Use of pheromones and other semiochemicals in integrated production
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Alternative methods for controlling the olive fly, *Bactrocera oleae*, involving semiochemicals

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Abstract: The use of semiochemicals, both sex pheromones and food attractants, in monitoring the olive fly, *Bactrocera oleae,* has become well established in most olive-growing countries of the Mediterranean basin. There is an ever-increasing degree of sophistication that is being introduced in the way trap catch data are collected and interpreted, making for a substantially more rational use of conventional insecticides.

The introduction of semiochemical-based products as control methods in IPM packages for *B.oleae* has been very successfully accomplished on a pilot scale in a number of olive growing countries. These pilot scale trials are now being extended into area-wide programmes in Spain, Italy and Greece and will, in due course, be extended to the whole of the Mediterranean basin.

Key words: sex pheromones, food attractants, monitoring, control, mass trapping, lure and kill, olive fly

Introduction

The olive tree is regarded as being of significant socio-economic importance in the Mediterranean basin which has 98% of the world's cultivated olive trees. These trees number about 800 million and occupy a surface area of approximately 10 million hectares. They produce about 1.6 million metric tonnes per annum of olive oil, in addition to 750,000 metric tonnes of table olives - about 9% of the area's production of olives.

The losses, cause in this crop by insect pests, fungi and weeds, have been quoted by some authors to be as high as 30% of production. It is reasonable to estimate therefore that the damage caused to harvested fruits by insect pests to be at least 15% of production, which equates to 800 million US dollars per annum. This comes despite the fact that olive growers spend annually more than 100 million US dollars combating these pests and of which 50% corresponds to pesticides.

The predominant method of insect pest control has been through the use of conventional pesticides. They have been very effectively used over the last forty years and have ensured yields and benefits to the olive growers. The continued use of such products has however been questioned in recent years especially by environmentalists. Residues of pesticides have been detected in olive oil and in the environment where olives are grown.

This has caused concern in most olive growing countries and has lead to a concerted effort to reduce the amount of pesticides that is being used to control pests in olive groves. As in many other agricultural crops, the concept of Integrated Pest Management (IPM) has also been developed in the olive growing industry as a means of rationalising the use of pesticides. IPM has been defined by the International Organisation of Biological Control (IOBC) as “a pest management strategy employing all methods consistent with economic, ecological and toxicological requirements to maintain pests below economic threshold while giving priority to natural limiting factors”. IPM systems are now widely accepted as the best strategies for sustainable crop protection.

Technologies and techniques which have found a useful role in IPM strategies include; the use of resistant plants varieties, cultural practices, the use of predators and parasites, microbial pesticides (entomopathogenic bacteria, viruses and fungi), botanical insecticides, insect growth regulators and semiochemicals. Many of these have been researched as constituents of an IPM strategy for olive pests. However, for the purposes of this paper, only the role of semiochemicals in the monitoring and control of *B. oleae* will be discussed.

The use of semiochemicals in olive fly management

Semiochemicals are defined as ‘substances which transmit messages between living organisms, both plant and animals’ (Law and Regnier, 1971). Semiochemicals which areemitted by an individual and produce a response in another individual of the same species are referred to as pheromones (Karlson & Luscher,1959). Pheromones can be classified interms of the response which they produce (Shorey, 1977) e.g., aggregation pheromones, alarm pheromones, recognition pheromones and sex pheromones.

In the case of the olive fly it has long been known that the species uses a sex pheromone as part of its mating behaviour. A sex pheromone released by virgin females attracts male *B.oleae* (Haniotakis, 1974); Haniotakis *et al.*, 1977). The principal component of this sex pheromone was identified in late 1979 as 1,7-dioxaspiro [5.5] undecane (Baker *et al.* 1980). Other components were identified from the sex pheromone by various authors but none were found in subsequent field trapping experiments to be critical in attracting male *B.oleae* to traps. It has also been shown that during periods without reproductive activity in early summer, male *B.oleae* can also produce measurable quantities of the spiroacetal major component described above and the authors concerned think that it could act as an aggregation signal during such times to bring others of the same species to food sources (Mazomenos and Pomonis, 1983).

