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Scientific review

Biological Control and Integrated Pest Management of olive fly *Bactrocera oleae* (Rossi) (*Diptera: Tephritidae*): a briefly review

Biološko suzbijanje maslinine muhe *Bactrocera oleae* (Rossi) (*Diptera: Tephritidae*) u sustavu integrirane zaštite: kratak pregled

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ABSTRACT

State-of-the-art and research prospectings in biological and integrated control of the olive fly *B.oleae* were briefly discussed.

Key words: olive, olive fly, biological control, integrate pest management

SAŽETAK

U radu su, na osnovi literaturnih podataka, prikazana aktualna znanja o maslinovoj muhi i moguće mjere suzbijanja u sustavu integrirane proizvodnje masline.

Ključne riječi: maslina, maslinina muha, biološke mjere suzbijanja, integrirana zaštita

INTRODUCTION

In an olive agro-ecosystem, the olive fly *Bactrocera oleae* (Rossi) (*Diptera: Tephritidae*) is the most dangerous and widespread among over 100 phytophages, together with the moth *Prays oleae* (Bernard) (*Lepidoptera: Yponomeutidae*) and the black scale *Saissetia oleae* (Oliv.) (*Homoptera: Coccidae*).

Following, *Palpita unionalis* (Hb.) (jasmine moth), *Liothrips oleae* (Costa) (thrip), *Zeuzera pyrina* (L.) (leopard moth) are equally important but of occasional and localized significance.

This paper provides a briefly view of the issues related to *B.oleae*, that are predominantly important.

Fig. 1 *B.oleae* (Rossi) adult male; N. Wright, Florida Department of Agriculture and Consumer Services, Bugwood.org

BIOLOGICAL CONTROL

Fly's most active entomophages are listed: *Eurytoma martelii* (Dom.) (solitary ectophage), *Pnigalio mediterraneus* (Ferr. e Del.) (polyphagous ectophage, one of the most active fly's parasitoid), *Eupelmus urozonus* (Dalm.) (ectophage, polyphage, with a marked bent for hyperparasitoidism), *Cyrtoptix latipes* (Rond.) (quite rare and less known ectophage), *Prolasioptera berlesiana* (Paoli) (oophage). Nevertheless their significance varies through space and time, and also it needs to know more about these entomophages' host ranges.

Fig. 1 Parasitized egg

Attempts of inundative releases using *Opius concolor* (Szepl.) (endophage) didn't succeed (Delanque 1964, Monastero e Genduso, 1964; Genduso et al., 1969; Lotta et al. 1969; Fimiani, 1982). Sufficiently untouched ecosystems preserve a considerable cohort of fly's natural enemies with a steady consistence (Roberti, 1967; Fimiani, 1982). The lack of real knowledge and understanding of parasites' bio-ethology, their rarefying because of chemical treatments, the agro-ecosystems' biotic potential strongly benefiting the phytophages, the need to work on a large scale, are just some of the reasons that led to a poor efficiency of the biocontrol methods traditionally applied. How abiotic factors affect the parasitization level of the fly's instars, particularly the temperature inside the drupes, was studied (Pucci et al., 1981).

INTEGRATED PEST MANAGEMENT

The amount of chemical treatments for olive groves is not as appreciable as for other cultures. Nevertheless, providing better quality oils, within strict qualitative and organoleptic parameters, needs to look carefully over the product's sanitary safety ("toxicological quality", Delrio 2000), concerning for public and environmental health. It's hoped for cultivation's more rational managements, following IPM ecological, economic and toxicological criteria.

Currently, IPM is the most promising pest management strategy: synthetic active principles having the least environmental impact are used as the last resort, when the population reaches concrete levels cause of considerable economic losses. There are significant opportunities researching and developing new IPM methods in oleaculture: nowadays just few of the economic thresholds are specified through scientific methodologies.

The broad-sense Integrated Pest Management considers agronomic practices and physical, biological, biotechnological treatments to be effective tools against pathogen, allowing just a subsidiary functions to the chemical ones.

