 3. | Consejera de agricultura y pesca Andalucia | Government ministry | Spain | Basic research in entomology, field experimentation and trials |
| 4. | CSIC, Estacion Exp. Zaidin, Granada | Government research council | Spain | Basic research in entomology, chemistry and field experimentation |
| 5. | Energia e Industrias Aragonesas SA | Commercial firm | Spain | Supply of agro-chemicals, development work, field trials |
| 6. | CSIC, Instituto de la Grasa, Seville | Government research institute | Spain | Biochemical research on olive oil |
| 7. | AgriSense-BCS Ltd | Commercial firm | UK | Development of semio-chemical formulations, releases and traps |
| 8. | Inst. of Biology, National Research Centre, Athens | Government research institute | Greece | Basic and developmental research in chemistry of semio-chemicals and trapping systems |
| 9. | Division of Agrobiotechnology, ENEA, Rome | Government research institute | Italy | Development of IPM systems |
| 10. | Co-operative Energia e Territorio, Viterbo | Commercial firm | Italy | Development of forecasting models for IPM and related field work |

The proposal formulated by this group of collaborators was successful and the ECLAIR 209 project commenced work in March 1990 with a total budget of some 6.4 million ecu (more than £4 million) for four years.

The major objectives of the programme may be summarised as follows:

1. To reduce the environmental effects of pesticides in European olive production, so as to safeguard operators and consumers, and to improve fruit and oil quality.
2. To reduce chemical inputs in general in European olive production.

3. By reducing these agricultural inputs, to increase profitability of high quality oil.
4. To develop and test an integrated pest management (IPM) system in several countries and develop a technology transfer package for general European use.
5. To maintain a long term aim to develop a system for the production of "biological" olive oil, with minimal chemical inputs.

The major insects pests of olives in the countries participating in the project are as follows:

| | |
|---|---|
| *Prays oleae* | Olive moth |
| *Bactrocera oleae* | Olive fly |
| *Phloeotribus scarabaeoides* | Olive beetle |
| *Saissetia oleae* | Olive scale |
| *Margaronia (= Palpitia) unionalis* | Pyralid moth |
| *Euzophera pinguis* | Pyralid moth |
| *Liothrips oleae* | Olive thrips |

Initially, it was agreed that the development of an IPM programme required an R&D effort in the following five main areas:

1. Microbial biotechnology, for the production, development, testing, formulation and application of microbial pesticides which would be specific to the lepidopterous and dipterous pests.
2. The development, production and field-utilisation of behaviour modifying chemicals for use in monitoring, mating disruption and mass trapping systems for pest forecasting and control.
3. The development, testing and field application of techniques for biological control of pests by conservation, augmentation and manipulation of the existing natural enemy complex.
4. Research on fruit and oil biochemistry in relation to the effects of pest attack, measurement of pest/host interaction, effect on oil, and the possibility of deriving food attractants for the behaviour manipulation programme.
5. The technical developments arising from the above sub-programmes to be integrated into an overall IPM system. This will be achieved through the use of computer modelling systems that can then be adapted and developed further to provide practical guidelines for use by growers. The involvement and cooperation of growers will be encouraged in all aspects of the programme to ensure the research is targeted effectively.

The papers in this volume report what is effectively the half way stage of the project and, as can be appreciated, very good progress has been made in several areas.

There can be no doubt that the project has produced dividends for all participants in being able to carry out, or participate in, research in an area or at an intensity which would have been impossible for them on their own. Also the hard lessons of international management, which have involved overcoming barriers of language, custom and usage have resulted in a scientific team with confidence in each other and a willingness to work for the programme as a whole. This was, of course, one of the objectives of the EC programme – to promote cooperation between both organisations and individuals; clearly such co-operation must figure more and more in the scientific sphere as the European Community develops. In crop protection, for example, both the EC and several member countries are producing, or have produced, new legislation affecting the use of agrochemicals and the mechanism of the Common Agricultural Policy has been greatly changed to relate to the problems of over production and subsidy. It cannot be doubted that this process will continue and crops may well be protected in future by a control system agreed by all producers as the best available, the only variations allowable being related to the differences caused by the variability of the agroecosystem involved in the various countries.

For major crops grown in several EC countries such "universal" control systems can only be produced by collaborative research on a Europe-wide basis, as in the ECLAIR 209 project. It was for this reason that the BCPC felt this subject to be appropriate for the Pre-Conference Symposium, especially as several conference sessions are devoted to IPM and EC pesticide regulation.

However, it is already clear from previous work that it is one thing to develop an IPM approach, or even an IPM system, but it is another matter getting farmers and growers to accept and operate the system which has above all to be practical and economically viable. This is indeed the subject of one of the papers in this volume, which outlines these problems in Italy; and it is therefore of interest that the participants in ECLAIR are now developing proposals to carry their research a stage further to introduce new IPM systems which will be acceptable to growers, farmers and consumers.

It was therefore felt that this symposium would be of interest and value to BCPC participants, partly because of the research results but also because the project itself and its management may foreshadow the type of collaborative research which will figure largely in the future development of European agriculture.

Finally, I would like to express the appreciation of all the participants in the ECLAIR 209 project to the BCPC for its invitation to give this symposium and to everyone in the Councils organisation – and there have been many – who have helped us with the symposium and this publication.

P. T. HASKELL
Coordinator, ECLAIR 209,
1990–1992

# Introductory Session – Research Collaboration in European IPM Systems

Session Organiser and Chairman:
DR PETER HASKELL

# THE EUROPEAN OLIVE AND ITS PESTS - MANAGEMENT STRATEGIES

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## ABSTRACT

Olive, *Olea europaea*, is an ancient and very important endemic crop of the Mediterranean region. The three major pests are currently the olive fly, *Bactrocera oleae*, the olive moth, *Prays oleae*, and the olive scale, *Saissetia oleae*. For all three the favoured methods of control until recently have been the application of broad spectrum insecticides, usually from the air.

The CEC funded ECLAIR project aims to develop an integrated pest management package applicable across the Mediterranean region that will lead to increased biological control and decreased use of pesticides.

## THE OLIVE PLANT

The olive (*Olea europaea* L.) is one of the most characteristic trees of the Mediterranean region. It is of great nutritional, social, cultural, economic and political importance to the people of the area and is widely distributed around the Mediterranean basin (Figure 1).

**Figure 1.** Distribution of Olives in the Mediterranean region. (after Polunin and Huxley, 1967)

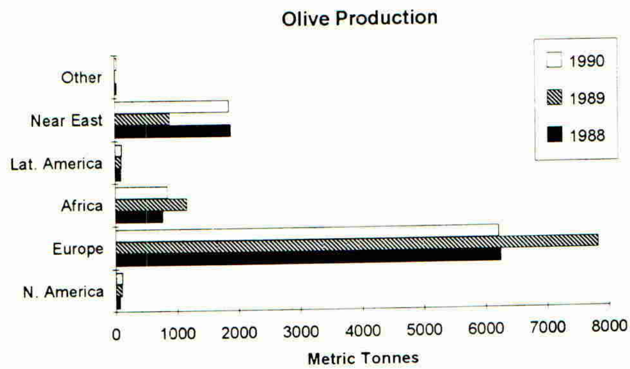
The olive belongs to the family Oleaceae, and is a long-lived evergreen of medium-to-tall height (10-15m), with grey green leaves. It is wind pollinated and displays characteristic year-to-year fluctuations in fruit yield. In general the trees are robust and may grow and produce a good crop in hilly, rocky and arid areas where other permanent crops cannot survive. Many olive cultivars resulting from clonal selection have been identified in different Mediterranean countries. These are distinguished mainly on a basis of characteristics of their leaves, flowers and fruits. Most are cultivated for their oil, some for table fruit and some for both purposes.

The genus *Olea* contains about 35 species distributed widely in the Old World. The cultivated form of *O. europaea* known as variety *europaea* is generally thought to be derived by hybridization, probably between *O. laperrinii* and *O. africana* (=*chrysophylla*). The wild relative of *europaea* commonly found now in Mediterranean scrub woodlands is known variously as variety *sylvestris* or *oleaster*. It is thought that *O. europaea* arose as a hybrid swarm in the eastern Mediterranean, perhaps with Lebanon and Syria as the primary region of diversity. It then spread westwards with a second centre of diversity in the Aegean and a third one in Tunisia and southern Italy (Simmonds, 1976). It is known to have been an important crop for the earliest agricultural communities in the eastern Mediterranean (Hawkes and Wooley, 1963).

Today, approximately 98% of cultivated olive trees in the world occur in the Mediterranean basin. The remaining 2% are found in North and South America, Australia, South Africa, Iraq, Afghanistan and, as a recent development, in China.

## ECONOMIC IMPORTANCE

The olive tree is essential to the economic as well as the ecological well-being of the Mediterranean region, with more than half of the world's olive trees occurring in the northern Mediterranean (67.3%) (FAO, 1991). Most of the remaining 32.7% are grown in the developing countries of the southern Mediterranean where the crop usually accounts for a large proportion of the total agricultural production.



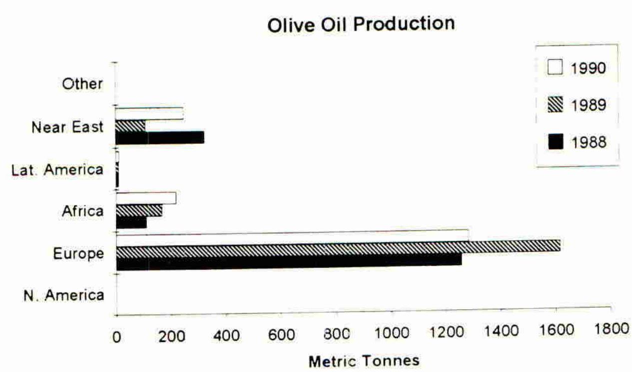




**Figure 2** World Production of Olives and Olive Oil 1988-1990 (data from FAO, 1991)

Total world production of olives and oil in the period 1988-1990 averaged 9.51 million tonnes and 1.79 million tonnes per year respectively (FAO, 1991) (Figure 2). About 9% of production was used for table olives and the remaining 91% for producing olive oil and olive-residue oil. Average world production of olives has increased steadily since the early 1950's, due partly to increased size and number of olive groves but also to improvements in cultural practices and crop protection.

**PESTS**

A major constraint on olive production, at least since the early years of this century, has been caused by the ravages of pests, diseases and weeds. Although insect pests cause the major losses to the olive crop in Europe, weeds and diseases may also result in significant yield reductions (Katsoyannos, 1992). Attack by the fungi, *Verticillium dahliae* Kleb., *Cycloconium oleaginum* (Cast) and *Gloeosporium olivarum* (Alm), causes premature fruit and/or leaf fall, dehydration of leaves and fruit as well as acidification of the extracted oil. The most frequent bacterial infection is by *Pseudomonas savastanoi*, which produces tumours on tree branches that may lead, in severe cases, to death of the infected branch. Infection by this organism is usually caused through pruning and/or harvesting wounds.

The olive tree is adapted to survive in semi-arid conditions. However, many weeds are similarly adapted and therefore provide strong competition for water and nutrients (Ruiz, 1951). Given the highly competitive nature of many of the perennial weeds found in olive groves, weed control is generally carried out 4-6 weeks before visible spring growth of the tree. However, this practice may be detrimental to some natural enemies of insect pests (Ruiz, 1951 and see also Jervis *et al*., this volume).

Eighteen insect pests are well known to attack and damage olive trees in the Mediterranean region (Appendix). Of these the key species are generally considered to be the olive fruit fly, *Bactrocera (=Dacus) oleae*, the olive moth, *Prays oleae*, and the olive scale, *Saissetia oleae*. All three are widely distributed in the area and regularly cause economic damage to the crop. Of the other insects, the olive beetle, *Phloeotribus scarabaeoides*, the olive thrips, *Liothrips oleae*, and the pyralid moths, *Margaronia unionalis* and *Euzophera pinguis*, may cause serious damage under certain conditions. Damage caused by any of these pests may result in a reduction in the number and/or size of the fruits with a subsequent reduction in yield and quality of the resulting fruit and oil.

*Bactrocera (=Dacus) oleae*

The olive fly (Figure 3) is found throughout the Mediterranean area and is generally considered the most damaging of the insect pests, especially later in the growing season or in areas of higher temperature and humidity (*e g* near the sea) which are more favourable to its development.

In the Mediterranean region, the fly normally has three generations each year, the first occurring from June to August, the second from August to September and the third from October to June (Figure 4). The winter is spent as a puparium either underground or in crevices in the bark of trees. Adult emergence starts in March/April, depending on ambient temperature, but the insects do not reach reproductive maturity and mate until later in the summer. Females lay eggs in healthy developing fruits. 2-6 days later the eggs hatch and the larvae bore a gallery within the fruit. The larval stage consists of 3 instars and lasts for 10-25 days and, with the exception of the last generation which overwinters in the ground or under bark, pupates beneath the fruit epidermis and emerges later as an adult fly.

It has been estimated that damage due to *B. oleae* may account for 50-60% of the total insect pest damage. This damage falls into three main categories -

a) Premature fruit fall,
b) Decreased yield and quality of oil, and
c) Spoiling of fruit for consumption as table olives.

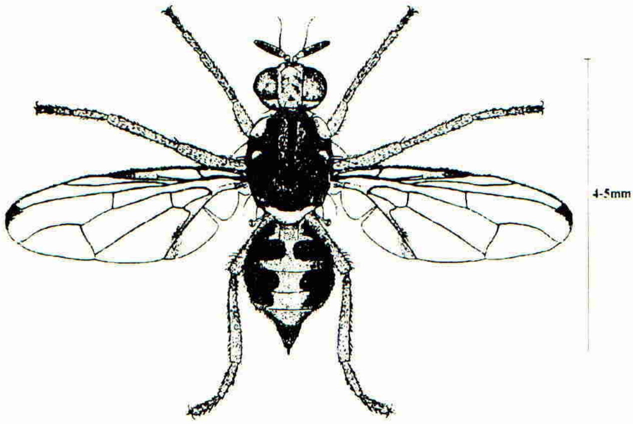



**Figure 3** *Bactrocera oleae*, adult female (after White and Elson-Harris, 1992)

Control of this pest in recent years has relied mainly on the use of chemical pesticides often applied from the air. When applied correctly these methods give good levels of control. However, misuse of such control methods may lead to pesticide resistance in *B. oleae* and also to destruction of natural enemies.

Two types of insecticide treatment have generally been used: preventative treatment against the adults and curative treatment against larvae already living in the fruit. For adult control, baited sprays may be used which reduce the quantity of pesticide required and the impact on beneficial natural enemies. However, for practical and economic reasons, application is often by air as "low volume" or "ultra low volume" sprays. Treatment against larvae is usually by cover spraying of insecticides such as dimethoate applied at ground level or by air. The decision when to apply pesticide is usually based on counts of living larvae in fruit samples.

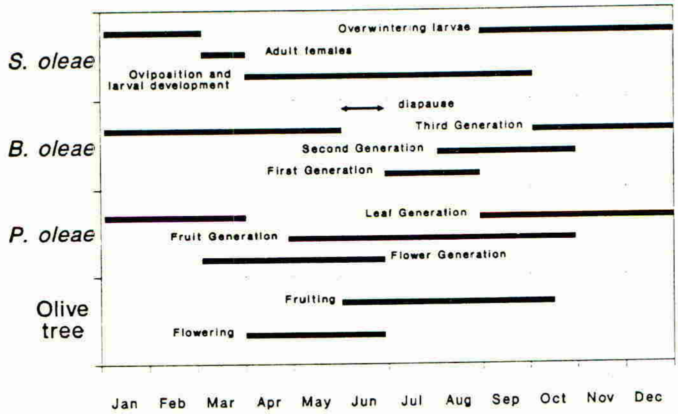



**Figure 4** Diagram showing the life cycle of the olive tree together with it's three main insect pests.

Alternative control methods that are currently being investigated or have been tried include -

1) Male sterilization and release,
2) Biological control using natural enemies such as the parasitoid *Opius concolor* (Szpel), and
3) Use of pheromones for trapping adult flies and for mating disruption.

*Prays oleae*

The presence of this moth in olive groves is often not so obvious as that of *B. oleae* but significant reduction in oil yield and quality often result from attack by the larvae.

*P. oleae* (Figure 5) typically has three generations each year; the first March/April to May/June is the "flower generation", the second, May/June to September/October is the "fruit generation" and the third is the "leaf generation" which occurs from September/October to March/April (Figure 4).

In the flower generation, females from the overwintering leaf generation lay eggs on the flowers. After 7-12 days larvae emerge and feed on the buds and flowers. Although such feeding does not generally destroy either the bud or the flower, it is sufficient to prevent fruit formation and thus cause a significant reduction in fruit yield. The larvae mature on the flowers, pupate in a loose silken cocoon and 10-12 days later emerge as adults. After mating they lay eggs on the developing fruits to form the fruit generation. Eggs are preferentially laid on the calyx near to the fruit peduncle. Hatching occurs 3-7 days later and the larvae bore into the fruit feeding on the pulp as they form galleries that penetrate to the developing seed which at this stage is still soft. This manner of attack often leads to premature dropping of the fruit, as with *B. oleae*. The larval stage of this generation lasts for 3 to 4 months. The pupal stage lasts for 10 to 15 days and usually occurs inside the fruit, although in some cases it may take place in the ground or under the bark of the tree. In the final leaf generation, females from the fruit generation lay their eggs on the leaves, near to the central vein. Depending on prevailing temperatures, emergence takes place one week to two months later. The larvae then penetrate the leaf forming galleries in the parachyma. Later they emerge through and feed on the lower leaf surface and terminal buds. The pupal stage lasts from two to four weeks and adults live for 20-40 days.

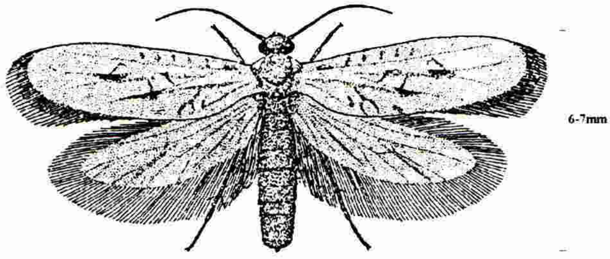



**Figure 5** Adult *Prays oleae* (after Ruiz, 1951)

Damage caused by this pest generally accounts for between 30 and 40% of total insect caused losses. Damage by the leaf generation is of lesser importance whereas that by the flower and fruit generations can often lead to a significant yield loss. Larvae in the flower generation may consume 20-40 flowers whilst the fruit generation can induce fruit fall during penetration into, and emergence from, the fruit.

As for *B. oleae* the favoured method of control for *Prays* has been the use of chemical pesticides. To date this has relied mainly on the use of organophosphates and carbamates directed against the larval stage. These are applied on a basis of host plant developmental stage. In addition, sex-pheromone traps are being introduced for monitoring moth populations prior to insecticide treatment. Deleterious environmental and health problems due to the widespread use of organophosphate and carbamate pesticides have prompted research into alternative methods for *Prays* control. Those currently under investigation include -

1) Biological control by natural enemies such as *Chelonus eleaphilus* and *Ageniaspis fuscicollis praysincola*,
2) Control of the flower generation using the microbial pesticide, *Bacillus thuringiensis*, and
3) The use of the sex pheromone of *Prays oleae* for trapping and/or mate disruption.

*Saissetia oleae*

*S. oleae* has come to prominence as an olive pest only in the last 10 years, due mainly to the indiscriminate use of pesticides to control *B. oleae* and *P. oleae*. These pesticides destroy many of the natural enemies of the scale whilst being ineffective against the scale itself. This has led to the rise of the olive scale to major pest status.

Adult males of *S. oleae* are comparatively rare since reproduction is mainly parthenogenetic. Females lay eggs underneath their scale and against the leaf surface. The incubation period is dependent on temperature but is generally about three weeks. Two generations can occur during a year, the first from May to June and the second from August to November although in inland areas only the Autumn generation is found. Following emergence, the larvae or "crawlers" remain beneath the female's scale for a few days. They then disperse to young branches and leaves where they pierce and feed from the phloem sap. The larval period consists of three instars and lasts for 35-50 days. Third instars generally metamorphose to females which settle usually on stems, particularly at nodes, and form the distinctive scales. The total length of life-cycle varies greatly between individuals and so generations are not discrete and adults may be found on the tree throughout the year. Overwintering normally takes place as third instar larvae.

Direct damage by *S. oleae* is caused by phloem feeding which debilitates the tree, whilst indirect damage is caused by fungal attack encouraged by the production of honeydew. The latter attack, in severe cases, may lead to the death of the tree itself. The honeydew may also act as an attractive food source for adult olive flies.

As with both *B. oleae* and *P. oleae*, chemical control of *S. oleae* still predominates in most mediterranean olive-growing countries, but some biological control methods are being applied. Organophosphorous insecticides and oil emulsions are used as cover sprays at times of the year when the most susceptible first, second and early third instars are abundant in the field. However, these sprays are potentially phytotoxic.

Classical biological control, as well as mass-rearing and inundative releases of natural enemies have been exploited in some areas. In most mediterranean countries, natural enemies can maintain populations at a low level if they are not themselves killed by pesticides.

## PEST CONTROL AND INTEGRATED PEST MANAGEMENT

As described above, until recently pest control in european olive groves has relied almost totally on the use of chemical pesticides, often by aerial application. Such continuing application may have serious ecological consequences. Most obvious and common is the destruction of, or great reduction in, populations of naturally occurring beneficial insects so that some pest problems may be exacerbated. The emergence of the olive scale as an important pest in our region where it had previously been kept naturally below an economic threshold is a good example of this (Delrio, 1985). Widespread chemical pesticide control is not easily compatible with biological control measures since released natural enemies are adversely affected by the pesticides (Katsoyannos, 1992).

