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Field selectivity of a spinosad-poisoned bait toward target tephritids and non-target insects

Riassunto: *Selettività in campo di un'esca avvelenata con spinosad nei confronti di Diptera Tephritidae e insetti non bersaglio.*
Uno dei punti chiave dell'agricoltura sostenibile è quello di ridurre al minimo la quantità di pesticidi introdotti negli agroecosistemi aumentando la selettività dei principi attivi sugli insetti nocivi bersaglio. Da questo punto di vista, rivestono crescente interesse le strategie di controllo con esche. Di recente è comparsa sul mercato un'esca a base di zucchero avvelenata con spinosad, denominata GF-120, utilizzata contro i Diptera Tephritidae. Molti autori hanno dimostrato la tossicità dello spinosad per gli insetti non bersaglio. Tuttavia, la quantità di pesticida impiegata è fortemente ridotta se quest'ultimo viene usato con un'esca attrattiva alimentare, anche se mancavano prove di campo riguardo l'attrazione selettiva di tale esca. Lo scopo di questo lavoro è stato di valutare in condizioni di campo la selettività dell'esca GF-120 rispetto a insetti target e non target, concentrando l'attenzione sugli impollinatori. Le prove di campo sono state effettuate in un uliveto di 20 anni in cui sono state collocate 12 trappole con esca e 12 senza esca per il monitoraggio degli insetti. È stata valutata l'abbondanza degli ordini di insetti più comuni e delle specie di insetti nocivi bersaglio *Bactrocera oleae* e *Ceratitis capitata*. Il risultato principale di questa ricerca è che molti impollinatori non sono attratti dall'esca, mentre tutti i Diptera ne sono significativamente attratti, ad eccezione dei Muscidae. Si dovrebbe indagare ulteriormente sull'attrazione dei Diptera non bersaglio allo scopo di evitare l'impatto negativo sulle specie utili e su quelle non bersaglio. La necessità di elaborare strategie di controllo con pesticidi più sicuri per l'ambiente e per le popolazioni selvatiche di organismi non bersaglio sembra essere soddisfatta dall'utilizzo di questa esca.

Abstract: One of the key-points in sustainable agriculture is to minimize the amount of pesticides inputs in agro-ecosystems increasing selectivity of active agents on target pests mainly. According to this perspective, control strategies utilising baits receive a growing interest. A spinosad-poisoned sugar-based bait, the so called GF-120 bait, utilised against Diptera Tephritidae, recently appeared on the market. The toxicity of spinosad for non-target insects is demonstrated by several authors. However, the amount of pesticide applied is strongly reduced by using it with an attractive food-bait, even if field evidences on the selective attraction of this bait are missing. The aim of this paper is to evaluate the selectivity of GF-120 bait toward target and non-target insects under field conditions, focussing our attention on pollinators. Field trials were performed in a 20 years old olive orchard, where 12 baited and 12 unbaited traps were positioned for insect monitoring. The abundance of the most common orders of insects and target pest species *Bactrocera oleae* and *Ceratitis capitata* has been assessed. The main finding of this research is that many pollinators are not attracted by the bait, while target and non-target Diptera are significantly attracted by the bait with the exception of Muscidae. The attraction toward a part of non-target Diptera should be better explored in order to avoid negative impact on beneficial and non-target species. The need of pest control strategies safer for the environment and the wild populations of non-target organisms seems to be satisfied by the use of this bait.

Key words: *Bactrocera oleae*, *Ceratitis capitata*, GF-120, Sustainable agriculture.

Introduction

One of the key-points in sustainable agriculture is to minimize the amount of pesticides inputs in agro-ecosystems increasing selectivity of active agents on target pests. In fact, a reduction of chemical applications increases biodiversity in agro-ecosystems and facilitates ecosystems' services (Altieri, 1999). According to this perspective, control strategies utilising baits or traps receive a growing interest due to their selective action against pest species (Cork *et al*., 2005; Hegazi *et al*., 2006; Noce *et al*., 2009). Several kinds of devices utilise pheromones, the most species-specific attractants in nature and then the most environmentally friendly. Unfortunately, there are evidences that pheromone traps can act as "kairomone traps" for pest parasitoids (McClain *et al*., 1990) causing a reduction of population of species-specific natural enemies, while generalist predators and parasitoids are less affected. Some traps utilise

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olfactory and alimentary attractants in conjunction with pheromones in order to control both sexes. Different kinds of insecticides acting by contact, such as deltamethrin and lambda-cyhalothrin, or by ingestion, such as spinosad, are utilised. Poisoned baits seem to be safer for parasitoids of target pests (Stark *et al*., 2004), but the efficacy on target pests and impact on non-target insects strongly depends on their selective attractiveness.

