

Management of Thrips Species in Citrus Groves in the Marrakech Region: Exploring Biological Control Methods as Alternatives to Chemical Methods

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ABSTRACT

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Thrips, which historically caused minimal damage to Moroccan citrus orchards, have become a significant concern since 2018. A study was conducted from March to July 2021 in a citrus orchard in the Marrakech region and aimed to identify thrips species and natural enemies, monitor population dynamics, and evaluate alternative control methods. Two trials were conducted on the effect of several products on thrips species in the citrus orchards; the first one (chemical trial) where Flonicamid, Spirotetramat, Formetanate, Acetamiprid, Cyantaraniiprole, and Abamectine were assessed, the second trial (biological control), Pyrethrum, Neem oil, *Beauveria bassiana*, a mixture of Azadirachtin and paraffinic mineral oil, a mixture of Pyrethrum and neem oil, and a mixture Pyrethrum and azadirachtin were evaluated. Six thrips species were recorded: *Frankliniella occidentalis*, *Thrips tabaci*, *Pezothrips kellyanus*, *Scirtothrips* sp., *Aeolothrips* sp., and *Haplothrips* sp. Population peaks varied by citrus variety, with adult thrips reaching their highest levels during petal fall for clementine Nules (4 ± 1 individuals/beat) and during summer shoot growth for mandarin Afourer (8.8 ± 1 individuals/beat), while larval populations peaked 10 days later on Nules but remained low on Afourer. Four predatory; *Coccinella septempunctata*, *Orius* sp., *Chrysoperla carnea*, and *Aeolothrips* sp. were found on citrus trees and their population peaked during petal fall. Formetanate showing the highest efficacy (88.7% after 3 days), while Spirotetramat was less effective to control thrips species. *Beauveria bassiana* and the mixture of Azadirachtin and paraffinic mineral oil were two treatments that showed the highest significant efficacy (75.9% and 78.82 %, respectively, after two weeks). These findings underscore the increasing threat of thrips species in commercial Moroccan citrus orchards and highlight the potential of

integrated pest management strategies that combine chemical and biological control for sustainable thrips management.

Keywords: Biopesticides, Citrus, Insecticides, Morocco, *Pezothrips kellyanus*, *Scirtothrips* sp.

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Thrips species (Thysanoptera: Thripidae) represent a diverse group of tiny insects, with nearly 6000 species described worldwide, many of which are associated with cultivated plants (Cloyd 2016, Morse, and Hoddle 2006, Mouden et al. 2017, Nault, and Shelton 2010, Reynaud 2010, Reitz et al. 2011, Reitz et al. 2020). While most species are innocuous (Mound et al. 2022), several have emerged as key agricultural pests due to their capacity to cause direct feeding damage, transmit plant viruses, and reduce the marketability of fruits and vegetables. Citrus crops are no exception, and numerous thrips species have been reported as economically significant pests in citrus orchards (Blank, and Gill 1997, Costa et al. 2006, Mueller et al. 2019, Navarro-Campos et al. 2013, Rao et al. 2019, Vassiliou 2007, 2008).

Several thrips species are known to infest citrus flowers, leaves, and fruits, resulting in scarring, silverying, and deformation that substantially reduce fruit quality and commercial value. *Scirtothrips citri* (Moulton) is considered a major pest of citrus in California (Flint et al. 1991, Mueller et al. 2019), whereas *Pezothrips kellyanus* (Bagnall) has become a primary citrus pest in Australia (Mound, and Jackman 1998) and in several Mediterranean countries, including Spain (Navarro-Campos et al. 2011, 2013), Italy (Conti et al. 2001, Marullo 1998), Cyprus (Vassiliou 2007, 2008), Tunisia (Belaam-Kort, and Boulahia-Kheder 2017, Belaam-Kort et al. 2020a), and Morocco (Abbassi 2014). Other species, such as *Frankliniella*

occidentalis (Pergande) and *Thrips tabaci* (Lindeman), are also frequently recorded in citrus groves and are among the most destructive and polyphagous pests worldwide (Belaam-Kort et al. 2021, Cloyd 2016, De Grazia, Marullo 2013, Donghwang et al. 2000, Makabe et al. 2014, Reitz 2009, Reitz et al. 2020, Tsuchiya, and Furuhashi 1993).

Thrips control has been based on chemical sprays, especially organophosphates (i.e., chlorpyrifos), carbamates (i.e., methomyl), neonicotinoids (i.e., imidacloprid and acetamiprid), and microbial pesticides (i.e., Spinosad) (Childers 1992, Colloff et al. 2003, Conti et al. 2001, Rao et al. 2019, Vassiliou 2007). Although these compounds provide effective short-term control, their repeated use has resulted in widespread resistance. Documented cases include resistance of *P. kellyanus* to chlorpyrifos (Baker et al. 2004, Purvis 2002), *Scirtothrips aurantii* (Faure) to pyrethroids such as cypermethrin, deltamethrin, and lambda-cyhalothrin (Rattan 1992), *S. citri* to dimethoate and formetanate (Immaraju et al. 1989, 1990), and *F. occidentalis* to a wide range of both chemical and biological pesticides (Gao et al. 2012). Beyond resistance concern, the use of broad-spectrum insecticides has severe ecological drawbacks, often disrupting beneficial arthropods including natural enemies such as predators, parasitoids, and pollinators that are crucial for citrus ecosystem resilience (Belaam-Kort et al. 2020b, Jacas et al. 2010, Mansour et al. 2018).

