Effectiveness of spinosad and mineral oil for control of *Grapholita funebrana* Treitschke in organic plum orchards

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Abstract

An experiment was conducted in an organic plum orchard in Sicily to evaluate the damage caused by the plum moth Grapholita funebrana *Treitschke; to three plum cultivars (Angeleno, Friar, and Stanley) and to evaluate plum moth control provided by mineral oil applied every 20 days (Moil), spinosad applied every 10 days (S10), or spinosad and mineral oil applied alternately (S/Moil). Treatment application began when eggs were first observed on fruits. S10 and S/Moil effectively reduced plum moth damage on all cultivars but Moil did not. Plum moth infestation was significantly lower on Stanley than on Friar and Angeleno.*

Keywords*: Plum moth, organic plum orchards, spinosad, mineral oil, cultivar susceptibility.*

Introduction

The tortricid *Grapholita funebrana* Treitschke, also known as the plum moth, is considered the most important pest of plum orchards. The moth completes three generations per year in Italy (Molinari, 1995) but only one or two generations in many areas of central and eastern Europe (Butturrini et al., 2000). Damage is due to the trophic activity of larvae in fruit. Infested fruits exhibit colour changes, penetration holes made by neonate larvae, gumming at the penetration holes, exit holes made by mature larvae leaving fruits, and early ripening and fruit fall (Alford, 1987).

In the last 10 years, the hectarage planted to plum has increased in southern Italy and elsewhere, probably because of the increased availability of cultivars that are adapted to different environments. Plum moth control in southern Italy is difficult, because the susceptibility of different cultivars and the insect's life cycle have not been studied in this region. Plum moth control usually depends on systemic insecticides or anti - ovipositional chemical products, but timing of their application is critical and difficult (Butturrini et al., 2000). Furthermore, systemic products are not permitted in organic agriculture, and their effectiveness has not always been clear. The effectiveness of mineral oil and spinosad for plum moth control in southern Italy is evaluated in the current paper.

Mineral oil has been used to control a large number of pest species on a variety of crops for many years (Davidson et al., 1991; Agnello, 2002). Mineral oil has ovicidal activity (Smith and Pearce, 1948) and also may prevent oviposition (Zwick and Westigard, 1978; Riedl et al., 1995; Fernadez et al., 2001).

Spinosad, a mixture of spinosyns A and D obtained from the fermentation of an actinomycete bacterium, *Saccharopolyspora spinosa* Mertz & Yao, is considered effective against tortricids and other Lepidoptera (Doerr et al., 2004; Smirle et al., 2003). It is also effective against species of Diptera, Coleoptera, Thysanoptera, and Hymenoptera (Bret et al., 1997; Dutton et al., 2003; Thompson and Hutchins, 1999). Like mineral oil, spinosad has been also included in the list of products permitted in organic agriculture (Annex II B, EEU Regulation 889/08).

The objectives of the present research were to evaluate the damage levels caused by *G. funebrana* on three plum cultivars (Angeleno, Friar, and Stanley) and the effectiveness of spinosad and mineral oil for control of this insect pest in Sicily.

Materials and Methods

The research was carried out in 2011 in Sicily (San Giuseppe Jato, Palermo Province) in a 5-ha organic plum orchard planted with three cultivars that differed in ripening time: the cultivar Friar ripens in late July, the cultivar Stanley ripens in late August, and the cultivar Angeleno ripens in the first half of September. The orchard was divided into four blocks with eight rows and about 90 trees per block. Each cultivar was represented by two rows in each block. For each cultivar and treatment, a group of nine trees randomly assigned to three blocks were used. The following treatments were applied: mineral oil every 20 days (Moil); spinosad every 10 days (S10); spinosad and mineral oil in alternation (S/Moil; spinosad was applied on 11 May, 21 May, and 20 June, and mineral oil was applied on 31 May, 30 June, and 20 July); and an unsprayed control (NT). Treatment applications began on 11 May, after the first eggs were observed on the fruit. The commercial products used were Succes (Dow AgroSciences) for spinosad and UFO (Ultra Fine Oil) (Bio-Intrachem, Italy) for mineral oil at doses of 120 ml and 1.5 l in 100 l of water, respectively, as suggested by the manufacturers.

