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Article in Bulletin of Insectology · March 2020

4 authors:

Imen Belaam Kort
National Institute of Agronomy, Tunis

Rita Marullo
Mediterranean University of Reggio Calabria

Sabrine Attia
Université Catholique de Louvain - UCLouvain

Synda Boulahia Kheder
Institut national agronomique de Tunisie (INAT)

February 17, 2020 - corrected PROOF Bulletin of Insectology **73** (1): xxx-xxx, 2020
ISSN 1721-8861 eISSN 2283-0332

Thrips fauna in citrus orchard in Tunisia: an up-to-date

Imen BELAAM-KORT[1], Rita MARULLO[2], Sabrine ATTIA[1], Synda BOULAHIA-KHEDER[1]
[1]*Laboratory of Bio-aggressors and Integrated Pest Management in Agriculture, National Agronomic Institute of Tunisia (INAT), University of Carthage, Tunisia*
[2]*Department of Agriculture, Mediterranean University of Reggio Calabria, Italy*

Abstract

Thrips species that damage citrus are very little known in Tunisia. As a first step to establish an IPM strategy against thrips in citrus orchards, an inventory of species was carried out from Navel oranges trees and herbaceous plants in the vicinity. The status of each species was determined and the relationship between thrips damaging citrus, predaceous thrips and both agroecosystem were investigated. Samples of thrips were collected from orange trees, herbaceous plants and soil under canopy. A total of twenty-one thrips species were collected with 6 new findings. To help identification of these species likely to be found in Tunisia, an easy-to-use dichotomous key of all recorded species was designed. The most abundant species in navel oranges trees were *Frankliniella occidentalis* (Pergande), *Thrips major* Uzel and *Pezothrips kellyanus* Bagnall. Six species among the total identified were predators. The thrips fauna living in citrus groves between citrus and weeds is rich, but not all species have the same economic importance for citrus. Here, *F. occidentalis*, *P. kellyanus* and *T. major* are the major species at least regarding their abundance. Herbaceous plants in citrus orchards may play a key role in maintaining these species and also predaceous ones providing food when the susceptible citrus organs are not available. The data obtained are critical for biological conservation strategies.

Key words: thrips species, citrus tree, herbaceous plants, sampling, Tunisia.

Introduction

Thysanoptera are one of the insect orders widespread throughout the world with about 6,164 species belonging to 782 genera and 2 suborders, Terebrantia and Tubulifera (ThripsWiki, 2017). Thrips are minute insects characterized by asymmetric mouth-parts and by four slender wings with a long fringe of marginal cilia (Lewis, 1997). Some species like *Frankliniella occidentalis* (Pergande) and *Thrips tabaci* Lindeman are of economic importance mainly due to their polyphagy and ability to transmit pathogens to crops (Mortazavi and Aleofoor, 2015). In the case of citrus orchards, thrips have been reported as new important economic pests in several countries including Tunisia where fruit scars attributed to thrips are increasingly being reported in recent years (Conti *et al.*, 2001; Marullo and De Grazia, 2012; Planes *et al.*, 2015; Belaam-Kort and Boulahia-Kheder, 2017a). In different regions of the world many thrips species are considered pests of citrus such as: *Pezothrips kellyanus* (Bagnall), *Scirtothrips aurantii* Faure, *Scirtothrips citri* (Moulton), *Scirtothrips dorsalis* Hood, *Scirtothrips inermis* Priesner, *Chaetanaphothrips orchidii* (Moulton 1907), *Chaetanaphothrips signipennis* (Bagnall), *Frankliniella bispinosa* (Morgan), *Heliothrips haemorrhoidalis* (Bouche) and *Thrips hawaiiensis* (Morgan) (Quayle, 1938; Ebeling, 1959; Blank and Gill, 1997; Parker and Skinner, 1997; Lacasa and Llorens, 1998; Bedford, 1998). In the Mediterranean Basin, only three species are considered as citrus pests: *P. kellyanus* which has recently become a harmful insect in some Mediterranean regions such as Italy, Spain and Greece (Marullo, 1998; Varikou *et al.*, 2009; Navarro *et al.*, 2013), *H. haemorrhoidalis* and *S. inermis* which have been recorded for their severe damage in several regions of Spain (Longo, 1986; Lacasa *et al.*, 1996; Marullo and De Grazia, 2012). In addition, others thrips associated with citrus fruits have been cited such as *F. occidentalis*, *Thrips major* Uzel 1895, *T. tabaci*, *Thrips meridionalis* (Priesner), *Thrips angusticeps* Uzel (Navarro *et al.*, 2008; Teksam and Tunç, 2009). These thrips are polyphagous but they were not reported to cause damage on citrus fruits. According to Lacasa *et al.* (1996), the diversity of plants that grow in citrus orchards may favour the spread of these thrips and enhance their presence in citrus flowers.