These limitations have prompted increasing attention to more sustainable, eco-friendly strategies. Biorational approaches, such as the release of predators (i.e., *Chrysoperla carnea* (Stephens), *Coccinella septempunctata* (Linnaeus)) and parasitoids, or the application of entomopathogenic fungi like *Beauveria bassiana*, are being explored as alternatives to conventional pesticides (Crisp, and Baker 2011, Baker 2016, Wu et al. 2016, Navarro-Campos et al. 2020). In Mediterranean citrus orchards, surveys revealed a diverse thrips fauna, but only a few species consistently reached pest status. For instance, in Tunisia, 21 thrips species were recorded in citrus, though *P. kellyanus*, *F. occidentalis*, and *Thrips major* (Uzel) were the most prevalent (Trabelsi, and Boulahia-Kheder 2009, Belaam-Kort, and Boulahia-Kheder 2017, Belaam-Kort et al. 2020a). In Morocco, recent studies reported the presence of *P. kellyanus* and *F. occidentalis* in major citrus-growing regions such as Souss Massa and Marrakech-Safi, where they have been associated with significant fruit scarring and economic losses (Abbassi 2014, Smaili et al. 2018, 2020). Recent studies by Belaam-Kort and Boulahia-Kheder (2019) reported that fruit scarring caused by thrips affected approximately 20% of fruits across all citrus species and orange varieties. Such levels of damage lead to significant downgrading of fruit quality and consequently substantial economic losses. Recently, emphasis has been placed on implementing safer and sustainable pest management strategies to control the thrips insects in Morocco. This requires a deeper understanding of thrips population dynamics, their relative abundance across citrus phenological stages, the role of native natural enemies, and the efficacy of alternative control measures. In this context, the present study

aimed to (i) identify the thrips species present and their associated natural enemies, (ii) assess the seasonal abundance and crop damage caused by thrips populations, and (iii) evaluate the effectiveness of selected biological, botanical, and chemical insecticides under field conditions. By integrating ecological observations with control efficacy trials, this research provides insights that may guide the development of integrated pest management (IPM) programs tailored to Moroccan citrus systems.

MATERIALS AND METHODS

Study sites.

The study was conducted within a commercial citrus orchard with approximately 500 ha in the Marrakech-Safi region at El Bahja (Les Domaines Agricoles, Morocco; 31.608975° N, 8.123152° W). The orchard comprises a wide range of citrus species, including clementines, mandarins, and oranges. Two experimental plots were selected for thrips monitoring and control trials: i) Afourer plot for control trial (a Mandarin *Citrus riticulata* Blanco var. Afourer), planted on 25/06/2019, grafted on C35 rootstock, with a planting density of 6 m × 2 m and covering 2.26 ha, where chemical and biological applications were conducted; and ii) Nules (Clementine *Citrus clementina* var., Nules) with four plots for monitoring (P1, P2, P3, P4), planted on 30/07/2008, grafted on *Citrus volkameriana* rootstock, with a planting density of 6 m × 2 m and covering 2.3, 2.5, 3, and 5 ha. Throughout the experimental period, the plot designated for the trial was not subjected to any phytosanitary treatments, nor in the three months prior to the trial.

Thrips species identification and population monitoring.

Thrips adult specimens were collected from citrus trees between March and July 2021 using beating method with Fauvel funnel method (Fauvel et al., 1981). Thrips were sampled from all citrus varieties present in the orchard, including *Citrus sinensis* (var., Navel), *Citrus clementina* (var., Orogrande, var., Nules, var., Bruno, and var., Nour), and *Citrus reticulata* (var., Afourer). For each variety, thrips were collected by beating 60 citrus twigs obtained from 10 trees (i.e., six twigs per tree). Each twig was gently struck over a white tray to dislodge adult and larval thrips, which were then collected using a fine brush and preserved in 70% ethanol for identification.

For the ground vegetation, twelve weed samples were collected beneath the canopy of the same trees, mainly belonging to the genus *Sinapis*. Weed foliage was shaken over a tray using the same procedure to collect thrips individuals. All collected individuals were preserved in 70% ethanol for subsequent laboratory identification. Specimens were examined using an Olympus CX23 compound microscope and identified based on morphological keys provided in Mound, and Palmer (1981) and Navarro-Campos (2013).

Population monitoring of adults and larvae, however, was concentrated on the Nules variety, which exhibited the most significant thrips infestation. To ensure robust and representative observations, monitoring was carried out across several spatially separated four Nules plots within the same farm.

Monitoring focused on three key periods: flowering, fruit set, and 6-8 week post-petal fall. During flowering, 50

southeast-facing branches per plot (25 cm each) were tapped five times into plastic funnels to collect thrips and natural enemies. Predatory mites were sampled weekly from 100 leaves per plot. Observations for the Nules variety were conducted weekly from early April to mid-May. Natural enemies were identified using keys and illustration in Marullo (2003) and Déroulez et al. (2014).

Chemical trials.

The chemical control trial was conducted on the Afourer variety, as the thrips populations on other citrus varieties were insufficient to allow several replicates. Thrips sampling was conducted during a single trial in 2021, specifically during the fruit enlargement period, when thrips density typically reaches its peak. This timing was selected based on preliminary observations and because a notably high population was recorded on the Afourer mandarin variety, using a 16 L backpack sprayer with an adjustable nozzle to ensure uniform coverage of fine droplets capable of reaching larvae within fruit crevices. Each tree received 1.2 L of solution, and four young shoots per plot were observed, with buffer zones of one row of trees separating the plots to prevent cross-contamination. Seven chemical treatments were evaluated: T0 (untreated control), T1 (Flonicamid, 10 g/hl), T2 (Spirotetramat, 100 cc/hl), T3 (Formetanate, 50 g/hl), T4 (Acetamiprid, 30 g/hl), T5 (Cyantraniliprole, 100 cc/hl), and T6 (Abamectin, 15 cc/hl). A Completely Randomized Block Design with four replications was used within the Afourer plot (Fig. 1, Table 1). The trial was not repeated in the following year due to the low thrips population, which would not have allowed meaningful replication.

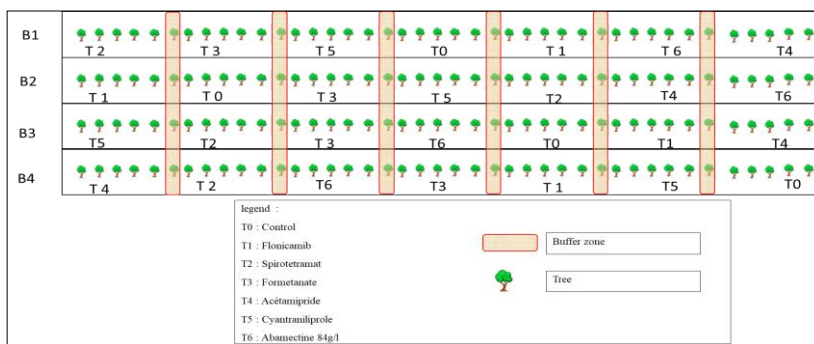


Fig. 1. Experimental set-up for the chemical control trial on the Afourer variety during 2021.