A further problem with the relatively indiscriminate use of pesticides is the potential evolution of resistance in the target pests. In the olive crop an additional difficulty with pesticide use is the fact that the fruits tend to accumulate residues. Thus the aim of producing high quality "biological" olive oil is not compatible with such systems of control.

Attempts to reduce the input of pesticides and to target their use, where necessary, is an important element of modern pest control strategies for all crops. Integrated pest managment (IPM) has been defined by the International Organization for Biological Control (IOBC) as "a pest management strategy employing all methods consistent with economic, ecological and toxicological requirements to maintain pests below the economic threshold while giving priority to natural limiting factors" (in Katsoyannos, 1992). Systems of IPM are now widely accepted as the best strategies for sustainable crop protection (Dent, 1991). Not only do such programmes provide the most economic and sustainable crop protection systems, but also they pay attention to environmental concerns and the need for conservation of biological diversity. Unlike the use of broad spectrum general pesticides, the development of IPM strategies requires a full understanding of the biology and life history of each pest and of its natural enemies within any ecosystem. Each pest and each crop requires detailed research in different regions in order to formulate a real IPM programme. Continuous monitoring of pests and natural enemies is central to any IPM programme. It is perhaps not surprising then that few such complete programmes have yet been implemented. Considerable progress has been made already in Mediterranean countries towards developing and adopting pest management strategies for olives consistent with current IPM technology and compatible with economic and environmental quality needs. Much is already known about many of the elements that go together to make a successful IPM package. These include -

1. Biological control by the conservation and augmentation of naturally occurring and exotic predators, parasitoids and disease organisms. For example, for *B. oleae* several non-Mediterranean exotic parasitoids from North Africa have been imported and established.

2. Sampling and monitoring of pest and natural enemy populations to allow the determination of economic threshold population levels of pests below which other control methods need not be used.

3. Cultural practices. These include the use of cultivars resistant to particular pests and also farming systems such as weeding and cultivation programmes that may encourage beneficial organisms and discourage pests.

4. Behaviour modifying chemicals. In particular pheromones may be used selectively to sample pest populations in monitoring programmes. They may also be used in trapping programmes to lure and kill pests selectively. There are also possibilities in some species to disrupt mating behaviour and thus reduce pest populations.

5. Selective pesticides. There are few agroecosystems where pesticide application can be totally eliminated in the foreseeable future. In IPM systems selective pesticides must be sought which can be applied in minimal concentrations.

Coordinated research efforts to date into IPM in olives have been funded mainly by international organisations including FAO and UNDP although other organisations such as IOOC and IOBC have also played important parts.

The current CEC funded ECLAIR 209 programme aims to develop an overall IPM programme. This has required a research and development effort in the following four main areas -

(a) Microbial technology, for the production, development, testing, formulation and application of microbial pesticides which will be specific to lepidopterous and dipterous pests.
(b) The development, production and field-evaluation of behaviour modifying chemicals for use in monitoring, mating disruption and mass-trapping systems for pest forecasting and control.
(c) The development, testing and field-application of techniques for biological control of pests by the conservation, augmentation, and manipulation of natural enemies.
(d) Research on fruit and oil biochemistry in relation to the effects of pest attack on oil quality.

The technical developments which are now emerging from the above programmes of research will be integrated harmoniously into an overall management system. This will be achieved through the use of theoretical computer models which will be adapted and further developed to provide practical guidelines for use by growers (see Kidd *et al.*, this volume). The involvement and cooperation of growers and processors is a vital element in the programme and is being encouraged to ensure that the research is effectively targeted. Detailed results of the research after 2 years of the programme are given below by our colleagues.


## ACKNOWLEDGEMENTS

We are deeply indebted to our colleagues in all collaborating institutes for the help and cooperation in managing the ECLAIR project. Particularly we thank Peter Haskell, the first coordinator of the project, for his interest and enthusiasm. Without him the project would never have got off the ground. We thank also FAO for allowing us access to unpublished reports. We are also grateful to Mr K. Munn for technical assistance in the preparation of this paper. Finally we are very pleased to acknowledge the financial assistance of CEC without which this programme of truly international collaboration would not be possible.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Appendix - Main insect pests of *Oleae europaea* - (after Katsoyanos, 1992)

## Hemiptera - Homoptera

*Euphyllura olivina* Costa (Psyllidae) - Olive psyllid

Host plant/Damage. Monophagous on olive only, causing damage by sap-sucking and reducing flower fertility.

Geographical Distribution. Throughout the Mediterranean basin and into central Asia.

*Saissetia oleae* Olivier (Coccidae) - Olive scale (Black scale)

Host plant/Damage. Attacks a very large number of host plants of many different families, including the Oleaceae. Sap-sucking weakens trees and production of honeydew is associated with fungal attack.

Geographical Distribution. Widely distributed from central Asia throughout the western Palaearctic and into Africa. Attacks olives in all Mediterranean countries, also North and South America.

*Philippia follicularis* Targioni-Tozzetti (Coccidae)

Host plant/Damage. Attacks only olive trees and heavy infestations lead to distortion of leaves and debilitation of the tree with subsequent reduction in fruit and/or oil yield.

Geographical distribution. France, Italy, Greece, Turkey and Isreal.

*Lichtensia viburni* Signoret (Coccidae)

Host plant/Damage. Feeds mainly on olive but has been found on other Oleaceae species as well as members of some other families (e.g. Leguminoseae and Rubiaceae). Causes similar feeding damage to *P. follicularis*.

Geographical distribution. Found in all olive-growing regions of the Mediterranean.

*Aspidiotus nerii* Bouchée (Diaspididae)

Host plant/Damage. Cosmopolitan and polyphagous species attacking a wide range of host plants. Damage caused to the fruit which may not grow to normal size and might also be deformed.

Geographical distribution. Widespread in many parts of the world.

*Lepidosaphes ulmi* L. (Diaspididae)

Host plant/Damage. A polyphagous scale insect occurring on many host plant species. Marks on the cuticle and deformation of fruit reduce oil yield and make them unsuitable for table use.

Geographical distribution. Throughout the Mediterranean, but also reported in many other parts of the World (Asia, America and Australia).

*Parlatoria oleae* Colvée (Diaspididae)

Host plant/Damage. Polyphagous feeding on more than 200 plant species including olive. Injury causes fruit to develop darkly pigmented spots making them unsuitable for table use.

Geographical distribution. All regions around the Mediterranean as well as further east in central Asia and China.

*Pollinia pollini* Costa (Asterolecaniidae)

Host plant/Damage. Monophagous on olive, terminal and axliary bud development is impeded causing withering and deformation of leaves.

Geographical distribution. Throughout Mediterranean, also established in California and Argentina.

## Thysanoptera

*Liothrips oleae* Costa (Phloeothripidae)

Host plant/Damage. This thrips may cause considerable loss at times of high infestation due to deformation of fruit, premature fruit fall and damage to leaves.

Geographical distribution. Throughout the Mediterrean basin.

## Coleoptera

*Phloeotribus scarabaeoides* Bern. (Scolytidae)

Host plant/Damage. Attacks various Oleaceae. Signficant damage to the tree may be caused by larvae tunnelling in twigs and beneath the bark.

Geographical distribution. All around the Mediterranean.

## Diptera

*Bactrocera oleae (Gmelin)* (Tephritidae) - olive fruit fly

Host plant/Damage. Oviposition and larval feeding is restricted to fruits of species and varieties of *Olea*. In cultivated olives feeding damages fruit and causes premature fruit fall.

Geographical distribution. Widespread from the Canary islands as far east as India and in all Mediterranean olive-growing countries.

*Dasineura oleae* F. Löew (Cecidomyiidae) - Olive leaf gall midge.

Host plant/Damage. Attacks only species of *Olea* and damages leaves and flowers of the olive tree.

Geographical distribution. Italy and the eastern Mediteranean.

*Prolasioptera berlesiana* Paoli (Cecidomyiidae) - Olive fruit midge.

Host plant/Damage. In common with the other gall midges this species occurs on several species of *Olea* In cultivated olive it oviposits in puncture wounds made by *B. oleae*. so further damaging fruit. Larvae feed on fungi inside damaged olives.

Geographical distribution. Throughout the Mediterranean.

*Rosseliella oleisuga* Targioni-Tozzetti (Cecidomyiidae)

Host plant/Damage. This gall midge attacks several species of *Olea* and damages the bark.

Geographical distribution. Widely distributed all around the Mediterranean.

## Lepidoptera

*Euzophera pinguis* (Haw.) (Pyralidae) - Olive pyralid moth.

Host plant/Damage. Attacks various Oleaceae. Larvae very active borers which can attack the trunk and forks of even strong, healthy trees. Infestation by several larvae may lead to the death of the tree.

Geographical distribition. Occurs in several parts of northern and central Europe but most common in Mediterranean olive-growing regions and north Africa.

*Margaronia unionalis* Hübn. (Pyralidae)

Host plant/Damage. Lives primarily on plants of the genus *Olea*. Larvae first attack young shoots and then the leaf paranchyma. In heavy infestations larvae may also attack fruits.

Geographical distribution. Throughout the Mediterranean basin.

*Prays oleae* Bern. (Hyponomeutidae) - Olive moth (olive kernel borer).

Host plant/Damage. Infests all cultivated varieties of olives, feeding on flowers, fruits and leaves. Also attacks wild species of the genus *Olea* and some other Oleaceae.

Geographical distribution. Across the Mediterranean basin and extends east to the Black Sea.

*Zeuzera pyrina* L. (Cossidae) - leopard moth

Host plant/Damage. Widely polyphagous species attacks more than 70 plant species including members of the Rosaceae and Oleaceae. Larvae attack living wood by drilling deep tunnels in the main branches and trunk.

Geographical distribution. Widely distributed throughout the western palearctic region, Europe, across the Mediterranean and into Asia and the United States. Most common in eastern Mediterranean regions.

# APPLICATIONS OF MICROBIAL PESTICIDES IN INTEGRATED MANAGEMENT OF PESTS OF OLIVES.

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## ABSTRACT

The use of microbial pesticides in IPM is described, first in general and then in the case of olive groves. The necessity of avoiding negative interactions between microbes and other control techniques is stressed.

## INTRODUCTION

The idea of controlling insects through disease is long established (Miller *et al,* 1984). In recent times microbial pesticides have come to be regarded as just one weapon in the armoury of techniques brought to bear in IPM systems (Fuxa, 1987; Croft, 1990). As such they must interact with biological controls, behavioural disruptants, natural and synthetic chemicals, and physical and cultural controls. In order to be effective they must be shown to be synergistic or at least offer non-interference with other techniques. If various treatments are known to interfere negatively there is a need for managerial decisions as to the appropriate treatment.

Microbial pesticides encompass a range of viruses, bacteria, fungi and several other types of microorganism pathogenic to invertebrates. While their effects may range from subtle debilitating

TABLE 1. Microbial insecticides developed as commercial products.

| Microbe | Strain | Product Name (Examples) | Target |
|---|---|---|---|
| Bacteria | *Bacillus thuringiensis* | | |
| | var. *kurstaki* | Dipel | Many Lepidoptera |
| | var. *aizawai* | Certan | *Galleria mellonella* |
| | var. *palo alto* | M-One | Coleoptera |
| | *B.popilliae* | Doom | Scarabs |
| Viruses | *Heliothis* NPV | Elcar | *Heliothis* spp. |
| | *Neodiprion* NPV | Virox | *Neodiprion sertifer* |
| Fungi | *Metarhizium anisopliae* | Metaquino | Coleoptera |
| | *Beauvaria bassiania* | Boverin | Coleoptera, Homoptera |
| | *Verticillium lecanii* | Vertilec | Hemiptera |

disease to acute, lethal poisoning it is the latter that usually receives attention since this can be exploited to replace chemical insecticides in schemes where the use of xenobiotics is to be avoided.

Application of microbial pesticides to commercial agriculture requires the use of fully developed, registered products. Despite a great deal of work over the years surprisingly few microbial pesticides have emerged as fully developed products. If we restrict discussion to control of agricultural pests (thus excluding controls of vectors of human disease) the range is very limited (Table 1).

Among bacteria there are a few strains of *Bacillus thuringiensis* developed as products for control of Lepidoptera and Coleoptera and, as a marginal product, *B. popilliae* for the control of scarabs (Dulmage, 1989; Krieg *et al*, 1983; Herrnstadt *et al*, 1986; Klein, 1981). Nevertheless, bacteria (in particular *B. thuringiensis* var. *kurstaki* strain HD1) provide by far the greatest economic activity in relation to microbial insecticides and to a considerable extent they can be used off-the-shelf (Payne, 1988). There is also a range of baculoviruses used for pest control. However, few seem to have reached full commercial development, the closest being the *Heliothis* virus (Huber,1990). Among the fungi, the commercial product range really amounts to *Metarhizium, Beauvaria* and *Verticillium lecanii*. Arguably, none of these has reached full potential as a straightforward method of pest control. Many other microbes of all classes have been used in research exercises (e.g. see Burges and Hussey, 1971; Burges, 1981) but they don't amount to products that can simply be bought and used as the situation dictates.

Most microbial insecticides act through the digestive tract so that they have to be ingested. This can act as a severe limitation for insects that feed by piercing plant tissue or in other ways that prevent oral uptake. The exception is the fungi where invasion may be through the integument. However, fungi have their own limitations such as the fact that initiation of infection is dependent on humid conditions.

How microbial pesticides are used depends on the crop and the pest. They may be applied with the intention of exerting control epizootically or enzootically. The crop may be grown essentially in monoculture or it may represent an element of a diverse environment. The pest may be an introduced one or indigenous, with its own, relatively-stable, associated fauna.

The costs of development of microbial pesticides as commercial products and the accumulating body of case information that goes with development select for products with wide application and act to inhibit development of new products in favour of adaptation of use of established ones. Obviously, strains with high specificity can only be developed as products with limited uses and thence of little commercial interest. This has usually lead to the intervention of governmental or institutional funding for the development of such products (e.g. Velvet Bean caterpillar. *Anticarsia gemmatalis,* NPV. Moscardi, 1983.).

In most cases products have been used to control pests of crops in monoculture (e.g. *B.thuringiensis* on maize, cotton, forest trees) by initiating epizootics, or to limit numbers of accidentally introduced pests (e.g. *Popillia japonica* (Japanese beetle) in Eastern USA (Dutky, 1963), *Oryctes rhinoceros* (Rhinoceros beetle) in Pacific Islands (Bedford, 1976) ) by enzootic control. In both cases their use has usually been responsive to a single major pest rather than a spectrum of pests of diverse type.

To be incorporated into an IPM scheme the use of microbial pesticides may have to be more stringent and they may need to be shown to interact predictably with the other control components.

## INTERACTIONS OF MICROBIAL PESTICIDES WITH OTHER CONTROL METHODS USED IN IPM

It is a feature of chemical insecticides that often their effects are so massive as to dominate the situation. Usually they fail to discriminate beneficial species from pest species. So, apart from considerations relating to 'organic agriculture' and 'biorational' treatments their use would normally be precluded in an IPM system merely on the grounds that their effects may be so massive as to dominate and thence to disrupt it in the longer term. Those planning IPM systems often reserve the right to use chemicals, *in extremis*, but in the hope that it will not be necessary. The same may be true for microbial insecticides, though to a lesser extent. The dominance arises, not necessarily from direct lethal effects on non-target and beneficial insects since it may be argued for viruses (and to a lesser extent bacteria and fungi) that they are sufficiently specific so as not to decimate other insects in the biota.

In some cases microbial pesticides are not necessary because of the efficacy of alternative methods. e.g. the best sterile male programs or disruptant schemes. In other cases where these methods are less effective, use of a good microbial pesticide would soon preclude the use of other methods. However, if they are effective, the populations of predators, parasites and parasitoids are liable to be reduced through lack of targets and by other more subtle effects. The treatments have to be integrated across-the-board to avoid problems such as disrupting natural enemies of one insect in the control of another. In their interactions with other techniques used in IPM, the microbial insecticides are thus liable to be disruptive and need careful handling.

Interaction of microbial pesticides with natural enemies and other non-target organisms

As for any type of pesticide the effects on the non-target organisms has to be known, but more in the case of their use in an IPM system, where the use of natural enemies is an important feature in the techniques used to control the pest on the day-to-day level. As it is impossible to test all the organisms present in the ecosystem, some principles for choosing must be developed. In a complex habitat such as an olive grove there are lots of other organisms that have to be taken into account. A good knowledge of the ecological relationships and biologies of most of the species present in the ecosystem is a pre-requisite.The testing should to be done on :

- pollinators. Legally, bees are tested before the commercialisation of the product but other insects may function as pollinators.
- the natural enemies of the pest in focus, and secondary pests.
- if necessary, the natural enemies of pests of other crops in the same field or in the area.
- the secondary hosts of the natural enemies. Keeping alternative hosts alive is often important for the stability of parasitoid populations, when part of the life-cycle of the parasitoid is on a different host. The same is true for polyphagous predators, which need enough of other prey when the pest is not available.
- others such as soil invertebrates.

Testing methods

The sort of test to use needs to be defined; results with the same organisms in different conditions may lead to entirely different conclusions. The problem is not only to optimise laboratory experimentation, but also to make it relevant to the field situation. It is a problem to decide when the tests are to be made: early, when developing the microbial insecticide, if some strains or formulations are more toxic than others to non-target organisms, or late when the formulation to be used has been decided on the basis of toxicity to the primary target.

A lot of the laboratory experimentation on toxicity of the pesticides to the non-target organisms is done through contact toxicity (Hassan 1985), which in the case of microbes ( except fungi ) could lead to false security. The effects of adult feeding are generally very weak for the hymenopteran parasites (Flexner *et al.*, 1986), and the predators (Salama *et al.*, 1982). Deleterious effects on adults can be sometimes related to the "inert" components of the formulation rather than the microbe itself (Haverty 1982).

The development time can be slower for predator larvae (Chrysopids, Coccinelids) reared on treated larvae and their consumption may be decreased (Salama & Zaki, 1982). Development of parasitoids inside treated larvae leads to lower levels of emergence, through indirect effects: the death of the larvae prevent the completion of the parasitoid's development (Flexner *et al.*, 1986).

If a precise phenology is necessary for the parasitoid to attack an alternative host, other effects such as delays in the development time of the pest and its parasitoid when the dose is sub lethal may need to be examined (Weseloh *et al.*, 1982). Full-scale field trials are needed to really understand the situation as a whole. Forest experimentation has shown that the effects of the treatment can vary depending on the species of parasitoid. The phenology of the parasitoid's attack is the most relevant factor. In some cases the frequency of parasitization and hence the control efficiency can be increased by the treatment (Ticehurst *et al.*, 1982). Diseased larvae may be more susceptible to predator or parasitoid attack leading to synergistic effects. Also, intoxicated pest larvae can be repellent to the parasitoid (Temerak, 1980) leading to a higher parasitization of the remaining, undiseased insects.

Thus, extensive field work to determine how reduction in the parasitoid numbers affects their efficiency in relation to reduced numbers of the prey is needed. The data needs to be incorporated into models for the prediction of pest populations and the suggestion of management solutions.

## ROLE OF MICROBIAL PESTICIDES IN THE MANAGEMENT OF INSECT PEST OF OLIVES

The system of culture of olive (*Olea europaea*) is a very ancient one. Olive orchards are often very long established. In some systems of commercial management the crop is grown essentially in monoculture. Elsewhere it may form part of a very diverse habitat, often with other crops interspersed. It is an evergreen tree which is grown in a wide range of environmental conditions varying from coastal and relatively humid to mountainous and relatively arid. The species is slow to bear fruit and, for the moment at least, selection of plant strains with intrinsic pest resistance is liable to be at best an adventitious affair.

There are quite a number of insect pests of olive of varying economic importance (Table 2). The first three species are the major pests for which control by IPM would make an important economic contribution. The other species are of local significance or are only major pests sporadically.

Conditions such as the low relative humidity and high temperature of the environment seems to have selected for a group of insects that, in their larval phase at least, burrow, bore and mine the plant tissue. This contributes a peculiar difficulty for the control of these pests since they are often inaccessible.

TABLE 2. Major insect pests of olives in Europe.

| | | | |
|---|---|---|---|
| *Bactrocera (=Dacus) oleae* | Tephritidae | Olive Fly | Larvae in fruit flesh |
| *Prays oleae* | Plutellidae | Olive Moth | Larvae in fruit stones |
| *Saissetia oleae* | Coccidae | Black Scale | Encrusts foliage and fruits. |
| *Phloeotribus scarabeoides* | Scolytidae | Olive Bark Borer | Bark borer |
| *Euzophera pinguis* | Pyralidae | | Bark borer |
| *Palpita unionalis* | Pyralidae | | Larvae eat young foliage |
| *Liothrips oleae* | Thripidae | Olive Thrips | Infest foliage |

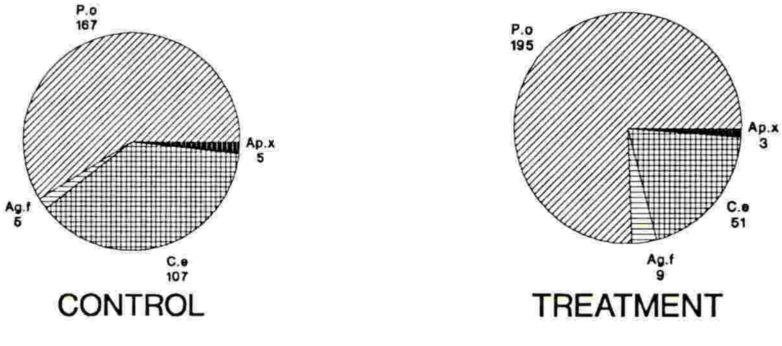
The use of fungi, viruses, etc. enzootically is unlikely to be effective since the cultural environment is too long-established and stable for such controls to gain a foothold.