In Tunisia, an inventory achieved in 2012 in citrus orchards reported the presence of 14 species of thrips among them the most abundant was *T. major* with 90%, then *P. kellyanus* and *F. occidentalis* with 3.3% and 2.6% of the thrips respectively (Belaam-Kort and Boulahia-Kheder, 2017a).

The objective of this research was to improve knowledge about citrus thrips as emerging pests and precisely to determine the status of phytophagous species found and distinguish dominant from minor species. During three years a more comprehensive inventory of thrips fauna living in Tunisian citrus orchards was performed on orange trees, which represent the main citrus orchards grown in the monitored area on weeds and in soil, to investigate the relationship between these strata regarding thrips damaging citrus fruits and predaceous thrips.

Finally, to facilitate the determination of species likely to be found in Tunisia, a simplified identification key to thrips living in citrus orchards has been developed based on some important criteria such as wing venation, antennal sensoria and number of segments.

Materials and methods

Collecting thrips from citrus and herbaceaous plants

This work was carried out in four citrus orchards of Navel oranges variety, two located in Bizerte (Ghar Melh and Alia) (37°10.1466'N 10°2.0868'E, elevation: 100 m a.s.l.) and the others in Mornag (Sidi Saad and Khlidia) (36°40.7586'N 10°17.517'E, elevation: 32 m a.s.l.). In each orchard, thrips were collected weekly or monthly on orange trees from March to the end of June during the 3 years 2015-2017, by picking 50 flowers or fruitlets which is a standard method used to sample thrips (Navarro *et al*., 2011) and also by hitting branches onto a funnel of 18 cm diameter (Fauvel *et al*., 1981) from March 2015 until September 2017.

Concomitantly flowers of herbaceous plants beneath trees were collected and placed in tubes filled with alcohol 70° to be examined for thrips species, from orchards of investigation as well as from others in Tunis and Menzel Bouzelfa.

Collecting thrips from soil of citrus orchards

Samples of leaves litter and surface soil were also taken monthly in the same citrus groves under the citrus canopy at the rate of 4 samples per orchard. Each sample consisted of a quantity of soil that fills a cylinder of diameter 15 cm/ 10 cm height. The samples were taken randomly from a surface area of 20 × 20 cm and 5 cm depth. They were taken back to the laboratory where thrips were extracted using the Berlese funnel. This device allows the extraction of insects from a litter/soil by a heating system that makes insects escape and fall in 70° alcohol tubes. Then thrips were separated from others insects and mites under a binocular microscope.

Mounting and identification of thrips

In the laboratory, the adult of thrips were mounted onto slides in Canada balsam medium by using the protocol of Mound and Kibby (1998). Larvae were mounted directly into Hoyer’s medium.

Thrips were identified based on a combination of several recognized keys: Palmer *et al.* (1989), Mound and Kibby (1998), Zur Strassen (1996; 2003), Moritz *et al.* (2004), Marullo (2003) and Mound and Reynaud (2005).

The effort deployed to identify the collected material allowed to build a dichotomous key for identification of citrus thrips of Tunisia, based on the major and easy to observe morphological characters reported in the literature-selected texts.