Biological trials.

The biological control trial was conducted on the Afourer variety due to insufficient thrips populations on other citrus varieties to allow meaningful replication. The trial evaluated the efficacy of several organic products, including Azadirachtin, Pyrethrum, Neem oil, and *Beauveria bassiana*, selected because of the lack of registered active ingredients for thrips control on citrus in the country. Seven modalities were assessed: T0 (untreated control), T1 (Pyrethrum, 1.5 l/ha with 1000 l/ha spray volume), T2 (Neem oil, 1 l/hl), T3 (*B. bassiana*, 40 cc/hl), T4 (Azadirachtin, 100 cc/hl +

paraffinic mineral oil, 2 l/hl), T5 (Pyrethrum + neem oil), and T6 (Pyrethrum + azadirachtin, 100 cc/hl) (Fig. 2, Table 1).

The experiment was arranged as a randomized block design with four replications, including buffer zones between plots to minimize drift and mitigate the effect of the prevailing west-to-east wind gradient. Trees were evenly distributed across the plots to ensure consistent assessment of efficacy assessment. This trial was not repeated in the following year due to the low thrips population, which would not have allowed meaningful replication.

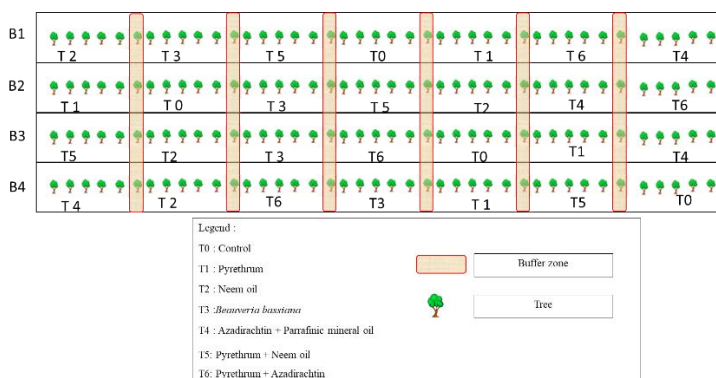


Fig. 2. Experimental set-up for the organic trial on the Afourer variety during 2021.

Table 1. Insecticide treatment used in field trials in 2021

Treatment	Active ingredient	Commercial name	Dose
Chemical	Flonicamid	TEPPEKI WG 500 WG	10 g/hl
	Spirotetramat	MOVENTO 100 SC	100 cc/hl
	Formetanate	DICARZOL 500 SG	50 g/hl
	Acetamiprid	MOSPILAN 20 SP	30 g/hl
	Cyantraniliprole	EXIREL TM	100 cc/hl
	Abamectin	AGRIMEC GOLD SC	15 cc/hl
Biological	Pyrethrum	PYRECRIS 20 EC	150cc/hl
	Neem oil	TRIACT 90 EC	1 L/hl
	<i>Beauveria bassiana</i> souche ATCC 74040	NATURALIS OD	40 cc/hl
	Azadirachtin	NEEMIX 4,5 EC	100 cc/hl
	Paraffinic mineral oil	INSECTICIDE 101 TOP	2%

Statistical analysis.

All statistical analyses were conducted using IBM SPSS Statistics (Version 21). Data obtained from the randomized complete block design were analyzed using one-way analysis of variance (ANOVA) to assess the effect of treatments on the number of adult thrips per beating. The effects on larval stages and beneficial organisms were not analyzed because their abundances were too low across the experimental units. When significant differences were detected, means were separated using the Student-Newman-Keuls (SNK) test at a significance level of $p \leq 0.05$, after verification of data normality. Treatment efficacy was evaluated using two complementary indices. The percentage reduction (Ri) was calculated as: $Ri (\%) =$

$(1 - Ti/T0i) \times 100$; where Ti is the mean of the studied variable (count) in treated plots, and $T0i$ is the mean control plots (Abbott 1925). The treatment efficacy (Ei) was calculated according to Henderson, and Tilton (1955) as: $Ei (\%) = [(1 - T0i \text{ before treatment} \times Ti \text{ after treatment}) / (T0i \text{ after treatment} \times Ti \text{ before treatment})] \times 100$; where $T0i$ and Ti represent the mean of the studied variable in control and treated plots, respectively, before and after treatment (Henderson, and Tilton 1995).

RESULTS

Thrips species and natural enemies.

During this survey, six thrips species associated with citrus were identified; *F. occidentalis*, *T. tabaci*, *P. kellyanus*, *Haplothrips* sp., *Aeolothrips* sp., and *Scirtothrips* sp. (Fig. 3, Table 2).

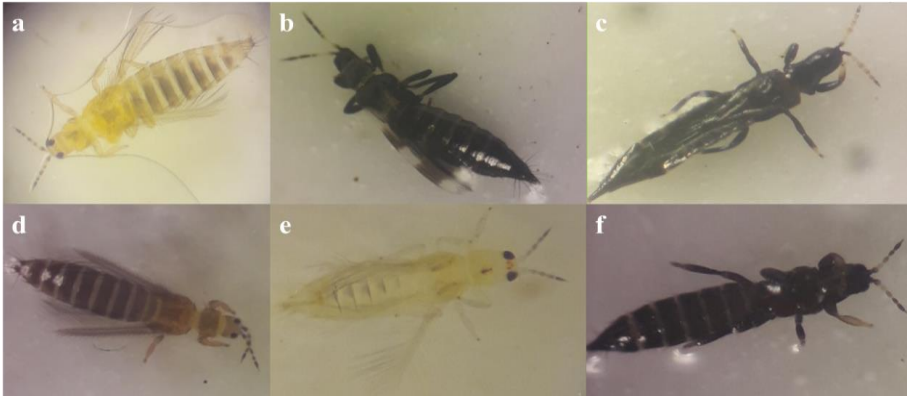


Fig. 3. Thrips species associated with citrus orchards in Marrakech during 2021: **A.** *Frankliniella occidentalis*, **B.** *Aeolothrips* sp., **C.** *Haplothrips* sp., **D.** *Thrips tabaci*, **E.** *Scirtothrips* sp., and **F.** *Pezothrips kellyanus*.