*Prays oleae*

This moth has three generations per annum described from the feeding habits of their larvae as phyllophagous, anthophagous and carpophagous generations, i.e the over wintering generation mines leaves, the next (spring generation) lives within and on the flowers and the third, and most directly economically-destructive generation, bores within the stone of the fruit during summer and autumn. The leaf generation's larvae are considered relatively inaccessible by insecticides because of their mining activities. Similarly, the fruit generation is derived from eggs laid on fruits close to the peduncles; the emergent larva bores through to the developing stone inside which it matures; the concomitant weakening of the fruits' attachment to the peduncles often causes spectacular premature fruit drop with major loss of yield. Only the flower generation is regarded as accessible to insecticides, because during the latest instars, the larvae feed externally on the flowers. The larvae are quite susceptible to standard strains of Bt such as HD1. In the best conditions greater than 90% kills have been reported (Yamvrias *et al*., 1986). However, the success of treatments is very mixed, reflecting the sensitivity of such methods when they are dealing with mining/boring types of insects. Nevertheless, Bt does offer a solution and is being actively developed for control of *P. oleae*. There is some scope for improving strains or formulations but the prime limitations seem to be sensitivity of timing of application due to the short window of opportunity when the target larvae are accessible.

Other IPM methods for the control of *P. oleae* could include the use of pheromone traps and attempts at mating disruption. In general, Bt treatment of *P. oleae* need not upset pheromone operations because they are directed at different stages of the life cycle and are liable to be deployed separately. The natural enemies of *P. oleae* need to tested for the effect of Bt because they are also effective in the flower generation. One of the main predators is the lacewing *Chrysoperla carnea*, which is not sensitive to most Bt formulations (Flexner *et al.* 1986). Other natural enemies are various species of parasitoids such as *Chelonius eleaphilus, Ageniapsis fuscicollis* var. *praysincola*. In a trial in Spain (Fig. 1), the levels of parasitism were decreased by 40% after treatment by Bt (Varlez *et al.*, submitted for publication). This shows that a microbial pesticide without direct effects can be harmful to the natural enemy population.

FIGURE 1. Differences in the proportions of pest and parasitoid adults emerging from the control and BT treatments.
P.o: *P.oleae*, Ap.x: *A.xanthostigmus*, C.e: *C.eleaphilus*, Ag.f: *A.fuscicollis*.



In general, Bt is a useful treatment for the control of *P. oleae* so long as it is used at the critical time in the flower generation. Highly persistent strains of Bt could be used for the phyllophagous generation to take effect when larvae switch leaves. However, it is not known whether targeting this generation is too remote from the carpophagous generation so as allow re-expansion of populations in the intervening time.

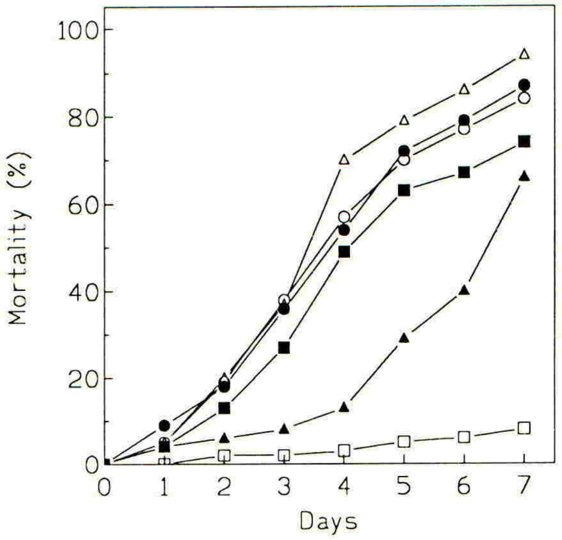
Use of Bt may be augmented by use of chemicals - either natural or synthetic. It has been demonstrated in several situations that synergistic effects may be obtained when Bt use is combined with chemicals .

*Bactrocera (=Dacus) oleae*

This fruit fly is a difficult target for microbial insecticides; the adult flies are dispersed in the environment. Eggs are deposited just under the skin of olive fruit and the larvae grows to prepupation or pupation within the fruit. Thus, this stage is not accessible to conventional microbial insecticides nor to natural enemies. Little success has been gained from the use of parasitoids of *B. oleae* (Jimenez 1986). Control of *B. oleae* is usually attempted through use of traps incorporating a pheromone and/or nitrogenous baits to trap adults.

With the exception of ß-exotoxin of Bt there are few components of microbial insecticides effective against Diptera other than nematocera. There are almost no reports of actions against adult flies and yet this is the only realistic target for *B. oleae*.

FIGURE 2. Toxicity of *B.thuringiensis* to *Bactrocera oleae*
Adult flies were allowed to feed *ad libidum* on a mix of sucrose and Bt preparation. Mortalities were scored over seven days values being taken from triplicate cages, each containing about 30 flies. □, Control; ●, strain HD1;○, strain HD1 cry-; Δ, strain HD 72 ( var. *alesti* ); ■, strain CCEB460 ( var. *finitimus* ); ▲, strain NRRL B4039 ( var. *thuringiensis* ).



Preliminary experiments with laboratory reared *B. oleae* showed that Bt has weak toxicity to *B. oleae* adults ( Karamanlidou *et al,* 1991; Groundwater and Dancer, manuscript in preparation) ( Fig.2 ). The effect is not due Bt endotoxin nor to the ß-exotoxin since strains lacking these components are just as toxic. However, the effect is weak one and is not effective against wild insects in field cages. Nevertheless, the toxic activity may be enhanced by strain development. However, for the moment, the dispersed phase of fruit flies must remain a remote target for microbial insecticides and any other method that does not concentrate the population.

*Saissetia oleae*

Like all scales this insect draws its nutrient directly from the plant by piercing the vascular system. As such it is not accessible by stomach poisons (bacteria, viruses, etc.). The only point of attack for microbial insecticides is through the integument i.e. fungal infection.

Some strains of *Verticillium lecanii* have been isolated from scales (Hall,1981). However, these strains in common with other entomocidal fungi seem to require a humid environment to germinate. Such conditions are unusual or at best only sporadically available in olive groves. There may be some scope for development of strains able to germinate in lower than usual humidity and in any case such strains would be of widespread interest.

To interface with other methods of control in an integrated scheme might prove problematic. The target is largely sessile and hence there is liable to be interference with biological control at the level of predators and parasites. Controls based on disruptants are in their infancy but yet again there is liable to be negative interference at least on economic considerations between an effective microbial pesticide and a disruptant control strategy.

Other pests

There are a range of other pests of olive that must be considered as of secondary importance. These include several bark borers, a young foliage eater (*Palpita unionalis*) and thrips. The prospects for using microbial pesticides for these must remain remote or at least be restricted on economic grounds to the use of products optimised for different situations but which can be made to work. For the wood borers it is likely that other methods of biological control would be more effective than microbes.

For *P.unionalis,* since there a no special problems in relation to accessability, a ready-to-use formulation of Bt HD1 is likely to be as effective . However, in an IPM system it would be necessary to ensure that application of Bt for the control of *Palpita* does not interfere with the natural enemies of other more important pest species or a managerial decision might be necessary to decide whether to suffer the damage of a minor pest to avoid decimation by the major one. This is, in part, a consequence of the dearth of products based on different microbes. Ideally, it would be best to be able to reserve a different microbe for each pest to be treated.

*Beauvaria bassiania* has been reported as effective against some thrips (Saito, 1991). These insects are known, in some cases, to shelter alongside or even under scales but whether this would protect them from *Beauvaria* or even whether there are possibilities of using mixed fungal products to simultaneously effect control of thrips *and Saissetia* is not yet known.

## CONCLUSIONS

In developing IPM systems, it is usual to include chemicals as agents of last resort to save the crop. This would apply as much to most 'natural chemicals' as it does to xenobiotics. It may be that the same applies, perhaps in lesser degree, to microbial pesticides, i.e. because they can be so powerful they should only be used when they will not disrupt other, perhaps carefully-constructed, schemes, or as a weapon of penultimate resort. Thus, if Bt is shown to be disruptive to the natural enemy complex of *Prays oleae* its use may be reserved for extreme situations. In any case, in an ideal situation one would have independant microbial pesticides for each pest of significance to avoid priority clashes in the treatment of various pests.

In setting up IPM systems and minimising the use of chemical insecticides it is possible that the natural enemies complex may be promoted sufficiently to allow it to effect routine control of pest species. This has been shown to occur in plant hoppers where populations are reduced to below economic threshold for damage in areas with a resurgent natural enemy complex after cessation of routine chemical spraying (Denno and Roderick, 1987). It is possible that for example *P.oleae*, which is not an economic pest every year, may be usually controllable by natural enemies and perhaps pheromones in an IPM system. Limiting the use of Bt in this way may have additional advantages in cost savings and decreasing the likelihood of emergent resistance.

For both *B. oleae* and *S. oleae* there are liable to be clashes in approach because controls necessarily focus on the same stages. For *B.oleae* the problem relates to fact that only the dispersed, adult phase is accessible for control. For S.oleae, the insects are largely sessile and there is liable to be negative interference between natural enemies and microbes. In principle it would best if the least tolerant control mechanism is exploited first and the most powerful, last. Of course to understand the interactions between the methods there is a need for a great deal of interdisciplinary collaboration in research. In terms of sensitivity to disruption the general order of use is likely to be natural enemies & pheromones before enzootic microbes, before epizootic microbes before chemicals. Whether such precise management can be sustained is, in effect, the crux of an IPM system.

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# THE IDENTIFICATION AND SYNTHESIS OF OLIVE PEST SEMIOCHEMICALS

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## ABSTRACT

Recent developments in the analysis of semiochemicals of the olive pests, *Bactrocera oleae*, *Prays oleae*, *Saissetia oleae*, *Euzophera pinguis*, *Phloeotribus scarabeoides* and *Palpita unionalis* are described, together with relevant bioassay and field trial data.

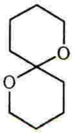
## INTRODUCTION

Several major behaviour patterns of insects are controlled by a range of semiochemicals produced by members of the same species (pheromones), hosts or predators (allelochemics). Although there are more than 30 species of insect that attack olive trees and their fruit, only half a dozen of these are economically important. However the only useful pheromone monitoring systems currently in use are those for the olive fly and the olive moth. The purpose of our work is to improve the current systems and identify the semiochemicals of the four other major pest species.

[1] Olive fruit fly, *Bactrocera oleae* (formerly *Dacus oleae*) Gmelin (Diptera: Tephritidae)

1,7-Dioxaspiro[5.5]undecane [1] is is the major component of the female Olive Fruit Fly released sex pheromone (Baker and Herbert 1987, Mazomoneos, 1989a). We have studied the binding of this pheromone and a large number of analogues [2-8] using electroantennogram (EAG) measurements with the goal of developing new parapheromones that will be more effective in the field. These studies have been supported by limited field trials.

**Materials:** The analogues were prepared by Claisen condensation and acidic decarboxylation of butyrolactone and valerolactone [3][4], by acid catalysed ketalisation of cyclopentanone [6][7] or cyclohexanone [5][8] and by orthoesterification of valerolactone [2].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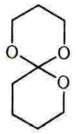
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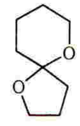
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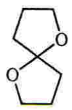
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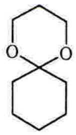
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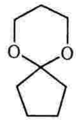
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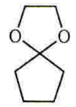
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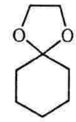
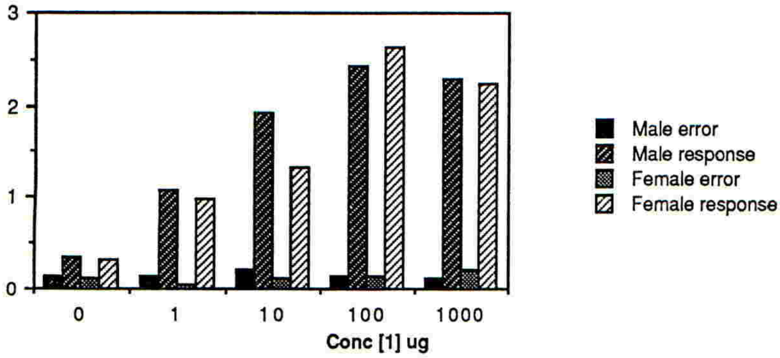

[8]

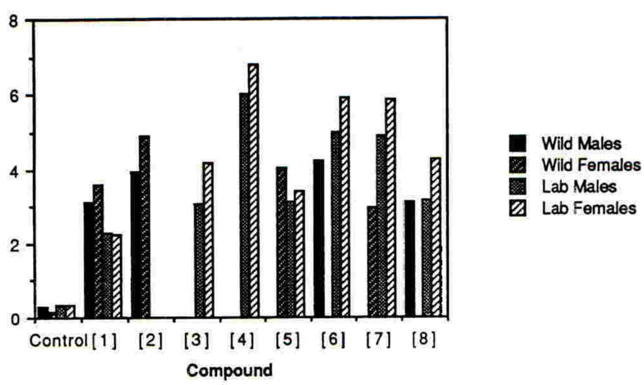
**Method:** Serial dilutions of the semiochemicals were placed on filter paper (0.5X1cm) inside a Pasteur pipette and puffed over (0.5 sec.) an excised *Bactrocera oleae* head in an air flow of 0.7L/min. The head and the tip of the antenna were connected by (glass electrodes containing 0.1N KCl and 2.5% polyvinyl-phenylpyrrolidone) to a high impedance amplifier (Syntech). The signal was recorded on an IBM PC. using the Syntech program PC-EAG Version 3.

**Results:** Males are more slightly more sensitive to the natural pheromone [1] than females; however in the field, pheromone traps capture the same number of females as controls.




**Graph 1:** EAG response in mV of laboratory reared *Bactrocera oleae* to 1,7-dioxaspiro[5.5]undecane [1]

All of the parapheromones elicit responses that are similar to or greater than the pheromone [1] at the 1mg level. However when the concentration is reduced the response to the parapheromones drops quickly whereas the response to the natural pheromone [1] is maintained. In the language of enzyme kinetics the pheromone [1] has a lower $K_M$ and higher affinity, whereas the parapheromones have a higher $V_{Max}$ or stimulation. This is borne out by saturation studies. Presaturation with the pheromone [1] effectively obliterates response to further stimulus whereas presaturation with the analogue [5] still allows response to the pheromone [1]. The trioxa-analogue [2] has comparable activity in the field to the natural pheromone (Haniotakis *et al*, 1989), but the homologous dioxa- compounds [3][4] have little or no activity. Further studies are in progress to elucidate the geometrical requirements for binding.




**Graph 2:** EAG response in mV of wild and laboratory reared *Bactrocera oleae* to 1mg of 1,7-dioxaspiro[5.5]-undecane [1] or parapheromones [2-8]

[2] Olive moth, *Prays oleae* Bernard (Lepidoptera: Yponomeutidae)

Female *Prays oleae* release a sex pheromone, which was identified by (Campion *et al,* 1979) as (Z)-7-tetradecanal and the same pheromone was identified for the closely related species *Prays citri* (Nesbitt *et al*, 1977). The reproductive isolation of these species suggest that secondary components may also be released. Infested olive flowers were collected from the field and stored at constant temperature (25 +/- 2°C, 65 +/- 5% humidity, 16:8 L:D regime) for 6-15 days, in order to allow the moths to emerge. The sexes were separated one day after emergence and were provided with 10% sucrose solution. The last two abdominal segments were removed 5 hours into the scotophase and pheromone was extracted with methylene chloride for 20 minutes. Bioassays were performed by placing the material on a filter paper in a large cage and counting the number of visits by males for 10 minutes (Mazomenos, 1989 ). Although a good biological response was obtained with this material, analysis by GC-MS was too insensitive to allow reliable identifications. Mass scanning of the TIC allowed tentative identification of a 16 carbon acetate with 2 double bonds and a monounsaturated-14:Ac. We tested several combinations of (Z)-7-tetradecenal with (Z,Z)-7,11-hexadecadienyl acetate, (Z,E)-7,11-hexadecadienyl acetate, (Z)-7 tetradecenyl acetate and (Z)-5-tetradecenyl acetate but in no case was the combination more effective than (Z)-7-tetradecenal alone.

**Male *Prays oleae* captured in traps baited with various combinations of synthetic pheromone components. Markopoulo, Attikis, Greece, May 29th-July 5th 1992.**

| Bait | Conc (mg) | Total males trapped | Males/trap/ week |
|---|---|---|---|
| Z-7-14:Ald | 1 | 1,151 | 76.7 |
| Z-7-14:Ald<br>Z-7-14:Ac<br>Z,Z-7,11-16Ac | 1<br>1<br>1 | 1,089 | 72.6 |
| Z-7-14:Ald<br>Z-7-14:Ac | 1<br>1 | 1,024 | 68.3 |
| Z-7-14:Ald<br>Z,Z-7,11-16:Ac | 1<br>1 | 968 | 64.5 |
| Z-7-14:Ald<br>Z-5-14:Ac | 1<br>1 | 942 | 62.8 |
| Z-7-14:Ald<br>Z-7-14:Ac<br>Z,E-7,11-16:Ac | 1<br>1<br>1 | 696 | 46.5 |
| Z-7-14:Ald<br>Z,E-7,11-16:Ac | 1<br>1 | 682 | 45.5 |

[3] Mediterranean black scale, *Saissetia oleae* Olivier (Homoptera: Coccidae)

**Introduction:** Scale insects feed on the sap in the phloem of plants through a thin pair of tubes called stylets. They excrete prodigous amounts of material which is variously termed honeydew, manna or tears. Adult scales are usually found on trees where the bark is thinnest eg. at the junction of branches and the main stem, in the lowest parts of the canopy and on younger branches, whereas the crawlers prefer the undersides of leaves. They cause little damage themselves unless the infestation is particularly severe, but the scars left after feeding weaken the tree and honeydew residues promote attack by black mold fungi (Podoler *et al* 1979). Honeydew also stimulates the oviposition of the lacewing *Chrysoperla carnea* (Steph.) which is a predator of other olive pests, such as the Olive Moth *Prays oleae*. Several workers have prepared artifical "honeydews" for use as an attractant, which are chiefly based on yeast protein hydrolysates or tryptophan and sucrose. We thought that it would be of interest to investigate the chemical constituents of "natural" honeydew in order that the attractivity of the artifical material could be enhanced. We have also investigated the volatiles produced by the crawler stage in order to discover if they use a disaggregation pheromone to promote dispersion throughout the tree.

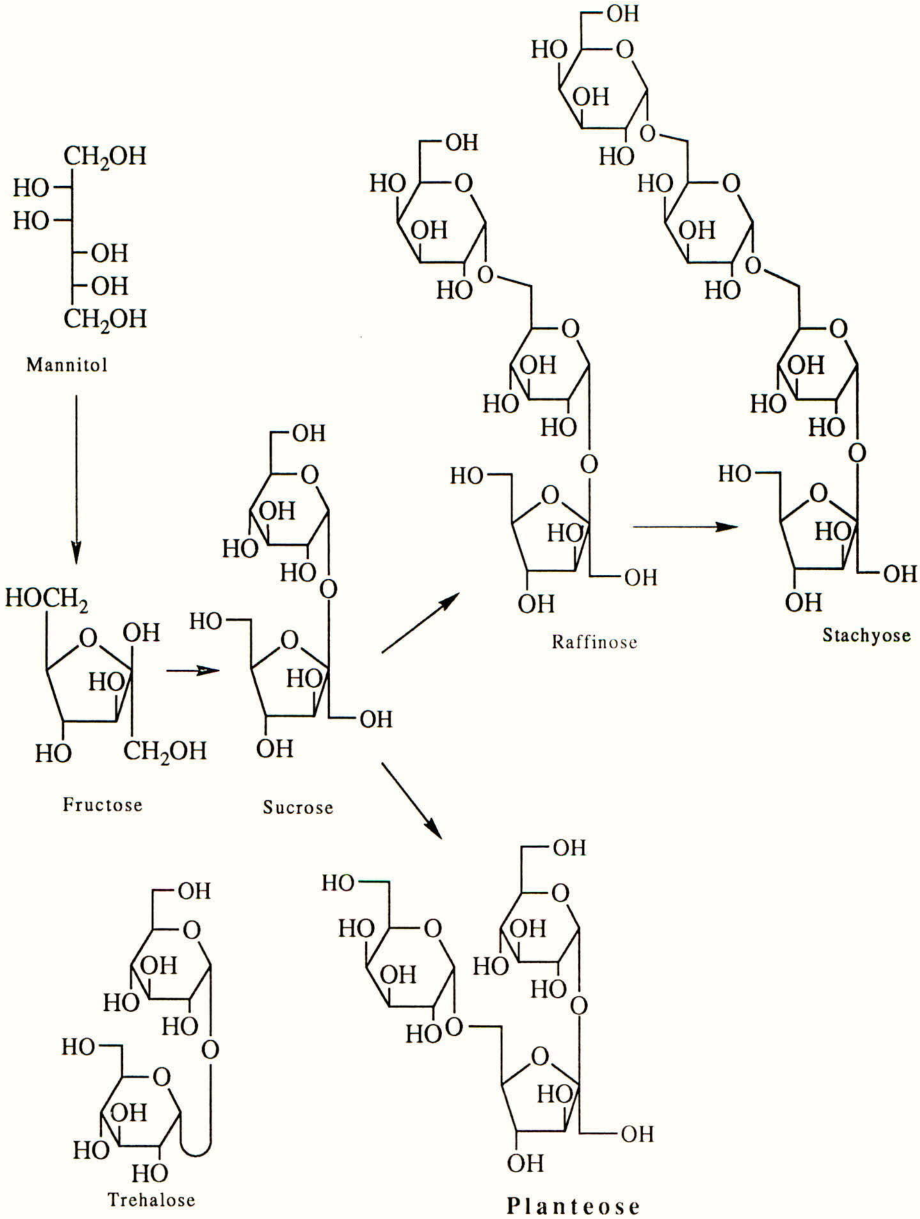
**Analysis of Sugars:** In 1991 we found that several of our young laboratory olive trees *Olea europaea* (typically 20-50cm high) were producing much larger amounts of honeydew than normal, due to a combination of scale attack and overwatering. The white material was scraped from the leaves of six trees or collected on aluminium foil laid underneath the plants. In 6 months a total of approximately 10 grms was collected. The crude material was insoluble in organic solvents, but was completely soluble in water. $^1$H NMR spectra of this material indicated resonances typical of sugars and the absence of alkenes, hydrocarbons and aromatics. The complex mixture was methylated by treatment with potassium hydride in dimethyl sulphoxide, tetrahydrofuran and methyl iodide. The components were separated by repeated column chromatography over "flash" silica gel eluted with hexane, diethyl ether, ethyl acetate and methanol sequentially. All the components (with the exception of planteose) were identified by comparison of the $^1$H NMR spectra of the fractions and authentic materials prepared in this laboratory. Planteose is not commercially available and there is no unambiguous natural source. The major component (typically 50%) was mannitol, with smaller amounts of the monosaccharides, disaccharides and trisaccharides. The structures of the sugars suggest a biosynthetic pathway originating with mannitol. Oxidation gives fructose and then sequential addition of glucose, galactose and a second galactose unit ultimately gives stachyose. Planteose may be the first representative of a series of homologous 6-galactosyl fructose derivatives. We are currently studying the sugars present in olive leaves, so as to determine if the sugars undergo modification in the gut of the olive scale.