Statistical analysis

Data were analysed using the Graph Pad Prism for analysis of variance (ANOVA), version 5.01 for Windows, Graph Pad Software, San Diego, California, USA (http://www.graphPad.com). All tests were applied under two-tailed hypotheses and the significance level P was set at 0.05. Tukey’s test was used to compare means.

Results

Composition of thrips species on Navel oranges trees and in the soil

Twenty-one thrips species distributed in 3 families were identified from 2290 specimens collected from citrus trees during 2015-2017 (table 1). Five species belonging to both families Thripidae and Aeolothripidae,

Table 1. List of Thysanoptera species identified from Navel orange orchards (trees and soil).

Species	Families	Sub-orders
Melanthrips fuscus (Sulzer 1776) *	Aeolothripidae	Terebrantia
Melanthrips pallidior Priesner 1919 **		
Ankothrips niezabitowskii (Schille 1910) **		
Aeolothrips intermedius Bagnall 1934		
Aeolothrips collaris Priesner 1919		
Franklinothrips megalops (Trybom 1912)		
Franklinothrips vespiformis (D.L. Crawford 1909) **		
Thrips major Uzel 1975 *	Thripidae	
Thrips tabaci Lindeman 1889 *		
Thrips angusticeps Uzel 1895		
Thrips meridionalis (Priesner 1926)		
Frankliniella occidentalis (Pergande 1895) *		
Pezothrips kellyanus (Bagnall 1916) *		
Megalurothrips sjostedti Trybom1908 **		
Limothrips cerealium Haliday 1836		
Stenothrips graminum Uzel 1895		
Chirothrips manicatus Haliday 1836 **		
Scolothrips longicornis Priesner 1926 **		
Haplothrips tritici (Kurdjumov 1912)	Phlaeothripidae	Tubulifera
Haplothrips minutus (Uzel 1895)		
Liothrips oleae (Costa 1857)		

* species collected from both soil and trees; ** species recorded for the first time in Tunisian citrus orchards.

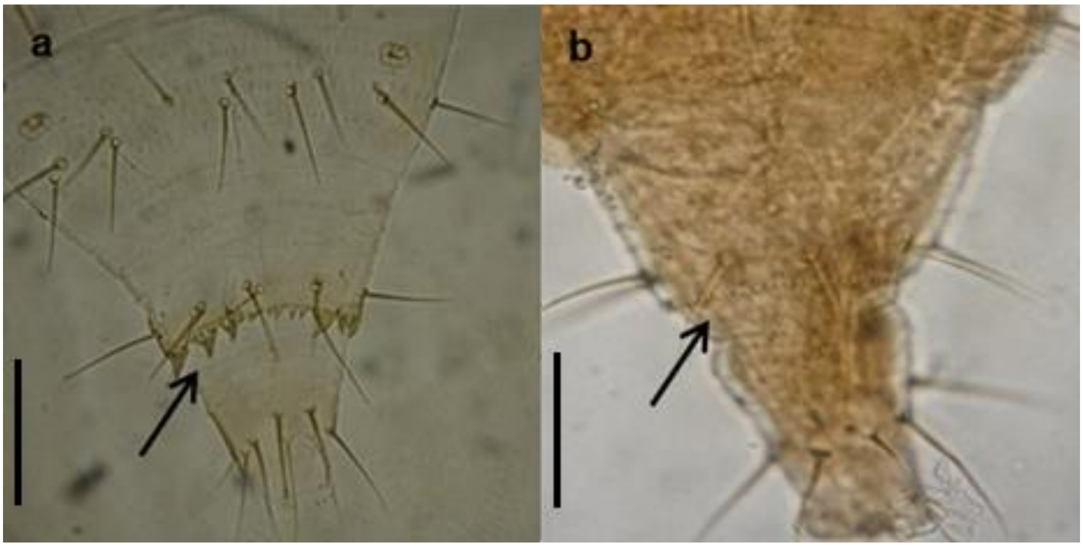

Figure1. Ventral abdominal tergite VIII of second instar larva. **a)** sclerotized teeth for *P. kellyanus*. **b)** long finely pointed microtrichia for *F. occidentalis*. (Scale bars: 30 µm).

belonging to both families Thripidae and Aeolothripidae, also recovered from citrus trees were identified from a total of 341 thrips (148 adults, 60 larvae and 133 nymphs) found in the litter/surface layer soils of the four orchards in 2016 and 2017 (table 1). Fourteen species belonging to Thripidae and Phlaeothripidae are phytophagous and seven belonging to Aeolothripidae. Among all these species identified 6 are known as predators.

