We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS BOOK CITATION INDEX INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

15

Management of *Tuta absoluta* (Lepidoptera, Gelechiidae) with Insecticides on Tomatoes

Mohamed Braham and Lobna Hajji
Centre régional de recherche en Horticulture et Agriculture Biologique; Laboratoire d'Entomologie – Ecologie; Chott-Mariem, Tunisia

1. Introduction

Tomato, *Lycopersicon esculentum* Mill is a vegetable crop of large importance throughout the world. Its annual production accounts for 107 million metric tons with fresh market tomato representing 72 % of the total (FAO, 2002). It is the first horticultural crop in Tunisia with a production area of 25,000 hectares and a total harvest of 1.1 million metric tons (DGPA, 2009) of which nearly 70 % are processed (Tomatonews, 2011). Tomatoes are grown both under plastic covered greenhouses and in open field.

The tomato leafminer, *Tuta absoluta* Meyrick, (Lepidoptera : Gelechiidae) is a serious pest of both outdoor and greenhouse tomatoes. The insect deposits eggs usually on the underside of leaves, stems and to a lesser extent on fruits (photo 1). After hatching, young larvae penetrate into tomato fruits (photo 2), leaves (photo 3) on which they feed and develop creating mines and galleries. On leaves, larvae feed only on mesophyll leaving the epidermis intact (OEPP, 2005). Tomato plants can be attacked at any developmental stage, from seedlings to mature stage.

Photo 1. *T. absoluta* egg

Photo 2. Larvae on fruit

Photo 3. Larva of *T. absoluta*

Originated from South America, *T. absoluta* was reported since the early 1980s from Argentina, Brazil and Bolivia (Estay, 2000); the insect rapidly invaded many European and

Mediterranean countries. It was first recorded from eastern Spain in late 2006 (Urbaneja, 2007), then Morocco, Algeria, France, Greece, Malta, Egypt and other countries (for a complete list see www.tutaabsoluta.com; Roditakis *et al*., 2010, Mohammed, 2010).
Chemical control using synthetic insecticides is the primary method to manage the pest, but it has serious drawbacks, including reduced profits from high insecticide costs, destruction of natural enemy populations (Campbell *et al*., 1991), build-up of insecticide residues on tomato fruits (Walgenbach *et al*., 1991) and in the environment and fundamentally the rapid development of insecticide resistance. For example, resistance development has been reported against abamectin, cartap, methamidophos and permethrin in Brazil (Siqueira *et al*., 2000a, Siqueira *et al*., 2000b) and against deltamethrin and abamectin in Argentina (Lietti *et al*., 2005). Thus, in order to avoid selection of resistant biotypes, a careful management with frequent changes of active ingredients is desirable. Furthermore, modern integrated pest management recommends effective pesticides that have low mammalian toxicity, low persistence in the environment and high degree of selectivity. Since insecticide control currently remains an indispensable tool, the goal is to minimize the amount and impact of pesticides through the diversification of active ingredients used.
In this paper, we present the data from insecticides trials conducted in 2009 and 2010 under laboratory and field conditions, in which the efficacy of several hitherto untested insecticides and natural products was compared with that the widely used insecticides to manage *T. absoluta* in Tunisia such as spinosad, indoxacarb and pyrethroids compounds.

2. Material and methods

2.1 Laboratory trials

2.1.1 Laboratory assays in 2009

Tomato seeds (cv Topsun) were sown on 30 January 2009. Seeds were deposited in 110 cm3 cells in a rectangular polyester tray of 60 cm x 40 cm x 5 cm filled with peat (Potgrond H, Germany). On March 3, 2009, seedlings were transplanted into 1 liter plastic flowerpot (bottom diameter =8 cm, top diameter = 12 cm and height = 12 cm) filled with peat without fertilization and watered as required. The tomato plants were maintained in the laboratory until use. Three days before the assay, plants (having four to six true leaves) were deposited in a tomato crop situated in the vicinity of the laboratory to permit *T. absoluta* egg-laying then transferred to the laboratory. Leaves were examined under binocular microscope and *T. absoluta* larvae were counted. Insecticides were sprayed using a hand sprayer (1 liter of capacity). After drying, the treated plants were kept in an unsealed empty greenhouse bordering the laboratory. There were four replications (plants) for each product and an untreated plant was used as a check. The efficacies of the products were tested twice: 48 hours following sprays and 12 days later. The Insecticides and natural plant extracts used are given in table 1.

2.1.2 Laboratory assays in 2010

A colony of *T. absoluta* was established from larvae and pupae collected from tomato infested field in the Chott-Mariem region. The insect was reared and maintained in a small greenhouse (10*6 m). From time to time, tomato leaves harboring *T. absoluta* pre-imaginal stages collected in the field were introduced in the rearing greenhouse.
Tomato seeds (cultivar Riogrande) were sown on February 13, 2010 in a rectangular polyester tray as mentioned before. Plants having four to six true leaves were transferred to the rearing greenhouse and remained there for 2 to 3 days to allow egg-laying. Thereafter

Active ingredients	Trade name	Companies	Dose cc/ hl water
deltamethrin	Decis EC25	Bayer Crop Science	100 cc/hl
bifenthrin	Talstar	FMC Corporation	100 cc/hl
acetamiprid	Mospilan 200 SL	Basf	50 cc/hl
methomyl	Lannate 25	Dupont de Nemours	150 cc/hl
metamidophos	Tamaron 40	Bayer Crop Science	150 cc/hl
abamectin	Vertimec	Syngenta	30 cc/hl
Spinosad	Tracer	Dow-Agroscience	60 cc/hl
Rotenone	Rotargan	Atlantica Agricola (Spain)	300 cc/hl
Neem extract	Oleargan	Atlantica Agricola	100 cc/hl

Table 1. Insecticides and natural plant extracts used in the laboratory trial in 2009.

returned to the laboratory and put in wooden cages for insecticide trials. Leaves were examined under binocular microscope and *T. absoluta* larvae were counted just before insecticide spray (April 3, 2010) and regularly after 2 to 3 days post-treatment. Dead larvae following trial were recorded. The second insecticide spray was done on April 19, 2010 (two weeks later). The Insecticides and natural plant extracts used are given in table 2.

Active ingredients	Trade name	Companies	Dose cc/ hl water
diafenthiuron	Pegasus	Syngenta	125 cc/hl
triflumuron	Alystin SC 480	Bayer Crop science	50cc/hl
emamectin benzoate	Proclaim®	Syngenta	2500 grams/hl
Plant extracts	Tutafort	AltincoAgro (Spain)	125 cc/hl

Table 2. Insecticides and natural plant extracts used in the laboratory in 2010.

2.2 Field trials

2.2.1 Trials using natural products

Field experiments using botanical extracts, Spinosad and Kaolin Clay were conducted from March 2010 to May 2010 in a half commercial tomato greenhouse (34 meters long x 8 meters width) in Saheline region, Tunisia (35°42' North, 10°40'East). Tomato seeds (cv Sahel) were sown on 27 October 2009 in an expanded polyester tray under plastic protected nursery bed. Four double rows of tomato were transplanted on 23 November 2009. The plot (greenhouse) was prepared according to usual cropping practices in the region. Ploughing, tillage and second tillage to incorporate manure, bed formation, irrigation device establishment and drip irrigation.

Active ingredients	Trade name	Companies	Dose cc/ hl water
Spinosad	Tracer 240	Dow- Agroscience	60 cc/hl
Neem extract	Oleargan	Atlantica Agricola (Spain)	100 cc/hl
Kaolin Clay	Surround WP™	Engelhard Corporation (NJ.U.S.A)	5 kg/hl
Orange extract	Prev-am™	ORO Agri International Ltd	300 cc/hl
Botanical extracts	Deffort	AltincoAgro (Spain)	350 cc/hl
Botanical extracts	Armorex	Soil Technologies Corp (U.S.A)	60 cc/hl
Botanical extracts (*Quassia amara* and Neem)	Conflic	Atlantica Agricola (Spain)	250 cc/hl

Table 3. Natural products experimented in 2010.

Plots measured 4 m2 each (10 plants) arranged in a randomized block design with four replications. The active ingredients, the trade name and doses of the natural products are given in table 3. The products were diluted with tap water and applied at field rates based on the recommended label dilutions without surfactants.

2.2.2 Trials using insecticides

Trials using insecticides were undertaken during the same period in the second half greenhouse. Plot measured 8 square meters each (20 plants) arranged in a randomized block design with four replications. Three chemical compounds were used (table 4).

