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Threshold-based spraying decision programs for the tomato leafminer, *Tuta absoluta* on tomato greenhouse

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Abstract - The tomato leafminer miner, *Tuta absoluta* (Meyrick) (Lepidoptera, Gelechiidae) is an important insect pest of greenhouse tomatoes, *Lycopersicon esculentum* in Tunisia. The damages are severe and caused huge economic losses. Because no threshold levels are available for *T. absoluta*, many growers are applying chemicals at a calendar-based interval in which up to 20 sprays are provided. In order to diminish pesticide applications and to preclude damages to leaves and fruits, the implementation of a threshold level for optimum timing of chemical applications is required. A study was conducted in Saheline region of Tunisia to compare 8 alternative strategies for the control of the tomato leafminer, *Tuta absoluta* under greenhouse during two tomato cropping seasons in 2010 and 2011. The intervention protocols (strategies) included (1) ST1 = density of 1-4 galleries or larvae per plant , (2) ST2 = density of 5-8 galleries or larvae per plant, (3) ST3 = 9-16 galleries or larvae per plant (4) ST4= superior to 16 galleries or larvae per plant, (5) ST5 =systematically sprayed with chemicals, (6) ST6= systematically sprayed with organic product (spinosad), (7) ST7 unsprayed (control) and (8) ST8 = Sprayed alternatively with conventional chemical and plant extracts. The alternatives were evaluated with (1) the density of *T. absoluta* biological stages (eggs-pupae) in tomato leaves, (2) the percentage of larval mortality and (3) the fruit quality (the percentage of infested fruits).
Results demonstrate the good performance of spinosad (ST6) in the reduction of fruit infestation. There is a difference between ST1, ST2, ST4 and ST5 regarding the larval density suggesting shifting from systematically chemical spray to spraying when population densities reach more than 16 galleries or larvae per plant (ST4). The strategy 8 (combination chemical – organic sprays) seems to be better than Strategy 5 (chemical control only) suggesting the need to integrate plant extracts as soft insecticides in the integrated pest management of the tomato leafminer.

Keywords: *Tuta absoluta,* tomato greenhouse, threshold level; insecticide sprays, plant extract, Tunisia.

1. Introduction

In Tunisia, tomato, *Lycopersicon esculentum* Mill is the leading horticultural crop with a production area of 25,000 hectares and a total harvest of 1.37 million tons in 2012 (Onagri, 2015). Tomatoes are grown both under plastic covered greenhouses and in the open field.
Tomato raised under greenhouse cannot be grown successfully if it is not protected against insect pests. For that reason, the pest control strategies have relied heavily on insecticides applied on a calendar program which constitutes a simple way to increase yield and production. The problem become more acute with the detection of the tomato borer, *Tuta absoluta (*Lepidoptera: Gelechiidae) in the country in late 2008 (OEPP, 2009). Originating from South America, the insect was first detected in Eastern Spain in late 2006 (Urbaneja *et al*., 2007,), and then rapidly invaded many other European and Mediterranean countries (Desneux *et al*., 2010, Gonzalez-Cabrera *et al*., 2011, Urbaneja, 2010). No threshold for tomato borer is used in Tunisia; growers generally rely on insecticide applications usually at 7 to 14 days interval without regards to larval density of the insect (Braham, unpublished data). This technique often results in poorly timed or unnecessary application of insecticides.

Thus, this study aims at assessing from a greenhouse trial, the effectiveness of potential alternative management strategies including larval density, conventional chemical versus organic farming acceptable products sprays in order to select the most feasible approach to control the tomato leafminer.

2. Material and methods

2.1. General procedures

Trials were conducted during two consecutive years (2010 and 2011) in a plastic greenhouse (64 m in length, 8 m width and 3 m height) at the research station belonging to Regional Research Center in Horticulture and Organic Agriculture based in Saheline region (35°40'N 10°45'E). In 2010 season, Tomato seeds with undetermined growth habit (cv Pacal) were sown under a greenhouse on October 27, 2009 in nursery beds and transplanted in 4 double rows on 23 November 2009. In 2010, seeds (cv Pacal) were sown on 7 October 2010 and transplanted on 1st November 2010. The distance between each double row was 1 meter. On the row, plants were separated by 0.75 x 0.4 meters for a density of 2.5 plants per m^2. Plants were grown by twisting the stem to horizontal support wires above. Basal leaves were periodically pruned as they became senescent and lateral shoots were regularly removed.

A water bucket trap harboring a pheromone plug (Tutasan, Koppert) was setup in the middle of the central row (height = 20 cm) on 18 March 2010 and on 19 March 2011to monitor the activity of the moth. Pheromone capsules were removed at a month interval.