On Navel oranges, larval instars were found only for three species: *P. kellyanus*, *F. occidentalis* and *Franklinothrips* sp. The larval stages I and II of *P. kellyanus* and *F. occidentalis* were observed mainly in citrus flowers and on fruitlets.

Some morphological features allow the distinction between larvae of *F. occidentalis* and *P. kellyanus*, the 2 major species found on citrus. Indeed, the second instar of *P. kellyanus* is whitish or yellowish and has sclerotized teeth on the eighth abdominal segment that facilitate its movement between the soil particles when it goes to pupate (figure 1a) (Kirk, 1987; Webster *et al*., 2006). The second instar of *F. occidentalis* is also yellowish and characterized by the presence of 12-15 posteromarginal teeth between the D_2 setae and 4-6 teeth between the D_1 setae of tergite IX and a long finely pointed microtrichia on abdominal tergite VIII (figure 1b).

Abundance and frequency of thrips on Navel oranges trees and in the soil

On Navel oranges trees:

The majority of thrips species found on Navel oranges belongs to the family Thripidae (table 2). Among them *P. kellyanus*, known as a citrus pest, *F. occidentalis* and *T. major* were the most represented species. A statistical difference was observed between these species and between years ($F_{3, 36}$ = 19.88, P < 0.0001 and $F_{6, 36}$ = 14.66; P < 0.001 respectively (figure 2, table 2). The densities of the three species increased from year to year, but *F. occidentalis* has risen dramatically in 2017 compared to previous years and also to the other species. *T. tabaci* was collected during the 3 years but with less abundance.

In the Phlaeothripidae family, the abundance of species recovered in the 3 years of study was very low.

Regarding the Aeolothripidae family, *Melanthrips fuscus* (Sulzer) was the most abundant species in 2015 and 2017, while the predaceous species were recovered very rarely.

Regarding larvae, those of *P. kellyanus* were the most abundant with 59.09%, 60.58% and 52.65% of the total of larvae collected from Navel oranges in 2015, 2016 and 2017 respectively. It was also the same for *F. occidentalis* with many larvae on Navel with 31.81%, 39.41% and 47.34% respectively from 2015 to 2017

Table 2. Frequency of thrips species identified on orange trees between 2015-2017.

Thrips species	2015 Number of specimens	2015 (%)	2016 Number of specimens	2016 (%)	2017 Number of specimens	2017 (%)	Average 2015-17 (%)
F. occidentalis	91	35.68	156	38.32	1287	79.05	51.1
T. major	107	41.96	112	27.51	20	1.22	23.43
P. kellyanus	12	4.70	96	23.58	296	18.18	15.54
T. tabaci	5	1.96	15	3.68	2	0.12	5.96
Other species	40	15.68	28	6.87	25	1.53	8.02
Total	255		407		1628 (+2 not identified)		

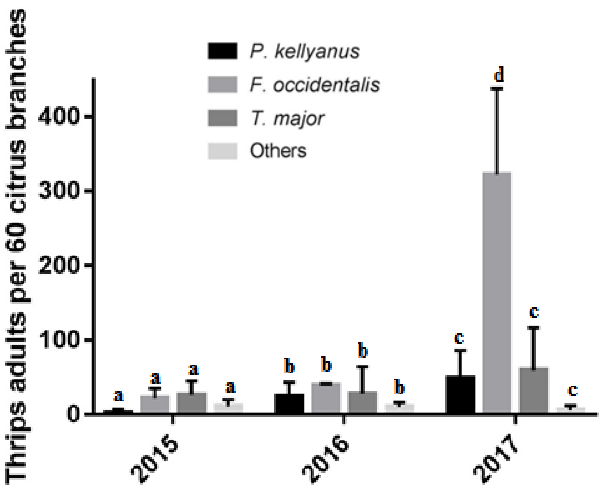

Figure 2. Abundance of adults of thrips collected between 2015-2017 in the 4 citrus orchards. Each bar represents the mean of 4 replicates ± SE. Different letters indicate significant differences between thrips for each year (Tukey's test; p ≤ 0.05).