Active ingredients	Trade name	Companies	Dose cc/ hl water
indoxacarb	Avaunt 150EC	Dupont	50 cc/hl
triflumuron	Alsystin SC 480	Bayer Crop science	50 cc/hl
diafenthiuron	Pegasus 500SC	Syngenta	125 cc/hl

Table 4. Insecticides compounds experimented under tomato greenhouse in 2010.

Insect monitoring

To assess the *T. absoluta* infestation prior to the trial, thirty leaf samples, taken from about 30 different plants were weekly collected (from January to March 2010) at random from the entire greenhouse. The sample was placed in a plastic bag and taken to the laboratory. Leaves were examined under binocular microscope (Leica MZ12.5); eggs, larvae pupae, of *T. absoluta* live or dead as well as mines were recorded. However, only larvae (live or dead) were presented in this study.

2.3 Statistical analysis

Data on the effectiveness of various insecticides were analyzed using the Minitab Software for Windows (Minitab 13.0). The mean number of live larvae per plant or per leaf was tested for Normality assumption by Kolmogorov-Smirnov test then the data were square root transformed. General linear model procedures were used to perform the analysis of

variance. Wherever significant difference occurred, Tukey's multiple comparison test was applied for mean separation.
In the laboratory trial of 2010, due to the low number of live larvae in the control, a one way-ANOVA percentage of mortality was used instead of corrected mortality.
The percentages of efficacies of insecticides were evaluated either:

i. Abbott formula : the percentage of efficacy = (Ca-Ta)/Ca*100 where Ca is the average live larvae in the control and Ta is the mean survival score in the treatment.
ii. The percentage of larval mortality = mean number of dead larvae/(mean number of dead larvae + mean number of live larvae)*100.

3. Results

3.1 Laboratory trials

3.1.1 Assays in 2009

One day before the assay, the mean number of total live larvae (L1 to L4 instars) per plant varied from 0.75 to 3. There is no significant difference between treatments (GLM-ANOVA. F= 0.99, df= 9,30; P = 0.47, table 5). Three days after the first application, the mean number of live larvae per plant decreases in all treatments except in the control (Table 5). All insecticides significantly reduced *T. absoluta* larvae when compared with non treated control (F= 4.24, df = 9,30; P= 0.001, Table 5). However, the level of suppression by acetamiprid and bifenthrin did not differ significantly from the control (Table 5).

Mean number of larvae/plant on indicated days before treatment (DBF) and days after treatment (DAT)					
Insecticides !	1DBT1!!	3DAT1	5DAT1	8DAT1	12DAT1
spinosad(1)	1.75a	0.5a(86.66)*	0.50a(85.71)*	0.5a (87.5)*	0.25a(93.75)*
neem extract(2)	1.5a	0.75a(80)	0.75a(78.50)	0.5a(87.5)	0.5a(87.5)
rotenone(3)	0.75a	0.25a(93.33)	0.25a(92.90)	0.5a(87.5)	0.75a(81.25)
deltamethrin(4)	0.5a	0a(100)	1a(71.42)	0.75a(81.25)	1.5ab(62.5)
acetamiprid(5)	2a	1.25ab(66.66)	1.25ab(64.28)	1.25ab(68.75)	0.50a(87.5)
methomyl(6)	3a	0.5a(87)	0.5a(86)	0.50a(88)	0.75a(81)
metamidophos(7)	2a	0.75a(80)	0.75a(79)	0.75a(81)	1.00a(75)
abamectin(8)	2.25a	0.75a(80)	0.75a(79)	0.5a(88)	0.25a(94)
bifenthrin(9)	2a	1.25ab(67)	2ab(43)	1.25ab(69)	1.00a(75)
Control	2.5a	3.75b	3.5b	4b	4b
Statistical analysis	F= 0.99	F= 4.24	F= 3.69	F= 4.20	F= 4.66
ANOVA-	df = 9,30	df = 9,30	df = 9,30	df = 9,30	df = 9,30
GLM	P = 0.47	P= 0.001	P= 0.003	P= 0.001	P=0.003

! denote commercial compounds: (1): Tracer, (2): Oleargan, (3): Rotargan, (4): Decis, (5): Mospilan, (6): Lannate (7): Tamaran, (8): Vertimec, (9): Talstar
!! Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison
* Data in brackets denote percent Abbott mortality (Abbott, 1925)

Table 5. Mean number of *T. absoluta* total live larvae/plant on indicated days before treatment (DBF) and days after treatment (DAT) (the first treatment was done on April 1, 2009).

Five days following the first application, all the products performed well except acetamiprid and bifenthrin which show no significant difference compared with the control (Table 5). Eight days after the first application, the mean number of total live larvae per plant varied from 0.5 to 4. All the tested products reduced significantly the density of live larvae per plant compared with the control (F= 4.20; df = 9,30; P= 0.001). Still, acetamiprid and bifenthrin showed mild efficacy (table 5). At 12 days following treatments, all the products performed well (F= 4.66, df = 9,30 ; P= 0.003), yet the plants treated with deltamethrin show increasing mean live larvae per plant (table 5).
Regarding the corrected mortality according to Abbott formula, Spinosad and rotenone gave satisfactory results post-treatment (88.4 % and 88.7% respectively) followed by Lannate (85%), Vertimec (85%), neem extract (83. 22), and Tamaran (79%). However, Decis (78.8%), Mospilan (71.8) and Talstar (63%) showed mild efficacy. Though, Decis performed well till 8 days following the first application (84.2%).

Mean number of total live larvae/plant on indicated days after the second treatment (DAT)				
Insecticides	0DBT2!!	2DAT2	4DAT2	8DAT2
spinosad	0a	0a(100)*	0a(100)*	0.75a(83.33)*
neem extract	0.5a	0.5a(92.85)	0.75a(78.60)	1.75a(61.11)
rotenone	0.25a	0.5a(85.71)	0.5a(85.71)	1.25a(72.22)
deltamethrin	0.75a	0.75a(78.60)	1a(71.42)	1.25a(72.22)
acetamiprid	0.5a	0.5a(85.71)	0.75a(78.60)	1.5a(66.66)
methomyl	1.25a	0.75a(78.60)	0.75a(78.60)	2a(83.33)
metamidophos	0.75a	0.75a(78.60)	0.5a(85.71)	1a(77.71)
abamectin	0.5a	0.5a(85.71)	0.5a(85.71)	1.5a(66.66)
bifenthrin	1a	1a(64.28)	1.5ab(57.14)	2a(55.55)
Control	3.5b	3.5b	3.5b	4.5b
Statistical analysis	F= 6.07	F= 7.24	F=5.84	F= 4.39
	df = 9,30	df = 9,30	df = 9,30	df = 9,30
	P = 0.00	P= 0.00	P= 0.00	P= 0.001

* Data in brackets denote percent Abbott mortality (Abbott, 1925)
!! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 6. Mean number of total *T. absoluta* live larvae/plant the day of the second treatment and thereafter (DAT2) (the treatment was undertaken on April 21)

Just before the second application, the mean number of live larvae in treated plants remained low compared with the control. It varied between zero (Tracer) and 3.5 (control) (table 6). Two days following the second insecticide application, all tested compounds show good efficacy compared with control (F=4.24; df = 9,30; P<0.001). Spinosad (Tracer) performed well (100 % efficacy according to Abbott corrected mortality formula). However, bifenthrin (Talstar) shows mild efficacy (table 6). The same conclusion can be formulated four days following treatments (table 6). At eight days after trial, the insecticide spinosad remains active and performed well (83.33 % efficacy) (table 6).
The overall efficacy according to Abbott formula (1925) shows the good performance of spinosad (Tracer), rotenone (Rotargan), methomyl (Lannate), abamectin (Vertimec) (Fig. 1.).

However, the percentage of larval mortality (number of dead larvae/sum of dead and live larvae) following the first and second insecticide application shows the best performance of spinosad (91 %), neem extract (71 %) and abamectin (71%).