The nitrogen content of the honeydew was determined by combustion analysis of the crude material scraped directly from the leaves. No detectable amount of nitrogen (+/-0.2%) was present and thus the protein content must be less than 1%. Therefore the field observation that yeast hydrolysate and tryptophan increase the attractivity of artifical honeydew is a wholly abiotic phenomenon.

**Analysis of Crawler Volatiles:** The volatiles from newly emerged crawlers were collected on silica gel or Tenex in an air entrainment system or by allowing them to crawl over silica gel plates. In each case control experiments were performed in which the crawlers were absent. The major components identified by GC-MS were squalene, decanal, dodecanal, tetradecanal and 2-ethyl-hexanol (racemic, Cyclodex-B, capillary GLC Column). These were presented to crawlers in a petri dish in a puffed air flow from a Pasteur pipette. None of the components caused a behavioural response except for 2-ethyl-hexanol which caused rapid movement away from the stimulus and "milling" around.

[4] *Euzophera pinguis* Haw. (Lepidoptera: Pyralidae)

*Euzophera pinguis* emerge from their pupae after sunset and commence calling within a few hours. The females raise the abdomen between the opened wings, whilst the males circle behind, hover above them and then commence mating. The eggs are laid in the bark of olive or ash trees, preferentially at wounds, tuberculae or other points of damage. The larvae excavate a gallery at the bark phloem interface, which may be up to 7cm long and in severe infestations the supply of sap to branches may be cut off entirely. Prior to our work very little was known about the natural history of these insects, because it is very difficult to remove them from their galleries in the tree. We currently have a small collection of pupae and are collecting the volatiles released by the adults during calling, by air




**Sugars Identified in Olive Tears**

entrainment (methods as *Saissetia oleae*). We have also investigated oviposition stimulants by comparing extracts of olive tuberculae (*Pseudomonas savastanoi*), ash branches, olive branches and *Artemisia absinthium*. The latter is a host for the related species *Euzophera cinerosella* (Zell). The sesquiterpene Shybunol acetate was a common component in all the extracts except the olive branches, and we are currently attempting to confirm this provisional assignment by extraction of authentic material from Calamus oil.

[5] The olive bark beetle, *Phloeotribus scarabaeoides* Bern. (Coleoptera, Scolytidae)

Adult olive bark beetles reproduce during spring and early summer in olive tree prunings. The emerging young fly to living trees to feed and in September they excavate overwintering galleries. These activities are the major causes of economic loss and up to 70% of the crop may be lost (Campos and Gonzalez, 1990). We have studied the attraction of the insects to the logs. The most promising results have been obtained from the frass of virgin females, which was analysed directly by GC-MS using a solid injector. All of the aldehydes in the homologous series from heptanal to dodecanal were identified, plus 2-octanone, 2-nonanone and 2-decanone. These typically had an attractivity index of 50-60% in a Y-tube bioassay (Campos et al, 1990b). In addition the artifical plant growth stimulant; etherel has been found to be highly attractive. We surmise that the ethylene released by this chemical mimics the ethylene released by punings.

[6] Jasmine moth, *Palpita unionalis* (Lepidoptera: Pyralidae)

Recent studies on the mating behaviour of the jasmine moth have shown that the females produce and release a sex pheromone which attracts males. The site of pheromone production is a gland located in the last abdominal segment. The pheromone was extracted from the gland with methylene chloride, isolated, identified and evaluated under laboratory and field conditions (Mazomenos *et al.* in preparation; Mazomenos and Mayridis-Moustakali, 1991, European Patent No. 92401709.8).

**Insects:** The insects used were obtained from a culture established from larvae collected in the field and reared under laboratory conditions. The insects were sexed at the pupal stage and the adults were kept in separate rooms under 16:8 dark:light regime and 25 +/-1°C. 10% Sucrose was provided to the adults.

**Pheromone collection:** The pheromone was collected from the pheromone gland of 2-3 days old virgin females exhibiting calling behaviour. The glands were removed with forceps and extracted with methylene chloride for 20 mins. The extracts were filtered and concentrated under a 8 cm Vigreux column.

**Pheromone purification:** The concentrated crude extract was first purified through a glass column packed with silica gel (0.2-0.5mm). The components were eluted with 100ml of hexane, 200ml 10% diethyl ether in hexane and 250 ml diethyl ether. The biological activity was recovered in the 10% ether fraction and purified by preparative gas liquid chromatography over 5% OV-101 on chromsorb G/HP 80-100 mesh. The column temperature was held at 120°C for 5min and was then raised to 240°C at 6°C/min. Helium was used as a carrier gas at a flow rate of 20ml/min. Consecutive 6 minute fractions were collected in liquid nitrogen cooled glass capillaries and each was tested for biological activity.

**Field trials:** Field trials were conducted during June-October 1991 in two locations, Papagou and Markopoulo, Attikis. The attractiveness to males of each of the pheromone components individually or in combinations and their geometrical or positional isomers were evaluated.

**GC and GC-MS analyses:** The active fractions collected from the preparative GC were analysed on DB-5 30m X 0.32mm (ID) and CW 20M 30m X 0.32mm (ID) silica fused capillary columns. The retention times of the two major peaks on both columns corresponded to those of synthetic monounsaturated 16 carbon aldehydes and acetates. GC-MS analyses of the two major components supported the retention time data. The mass spectrum of component one indicated a $C_{16}$ unsaturated aldehyde with diagnostic peaks at m/z 240 ($M^+$) and 222 ($M^+$-18). The mass spectrum of the second component indicated a C16 mono-unsaturated acetate, m/z 282 ($M^+$), 222 ($M^+$-60). The double bond geometry and positions could not be deduced from the mass spectra, but the spectra were identical to that of E-11-hexadecenal (E-11-16:Ald) and E-11-hexadecenyl acetate (E-11-16:Ac). These assignments were supported by field trials. E-11-16:Ac and E-11-16:Ald tested individually were not attractive to males, but the attractivity was restored when the components were combined. When geometric isomers were added the attractiveness to males was inhibited.

**Male P. unionalis captured in traps baited with different combinations of synthetic sex pheromone components, Markopoulo Attikis, Greece, June 12th-July 17th, 1991.**

| Bait | Conc (mg) | Total males captured | Males/trap/ week |
|---|---|---|---|
| E-11-16:Ac | 1 | 0 | 0 |
| E-11-16:Ald | 1 | 0 | 0 |
| E-11-16:Ac | 1 | 164 | 18.2 |
| E-11-16:Ald | 1 | | |
| E-11-16:Ac | 1 | | |
| Z-11-16:Ald | 1 | 36 | 4 |
| E-11-16:OH | 1 | | |
| E-11-16:Ac | 1 | 0 | 0 |
| Z-9-16:Ald | 1 | | |
| E-11-16:Ac | 1 | 0 | 0 |
| Z-9-16:Ald | 1 | | |

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# BIOLOGICAL CONTROL STRATEGIES IN OLIVE PEST MANAGEMENT

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## ABSTRACT

We review various approaches to biological control of some olive pests, *Bactrocera oleae*, *Prays oleae*, *Saissetia oleae* and *Phloeotribus scarabaeoides*. Rates of establishment and success for past classical biological control attempts against *B.oleae* and *S.oleae* are calculated, and their significance discussed. Other approaches we discuss are the conservation and augmentation of natural enemies.

## INTRODUCTION

In this paper, we consider the opportunities that exist for improving the biological control of some insect pests (*Bactrocera oleae*, *Prays oleae*, *Saissetia oleae*, *Phloeotribus scarabaeoides*) of olives in the northern Mediterranean region. We discuss only the use of insect predators and parasitoids; Dancer and Varlez (this Symposium) deal with pathogens and their products.

## CLASSICAL BIOLOGICAL CONTROL (INTRODUCTIONS)

### Rates of establishment and success

To date, at least 63 introductions of natural enemies have been made against *B.oleae*, *P.oleae* and *S.oleae* in the northern Mediterranean region (Table 1), involving 3 species of predator and 35 species of parasitoid (Table 2). Both the degree of success in natural enemy establishment and the degree of success in control following introduction are difficult to calculate, because of the large number of introductions whose outcome is not known (18). If we ignore such introductions, the overall establishment rate (proportion of introductions that have resulted in establishment) for natural enemies in classical biological control of olive pests is 0.49, while the overall rate of success (proportion of introductions that have resulted in some degree of control) is 0.15. The former figure compares favourably with the establishment rates calculated for (a) introductions of natural enemies against *S.oleae* in California (0.33, Daane *et al.* (1991)), and (b) field introductions of natural enemies against pests in orchards and other perennial habitats in Canada (0.43, Beirne (1975)) and throughout the World (0.32, Hall & Ehler (1979)). The latter figure unfortunately cannot be compared with the success rate given by Hall *et al.* (1980) for introductions against perennial crop pests worldwide, because of the way those authors calculate success rates; they consider all introductions against a given pest species in a given geographical area as a single attempt, thereby tending to overestimate success rate, as defined here. Nevertheless, it is reasonable to regard a success rate of 0.15 for introductions against olive pests as rather poor.

**TABLE 1**. Results of classical biological control introductions against *B.oleae*, *P.oleae* and *S.oleae* on olives (as opposed to citrus) in the northern Mediterranean region. Analysis based on records in CABIIC's *BIOCAT* data base, Jimenez *et al.* (1990) and Katsoyannos (1992). *E*, natural enemy became established, but did not control pest; *C*, pest completely controlled; *S*, pest substantially controlled; *P*, pest partially controlled; *F*, natural enemy failed to become established; *N*, outcome not known. The two known cases of substantial control achieved in introductions against olive pests on olives, as opposed to other crops (i.e. citrus), are *Metaphycus helvolus* used to control *S.oleae* in Crete (Argyriou, in Greathead (1976)) and *Opius concolor* used to control *B.oleae* in Italy (Silvestri, 1938; Monastero, 1965; Monastero & Delanoue, 1966, 1967; Liotta & Mineo, 1968).

| | E | C | S | P | F | N | TOTAL |
|---|---|---|---|---|---|---|---|
| *B.oleae* | 0 | 0 | 1 | 2 | 19 | 5 | 27 |
| *P.oleae* | 3 | 0 | 0 | 0 | 0 | 4 | 7 |
| *S.oleae* | 12 | 0 | 1 | 3 | 4 | 9 | 29 |
| TOTAL | 15 | 0 | 2 | 5 | 23 | 18 | 63 |

The apparently good establishment rate achieved for introduced natural enemies is interesting, as most introductions carried out in the northern Mediterranean region have been made in coastal and sub-coastal regions and on islands; few have been carried out in areas far inland. Daane *et al.* (1991) remark on the difficulty with which natural enemy establishment and control have been achieved in the Central Valley of California, compared with coastal areas. They attribute this difficulty to the relatively harsh climate (hot, arid) of the Central Valley. The climate in the valley causes individuals of *S.oleae* to be synchronised in their development, with little overlap between stages, the result being that there are temporal gaps in the availability of suitable host stages for parasitism and predation. Changes in cultural practices are being made to mitigate these effects of Central Valley climate on biological control (see *Conservation and augmentation*, below). Note that a *Metaphycus* species (*M.zebratus*) indigenous to Spain was recently chosen for release into California partly because of its presumed tolerance to hot summers (Daane & Caltigirone, 1989).

One possible reason for the very low success rate, and also the absence of any cases of complete control in the northern Mediterranean olive agroecosystem, is the very drastic vegetation management practised in many olive orchards. The high degree of habitat disturbance resulting from such management is likely to have an adverse effect upon populations of natural enemies (for further discussion, see *Conservation and augmentation*).

<u>Establishment and success in relation to pest species</u>

Examining establishment rate and success rate on a pest species basis (ignoring *P.oleae*, due to the small number of introductions against that pest), we find that the establishment rate of natural enemies used against *B.oleae* is much less than that for natural enemies used against *S.oleae* (*B.oleae*: 0.14, *S.oleae*: 0.8). This disparity also applies if only introductions of parasitoids are considered (*B.oleae*: 0.05, *S.oleae*: 0.8). Similarly, the success rate of natural enemies used against *B.oleae* is less than that for those used against *S.oleae* (*B.oleae*: 0.14, *S.oleae*: 0.2). If only parasitoids are considered, the success rates are the same.

Success rates might be expected to vary with pest species, as *S.oleae* and *B.oleae* occupy very different feeding niches, in the sense that *S.oleae* is exophytic and *B.oleae* endophytic. Hawkins & Gross (1992) considered classical biological control attempts worldwide from the point of view of pest feeding niche, in order to determine whether niche type has had any effect upon the outcomes of introductions. Their analysis revealed that introductions have been more successful where they have made against (a) hosts whose vulnerable stages feed unconcealed on foliage, and (b) hosts whose vulnerable stages are poorly protected by plant tissues, than where they have been made against (c) hosts whose vulnerable stages are well protected by plant tissues e.g. in fruits. These differences in success rates support the hypothesis of Hawkins & Gross (1992) that host/prey species well protected by refuges should not be as strongly limited by natural enemies as host/prey species less well protected; in other words, the greater the protection the refuge affords, the less the probability that parasitoids will be able to respond to changes in host density. The data set on parasitoids of olive pests is not strictly comparable with that used by Hawkins & Gross (1992), since the latter is based solely on holometabolous insects. However, it is not unreasonable to conclude that the feeding niche difference between *B.oleae* and *S.oleae* has been at least partly responsible for the observed difference in success of introductions against the two pests.

**TABLE 2**. Predator and parasitoid species used in classical biological control programmes directed at olive pests in northern Mediterranean countries. Indicated in parentheses are the countries into which the predator or parasitoid was released: *F*, France (mainland and islands); *G*, Greece (mainland and islands); *I*, Italy (mainland and islands); *S*, Spain (mainland); *Y*, Yugoslavia (mainland).

| Target pest | Predators/parasitoids |
|---|---|
| *Bactrocera oleae* | *Belonuchus rufipennis* (I), *Bracon celer* (I), *Opius africanus* (I), *Opius concolor* (F,G,I,S,Y), *Opius dacicida* (I), *Opius trimaculatus* (I), *Biosteres longicaudatus* (G), *Biosteres oophilus* (G), *Biosteres tryoni* (G), *Triaspis daci* (I), *Trybliographa daci* (G) *Dirhinus giffardii* (G,I), *Halticoptera daci* (I), *Mesopolobus modestus* (I), *Eupelmus afer* (I), *Cirrospilus variegatus* (I), *Euderus cavasolae* (I), *Achrysocharella formosa* (I), *Tetrastichus giffardianus* (G,I) |
| *Prays oleae* | *Chelonus elaeaphilus* (G), *Trichogramma* sp. (G), *T. cacoeciae* (G), *T.dendrolini* (G), *T.minutum* (G), *T.pretiosum* (G) |
| *Saissetia oleae* | *Rhyzobius forestieri* (G), *Moranila californica* (F), *Scutellista cyanea* (F,G), *Diversinervus elegans* (F,G,I), *Microterys flavus* (I), *Metaphycus bartletti* (F,G,I,S), *Metaphycus helvolus* (F,G,I,S), *Metaphycus lounsburyi* (F,I), *Metaphycus stanleyi* (I), *Metaphycus swirskii* (F,G,I), *Encyrtus lecaniorum* (F), *Coccophagus rusti* (G), *Aneristus ceroplastae* (F) |

Hawkins & Gross (1992) do not consider whether establishment rates, as defined above, should vary similarly, but our analysis of their data set (Table 1 of Hawkins & Gross (1992)) reveals that the establishment rates for parasitoids of both category (a) and (b) hosts are higher than for parasitoids of category (c) hosts. As noted above, the establishment rates for parasitoids of *S.oleae* and *B.oleae* follow this pattern. We cannot at present explain why establishment rates should vary thus.

Opportunities for future introductions

Bearing in mind that some olive pests may be intrinsically more difficult to control than others, opportunities exist for further introductions of natural enemies, involving either species already used (i.e. those in Table 2) or additional exotic species. There appear to be many of the latter, e.g. see Annecke & Mynhardt (1971, 1972) and Myartseva (1988) for possible candidate species of *Metaphycus* among the African and central Asian faunas. Note in particular that no parasitoid introductions have so far been made against *Phloeotribus scarabaeoides*. Introduction as a biological control strategy ought still to be given serious consideration, since, when successful, it produces long-term results and little or no further input may be required. However, we feel that biological control workers ought not to proceed with further introductions unless they also pay attention to the conservation of natural enemies.

## CONSERVATION AND AUGMENTATION

Potential importance of non-crop vegetation

Although Ruiz (1951) suggests that natural control of *B.oleae* might be improved by allowing certain non-crop plants to flourish near orchards, because they could harbour alternative hosts for parasitoids, conservation of natural enemies has only very recently been considered as a biological control strategy in the olive agroecosystem. In our view, current practices of non-crop vegetation management in olive orchards require close examination, to determine whether they conflict with the requirements of natural enemies for non-crop plants as food, alternative hosts, and prey, and shelter. For example, in many areas of Spain olive-growers drastically suppress the growth of non-crop ('weed') vegetation between olive trees, either by applying herbicides (e.g. Castellón, Spain) or by raking the soil (e.g. Granada and Jaén, Spain). This vegetation management is carried out to conserve water and nutrients for the olive trees, and to facilitate harvesting of the olive fruits. However, some of the plants that might otherwise flourish between trees could: (a) provide nectar and pollen, and even honeydew (from Homoptera feeding on those plants) for adult parasitoids and both larval and adult predators; (b) support alternative host and prey species that might sustain natural enemies during periods of olive pest scarcity; (c) provide shelter from excessive heat and dryness.

The adults of many hymenopteran and dipteran parasitoids habitually consume, for egg development and maintenance, naturally occurring non-host and non-prey foods such as nectar, pollen and honeydew (Jervis *et al.*, 1992a,b). In a variety of habitats other than olive orchards, adults and larvae of the green lacewing, *Chrysoperla carnea*, have commonly been recorded feeding at the inflorescences of a wide variety of Umbelliferae (Jervis, unpublished observations), and we consider it highly likely that *C.carnea*, an important predator of *P.oleae* eggs, will, given the opportunity, visit umbellifers for food in olive orchards. We have begun survey work, in which we are seeking evidence of olive pest parasitoids and predators feeding at the inflorescences of plants that have survived vegetation management and which occur around tree bases and along orchard margins. Depending on our eventual findings, olive-growers may be recommended to modify their vegetation management practices so that certain plant species are encouraged, and the nutritional requirements of natural enemies catered for.

Artificial honeydews

The spraying of arable crops with artificial honeydews (mixtures of water, yeast hydrolysate or autolysate and sucrose) has been carried out in order to increase predation of pests (Ben Saad & Bishop, 1976; Carlson & Chiang, 1973; Schiefelbein & Chiang, 1966). Hagen *et al.* (1976) showed that by adding tryptophan to such honeydews, their attractiveness and therefore the immigration of predators into the crop could be greatly increased. Tryptophan itself is not attractive to *C.carnea*, being non-volatile at ambient temperatures. Its breakdown products (indole aldehyde and tryptamine, according to van Emden & Hagen (1976)) (but see Dean & Satasook (1983)) are the attractants; they are said to mimic the natural odour of prey honeydew. Adults of *C.carnea* are attracted to the honeydew of *S.oleae* (Alrouechdi *et al.*, 1981).

Liber & Nicolli (1988) investigated the spraying of olive trees with artificial honeydew containing acid hydrolysed L-tryptophan as a potential method for improving the control of *P.oleae* by *C. carnea* and other Chrysopidae. Although they found that significantly more adults of *C.carnea* were captured in Berlese traps in the test plot than in the control plot, and that percentage mortality of *P.oleae* (assumed to be caused by chrysopid predation) was higher in the test plot, they could not rule out the possibility that the lacewings were responding to the perhaps greater quantities of honeydew being secreted by the higher densities of olive scale in the test plot.

