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Effect of tomato deleafing on mirids, the natural predators of whiteflies

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Abstract – Sustainability in Mediterranean greenhouse agrosystems involves environmentally-friendly techniques based on biological and non-chemical methods. Deleafing is a common agricultural practice used to accelerate fruit ripening and facilitate farming methods. However, deleafing may have an impact on mirids, a natural predator used to control whiteflies, which are considered among the most noxious insect pests of field and greenhouse crops worldwide. Here we studied the impact of leaf removal on populations of mirids. Two deleafing practices were tested: (a) regular deleafing, with the first removal of 2 leaves per plant 10 weeks after sowing; and (b) delayed deleafing, in which the first removal was delayed by 14 days. Our results show that regular deleafing had a strong negative impact on mirid populations. Indeed, the first deleafing of the regular method eliminated 74% of young nymphs. Such a loss was not observed with the delayed method because nymphs were older and already distributed on leaves which were never thinned. As a consequence of this initial difference, mirid populations were 60% higher in the delayed than in the regular deleafing treatments at the end of the crop. The biological control of whiteflies was less efficient in the regular deleafing crop for which densities were, on average, 30% higher than in the delayed deleafing crop. Such inefficiency could call into question the sustainability in protected tomato crops of environmentally-friendly techniques focused on reducing the pesticides used.

deleafing / impact / ***Macrolophus caliginosus*** **/** ***Bemisia tabaci*** **/** ***Trialeurodes vaporariorum*** **/ tomato**

1. INTRODUCTION

The seriousness of the economic impact of whitefly and whitefly-transmitted virus complexes worldwide, up to 85% of crop yield losses, has resulted in accelerated research to provide acceptable management methods in crop protection (Oliveira et al., 2001). Integrated pest management (IPM), based on the integration of cultural, biological and non-chemical methods, is a goal for sustainable greenhouse crops (Ferron and Deguine, 2005), particularly vegetables and ornamentals (Van Lenteren, 2000). Sustainability in Mediterranean greenhouse agrosystems is mainly characterised by environmentally-friendly techniques focused on the high quality of the products such as high percentage of dry matter, low pesticide residues and low nitrate content (De Pascale and Maggio, 2005). Although biological control agents, such as predators and parasites, are the cornerstone of the success of IPM (Van Lenteren and Van Woets, 1988), little attention has been paid to quantifying the indirect impacts of crop practices on natural enemy action. In the Mediterranean region, the mirid *Macrolophus caliginosus* (Wagner) is an efficient predator commonly used to control the whiteflies *Trialeurodes vaporariorum* (Westwood) and *Bemisia tabaci* (Gennadius) in greenhouse crops of tomatoes (Malausa and Trottin-Caudal, 1996; Sampson and King, 1996; Schelt et al., 1996). However, difficulties are regularly encountered to establish the predator (Ridray and Trottin-Caudal, 2001).

It has been hypothesised that crop practices such as deleafing could have an impact on *Macrolophus* populations. Deleafing is a common agricultural practice in tomato crops and essentially responds to specific criteria, i.e., production and yield quality (Slack, 1981, 1986). It consists of progressively removing old leaves with poor photosynthetic activity from the lower strata. Leaf removal accelerates fruit coloration and maturation by improving light conditions. In addition, it facilitates fruit harvest and, by increasing air circulation between plants, reduces the development of fungal diseases. However, the effect of deleafing on mirid populations, which protect tomato plants by preying upon whiteflies, is not known. Here we investigated whether deleafing could eliminate eggs of mirids, which are inserted into the leaf tissues, and whether it could increase the mortality of young nymphs, which may be unable to move to tomato plants from the leaves left on the ground.

