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Monitoring strategies for the Citrus Mealybug in Citrus orchards

Abstract - The Citrus Mealybug (CM), *Planococcus citri* (Risso), is a major pest in many citrus growing areas. Sampling of CM prior to fruit colonisation in the spring is difficult and presents an obstacle to CM management. Monitoring population densities is based on male capture using traps baited with female sex pheromone. In an attempt to establish the basis for a reliable monitoring of CM population, the correlation between male captures by pheromone traps and fruit infestation levels was investigated in the citrus orchards of Portugal, Israel and Italy simultaneously. No significant linear relationship was found between male captures and fruit infestation at subplot level in all three countries, which suggests that the range of attraction of each pheromone trap extend further than the distance between the trap and neighbouring trees sampled for estimation of mealybug density. It is likely that the high flight activity and high mobility of the males render irrelevant the contribution of the male population to the total amount of male capture inside the subplots. At the orchard level, the diverse population density between plots allowed significant linear relationship in certain trapping periods between male capture and fruit infestation. Information on the level of male capture in spring or early summer by application of pheromone traps may be used to predict mealybug density or percentage of fruit infestation and consequently to assist in the decision making for the purpose of CM management.

Key words: *Planococcus citri*, pheromone traps, decision tools.

INTRODUCTION

The Citrus Mealybug (CM), *Planococcus citri* (Risso) (Hemiptera, Pseudococcidae), is a major pest in many citrus growing areas, including Israel, Italy and Portugal (Franco *et al.*, 2000, 2001, Russo *et al.*, 2000). Major damage is related to the colonisation of fruitlets and young fruits in late spring. Mealybugs settle mainly under sepals and later in the navel, these being optimal feeding sites, with moderate temperature and humidity and, in addition, a possible refuge from natural enemies and pesticides. Cosmetic defects on fruits, caused by feeding and honeydew excretion, reduce their market value and affect export opportunities, due to quarantine regulations. Fruit moths attracted to honeydew further compound the injury.

Sampling of CM prior to fruit colonisation in spring is difficult and presents an obstacle to the CM management. The identification of the pheromone of CM (Bierl-Leonhardt *et al.,* 1981) has opened new management opportunities. Although the pheromone has been tested by different research teams and proposed as a monitoring tool (Rotundo & Tremblay, 1982; Ortu & Delrio, 1982; Hefetz & Tauber, 1990), the relationships between male catch employing pheromone traps and population density on fruits has not yet been studied.

Monitoring may be used with different objectives (Howse *et al.*, 1998). In the case of CM, monitoring may serve for early warning of high mealybug levels, timing of control treatments and as a mean for evaluation of the effectiveness of management procedures.

Monitoring of population levels using sex pheromone traps is possible if good correlation between male captures and population density or the fruit infestation level exists. Our aim is to discuss the feasibility of using pheromone traps as a monitoring tool for CM management, based on information accumulated in field trials carried out in Israel, Portugal and Italy, simultaneously.

MATERIAL AND METHODS

Experiments were carried out in five citrus orchards in each country, from 1999 to 2001. The monitoring period of male flight was defined in order to include the major peak of flight, usually May-June. Each experimental plot was divided into nine sub-plots of about 25 m x 25 m (Israel) or four sub-plots of about 50 m x 50 m (Italy and Portugal). One 15 cm x 15 cm sticky plate trap, baited with 50 μg (Israel) or 200 μg (Italy and Portugal), was activated in May-July in the centre of each sub-plot, at least, during two different periods. CM density on fruits was estimated in late July - early of August, counting the number of mealybugs per fruit (under a ten fold magnification), by sampling 8-10 fruits in each of four to six trees per sub-plot. Data were studied by linear regression analysis at the sub-plot and plot levels, using male catches on a weekly basis and taking into account different mealybug stages in fruit density estimates.

RESULTS

At sub-plot level, considering all sub-plots of each citrus orchard (plot), no significant (p>0.05) linear relationship was found between male catches and mealybug density on fruits, except for a few plots and trapping periods (Table 1). Similar results were obtained when all sub-plots were combined for each trapping period (Table 1). At the plot level, a significant linear relationship was proved between male catch and mealybug density on fruits in one and three trapping periods, in Israel and Portugal, respectively, but not in Italy (Table 1). The mealybug density ranged from 0.02 and 7.16 mealybugs/fruit (CV=0.49), in Portugal, from 1.73 and 7.10 mealybugs/fruit (CV=0.21), in Israel, and from 0.2 to 1.89 mealybugs/fruit (CV=0.26), in Italy. The relationship between male catch and mealybug density on fruits was affected by the age structure of the mealybug population. The number of cases where a significant linear relationship had been found, increased when the number per fruit of third instar nymphs and adult females (N_3N_4) (Table 2) was considered instead of the total number of mealybugs (Table 1) or the number of young nymphs, i.e., first and second instar nymphs (N_1N_2) (Table 2). On the other hand, at the plot level, the linear relationships

Table 1- Relationship (R^2) between male capture per trap (dependent variable) and mealybugs per fruit (independent variable) for different space levels, in 1999.