In the spring of 1991, at a site in Granada, we used an artificial honeydew based on the same recipe as Liber & Nicolli's (1988), and measured the mortality of *P.oleae* eggs (presumed to be caused mainly by *C.carnea*) in both the flower and the fruit generations of the moth. Predation appeared much earlier in the test trees than in the control (unsprayed) trees, but otherwise we observed no significant effect of spraying. Since the concentration of the tryptophan component of the honeydew used by Liber & Nicolli (1988) was low (0.63 g per litre sprayed), compared with that used in other studies (0.74-1.67 g per litre sprayed), we have decided to repeat the above experiment, using a honeydew relatively rich in tryptophan.

Field evidence that the tryptophan component of artificial honeydews attracts natural enemies into olive tree canopy was provided by an experiment in which we compared the numbers of adult *C.carnea* caught in non-coloured sticky traps placed in the canopies of untreated trees with the numbers caught in identical traps placed in trees sprayed with a solution of L-tryptophan (where each tree received 2 g of tryptophan in 30 ml of 2M HCl in 800ml $H_2O$, i.e. a tryptophan concentration of 2.5 g per litre sprayed). Over twice as many insects were caught in the canopies of the treated trees as in the control trees (test: $\bar{x} = 78$, control: $\bar{x} = 36$; $\chi^2 = 30.95$, $P<0.001$, 1 df).

As well as undesirable side-effects such as the encouragement of sooty moulds on foliage, there are other potential problems associated with the spraying of the olive tree canopy with artificial honeydews and solutions of food-related semiochemicals such as tryptophan: (a) the natural enemy population in the sprayed plots of olive trees may simply be augmented by insects from surrounding unsprayed plots, resulting in reduced predation and parasitism and therefore increased crop damage in the latter. This problem may be much less important where small, relatively isolated orchards are sprayed, as the immigrants might originate mainly from non-crop habitats; (b) sprays will attract not only beneficial natural enemies but also undesirable ones such as hyperparasitoids and parasitoids of predators (e.g. *Dichrogaster* sp., a common parasitoid of pupal Chrysopidae).

Cultural practices

The spacing of olive trees and also pruning practices may need to be reviewed from the standpoint of natural enemy conservation. As we have already noted, climatic conditions in the Central Valley of California are inimical to biological control of *S.oleae*. However, Daane & Caltigirone (1989) report on how establishment of parasitoids and the degree of control they exert on *S.oleae* depend on the type of pruning carried out, the type of irrigation practised, and the presence of ground cover (Table 3).

Plant breeding

There are also potential conflicts between crop improvement and the habitat requirements of parasitoids. Varietal differences in susceptibility of olive trees to *S.oleae* have been linked to canopy structure. The denser foliage of some varieties provides a more humid and therefore more favourable habitat for the scale (Rosen *et al.*, 1971). However, whilst a more open canopy might at first sight seem a desirable trait from the point of view of plant resistance to scale attack, it is likely to hinder control by parasitoids such as *Metaphycus* species (see *Cultural practices*, above).

**TABLE 3.** Differences in cultural practices within California's Central Valley, their effects on the population dynamics of *S.oleae*, and the consequences for biological control by parasitoids (abstracted from Daane & Caltigirone (1989)).

| | SAN JOAQUIN VALLEY | SACRAMENTO VALLEY |
|---|---|---|
| CANOPY | Pruned low to ground, branches of different trees do not touch | Pruned high above ground, branches of different trees touch |
| GROUND COVER | Absent | Present |
| IRRIGATION | Low | High |
| S. OLEAE | High summer mortality of crawlers due to adverse microclimate (high temperatures, low humidity) in canopy - little overlap between stages, causing temporal gaps in host availability, so making it difficult for parasitoid population to establish itself | Low summer mortality of crawlers due to favourable microclimate (low temperatures, high humidity) in canopy - much overlap between stages, host availability less of a problem, so making it easy for parasitoid population to establish itself |
| CONSEQUENCES | Low winter & spring mortality of scale - frequent & damaging scale outbreaks | High autumn & spring parasitism of scale - good control |

Latière (1917) suggested that the failure of parasitoids to control olive fly in cultivated olives was a result of the inability of females to pierce the tough skins of those olives, compared with wild olives. Greathead (1986) also suggests that the breeding of unnaturally large fruits has made parasitoids less effective, by increasing the distance between the olive fly larvae and the fruit surface, so preventing female parasitoids from reaching hosts.

Pest trapping and monitoring

Concern about the large numbers of beneficial insects such as predators and parasitoids that might be caught by pest trapping/monitoring methods was first expressed by Neuenschwander (1982). The use of coloured (especially yellow) sticky traps and traps that employ ammonium salts (e.g. McPhail traps), at high densities within orchards, ought to be avoided, as both types of trap can attract and kill significant numbers of predators and parasitoids. The current widespread practice of controlling *B.oleae* by the use of protein hydrolysate sprays incorporating insecticides is also questionable, in view of the attractiveness of protein hydrolysate to entomophagous insects generally.

Inundative release

Inundative releases of natural enemies, both established exotic species (*Opius concolor*, *Metaphycus helvolus*) and indigenous species (*Chelonus elaeaphilus*), have been carried out for the control of *B.oleae*, *P.oleae* and *S.oleae* with, in some cases, a high degree of success (for reviews, see Greathead (1976) and Katsoyannos (1992)). Improvements in the mass-rearing of these natural enemies continue to be made (e.g. Piedade-Guerreiro & Guardada (1988)). Inundative releases of *Chrysoperla carnea* against *P.oleae* are currently being considered, particularly as this predator can now be reared in substantial numbers. Mass release of the eggs or larvae, rather than the adults, of *C.carnea* is thought to be the better strategy, as female *C.carnea* undergo an obligatory preoviposition migratory flight (Duelli, 1980a,b) such that significant emigration of adults from release areas is likely. Releases of eggs resulted in significant reduction of mealybug populations on pears (Doutt & Hagen, 1950).

## DISCUSSION

To date, natural enemy introductions and mass, in some cases inundative, releases of natural enemies, have been the only biological control strategies employed in olive pest management and they remain useful potential methods of pest control. Additional strategies need, however, to be considered, especially conservation. The latter approach requires that more attention be paid to cultural practices such as the pruning and spacing of trees, and particularly the management of non-crop vegetation. The role of such vegetation in the olive agroecosystem is in need of urgent review in any case, as soil erosion resulting from current vegetation management practices causes increasing concern.

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# DEVELOPMENT OF POPULATION MODELS FOR OLIVE PEST MANAGEMENT

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## ABSTRACT

Population models of the olive fly and olive moth are currently being developed for use in IPM programmes. The objectives are to be able to predict population phenologies and changes in abundance, both within and between years, with a view to assessing the effects of applying different control measures and defining optimum management strategies for particular regions or situations. The structure and rationale of the models are discussed, together with an indication of their current state of development. So far, both models provide predictions of phenology which are sufficiently accurate to be useful in pest management programmes. However, further refinements will be required before either model can accurately predict abundances. Nevertheless, some tentative simulations have been carried out using the moth model to demonstrate its potential value in defining optimal pest management strategies.

## INTRODUCTION

In evaluating the likely success of an integrated pest management programme, two basic questions have to be answered: what is the best combination of available control measures and how best to integrate them to achieve the maximum benefit? One approach which is becoming increasingly important in the attempt to answer these questions involves the development of realistic computer-based simulation models of the pest populations, and to use these as an experimental system for judging the efficacy of different management strategies. Because of the relative complexity of the current olive pest management programme, involving investigations into pheromones, microbial pesticides, natural enemies and habitat management, this type of modelling approach is considered to be of central importance. Our aim in the ECLAIR 209 programme was to develop population management models for the three major pests of olive, namely, *Bactrocera oleae* (the olive fly), *Prays oleae* (the olive moth) and *Saissetia oleae*, (the black scale). To date, most of our effort has been concentrated on the two principal pests, the olive fly and the olive moth. Our purpose in this paper is to outline the modelling approach which we have adopted, and to provide some of the results to date, relating particularly to the olive moth which, to our knowledge, has not been modelled before.

The specific objectives of the models are to predict:

1) the phenologies of the different stages of the pests.
2) the numbers of insects in all stages at different times of the life cycle.
3) the variations in numbers from generation to generation, year to year and place to place.
4) the effects of applying different control measures, with a view to defining optimum management strategies for particular regions or situations.

To meet the last objective requires the successful completion of the first three. The prediction of phenologies is important if the application of management techniques is to be timed effectively, while a detailed quantitative understanding of the factors driving changes in pest numbers is likely to be crucial in any predictive impact assessment.

## STRUCTURE OF THE MODELS

The respective models for the olive moth and fly have so far been developed independently in Cardiff (NACK) and Italy (SG), but future work aims to develop a common approach by integrating the best elements of both model structures. So far, the moth model has been developed and tested using data collected from the Granada and Jaen regions of Spain, while the fly model has used information from the Canino and Viterbo regions of Italy. For both models, we have produced user-friendly interactive computer program 'shells', within which the pest management models can be run. These have been developed using structured BASIC compilers, so that the models can be run on IBM compatible computers. An important consideration of the research programme was that the models should be portable and easy to use by pest managers or extension workers in different countries.

The models are of the discrete, deterministic, box-car type, using temperature as the main driving variable with a time step of one day. As the rate of insect development is temperature dependent, individual development and population growth are modelled on a physiological time scale using day-degrees. The rate of insect development is determined by mathematical functions relating daily development increments to average daily temperatures between high and low developmental thresholds. The fly model used the functions developed by Fletcher and Kapatos (1983) and Fletcher and Comins (1985) while the moth model used those of Kidd (1991a,b). Temperature data were obtained from meteorological stations (Spain, Italy), or from locally-used temperature-integrators (Italy). Development times in day-degrees were calculated for each stage of both insect species from laboratory experiments.

As future temperatures are unknown, the models in theory can only be run 'after the event', providing retrospective 'predictions'. This problem, however, has been partially overcome by the simple expedient of using averaged daily temperatures from the previous 10 years to simulate future daily temperatures. As seasonal weather patterns are broadly repetitive from year to year, this can give reasonably accurate temperature predictions, at least up to one or two weeks ahead. Beyond that, accuracy declines. Work is currently in progress to further refine the technique, by statistically identifying recurring temperature patterns within particular years, which may more closely resemble the pattern unfolding in the current year.

Life-stage mortalities have been calculated from published life tables in the case of the olive moth (Ramos *et al.*, 1976, 1978a), and from field experiments in the case of the olive fly. At the moment, some of the relationships and parameter values used to describe mortalities have to be considered as tentative, but these are continually being upgraded from experimental work currently in progress.

Emigration and immigration of adult moths and flies is assumed at the moment to be an unimportant factor, and is ignored in the models at this stage. Olive orchards in Spain are extremely large and uniform, so that, except at the boundaries, dispersive movements of adults are likely to cancel out. In central Italy, however, where orchards tend to be smaller, adult dispersal could be important.

For both insects, initial input for the model is taken at this stage from pheromone trap catches of emerging adults in the spring and early summer. These records, together with the first recorded date of oviposition, define the pattern of oviposition on the flowers (moth) and fruits (fly). Development of the eggs, hatching larvae, and the resulting pupae is under temperature control, the rates of development driven by mean daily temperatures in the field. Emerging females mate immediately, each subsequently depositing eggs according to patterns deduced by confining individual mated females on branches within sleeve cages. With the olive moth, females oviposit only when the fruits are at a certain stage of development, but so far there is no means of predicting this. At the moment, the start of oviposition has to be set from field data.

## RESULTS

### Predicting phenology

Current versions of the models developed for both insects predict the appearance and disappearance of successive stages and generations with encouraging accuracy. For the olive moth flower-generation adults, for example, predicted dates of appearance and disappearance in 1990 were within two days of those observed in the field (Figure 1; Table 1).

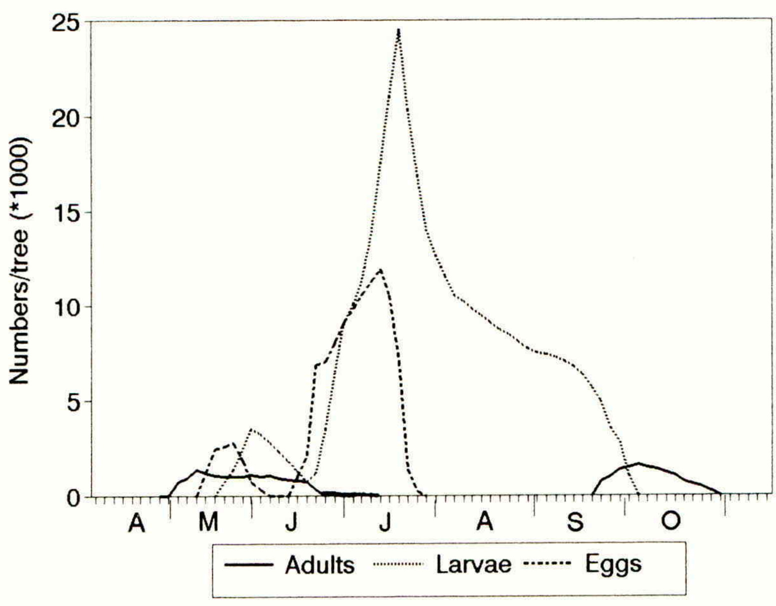


**FIGURE 1.** Seasonal changes in population numbers of the olive moth predicted by the model for 1990.

**TABLE 1.** Predicted and observed dates of first appearance and disappearance of flower generation adults in 1990.

| | Appearance | Disappearance |
|---|---|---|
| Observed | 24th May | 15th July |
| Predicted | 26th May | 14th July |

As yet there is no available field data for emergence and disappearance of fruit generation adult moths, with which to compare the model output, although the general timing is correct, i.e. September/October (Fig. 1). Thus the models can be used with some confidence in their current form with data from spring trap catches of adults to predict the timing of appearance of all stages of successive generations, where prevailing temperatures are known. With fine-tuning for particular localities, it should therefore be possible to use current versions of the model to time more accurately the application of pest management measures.

Predicting abundance

So far neither model is capable of predicting population numbers accurately, although the moth model is capable of reproducing the general pattern of within-season population changes (Fig 1). The fly model, however, overestimates the rate of population growth, such that population levels have to be corrected a number of times during the summer. Experiments with the fly model indicate that one possible source of error is likely to lie in underestimating winter mortality and thus the number of flies emerging from diapause in early summer. Laboratory and field experiments are currently in progress to obtain revised mortality estimates.

With the olive moth, the most serious gaps in our knowledge of the factors influencing abundance relate to the leaf generation. Ramos *et al.* (1978b) have shown that higher mortalities of winter larvae are correlated directly with the number of days during which mean temperature falls below $0^oC$. Clearly, the severity of winters may play an important role in determining population growth rates in the spring, by affecting the number of adults emerging from the leaf generation. Future versions of the model will attempt to integrate mortality factors acting on all three generations, in order to predict changes in abundance from one year to the next, as well as changes within years.

Effects of pest management strategies

Simulations of within-year population dynamics have been carried out to assess the possible impact of applying different management strategies to moth populations. It should be stressed that these are only tentative predictions at this stage, provided more as an illustration of the pest management possibilities, than as strict recommendations.

A 60-80% mortality acting on the leaf and flower generation adults is unlikely to reduce the larval population in fruit by more than 20% (Fig 2), simulating the maximum impact that the use of pheromone traps alone can be expected to have on the population. In combination with microbial pesticides applied to the flower-generation eggs and larvae, a reduction of 40% can be achieved (Fig 2). However, if egg predation on the fruits can also be raised consistently to 90% (achieved occasionally), then a more acceptable reduction of 60% could be achieved (Fig. 3). These results could conceivably be improved by optimal timing of applications, facilitated by the phenological predictions of the model.

However, the model also predicts that a 90% reduction in fruit infestation could be achieved by increased flower generation egg mortality, suggesting more emphasis should perhaps be placed on the possibilities offered by mass release of egg predators and parasites in the spring (Fig 3).

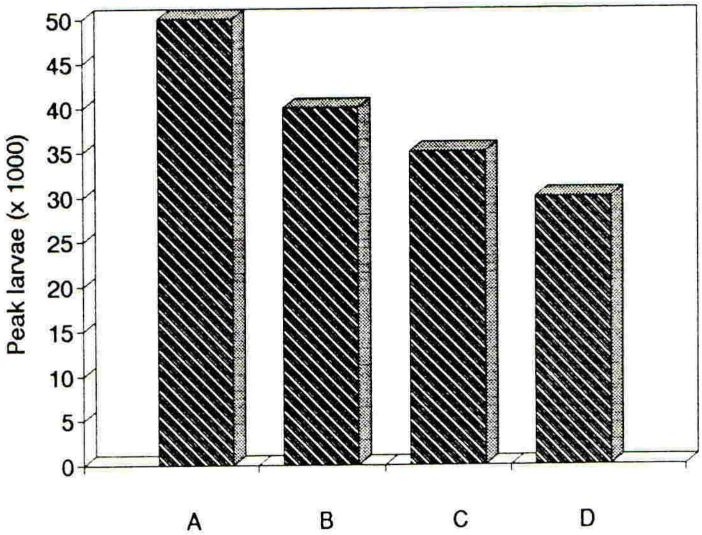


**FIGURE 2.** Predicted peak number of fruit g eneration larvae per tree with A) natural background mortalities, B) background plus 60% adult mortality, B) background plus 80% adult mortality, D) background plus 60% adult mortality plus 60% larval mortality in flower generation.

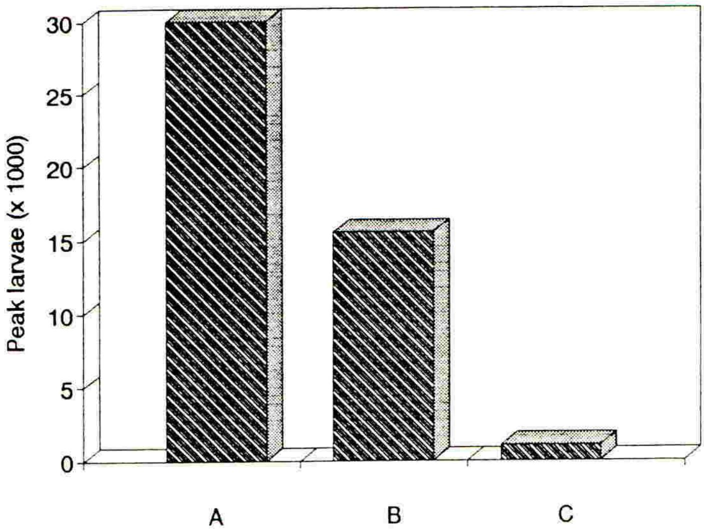


**FIGURE 3**. Predicted peak number of fruit generation larvae per tree with A) background plus 60% adult mortality plus 60% larval mortality in flower generation, B) as in (A) plus 90% egg mortality in fruit generation, C) as in (B) plus 50% egg mortality in flower generation.

## CONCLUSIONS

The above simulations demonstrate that the models in their fully developed form are likely to have a critical role to play in determining which combination of control methods are likely to have most impact in reducing pest damage. By using the models to predict in advance the appearance of stages, the timing of management practices can also be optimised.

Nevertheless, to achieve this goal further work is necessary. Future modelling efforts will be concentrated on:

a) the development of flowering and fruiting submodels, a necessary prerequisite for predicting the first ovipositions on flowers and fruits.

b) the development of predation and parasitism submodels. These submodels will be needed to allow prediction of the impact of proposed biological control measures (Jervis *et al.*, this symposium).

In summary, we are confident that the simulation models being developed for use in the ECLAIR 209 programme will play an important role in formulating a successful pest management package for the olive industry.

## ACKNOWLEDGEMENTS

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# INTEGRATED PEST MANAGEMENT FOR OLIVE GROVES IN ITALY

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## ABSTRACT

Application of Integrated Pest Management (IPM) is very limited in Italy. After considering the reasons for the lack of widespread application of IPM, this paper illustrates some of the ecological aspects of the agroecosystem of olive groves and assesses the possibilities of use of various pest control techniques. A strategy for implementation of the proposed IPM programme is described, along with the national programme currently under way.

## INTRODUCTION

In the EC, Italy possesses 20 percent of the land dedicated to olive-growing, produces 40 percent of the olive oil (by weight) and accounts for 50 percent of the total consumption of olive products. Consequently, development of Integrated Pest Management (IPM) is not only necessary as an adaptation to the integrated production system in this sector, but also urgent in view of the entry into force of the single European market in 1993.

Despite numerous national and international programmes, such as those sponsored by the FAO in 1971, the IOBC in 1976 and the EC more recently, integrated pest control in olive groves in Italy has not lived up to initial expectations in terms of either development or general acceptance.

In Italy, as in other olive producing countries, even the application of supervised pest control is still limited, with the exception of a few pockets of advanced and profitable olive production. It is in fact estimated that supervised pest control is only used on 10 percent of the land involved in olive production in Italy, i.e., little more than 100,000 hectares.

Thus, pest control in olive cultivation is still based on traditional chemical control. But the use of synthetic pesticides can no longer be simplistically advocated in the modern agro-industrial system. Not only are these polluting chemicals strongly criticized for their dangerous effects, but market demands are now rewarding quality production.

Nevertheless, several main problems block widespread use of integrated pest control:

* the diversity of the Italian olive-agro ecosystem;
* the criteria used to define a pest and to define the economic injury threshold;
* lack of technical assistance to farmers;
* lack of promotion and organization of this new approach.