In a pest management context, however, it is the practical use of these substances, which is of interest, and their use to date can be divided into two main categories, pest monitoring and pest control.

Monitoring of *Bactrocera oleae*

In order to monitor insect populations adequately, it is important to have systems, which record both biological and climatic data. These data need to be collected in real time and give us information about both adult and larval stages. The use of such information is only valid if it is incorporated into pest management models, which in turn allow us to foresee and prevent damage to the crop. In the case of *B.oleae*, monitoring of adults in traps and observations of larval stages in fruit samples are coupled with climatic data to make predictions of damage and take preventive measures. Such climatic data is collected from automatic agro-climatic weather stations, which are capable of recording and storing great quantities of climatic data and sending it automatically via a phone line to a central collection point.

Traditionally, water based trapping devices baited with olfactory attractants such as ammonium salts or protein hydrolysates have been used to monitor adult populations of the olive fly. Traps such as the McPhail traps are still in use today and give very useful information especially about female *B.oleae* activity, although in some quarters they may be considered as old fashioned. They do however have some disadvantages such as their low efficacy during periods of high humidity, especially during rainy periods, and their lack of specificity in that they also attract non-target insects, some of which are beneficial predators or parasites in the olive grove.

It has long been known that yellow colours are attractive to Tephritid Diptera. This has lead to the development of trapping devices consisting of plastic strips of approximately 17 x 23 cm which have the appropriate shade of yellow for maximum attraction and which is covered in a non-drying adhesive. The distance of attraction of such traps however is not very great and in general does not go further than the immediate surroundings of the tree in which it is suspended and for this reason the trap usually has a very low trapping efficiency (Delrio, 1985).

When these visual traps are baited with vials containing 25 mg of the spiroacteal major component of the sex pheromone, their efficacy and radius of attraction is significantly increased (Jones *et al.,* 1983; Delrio, *et al.*, 1983). The enhanced attraction of males to such traps when baited with pheromone was clear from the very beginning but there was also some evidence that the traps were more attractive to females (Montiel and Jones, 1989) - this fact was later to prove important in the use of this pheromone for control purposes as discussed in Section 2 of this paper.

For most of the 1980's the pheromone dispenser used consisted of a polyethylene vial which required changing every 6 to 8 weeks. However, long life lures are now available which are loaded with 80 mg of spiroacetal and which last over 6 months. These are very useful not only in monitoring traps but also in lure and kill target devices used to suppress *B. oleae* populations as is discussed later in this paper.

One disadvantage of this trap, which is based totally or partially on attraction to colour, is that it also attracts non-target insects, and at high trap densities, such traps can cause damage to beneficial insect populations (Neuenschwander, 1982). This problem can be overcome or eliminated using traps of a colour other than yellow, which is not attractive to beneficial insects (Haniotakis *et al.*, 1982), or by installing the traps in the tree in such a way that they selectively catch *B. oleae* (Jones *et al.*, 1985).

In terms of practical application in the field, it has been found in Jaén, Spain, that a combination of traditional trapping systems such as the McPhail trap and the more recent sex-pheromone baited traps gives the best population monitoring information for pest management purposes (Montiel, 1987). While the pheromone system gives the best information about pest populations and their dynamics (Montiel and Madueño, 1995a,b), the McPhail traps are used to generate extra information such as female fecundity levels, which is obtained by dissecting females caught in these traps and assessing the stage of development of the ovaries.

When used correctly this combination system can give information on (1) the presence or absence of B. oleae in the olive grove; (2) the period of sexual activity in the fly population. During early summer, when temperatures are high and the olive fruit is still not of a sufficient size for the females to oviposit, there is a cessation of sexual activity. However, as autumn approaches and the fruits mature, sexual activity is initiated once more, and the yellow traps baited with the pheromone at this point immediately start to catch a much larger number of male *B. oleae* than other yellow traps which are not baited with the pheromone. This information helps the field operator to decide on the optimum time for spray applications (Delrio, 1985; Montiel, 1987).