2.2. Management strategies

Eight management strategies were evaluated within a randomized block design with four replicates. The intervention protocols (strategies) included (1) ST1 = density of 1-4 galleries or larvae per plant, (2) ST2 = density of 5-8 galleries or larvae per plant, (3) ST3 = 9-16 galleries or larvae per plant (4) ST4= superior to 16 galleries or larvae per plant, (5) ST5 =systematically sprayed with chemicals, (6) ST6= systematically sprayed with organic product (spinosad). Spinosad was used in this study because it is one of theenvironmentally friendly and is significantly proven to be effective against *T. absoluta* (Braham *et al.*, 2012) and it is the mostly common used insecticide by growers in the region (7) ST7 unsprayed (control) and (8) ST8 = Sprayed alternatively with conventional chemical and plant extracts. To evaluate the proposed thresholds (strategies), weekly scooting of 5 randomly selected plants per treatment per block was conducted to determine if threshold had been reached (from 29 March to 12 June, 2010 and from 18 March to 9 May in 2011). Concerning the strategies ST1, ST2, ST3 and ST4, the first spray was undertaken within 48 hours when the threshold had been reached followed by regular spraying (every 10 to 12 days). All chemicals used are authorized for use against *T. absoluta* on tomatoes in Tunisia. The doses of active ingredient and commercial product are given by Braham and Hajji (2012).

For strategies ST5, ST6, and ST8 the first spay was undertaken when infestation appeared followed by regular spraying every 10 to 12 days (Table II). All the chemicals were applied with a backpack sprayer manually operated.

2.3. Sampling

To determine the tomato leaf miner level, 10 leaves per bloc (10 x 4 = 40 per treatment) were collected (total 320 per greenhouse 40 x 8 Strategies) at random at different plant height. Leaves infested by *T. absoluta* harbor live or dead biological stages (eggs, larvae, pupae) and empty galleries. Although empty galleries were not biological stages, since no larvae or pupae were present, they were considered in this study in order to quantify insect infestation. Number of galleries and live/or dead *T. absoluta* biological stages (eggs, larvae, and pupae) were counted in the laboratory.

In 2010, tomatoes were harvested on 15 April, 27 April, 4 May and 11 May 2010 and in 2011 on 8, 15,27 April and 11 May 2011. All fruits were counted and graded as infested by *T. absoluta*, and considered as unmarketable and healthy fruits.

Table 1. Spraying schedules carried out in 2010 and 2011 according to strategies

Dates	Strategies	Sprays
2010 Study year		
26 March	ST1, ST2, ST5, ST6, ST8	Oxamyl for ST1, ST2, ST5, ST8. Spinosadfor ST6
05 April	ST1, ST2, ST3, ST5, ST6, ST8	Oxamyl for ST3. Armorex for ST8. Ampligo for ST1, ST2, ST5. Spinosad for ST6
8 April	ST4	Oxamyl for ST4
14 April	ST1, ST2, ST3, ST4, ST5, ST6, ST8	chlorantraniliprole + abamectin for ST8. Emamectin benzoate for ST1, ST2, ST3, ST4, ST5. Spinosad for ST6
23 April	ST1, ST2, ST3, ST4, ST5, ST6, ST8	Tutafort (plant extracts) for ST1, ST2, ST3, ST4, ST5
5 May	ST1, ST2, ST3, ST4, ST5, ST6, ST8	Konflic (plant extract) for ST8. Tracer for ST6 Cyromazine for ST1, ST2, ST3, ST4, ST5. Spinosad for. ST6. Thiamethoxam + lambda-cyhalothrin) for ST8
29 May	ST1, ST2, ST3, ST4, ST5, ST6, ST8	Lambda-cyhalothrin for ST1, ST2, ST3, ST4, ST5. Spinosad for ST6. Deffort (plant extract) for ST8
2011 Study year		
04 April	ST1, ST2, ST5, ST6, ST8	Oxamyl for strategies ST1, ST2, ST5, ST8. Spinosad for ST6
18 April	ST1, ST2, ST5, ST6, ST8, ST3	Oxamyl for ST3. Armorex for ST8. Ampligo for ST1, ST2, ST5. Spinosad for ST6
2 May	ST1, ST2, ST3, ST4, ST5, ST6, ST8	chlorantraniliprole + abamectin for ST8. Emamectin benzoate for ST1, ST2, ST3, ST5. Tracer for ST6
18 May	ST1, ST2, ST3, ST4, ST5, ST6, ST8	Tutafort (plant extracts) for ST1, ST2, ST3, ST4, ST5. Konflic (plant extract) for ST8. Tracer for ST6.
30 May	ST1, ST2, ST3, ST4, ST5, ST6, ST8	Cyromazine for ST1, ST2, ST3, ST4, ST5. Tracer for ST6. thiamethoxam + lambda-cyhalothrin for ST8

2.4. Statistical analysis

Data regarding the number of biological stages, and empty galleries were analyzed using a one-way analysis of Variance ANOVA ($P<0.05$) and differences between strategies means were compared using the Student- Newman-Keuls test. All statistical analyses were carried out using the SPSS version 20 (IBM, SPSS). The 5% level of significance was used for all analyses.

3. Results and Discussion

3.1. Dynamic of adult population

In 2010, the number of males captured in water pheromone trap varies between 59 and 390 with a maximum four days following the trap setup to remain almost constant (130 males on average) at every inspection date (Fig. 1). In 2011, the number of males captured varied between 23 and 360 with an average of 148 insects. For both years the maximum of adults were captured during April-May (Fig. 1).

3.2. Density of biological stages

3.2.1. Year 2010

Overall, considering all sampling dates, the mean number of eggs, larvae and pupae per tomato leaf shows no significant difference between strategies (ANOVA, 1 factor, $F_{3,96} = 0.96$; $P= 0.46$). However, ST7 (control) harbored the maximum density (Table 2). Two sampling dates show significant differences between strategies (on 29 March and on 29 May 2010). On the first date this difference may be due to sampling procedures and on the second Strategy 3 shows the maximum of biological stages densities.