## THE ECOLOGICAL BACKGROUND

### Olive cultivation in Italy

In Italy, olive growing extends from the 30° to 45° N parallel and from sea level to an altitude of 700 meters, implying considerable diversity in climatic, biological, agronomic, socio/economic and cultural factors. As a result, approaches to plant protection are strongly conditioned by the kind of agroecosystem present in the olive-growing areas.

Because of the favourable climatic conditions, olive production is concentrated principally in Italy's southern regions and in particular in Puglia, which alone produces approximately 250,000 to 300,000 tonnes of oil per year, equal to one half of total national production.

The olive agroecosystem can, however, be considered substantially stable with respect to its presence over time, plant genetic variability (about 100 olive cultivars), productivity, biocenosis, and socio-cultural organization, and this has allowed the evolution and persistence for hundreds of years of the same set of pests presently found in olive groves.

Olive pests and diseases

Using the basis of their broad territorial diffusion and their frequency and severity of attack, only four species can be considered the main pests of olive trees, while approximately ten secondary species occasionally inflict quantifiable economic losses in certain olive-growing areas. Yet the ecological characteristics of the various agroecosystems such as climate, soil, agricultural techniques and cultivars, not only determine the specificity of the pests or more generally the biotic community present, but also significantly affect fluctuations in their numbers. Thus, as a result of the presence in the biotic community of a few hundred entomophagous species which provide good natural control of the phytophagan population, there are no more than two major crop pests and from two to four minor ones.

Of the phytophagans, the majority are monophagous or oligophagous, multivoltine, highly fertile and have no diapause.

The most common pests and the parts of the plant that they attack are listed below. The pests that create the greatest economic injury and have the greatest diffusion are indicated in bold print.

Trunk: *Zeuzera pyrina*;
Branches: *Hylesinus oleiperda, Phloeotribus scarabaeoides,* ***Saissetia oleae****, Parlatoria oleae, Zeuzera pyrina, Spilocaea oleaginea, Pseudomonas savastanoi;*
Leaves and buds: ***Saissetia oleae****, Prays oleae, Palpita unionalis, Ephyllura olivina, Parlatoria oleae,* ***Spilocaea oleaginea****,* ***Capnodium elaeophilum***;
Flowers: *Prays oleae, Euphyllura olivina*;
Fruit: ***Bactrocera oleae, Prays oleae****, Palpita unionalis, Parlatoria oleae, Spilocaea oleaginea, Sphaeropsis dalmatica.*

The bio-ecological characteristics of the species most harmful to olive trees (Table1) vary substantially and decisively condition the farmers' choices of control techniques and operative programmes.

Economic considerations

The olive fruit fly and the olive moth are the pests that cause farmers the greatest concern because of their direct damage to fruit. But while the former has an economic injury level (EIL) far below the general equilibrium position, the latter causes damage only when the population density is very high and, therefore, has an economic injury level that is above the equilibrium position.

Determining the EIL is very complex and demands increasing research into the ecology of the harmful species in relation to even the most minute details of the target territory (Cirio et al., 1989; Calvi Parisetti et al., 1989). But, the more minute the detail, the greater the workload: the lower one goes into the stratification of the territory, the more difficult the sampling. Thus, increased monitoring is required to obtain a valid representation of the territory. For these reasons, the economic injury threshold is not only difficult to determine for a single farm (because of differences in the olive groves present in the territory, sampling complexities, fluctuations in the pest population in terms of time and location, operating costs), but it also has limits with regard to the different types of damage caused by the various pests.

In Italy, because of the lack of state-supplied technical assistance, of a pest monitoring system and of detailed information on the economic injury threshold, individual farmers tend to take an empirical attitude towards chemical pest control, using far more pesticides than necessary.

The average cost of protection against pests in modern olive groves in southern Italy is estimated at $120/ha. The introduction of non-chemical methods, on the other hand, is hindered by the fact that they are less effective and more costly than pesticides.

Factors favourable to IPM

The agroecosystemic factors listed below are particularly suited to the application of integrated pest management:

* a limited number of pests to control;
* a low level of disease;
* a prevalence of monophagous key species;
* stability in harmful species and in the biological community throughout thousands of years of plant/pest co-evolution;
* a high host plant tolerance to pest damage (economic threshold);
* good plant capacity to recover from pest damage.

## CONTROL TECHNIQUES

While the prospects for changing the traditional techniques of chemical pest control in olive production look good, the implementation of new control techniques alternative to pesticides seems difficult (Cirio, 1990; Longo, 1992; Del Rio, 1985; Viggiani, 1989).

Alternative techniques - mainly biological and advanced chemical methods - include the use of entomopathogenic microorganisms (Bacillus thuringiensis against Prays oleae and Palpita unionalis, Nematodes for Zeuzera pyrina) and semiochemicals (sexual pheromones that create sexual confusion) in the fight against the olive fruit fly and the olive moth, the liberation of useful insects against black scale, the olive moth and the olive fruit fly, and the use of bait for massive capture of both of the latter.

As they are directly mainly against adult pests, the new techniques tend to be more effective as the population density of the insect decreases and the area to be protected increases.

The use of growth-inhibiting substances such as fenoxycarb (extremely effective even at doses of 10-15 g/hl) against Saissetia was recently prohibited in Italy by the Ministry of Health because of its very serious environmental impact and in particular it harmful effects on useful insects (neuropterons, coccinellids, etc.).

In many cases, traditional techniques such as pruning, working the soil, capturing adult insects and using traditional fungicides are being reassessed.

Of interest in weed control are experiments replacing chemical weed-killers with the cultivation of leguminous plants such as certain species of clover.

From a practical point of view, the control techniques used for each species can be summarized as follows:

Olive fruit fly:
a) preventive method, based on the use of poisoned protein bait; directed against adults, in relatively interior areas, on cultivars with late maturation, when the Bactrocera population is rather low and/or arrives late in the season;
b) therapeutic method, based on the use (up to the tolerance threshold) of water soluble cytotropic organic phosphorous insecticides, such as dimethoate and formothion.

c) agronomic method, based, whenever possible, on the early picking of the olives upon commercial maturation, which is known to be earlier than physiological maturation.

Olive moth:
a) chemical method, based on the use of phosphoric ethers such as triclorfon and dimethoate for control of the carpophagous population, normally limited to early cultivars that produce more than 20 kg/plant.

Black scale
a) agronomic method, involving regular pruning, balanced fertilization and irrigation;
b) chemical method, based on the use of organo-phosphorous insecticides and/or white oils, usually in July, when the average density is 2-5 individuals/leaf and 90 percent of these are immature forms.

Cycloconium oleaginum
a) chemical method, involves the application of copper-based products in spring before vegetative activity begins, possibly repeated in autumn, depending on the sensitivity of the cultivar and on climatic conditions;
b) agronomic method, pruning and other measures aimed at reducing the humidity and shade of the plant.
Table 2 gives a brief technical/economic assessment of each kind of control technique.

## THE IPM STRATEGY

The fact that IPM has not developed and spread more broadly in Italy cannot be attributed to a lack of information on the olive agroecosystem, in that considerable effort has been dedicated to research on the bioecology of pests, to experimentation on control biotechnologies and to disseminating information.

Therefore, other factors that were probably underestimated previously must be hindering its wider application. Strategies must be worked out to aid the implementation of IPM in the olive-producing sector in Italy.

One strategy that has achieved extremely positive results is the programme worked out by ENEA in the early eighties. It is substantially based on the idea that the farmer's level of experience or the degree of applicability of the technique conditions the effectiveness of integrated pest management (Table 3).

In the first stage, in which the experience level of the farmers is low, and they are generally reluctant to accept new criteria and methods of pest control, efforts are made to further the comprehension of IPM. This is pursued by means of demonstrative pilot projects, agricultural assistance and training courses to develop operative technical abilities.

The next stage, in which the experience level is satisfactory and the farmers have understood the technology, is based on adaptation and rationalization of IPM through standardization of methodologies such as monitoring, information, cost/benefit analysis, study of new projects.

The third or mature stage of the programme is aimed at large-scale application of IPM. Overall technical abilities have been developed and farmers are fully aware of the advantages offered by the technology, which has been assimilated by society.

It is obvious that the farmer's experience level and the operational complexity increase from the first to the third level.

## THE IPM PILOT PROJECT

Since 1980, ENEA's Department of Agrobiotechnologies has been engaged in a remarkable pilot project aimed at developing integrated pest control in olive production (Cirio, 1984; Cirio et al., 1985; Cirio et al., 1987; Cirio, 1992; Cirio et al., in press).

The territory of Canino (in the province of Viterbo) was chosen as the trial area. It has 4000 ha of olive groves with about 200,000 plants distributed over an area of 15,000 ha. The farmers association is strong and has 1200 members.

In this territory, as in many other areas where olives are grown in Italy, the problem of pest control was approached irrationally and on an individual basis. This led to the calendar planning of 5-7 chemical treatments per year, at an average cost of $120/ha in specialized olive groves.

The project - initially oriented toward developing a control strategy based on low consumption of pesticides and a high level of data processing - demanded thorough study of the territory. This was needed to qualify initial parameters, to define techniques and methodologies, and to confirm results and extend application.

The transformation from an individual to a collective approach to pest control was carried out by offering farmers in the area a technological/data service capable of:

* rapidly identifying the cause of pest damage using a video-disk called ENEA "Olea-finderpest";
* establishing a bioclimatic monitoring system for the main pests, setting up parameters for action against each species on the basis of either tolerance thresholds (Olive fruit fly) or the risk of damage (Olive moth);
* containing the cost of the pest control service within approximately $25/ha, or 0.2$/l of oil produced, a cost amply compensated by the reduction in the number of chemical treatments required and the enhanced quality of the product;
* setting up an entomology laboratory in Canino and providing a data/information service informing farmers in good time when and where to intervene to control harmful populations;
* guaranteeing speedy analysis for additional samples collected by farmers to determine olive pest infestation.

This new approach to pest control persuaded the farmers to abandon their traditional strategy of polluting and dangerous chemical control and to accept the cooperative strategy based on the forecast of probable damage in certain homogeneous olive-growing areas in the territory. After eight years of operation, project results were as follows:

* almost all local olive growers participated in the programme;
* the number of chemical treatments had been drastically cut back, with an 80 percent reduction in pesticide consumption;
* the savings in the cost of pest control was about 52 $/ha per year in specialized olive groves;
* natural pest enemies (parasites and predators) returned improving the agroecosystem's self-defence capacity against black scale;
* the value of the produce increased as a result of greater demand for the guaranteed high-quality oil;
* technical assistance improved;
* the technical capacity of the local oil press increased, leading to an expansion not only of its technological facilities, but also of its membership (300 new olive growers for a total of 1213 members).

ENEA, which coordinated the programme, was aided in its implemention by:

* the Oleificio Sociale di Canino (the local oil press), in the monitoring of harmful populations, sample analysis, management of video-disks and computer models;
* ERSAL (Lazio Agricultural Development Agency) in conducting experiments and providing technical assistance;
* Cooperative Energia e Territorio in the development of the control programme's computer models and in setting up the data bank.

## IPM IMPLEMENTATION

The positive results obtained by this pilot project made it possible to work out, in accordance with EC regulation 3868/87 et seq., 53 zonal projects for integrated control of Dacus. These projects are located in 12 Italian regions and cover a total area of approximately 270,000 ha of olive producing land.

The Ministry of Agriculture and Forestry (MAF), responsible for the implemention of EC regulations, has not only adopted the IPM methodology worked out by ENEA in Canino, but has also qualified this pilot area as a support for the training of technicians and R&D of control biotechnologies in all regional projects.

The structure and the organization of Italian olive production are extremely diversified, both at the individual farm and at the state organization levels. As a result, local situations must be studied in detail and projects supported by adequate information campaigns to assist olive growers in decision-making.

In order to rationalize this enormous effort, the MAF is coordinating a series of actions involving ENEA, AGRISIEL SpA (Agricultural computer services), CO.N.OL (National olive growers association) and some MAF experimental institutes.

In particular, ENEA's activity is focussed on providing technical and scientific assistance for the zonal projects and on setting up the national information network for olive growers.

Approximately 50 percent of the projects - for an area of over 100,000 ha - are already operative, the others are about to be launched. The strategy for implementation of IPM is proving valid, although organizational/management problems still persist about the use of EC funds.

Coordinating different operative structures, various technical and scientific abilities, and diverse olive-growing situations at the national and regional levels is indeed a complex and probably impossible task, but the effort is expected to bring about a real change in the approach to pest control.

## CONCLUSION

Although integrated pest control offers many advantages, there are still a number of problems hindering its widespread diffusion. Extensive implementation of IPM and the ecological criteria it involves calls for coordinated and inter-disciplinary action, the development of easily-to-use methodologies and specific techniques, the participation of the farming community and, of course, the prospect of economic returns.

The IPM strategy worked out by ENEA, based on the integrated control pilot project conducted in the Canino area, demonstrated that the involvement of the farmers and the small-scale use of information technologies at the local level were decisive not only in making the transition from individual to collective pest control effective, but also in integrating research, experimental application and technical assistance.

This approach to pest control increased farmers' profits by reducing by approximately 80 percent the quantity of chemical products used and by enhancing the value of the oil produced. This indirectly increased the property value of the olive groves in the area.

On the other hand, extending implementation of IPM must be undertaken with realism, reviewing the applicability of the economic injury threshold for certain species, using probabilistic rather than deterministic criteria, improving supporting structures, qualifying technical assistance and involving farmers.

Moreover, if IPM is not state-supported, it will be implemented only in the more advanced olive-growing areas that are structurally better organized. In these areas of real social and cultural growth, pest control techniques are considered an integral part of the agricultural process. This makes the planning of strategies for the spread of IPM all-important for the Italian olive-growing sector.

EC regulations and projects for the development and application of ecologically compatible biotechnologies for pest control represent an indispensible support in transforming the approach to the protection of this Mediterranean crop.

Commitment of the technical and scientific organizations directly involved, and also of the local associations of olive growers, is essential to success.

TABLE 1. Main characteristics of the most common pests of olive trees.

| MAIN FEATURES | OLIVE FRUIT FLY | OLIVE MOTH | BLACK SCALE |
|---|---|---|---|
| BIOLOGICAL | holometabolic | holometabolic | eterometabolic |
| | monophagous | oligophagous | polyphagous |
| | 3-5 generations | 3 generations | 1.5 generations |
| | good progeny production | good progeny production | high progeny production |
| | not diapousing | diapousing | diapousing |
| | high mobility | low mobility | low mobility |
| | fruit damage | leaves, flowers, fruit damage | leaves,branch damage |
| | main key mortality factors are density independent | main key mortality factors are density dependent | main key mortality factors are density dependent |
| | few natural enemies | many natural enemies | several natural enemies |
| ECONOMIC | low damage | high damage | high damage |
| | low threshold | high threshold | high threshold |

TABLE 2.Evaluation of some technical/economic parameters relative to main olive pest techniques.

| CONTROL TECHNIQUE | EFFECTIVENESS | COST | OPERATIONAL DIFFICULTIES | ENVIROMENTAL IMPACT |
|---|---|---|---|---|
| | | | | |
| **Olive fruit fly:** | | | | |
| *biological control (*Opius concolor*) | low | high | high | low |
| *massive capture | low | medium | medium | low |
| *poisoned protein bait | medium | low | low | low |
| *chemical control | high | low | low | high |
| **Olive moth:** | | | | |
| *biological control (*B. thuringiensis*) | medium | medium | low | low |
| *sexual confusion | low | high | high | low |
| *massive capture | low | high | medium | low |
| *chemical control | high | low | low | high |
| **Black scale:** | | | | |
| *agronomic control | high | medium | low | low |
| *chemical control | high | low | low | high |

TABLE 3. Stages in the application of IPM.

| | STAGE | EXPERIENCE/ COMPLEXITY LEVEL | CHARACTERISTICS |
|---|---|---|---|
| 1. | Understanding and assimilation of the tecnology | low | Farmers recognize the potential of the technology.<br><br>Pilot projects.<br><br>Training courses to develop technical abilities. |
| 2. | Adaptation and rationalization | medium | The technology is reasonably well understood.<br><br>Standard procedures are developed (monitoring, management).<br><br>Costs/benefits analysis.<br><br>Subsequent project are studied. |
| 3. | Maturity | high | Farmers gain technical know-how, achieve awareness of the technology's full potential, pest are brought under control.<br><br>The technology is correctly assimilated in society.<br><br>Widespread application. |

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## BIOCHEMICAL RESEARCH RELEVANT TO OLIVE OIL QUALITY AND IPM

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### ABSTRACT

The quality of an edible oil, such as that from olives, is dependent mainly on the composition of the fatty acids available for esterification and the substrate specificities of the acyltransferases involved. Factors which can affect olive oil quality, especially in relation to changed enzyme activity are described. In addition, the development of a tissue culture system for testing effects directly is detailed.

### INTRODUCTION

The biosynthetic pathway for the formation of triacylglycerols has been well studied in oilseeds (Stymne and Stobart, 1987). It takes place by the classic Kennedy pathway in which glycerol 3-phosphate is successively acylated at the sn-1 and sn-2 positions, the product phosphatidate (PA) is hydrolysed to diacylglycerol (DAG) and a final acylation yields triacylglycerol (TAG). During the biosynthetic process additional reactions can take place, especially those involving phosphatidylcholine which can equilibrate with the diacylglycerol pool through the activity of cholinephosphotransferase (see Stymne and Stobart, 1987).

In contrast, to the extensive information on edible oil production in seeds, little work has been done with oleaginous fruits such as avocado, palm and olive. This is despite the high commercial value of such crops. Part of the reason for this experimental neglect probably relates to the fact that fruits at the correct state of development (when all triacylglycerol biosynthetic enzymes are active) are not so readily available as are ripening seeds. Moreover, there are often problems in preparing active subcellular fractions and in making enzyme extracts because of the high amounts of polyphenols and tannins in the mesocarp of these fruits, particularly olives.

Olive oil is the major edible oil of countries of the Mediterranean Basin. World production in 1983 amounted to 2.16 million tonnes (Gunstone et al., 1986), two-thirds of which was produced in Southern Europe. The value of a vegetable oil is determined by the acyl composition of its triacylglycerol. Olive oil is characterised by very high amounts (70-75%) of oleate with palmitate (10-15%) as the next most abundant component. Smaller, but nutritional important, amounts of the essential fatty acid, linoleate, are also present. It is well proven that in plants lipid quality can be altered by various environmental factors (see Harwood, 1989), including pesticides (Harwood, 1991). Thus, in any study of pest attack, pesticide treatment or the implementation of IPM it is vital to assess any possible effects on edible oil quality (and quantity). Accordingly, we have been studying the biochemical characteristics of triacylglycerol formation in olives. Particular attention has been paid to factors which can regulate the quantity or quality of the final storage oil product. In addition we have developed test systems (utilising tissue cultures) which allow us to monitor lipid synthesis in olives all year round.

## METHODOLOGY

Olea europea cv. Picual fruits used in experiments were grown and harvested as described before (Sanchez et al., 1992a). Details of tissue slice (Sanchez et al., 1990), microsomal fractions (Sanchez et al., 1992a) and tissue cultures (Rutter et al., 1992b) were as previously described. Extracted lipids were separated by thin layer chromatography and acyl quality analysed by gas liquid chromatography. For incubation conditions with various radioactive precursors see Sanchez et al., 1990, 1992a, 1992b and Rutter et al., 1992a,b).

## DETERMINANTS OF OLIVE OIL QUALITY

The major component of olive oil is triacylglycerol and the composition of this fraction, therefore, largely determines olive oil quality. The acyl composition of the total oil may vary due to environmental conditions and also due to the particular olive variety grown. Some examples of variability are shown in Table 1.

The physical properties of an edible oil as well as its susceptibility to oxidation, enzymic degradation etc. are controlled by the individual molecular species of triacylglycerol (i.e. the exact combinations of fatty acids that are found). For a typical olive oil the molecular species pattern is dominated by three major components (POO, OOO and LOO). Some other details are shown in Table 2.

Clearly, any change in the metabolism leading to triacylglycerol accumulation is likely to affect the molecular species pattern and, hence, the quality of the olive oil. Examples of environmental parameters which can affect quality in different oil crops are temperature, agricultural practice and the use of pesticides. Therefore, we have been concerned to fully evaluate possible regulatory influences of olive triacylglycerol synthesis and accumulation.

**TABLE 1.** Variation in acyl composition for olive oils from different countries (from Gunstone et al., 1986 and *R. Aparicio and V. Alonso, personal communication).

| Country | Fatty acid (% total) | | | | | |
|---|---|---|---|---|---|---|
| | 16:0 | Other sats. | 18:1 | Other monoenes | 18:2 | 18:3 |
| Greece | 8-16 | 1-4 | 68-80 | - | 6-16 | - |
| Iran | 10.0 | 2.8 | 78.2 | 0.9 | 7.9 | 0.2 |
| Italy | 7-17 | 2-6 | 63-83 | tr.-4 | 5-14 | tr.-2 |
| Libya | 17.8 | 2.6 | 43.7 | 2.8 | 32.3 | 0.8 |
| Portugal | 12.1 | 3.1 | 75.3 | 1.5 | 6.1 | 1.0 |
| Spain | 6-17 | 1-4 | 65-85 | - | 3-18 | tr.-2 |
| Turkey | 11.1 | 3.4 | 74.1 | 0.9 | 9.4 | 0.2 |

**TABLE 2**. Molecular species distribution of olive oil triacylglycerols (from Gunstone et al., 1986).

No double bonds
0.1%
One double bond
4.5% (4.3% in configuration sat.0sat.)
Two double bonds
26.8% (26.0% as POO and StOO)
Three double bonds
47.3% (39.2% as OOO, 4.5% as sat.OL, 3.0% as sat.LO)
>Three double bonds
21.3% (13.7% as LOO, 4.6% as OLO)

Abbreviations: sat. = saturated; O = oleate; P = palmitate;
st. = stearate; L = linoleate.