Country	Trapping period	Fruit sampling	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	All plots	All sub-plots
Israel	June 7-14	August 2	0.153	0.141	0.431*	0.029	0.021	0.004	-
	July 8-15		0.009	0.342	0.174	0.020	0.126	0.892*	0.443*
Portugal	May 6-13	July 26 - August 1	-	-	-	0.696	-	0.226	0.046
	June 9-17		-	-	-	0.861*	-	0.849*	0.002
	June 17-24		-	0.945*	-	0.839	-	0.982*	0.166*
	June 24-July 1		-	-	0.786	0.602	-	0.421	0.206*
	July 1-8		-	-	-	0.259	-	0.719*	0.267*
Italy	June 16-23	July 21 - August 4	0.413	0.840	0.601	-	0.708	0.323	0.055
	June 23-30		-	-	-	-	0.959*	-	-
	July 14-21		0.590	0.463	0.586	0.887*	0.088	-	0.043
	July 21-28		0.210	0.090	0.403	-	0.996*	0.186	0.023

* significant values (p<0.05)

Table 2 - Relationship (R^2) between male capture per trap (dependent variable) and mealybugs per fruit (independent variable) for each citrus orchard (plot), considering different mealybug stages (N1N2, first and second instars, N3N4, third instar and adult females), in Portugal in 1999.

Trapping period	Mealybug stage	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
May 6-13	N1N2	-	-	-	0.695	0.189
June 9-17		-	-	-	0.852*	-
June 17-24		-	0.930*	-	0.822	-
June 24-July 1		-	-	0.765	0.518	-
July 1-8		-	-	-	0.171	-
May 6-13	N3N4	-	-	0.716	0.213	0.223
June 9-17		-	0.723	0.972*	0.372	0.945*
June 17-24		0.023	0.568	0.968*	0.431	0.496
June 24-July 1		-	0.157	-	0.968*	-
July 1-8		0.039	0.099	-	0.910*	0.590

* significant values (p<0.05)

Table 3 - Relationship (R^2) between male capture per trap and mealybugs per fruit, considering all plots and different mealybug stages, in Portugal in 1999 (see Table 2).

Trapping period	**Mealybug stage**	**All plots**
May 6-13	N1N2	0.231
June 9-17		0.851*
June 17-24		0.983*
June 24-July 1		0.423
July 1-8		0.721*
May 6-13	N3N4	0.141
June 9-17		0.827*
June 17-24		0.958*
June 24-July 1		0.382
July 1-8		0.675

* significant values ($p<0.05$)

improved slightly when the number per fruit of N_1N_2 was taken into account instead of either the number of N_3N_4 (Table 3) or the total number of mealybugs (Table 1).This linear relationship was consistent during the three years of the study. Analysis of residuals showed normal distribution (Kolmogorov-Smirnov test Z=0.884, p=0.415), homoscedasticity and no autocorrelation (r= -0.323 ± 0.284), permitting the combining of all three years data in a general model (Fig. 1). The highest correlation was found with male catch obtained one or two weeks after the peak of the flight (Fig. 3). A

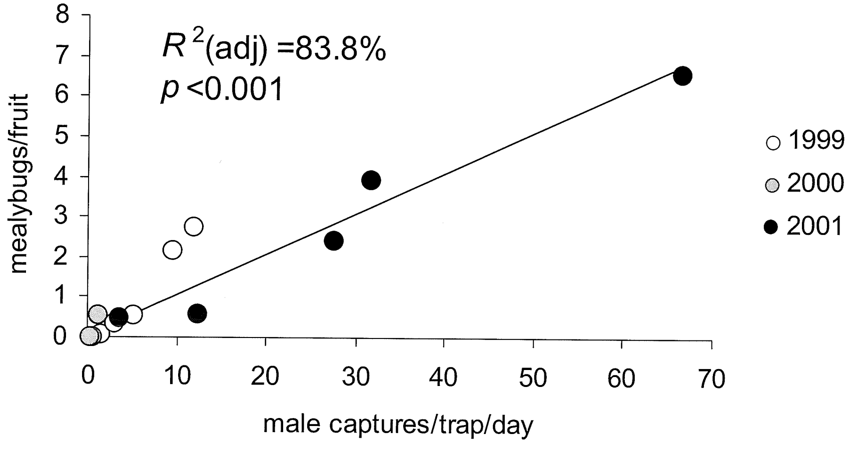

Fig. 1 - Linear relationship between male captures obtained one or two weeks after the pick of flight (i.e., June 24th, in 1999, July 3rd, in 2000, and June 19th, in 2001) and the number young nymphs (N1N2) per fruit in the end of July, at plot level, in Portugal.