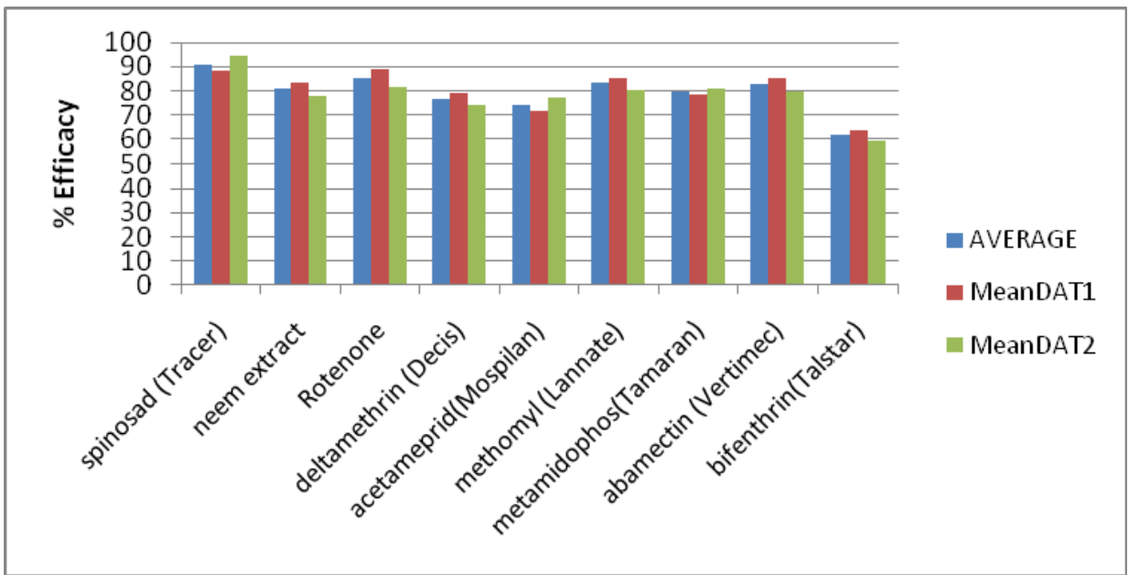


Fig. 1. Overall percentage of efficacy according to Abbott formula (1925). DAT1 = days after the first treatment, DAT2 = days after the second treatment (laboratory trial, 2009).

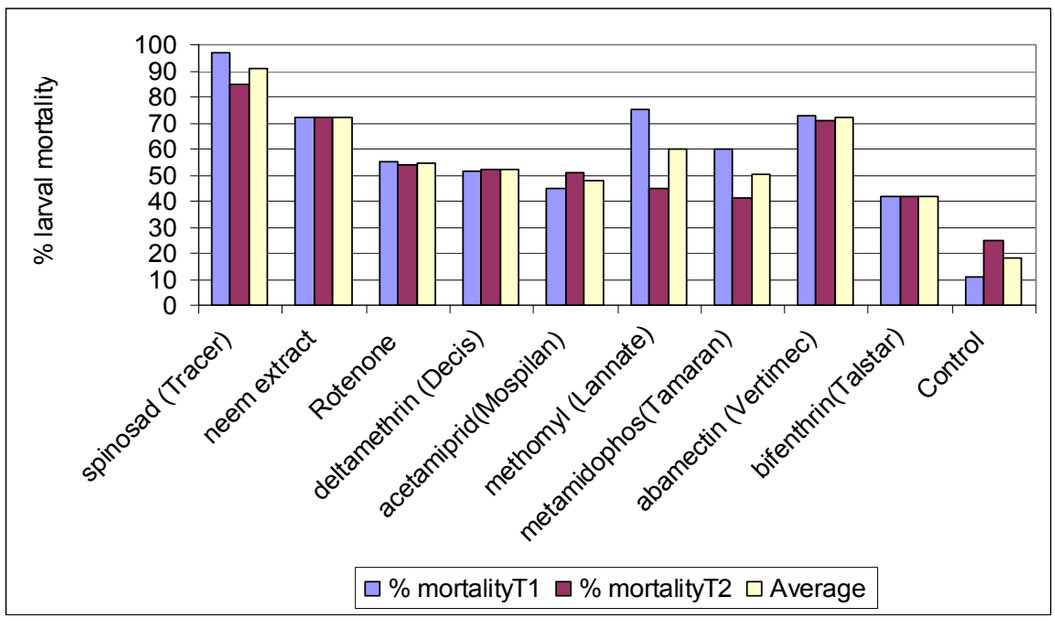


Fig. 2. Percentage of larval morality following the first (T1) and the second treatment (T2) (mean number of four dates after the fist treatment and 3 dates after the second treatment).

3.1.2 Assays in 2010

Just before the first spray (April 3, 2010), the mean number of live larvae (first to fourth instars) per leaf varied from 0.12 (Control) to 0.52 (Proclaim®). Although there is no significant difference between treatments (ANOVA-GLM F= 1.37, df = 4, 116; P=0.24), the control plants harboured less live larvae (table 7). There is no larval mortality.

Two days following the first spray (April 5), there is no significant difference between treatments regarding live larvae (GLM; F= 0.93, df = 4, 116; P= 0.46. Table 7). However, the percentage of larval mortality did vary (ANOVA, 1 factor, F = 4.17; df = 4, 120; P= 0.003) showing the best performance of Proclaim® (57.14 %; Table 7).

Nine days after the first insecticide application (April 12), the mean number of live larvae per leaf did not significantly vary between treatments (ANOVA-GLM procedure Table 7). However, the percentage of mortality significantly varies between treated and untreated plants (ANOVA 1 factor, F= 3.07; df = 4, 120; P= 0.021). The maximum percentage of mortality is given by Proclaim® (45.70%, table 7).

At 11 days after the first insecticide application (on April 14), the mean number of live larvae did not significantly vary among treated and untreated plants (ANOVA - GLM procedures Table 7). However, the percentage of mortality did vary according to treatments (F = 3.16, df = 4, 120; P= 0.017) showing the good efficacy of Proclaim® (52.93 % Table 7).

Mean number of live larvae/leaf on indicated days before treatment (DBF) and days after treatment (DAT)µ					
Insecticides!	0DBT! !	2DAT1	9DAT1	11DAT1	13DAT1
(1)	0.36(0)a	0.36(10)a	0.37(13.61)a	0.44(12.66)a	0.34(12.82)a
(2)	0.32(0)a	0.2(37.5)a	0.24(29.47)a	0.34(23.52)a	0.34(20.05)a
(3)	0.52(0)a	0.24(57.14)a	0.29(45.70)a	0.25(52.93)a	0.23(51.51)a
(4)	0.44(0)a	0.48(0)a	0.26(17.91)a	0.20(21.91)a	0.18(27.39)a
(5)	0.12(0)a	0.24(0)a	0.22(0)a	0.25(0)a	0.20(0)a
Statistical analysis	F= 1.37	F=0.90	F= 0.57	F=0.63	F=0.27
ANOVA	df =4,116	df =4,116	df =4,116	df =4,116	df =4,116
-GLM	P =0.24	P =0.46	P = 0.67	P=0.64	P= 0.89

! :(1):triflumuron(Alystin), (2) plant extract (Tutafort), (3) emamectin benzoate (Proclaim®) (4) diafenthiuron (Pegasus) and (5) Control.
µ: Data under brackets denote percentage of mortality
! ! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 7. Mean number of live *T. absoluta* larvae on indicated days before treatments and days after treatments (laboratory trial, 2010)

At 13 days after the first application, the mean number of live larvae did not significantly vary between treatments and control (Table 7). However, the percentage of mortality significantly varies between treated and control plants (F = 3.53 df = 4, 120; P= 0.009) showing the good efficacy of the compound Proclaim® (51.51 %, table 7).

At 16DAT1 and just before the second spray, the mean number of live larvae shows no significant difference between treated and control plants (table 7. continued). However, the percentage of mortality did significantly vary between treated and control plants (One way

ANOVA F= 4.95 df = 4, 120; P= 0.001). The compound Proclaim® shows the highest mortality percentage (54.83 % table 7.Cont.).
At three days after the second insecticide application, there is no significant difference regarding the mean number of live larvae per leaf (GLM-ANOVA). Nevertheless, plants treated with the product Proclaim® harbour zero live larvae per leaf suggesting the good efficacy of this insecticide. This is confirmed by the high percentage of mortality (100 %) as well as the significant difference between treated and control plants (One way ANOVA, F= 4.51 df = 4, 120; P= 0.002).