Table 2. Species of thrips found on citrus crops in the Marrakech region in 2021

Suborder	Family	subfamily	Species
Terebrantia	Thripidae	Thripinae	<i>Frankliniella occidentalis</i> (Pergande)
			<i>Pezothrips kellyanus</i> (Bagnall)
			<i>Scirtothrips</i> sp.
			<i>Thrips tabaci</i> (Lindeman)
Aeolothripidae	Aeolothripinae	-	<i>Aeolothrips</i> sp.
Phlaeothripidae	Phlaeothripinae	-	<i>Haplothrips</i> sp.

In parallel, only a few beneficial species were observed during the study period (Table 3). These included *C. carnea*, the seven-spotted lady beetle *Coccinella septempunctata*, the predatory

thrips *Aeolothrips* sp., the minute pirate bug *Orius* sp., and the predatory mite *Euseius* sp. In addition, several unidentified spider species were also noted in the orchards.

Table 3. Natural enemies collected in citrus orchards in the Marrakech region during 2021

Order	Family	Species
Neuroptera	Chrysopidae	<i>Chrysoperla carnea</i> (Stephens)
Coleoptera	Coccinellidae	<i>Coccinella septempunctata</i> (Linnaeus)
Thysanoptera	Aeolothripidae	<i>Aeolothrips</i> sp.
Hemiptera	Anthocoridae	<i>Orius</i> sp.
Mesostigmata	Phytoseiidae	<i>Euseius Stipulatus</i> (Athias-henriot)
Araneae	-	Several species

Dynamics of thrips densities and naturel enemies on citrus fruit.

Population monitoring highlighted clear differences among thrips species. *T. tabaci* and *F. occidentalis* were consistently more abundant than the other recorded species. The population of *T. tabaci* increased rapidly from early April, reaching a maximum of approximately two individuals per strike in parcel P2, and then declined sharply, dropping below 0.2

individuals per beating by April 20. Similarly, *F. occidentalis* densities rose after early April, reaching a maximum approximately 12 days later, and subsequently declined to near-zero levels after May 10. In contrast, *P. kellyanus* remained scarce throughout the observation period, with mean densities below 0.1 individuals per strike during flowering, and disappeared completely thereafter (Fig. 4).

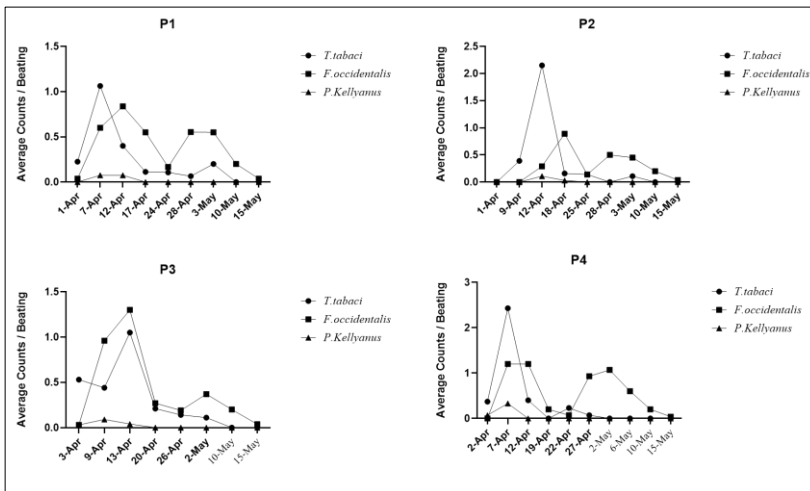


Fig. 4. Dynamics of thrips species on the Nules variety (P1-P4) in Marrakech during 2021.

At the larval stage, the first individuals were detected around April 7, with maximum densities observed on April 22. Adult populations increased rapidly across all four parcels from early April, reaching a maximum of 2.5 individuals per strike in parcel P2. This peak was followed by a pronounced decline by mid-April, coinciding with the

end of petal fall. Thrips adult densities decreased sharply from the second week of May and reached undetectable levels across all parcels by May 15 (Fig. 5). The temporal overlap between adults (at the end of flowering) and larvae (during petal fall) highlights the close synchrony of thrips population dynamics with citrus phenology.

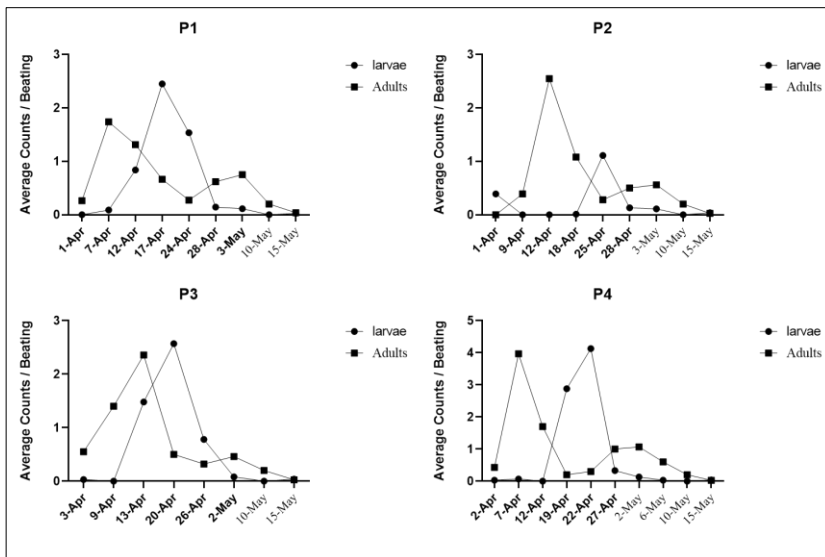


Fig. 5. Dynamics of thrips populations in Marrakech citrus orchards during 2021 at four parcels (P1-P4).

Monitoring of natural enemies associated with thrips revealed distinct temporal dynamics across the four studied parcels (Fig. 6). Among the recorded predators, spiders were by far the most abundant, with densities peaking between late April and early May, reaching values above 0.8 individuals per beating in

parcels P2 and P3. Other natural enemies such as *C. septempunctata*, *C. carnea*, *Orius* sp., and *Aeolothrips* sp. were detected only sporadically and in much lower numbers (≤ 0.2 individuals per beating). Their occurrence was generally restricted to the flowering and early fruit set stages.