The efficacy of spinosad-based insecticides has been confirmed against several pests. Spinosad is a mixture of spinosyns A and D produced by the Actinomycetes *Saccharopolyspora spinosa* (Mertz & Yao, 1990) altering nicotinic and gamma-aminobutyric acid receptors functions acting mainly by ingestion. A spinosad-poisoned sugar-based bait, GF-120 bait, recently appeared on the market, is mainly utilised against tephritid fruit flies (Diptera: Tephritidae) *Ceratitis capitata* (Wiedemann, 1824) in citrus orchards and *Bactrocera oleae* (Rossi, 1790) in olive groves. It is applied only in a spot of droplets on the tree canopy.

The toxicity of spinosad for non-target insects is demonstrated by several authors (Mayes *et al*., 2003; Miles, 2003, 2006), depending on the concentration of the active ingredient. However, the amount of applied pesticide is greatly reduced by using it in the GF-120 food-bait, becoming an environmentally friendly strategy against tephritid flies (Michaud, 2003; Williams *et al*., 2003). Previous studies performed under laboratory conditions demonstrated that this spinosad-poisoned bait has a negative impact only on non-target flies (Wang & Messing, 2006). Scalercio *et al*. (2010) pointed out that baited and unbaited olive groves inhabit the same density of flying insects, suggesting no attractions of the GF-120 toward non-target insects. However, field evidences on the selective attraction of this bait must be better evaluated because similar abundances of non-target insects within baited and unbaited groves can conceal an attraction explicated at a micro-scale leaving unchanged population densities at farm scale.

The aim of this paper is to evaluate the selectivity of GF-120 bait toward target and non-target insects, such as pollinators, under field conditions, those really experienced by the wild populations of insects.

MATERIALS AND METHODS

Field trials were carried out in a 20 years old olive orchard, in the municipality of Rende, Southern Italy. The experimental olive grove covered 1.4 hectaresand included 676 olive trees. The survey started in the middle of September 2008 and lasted one month.

Twenty-four white sticky plastic traps (size: 17×25×0.3 cm) were distributed in the olive grove (planting frame: 6×4 m) (Fig. 1). Traps were positioned at 150 cm above the soil, near the olive tree canopy. A commercial synthetic rat glue diluted with petrol ether was utilised to stick traps dipping them into the solution. Two traps, one baited and one unbaited, represented an experimental unit, for a total of 12 experimental units. Within any experimental unit the traps were positioned on the opposite side of the same tree to reduce the effect of location on the results. For the same reason the position of baited and unbaited traps was inverted every seven days. At the end of the survey a total of 24 samples was obtained, 12 from baited traps and 12 from control traps.

According to the label of the commercial product, the required amount of active ingredient (a.i.) for tephritid flies control is 0.24 g per hectare/per week, equivalent to 1 L of commercial product diluted with 4 L of water. It is usually applied by spraying a small spot (diameter: 30 cm) of the tree foliage on the 50% of trees.

We applied 5 mL of solution on each trap with a brush every 2 days in order to maintain the attractiveness of the bait and respect the rate of a.i. per spot on the tree foliage suggested on the label.

Relative abundance of some orders of insects and of the target pests species *Bactrocera oleae* and *Ceratitis capitata* was weekly assessed (Tab. 1). Abundance data of Diptera Muscidae, other Diptera (all Diptera excluding Muscidae, *B. oleae* and *C. capitata*), Hymenoptera Formicidae, Hymenoptera Ichneumonoidea, other Hymenoptera (all Hymenoptera excluding Formicidae and Ichneumonoidea), Coleoptera, Ephemeroptera, Homoptera Cicadellidae, Lepidoptera, Heteroptera, Mecoptera, Blattoidea, Neuroptera, Trichoptera, and Orthoptera were recorded. Insects smaller than 2 mm were excluded from our analysis because their identification and quantification are very hard on sticky traps.