Mean number of live larvae/leaf on indicated days before treatment (DBF) and days after treatment (DAT)(μ)					
Insecticides	16DAT1!	3DAT2	5DAT2	8DAT2	10DAT2
(1)	0.33(12.55)a	0.19(51.71)a	0.16(59.91)ac	0.15(59.4)ac	0.15(59.14)ac
(2)	0.31(21.47)a	0.06(80.15)a	0.06(83.64)ac	0.06(83.35)ac	0.06(83.35)ac
(3)	0.20(54.83)a	0(100)a	0(100)bc	0(100)bc	0(100)bc
(4)	0.20(19.60)a	0.16(0)a	0.1(59.55)ac	0.09(59)ac	0.09(59)ac
(5)	0.20(0)a	0.16(0)a	0.16(0)a	0.16(0)a	0.06(0)a
Statistical analysis	F= 0.27	F= 2.02	F= 1.85	F= 1.85	F= 1.56
	df =4, 116	df =4, 116	df =4, 116	df =4, 116	df =4, 116
GLM-ANOVA	P= 0.89	P= 0.096	P= 0.123	P= 0.096	P=0.189

μ : Data under brackets denote percentage of mortality
! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 7. (continued). Mean number of live *T. absoluta* larvae on indicated days before treatments and days after treatments (laboratory trial, 2010)

Five days after the second spray, the mean number of live larvae did not vary among treated and untreated plants (table 7. Cont.). But the percentage of mortality significantly varies (ANOVA one factor F= 3.98 df = 4, 120; P= 0.03) showing again the good performance of Proclaim® (table 7.Cont.).
At eight days after the second spray, there is no significant difference between treated plants and control regarding the mean number of live larvae (table 7.Cont.). However, the percentage of mortality varies (ANOVA, one factor, F= 3.88 df = 4, 120; P= 0.005). The compounds Proclaim® and Tutafort are the best (100 % and 83.35 respectively, table 7.Cont.).
At 10 days after the second insecticide application, there is no significant difference between treated plants and control (GLM-ANOVA, Table 7.Cont.). Concerning the percentage of mortality, there is a significant difference between treated and control plants (ANOVA, one factor, F= 3.99 df = 4, 120; P= 0.006). Proclaim® followed by Tutafort performed well (100 % and 83.35 respectively, table 7.Cont.).

3.2 Field trials

3.2.1 Natural products experimented in 2010 under greenhouse

The first spray was undertaken on March 26, 2010, then on April 8 and on April 19, 2010.
At three days following the first application, the mean live larvae (small and old larvae) per leaf did not significantly vary between treated and control plots (GLM-ANOVA Procedure,

P= 0.09). Although, plots treated with spinosad show the minimum live larvae as demonstrated by 70% efficacy according to Abbott formula (Table 8). The details of larval instars (small larvae: first and second instars and old larvae: three and fourth instars) show a significant difference between insecticides tested. The compounds Tracer, Armorex and Deffort performed well (table 9).

Mean number of total larvae/leaf on indicated days before treatment (DBF) and days after treatment (DAT)					
Insecticides	1DBT! !	3 DAT1*	10DAT1(µ)	2DAT2	6DAT2
Armorex(1)	0.30a	0.20(20)a	0.1(69.23)a	0(100)a	0.325(0)a
Deffort(1)	0.30a	0.25(0)a	0.45(0)a	0.475(0)b	0.3(0)a
Oleargan (1)	0.20a	0.32(0)a	0.225(30.76)a	0.05(33.33)a	0.25(0)a
Konflic(1)	050a	0.57(0)a	0.2(38.46)a	0.125(0)a	0.075(0)a
Prev-am™ (2)	0.32a	0.37(0)a	0.45(0)a	0.1(0)a	0.2(0)a
Surround WP™ (3)	0.30a	0.32(0)a	0.25(23.07)a	0.075(0)a	0.15(0)a
Tracer(4)	0.1a	0.075(70)a	0.05(84.61)a	0(100)a	0.025(0)a
Control	0.20a	0.25a	0.325a	0.075a	0.025a
Statistical Analysis	F= 1.42	F= 1.94	F= 1.61	F= 1.61	F= 1.92
	df =3, 309	df =3, 309	df =3, 309	df =3, 309	df =3, 309
GLM- ANOVA	P= 0.120	P= 0.09	P= 0.131	P=0.008	P=0.066

(1): Botanical extracts
(2): Orange extract
(3) : Kaolin
* Corrected mortality according to Abbott formula
µ = second spray
! ! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 8. Mean number of total live larvae following natural products applications under tomato greenhouse (Saheline, Tunisia, 2010).

At 10 days after the first natural products applications, the ANOVA-GLM procedure shows no significant difference between treatments regarding the mean number live larvae (Table 8). The Abbott's percentages of efficacy show the performance of spinosad (84.61 %) and the plant extract (Armorex; 69.23%).
At two days after the second spray, (April 10) there is a significant difference between treated plots (AVOVA-GLM procedure, P= 0.008, table 8). The plots treated with Deffort show the maximum density of mean live larvae per leaf (table 8). However, there is no significant difference between the other products and control. The details of larval stages confirm the low efficacy of Deffort compared with the other products and control (small larvae : P= 0.026; Old larvae P= 0.019; table 9).
Six days following the second application (April 14), the mean number of live larvae shows no significant difference between treated and untreated plots (Table 8).
At eleven days after the second spray, the mean number of live larvae per leaf is relatively similar among treatments and did not significantly vary (ANOVA-GLM procedure P= 0.211) varying from 0.1 to 0.9. Plots treated with Kaolin (Surround) harbour the minimum density.
Four days after the third spray (April 23, 2010), the treated plot differed significantly showing the good performance of the compounds neem extract, Tracer and Konflic (table 8). This is confirmed by the analysis of detailed larval instars (table 9).

At nine days after the third spray, the mean number of total larvae varied between 0.2 and 2.05. The ANOVA-GLM procedure showed a significant difference between treatments. The products Tracer, Armorex and Deffort were effective in reducing *T. absoluta* larval densities (table 8).

Mean number of total larvae/plant on indicated days before treatment (DBF) and days after treatment (DAT)				
Insecticides	11 DAT2!	4DAT3! !	9DAT3	18DAT3
Armorex(1)	0.525(0)a	0.1(85.18)a	0.3(85.36)b	0.9(12.2)a
Deffort(1)	0 .925(0)a	0.3(55.55)a	0.2(90.24)b	0.65(36.85)a
Oleargan (1)	0.325(13.33)a	0.075(88.88)ab	0.55(73.17)b	0.375(63.4)a
Konflic(1)	0.475(0)a	0(100)ab	0.825(59.75)a	0.325(68.3)a
Prev-am™ (2)	0.225(40) a	0.175(74.07)a	1.675(18.30)a	0.7(31.7)a
Surround(3)	(3)0.1(73.33)a	0.2(70.37)a	0.55(73.17)b	0.375(63.4)a
Tracer(4)	0.35(6.66)a	0.1(85.18)a	0.25(87.80)b	0.75(26.8)a
Control	0.375a	0.675a	2.05a	1.025a
Statistical Analysis	F=1.41	F=2.49	F=2.49	F=1.36
	df= 7,309	df= 7,309	df= 7,309	df= 7,309
GLM-ANOVA	P=0.201	P=0.017	P=0.000	P=0.220

! : third spray

! ! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 8. (Continued) Mean number of total live larvae following natural products applications under tomato greenhouse (Saheline, Tunisia, 2010).

Mean number of live larvae/leaf on indicated days before treatment (DBF) and days after treatment (DAT)				
Insecticides	3DAT1! !		10DAT1	
	SL*	OL*	SL*	OL*
Armorex(1)	0.075(40)a	0.125(0)a	0.1(50)a	0(100)a
Deffort(1)	0.05(60)a	0.2(0)a	0.225(0)a	0,225(0)a
Oleargan (1)	0.2(0)a	0.125(0)a	0.175(12.5)a	0.05(60)a
Konflic(1)	0.425(0)b	0.15(0)a	0.1(50)a	0.1(20)a
Prev-am™ (2)	0.25(0)ab	0.125(0)a	0.275(0)a	0.175(0)a
Surround WP™ (3)	0.3(0)a	0.025(80)a	0(100)a	0.25(0)a
Tracer(4)	O(100)a	0.075(40)a	0.05(75)a	0(100)a
Control	0.125(0)ab	0.125(0)a	0.2(0)a	0.125(0)a
Statistical Analysis	F= 4.03	F= 0.77	F= 1.76	F= 1.53
	df= 3,309	df= 3,309	df= 3,309	df= 3,309
GLM-ANOVA	P= 0.00	P= 0.611	P= 0.096	P=0.157

*: SL : Small larvae (L1-L2), OL: Old larvae (L3-L4)

! ! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison.

Table 9. Mean number of live small and old larvae following natural products applications under tomato greenhouse (Saheline, Tunisia, 2010).