2. MATERIALS AND METHODS

The experiments were conducted between October 2002 and June 2003 at the INRA centre in Alenya (southern France) in a greenhouse which was split into 4 identical compartments of 150 m^2 each using whitefly-proof screen. The tomato variety "Clotilde" ("cluster type") was sown during the last week of October 2002, and grown in a nursery for one month under a whitefly-proof screen. The predator *M. caliginosus* was introduced on plants once in the nursery 2 weeks after sowing, at a density of 1.75 adults per plant. On the day of introduction, the bugs were fed with eggs of *Ephestia kuehniella* (0.03 g/plant) as recommended by Ridray et al. (1998). Thereafter, the crop was grown in the greenhouse. The plants were naturally infested by *T. vaporariorum* and *B. tabaci*. Emergence of 1st

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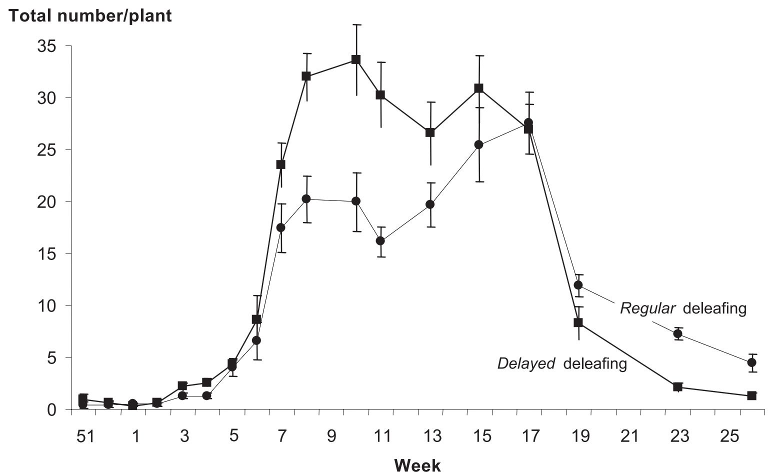

Figure 1. Number of whiteflies (adults and old nymphs) on tomato plants for the two deleafing practices (*delayed* and *regular*) tested. The biological control of whiteflies by the predatory bug (mirid) was less efficient in the *regular* deleafing crop for which densities were, on average, 30% higher than in the *delayed* deleafing crop.

generation *Macrolophus* nymphs began one month after the introduction of the adults. During the 3 weeks following nymph emergence, 0.02 g of eggs of *E. kuehniella*/m^2 were provided weekly to avoid food limitation and thus facilitate predator development.

Whiteflies and *M. caliginosus* populations were monitored in each of the four compartments throughout the experiment. The sampling unit was an entire plant. All plants belonging to a compartment were numbered and 12 plants per compartment were chosen by drawing lots. Each plant (sample) was stratified into levels, each level corresponding to the leaves (usually 3) present between two bunches. The lowest and oldest leaves situated under the first bunch were called level 0. At each sampling, the young and old nymphs and adults of *Macrolophus* and old nymphs and adults of whiteflies found at each level were counted separately. *Macrolophu*s nymphs present on the leaves that were removed were also counted. Sampling was done weekly from week 8 after sowing to week 17 after sowing. From week 18 to the last harvest, at week 35, eight further samplings were carried out.

Two deleafing methods were tested, the *regular* procedure in two compartments (R_1, R_2) and the *delayed* procedure in the two others (D_1, D_2):

The *regular* procedure is commonly used by producers. In our study the first removal of 2 leaves per plant took place 10 weeks after sowing, followed one week later by the removal of 5 more leaves per plant; then from week 15 until week 19, three more deleafings of 3 leaves per plant were carried out to obtain plants with only 16 leaves one week before the first harvest. Sixteen leaves per plant were maintained from week 19 until the end of the crop by removing the necessary number of leaves at two-weekly or monthly intervals.

In the *delayed* procedure, the first removal (2 + 5 leaves/plant) was delayed by 14 days until weeks 12 and 13 after sowing. In addition, to facilitate optimal migration of *Macrolophus* nymphs within the tomato plants, 20 leaves were left on each plant one week before the first harvest in week 19 and subsequently the plants were maintained with 22 leaves.