The bait effectiveness against target tephritid species was tested. A particular attention was focused onto the capture of pollinators, putatively the non-target insects most sensitive to sugar-based baits, and predators, a group of insects useful for conservative biological control strategies against some insect pests.

Data were analysed by using ANOVA followed by a least significant difference (LSD) *post-hoc* test.

Results

A total of 12,180 insects belonging to the selected taxa was collected (Tab. 1), the 66.9% of which were Diptera. Formicidae represents the most abundant non-dipteran taxon, because during our field work a very large number of winged ants leaved their nests. Also Coleoptera and Lepidoptera were abundant in our samples, but lesser than expected. A very small number of Hymenoptera was collected (Tab. 1).

Baited traps collected significantly more insects than unbaited ones, but the abundance of non-dipteran insects was not affected by bait (Tab. 1). Diptera are strongly attracted by bait, especially the target species *Bactrocera oleae* and *Ceratitis capitata*, which are ten times more abundant on baited devices (Tab. 1). No significant attraction was detected for any non-dipteran taxon, neither separately nor cumulatively analysed. Furthermore, a highly significant repellent effect seems to be experienced by Cicadellidae, that occurred more abundantly on unbaited traps (Tab. 1). Pollinators such as Muscidae, Hymenoptera and Lepidoptera did not show preferences for baited traps. Parasitoids (Ichneu-