Mean number of larvae/plant on indicated days before treatment (DBF) and days after treatment (DAT)				
Insecticides	2 DAT2! !		6DAT2	
	SL*	OL*	SL*µ	OL*
Armorex(1)	0(100)a	0(100)b	0.1b	0.225(0)a
Deffort(1)	0.175(0)b	0.3(0)a	0.025a	0.275(0)a
Oleargan (1)	0.025(0)a	0.025(50) b	0.175b	0.075(0)a
Konflic(1)	0.05(0)a	0.075(0)b	0a	0.075(0)a
Prev-am™ (2)	0(100)a	0.1(0)b	0.125b	0.075(0)a
Surround(3)	0.025(0)a	0.05(0)b	0.1b	0.05(0)a
Tracer(4)	0(100)a	0(100)b	0a	0.025(0)a
Control	0.025a	0.05b	0a	0.025a
Statistical analysis GLM-ANOVA	F= 2.31	F= 2.44	F= 2.18	F= 1.34
	df= 3,309	df= 3,309	df= 3,309	df= 3,309
	P= 0.026	P=0.019	P=0.036	P=0.069

µ: undetermined Abbott percentage of efficacy (zero Small larvae in the control plot)
SL: Small larvae (L1-L2), OL: Old larvae (L3-L4).
! ! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 9. (Continued) Mean number of live small and old larvae following natural products applications under tomato greenhouse (Saheline, Tunisia, 2010).

Mean number of larvae/plant on indicated days before treatment (DBF) and days after treatment (DAT)				
Insecticides	11 DAT2! !		4DAT3	
	SL*	OL*	SL*	OL*
Armorex(1)	0.375(0)a	0.15(0)a	0(100)a	0.1(84.61)ab
Deffort(1)	0.7(0)a	0.225(0)a	0.15(0)b	0.15(76.9)ab
Oleargan (1)	0.25(0)a	0.075(50)a	0.025(0) a	0.05(92.30)b
Konflic(1)	0.425(0)a	0.05(66.66)a	0(100)a	0(100)b
Prev-am™ (2)	0.075(66.66)a	0.15(0)a	0(100)a	0.175(73.0)b
Surround WP™ (3)	0.07(66.66)a	0.02(83.33)a	0.125(0)b	0.075(88.4)b
Tracer(4)	0.275(0)a	0.075(50)a	0.075(0)ab	0.02 (96.15)b
Control	0.225a	0.15a	0.025a	0.65a
Statistical Analysis	F=1.31	F=1.10	F=2.75	F=2.82
	df=3,309	df=3,309	df=3,309	df=3,309
GLM-ANOVA	P=0.246	P=0.361	P=0.009	P=0.007

*: SL : Small larvae (L1-L2), OL: Old larvae (L3-L4)
! ! : Means followed by the same letter within a column are not significantly different at P= 0.005 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 9. (Continued) Mean number of live small and old larvae following natural products applications under tomato greenhouse (Saheline, Tunisia, 2010).

Mean number of larvae/plant on indicated days before treatment (DBF) and days after treatment (DAT)				
Insecticides	9 DAT3! !		18DAT3	
	SL*	OL*	SL*	OL*
Armorex(1)	0.125(72.22)a	0.175(89.06)b	0.75(0)a	0.15(75) a
Deffort(1)	0.025(94.44)b	0.175(89.06)b	0.4(5.88)a	0.25(58.33)a
Oleargan (1)	0.225(50)a	0.325(79.68)b	0.075(82.35)a	0.3(50)a
Konflic(1)	0.275(38.88)a	0.55(65.62)a	0.175(58.82)a	0.15(75) a
Prev-am™ (2)	0.375(16.78)a	1.3(18.75)a	0.45(0)a	0.25(58.33)a
Surround WP™ (3)	0.1(77.77)a	0.45(71.87)a	0.2a	0.175(70.83)a
Tracer(4)	0.125(72.22)a	0.125(92.18)b	0.45(0)a	0.3(50)a
Control	0.45a	1.6a	0.425a	0.6a
Statistical Analysis	F= 2.33	F=5.68	F=1.41	F= 1.97
	df = 3,309	df = 3,309	df = 3,309	df = 3,309
ANOVA-GLM	P= 0.00	P=0.000	P=0.201	P=0.06

* Data in brackets denote percent Abbott mortality (Abbott, 1925)
! !: Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 9. (Continued) Mean number of live small and old larvae following natural products applications under tomato greenhouse (Saheline, Tunisia, 2010).

Three days following the first insecticide application, the mean number of live larvae (small and large) did not vary significantly between treated and untreated plots (ANOVA-GLM Procedure F= 1.94, df = 3, 309 P= 0.063). However, the plants treated with spinosad (Tracer) harbor the minimal larval density (Table 9).

3.2.2 Insecticides compounds experimented under tomato greenhouse in 2010

Four days before the first insecticide application, the mean number of live larvae per leaf varied between 0.6 and 0.97 showing no significant difference between treatments and control (ANOVA. GLM, F= 0.82, df =3, 156; P=0.82).

Two days following the first treatment (March 24), the mean number of live larvae remains relatively low and did not significantly vary between treatment and control (F = 0.34; df = 3, 153; P= 0.79). The corrected mortality according to Abbott formula shows slight efficacy of tested products (Table 10).

At 12 days following the first application, the mean number of live larvae significantly differed between treatments (GLM, F=2.90, df = 3, 156; P= 0.037). The Tukey multiple comparisons showed the good performance of indoxacarb (Avaunt) (Table 10). There is no significant difference between plot treated with triflumuron (Alystin), diafenthiuron (Pegasus) and untreated plots.

Three days after the second treatment, there is a significant difference between treated plots and control (GLM, F= 16.45 df = 3, 153; P= 0.000). The three compounds performed well particularly Avaunt (92.30 % according to Abbott formula).

Nine days following the second spray, all insecticides performed well compared with the control (F= 46.7 df =3,153; P=0.000) with the best performance of indoxacarb (Avaunt) (96.87 % efficacy according to Abbott formula, Table 10).

Mean number of larvae/leaf on indicated days before treatment (DBF) and days after treatment (DAT)μ					
Insecticides	4DBT1! !	2 DAT1	12DAT1	3DAT2	9DAT2
indoxacarb	0.87a	0.7(15. 15)a!	0.2(71.42) a!	0.05(92 .30)a	0.075(96.87)a
triflumuron	0.97a	0.6(27.27)a	0.52 (25)ab	0.1(84.61)a	0.4(83.33)a
diafenthiuron	0.6a	0. 72 (12.12)a	0.4(42.85)ab	0.125(80.76)a	0.30(87.5)a
Control	0.87a	0.85a	0.7 b	0.65b	2.4b
Statistical analysis	F=0.82	F= 0.43	F=2.90	F= 16.45	F= 46.7
	df =3, 153	df = 3, 153	df = 3, 153	df =3, 153	df =3, 153
GLM-ANOVA	P=0.48	P=0.72	P=0.037	P=0.000	P=0.000

μ : the first treatment was undertaken on March 22, 2010.
! : data in brackets denote percentage of efficacy (Abbott Formula)
! ! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 10. Mean number of *T. absoluta* larvae/leaf on indicated days before treatment (DBF) and days after treatment (DAT) (Saheline tomato greenhouse, 2010).

Mean number of larvae/leaf on indicated days before treatment (DBF) and days after treatment (DAT)			
Insecticides	18DAT2! !	3DAT3	12DAT3
indoxacarb (Avaunt)	0.05(95.83)a	0.075(95.45)a	0.35(78.12)a
triflumuron (Alystin)	0.05((95.83)a	0.5(69.69)a	0.7(56.25)a
diafenthiuron (Pegasus)	0.075(93.75)a	0.325(80.30)a	0.32(87.5)a
Control	1.2b	1.65b	1.6b
Statistical analysis	F= 40.88	F= 20.91	F=10.87
	df =3, 153	df =3, 153	df =3, 153
	P = 0.00	P= 0.00	P= 0.000

! ! : Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison

Table 10 (continued). Mean number of *T. absoluta* larvae per leaf on indicated days before treatment (DBF) and days after treatment (DAT) (Saheline tomato greenhouse, 2010).