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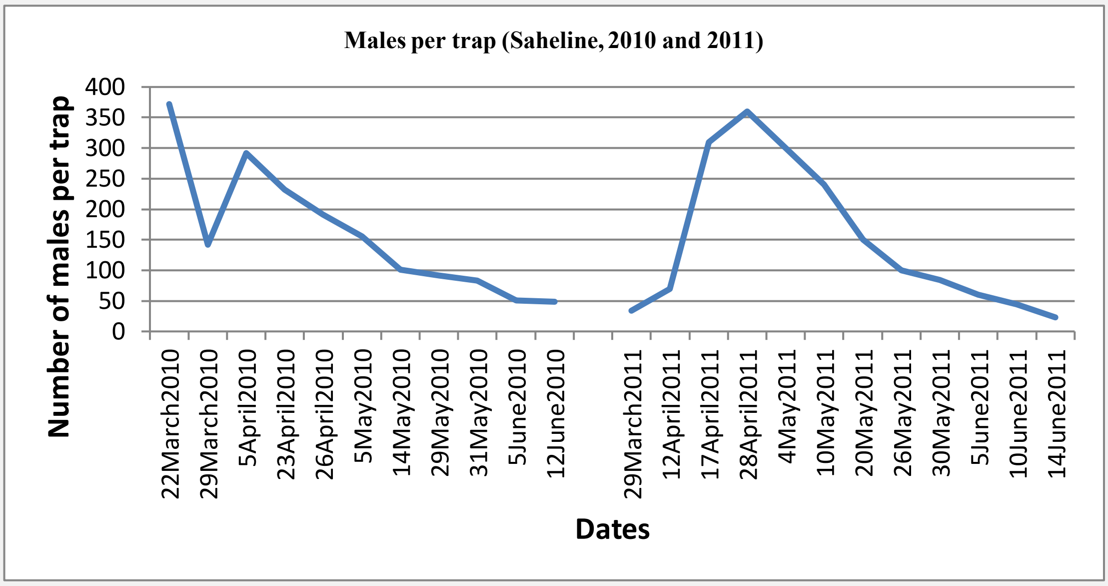

Figure. 1. Number of *T. absoluta* males captured in wáter traps during the two study years (2010 and 2011)

Table 2. Mean number of biological stages (eggs, larvae, pupae) per tomato leaf in 2010

Dates	ST1	ST2	ST3	ST4	ST 5	ST6	ST7	ST8	ANALYSIS
29March	1±0ab	1.25±0.9b	1±0ab	0.25±0.5a	1.5±0.6b	1.75±0.5b	2±0b	1.5±0.6b	$F_{7,24}$ =4.5; P= 0.003
8April	0.75±1.5	0.25±0.5	0.75±0.95	0.75±0.95	0.5±0.95	0	1.25±1.8	1.25±1.25	$F_{7,24}$ =0.62; P= 0.73
10April	0.25±0.5	0	0	0.5±1	0.5±1	0.5±0.57	0.25±0.5	0	$F_{7,24}$ =0.6; P= 0.74
14April	0.75±0.5	0	0.25±0.5	0.75±0.95	0.75±0.5	0.25±0.5	1.25±1.2	0.25±0.5	$F_{7,24}$ =1.4; P= 0.23
23April	0.25±0.5	0.5±1	0	0.5±1	1±1.4	0.5±0.5	0.75±0.0	1.5±1.7	$F_{7,24}$ =0.80; P= 0.59
26April	1.5±1.7	1±.1	0.75±0.95	1.25±1.25	1±0.8	1±0.8	2.75±2.6	0.25±0.5	$F_{7,24}$ =1.1; P= 0.39
3May	0.8±0.5	0.6±0.4	0.7±0.4	0.7±0.4	1.2±1.4	0.6±0.6	0.5±0.4	0.9±0.4	$F_{7,24}$ =0.51; P= 0.81
7May	0.5±0.5	0.75±0.95	1.25±1.5	0.5±0.5	0.5±0.5	0	0.5±0.5	1.75±0.5	$F_{7,24}$ =1.9; P= 0.10
14May	0.5±0.5	1.75±0.5	1.25±0.5	1.5±0.5	0.75±0.5	0.75±0.9	1.75±1.7	1.7±1.5	$F_{7,24}$ =1.14; P= 0.37
29May	3±0bc	3.2±0.9bc	4c	1.7±0.9ab	1a	3.75±1.5c	2.25±1.2abc	2.25±0.5abc	$F_{7,24}$=5.6; P= 0.001
31May	4.75±5.5	3.75±2.8	2.25±1.25	4.25±2.5	4.75±1.5	4.25±3.3	6.5±1.7	3±1.15	$F_{7,24}$ =0.8; P= 0.58
5June	1±0.8	2.25±0.5	5.5±7	2±1.15	2±1.4	2.5±1.2	4.25±1.5	2±0.8	$F_{7,24}$ =1.16; P= 0.36
12June	2±0.8	1.75±0.5	3.75±2.3	1.75±0.5	2.25±0.9	2.25±0.5	3±0.8	1.75±0.5	$F_{7,24}$ =1.86; P= 0.12

On the row, means with the different letters were not significantly different at P< 0.05 (Student-Newman-Keuls test)

3.2.2. Year 2011

There is no significant difference between strategies relating to sampling dates except on the dates of 1 April and 2 May where strategy 7 (control) harbor the maximum of biological stages (Table 3).