Four pheromone traps were used to monitor the flight activity of the plum fruit moth males; the traps were baited with

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a synthetic sexual pheromone blend containing dodecyl acetate (50%), Z8-dodecenyl acetate (49%), and E8-dodecenyl acetate (1%) (Isagro, Italy). Traps were placed in the field on 5 February 2011 and checked every 2 weeks until November 2011, when no additional males were caught. Pheromone dispensers were replaced every 4 weeks, and the sticky board of each trap was replaced every 2–4 weeks**.** Because the main component of the *G. funebrana* pheromone is the same as that for the congeneric *Grapholita molesta* (Busck), the trapped males were identified to species in the laboratory on the basis of male genitalia morphology (Hrdý et al., 1979); this was done with all males in traps with < 50 catches and with 50% of males in traps with > 50 catches.

For field observations, 10 fruit per tree were examined with a magnifying glass for the presence of eggs on 9 April (when the first males were caught in traps), 6 May, 10 June, 1, 19 and 29 July and 5 August. When the first eggs were observed in the field (on 6 May) and on all subsequent dates, the examined fruit were taken to the laboratory and examined with a stereomicroscope for the occurrence of preimaginal stages of *G. funebrana* and entry or exit holes. A fruit was considered to be infested if a larva was present or if penetration or exit holes.

Because the response data were binary, i.e., fruit were rated as infested or uninfested, a logistic regression was used to assess the significance of the independent factors. This methodology, which is based on the Odds Ratio (ratio of percentages, OR), compares one or several percentages (in our case the infestation level) obtained with different conditions or treatments. The regression was applied for three independent factors: *Cultivar*, *Treatment*, and *Date*. *Cultivar* was a three-level factor (Angeleno, Friar, and Stanley), *Treatment* was a four-level factor (NT, S10, Moil, and S/Moil), and *Date* was the sampling time. In using the logistic regression to determine whether a factor significantly affects a response variable (infestation percentage in this case), a reference level for each factor must be selected to calculate the Odds Ratio. Choosing a different reference level of a factor does not affect the significance of that factor, although leading to different Odds Ratio.

Results and discussion

Of the 2000 males caught in the traps, 1279 were identified to species. Most (1178 or 92.1%) were *G. funebrana,* and only 101 (7.9%) were *G. molesta*.

Males were first captured in the pheromone traps on 6 April, but fewer than 20 males were captured per trap per week until 19 July (Fig. 1). Nevertheless, the number of catches increased in May, corresponding to the first generation. Trapping increased again in June, peaked on 19 July (97 males per trap per week), and then decreased (Fig. 1).

Eggs were first detected on plum fruits on 6 May for cultivar Angeleno and on 10 June for the other two cultivars (Tab. 1). The maximum infestation on the control trees was 43% for cultivar Angeleno (on 29 July), 20% for cultivar Friar (on 29 July), but only 6% for cultivar Stanley (on 5 August).

In the logistic regression analysis, the Odds Ratios were calculated using as the reference level the first sampling time for

Figure 1 - *Average number of* G. funebrana *males caught per trap per week in an organic plum orchard in Sicily in 2011. Temperature data, sampling dates, and treatment dates are also indicated.*

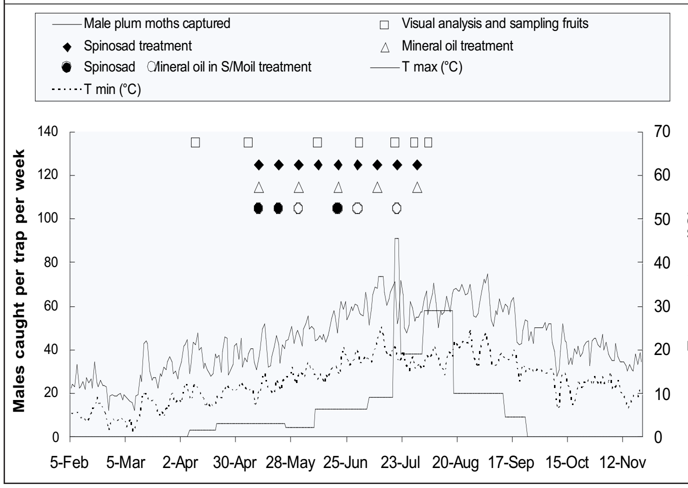

Table 1 - *Percentage (mean + SE) of plum fruits of three cultivars (Angeleno, Friar, and Stanley) infested by the plum moth on different sampling dates in 2011.*