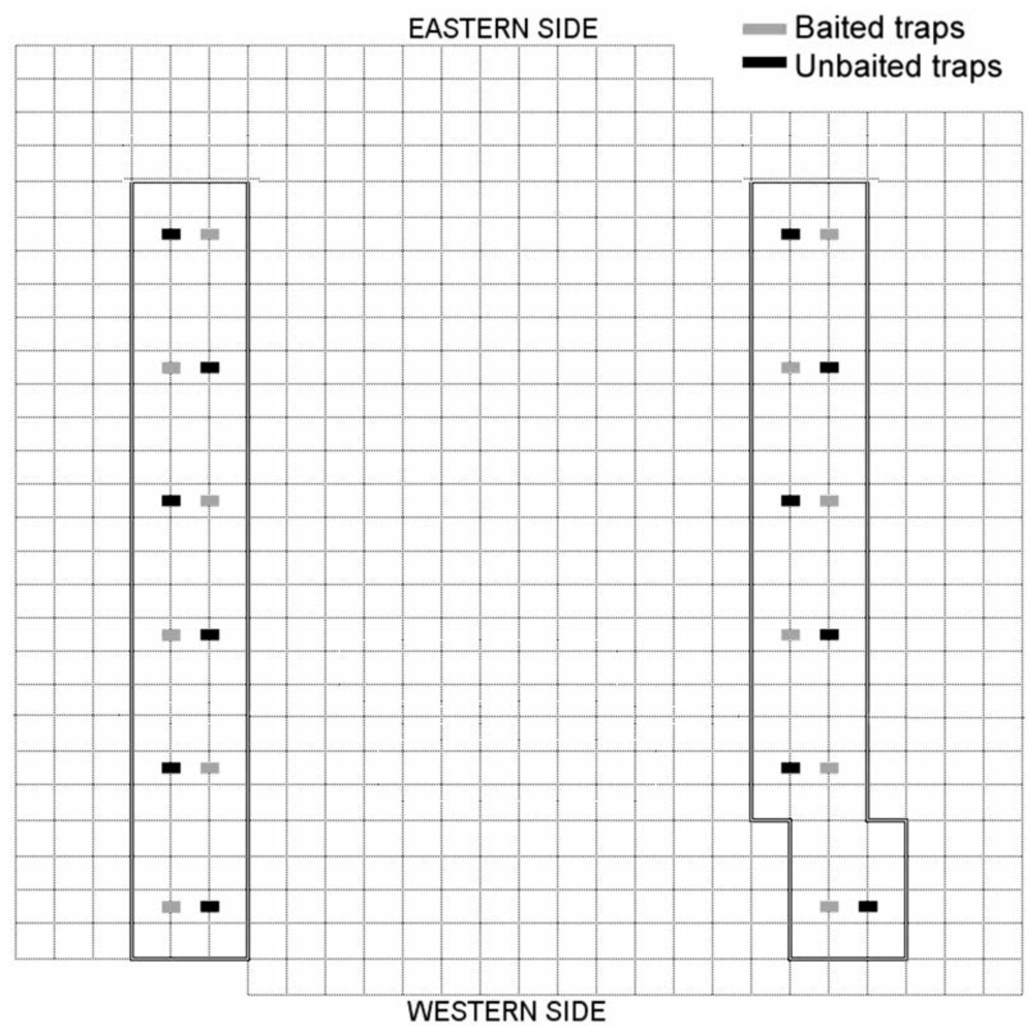

Fig. 1. Experimental design. Each square corresponds to an olive tree. The olive grove continues on the right of the experimental core area.

monoidea) and predators (Neuroptera), very scarcely represented in our samples, were not attracted by bait (Tab. 1).

DISCUSSION AND CONCLUSIONS

The main finding of this research is that non-dipteran insects, and particularly pollinators such as Lepidoptera and Hymenoptera, are not attracted by the poisoned bait under field conditions, those really experienced by wild insect communities. The toxicity of spinosad on honeybees, and pollinators in general, has been demonstrated under laboratory conditions (Mayes *et al*., 2003; Miles, 2003). Honeybees, strongly declining in agro-ecosystems throughout the world (Vanengelsdorp *et al*., 2008), could be exposed to an increasing risk if sugar-based poisoned baits are used on large areas, mainly in Mediterranean countries, where control strategies of olive and citrus tephritid flies can utilise such kind of bait. During our study only three honeybees (data not shown) have been captured by sticky traps, although a wild hive was located only 25 metres from the experimental field.

Lepidoptera are usually attracted by artificial sugar-based bait (Süssenbach & Fiedler, 1999), and the application of the GF-120 should be detrimental for this group of insects. This risk is increased by the scarcity of natural nectar sources in Mediterranean areas during late summer and early autumn. Our data demonstrate that the GF-120 is not attractive for this insect group, showing no negative impact on moths and butterflies.

Target and non-target Diptera are significantly attracted by the bait with the exception of Muscidae. The attraction toward target tephritids is largely expected, while the attraction toward some non-target Diptera could be a problem from a conservation point of view. Diptera provide several ecological services, *e.g.* as biological control agents of weeds and pests, and include endemic species. The indiscriminate use of GF-120 bait can cause the reduction of population of important dipteran species, mainly in islands (Wang & Messing, 2006). Faunistic knowledge on Diptera is very scarce and the distribution of species in the Mediterranean Basin is poorly known. In order to minimize the

Tab. 1. Mean abundance of insects collected by baited and unbaited traps. Insects smaller than 2 mm were not taken into account.

	Baited traps	Unbaited traps	$F_{1,22}$	P
Diptera Muscidae	265.2	219.1	1.30	0.270
Bactrocera oleae	40.3	3.4	14.41	<0.01
Ceratitis capitata	18.6	0.8	8.73	<0.01
Other Diptera	93.4	38.8	13.92	<0.01
Hymenoptera Formicidae	114.3	142.3	0.26	0.612
Hymenoptera Ichneumonoidea	0.8	0.8	0	1
other Hymenoptera	6.3	4.3	2.68	0.116
Coleoptera	18.5	19.1	0.01	0.912
Ephemeroptera	0.1	0.2	0.34	0.564
Homoptera Cicadellidae	1.7	3.8	6.37	0.020
Lepidoptera	8.5	6.2	4.01	0.058
Heteroptera	2.3	3.2	0.97	0.334
Mecoptera	0.4	0.5	0.07	0.786
Blattoidea	0.08	0.17	0.34	0.564
Neuroptera	0.6	0.3	1.56	0.226
Trichoptera	0	0.3	5.25	0.032
Orthoptera	0.2	0.6	3.52	0.074
Total insects	571.3	443.8	4.57	0.044
Total non-dipteran insects	153.8	181.7	0.26	0.613

risk for beneficial and rare fly species, it should be important to increase knowledge on this taxonomic group in geographic areas where the target tephritid species are important pests on olive and citrus.