Table 3. Mean number of biological stages (eggs, larvae, pupae) per tomato leaf in 2011

Dates	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ANALYSIS
18March	0.5±01.2ab	0.8±0.6b	0.1±0.2a	0.2±0.5ab	0.3±0.5ab	0.1±0.3ab	0.5±1ab	0.6±0.6ab	$F_{7,152}$ =2.2; P= 0.03
23March	0.15±0.4	0.6±1.1	0.65±1.4	0.65±1.4	0.75±1.6	0	0.55±1	0.9±1.5	$F_{7,152}$ =1.3; P= 0.65
1April	0.2±0.2a	0.1±0.3a	0.3±0.9a	0.2±0.5a	0.1±0.3a	0.1±0.4a	1.4±3.1b	0.2±0.5a	$F_{7,152}$ =2.7; P= 0.01
14April	6±6.4	2.4±2.1	4.9±4.1	5.3±3.9	4.7±6	5.5±4.7	2.8±5	4.2±4.5	$F_{7,152}$ =1.5; P= 0.16
20April	1.2±1.4	0.9±1	0.9±1	1.5±1.5	1.3±1.5	1.4±1.7	1.5±2.7	1.5±1.6	$F_{7,152}$ =0.5; P= 0.85
2May	0a	0a	0.1±0.3a	0.3±0.4ab	0a	0.4±0.9ab	0.7±0.9b	0.3±0.5ab	$F_{7,152}$ =4.5; P= 0.00
9May	0.5±0.8	0.8±1.1	0.9±0.9	1.3±1.2	1.2±1.3	0.7±0.9	1±1.1	0.9±1.1	$F_{7,152}$ =1.1; P= 0.39

3.3. Density of empty galleries

In 2010, the densities of empty galleries show no significant differences among strategies for all sampling dates except on the sampling of 29 May 2010 where strategies 1 and 2 have the maximum of empty galleries. This is may be due to sampling procedures (Table 4).

Table 4. Average number of empty Galleries per leaf (2010)

Dates	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ANALYSIS
29March	2.75±0.9	2.2±0.5	2.25±0.5	2±0.8	2.2±0.8	2±0.8	2±0.8	2.25±1.25	$F_{7,24}$ =0.42; P= 0.87
8April	2±2.1	2.7±0.9	3.5±2.3	4.2±2	3±1.8	2.2±0.9	4.2±2	5.5±2	$F_{7,24}$ =1.56; P= 0.19
10April	1.5±1.3	1.2±0.5	2.2±	3.5±1.3	3.2±1.7	2.2±1.2	2±1.8	1.7±0.5	$F_{7,24}$ =1.6; P= 0.18
14April	3.7±1.5	2.7±0.9	3.75±2	5.2±1.5	3.2±1.5	3±1.1	5±3.3	3.5±0.6	$F_{7,24}$ =1.04; P= 0.42
23April	5.7±2.8	4.2±2.6	5±1.8	4±2.8	4.7±4.2	2±1.1	4.2±1.9	4.2±3.2	$F_{7,24}$ =0.62; P= 0.73
26April	8±6.2	6.2±1.7	4.7±2.5	4.75±2.8	4.2±2.7	5±2.1	8.7±7.8	5.5±3	$F_{7,24}$ =0.62; P= 0.73
3May	9±4.6	7±3	7.5±3.3	7.25±2.3	8±4.7	7.5±5	5.7±1.7	10.7±4.6	$F_{7,24}$ =0.59; P= 0.75
7May	4±2	3.5±1	7.2±5.3	4.5±3.5	3.25±2	5±2.9	2.9±1.9	1.9±0.9	$F_{7,24}$ =1.04; P= 0.42
14May	3.5±1	9.25±6	7.25±3	9.75±4.3	7.5±5.6	6.5±1	6.75±0.9	10.2±3.7	$F_{7,24}$ =1.33; P= 0.27
29May	10b	8.7±0.9ab	0ab	2.5±1.25ab	0ab	1.8±0.9ab	3.5±1.7ab	2.5±1.25a	$F_{7,24}$ =2.76; P= 0.03
31May	9.75±2.5	11±5	8±0.8	9±3.5	10.75±2.7	8.33±3.7	11.5±1.7	9.5±3.7	$F_{7,24}$ =0.6; P= 0.74
5June	6.75±3.2	6.25±3.2	10.5±7.14	10.25±7.5	12±8	6±2.8	5.5±1.9	15±10.23	$F_{7,24}$ =1.22; P= 0.32
12June	7.5±3.5	6.25±1.7	11±4.7	8±3.7	8.5±4.1	8.5±7	7±2.16	7.75±3.4	$F_{7,24}$ =0.46; P= 0.85

On the row, means with the same letters were not significantly different at P< 0.05 (Student-Newman-Keuls test).

In 2011, the average empty galleries per leaf varied according to sampling dates except of the sampling of 23 March and 9 May 2011 (Table 5).