Statistical analyses. Before pooling replicates to obtain one set of data per treatment (*regular* or *delayed*) and per population (whiteflies or predators), a Mann-Whitney test was performed between replicates, i.e. R_1 compared with R_2, and D_1 with D_2. Data for weeks 10, 12, 16, 19 and 25 after sowing and for week 34 (the end of the experiment) were analysed. The number of *M. caliginosus* present before and after leaf removal in each treatment was compared with a Mann-Whitney test ($\alpha = 0.05$). The proportion of young and old nymphs observed before deleafing (*regular* or *delayed*) was compared using a χ^2 test ($\alpha = 0.05$).

3. RESULTS AND DISCUSSION

3.1. Phenology of whiteflies and *M. caliginosus* populations

Whiteflies and mirid populations were monitored on plants in each of the four compartments. Compartments R_1 and R_2 correspond to the *Regular* deleafing method tested, and D_1 and D_2 to the *Delayed* one. Because no significant difference was found between R_1 and R_2 or between D_1 and D_2 ($P < 0.05$, $\nu = 22$), data were pooled for each treatment (*regular* or *delayed*). Whitefly populations consisting mostly of *Trialeurodes vaporariorum* (85%) were observed 3 weeks after transferral of plants from the nursery to the greenhouse (Fig. 1).

From week 11 to week 18, whiteflies increased rapidly at a similar rate in both procedures to reach a maximum of 33 and 17 individuals per plant with the *delayed* and *regular* procedure, respectively. From week 25 on, a constant decrease was observed until the end of the cropping cycle. For *M. caliginosus* (Fig. 2), a very homogeneous cohort of young 1st generation nymphs was observed from week 7 onwards, with similar densities in both treatments. In week 11, a drastic decrease associated with the first deleafing was observed with

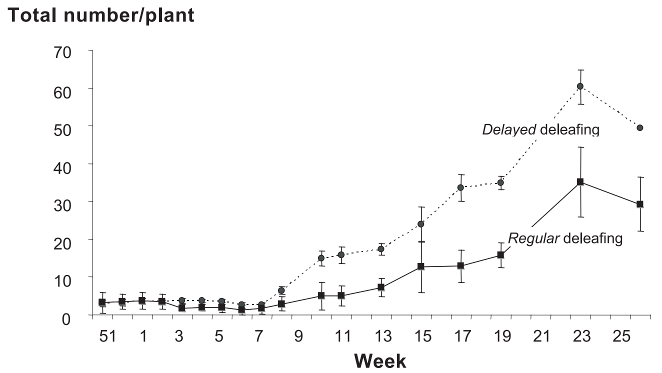

Figure 2. Number of *Macrolophus caliginosus* (adults and old nymphs) on tomato plants for the two deleafing practices (delayed and regular) tested. The gap created by the first leaf removal increased and led to significant differences between mirid populations which were, at the end of the crop, 60% higher in *delayed* than in *regular* deleafing.

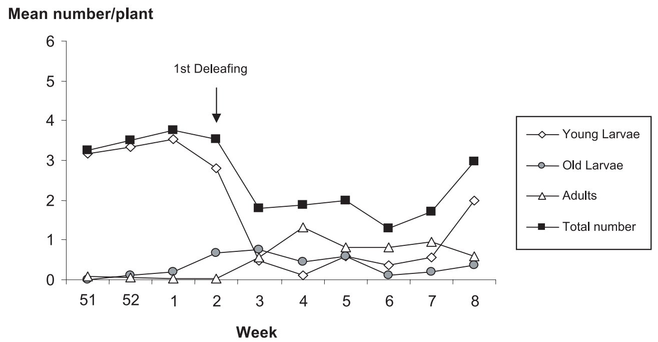

Figure 3. Population structure of *Macrolophus caliginosus*, a biological agent used to control whiteflies on tomato, for the *regular* deleafing practice. The drastic decrease in young nymphs observed just after the first deleafing was not offset by an equivalent increase in the number of older nymphs and there was thus a significant loss of predators.