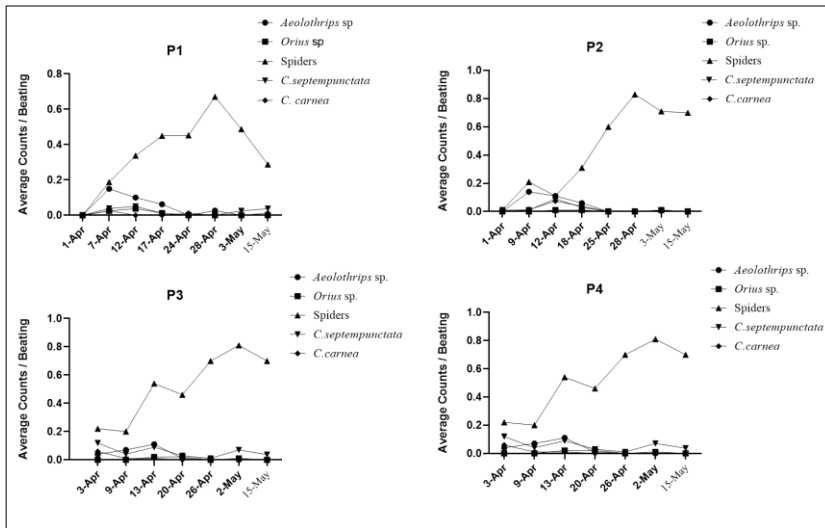


Fig. 6. Dynamics of natural enemy in citrus orchards of Marrakech during 2021 at four plots (P1-P4).

Chemical trial.

Field trials conducted in Marrakech region during 2021 revealed differences in efficacy between the insecticide formulations in suppressing thrips populations on citrus. Before treatment application, thrips counts did not differ significantly among treatments, including the untreated control ($F_{(6,18)} = 0.45$; $p = 0.83$). One day after spraying, however, significant reductions were recorded in most treatments relative to the control ($F_{(6,18)} = 4.54$; $p < 0.05$). The untreated control averaged 8.81 ± 1.7 adults per tap, whereas Spirotetramat-treated plots still harbored relatively high densities (4.6 ± 1.4 adults per tap). By day three, all treatments except Spirotetramat induced significant declines in thrips populations ($F_{(6,18)} = 6.6$; $p < 0.01$). At seven and fourteen days post-application, all insecticides exhibited strong

suppressive effects, with thrips densities reduced to near-zero levels ($F_{(6,18)} = 14.95$, $p < 0.05$). By day 21, no significant differences were detected among treatments ($F_{(6,18)} = 1.3$; $p = 0.263$), largely due to a natural decline in thrips abundance across all plots, including the control (1.5 ± 0.15 adults/ beating method), similar to Abamectin-treated plots (0.4 ± 0.12 adults/ beating method per tap) (Table 4).

These results highlight the short-term effectiveness of most of the insecticides tested in reducing thrips infestations, while also highlighting the limited and inconsistent performance of Spirotetramat. The observed population collapse by the third week suggests that chemical interventions may only provide transient benefits and should be strategically integrated with other sustainable management approaches.

Table 4. Average number of adults by beating method (% ± SE), ANOVA with One Factor used to compare the effect of chemical treatments on captured populations J-1 and DAT in Marrakech region during 2021

Active Ingredient	BFA	d+1	d+3	d+7	d+14	d+21
Control	10.19±1.33a	8.81±1.7b	5.94±0.87c	4.75±0.88b	1.94±0.23c	1.56±0.16a
Fonicamib	8.31±1.01a	1.25±0.39a	1.88±0.44a	1.19±0.29a	1.25±0.30abc	1.44±0.18a
Spirotetramat	8.06±1.20a	4.63±1.46a	6.06±1.43bc	0.75±0.23b	1.63±0.41bc	1.56±0.16a
Formentanat	6.63±0.85a	1.58±0.52a	0.44±0.22a	0.31±0.12a	0.38±0.13a	0.19±0.14a
Acetamiprid	8.50±0.99a	4.19±1.73a	2.13±0.85a	0.63±0.29a	0.38±0.13a	0.19±0.10a
Cyantaraniiprole	8.56±1.29a	2.31±0.75a	2.06±0.52a	1.06±0.27a	0.75±0.19ab	0.19±0.10a
Abamectin	8.69±1.01a	2.31±0.55a	3.13±0.74ab	1.25±0.27a	0.94±0.27ab	0.44±0.13a
F	F(6,18)=0.45	F(6,18)=4.54	F(6,18)=6.65	F(6,18)=14.95	F(6,18)=5.96	F(6,18)=1.30
p	0.833>0.05	0<0.05	0<0.05	0<0.05	0<0.05	0.263>0.05

*BFA: before foliar product application, d: day.

The efficacy and reduction rates of the tested insecticides against thrips are summarized in Table 5. One day after application, Fonicamid exhibited the strongest performance, with an efficacy of 82.60% and a reduction rate of 85.81%, while Spirotetramat remained the least effective, with efficacy not exceeding 33.56%. At three days post-treatment, all insecticides except Spirotetramat achieved efficacy levels above 50%, with Formentanat displaying the highest efficacy at 92.59% and a corresponding reduction rate of 88.62%. Spirotetramat, in contrast, showed no measurable efficacy or reduction at this stage.

By day seven, all products maintained high levels of efficacy, ranging from 69.14% for Abamectin to 89.97% for Formentanat. At day fourteen, efficacy values generally declined, with Fonicamid showing only 20.99% efficacy

compared to 76.52% for Acetamiprid and 69.89% for Formentanat. Interestingly, the long-term effectiveness of certain compounds, such as Acetamiprid and Cyantraniliprole, remained relatively stable, achieving efficacy levels of 85.59% and 85.69%, respectively, by day 21. Formentanat also demonstrated consistent performance, maintaining an efficacy of 81.28% after 21 days (Table 5).

Overall, with the exception of Spirotetramat, all insecticides provided significant and sustained reductions in thrips populations, with Formentanat, Acetamiprid, and Cyantraniliprole emerging as the most reliable options under field conditions. These findings highlight the importance of selecting compounds with both immediate and persistent activity when developing integrated pest management strategies for thrips in citrus orchards.