It can show the efficacy of treatments against the pest by measuring levels of adult captures before and after treatments. Correlations can be obtained between trap catches and infestation of fruit (Ballatori *et al*., 1980; Montiel and Moreno, 1983; Crovetti *et al.*, 1983) so that spray thresholds can be established (Delrio, 1985; Montiel & Madueño, 1995 a,b) and with which population models can be established which predict levels of risk of attack from the pest (Montiel and Moreno, 1983; Montiel & Madueño, 2000 – in press).

Since 1990, there has been in place in Spain a Programme for the Improvement of Olive Oil Quality, which is regulated by the European Union and financed by retaining 1.4% of the aid directed at olive production. This is used to monitor olive fly populations and co-ordinate and carry out control measures against it. During 1999, 1,313,858 ha of olives (in 24 provinces of 10 autonomous regions) were involved in the programme. This entailed having 1,142 monitoring points for adults and larvae and 82 meteorological stations. Data from these were sent via 24 provincial micro-processors to two central mini-computers where all the data was finally processed.

The Control, Alerting and Validating features of this system consists of the following characteristics: (1) A dividing of the olive growing areas into 10,000ha blocks; (2) a meteorological station in every block; (3) within each block, the olive groves are subdivided into homogeneous sub-blocks of about 100 ha each; (4) within each homogenous sub block a monitoring point is established consisting of 5 McPhail traps, and 5 yellow sticky traps with long life pheromone dispensers; (5) monitoring of adult populations of *B.oleae* is by weekly trap counts at each monitoring point; (6) monitoring of larval populations is weekly fruit samples.

Information Processing Levels are: (1) Monitoring points and meteorological stations integrate basic biological and climatic data; (2) transmission of level 1 data via telephone lines to the provincial micro-processors; (3) receipt and processing of data received in the provincial micro-processor (integration of provincial biological and climatic data); (4) receipt and processing of data at a national level in the mini computers. (integration of biological and climatic data with historical information)

Over the last decade, the collection and handling of data from such trapping devices has become clearly more sophisticated. The Spanish system described above has worked very well and has allowed the authorities there to foresee and prevent major damage by *B. oleae* in all the olive growing areas of Spain. Italy and Greece are also developing similar early warning systems as part of IPM packages for *B. oleae* and such systems will undoubtedly be extended to other countries in the Mediterranean basin.

Controlling *Bactrocera oleae*

Three main strategies involving Semiochemicals (mass trapping, lure and kill and mating disruption) have been pursued in the development of integrated pest management strategies for olive pests.

Mass trapping

The concept of mass trapping, in principle, is very simple; place a sufficiently high number of traps in an olive grove and achieve a satisfactory level of control through the capture of large numbers of adult flies. In practice, however, several factors influence the success of such efforts and cause some doubt as to the viability of such a technique for olive fly control on a large scale. Yellow traps coated with non-drying adhesive have been used successfully on both a small and a largescale for controlling olive fly populations. However, the high density of traps used required in some cases as many as five traps per tree, which made the technique uneconomic and very destructive to the natural enemy population in those olive groves (Economopoulos, 1979; 1980).

The number of traps required can be reduced substantially if the traps are baited with and olfactory attractant, a food attractant, a sex pheromone or both. Experiments carried out in Italy have demonstrated that, with one yellow trap per tree baited with ammonium carbonate and the sex pheromone, very acceptable results were obtained if the olive harvest was good and the population of olive fly was low. However, the results obtained in those years where the population of olive fly was high and the olive harvest was low were not satisfactory (Delrio, 1985). Traps baited in a similar way, but used at a density of 1 per 9 trees, when used on a grand scale in Greece have lead to a reduction in the number of treatments required to control olive fly from 3 to 1 (Broumas *et al*, 1983).

Several factors therefore make the technique non-viable on a large scale. These include: (1) The lack of good attraction of females by the attractant source used; (2) the lack of highly efficient traps; (3) the problem of high insect populations and trap saturation; (4) the destruction of natural enemy populations if they are attracted to the same traps; (5) the need for a high density of traps per unit of surface area which in turn renders the technique too costly.