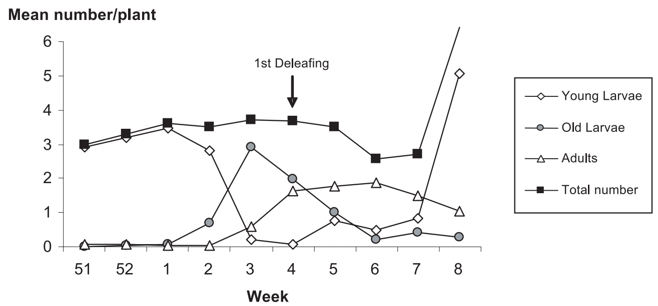

Figure 4. Population structure of *Macrolophus caliginosus*, a biological agent used to control whiteflies on tomato, for the *delayed* deleafing practice. The first deleafing had no effect on young nymphs because they had already passed to an older stage and there was thus no significant loss of predators.

the *regular* treatment. The difference between the two treatments remained stable until week 15 after sowing. Thereafter, corresponding to the emergence of 2nd generation nymphs, the difference between the two treatments increased, with the lowest densities of *M. caliginosus* observed with the *delayed* treatment. Statistical analyses performed in weeks 10, 12, 16, 19, 25 and 34 (after sowing) showed that except for week 10 where $P > 0.05$, there was always a significant difference in *M. caliginosus* populations between the *delayed* and *regular* treatment ($P < 0.001$).

3.2. Impact of the first deleafing on *M. caliginosus* dynamics

Special attention was paid to the age-structure relationship of the population in the period encompassing first leaf removal for both practices. With the *regular* treatment, a drastic decrease in young nymphs was observed just after the first deleafing (Fig. 3), which was not offset by an equivalent increase in the number of older nymphs. Thus, one week after deleafing, the total number of *M. caliginosus* (nymphs and adults) decreased significantly by almost 50% ($P < 0.001$; $Z = 1.96$; $Z_{calculated} = 7.85$). In the *delayed* treatment (Fig. 4), leaf removal had no effect on young nymphs because they had already passed to an older stage by the time deleafing took place, and there was thus no significant loss of predators ($P > 0.05$; $Z = 1.96$; $Z_{calculated} = 1.65$).

Intra-plant distribution of *Macrolophus* nymphs was also studied. For both practices, until week 2, 80% of the first generation of young nymphs was recovered at level 0, which is the oldest level (Tab. I). Subsequently, the nymphs were distributed among higher levels that were never thinned. When the first *regular* thinning took place, 80% of the nymph population was located under the first bunch and comprised 80% of young individuals with poor moving ability. Two weeks later, in the *delayed* procedure, the nymphs were older, mobile and already present at all plant levels. Only 20% of the nymphs were recovered at level 0. To support the hypothesis that exportation of nymphs at first deleafing was responsible for the difference in population densities between the two practices, at each leaf-removal operation (except the last one) we also counted the number of nymphs present both on the plant before deleafing and on the leaves that were removed (Tab. I). Our results showed that at the first deleafing in the *regular* treatment only, a significant number of nymphs was eliminated (74%).

4. CONCLUSION

We showed that the common practice of *regular* deleafing has a strong negative influence on the development of *M. caliginosus* mirid populations. The first deleafing is highly effective as it eliminates almost all the young nymphs (74%) belonging to the first generation, thereby delaying the increase in the population. Because *M. caliginosus* mirids are used as a biological agent to control whiteflies, it is important that populations of this natural enemy of whiteflies reach high densities as fast as possible. Well-established populations of mirids are

Table I. Percentage of young and old nymphs of *Macrolophus caliginosus* found on level 0 of tomato plants before the first *deleafing* of both the *regular* and *delayed* practices and percentage of nymphs (old and young) removed by deleafing.

	Regular	*Delayed*
% of individuals present		
Young nymphs	80	10
Old nymphs	20	90
% of nymphs removed	74	0.1

able to maintain whiteflies at low densities and therefore drastically reduce pesticide use. A two-week delay in deleafing, which corresponds to approximately 6 leaves, significantly reduced losses of the *M. caliginosus* mirids. The young nymphs had already developed to older stages, and were thus more mobile and better distributed throughout the plant. Therefore, only 0.1% were lost, compared with the 74% in the *regular* deleafing. Because deleafing essentially corresponds to production and yield quality criteria, the delayed practice we propose represents a good compromise between production requirements and the sustainability of non-chemical methods.

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