Angeleno	9 April	5 May	10 June	1 July	19 July	29 July	5 August
S10	0.0	2.0 ± 1.4	2.0 ± 1.4	8.0 ±2.7	12.0 ±3.3	6.0 ±2.4	
S/Moil	0.0	2.0 ± 1.4	0.0	6.0 ±2.4	8.0 ±2.7	16.0 ±3.7	
Moil	0.0	0.0	4.0 ±2.0	8.0 ±2.7	16.0 ±3.7	18.0 ±3.9	
NT	0.0	0.0	4.0 ±2.0	18.0 ±3.9	32.0 ±4.7	42.0 ±5.0	
Friar							
S10	0.0	0.0	2.0 ±1.4	0.0	6.0 ±2.4	6.0 ±2.4	
S/Moil	0.1	0.0	4.0 ±2.0	0.0	10.0 ±3.0	12.0 ±3.3	
Moil	0.2	0.0	4.0 ±2.0	4.0 ±2.0	12.0 ±3.1	14.0 ±3.5	
NT	0.3	0.0	2.0 ±1.4	12.0 ±3.3	14.0 ±3.5	20.0 ±4.0	
Stanley							
S10	0.0	0.0	0.0	4.0 ±2.1	0.0	0.0	0.0
S/Moil	0.0	0.0	0.0	0.0	2.0 ±1.4	4.0 ±2,0	3.0 ±1.7
Moil	0.0	0.0	1.0 ±1.0	4.0 ±2,0	2.0 ±1.4	4.0 ±2,0	3.0 ±1.7
NT	0.0	0.0	0.0	4.0 ±2.0	0.0	4.0 ±2,0	6.0 ±2.4

Date and Angeleno for *Cultivar*. The overall model was significant, i.e., the statistics (G = 325.003, with DF = 15) indicated that differences in infestation were unlikely to have resulted by chance (P = 0.00). The regression model fit the data well (Hosmer-Lemeshow Chi^2 = 11.78 DF = 7 P = 0.11).

For *Treatment*, the untreated control (NT) was used as the reference level, and the results indicated that the other three treatments (S10, S/Moil, Moil) significantly reduced the plum moth infestation on all three cultivars. The probability of infestation was reduced by about 50% by Moil (OR = 0.53), by about 75% by S10 (OR = 0.24), and by about 66% by S/Moil (OR = 0.35).

For comparison of S10, S/Moil, and Moil, the same analysis was applied but with S/Moil, which had an intermediate effectiveness (Table 1), as the reference. The percentage of infestation was significantly higher for MOIL than for S/MOIL but did not significantly differ between S/MOIL and S10 (Table 2).

Table 2 - *Binary logistic regression statistics for the effects of Treatment, Cultivar, and Date of sampling on plum moth infestation. Reference levels: S/Moil for Treatment, Angeleno for Cultivar, and 10 June 2011 for Date.*

Predictor	Coef.	Coef. SE	Z	P	Odds Ratio	Confidence Interval Lower	Upper
Treatment							
NT	1.49	0.25	5.86	***0.00***	4.45	2.70	7.33
MOIL	0.71	0.27	2.58	***0.01***	2.03	1.19	3.47
S10	-0.10	0.31	-0.31	0.75	0.91	0.49	1.68
Cultivar							
FRIAR	0.000	0.31	-0.00	1.00	1.00	0.55	1.83
STANLEY	-1.94	0.51	-3.79	***0.00***	0.14	0.05	0.39
Sampling date							
1 July 2011	0.99	0.25	3.90	***0.00***	2.69	1.63	4.42
19 July 2011	1.47	0.24	6.09	***0.00***	4.36	2.72	7.01
29 July 2011	1.94	0.23	8.31	***0.00***	7.01	4.43	11.10
5 August 2011	1.80	0.43	4.16	***0.00***	6.06	2.59	14.16

For comparison of cultivars, and with Angeleno as the reference, plum moth infestation was significantly lower for Stanley than for Friar or Angeleno but did not differ between the latter two (Table 2). With regard to *Date* and with the first sampling time as the reference, infestation levels were highest at the end of July (Table 2).

Conclusion

The best control of plum moth infestation was provided by the treatments S10 (spinosad applied every 10 days) and S/Moil (spinosad and mineral oil applied alternately). Although mineral oil alone significantly reduced the probability of infestation by half relative to the control, application of mineral oil alone cannot be considered economically sustainable.

Alternating a low number of spinosad applications with mineral oil applications provided good protection of fruits, in spite of the short period of effectiveness that characterizes spinosad. Moreover, the reduced use of spinosad in the S/MOIL treatment could reduce harmful side effects on beneficial arthropods like bees and natural enemies (Unruh et al., 2006; Arthurs et al., 2007) and could also reduce the probability of resistance development in the target pest populations (Sayyed et al., 2004; Herron and James, 2005).

Differences in plum moth infestation between the cultivars seemed unrelated to ripening period and could therefore reflect different susceptibilities to the pest. Additional research on the effect of different population levels of the plum moth on these cultivars could lead to further reductions in the use of chemicals to control this pest.

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