Many of these problems were initially found to apply in the case of *B. oleae* but have been overcome by abandoning sticky traps and turning instead to `target' devices with low visual stimulation for the flies but which were treated with insecticides to kill them once they made contact with them. In this way, problems of trap saturation were overcome because the insect once having picked up a lethal dose of insecticide from the target device, then flies or walks away from it until the toxic effects of the insecticide manifest themselves. Similarly, to use targets with grey, green or brown colours reduces the attraction of beneficial insects and thus conserves their populations in the olive grove.

Lure and Kill

Lure and Kill strategies for tephritid fruit flies fall into two groups; those that employ some form of target device and those that rely on attracting the insect onto a natural surface, e.g. host tree foliage, which has been treated with an attractant/insecticide mixture; this second technique will be referred to as sprayable formulations.

Target devices for Bactrocera oleae. Work in Greece over the last ten years, and more latterly in Spain, has been aimed at overcoming the short-comings of mass trapping using sticky traps through the development of target devices which carry an insecticide for killing the attracted flies instead of adhesives. The target devices used in most of the large scale trials undertaken in Greece consisted of plywood rectangles (15 x 20 x 0.4 cm) dipped into appropriate concentrations of the pyrethroid insecticide Deltamethrin for a sufficiently long period of time to saturate the wood with the insecticide solution. These devices were baited with ammonium salt dispensers (food attractant) and one target in 3 or 5 was also baited with a sex pheromone dispenser.

Fewer sex pheromone dispensers than the food attractants were thought necessary since their distance of attraction was shown in earlier experiments to be 60 - 80 m while that for the food attractants was only 15 - 20 m. Great logistical problems had to be overcome during the installation period of the devices in June and July, especially in years where over 2,000,000 trees were treated. As the controlled release devices for the food and sex attractants became more advanced it was possible to install the target devices during early summer and reasonably expect them to last until late autumn when olive fly populations reduce in importance through decreasing temperatures and the olives were harvested. Young agriculturalists monitored the effectiveness of the target devices throughout the periods of operation and they monitored olive fly populations by the use of traps and through taking samples of olive fruit for periodic examination of damage levels. They also took samples of the target devices back to the laboratory to verify by bioassay that the insecticide content of the plywood boards was still sufficient to kill the fly.

The results over five years from the area-wide application of these target devices in Greece can be summarised as follows:- Fly populations as measured by McPhail traps were consistently lower in target-device treated areas compared with conventionally treated controls. The average number of bait sprays that had to be used in target treated areas during the early years of the programme (1984/1985) was 1 as opposed to 2.5. No supplementary bait sprays were required in later years in the target-device treated areas. In most years, fruit infestation was lower than or equal to that in the controls where bait sprays were applied (Haniotakis *et al.*, 1991).

The target device method of controlling *B. oleae* therefore was very effective as a method of eliminating insecticide bait sprays and significant increases in beneficial insect numbers were observed in target-device treated areas (Paraskakis, 1989). However, for the method to work to its greatest effect, it has to be applied on a large area. In small plots, large-scale adult movements over short distances can significantly over-ride the effects of the devices. Similarly, when the system fails to contain pest populations, complementary measures are almost invariably required, significantly affecting the cost effectiveness of the technique.

In Spain similar target device technology has been tested on a relatively large scale since 1992. The device used in initial trials was similar to that used in Greece but it was made out of cloth, which was then soaked in deltamethrin rather than wooden boards. The types of baits used depended on the ease of access to the olive groves and the target devices. In groves where the trees and the targets are easily accessible the targets have been baited repeatedly with sprayable protein (1ml of protein hydrolysate) and/or sprayable pheromone (1ml of micro-encapsulated spiroacetal ‘Polycore SKL’). In groves which are difficult to access such as in steep mountainous terrain, the targets were baited with long life baits such as those used on monitoring traps (5g dispensers of ammonium salt and 80mg long life dispensers of spiroacetal). These baits usually last the whole season from June to November. The systems involving sprayable attractants need to be replenished several times during the season but are very low cost in materials but labour-intensive. With the long life lures, the up-front costs are greater but require very little maintenance thereafter during the rest of the season. The results obtained in both large and small plots were satisfactory using both systems. Reductions in infestation of at least 50% were observed in treated plots compared with untreated controls.