At 18 days following the second application, the mean number of live larvae significantly varies between treated and control plots (GLM F= 40.88; df = 3, 153; P= 0.000). The efficacy of tested insecticide remains high compared with the control.
At 3 and 12 days following the third insecticide application all tested insecticides continue to be effective compared with the control (F= 20.91 df =3, 153; P= 0.00 ; F=10.87; df =3, 153; P= 0.00). Nevertheless, indoxacarb (Avaunt) tend to be a powerful suppressor of *T. absoluta* larvae (table 10).

4. Discussion

In Argentina, the primary *T. absoluta* management tactic was chemical sprays (Lietti *et al*., 2005). Organophosphates were initially used for *T. absoluta* control then were gradually replaced by pyrethroids during the 1970s. During the early 1980s, cartap which alternates with pyrethroids and thiocyclam were sprayed showing the good effectiveness of the former. During the 1990s, insecticides with novel mode of actions were introduced such as abamectin, acylurea, insect growth regulators, tenbufenozide and chlorfenapyr (Lietti *et al*., 2005).
Our laboratory results demonstrate the efficacy of spinosad (Tracer), rotenone (Rotargan), methomyl (Lannate) and abamectin (Vertimec). Methomyl was only tried due to its highly used frequency in tomato production against Noctuid larvae in Tunisia.
Spinosad, a mixture of spinosyns A and D, is derived from the naturally occurring actionomycete, *Saccharopolyspora spinosa* (Sparks *et al.,* 1998). Because of its unique mode of action, involving the postsynaptic nicotinic acetylcholine and Gamma-aminobutyric (GABA) receptors, spinosad has strong insecticidal activity against insects (Salgado, 1998) especially Lepidoptera (e.g. *Helicoverpa armigera* (Wang *et a*l., 2009), *Spodoptera frugiperda* (Méndez *et al*., 2002), Diptera (King and Hennesey 1996; Collier and Vanstynwyk , 2003 ; Bond *et al*., 2004), some Coleoptera (Elliott et al., 2007) as well as stored grains (Hertlein *et al*, 2011).
To date, spinosad is considered a good alternative control of Lepidopteran pests due to its high activity at low rates and its use in integrated pest management programs. The product possesses advantages in term of safety for farm workers and consumers due to its low mammalian toxicity and rapid breakdown in the environment (Sparks et al., 1998). The compound is considered as a standard product for the control of *T. absoluta* in Brazil (Maraus *et al*., 2008) showing, however low efficacy compared with the insecticide novaluron.
Rotenone has been reported to be an excellent insecticide against a wide range of insect pests. Davidson (1930) found that rotenone was a toxic and effective contact insecticide against several species of whiteflies, aphids, caterpillars and mites. Also, Turner (1932) reported a high toxicity of rotenone to larvae of the Colorado potato beetle *Leptinotarsa decemlineata* (Say).
Azadirachtin, a tetranortriterpenoid isolated from the seeds of neem tree, *Azadirachta indica* (Meliaceae), and the fruit of chinaberry, *Melia azaderach* (Meliaceae) acts as an antifeedant and inhibits the growth and the development of several insects (Meisner *et al*., 1981, Raffa, 1987; McMillian *et al*., 1969). The antifeefant effects of azadirachtin are partly due to sensory detection and avoidance by insects (Simmonds and Blaney 1984).
Acetamiprid (Mospilan) is a neonicotinoid insecticide that is formulated for both soil and foliar application. It is a broad-spectrum insecticide effective against several groups of

insects including Lepidopterans, Coleopterans, Hemipterans and Thysanopterans. The insecticide has an ingestion and stomach action and has a strong osmotic and systemic action (Takahashi *et al*., 1998). The compounds interact with Acetylcholine receptors (AChRs) in a structure-activity relationship, resulting in excitation and paralysis followed by death (Ishaaya *et al*., 2007).

Abamectin a mixture of avermectins is extracted by the fermentation of the soil bacterium *Streptomyces avermitilis* (Strong & Brown 1987). The insecticide acts on the GABA receptor activating the chloride channel (nerve and muscles) (Aliferis and Jabaji, 2011).

Throughout the assay, the product emamectin benzoate (Proclaim®) showed the best efficacy strongly suppressed *T. absoluta* larval populations. Indeed, several authors reported the performance of this product against several insects, for example, Seal (2005), reported the efficacy of emamectin benzoate at various rates in reducing the densities of the melon thrips, *Thrips palmi* adults and larvae. Stanley *et al.,* (2005) reported the high acute toxicity of emamectin benzoate to *Helicoverpa armigera* under laboratory conditions.

Cook et al., (2004) conducted field and laboratory trials on cotton and soybean for the control of the beet armyworm *Spodoptera exigua* (Hübner) and the fall armyworm *Spodoptera frugiperda* using indoxacarb, pyridalyl, spinosad methoxyfenozide and emamectin benzoate demonstrated the good efficacy of tested products compared with the control. Plots treated with indoxacarb, spinosad and emamectin benzoate had significantly fewer beet armyworm larvae.

Avermectins are a family of 16-membered macrocyclic lactone natural product homologues produced by the soil microorganisms, *Streptomyces avermitilis.* They act as agonists on GABA and glutamate gated chloride channels. The chloride ion flux produced by the direct opening of channels into neuronal cells results in loss cell function and disruption of nerve impulses. Consequently, arthropods are paralyzed irreversibly and stop feeding. Maximum mortality is achieved within four days (Jansson *et al.,* 1997).

Emamectin benzoate (Proclaim) is a novel semi-synthetic derivative of the natural product abamectin in the avermectin family. This insecticide has a high potency against a broad spectrum of lepidopterous pests with an efficacy of about 1,500-fold more potent against certain armyworm species (Jansson *et al.,* 1996)

Insect growth regulators like triflumuron, lufenuron are claimed to be safe and have little impact on beneficial arthropods compared with conventional insecticides and thus attracted considerable attention for their inclusion in IPM programs (Ishaaya *et al*., 2007). In this study, triflumuron showed low efficacy against *T. absoluta* larvae. These results are in accordance with data reported by El-Sheikh and Aamir (2011) suggesting the greater efficiency of lufenuron in controlling *Spodoptera littoralis* Boisd compared with triflumuron or flufenoxuron. Similarly, low effectiveness of triflumuron (Alystin SC48) for the control of *Cactoblastis cactorum* (Lepidoptera: Pyralidae) was reported in Argentina by Labos et al., (2002). Yet the concentration used was lower (30 cc/ hl). Regarding the control of the Mediterranean fruitfly, *Ceratitis capitata*, triflumuron (Alystin 25) failed to give satisfactory results (a concentration of 150 ppm did not kill adults, Zapata *et al.,* (2006)).

Diafenthiuron (Pegasus) is a new type of thiourea derivative that affects respiration in insects. It disrupts oxidative phosphorylation by inhibition of the mitochondrial ATP synthase, an enzyme with essential role in cellular bioenergetics (Ishaaya, 2010). It is an insecticide and acaricide which kills larvae, nymphs and adults by contact and/or stomach action, showing also some ovicidal action (e-pesticide manual, 2005). In our laboratory trial, diafenthiuron (Pegasus) shows little efficacy in *T. absoluta* larval suppression (table 10).

Tutafort (plant extract) shows little efficacy after the first application but increases effectiveness after the second application engendering about 80 % of larval mortality (table 7.Cont.). Yet according to manufacturer, (Altinco, 2011), the product has a preventive action and should be applied against eggs and adults. The compound acts by contact penetrating the insect cuticle and dissolves the cell membranes causing the insect dehydrate and its death (Altinco, 2011).

Management of resistance to prevent or delay the development of resistance to an insecticide and cross resistance to additional insecticides is necessary for increasing the chance of chemical control of *T. absoluta*. Thus, the avoidance of resistance requires the development of pest management programs in which efforts are made to take advantages of natural enemies of pests, plant resistant cultivars, if available, appropriate cultural and physical methods.

Accordingly, diversification of control tactics should be implemented with the minimum use of chemicals. Insecticides should be applied only as needed basis and only used as the last form of control. When insecticides are applied, the way that they are used should be rationalized and optimized to exploit the full diversity of synthetic chemicals and natural products mostly used at rotational basis.

Development of resistance in *T. absoluta* is an important problem in regions where the insect is established. The expanding international trade of plant material not only spread the pest but also spreads the resistance genes associated with the pest (Denholm and Jespersen, 1998). It is possible that the Mediterranean populations of *T. absoluta* already carried gene resistance from South American counterpart populations and thus, may already express high level of resistance to one or multiple insecticide. Indeed, Cifuentes *et al*., (2011), demonstrated high genetic homogeneity of *T. absoluta* populations came from Mediterranean basin and from South America countries using ribosomal and mithochondrial markers.