Table 5. Average number of empty Galleries per leaf (2011)

Dates	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ANALYSIS
18March	0.4±0.6a	0.4±1a	1.0±1.6ab	1.6±1.5ab	2.5±4.1b	1.4±1.4ab	1.1±1.5ab	0.7±1.4a	$F_{7,152}$ =2.5; P= 0.02
23March	0.25±0.5	0.4±1.3	0.7±1.2	1±1.5	0.6±1	0.4±0.9	0.6±1.1	0.3±0.4	$F_{7,152}$ =0.95; P=0.46
1April	01±0.3a	0.3±0.7a	0.1±0.5a	0.2±0.5a	1.1±1.5b	1.3±2.1b	0.2±0.9a	0.2±0.4a	$F_{7,152}$ =3.9; P= 0.01
14April	0.3±0.4ab	0.1±0.2a	0.2±0.4a	0.3±0.5ab	0.4±0.9ab	0.2±0.6a	1±1.3b	0.3±0.9ab	$F_{7,152}$=2.5; P= 0.01
20April	4.6±5.2ab	3.3±2.9ab	2.9±3.5ab	5.9±4.4b	4.9±4.5ab	2.9±1.9ab	2.2±2a	2.2±1.7a	$F_{7,152}$=2.9; P= 0.007
2May	0a	1.1±3.4ab	2.9±4.3ab	7.5±6.4bc	7.3±6.2abc	3.1±5b	0.3±0.9a	10.6±17c	$F_{7,152}$=4.5; P=0.001
9May	1.8±1.8	1.9±2.1	1.9±1.5	2.4±2.1	2±2.4	1±0.7	1.6±1.3	1.8±1.5	$F_{7,152}$ =0.9; P= 0.50

3.4. Fruit infestation

In 2010, the first harvest (April 15, 2010), shows no significant difference between strategies regarding the percentage of fruit infestation (ANOVA, one factor, fruit weight; $F_{7,24}$ = 0.84, P= 0.56; Fig. 2, and fruit number ($F_{7,24}$ = 0.64, P= 0.72; Fig 3). The activity of the pest is rather slow as showed by the relatively low fruit infestation value (13.75 %). The second harvest (April 27, 2010) shows no significant difference among strategies (ANOVA, one factor, $F_{7,24}$ = 1.17 P= 0.39, Fig. 2). The third harvest (4 May) shows a significant difference between control and the other strategies (ANOVA, one factor, $F_{7,24}$ = 2.46 ; P= 0.04. but, there is no significant difference between the other strategies (Fig. 2, Fig. 3).
The final harvest (May, 11) shows a significant difference between control and the other seven strategies (ANOVA, one factor, $F_{7,24}$ = 2.80, P= 0.03, Fig. 2; Fig 3).

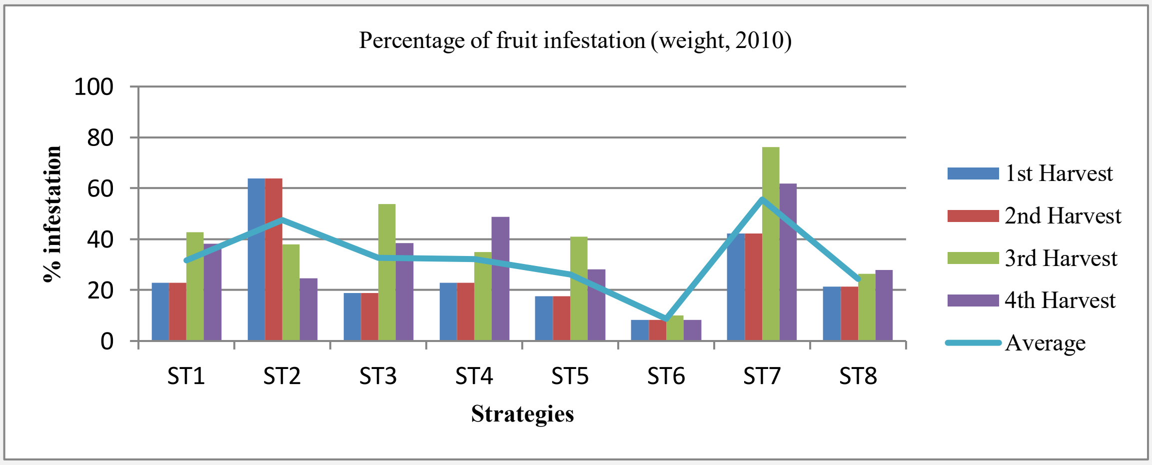

Fig. 2. Percentage of fruit infestation (weight) according to tested strategies in 2010