Since 1998, two industrially produced target devices have been tested in Spain. One is produced in Greece (Vioryl) and the other in the UK (Agrisense). Given the industrial scale of the production of these two products, the costs involved have been substantially reduced. The Greek target device consists of a green coloured bag containing 60g of ammonium bicarbonate and is covered on the outside with deltamethrin. It is also baited with a sex pheromone dispenser containing 80mg of spiroacetal. The target is used at a rate of one per tree and half the traps are placed in the grove at the start of the summer and the other half are placed in the autumn when the fly begins to attack the fruit.

The traps of UK origin consist of a square brown-coloured carton (19 x 19 cm) which is impregnated on both surfaces with at least 20mg of a pyrethroid such as Deltamethrin. Every target carries an ammonium bicarbonate dispenser and one in every three targets has a spiroacetal long life dispenser. The target device is easily attached to small branches by a hook and eye system that leaves the device in the form of a cone, which protects the attractant dispensers. All the devices are installed at the beginning of summer. Results obtained over the last two seasons have been very satisfactory with the commercial target devices although fly populations have not been very high. The levels of control obtained were in most cases similar to those obtained with bait sprays.

The target device method of managing *B. oleae* populations, although more labour intensive generally, will nevertheless be pursued in most olive growing countries since legislative and environmental pressures will eventually restrict the broad scale use of bait sprays.

Sprayable formulations for Bactrocera oleae. The wide scale use of protein/insecticide bait sprays for controlling *B. oleae*, has become well established in most Mediterranean olive growing countries, together with several disadvantages to its use. Probably the most important problem with this technique is its lack of selectivity. Many important insect predators and parasites are known to be attracted by the protein hydrolysate component of the bait spray mix and this often leads to substantial reductions in their populations with continued use of this technique.

With the isolation and identification of the sex pheromone of *B. oleae*, a selective attractant became available which could substitute the protein hydrolysate.

Trapping experiments showed the 1,7 dioxaspiro [5.5] undecane major component to be strongly attractive to the males (Jones *et al*., 1983).Observations made during attempts to disrupt the mating of *B. oleae* using techniques similar to those used for Lepidoptera, showed that instead of producing mating disruption, the wide-scale treatment of experimental olive groves with the pheromone produced in some instances only large immigration of *B. oleae* adults, both male and female. It appeared therefore that the pheromone, in addition to attracting the males in a clearly directed manner as seen with monitoring traps, was also attractive to females but not in such a strongly directed way. Attention was therefore moved from trying to achieve mating disruption with the pheromone to using the pheromone as a substitute attractant in bait sprays which were much more selective.

A sprayable formulation of the pheromone was therefore required which would slowly release it over a period of time consistent with the effective life of the insecticide once applied in the field. The pheromone was micro-encapsulated in Poly-urea type micro-capsules (5-10 micrometer) and in polymer entrapped micro beads (5-10 micrometer) (Polycore SKLä) containing 20 g spiroacetal per litre. More recently a concentrated polymeric formulation has been introduced with 150g spiroacetal per litre which has a similar field performance but which is much more cost effective. The formulated pheromone in every case is tank mixed with either malathion or dimethoate and applied aerially or from the ground.

In aerial sprays the plane delivers a 20 m wide swathe every 100 m of grove so that only 20% of the crop is treated. From the ground, the pheromone/insecticide mixture is applied either from a tractor mounted sprayer which applies the mixture to the south side of each row of trees or, if a knapsack sprayer is used, only 0.5 to1 square metre of foliage, again on the south side of each tree, needs to be treated. Trials carried out over many years in Southern Spain have shown that both application methods give consistently good results (Montiel, 1989). Indeed this technique is now being used on large areas of environmentally sensitive National Parks of Cazorla and Segura in Southern Spain totalling 13,800ha in 1996 (MAPA 1996).