Our field results (tomato greenhouse) suggest the good performance of the tested compounds (indoxacarb, triflumuron and diafenthiuron). So far, the product indoxacarb tend to be a powerful suppressor of *T. absoluta* larvae.

Indoxacarb is reported by several authors as a powerful insecticide in managing many Lepidopteran pests. Wakil *et al*. (2009) in their study for the management of the pod borer, *Helicoverpa armigera* Hubner (Lepidoptera : Noctuidae) in Pakistan showed the integration of weeding, larvae hand picking and indoxacarb sprays was the most effective in reducing the larval population, pod infestation and maximum grain yield. Also, in Cameroon, Brévault et *al*., (2008) reported a good efficacy of indoxacarb as a larval insecticide of *H. armigera.*

In the United Kingdom, three insecticides were registered for the control of *T. absoluta* under protected tomato, pepper and aubergine: *Bacillus thuringiensis var. kurstaki*, indoxacarb and spinosad (FERA, 2009).

Indoxacarb belongs to a novel class of insecticides, the oxadiazines. It a broad spectrum non-systemic insecticide active especially against Lepidoptera. Indoxacarb affects insect primarily through ingestion but also by contact with treated plant surface. It kills by binding to a site of sodium channels and blocking the flow of sodium ions into nerve cells. The result is impaired nerve function, feeding cessation, paralysis and death (Wing *et al*, 2000).

5. Conclusions

T. absoluta has been a serious pest of tomatoes in Tunisia since the autumn 2008. Farmers have gradually come to understand that conventional insecticides such as organophosphates and carbamates are not effective against the insect. Even though more expensive compared with other insecticides, spinosad (Tracer) is now the widely used bio-insecticide to manage the insect.

It is not the intent in this study to advocate one insecticide over another but to enlarge the array of effective insecticide and bio-insecticides with different modes of action. These studies clearly demonstrated the efficacious of several chemicals such as spinosad, abamectin, emamectin benzoate, triflumuron and diafenthiuron. Although, plant extracts such as Armorex and Deffort show mild efficacy in controlling *T. ab*soluta larvae, they can be used in conjunction with chemical products and integrated in a whole program of control.

The efficacies of sprayings using mixtures of natural products and synthetic chemicals for the control of the pest are planned in our laboratory studies. Indeed, insecticides that work in synergy when mixed together are an avenue to explore in *T. absoluta* control. It has been proposed that pesticides mixtures with different modes of action may delay the onset of resistance developing in pest populations (Bielza *et al*., 2009). However, some problems need to be considered when two or more insecticides are mixed together especially phyto-toxicity.

The use of insecticides to control *T. absoluta* must not divert attention from the implementation of alternative pest management strategies including cultural, mass-trapping and biological control that can reduce reliance to chemical products.

Chemical pesticides continue to be an important component of insect pest management even with the development of other control methods (mass-trapping, plant resistance…). The use of insecticides based on different chemistries and with varying modes of action is an important component of an integrated pest management strategy. Hence, insecticides will continue to be an integral component of pest management programs due mainly to their effectiveness and simple use. However, the principal factor account for the possible reluctance to shift to the newer insecticides is the high cost.

6. Acknowledgements

The financial support for this work was provided by the Institution of Agricultural Research and Higher Education (IRESA. Ministry of Agriculture and Environment. Tunisia) through the research project "*Tuta absoluta*". We wish to thank the former President Pr Mougou A. and the current President Pr Amamou H. for their help.

We thank Bensalem A., Benmaâti S., Hajjeji F., Ammar A. and Rhouma J. for technical assistance in both laboratory and field.

7. References

Abbott W.S. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265-267.

Aliferis K.A., & Jabaji, S., 2011. Metabolomics- A robust bioanalytical approach for the discovery of the modes of action of pesticides: A review. Pesticide Biochemistry and physiology. 100: 105-117.

Altinco, 2011. www.altinco.org. Accessed on July 7, 2011.

Bielza P., Fernández E., Graválos C., and Albellán J., 2009. Carbamates synergize the toxicity of acrinathrin in resistant western flower thrips (Thysanoptera: Thripidae). J. Econ. Entomol. 102: 393-397.

Bond J.G., Marina C.F., and Williams T., 2004. The naturally derived insecticide Spinosad is highly toxic to *Aedes* and *Anopheles* mosquito larvae. Medical and Veterinary Entomology 18: 50-56.

Brévault B., Oumarou Y., Achaleke J., Vaissayre M. & Nebouche S. 2008. Initial activity and persistance of insecticides for the control of bollworms (Lepidoptera : Noctuidae) in cotton crops. Crop Protection. 28: 401-406.

Campbell C.D., Walgenbach J.F., and Kennedy G.C., 1991. Effect of parasitoids on Lepidopterous pests in insecticide-treated and untreated tomatoes in western North Carolina. J. Econ. Entomol. 84: 1662-1667.

Cifuentes D., Chynoweth R., and Bielza P., 2011. Genetic study of Mediterranean and South American populations of tomato leafminer *Tuta absoluta* (Povolny, 1994) (Lepidoptera: Gelechiidae) using ribosomal and mitochondrial markers. Pest. Manag. Sci. Wileyonlinelibrary.com. DOI10.1002/ps.2166.

Cook D.R. Leonard B.R., and Gore J., 2004. Field and laboratory performance of novel insecticides against armyworms (Lepidoptera: Noctuidae). Florida Entomologist. 87(4): 433-439.

Davidson W.M. 1930. Rotenone as a contact insecticide. J. Econ. Entomol. 23 : 868-874.

Denholm I., and Jepersen J.B ., 1998. Insecticide resistance management in Europe: recent developments and prospects. Pesticide Science. 52: 193-195.

DGPA, Direction Générale de la Production Agricole 2009. Tunisian Ministry of Agriculture. Annual report.

Collier T.R., & Vanstynwyk R., 2003. Olive fruitfly in California: prospects for integrated control. California Agriculture, 57: 28-32.

EstayP. 2000. Polilla del tomate *Tuta absoluta* (Meyrick). http://alerce.inia.cl/docs/informativos/informativo09.pdf. Accessed, 12 May 2010.

Elliott R.H. Benjamin M.C., & Gillott G., 2007. Laboratory studies of the toxicity of spinosad and deltamethrin to *Phyllotreta cruciferae* (Coleoptera : Chrysomelidae). Can. Entomol. 139: 534-544.

El-sheikh E. A. and Aamir M. M., 2011. Comparative effectiveness and field persistence of insect growth regulators on a field strain of the cotton leafworm, *Spodoptera littoralis*, Boisd (Lepidoptera : Noctuidae). Crop Protection. 30 : 645-650.

E-pesticide manual. Version 3.3. 2005. Edited by British Crop Production Council (BCPC). ISBN. 1901396401.

FAO. 2002. Production year book 2000. Vol. 54. FAO. Italy.

FERA, 2009. The food and environment Research Agency. Plant Pest notice. South American tomato moth *Tuta absoluta*. N° 56: 1-4.

Hertlein M.B, Thompson G.D., Subramanyam B. & Athanassiou C.G. 2011. Spinosad : A new natural product for stored grain protection. Journal of stored products research. Doi : 10.1016/j.jspr.2011.01.004 : 1-15.

Ishaaya I., 2010. Biochemical sites of insecticide action and resistance. Isaac Ishaaya (Ed.) Springer-Verlag. Berlin, Heidelberg.

Ishaaya I., Barazani A., Kontsedalov S., & Horowitz A.R., 2007. Insecticides with novel modes of action : mechanism, selectivity and cross resistance. Entomological Research. 37 (Suppl.1) A2-A10.

Jansson R.K., Brown R., Cartwright B. Cox D., Dunbar D.B., Dybas R.A., Eckel C., Lasota J.A., Mookerjee P.K., Norton J.A., Peterson R.F., Starner V.R., & White S., 1996. Emamectin benzoate : a novel avermectin derivate for control of lepidopterous pests. Proceedings : the management of Diamonback Moths and other crucifers pests. Chemical control 171-177. Entomology. Cornell University.

Jansson R.K, Peterson R.F., Mookerjee P.K., Halliday W.R., Argentine J.A., & Dybas R.A., 1997. Development of a novel soluble granule formulation of emamectin benzoate for control of Lepidoptera pests. Florida Entomologist. 80(4): 425-443.