This is the first paper aimed to study the selectivity under field conditions of GF-120, a spinosad-poisoned bait. The experimental design recreates environmental conditions really experienced by insects, taking a picture of their abundance within the olive grove in study. Pollinators, a key group for the ecosystem functioning especially in cultivated lands, were not affected by spinosad-poisoned bait, underlining the sustainability of this control method against two of the major pests of permanent crops worldwide. The need of pest control strategies safe for environment and wild populations of non-target organisms seems to be satisfied by this technique, more and more applied for area-wide integrated pest management.

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References

Altieri M.A., 1999 - The ecological role of biodiversity in agro-ecosystems. Agriculture Ecosystems & Environment, 74: 19-31.

Cork A., Talekar N., Rouf F., Alam S., 2005 - Development of mass trapping technique for control of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Lepidoptera: Pyralidae). Bulletin of Entomological Research, 95(6): 589-596.

Hegazi E., Atwa A., El-Rahman S., Showeil S., Aggamy E., El-Aziz G., Konstantopoulou M., Khafagi W., Tawfik H., Raptopoulos D., 2009 - Efficient mass-trapping method as an alternative tactic for suppressing populations of leopard moth (Lepidoptera: Cossidae). Annals of the Entomological Society of America, 102(5): 809-818.

Mayes M.A., Thompson G.D., Husband B., Miles M.M., 2003 - Spinosad toxicity to pollinators and associated risk. Reviews of Environmental Contamination and Toxicology, 179: 37-71.

Mcclain D.C., Rock G.C., Woolley J.B., 1990 - Influence of trap color and San Jose Scale (Homoptera: Diaspididae) pheromone on sticky trap catches of 10 aphelinid parasitoids (Hymenoptera). Environmental Entomology, 19: 926-931.

Michaud J.P., 2003 - Toxicity of fruit fly baits to beneficial insects in citrus. Journal of Insect Science, 3(8): 9.

Miles M., 2003 - The effects of spinosad, a naturally derived insect control agent to the honeybee. Bulletin of Insectology, 56: 119-124.

Miles M., 2006 - The effects of spinosad on beneficial insects and mites used in integrated pest management systems in greenhouses. Pesticide and Beneficial Organisms IOBC/wrps Bulletin, 29(10): 53-59.

Nadel H., Johnson N.W., Gerik M., Daane K.M., 2008 - Ingestion of spinosad bait GF-120 and resulting impact on adult *Chrysoperla carnea* (Neuroptera Chrysopidae). Biocontrol Science and Technology, 17: 995-1008.

Noce M.E., Belfiore T., Scalercio S., Vizzarri V., Iannotta N., 2009 - Efficacy of new mass-trapping devices against *Bactrocera oleae* (Diptera Tephritidae) for minimizing pesticide input in agroecosystems. Journal of Environmental Science and Health part B, 44(5): 442-448.

Ruiz L., Flores S., Cancino J., Arredondo J., Valle J., Diaz-Fleischer F., Williams T., 2008 - Lethal and sublethal effects of spinosad-based GF-120 bait on the tephritid parasitoid *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae). Biological Control, 44: 296-304.

Scalercio S., Belfiore T., Noce M.E., Vizzarri V., Iannotta N., 2010 - The abundance of selected flying insects of the olive grove is unmodified by applications of a spinosad-based bait against the olive fly, *Bactrocera oleae* (Diptera: Tephritidae). Bollettino della Società Entomologica Italiana, 142(1): 35-38.

Stark J.D., Vargas R., Miller N., 2004 - Toxicity of Spinosad in protein bait to three economically important tephritid fruit fly species (Diptera: Tephritidae) and their parasitoids (Hymenoptera: Braconidae). Journal of Economic Entomology, 97: 911-915.

Süssenbach D., Fiedler K., 1999 - Noctuid moths attracted to fruit baits: testing models and methods of estimating species diversity. Nota Lepidopterologica, 22: 115-154.

Vanengelsdorp D., Hayes J., Underwood R.M., Pettis J., 2008 - A survey of honey bee colony losses in the U.S., fall 2007 to spring 2008. PLoS ONE, 3:1-6.

Wang X.G., Messing R.H., 2006 - Feeding and attraction of non-target flies to spinosad-based fruit fly bait. Pest Management Science, 62: 933-939.

Williams T., Valle J., Viñuela E., 2003 - Is the naturally derived insecticide Spinosad® compatible with insect natural enemies? Biocontrol Science and Technology, 13: 459-475.