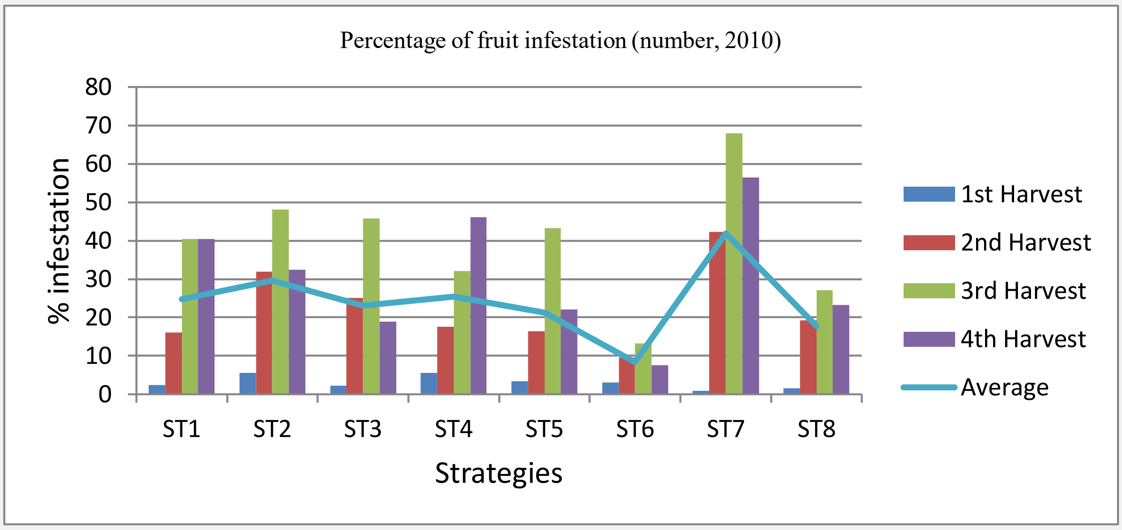

Fig. 3. Percentage of fruit infestation (number) according to tested strategies in 2010

Strategy 6 (exclusively organic sprays using spinosad) harbors very low fruit infestation for the second, third and fourth harvest. Spinosad is considered a good alternative control of Lepidoptera larvae due to its high activity at low rate and its use in integrated pest management programs. The product is highly used against *T. absoluta* in Tunisia (Braham and Hajji, 2012)

Strategy 8 (combination chemical – organic sprays) seems to be better than Strategy 5 (chemical control only). The combination of conventional chemical sprays and organic based insecticides is a key stone to establish an integrated pest management strategy targeting key insects shifting from calendar spraying program to a more reasonable treatment based on threshold data.

In 2011, for the four harvested times, there are no significant differences between strategies regarding the number of fruits (first harvest: $F_{7,24}$= 0.5; P=0.82. Second harvest: $F_{7,24}$= 0.47; P= 0.84; third harvest $F_{7,24}$= 1.08; P= 0.40; Fourth harvest $F_{7,24}$= 1.19; P= 0.34), Fig. 4. Fig 5)

Weight (first harvest: $F_{7,24}$= 1.16; P=0.36. Second $F_{7,24}$= 0.06 P= 0.92; third harvest $F_{7,24}$= F= 0.08 P= 0.50; Fourth harvest $F_{7,24}$= 2.3 P= 0.059); Fig. 4 and Fig 5.

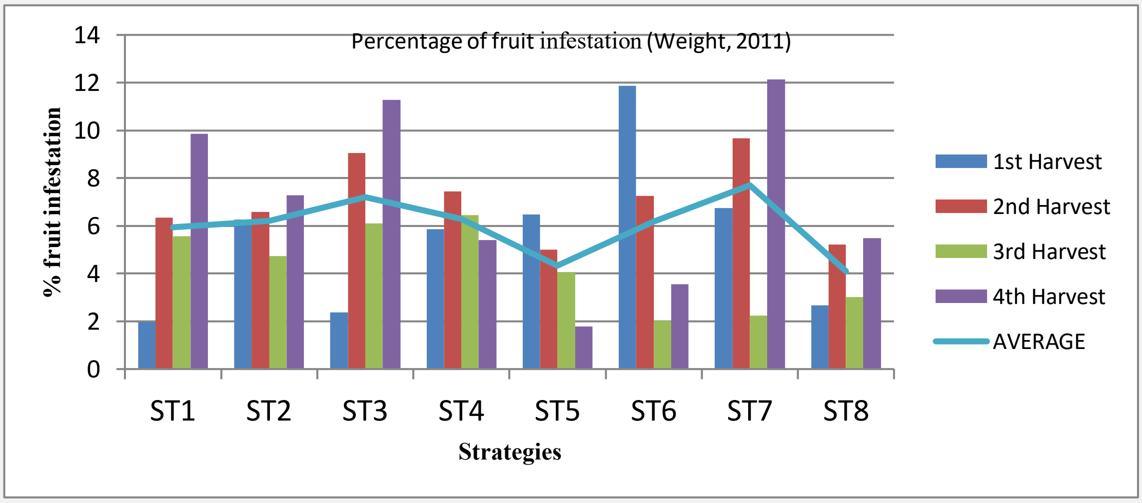

Fig. 4. Percentage of fruit infestation (in weight) relating to tested strategies (in 2011)