For organic olive oil production the same techniques can be used but the killing agent has to be changed for one approved by the various organic farming accreditation bodies. In Spain, about 1,200ha of olives are treated with the sprayable pheromone formulation mixed with natural pyrethrum and rotenone (two botanical insecticides approved by the Spanish organic growers association). Such olive oil commands a very good price premium for the producers and can more than compensate for the higher costs of the control mechanisms involved.

The introduction of semiochemical based products as control methods against *B.oleae* has been very successfully accomplished on a pilot scale in a number of olive growing countries and is now being applied on an area wide basis in Spain, Italy and Greece. Much further work is now required to transfer these newly developed techniques to the remainder of the olive growing regions of the Mediterranean Basin.

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References

Baker, R.; Herbert, R.H.; Howse, P.E.; Jones, O.T.; Franke, W.; Reith, W. (1980) Identification and synthesis of the major sex pheromone of the olive fly (*Dacus oleae*). *J.Chem. Soc. Chem* Commun. No 1106, 52-53.

Ballatori, E.; Pucci, C.; Ricci, C. (1980) Relation entre l'infestation des olives et les captures d'adultes de *Dacus oleae* (Gmel.) par pieges chromotropiques. *Redia* 63, 417-439.

Broumas, T.; Liaropoulos, C.M.; Katsoyannos, P.; Yamvrias, C.; Haniotakis, G.; Strong, F. (1983) Control of the olive fruit fly in a pest management trial in olive culture. In: *Fruit Flies of Economic Importance*. R. Cavalloro (Ed.) Proceedings of the CEC/IOBC International Symposium, Athens, Greece, 16-19 November 1982. pp. 584-592.

Crovetti, A.; Quaglia, F.; Malffati, P.; Conti, B. (1983) Research on different methods for the evaluation of the level of olive fruit fly infestation. results obtained in the experiments carried out in Tuscany in the biennium 1980-1981. In: *Fruit Flies of Economic Importance*. R. Cavalloro (Ed.) Proceedings of the CEC/IOBC International Symposium, Athens, Greece, 16-19 November 1982. pp 330-336.

Delrio, G. (1985) Biotechnical methods for olive pest control. In: *Integrated Pest Control in Olive Groves*. R. Cavalloro and A. Crovetti (Eds). Proceedings of the CEC/FAO/IOBC International Joint Meeting, Pisa, 3-6 April 1984. pp 394-410.

Delrio, G.; Economopoulos, A.P.; Economopoulos, P.V.; Haniotakis, G.E.; Prota, R. (1983) Comparative study of food, sex and visual attractants for the olive fruit fly. In: *Fruit Flies of Economic Importance*. R. Cavalloro (Ed.) Proceedings of the CEC/IOBC International Symposium, Athens, Greece, 16-19 November 1982. pp. 465-472

Economopoulos, A.P. (1979) Attraction of *Dacus oleae* (Gmelin) (Diptera Tephritidae) to odour and colour traps. *Zeitschrift fur Angewandte Entomologie* 88, 90-97

Economopoulos, A.P.(1980) Application of colour traps for Dacus oleae control; olive groves with different degrees of isolation, tree size and canopy density. In: *Integrated Control in Agriculture and Forestry*, K.Russ and H.Berger (Eds) Proceedings of an IOBC/WPRS International Symposium, Vienna, 8-12 October, 1979. pp 552-559.

Haniotakis, G.E. (1974) Sexual attraction in the olive fruit fly, *Dacus oleae* Gmel. *Environmental Entomol.*, **3**, 82-86

Haniotakis, G.E.; Mazomenos, B.E.; Tumlinson, J.M. (1977) A sex attractant of the olive fruit fly *Dacus oleae* and its biological activity under laboratory and field conditions. *Entomol. Exp. & Appl.*, 21, 81-87.

Haniotakis, G.E.; Mazomenos, B.E.; Hardakis, I.M. (1982) Monitoring and control of the olive fruit fly with pheromone traps. In: *L'état d'avancement des travaux et échange d'information sur les problèmmes posés par la lutte integrée en oleiculture.* Proceedings of CEC experts' meeting, 4-6 November, 1981 Antibes France pp. 46-60

Haniotakis, G.; Kozyrakis, M.; Fitsakis, T. (1991) An effective mass trapping method for the control of *Dacus oleae* (Diptera: Tephritidae). *J. econ. Entomol*. 84, 564-569.