Table 5. Reduction rate (R) and efficacy (E) of treatments against thrips populations assessed using the beating method ($[j + n]$ = days after treatment) in Marrakech region during 2021

Treatment	d+1		d+3		d+7		d+14		d+21	
	R(%)	E(%)	R(%)	E(%)	R(%)	E(%)	R(%)	E(%)	R(%)	E(%)
Flonicamib	85.81	82.60	68.35	61.19	74.95	69.28	35.57	20.99	7.69	0.00
Spirotetramat	47.45	33.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Formentanat	82.07	72.44	92.59	88.62	93.47	89.97	80.41	69.89	87.82	81.28
Acétamipride	52.44	42.98	64.14	57.01	86.74	84.10	80.41	76.52	87.98	85.59
Cyantaraniiprole	73.78	68.79	65.32	58.72	77.68	73.43	61.34	53.98	87.98	85.69
Abamectine	73.78	69.25	47.31	38.21	73.68	69.14	51.55	43.18	71.99	67.15

Biological trial.

Impact of biological control treatments on thrips species is presented in Table 6. On the first day prior to application, no significant differences were observed among treatments, including the control ($F_{(6,18)} = 0.98$; $p = 0.44$), indicating comparable initial thrips densities. On the first day after treatment, differences between treatments remained non-significant ($F_{(6,18)} = 1.67$; $p = 0.36$), with the control recording 7.05 ± 0.86 thrips per tap and the lowest count observed for the Pyrethrum + azadirachtin mixture (4.18 ± 0.50). On the third day post-treatment, thrips populations remained relatively stable across treatments ($F_{(6,18)} = 0.38$; $p = 0.89$), with the control at 5.31 ± 0.48 and the lowest density observed in the Azadirachtin + paraffinic mineral oil mixture (4.31 ± 0.66). By the seventh day, significant differences emerged between treatments and the control ($F_{(6,18)} = 3.36$; $p = 0.05$), with the control maintaining a high thrips population (7.43 ± 0.61), whereas the Azadirachtin + oil mixture showed the

greatest reduction (3.62 ± 0.43). On the fourteenth day, most treatments significantly reduced thrips numbers compared to the control ($F_{(6,18)} = 3.74$; $p = 0.013$), with thrips densities of 0.56 ± 0.18 for *B. bassiana*, 0.50 ± 0.42 for Azadirachtin + paraffinic mineral oil, and 0.75 ± 0.21 for Neem oil, compared to 1.93 ± 0.32 in the control. On the twenty-first day, no significant differences were noted between treatments ($F_{(6,18)} = 0.29$; $p = 0.94$), as all biological treatments maintained low thrips densities (0.50-0.93 individuals per tap), indicating sustained efficacy over time (Table 6).

Overall, these results demonstrate that the biological treatments particularly Azadirachtin + paraffinic mineral oil, *B. bassiana*, and Neem oil effectively suppressed thrips populations, with maximal reductions observed between 7 and 14 days post-application, and maintained low densities through day 21, supporting their potential integration into sustainable thrips management strategies in citrus orchards.

Table 6. Average number of Thrips captured by tapping (% ± SE), ANOVA with one Factor used to compare the effect of biological treatments on captured populations before and after treatment in Marrakech region during 2021

Treatment	BFA	d+1	d+3	d+7	d+14	d+21
Control	7.25±0.9a	7.05±0.86	5.31±0.48	7.43±0.61b	1.93±0.32b	0.93±0.39b
Pyrethrum	6.93±0.97a	5.37±0.86	5.87±0.88	6.56±0.75ab	1.37±0.31ab	0.81±0.33
Neem oil	7.12±1.59a	5.81±0.78	5.12±0.87	7.12±0.27b	0.75±0.21a	0.81±0.20
<i>B. bassiana</i>	8.75±1.34a	6.00±0.85	5.81±0.73	4.37±0.85ab	0.56±0.18a	0.81±0.20
Azadirachtin + paraffinic mineral oil	8.87±1.00a	5.75±0.88	4.31±0.66	3.62±0.43a	0.50±0.42a	0.81±0.24
Pyrethrum + neem oil	7.93±1.37a	4.06±0.69	4.81±0.47	7.50±1.03b	1.50±0.42ab	0.93±0.29
Pyrethrum + Azadirachtin	11.87±2.26a	4.18±0.50	5.75±0.64	6.18±0.83ab	1.93±0.29ab	0.50±0.24
F	F(6,18)=0.98	F(6,18)=1.67	F(6,18)=0.38	F(6,18)=3.36	F(6,18)=3.74	F(6,18)=0.29
P	0.44>0.05	1.36>0.05	10.888>0.05	0.05>0.05	0.013<0.05	0.939>0.05

* BFA: before foliar product application, d: day

The efficacy and reduction rates of the tested biological treatments are summarized in Table 7. Among the different options, the Azadirachtin + paraffinic mineral oil mixture demonstrated the highest and most consistent efficacy, reaching 78.82% at day 14 with a reduction rate of 74.09%. *B. bassiana* also performed strongly, with an efficacy of 75.96% and a reduction rate of 70.98% at the same period. In contrast, treatments such as Neem oil alone and the Pyrethrum + neem oil mixture provided only moderate suppression, with efficacy values peaking at 60.43% and 47.35%, respectively, and showing a decline by day 21 (Table 7).

Overall biological treatments contributed to reducing adult thrips

densities. However, because larval stages were not assessed in this study, the full effectiveness of the tested products cannot be fully determined. Within these limitations, the results nonetheless indicate that Azadirachtin + paraffinic mineral oil and *B. bassiana* showed the most consistent reductions in adult populations. These two treatments may therefore represent promising options for integration into Integrated Pest Management (IPM) programs aiming to limit reliance on synthetic insecticides, although further evaluations including effects on larvae are required before drawing definitive conclusions about their overall efficacy.