Researches developing integrated fly management programs moved on step by step: setting of population sampling and monitoring methods, defining the relationship between trapping and infestation, determining economic thresholds, testing different pest control strategies. It's going to outline some of the most significant issues.

FORECASTING MODELS

Building up forecasting models and suitable economic thresholds is essential to set up effective IPM tactics against the fly. There are many other factors affecting the infestation, apart from population density: mobility and behaviour of pests, predators and parasitoids incidence, cultivar, foliage density, crop productivity, climatic factors, *etc*. Despite that, forecasting models are usually based on a small number of easily quantifiable variables.

The models suitable for *B.oleae* are based either on the pest's phenology (predicting growth rates consequent on climatic seasonal trends) (Raspi, 1999), or on the population dynamics (correlating infestation trends with present population densities, according to climatic parameters too) (Pucci, 1993; Cossu et al., 2005).

About demographic models, two methodologies can be applied: starting from present pest infestation levels (detectable by drupes sampling), or through monitoring of adult populations (trap-testing); both are detailed hereafter.

Fig. 2 Fly's cocoon inside a drupe

To sample drupes needs simple techniques able to provide reliable evaluations of infestation rates. Different authors advice a simplified sample of just one olive per tree (Chesi e Quaglia, 1982; Chesi e Sandi, 1982), or a random sampling of a certain number of drupes. Pucci (Pucci et al., 1979) suggests to draw some trees per hectare, representative of the olive grove (subjective sampling), from which to select randomly some dozens of drupes per tree. The amount of sampled fruits directly affects the estimate's accuracy, but generally remains paltry respect to the great statistical variability, so that standard errors are usually rather significant.

In case of drupes sampling, forecasting models are based on the interrelation between active infestation at the moment t_n and infestation (type I, II or total[1]) at the previous t_0. The purpose is to build up a model that, applied, allows to foresee reliably the future infestation rate (t_n), using the present infestation (t_0)

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[1] Type I: eggs+L1; type II: L2+L3.

as known datum. These estimations generally consider quite a few variables: for instance cultivar and crop productivity. So once again great part of the variables really affecting the evolution of the infestation stays implicit and not expressed.

It's worth pointing out that whichever model remains valid in practice as long as the implicit variables (even the kind of infestation's course, Ricci et al, 1983) maintain the same characteristics of the year and the environment in which the model's correlations were carried out. If a range of models, settled following the same operational methodologies for different years and places, were hopefully available it would be possible to choose the model, or a combination of models, fitting real conditions at best (Ballatori et al., 1983).

Other than drupae sampling, several studies focus on the adult trapping methods and their possible positive correlations with the infestation (monitoring of adult populations and understanding of population dynamics) (Ricci et al., 1979; Ballatori et al., 1980; Bagnoli et al., 1982; Bagnoli et al 1983; Quaglia et al, 1982; Crovetti et al, 1983; Pucci et al., 1990; Cirrito e Genduso, 1990; Iannotta e Perri, 1990; Iannotta, 1991; Pucci, 1991; Castoro e Pucci, 1996). The interaction between trappings and infestation is dependent on different biotic and abiotic factors, by environment as well as time, thus the choice of variables, different experimental designs and statistical models, all apparently contribute to diverse Authors' outcomes (Ricci et al, 1983).

The forecasting model for central Italy developed by Pucci (Pucci, 1991) utilises a statistical correlation (Canonical Correlation Analysis) between the mean number of females catched per trap and per week together with the mean temperature of the week (Z), and the infestation (W). So that, the linear combination Z per each time t_0 gives back W, as useful indicator of the expected infestation at the following t_n.

$$Z = 0{,}039\ (Fm - 9{,}7) - 0{,}186\ (Tm - 22{,}1)$$

(where Fm = mean No ♀/trap week; Tm = mean temperature on the trapping week)

Z is calculated on a period from the lignifying stones growth stage to the first decade of October. W consists of the sum *eggs*+L_1+L_2+L_3+*pupae*+*empty cocoons*+*abandoned galleries* both for crown and dropped fruits.