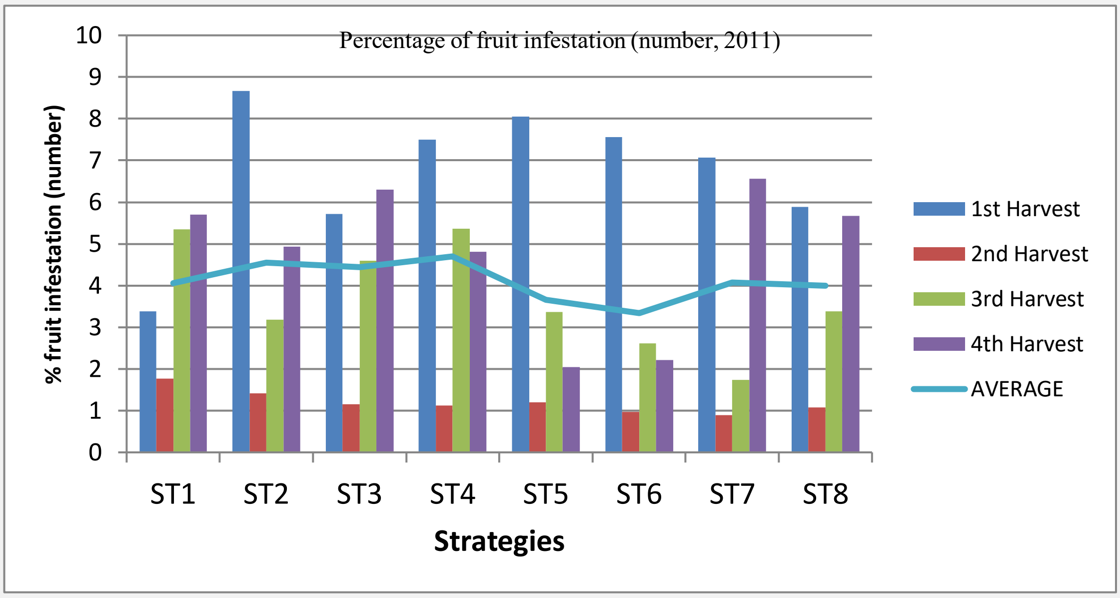

Fig. 5. Percentage of fruit infestation (in number) relating to tested strategies (in 2011)

3.5. Strategies comparison

3.5.1. Larval mortalities

The mean percentage of larval mortality during the two years of study shows high value (43 %) for Strategy 2, followed by strategies 1, 5 and 8 (Fig 6.). The low percentage is given in the strategy 7 (control) (Fig 6.). Both small and old *T. absoluta* larvae were found dead with no significant difference (Fig 7).

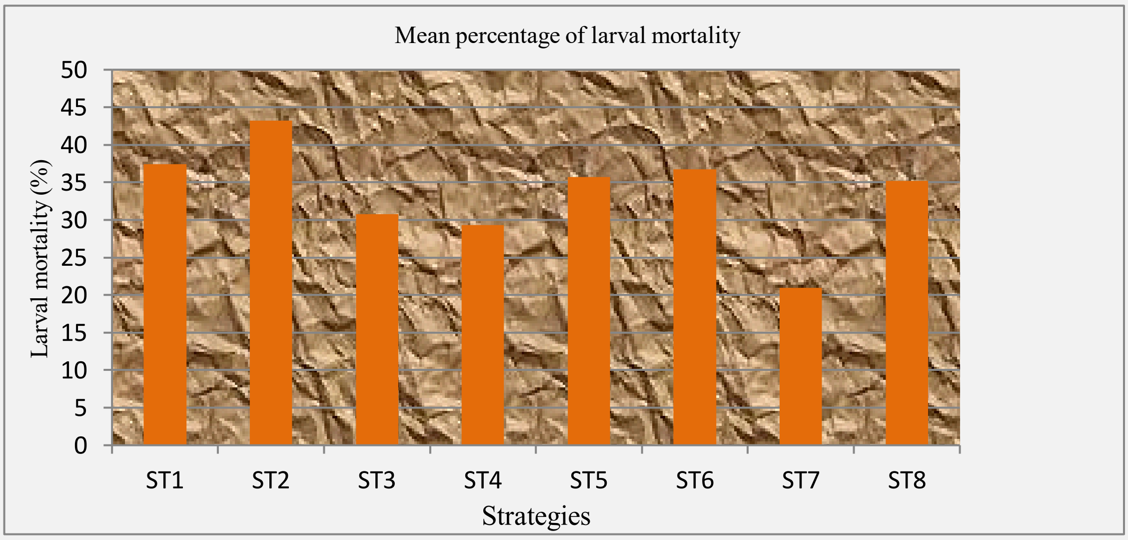

Fig. 6. Average percentage of larval mortalities according to strategies

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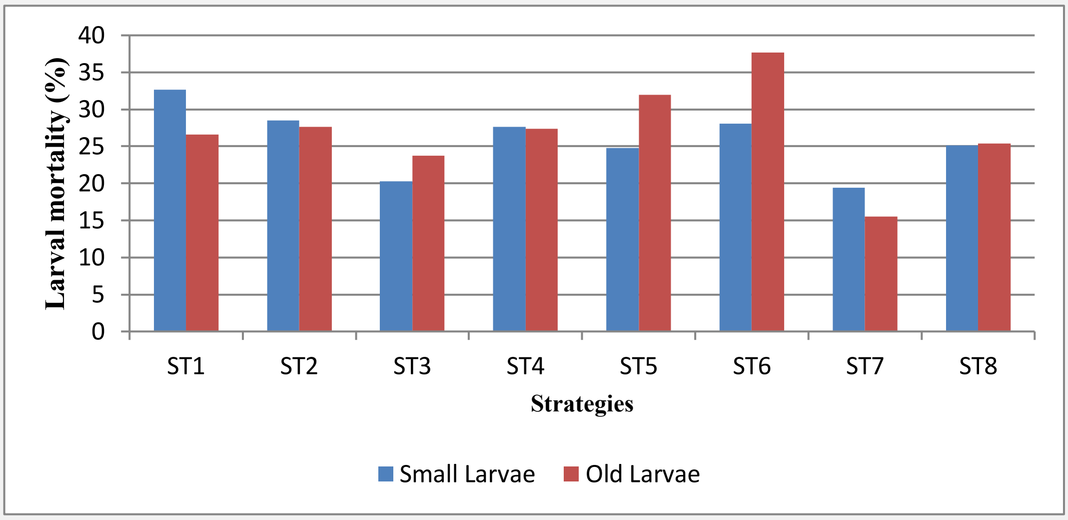