Table 7. Reduction rate (R) and efficacy (E) of treatments against thrips populations assessed using the beating method ((j + n) = days after treatment) in Marrakech region during 2021

Treatment	d+1		d+3		d+7		d+14		d+21	
	R(%)	E(%)	R(%)	E(%)	R(%)	E(%)	R(%)	E(%)	R(%)	E(%)
Pyrethrum	23.83	20.31	0.00	0.00	11.71	7.63	29.02	25.74	12.90	8.88
Neem oil	17.59	16.08	3.58	1.82	4.17	2.42	61.14	60.43	12.90	11.31
<i>B. bassiana</i>	14.89	29.48	0.00	9.50	41.18	51.27	70.98	75.96	12.90	27.83
Azadirachtin + paraffinic mineral oil ⁺	18.44	33.34	18.83	33.66	51.28	60.18	74.09	78.82	12.90	28.81
Pyrethrum + neem oil	42.41	47.35	9.42	17.18	0.00	7.71	22.28	28.94	0.00	8.58
Pyrethrum + azadirachtin	40.71	63.79	0.00	33.86	16.82	49.20	0.00	38.92	46.24	67.16

DISCUSSION

This study provides new insights into the composition, abundance, and population dynamics of thrips and their natural enemies in Moroccan citrus orchards, while also evaluating the efficacy of chemical and biological control methods. The identification of *F. occidentalis* and *T. tabaci* as dominant species, along with the detection of *P. kellyanus* at low abundances, is consistent with findings from other Mediterranean citrus-growing regions, such as Tunisia, Spain, and Cyprus (Belaam, and Boulahia-Kheder 2012, Navarro-Campos et al. 2012, Vassiliou 2010). Although *P. kellyanus* is considered a key pest in Spain and Italy, causing up to 70–80% fruit damage (Conti et al. 2001, Navarro-Campos et al. 2011), its low density in Marrakech region suggests that the species is not yet a major economic threat in Morocco. This situation is similar to observations in Tunisia, where *P. kellyanus* was reported but remained below damaging thresholds (Belaam, and Boulahia-Kheder 2012). However, regular monitoring remains essential given the

capacity of this species to rapidly increase under favorable ecological conditions.

The relatively low diversity of thrips in Moroccan citrus orchards, compared to regions such as Florida with 36 species, including several predators (Childers, and Nakahara 2006), may be linked to the sampling strategy, the dominance of monoculture citrus systems, and the absence of surrounding host plants that act as thrips reservoirs. Indeed, studies from Tunisia and Spain have shown that orchards bordered by mixed fruit trees or vineyards host higher thrips populations, due to continuous availability of flowering hosts (Navarro-campos et al. 2013). The predominance of *F. occidentalis* and *T. tabaci* also reflects their well-documented polyphagy, as they are known to infest a wide range of crops, including vegetables and ornamentals (Deligeorgidis et al. 2005).

The occurrence of *C. carnea*, *C. septempunctata*, predatory thrips, and spiders confirms their role in thrips suppression, as previously documented in Mediterranean orchards (Elimem, and Chermiti 2012; Smaili et al. 2020).

However, in this study their abundance was lower than other citrus growing area like Australia where diverse and abundant predator guilds contribute significantly to natural regulation (Baker et al. 2011). This discrepancy may be explained by the intensive use of insecticides, which reduce beneficial insect populations, as well as by climatic conditions such as high summer temperatures (> 40 °C) that may limit predator survival. The seasonal activity of *C. carnea* and *C. septempunctata*, peaking during flowering and petal fall, matches observations from Tunisia and Italy (Belaam Kort et al. 2020, Perrotta, and Conti, 2008), suggesting a strong phenological synchronization with thrips populations. This highlights their potential for augmentative release programs, which have been successful in California against *Scirtothrips citri* (Khan, and Morse 1999).

Chemical control trials confirmed the efficacy of several insecticides (Fonicamid, Formetanate, Cyantraniliprole, Abamectin) in reducing thrips populations, consistent with previous studies in Cyprus and Greece (Vassiliou 2007, 2008, Deligeorgidis et al. 2005). However, their declining performance after 21 days, coupled with concerns about resistance development in *F. occidentalis* (Bielza et al. 2007, Reitz et al. 2020), raises questions about the sustainability of relying solely on chemical strategies. Reports from Spain and Australia have already documented resistance to spinosad and acrinathrin (Herron, and James 2005), reinforcing the need for rotational use and integration with non-chemical tools.

Biological control trials revealed that while most botanical insecticides (Pyrethrum, Neem oil, Azadirachtin) showed limited field persistence, the combination of Azadirachtin + paraffinic mineral oil and the entomopathogenic fungus *B. bassiana* achieved significant

reductions at day 14, with efficacy exceeding 70%. These results are comparable to studies conducted in semi-arid environments, where environmental stressors (high temperatures, low humidity) reduced the persistence of microbial and botanical formulations (Lewis et al. 1997, Mouden et al. 2017). To enhance their performance, future research should focus on improved formulations with higher stability under heat stress, as well as optimized application timing (i.e., evening sprays to reduce UV degradation).

Overall, the results demonstrate that biological treatments, particularly *B. bassiana* and Azadirachtin + paraffinic mineral oil, represent promising alternatives to chemical insecticides, and should be considered as core elements of Integrated Pest Management (IPM) programs in Moroccan citrus orchards. However, their efficacy remains dependent on environmental conditions and should be complemented with conservation strategies, such as the introduction of flowering cover crops to sustain predator populations (Kirk, and Terry 2003).

This study is a first step toward a more comprehensive understanding of thrips dynamics in Moroccan citrus orchards. Its limitations include more precise identification of species based on microscopic preparations, the short trial duration, the focus on a single region, not having considered the larvae (the most important instar for damage), and the restricted sampling of associated vegetation. Future work should expand monitoring across different agro-ecological zones and for several years, assess inter-annual variability, and evaluate the compatibility of biocontrol agents with pollinators and other beneficial organisms. Such efforts will be crucial for developing sustainable and

locally adapted IPM strategies, particularly in the context of growing demand for residue-free and organic citrus production.

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RESUME

Khallou A., Smaili M.C., Mennani M., Haddad N., Kokiçi H., And Boutaleb-Joutei A. 2025. Management des espèces de thrips dans les vergers d'agrumes de la région de Marrakech: Exploration des méthodes de lutte biologique comme alternatives aux méthodes chimiques. Tunisian Journal of Plant Protection 20 (2): 97-116.