King J.R & Hennesey M.K.1996. Spinosad bait for the Caribbinean fruitfly (Diptera: Tephritidae). Florida Entomologist. 79(4):526- 531.

Labos E., Ochoa J., and Soulier C., 2002. *Cactoblastis cactorum* Berg (Lepidoptera: Pyralidae) preliminary studies for chemical control. Proc. 4th International Conference on Cactus pear and Cochineal. ISHS Acta Horticulturae. Eds. Nefzaoui & Inglese. N° 581: 247-254.

Lietti M.M., Botto E., & Alzogaray R.A., 2005. Insecticide Resistance in Argentine Populations of *Tuta absoluta* (Lepidoptera: Gelechiidae). Neotropical Entomology. 34(1): 113-119.

Maraus P.F., Catapan V., Faria D.S., Filho J.U.T.B., Santos H.S., & Hora R.C. 2008. Eficiência de insecticidas no controle da traça (*Tuta absoluta*) na cultura do tomateiro. Horticultura Brasileira 26: 2929-2933.

(McMillian W.W., Bowman M.C., Starks K.J., & Wiseman B.R., 1969. Extract of Chinaberry leaf as a feeding deterrent and growth retardant for larvae of the corn earworm and fall armyworm. J. Econ. Ent. 62: 708-710.

Meisner J., Ascher K.R.S., Aly R., & Warhben J.D.J. 1981. Response of *Spopdoptera littoralis* (Boisd.) and *Earias insulata* (Boisd.) larvae to azadirachtin and salannin. Phytoparasitica 9:27-32.

Méndez W.A., Valle J., Ibarra J.E., Cisneros J., Penagos D.I., & Williams T., 2002. Spinosad and nucleopolyhedrovirus mixtures for control of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize. Biological control 25:195-206.

Mohammed A.S. 2010. New record for leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae) infested tomato plantations in Kafer El-Sheikh region. J. Agric. Res. Kafer El-Sheikh. Uni. 36(2): 238-239.

OEPP/EPPO. European and Mediterranean Plant Protection Organization. 2005. *Tuta absoluta*. Bulletin OEPP/ EPPO Bulletin. 35:434-435.

Raffa, K.F., 1987. Influence of host plant on deterrence by azadirachtin of feeding by fall armyworm larvae (Lepidoptera : Noctuidae). J. Econ. Entomol. 80: 384-387.

Roditakis E., Papachristos D., & Roditakis N.E. 2010. Current status of the tomato leafminer *Tuta absoluta* in Greece. OEPP/EPPO Bulletin. 40: 163-166.

Salgado V.L., 1998. Studies on the mode of action of Spinosad: insect symptoms and physiological correlates. Pesticides Biochemistry and Physiology. 60: 91-102.

Seal D.R., 2005. Management of melon thrips, *Thrips palmi* Karny (Thysanoptera: Thripidae) using various chemicals. Proc. Fla. State. Hort. Soc. 118: 119-124.

Simmonds M.S.J., and Blaney W.M., 1984. Some neurophysiological effects of azadirachtin on lepidopterous larvae and their feeding response. Natural pesticides from the neem tree (*Azadirachta indica* A. Juss) and other tropical plants. Proc. 2nd. Int. Neem. Conf. Edited by Schmutter H. and Asher K.R.S. German Agency for technical cooperation. Germany.

Sparks T.C., Thompson G.D., Kirst H.A., Hertlein M.B., Larson L.L. Worden T.N & Thibault M.B 1998. Biological activity of Spinosyns, new fermentain derived insect control agents on tobacco budworm (Lepidoptera: Noctuidae) larvae. J. Econ. Ent. 91: 1277-1283.

Siqueira H.A.A, Alvaro A., Guedes R.N.C, & Picanço M.C., 2000a. Insecticide resistance in populations of *Tuta absoluta* (Lepidoptera : Gelechiidae). Agric. Forest. Entomol. 2:147-153.

Siqueira H.A.A, Guedes R.N., & Picanço M.C., 2000b. Cartap resistance and synergism in populations of *Tuta absoluta* (Lepidoptera: Gelechiidae). J. Appl. Ent. 124: 233-238.

Stanley J., Chandrasekaran & Regupathy A. 2005. Basesline toxicity of emamectin and spinosad to *Helicoverpa armigera* (Lepidoptera : Noctuidae) for resistance monitoring. Entomological Research. 39: 321-325.

Strong L., & Brown T.A., 1987. Avermectins in insect control and biology. Bull. Entomol. Res. 77: 357-389.

Takahashi H., Takakusa N., Suzuki J., & Kishimoto T., 1998. Development of a new insecticide, acetamiprid. J. Pestic. Sci. 23: 193-198.

Tomatonews, 2011. http://www.tomatonews.com/resources.html. Accessed March 10, 2011.

Turner N. 1932. Notes on rotenone as an insecticide. J. Econ. Entomol. 25: 1228-1237.

Tuta absoluta. 2011. www.tutaabsoluta.com/agrinewsfull.php?news=3. Accessed 15 March 2011.

Urbaneja A., Vercher R., Navarro V., Garcia-Mari F., & Porcuna J.L., 2007. La polilla del tomate *Tuta absoluta*. Phytoma España. 194:16-23.

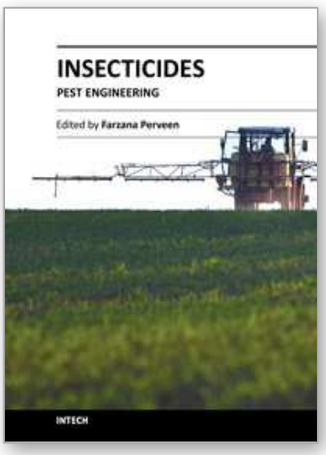
Wang D., Cong P.Y., Li M., Qui X.H., & Wang K.Y. 2009. Sublethal effects of Spinosad on survival, growth and reproduction of *Helicoverpa armigera* (Lepidoptera : Noctuidae). Pest. Man. Sci. 65: 223-227.

Wakil W., Ashfaq M., & Ghazanfar M.U., 2009. Integrated management of in chickpea in rainfed areas of Punjab, Pakistan. Phytoparasitica. 37: 415-420.

Walgenbach J.F., Leidy R.B., & Sheets T.J., 1991. Persistence of insecticides on tomato foliage and implications for control of tomato fruitworm (Lepidoptera : Noctuidae). J. Econ. Entomol. 84: 978-986.

Wing K.D., Sacher M., Kagaya Y., Tsurubuchi Y., Muldirig L.,& Connair M., 2000. Bioactivation and mode of action of the oxidiazine indoxacarb in insects. Crop Protection 19: 537-545.

Zapata N., Budia F., Viñuela E., & Pilar M. 2006. Laboratory evaluation of natural pyrehrins, pymetrozine and triflumuron as alternatives to control *Ceratitis capitata* adults. Phytoparasitica 34(4): 420-427.



Insecticides - Pest Engineering

Edited by Dr. Farzana Perveen

ISBN 978-953-307-895-3
Hard cover, 538 pages
Publisher InTech
Published online 15, February, 2012
Published in print edition February, 2012

This book is compiled of 24 Chapters divided into 4 Sections. Section A focuses on toxicity of organic and inorganic insecticides, organophosphorus insecticides, toxicity of fenitrothion and permethrin, and dichlorodiphenyltrichloroethane (DDT). Section B is dedicated to vector control using insecticides, biological control of mosquito larvae by Bacillus thuringiensis, metabolism of pyrethroids by mosquito cytochrome P40 susceptibility status of Aedes aegypti, etc. Section C describes bioactive natural products from sapindacea, management of potato pests, flower thrips, mango mealy bug, pear psylla, grapes pests, small fruit production, boll weevil and tsetse fly using insecticides. Section D provides information on insecticide resistance in natural population of malaria vector, role of Anopheles gambiae P450 cytochrome, genetic toxicological profile of carbofuran and pirimicarp carbamic insecticides, etc. The subject matter in this book should attract the reader's concern to support rational decisions regarding the use of pesticides.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Mohamed Braham and Lobna Hajji (2012). Management of Tuta absoluta (Lepidoptera, Gelechiidae) with Insecticides on Tomatoes, Insecticides - Pest Engineering, Dr. Farzana Perveen (Ed.), ISBN: 978-953-307-895-3, InTech, Available from: http://www.intechopen.com/books/insecticides-pest-engineering/management-of-tuta-absoluta-lepidoptera-gelechiidae-with-insecticides-on-tomatoes

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

IntechOpen