The value of Z in correlation with the infestation W, for an economic threshold of 15% (oil olive varieties), provides a threshold value of 0,10 overcoming whom it needs to work over blocking the infestation. This model appears to be profitably usable for southern Italy and Croatia (Zuzic et al., 1993; Castoro e Pucci, 1996).

Pheromone traps are widely employed to catch olive flies by now, both monitoring the population and mass-trapping.

The forecasting model based on the male trappings by means of pheromone traps (Lo Duca et al., 2003) follows the same modalities as before, resolving into the linear combination

$$Z = 0{,}027M_m - 0{,}339T_m + 8{,}71$$

(where Mm = mean No ♂/trap week; Tm = mean daily temperature on the trapping week)

The threshold value in this case corresponds to Z = -1.0

Comparing the two models along several years, with different olive cultivars and for different places (Spanedda e Pucci, 2006) both appear to be valuable, supplying a good forecast of the infestation trend, moreover sparing onerous samplings and fruits inspections to the farmers. However the model based on the females trapping allows less warning before reaching the threshold value (2-4 weeks), forcing to intervene imediately, while the second model allows a calm setting of the treatments according to climatic conditions.

Joining the previous two forecasting models (phenological and demographic models), the Time Distributed Delay forecasting Model TDDM both determines the population phenological trend basing on thermal summations (similarly to the phenological model), and provides informations on the population density for each different stage (as the demographic model) (Manetsch, 1976; Alilla et al., 2007). Alilla (*op.cit.*) applies successfully the MRV model simulating the development time of a *B.oleae*'s pupae cohort, with the temperature as driving variable and some other parameters representing the physiological characteristics of the species. For example the pupa stage has an accumulated temperature about on F=196DD and the developmental zero is T_0=9,3°C (valuations based on Crovetti et al., 1983). TDDM model provides useful informations not only about phenological trends of females' flights, but also on the infestation demographic dynamics, promising to be an acceptable integration of the demographic model CCA.

ECONOMIC THRESHOLDS

Economic thresholds for larvicides are quantified upon the interrelations existing between active infestation (given by sampling) and weight of the production's quali-quantitative damages. Several equations provides economic thresholds per uniform environments, per cultivar and per productivity, pondering over treatment costs in opposition to achievable benefits (Pucci et al., 1979; Pucci and Dominici, 1982). For Italian olive-growing regions it's currently applicable a threshold about on 10-15% of active infestation, treating with larvicides (Dimethoate, Formothion).

LURE AND KILL TECHNIQUES: POISONED BAITS

Poisoned protein baits (preventive method) fit better with IPM principles than larvicidal treatments (curative method) (Pucci, 1990; Bagnoli et al., 1984; Pucci, 1991; Viggiani 1989; Belcari e Dagnino, 1990), moreover it can be avoid to damage the useful entomofauna's consistency (Delrio 1982). Sure enough, baits seems to induce scarce mortality on predators and parasitoids (Avidov et al., 1963; Rosen, 1967; Broumas et al., 1977; Delrio, 1982). Furthermore, in spite of a more difficoult application, this kind of preventive control of adults results broadly similar to the classical use of larvicides, both in efficiency and cost effectiveness (Bagnoli et al., 1984; Pucci et al, 1993), if carried out promptly when it's exceeding the minimum trapping thresholds (about on 2 ♀/trap·week starting from lignifying stones growth stage according to Loi et al, 1982, Pucci 1990; an infestation of eggs and I instar larvae of 4-10% for Longo e Benfatto, 1981; 3-5 egg-bearing ♀/trap·week plus an olive active infestation of 4-5% according to Viggiani, 1989). The distribution of poisoned baits (Fenthion, Dimethoate or Deltamethrin) is localised on part of the crowns, or on alternate parts of the culture, ensuing a smaller environmental impact (Pucci, 1990).

CONCLUSION

State-of-the-art and research prospectings in biological and integrated control of the olive fly *B.oleae* were briefly discussed.

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