## OIL SYNTHESIS DURING OLIVE FRUIT MATURATION

As a generalisation the accumulation of oil in a storage tissue occurs in three phases (Gurr, 1980). The first stage involves cell proliferation and in olives lasts until about 15 weeks after flowering (WAF) (Fig. 1). In the second period, rapid deposition of the storage material (e.g. triacylglycerol) takes place. This stage is also characterised by the appearance of unusual (storage organ specific) compounds if they are produced. The period is about 15-30 WAF in olive. The final stage involves desiccation in seeds or further maturation in other tissues. It continues from 30 WAF until harvesting (40-45 WAF) in olives. Essentially all lipid metabolism has ceased by this stage.

Consideration of the implications of the pattern in Fig. 1 means that it is firstly essential to choose tissues in the right stage of development for biochemical studies. Second, the influence that environmental parameters will have vary depending on which stage the olive fruits are at. Thus, temperature will have little effect on oil quality after 40 WAF while chemicals which affect cell division will be maximally effective up to 15 WAF.

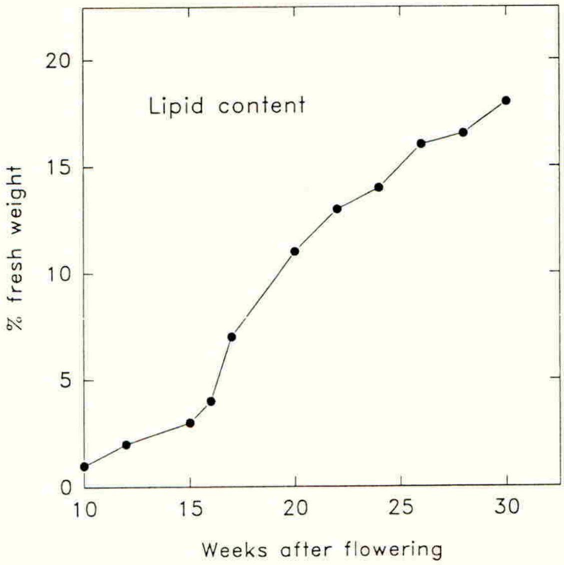


**FIGURE 1**. Lipid accumulation during olive maturation.

Table 3 illustrates the above points well and it will be seen that the ability of tissue preparations to synthesise triacylglycerols fits well with the in vivo data in Fig. 1.

**TABLE 3.** Ability of tissue slices from olives at different stages of maturation to synthesise lipids.

| Age of olive (WAF) | Total incorporation (nmol/h/g) | Distribution of label (%) Lipids | Other products |
|---|---|---|---|
| 8 | 8.0 | 21 | 79 |
| 16 | 18.5 | 20 | 80 |
| 19 | 21.1 | 35 | 65 |
| 26 | 65.0 | 60 | 40 |

Incorporation measured using $H^{14}CO_3$ precursor and 3h incubations (see del Cuvillo et al., 1992).

## FACTORS AFFECTING LIPID QUALITY

Based on previous work with higher plants, there are plentiful examples of how environmental factors including xenobiotics can alter lipid metabolism and, hence, lipid quality (see e.g. Harwood, 1984, 1989). These factors include natural phenomenon (e.g. temperature and light), pollutants where there can be limited control (e.g. ozone, $SO_2$) and chemicals which can be closely controlled (e.g. pesticides). At present we are evaluating the effect of these factors and their relative contribution to olive oil production and quality, bearing in mind the points made above the importance of olive development in determining susceptibility. From our results, several points can be made. First, olive fruits themselves are capable of fixing $CO_2$ (presumably by photosynthesis : note light-stimulation) and using photosynthate to generate triacylglycerol (Table 4). Other characteristics of this process conform with general aspects of 'fruit' photosynthesis (Blanke and Lenz, 1989). Second, not surprisingly in view of the above, the epicarp tissue is the most effective part of the fruit for de novo formation of oil. (On the other hand leaf photosynthate transported to fruits can be readily used to make fatty acids and storage oil as we have shown in independent experiments using different precursors). Third, although the pattern of lipid labelling is rather similar for mesocarp and epicarp (Table 4), these tissues make quite a different pattern of fatty acids (Sanchez et al., 1992b). This means also that the relative contributions of leaf to fruit photosynthate will influence the quality of triacylglycerol synthesised. In consequence, factors which alter one or the other contribution will likely affect lipid quality also.

## DEVELOPMENT OF A TISSUE CULTURE SYSTEM

We have been able to establish tissue cultures of olives (Rutter et al., 1992 a,b). These preparations have a number of advantages. First, they provide a year-round supply of tissue for experimentation. Second, the absence of a cuticular layer, with its attendant phenolic and other toxic compounds, makes preparation of active fractions much easier. Third, it is relatively easy to test individual parameters on tissue cultures with regard to possible effects on lipid synthesis. However, it is also necessary to evaluate tissue cultures carefully in order to ensure that they are an adequate model for the in vivo situation.

Figure 2 illustrates a typical time-course experiment showing the sequential accumulation of label in intermediates of the Kennedy pathway as radioactivity is incorporated from

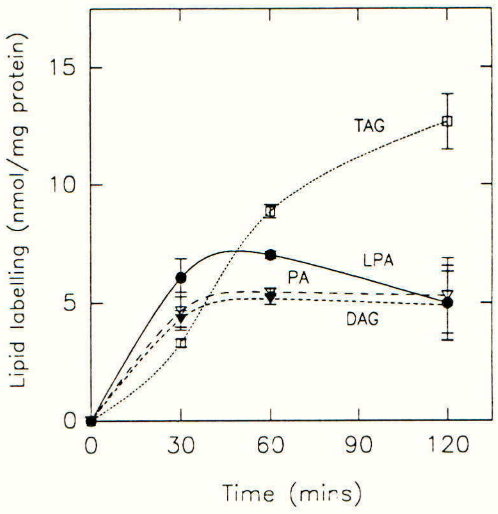


**FIGURE 2.** Time-course of labelling of Kennedy pathway intermediates by olive culture microsomes incubated with [$^{14}$C]glycerol 3-phosphate at 30$^{o}$C.

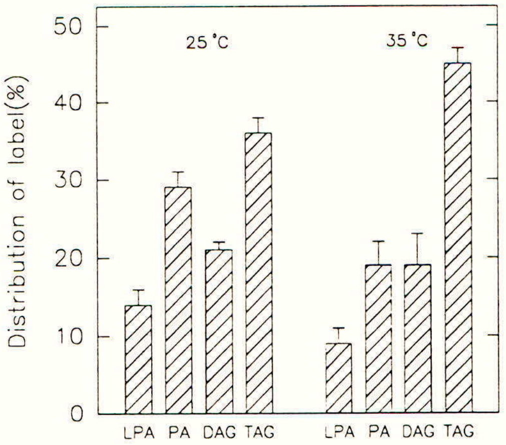


**FIGURE 3.** Influence of temperature on the pattern of lipid synthesis. Microsomes from olive cultures were incubated with [$^{14}$C]glycerol 3-phosphate.

**TABLE 4**. Labelling of lipids from $^{14}C$-bicarbonate in tissue slices from olive fruits: influence of tissue and light.

| Tissue | Light | Incorp. (nmol/h/g) | Distribution of label (%) TAG | DAG | Ptdcho | Others |
|---|---|---|---|---|---|---|
| Whole | + | 3.7 | 44 | 23 | 17 | 16 |
| | - | 0.1 | not determined | | | |
| Epicarp | + | 23.8 | 41 | 27 | 19 | 13 |
| | - | 0.2 | not determined | | | |
| Mesocarp | + | 0.5 | 40 | 17 | 19 | 24 |
| | - | 0.1 | not determined | | | |

See Sanchez et al., 1992b for full details.

[$^{14}$C]glycerol 3-phosphate into triacylglycerol. We have carefully evaluated other aspects of lipid synthesis and have found tissue cultures to mimick fruit tissue preparations in every detail. Thus, olive cultures seem to be a useful experimental system with which to understand the regulation of oil synthesis and to delineate factors affecting the process.

As an example of how cultures can be used to elucidate regulation we have examined temperature control of lipid synthesis. Figure 3 shows that growth temperature alters the balance of enzymes involved in lipid synthesis. This means that previous exposure of fruits to altered environmental temperatures will influence their subsequent ability to metabolise lipids. In addition, the actual environmental temperature at a given time has an effect also (Rutter et al., 1992a). This simple illustration shows how useful tissue cultures can be in unravelling the complexities of metabolic regulation.

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# THE ROLE OF INDUSTRY IN IPM SYSTEMS DEVELOPMENT

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## ABSTRACT

In this paper the two industrial partners in the ECLAIR 209 project, AgriSense BCS and Aragonesas, describe their roles in the project. Both companies fulfil an enabling role as well as being the main avenues for commercialisation for any new products or technologies which may arise from the project. Potential and actual problems which have been identified in the areas of conflicting objectives, project scope and regulatory issues are discussed.

## INTRODUCTION

There are two industrial companies who manufacture and market pest control products which are involved in the ECLAIR 209 project, namely, AgriSense BCS Ltd, based in South Wales, U.K., and Energia e Industrias Aragonesas, S.A., based in Madrid, Spain.

AgriSense BCS is a company which specialises in the development of biorational products for insect pest control. Its main area of interest is that of pheromones and other semiochemicals. AgriSense BCS was established initially as a joint venture with the University of Wales, Cardiff, another partner in ECLAIR 209, and has had the strategic intention since its formation in 1984 of being a key supplier of products for IPM in agriculture, forestry, public health and hygiene and stored products. Its early range of products consisted predominantly of traps and lures for insect pest monitoring, although in recent years it has also been developing pheromones for direct control of insect pests.

Aragonesas is one of the key agrochemical supply companies in the Spanish market with sales in 1991 equivalent to 5% of the Spanish pesticide market, placing it in seventh position that year. Aragonesas' strategic intent has been to become one of the leading suppliers of biorational-type products in the Spanish market. AgriSense BCS has been represented in Spain since 1984 by Aragonesas. Aragonesas and AgriSense together were the first to bring traps and lures for monitoring Olive Fly and Olive Moth into Spain. During these years of product introduction the two companies worked very closely with the entomologists based at Jaén, and Granada; Drs Montiel, Civantos, Campos and Ramos at these institutions actually tested the monitoring systems for the first time in commercial olive groves.

With this background of very successful collaboration in development and commercialisation of pheromone-based monitoring systems for insect pests of olives, it was decided that, in collaboration with other colleagues and institutions from Spain, the U.K., Italy and Greece, we would apply to the European Commission for financial support to develop IPM systems for the European Olive based on biorational products. In 1989 we were awarded the ECLAIR 209 grant which allowed the activities described in this symposium to be carried out; this paper described the role of the two above named industrial partners in the project.

## TECHNOLOGIES INVOLVED IN THE PROJECT

Several forms of biorational control technologies have been included in the project:

(i) pheromones and other semiochemicals,
(ii) microbial insecticides,
(iii) natural enemies - predatory and parasitic insects,
(iv) benign insecticides - eg. botanical insecticides.

The project aims to integrate some or all of these technologies in an integrated pest management package for olive pests in Europe.

## BASIC RESEARCH TO COMMERCIAL PRODUCT

Some of the basic research aspects of the project are aimed at isolating new pheromones and new microbial pesticides, and new ways of using conventional pesticides in a less contaminating way. Most of this work is being carried out by project partners based at academic institutions and at government research stations. The industrial partners in the project on the other hand have the responsibility for commercialising the products of these research activities both within the partner countries and in countries surrounding the Mediterranean basin where olives are grown.

As new pheromones are isolated and identified from olive pests which hitherto have not had their pheromones described, AgriSense BCS develops ways of synthesizing these pheromones on a large scale and also develops appropriate controlled release technology for the synthesized pheromones. AgriSense is also involved in developing new trap designs for use with these pheromones where the behaviour of the insect dictates that the designs already available are not suitable.

As these experimental systems are taken to the field for testing in Spain and other countries, Aragonesas helps the entomologists concerned through subsiding some of the product costs and in providing logistical support in supplying materials for field experiments. The two industrial partners also have a role in looking for products and technologies which are either on the market, or in development, both within and outside Europe, which could have a role in biorational olive pest management. In this way, Aragonesas, through its commercial links with the Danish fermentation company, Novo Nordisk, has been able to introduce a new formulation of the microbial insecticide *Bacillus thuringiensis* which is specially adapted for control of the Olive Moth. The results obtained to date have been very encouraging. Similarly, through AgriSense BCS's links with pyrethrum manufacturers and formulators, it has developed a micro-encapsulated formulation of the botanical insecticide pyrethrum which has proved very effective in controlling the Olive Moth.

The European Commission encourages industrial participation in research projects which it is financing, not only because the industrial partners contribute funds directly to the project, but also because they have an early input into the research activities which are being undertaken as part of the project. This assures that the commercial aspects of the research undertaken are not neglected and that commercialisation of new products and technologies is much easier and faster as a result of the industrialists' early involvement. Assured commercial exploitation in this way can only be of benefit to the partner countries and to the European Economic Community as a whole.

Since ownership and exploitation rights of any intellectual property which arises from the project is already agreed between the partners before the project starts and forms a part of the agreement which the partners sign at the start of the project, many problems which could arise in this area are avoided. To date this area has not been an issue in ECLAIR 209 and when the project draws to a close it will be interesting to see how many eventualities were foreseen and addressed in the original agreement as it related to IPR.

## PROBLEMS WHICH MAY BE ENCOUNTERED DURING THE COMMERCIAL DEVELOPMENT OF NEW BIORATIONAL PRODUCTS

### Conflicting objectives between partners.

Almost by definition it could be supposed that the industrialist and the academic researcher have conflicting objectives in any project where they are both engaged. The former would wish to see a saleable product emerge from the work which can be commercialised profitably at the end of the project. The researcher on the other hand gets recognition for his or her endeavours in terms of publications, higher degrees etc. and very little value has traditionally been placed on commercial successes which may arise from the researcher's efforts other than straight financial ones through royalties etc. The cynical industrialist may argue that industrial participation is required in a project simply so that the academics secure the grant from the awarding body which insists upon such participation. Fortunately such opinions are much less common these days, and academic researchers have become far more aware of the need to consider the industrial exploitation of the research they are carrying out.

It has been our experience in ECLAIR 209 that all the partners have been aware of the applied nature of the research project and that the need to transfer new technology to the farmer has been paramount. This view has not only been re-emphasised by the industrialists concerned but also by the field extension entomologists, the co-operatives and the provincial governments connected with the project. It would also be fair to say that as the project has proceeded the degree of focus on technology transfer and the need to resolve real practical problems in pest management in the field has intensified.

### Integration of technologies and the need for demonstration plots.

Any integrated pest management system involves several disciplines and technologies which have to be integrated into a management strategy which may have to be varied both with geographical location and during and between seasons. The sheer complexity of the ecosystem within which we are trying to operate is a significant barrier to developing such an IPM package for olives. The development of a computerised pest management model will however help in this process and should no doubt be our final objective. However, in the short term it will be important to tackle only certain components of this model at any one time and carry out field trials on a sufficiently large scale to be convincing to all the interested parties, otherwise we are in danger of losing the goodwill of the farmers and the political infrastructure supporting the project for the sake of developing the definitive, all encompassing model. The progress from conventional practices to fully integrated pest management should be gradual and step-wise over a number of years.

### Regulatory considerations

Semiochemicals by definition have a very narrow pest spectrum within which they are effective and as a result present problems to any company wishing to commercialise products based upon them.

Pesticides which are currently termed 'minor use' are already difficult to commercialise because of the large up-front investment which has to be made for a product with a very small market. Much of the up-front investment arises as a result of needing to develop a data package which satisfies various regulatory requirements around the world. If the standard pesticide regulatory requirements are used to register pheromone based products, which could be considered as extreme forms of 'minor use' products, then the costs of developing the products could be too high compared with their potential to generate sales in the niche markets where they are used. This problem has been highlighted before and has been the subject of a one day BCPC conference session in 1990 (Ridgway *et al.*, 1992). It was felt at that symposium and subsequently during meetings with regulatory bodies that mechanisms either exist already or could be developed whereby the registration of semiochemical based products can be adjusted to be consistent with the potential risk associated with their use and rate and method of application. Such flexibility is essential if the commercialisation of such high specificity, niche products is to be successfully carried out and our experience in the ECLAIR 209 project has confirmed that this is an important requirement.

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# SCIENTIFIC PROGRAMME MANAGEMENT IN COLLABORATIVE RESEARCH

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## ABSTRACT

There is an increasing demand by funding agencies for collaborative, well managed research programmes. The need for collaboration and research management in integrated pest management research programmes is considered with reference to the EC funded programme on the 'Development of Environmentally Safe Pest Control Systems of European Olives'. This programme of research is considered in relation to general principles on strategies for control and research in IPM, management and organisation of research and perception and goals of scientists. The need for training in research management is also considered. The final section provides a number of recommendations for IPM research based on experience gained in the olive IPM programme.

## INTRODUCTION

There is an increasing demand in Europe for collaborative research programmes that are well managed and thus able to make more effective use of available resources. Collaborative programmes aim to integrate the research skills from relevant experts, whilst the increasing requirement for proof of appropriate managerial skills stresses the need for well organised research programmes that are capable of meeting specified targets on time. And if research funding is to be utilised effectively then these requirements are appropriate. However, the requirement for collaborative and well managed research programmes does create some difficulties that are not always evident in non-collaborative programmes. This paper aims to identify some of these with particular reference to Integrated Pest Management (IPM) and specifically to the EC ECLAIR 209 research programme 'The Development of Environmentally Safe Pest Control Systems for European Olives'. In the process of doing this consideration will be given to some of the problems that have been encountered, the mistakes that have been made and what generally has been learned from the experience, and on the basis of these what recommendations would be made for the organisation and management of other IPM programmes.

In the first instance, it is necessary to establish why it is that IPM represents a good case for collaborative research and why there is a need in this area for research management.

## IPM: A NEED FOR COLLABORATION AND RESEARCH MANAGEMENT

There are various definitions of IPM available, each emphasising aspects most relevant to particular authors and their own interests. For the purposes of this paper, IPM will be taken to mean; a pest management strategy that in the socio-economic context of farming systems, the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible, and maintains the pest population levels below those causing economic injury (Dent, 1991). This definition has in common with many others a statement about combining control measures to optimise control, the need for environmentally friendly measures and maintenance of pest populations below economic threshold levels. Other definitions may emphasise sustainability, a systems approach or economics. What is clear and accepted by most is that IPM represents a philosophy rather than a control technique *per se*. Each IPM programme will be different and specific to a particular cropping/pest system, although IPM programmes may have in common the use of various control measures that may include hostplant resistance, use of natural enemies, cultural control, interference methods and pesticides.

Each of these control measures will have their advocates and scientists that specialise in their development and implementation. There is a tendency for scientists to specialize, so that often a scientist will have experience and interest in only one of the individual control measures that can contribute to an IPM programme. Although superficially scientists advocate the integration of control measures to produce an IPM programme, 'most remain *ad hoc* efforts by these individual pest control specialists, each developing so called integrated pest management programmes independently of one another' (Pimental, 1985).

There is no denying IPM research requires scientists specializing in the development of particular control measures but it also requires that such scientists work in collaboration in order to integrate the control measures to produce an integrated pest management programme. Research management is the means by which the collaboration is maintained and directed. Integration of research, to develop complete IPM programmes, requires both research collaboration and research management. However, for this collaboration and integration of research to take place there is a need for funding at a more holistic level. You cannot carry out research between different scientists, different institutes and different countries unless sufficient resources are available to cover the extra costs of collaboration. In pest management, in particular, there needs to be a move away from funding of individual research projects on specific pests and specific control measures to a more systems orientated approach that looks to develop complete IPM programmes, in a particular cropping/farming system for a whole range of key pests and utilising a variety of control measures. Only at this level will the integration of research necessary to develop complete IPM systems be achieved. This is one of the things that makes the ECLAIR 209 programme so special; it is an example of what can be achieved if such a systems approach is undertaken, and when sufficient resources are available to develop a 'complete' IPM programme utilizing expertise from different disciplines and different countries. This is not to say that the programme is a perfect example of how such work should be undertaken but it does provide an illustration of some of the advantages of the approach.

## A STRATEGY FOR CONTROL AND FOR RESEARCH

As a general ideal principle any IPM strategy should combine a number of components; (i) utilization of more than one control measure per pest, (ii) use of both prophylactic and responsive measures (where prophylactic control is any action that is taken without evaluating whether or not it will produce an economic gain and responsive control is any action taken after an evaluation of the potential economic gain of that action ie. control occurs in response to current pest status (Vandermeer & Andow, 1986)), (iii) a balanced use of both products and techniques (where a product is a thing or substance (which may be living organisms, chemicals, plant material) that is usually manufactured, produced, formulated or packaged for the purpose of sale and a technique is a form of procedure, skill or method that may be utilized by the farmer from available on-farm resources (Dent, in press), (iv) provide cost effective control, (v) use of environmentally friendly methods, (vi) utilisation of available natural mortality factors. While these components provide an idealised scheme for a control strategy for IPM, in reality decisions about each component are often more pragmatic and affected by historical influences and previous experience than they are by theoretical principles.

Pragmatic decisions are often made concerning the relative mix of control measures on the basis of availability of expertise within participating institutes, rather than a pre-defined requirement for specific types of control measure. The choice of control measures may also be based on precedent, on the basis of what has been tried before in similar situations or circumstances. Rarely is any new programme considered in isolation from work that has been previously carried out, and this work inevitably has a greater influence over the direction such programmes take rather than recourse to basic principles and theory. There is no serious disadvantage with this approach unless there is a tendency to continue with research into a control measures well after it should have been abandoned; work continuing in the hope that just one more season's work will prove the techniques real worth!