Les thrips, historiquement responsables de dégâts limités dans les vergers d'agrumes au Maroc, sont devenus des ravageurs préoccupant depuis 2018. Une étude a été menée de mars à juillet 2021 dans un verger d'agrumes de la région de Marrakech afin d'identifier les espèces de thrips et les ennemis naturels, de suivre la dynamique des populations et d'évaluer des méthodes alternatives de lutte. Deux essais ont été réalisés pour évaluer l'efficacité de différents produits contre les thrips dans les vergers d'agrumes. Le premier essai de lutte chimique a porté sur les insecticides Flonicamid, Spirotétramat, Formétanate, Acétamipride, Cyantranilprole et Abamectine. Le deuxième essai de lutte biologique a évalué les traitements aux Pyrèthre, Huile de neem, *Beauveria bassiana*, mélange Azadirachtine et huile minérale paraffinique, mélange Pyrèthre et huile de neem ainsi que le mélange Pyrèthre et azadirachtine. Six espèces de thrips ont été recensées: *Frankliniella occidentalis*, *Thrips tabaci*, *Pezothrips kellyanus*, *Scirtothrips* sp., *Aeolothrips* sp. et *Haplothrips* sp. Les pics de population ont varié selon la variété d'agrumes. Les adultes ont atteint leurs niveaux les plus élevés pendant la période de la chute des pétales chez la clémentine Nules (4 ± 1 individus/frappage) et pendant la pousse estivale chez la mandarine Afourer ($8,8 \pm 1$ individus/frappage), tandis que les populations larvaires ont été observées dix jours plus tard chez Nules et sont restées faibles chez Afourer. Quatre prédateurs ont été observés sur les agrumes : *Coccinella septempunctata*, *Orius* sp., la chrysope verte *Chrysoperla carnea* et *Aeolothrips* sp., avec des pics d'abondance durant la chute des pétales. Le Formétanate a montré l'efficacité la plus élevée (88,7 % après 3 jours), tandis que le Spirotétramat s'est révélé moins efficace contre les thrips. En lutte biologique, *Beauveria bassiana* ainsi que le mélange azadirachtine et huile minérale paraffinique ont montré l'efficacité la plus élevée significativement (75,9% et 78.82 %, respectivement, après deux semaines). Ces résultats mettent en évidence la menace croissante que représentent les thrips dans les vergers d'agrumes commerciaux au Maroc et soulignent l'intérêt de stratégies de lutte intégrée combinant méthodes chimiques et biologiques pour une gestion durable de ces ravageurs.

Mots clés: Agrumes, Biopesticides, Insecticides, Maroc, *Pezothrips kellyanus*, *Scirtothrips* sp.

ملخص

خَلُو، عبد الحق ومولاي شريف سماعيلي ومحمد مناني ونجاة حداد وحسين كوكيتشي وعبد الملك بوطالب-جوطي. 2025. إدارة حشرة التريبس في بساتين الحمضيات بجهة مراكش: استكشاف أساليب المكافحة البيولوجية كبديل للمكافحة الكيميائية. Tunisian Journal of Plant Protection 20 (2): 97-116.

تُعد حشرات التريبس من الآفات التي كانت تُسبب تاريخياً أضراراً محدودة في بساتين الحمضيات بالمغرب، غير أنها أصبحت منذ سنة 2018 تشكل مشكلة متزايدة الأهمية. أجريت دراسة خلال الفترة الممتدة من مارس إلى يونيو 2021 في بستان حمضيات بمنطقة مراكش، وهدفت إلى تحديد أنواع التريبس وأعدادها الطبيعيين، وتتبع ديناميكية تجمعاتها، وتقييم بعض وسائل مكافحة البديلة. تم تنفيذ تجربتين لتقييم فعالية عدة معاملات ضد التريبس في بساتين الحمضيات. شملت التجربة الأولى للمكافحة الكيميائية كلاً من المبيدات فلونيكاميد وسيبروتيتراميت وفورماتانيت وأسيثامبيريد وسيانترانيلبرويل وأبامكتين. أما التجربة الثانية للمكافحة البيولوجية فقد شملت المعاملات بواسطة البيريثروم وزيت النيم والفطر *Beauveria bassiana* ومزيج الأزاديلاختين + زيت معدني ومزيج البيريثروم + زيت النيم ومزيج البيريثروم + الأزاديلاختين. تم تسجيل ستة أنواع من التريبس وهي *Frankliniella occidentalis* و *Thrips tabaci* و *Pezothrips kellyanus* و *Scirtothrips sp.* و *Aeolothrips sp.* وقد اختلفت ذروات الكثافة العددية باختلاف صنف الحمضيات، حيث بلغت أعداد البالغات ذروتها خلال مرحلة تساقط البتلات في صنف الكليمنتين نوليس (4 ± 1 أفراد/ضربة) وخلال النمو الصيفي لصنف المندرين أفرير (8.8 ± 1 أفراد/ضربة)، في حين بلغت كثافة اليرقات ذروتها بعد عشرة أيام في صنف نوليس، وبقيت منخفضة في صنف أفرير. كما تم رصد أربعة مقترسات طبيعية على أشجار الحمضيات وهي *Coccinella septempunctata* و *Orius sp.* والدعسوقة الخضراء *Chrysoperla carnea* و *Aeolothrips sp.* حيث تزامنت ذروة كثافتها مع مرحلة تساقط البتلات. أظهر مبيد فورماتانيت أعلى فعالية في مكافحة (88.7% بعد ثلاثة أيام)، في حين كان المبيد سيبروتيتراميت أقل فعالية ضد التريبس. وفي المكافحة البيولوجية، كان الفطر *Beauveria bassiana* والمزيج الأزاديلاختين مع الزيت المعدني هما الأكثر فعالية بشكل معنوي (75.9% و 78.82% على التوالي، بعد أسبوعين). تؤكد هذه النتائج تزايد خطورة التريبس في بساتين الحمضيات التجارية بالمغرب، وتبرز أهمية اعتماد استراتيجيات المكافحة المتكاملة التي تجمع بين الوسائل الكيميائية والبيولوجية لتحقيق إدارة مستدامة لهذه الآفة.

كلمات مفتاحية: المغرب، حمضيات، مبيدات كيميائية، مبيدات بيولوجية، *Pezothrips kellyanus*، *Scirtothrips sp.*

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