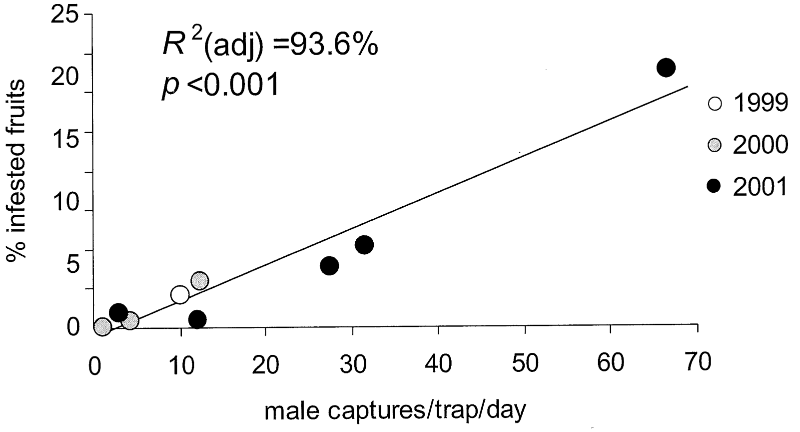

Fig. 2 - Linear relationship between male captures obtained one or two weeks after the pick of flight (i.e., June 24th, in 1999, July 3rd, in 2000, and June 19th, in 2001) and the percentage of fruits infested with colonies of young nymphs (N1N2>9) per fruit in the end of July, at plot level, in Portugal.

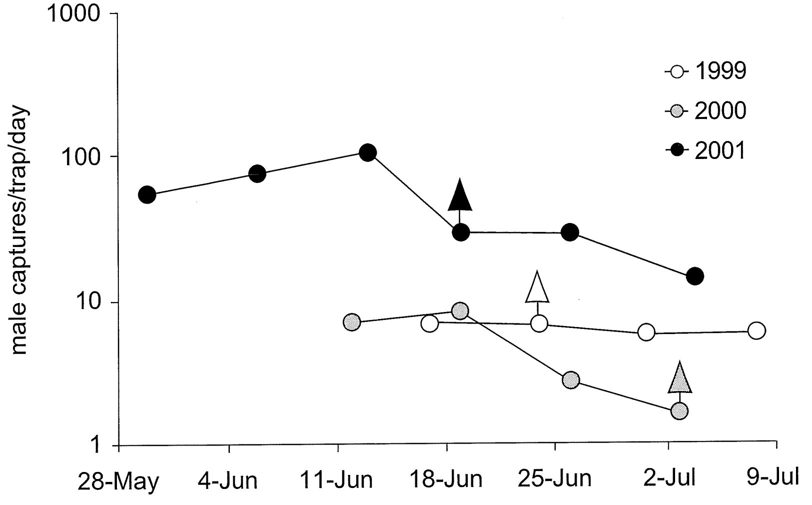

Fig. 3 - Trend of male captures (average of five citrus orchards) obtained in Portugal, from 1999 to 2001. The triangles correspond to the dates of male captures that presented the highest correlation with mealybug density on fruits in the end of July.

similar result was obtained when considering the percentage of fruits infested with colonies of young nymphs (N_1N_2>9, i.e., p_T with a tally threshold T= 9, Jones, 1994), instead of the number of mealybugs per fruit (Fig. 2).

DISCUSSION

At the sub-plot level, the lack of a consistent relationship between male capture by pheromone traps and mealybug density on fruits, both for baits of 50 µg (Israel) and 200 µg (Portugal and Italy) of the pheromone, suggests that the range of attraction of the pheromone trap extends far beyond the distance between the trap and sampling trees for estimation of mealybug density. These results agree with other experiments suggesting that males reach the trap from a distance of 100 m at least (Mendel and others, unpublished data) and most trapped males reached the plot from relatively long distances and not necessarily from the neighbouring trees (Gross *et al.*, 2001). At the orchard level, the diverse population levels between plots allowed a significant linear relationship between male capture in certain trapping periods, suggesting a dependence between male capture and population level as related to CM phenology. The narrow range of mealybug densities and low variability observed in the studied orchards may explain the lack of relationship observed in Italy. Further observations are needed in order to confirm this hypothesis. In Portugal, the intervention threshold recommended for the CM is 5-10% of fruits infested with colonies of young nymphs, during summer. The relationship found between male capture and the percentage of fruits infested with colonies of young nymphs can be used to figure out a new intervention threshold based on male capture early in the summer, i.e., 20 males/trap/day, one or two weeks after the male peak of the flight in June. In Israel, early summer (June) is thought to be too late for use as a decision tool for CM management purposes in June/July because most of the mealybugs have already settled under fruit sepals. The main damage by the mealybug to the studied varieties are feeding scars caused by injuries to fruitlets dating from mid-May to late June. Furthermore, no significant correlation could be observed in Israel between mealybug density per fruit or percentage of fruit infestation in early season (mid July) and late season samplings (mid October) ones (Gross *et al.*, 1999). This may be related to the fact that the dynamic of fruit infestation differed between subplots and therefore correlation could not be established between the infestation of young fruits in July and that observed in October at the time of fruit picking.

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