In the ECLAIR 209 programme, previous research on certain techniques and the availability of expertise has certainly influenced the choice of control measures that are being evaluated, but luckily the partners involved in the programme have the expertise required for a fairly balanced mix of control options. The programme has both responsive measures eg. *Bacillus thuringiensis* and prophylactic measures eg. natural enemies, and pheromone control measures that can be used as either. If anything however, there is a bias towards use of products, with techniques playing only a minor role in natural enemy conservation. There has also up to this point in time been too little consideration given to the economic aspects of control and insufficient attention paid to the socio-economic constraints of implementation. This latter aspect is a reflection of difficulties experienced in closely defining our final goals. The final goal of the programme is to produce an IPM programme and while in principle this is simply stated, in practice it is very difficult to define in any detail. This is largely because it is not possible to predict just how successful each control measure is going to be during the course of its development. It has been necessary for the programme to reconsider direction on a number of aspects of our work because potentially viable control measures were not producing the expected effects. Hence, it is only recently that we have been able to consider the options available and even then it has been necessary to develop three different strategies, reflecting the differing potential levels of success of the research.

## MANAGEMENT AND ORGANISATION

Rossini *et al* (1978) identified four processes that are used to achieve integration of research (i) common group learning, (ii) negotiation among experts, (iii) modelling and (iv) integration by leader. These represent idealized, mutually exclusive frameworks which in practice rarely exist.

Common group learning is a group exercise approach to defining problems and their boundaries. Each team member carries out mutually agreed, allotted tasks. When the results of the work are available, they are commented on by the group and a report is written by a non-specialist. The final report is then the common intellectual property of the group (Swanson, 1979).

Negotiation among experts differs from the group learning in that there is much greater emphasis on the role of the individual experts within each discipline. Each expert is allocated a problem and they bring the full power of their discipline to bear on this after which the group discusses the results, focussing on the overlaps and links between the different components. After these negotiations the individual experts write the report of their work, bearing in mind any comments they have received - but no common report by a non-expert is written in this case.

It is interesting that the Commission of the EC require the programme to produce a consolidated annual progress report that requires both a technical overview (written as a technical overview and synthesis of progress by a non expert) and detailed technical reports on the work carried out by each partner (written by each expert). Hence, editorial and reporting devices are being used here to ensure work is integrated in an appropriate form.

The modelling approach provides a definite focus for participation and tends to depersonalize any confrontation in favour of forcing individuals to meet the information demands of the model. Not all of the team need participate in the model construction but certainly all should agree on its form and should contribute data. Models provide a team with a shared paradigm especially where used at a conceptual level (Dent, 1991)

With the integration by leader approach as defined by Rossini *et al* (1978) and Swanson (1979), the leader functions as the sole integrator and interacts with each member, but members do not interact between themselves. This would mean that the success or failure of a project is totally dependent on the skills of the leader. Excessive demands placed on a leader in a larger group would make this approach impractical, but it is certainly feasible for smaller research teams.

Research programmes rarely deliberately select in advance the intellectual and social components that determine the particular socio-cognitive framework for their collaborative programme, more often organisation evolves into a stable pattern by trial and error (Swanson, 1979). This latter approach certainly occured with the ECLAIR programme; although it was recognised that the modelling should play an important role as a management tool, it was not brought to bear in this context until too late a date, by which time everyone had clearly established their roles in the programme. Had our initial meetings been used to construct a conceptual model of the programme and identified the role of each project and the contribution it was to make to the overall objectives then the initial definition, 'settling in' phase of the team may have been achieved with greater ease. Such a process may also have helped with defining the form of the initial IPM package, or at least helped to identify some of the difficulties that were going to be encountered in this, at an earlier date. However, the programme used a mixture of group learning and negotiation among experts to allocate and discuss research tasks which were then coordinated by Cardiff. However, the leadership provided by Cardiff was not of the form envisaged by Rossini *et al* (1978) where the leader functioned as the sole integrator but rather groups interacted with each other and the coordinator as the need arose. And this process has continued with an increasing frequency of informal, but productive meetings between relevant groups of scientists as the need to deal and solve particular problems arises.

At the annual technical meeting the various project managers, and as many other staff as resources permit, meet to review the year's progress in each aspect of the programme. Work is presented and its implications discussed. Scientists then break-up into smaller groups (roughly organised along specialist disciplines) and on the basis of what has been achieved decide on the research programme for the following year. Each group produces a schedule of operations, defining what work will be carried out and the deadline for its completion (Fig.1). These are then discussed and agreed by the whole programme. Whenever groups meet they review the work targets set in these schedules. The schedules provide the means by which the coordinator can keep track of the work being carried out and whether targets are being met as time progresses. This process of a single large annual meeting, where work is assessed and discussed combined with smaller more informal meetings, at that time and throughout the intervening period, where experiments can be considered in detail, has proved invaluable. There is a recognised need among colleagues to meet as often as possible, the limitations on the frequency being more financial than scientific.

## PERCEPTION AND GOALS

Collaborative research will often require scientists from different disciplines to work together to achieve a common goal. Such multidisciplinary research brings with it a host of difficulties that most often arise from differences in perceptions of scientists from different disciplines. A person's perception of any event will be influenced by their previous experience and hence everything will be interpreted in the light of this accumulated knowledge and 'wisdom'. Scientists that are trained in one discipline will have a framework of knowledge and understanding that relates to that discipline and hence may perceive things differently from a scientist trained in another, having a different framework of

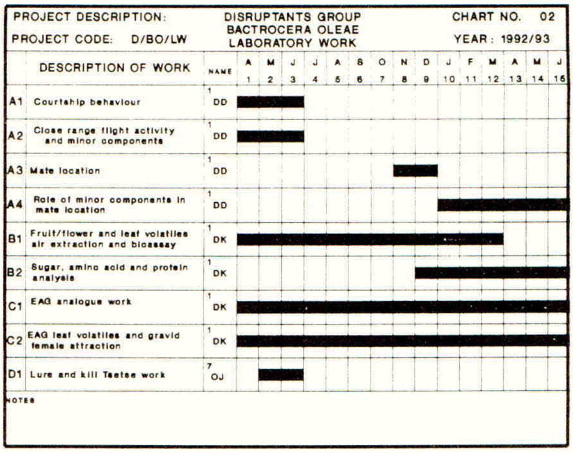


**Fig.1** An example of a Gantt chart defining research tasks and target dates.

knowledge etc. Disciplines each have their different modes of enquiry, specific key terms and vocabulary, standards of proof, basic concepts, observational categories, techniques (Petrie, 1976) and without some recognition of this, then misunderstandings may develop that can affect the working relationship of the collaborating scientists. For instance in Fig.2 you may see a rabbit or a duck.

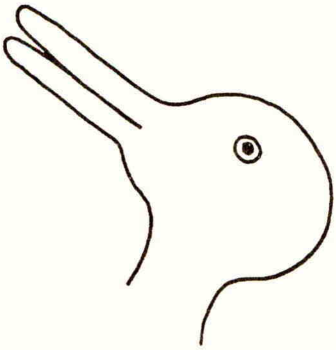

**Fig.2** A question of perception; is this a rabbit or a duck, or both?

What would happen if your discipline allowed you to see a duck while anothers discipline allowed them to see a rabbit and you did not <u>realise</u> the difference! Recognizing that such differences in perception are real is one of the first points that scientists working on collaborative research programmes need to appreciate, but sorting out how to minimize the differences is another matter. In the ECLAIR 209 programme there are scientists involved from a number of different disciplines (Table 1).

**Table 1**. Scientific disciplines represented in the ECLAIR 209 programme

| |
|---|
| BIOCHEMISTRY |
| BIOLOGICAL CONTROL |
| CHEMISTRY |
| MICROBIOLOGY |
| MODELLING & SYSTEMS ANALYSIS |
| PHEROMONE ENTOMOLOGY |

While certain groups had little problem understanding the detail and significance of each others' science eg. the biochemists and the chemists, others were less fortunate. It takes time to listen, to grasp and understand the arguments put forward by a scientist from another discipline, because they are using terms with which you are unfamiliar, and because there are so many basic concepts and principles that they take for granted that you don't even know - and you need to know to understand the significance of what is said. Over a number of meetings, the terms and ideas have become familiar and it is now possible for more of us to participate in multidisciplinary discussions - but it has taken a couple of years for that point to be reached. With hindsight, it would have been a good idea to have asked each discipline to have produced a simple glossary of key terms and a short compendium of basic concepts that could have been used in the initial stages of the programme to facilitate communication.

Communication has of course been another important element within this multinational programme, with four different languages being spoken. However, this has been less of a problem than might be thought, mainly because our continental partners have been kind enough to learn or use the language of the programme, English.

In any multidisciplinary, multinational programmes there are a number of other accepted potential barriers to collaboration eg. personalities, relative experience, but it is the institutional barriers to communication that deserve further explanation.

The institutional barriers to collaboration are those associated with the various goals and objectives that scientists/collaborators working in the different organisations may have. Scientists working in universities, want and need to publish papers, and to have students carry out and completing Ph.D.'s. Scientists in government research institutes want tangible results to present to the farmers, the general public and to politicians, while our collaborators in industry want to see development of marketable products for manufacture and sale. Of course all these are laudable objectives and everyone needs to be given the opportunity to satisfy their own goals. The 'trick' in research management, as in management in business, is to attempt to integrate these personal goals with the overall programme goals. To achieve this requires somewhat of a balancing act but during the course of our programme there have been scientists who have been asked to abandon aspects of their work because it was unlikely to yield results of practical value while encouragement has been provided to others to develop new approaches which, although somewhat innovative could potentially provide outstanding benefits. The magnanimity accompanying such changes of direction and emphasis has been possible because the individual members of the programme appreciate the overall need to ensure the programme achieves its objective of developing an IPM programme. To a large extent the objectives of individuals are being met by the objectives of the programme. This is helped by the fact that the criteria used by the CEC to evaluate the success of a programme have been well chosen to match the goals of the different types of partner. The CEC require that we publish scientific papers, that any IPR generated by the programme is fully exploited and that by suitable monitoring of our programme we are encouraged to meet our target of developing a practical working IPM programme.

The perception and goals of the individuals contributing to a collaborative research programme must be taken into account if collaborative effort is to be fully realised. It is not easy to develop collaborative programmes across disciplines! To do so requires a commitment to a common aim and the development of trust between individuals that can only develop with time. Barfield *et al* (1987) writing about a collaborative programme said 'Even though we shared a common philosophy and much of the altruistic attitude from the onset, it took our team some two full years to really learn how to cooperate effectively'. It has taken the ECLAIR programme a similar length of time but the benefits of the effort are now becoming clear to all involved in the programme.

## TRAINING

Collaborative research requires scientists with a sufficient breadth of interest and knowledge and necessary management skills at their head, to enable them to run the programmes effectively. However, there are too few scientists with these abilities and attributes. Science is taught at increasing levels of specialisation as a student progresses through the education system which ultimately leads to research specialisation and a Ph.D. From then on there is often some broadening of interests, but if you are in pheromones, you stay in pheromones, if you are a specialist in biological control you remain a specialist in biological control. There are too few opportunities for positions in pest management research, it is almost always some specialist aspect of pest management. On top of this, how many scientists have training in management? There is this expectation that scientists will acquire such abilities as they progress through their career - and yet in business people are expected to obtain degrees or higher degrees in the subject! If the need for collaborative research is recognised as a definite priority then the concomitant requirement for training of scientists as managers is also needed. Collaborative research will not function effectively without it!

## CONCLUSIONS AND RECOMMENDATIONS

Collaborative research is a growing requirement of funding agencies. IPM research is a good example of the type of programme that can benefit from collaborative work since it involves multidisciplinary teams and the final objective requires an integration of the results to produce a working system. Under such conditions there is a need for research management to promote the collaboration and to direct the integration of the work. This will be best achieved through more attention being paid to defining a strategy for control, and the use of conceptual models during the initial stages of the programme. In this way the team members will from the outset share a common paradigm. Efforts should also be made at these early stages to promote communication between disciplines through use of glossaries of key terms and compendia of basic concepts. Meeting as often as possible during these initial stages also facilitates ease of communication since the team gets to know and trust one another more quickly. A more definite approach to selection of the form of socio-cognitive framework to be utilised by the programme should be made by the management team to ensure that every opportunity is given to integrating activities in the most appropriate form for their particular work.

The long term success of collaborative research will be dependent to a large extent on the availability of scientists having the necessary management skills. To facilitate this there will need to be a commitment made to training scientists in relevant aspects of management, without which each new management team will be faced with a long learning curve which is inefficient and wasteful of resources and time.

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# THE INFLUENCE OF THE PROJECT ECLAIR 209 ON THE DEVELOPMENT OF THE NEW OLIVECULTURE

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## Introduction

During the 1970's, an intense technological revolution in the cultivation of the olive tree occurred in Spain - and in all the Mediterranean Region -, establishing the technical and scientific bases of what is called the New Oliveculture, that - with full social and economic approval - has continued to the present day.

A result of the advances achieved at that time on fertilisation systems, soil management, pruning, harvesting and control of pests and diseases, is the design of a productive system for the olive grove, whose environmental influence could be summarised as follows:

**TABLE I.** Influence of productive factors on the environment in the olive ecosystem

| FACTOR | % Production costs (*) | Environmental influence |
|---|---|---|
| Labour | 20 | MEDIUM. Depending on zone topography. Erosion. |
| Fertilisation | 10 | LIGHT-MEDIUM. Possible contamination by residues. |
| Chemical control of pests and diseases. | 11 | SEVERE. Contamination by residues. Development of resistance in insects. Elimination of auxiliary fauna. Appearance of secondary pests. Risks for users health. |
| Chemical control of weeds | 7 | SEVERE. Contamination by residues. Resistance in spontaneous flora. Risks for users health. |
| Pruning | 12 | NONE |
| Harvesting | 40 | NONE |

(*) Cost of the production factors = 124,648 Pts/Ha.

It is clear from Table I that the present technology for pest, disease and weed control, based on the use of synthetic organic pesticides, is what causes a major environmental impact in the olive ecosystem.

This technology is very effective, and its use has provided great benefits. However an irrational and abusive use of it, unfortunately very frequent, is causing serious damage to the olive tree, such as the development of resistance in pest-insects that require ever increasing doses of insecticide for control; the elimination of the natural enemy complex, that results in the appearance of new insect pests, considered to date as secondaries; the environmental contamination and the presence of residues that endanger the health of users and consumers.

To have an idea - in absolute terms - of what the control of pests, diseases and weeds represents on an economic level in our country - and the situation is similar in other olive producing countries - the volume of pesticides consumed in the olive groves during 1990 has been estimated, as well as the total cost of product acquisition and application:

**TABLE II.** Consumption of pesticides in Spanish olive groves. 1990.[1]

| Type of pesticide | Consumption M. Pts | Tm. | Application Cost M.Pts. | Total Cost M.Pts. |
|---|---|---|---|---|
| Insecticides | 947 | 1,894 | 4,762 | 5,709 |
| Fungicides | 1,500 | 3,750 | - | 1,500[2] |
| Weed-killers | 1,320 | 2,933 | 3,402 | 4,722 |
| TOTAL | 3,767 | 8,577 | 8,164 | 11,931 |

(1) AEPLA data and complementary information of businesses from the Agrochemical sector.

(2) Costs of pesticide application included.

It has been calculated that these treatments are carried out in more than 900,000 Has. of olive grove.

To summarise the previous figure (Table II), in our country we spend annually about 12,000 million pesetas on treatments for the control of pests, which represents 8.7% of the mean value of the net production of the olive grove, which amounts approximately to 136,500 million pesetas, not including the production subsidies.

Although the losses causes to the crops by insect pests, fungi and weeds are not known accurately, some authors have evaluated them as 30% of production. This would mean for Spain annual losses valued around 20,000 million pesetas, that in great measure can still occur, despite the annual expenditure carried out by the olive growers to combat pests.

**Sustainable agriculture as a frame for the new oliveculture**

If the 1970's defined scientifically and technically an oliveculture of a "productive" type, at the end of the 1980's a new concept of agriculture and as a consequence oliveculture too, appeared that is economically viable, commercially competitive, socially desirable and ecologically acceptable. It is a new agriculture - and oliveculture - that is described as "sustainable" to underline its capacity to maintain and perpetuate itself as the agriculture of the future.

Of the different definitions given for "Sustainable Agriculture", we chose that used by the American Agronomical Society: "sustainable agriculture is agriculture that in the long term improves the quality of the crop and of the basic resources on which it depends; it gives the food and fibre necessary for humanity; it is economically viable; it improves the quality of life for the farmer and for society as a whole".

In reality, the goal of "Sustainable Agriculture" is to abandon the criteria of maximum production/hectare, improving the productivity of exploitation by means of a better management of the productive factors.

The conversion of the actual oliveculture into one of a "Sustainable" type has to be carried out in a progressive and rational manner, modifying the technologies that generate an environmental risk or the excessive and inadequate use of productive inputs. Standing out from these, due to their greater aggressiveness, are the actual techniques for the protection of the crops, that can be immediately substituted by other available - technologies that are perfectly valid from the economic point of view as well as the environmental one.

## The Project ECLAIR 209 in the new oliveculture

The Project "Development of systems of environmentally safe pest control for European olives", which we refer to as Project ECLAIR 209, is a project of international research, subsidised by the E.E.C., in the framework of the community program ECLAIR, that seeks to link agriculture and industry through research.

This project has as its main objective the development of an integrated olive pest management system, able to reconcile the protection of the environment with the productivity of the European olive groves.

In the previous papers, the functional structure of the Project and the different areas of investigation in which work has been carried out have been sufficiently explained. We will not go into this here because it would be too extensive, given the large number of participant institutions (11) and of activities carried out during the first two years of execution of the Project (1990 and 1991). It is enough to mention that the Ministry of Agriculture and Fisheries of the Junta de Andalucía alone has developed, during this period of time, more than 48 different projects, distributed in the four areas of research in which the Project is structured.

I will restrict myself to present - very briefly - some of these projects which have already given acceptable results, and can be taken up by the olive growers with cost and efficiency levels that make them competitive with the conventional systems of pest control.

These methods and techniques have been developed for the two more important pests of the olive tree, that consume practically all the treatment costs incurred by the olive growers:

PRAYS OLEAE (The Olive Moth).

* Microbial technology and natural insecticides

\- B. thuringiensis, var. Kurstaki. Application techniques U.L.V. aerial and ground based. Dosage of 1 litre/Ha. (11,8 millions V.I./gr) per hectare. Competitive in efficiency and cost with conventional chemical treatments.

\- Natural Pyrethrum, (Crisantemun cinerariaefolium). Ground application techniques. Very reduced dosage (0.1%) up to 20 times inferior to the recommended one. Competitive in cost and efficiency with conventional chemical treatments.

* Semio-chemicals.

\- Monitoring. Different types of food traps with 1 mg. of Z-7- Tetradecenal. Very selective. Detect the insect populations in advance. Allow an assessment of the necessity of treatment and give a notable reduction in the use of pesticides (> 50%).

DACUS OLEAE (The Olive Fly)

* Microbial Technology and natural insecticides.

- Natural Pyrethrum (Chrisantemun cinerariaefolium). Techniques of food lure traps, ground and aerial. Dosage of 250 c.c./Ha. Efficiency inferior to that obtained with the conventional pesticides. Recommended in areas of ecological production.

* Semio chemicals

- Monitoring. Different types of traps and food and sexual lures. Long term formulations (80 mgs. Spiroketal) make the use of this system very economic. Detect insect populations. Allow a decision on the necessity of treatment and result in a notable reduction of the use of pesticides (> 50%).

- Lure and Kill Treatments. Micro encapsulated formulations of Spiroketal (20 grs/litre) are used as very selective attractants. Combined with pesticides chemically synthesised or of natural origin, they allow the use of lure-treatments, alternative to the conventional treatments.

- Aerial lure and kill treatments with chemically synthesised pesticides.
Similar technique to the conventional aerial lure-treatments. Treatment of 25% of the surface, with dosages of 2 grs. Spiroketal and 500 c.c. insecticide per treated hectare. Efficiency similar to conventional treatments, but more selective. Highly recommended in olive groves included in zones of special environmental protection.

- Aerial lure and kill treatments with natural pesticides. Technique similar to the previous one. Natural pyrethrum used instead of the conventional pesticides, with dosages of 250 cc/Ha. Efficiency inferior to the conventional treatments. Recommended in zones of ecological production.

- Ground lure and kill treatments with chemically synthesised pesticides. A minimum part of each tree is treated. Notable reduction (95%) of the expenditure in pesticides, that are used in a dosage of 25-5 c.c./Ha. High efficiency and economy of treatments. Competitive with the conventional treatments. In the case of ecological production the treatment can be applied locally to the upper part of the tree trunk only.

- Mass-trapping. Wooden traps, impregnated with Deltamethrin lure with 70 grs. of ammonium carbonate, and with 80 mgs of Spiroketal (only in 30% of the traps), are used in densities of 100 traps/Ha. Lower efficiency than the lure and kill treatment, although its use can be recommended in regions of ecological production.

These have been, very briefly, the technological innovations that our project ECLAIR 209 has developed for oliveculture. The rate of achievement of results in these first two years allows hope that at the completion of the project in 1994 a large number of the initial objectives will have been accomplished. This will contribute to the realisation of a new concept of oliveculture, in which an adequate system of integrated pest management (IPM) is used by the olive growers, without risk for their health or the environment, with reasonable economic costs.