Fig 7. Percentage of larval mortality for small and old *T. absoluta* larvae

3.5.2. Chemical sprays versus plant extract and combination for ST5, ST6, St7 and ST8

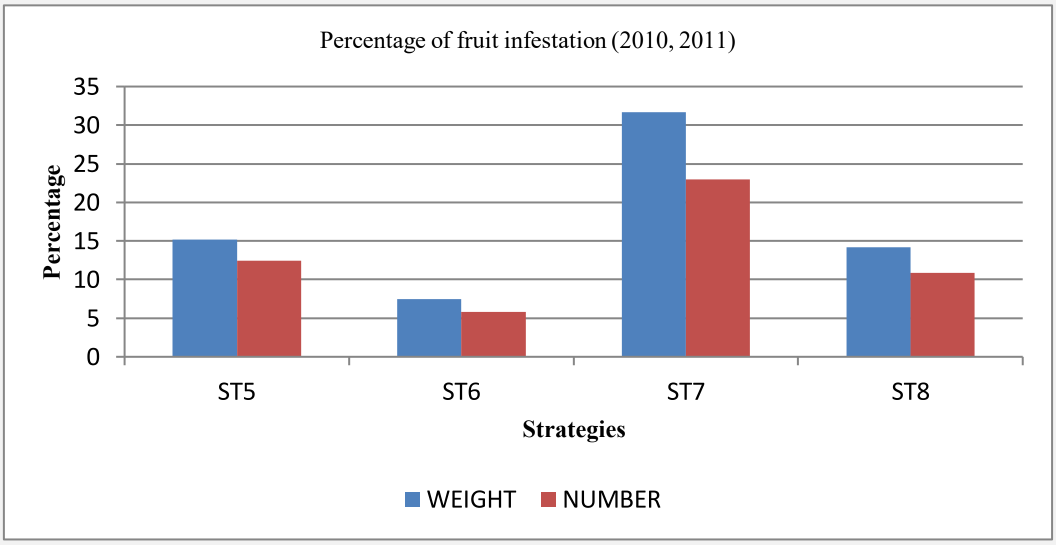

Fig 8. Percentage of fruit infestation for ST5, ST6, St7 and ST8

The comparison the effectiveness of the use of organic product (ST6, Spinosad) versus chemical (ST5) versus combination spinosad –chemical (ST8) showed the efficacy of spinosad followed by the using alternatively chemical products-Spinosad (ST8, Fig. 8).

In the early years of the reporting *T. absoluta* in the Mediterranean basin, empirical thresholds used in management programs to control *T. absoluta* infestations were based on male captures in pheromone traps (Monserrat, 2009). Adult catches in protected tomato crops can only be correlated with leaf infestation at low population density (Delrio *et al.*, 2012). Weekly adults captured in our study in more than 25 per week suggesting a high population density (Fig. 1). Thus, captures data cannot be considered as reliable information for spraying decision.

Threshold-based spraying decision programs are considered as important options in integrated pest management (Silvie *et al.*, 2001). Calendar- based sprays is the only option that has been followed by growers to reduce risk because of a lack of research information for the new invades tomato leafminer (Braham, unpublished data).

Threshold-based spraying to replace calendar-based chemical sprays to better control pests has been considered as an important strategy for sustainable agriculture. Our study suggests that a calendar based chemical sprays (ST5) is not a desirable pest control solution in terms of the safety of the growers and residue problems in tomatoes. In the Center-East of Tunisia, tomatoes grown under greenhouse, pest management strategies were based largely on chemical applications. Insecticide treatments targeted at controlling *T. absoluta* and other Lepidopteran insects (Noctuidae) were mostly calendar-based, normally starting off 15–25 days after transplant date.

Desneux *et al*., (2010) indicated that an effective integrated pest management strategy should be based on rigorous sampling protocols that combine pheromone trapping to monitor adult abundance with direct yield loss observations. In our case, we followed the leaf infestation to identify the periods of sprays. Indeed these authors suggest that once *T. absoluta* appears in pheromone traps, preventive measures such the use of safe chemicals such as the bacterium *Bacillus thuringiensis* should be initiated. Curative treatments with approved insecticides are suggested only in the case that *T. absoluta* outbreak levels are recorded.

4. Conclusion

Present management strategies aiming to control *T. absoluta* in tomato greenhouse cultivations have so far relied on calendar-based application of a wide range of pesticides. Practically, there is no efficacious other techniques to be used to control the tomato leafminer. The tomato raised under greenhouse has high input and pest control is fundamentally important. To reduce the frequency of insecticide sprays we suggest to adopt the threshold based spraying when the density of larvae or galleries per plant exceeds 16 and to combine the use of chemical products with organically acceptable insecticides (Spinosad, plant extracts).

5. Références

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