Jones, O.T.; Lisk, J.C.; Longhurst, C.; Howse, P.E., Ramos; P. & Campos,M. (1983) Development of a monitoring trap for the olive fly, *Dacus oleae,* (Diptera: Tephritidae) using a component of its sex pheromone as lure. *Bull. ent. Res.*, 73, 97-106.

Jones, O.T.; Lisk, J.C.; Mitchell, A.W.; Baker, R.;Ramos, P. (1985) A sex pheromone baited trap that catches the olive fruit fly (*Dacus oleae*) with a measurable degree of selectivity. In: *Integrated Pest Control in Olive Groves*. R. Cavalloro and A. Crovetti (Eds). Proceedings of the CEC/FAO/IOBC International Joint Meeting, Pisa, Italy, 3 - 6 April, 1984. pp 104 - 112.

Karlson, P.; Luscher, M. (1959) 'Pheromones' A new term for a class of biologically active substances. *Nature* 183, 55-56.

Law, J.H.; Regnier, F.E. (1971) Pheromones. *Annual Review of Biochemistry* 40, 533-548.

M.A.P.A. (1996) Memoria del Programa de Mejora de la Calidad del Aceite de Oliva en España, 1996. Ministerio de Agricultura, Pesca y Alimentacion, Madrid, Spain.

Mazomenos, B.E.; Pomonis, J.G. (1983).Male olive fruit fly pheromone: Isolation, Identification and lab. bioassays. In: *Fruit Flies of Economic Importance*. R. Cavalloro (Ed.) Proceedings of the CEC/IOBC International Symposium, Athens, Greece, 16-19 November 1982. pp.96-103.

Montiel, A. (1987) The use of sex pheromone for monitoring and control of olive fruit fly. In: *Fruit Flies*, A.P. Economopoulos (Ed) Proceedings of the Second International Symposium, Crete, Greece, 16-21 September, 1986. pp. 483-494.

Montiel, A. (1989) Control of olive fly by means of its sex pheromone. In: *Fruit Flies of Economic Importance* R. Cavalloro (Ed) Proceedings of the CEC/ IOBC International Symposium, Rome , Italy, 7-10 April, 1987. pp. 443-453

Montiel, A.; Jones, O.T.(1989) Estado actual del uso de feromonas en el manejo integrado de plagas del olivo. *Bol. San. Veg. Plagas*, 15, 161-173.

Montiel, A.; Madueño, C. (1995a) Determinación del umbral de tratamiento para la mosca del olivo (*Bactrocera oleae* Gmel., Diptera, Tephritidae) en olivar destinado a la producción de aceite. *Bol. San. Veg. Plagas* 21, 577-588.

Montiel, A.; Madueño, C. (1995b) Cálculo práctico del umbral de tratamiento para la mosca del olivo (*Bactrocera oleae* Gmel., Diptera, Tephritidae) en olivar de producción de aceite en Jaén. *Bol. San. Veg. Plagas* 21, 589-596.

Montiel, A.; Moreno, R. (1983) Methodologie utilisée en Espagne pour la realisation des études bioécologiques sur les populations naturelles de Dacus oleae (Gmel.) In: *Fruit Flies of Economic Importance*. R. Cavalloro (Ed.) Proceedings of the CEC/IOBC International Symposium, Athens, Greece, 16-19 November 1982. pp.31-37

Neuenschwander, P. (1982) Beneficial insects caught by yellow traps used in mass trapping of the olive fly, *Dacus oleae*. *Ent. exp. & Appl*. 32, 286-296.

Paraskakis, H.I. (1989) Results from the biological control of Saissetia oleae Oliv. on olive trees in Crete, Greece. In: *Proceedings of the 2nd panhellenic congress of entomology,* 11-13 November, 1987, Athens Greece pp. 274-284.

Shorey, H.H. (1977) *Animal Communication by Pheromones*. Academic Press, NewYork.