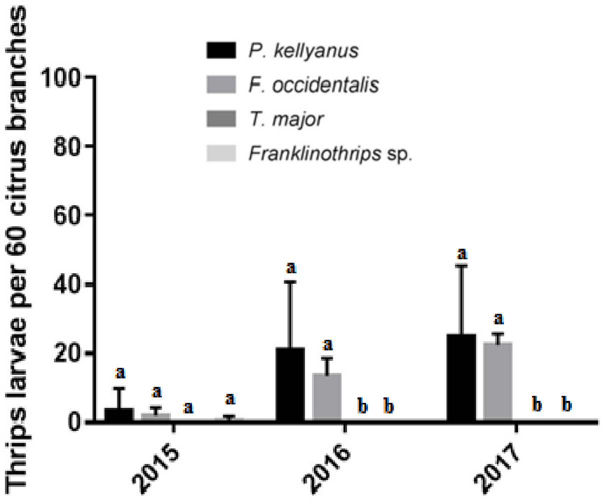

Figure 3. Larvae of thrips collected between 2015-2017 in the 4 citrus orchards. Each bar represents the mean of 4 replicates ± SE. Different letters indicate significant differences between thrips species for each year (Tukey's test; p ≤ 0.05).

Regarding larvae, those of *P. kellyanus* were the most abundant with 59.09%, 60.58% and 52.65% of the total of larvae collected from Navel oranges in 2015, 2016 and 2017 respectively. It was also the same for *F. occidentalis* with many larvae on Navel with 31.81%, 39.41% and 47.34% respectively from 2015 to 2017 (figure 3) with statistical difference between the number of larvae of these two species during the three years of study ($F_{6, 18}$ = 5.617; P = 0.0020).These two species clearly feed and reproduce on Navel oranges (Froud *et al*., 2001). The larvae of *P. kellyanus* on fruitlets may cause the ring of scar tissues around the calyx and rind blemish on young fruits. However, the damage/symptoms caused by larvae of *F. occidentalis* on young citrus fruits are not known yet. Apart from larvae of *P. kellyanus* and *F. occidentalis*, only two young larvae of the predatory *Franklinothrips* sp. were recovered from citrus (figure 3).

In the soil:

Thrips fauna was dominated by larvae and adults of *F. occidentalis* and *P. kellyanus* with 30.79% and 26.13% respectively. Adults of the three other species collected: *M. fuscus*, *T. tabaci* and *T. major*, were less represented (table 3). All species recovered from the soil are phytophagous and may colonize citrus trees and the plants around.

Host-plant range of important thrips collected in citrus orchards

Apart from the citrus varieties Bergamot, Orange, Clementine and Lemon, all belonging to Rutaceae family, twenty-three plant species referred to 15 botanical families are listed as hosts for thrips. Table 4 reports the host-plant range of the important thrips damaging citrus and predaceous thrips identified. *Diplotaxis erucoides* appears to be the most widespread species in citrus orchards and that hosts the largest number of thrips species. *F. occidentalis*, *T. major* and the predaceous genus *Aeolothrips* were collected in high numbers from this plant. Table 4 shows also that *T. tabaci* was the most widespread species as it was collected from 9 plant species out of 23 listed.

The predaceous species *Scolothrips longicornis* Priesner, *Franklinothrips vespiformis* (Crawford) and *Franklinothrips megalops* (Trybom) were collected only

Table 3. Thrips species identified from the soil of citrus orchards between 2015-2017.

Thrips species	2016		2017		Average 2016-17 (%)
	Number of specimens	(%)	Number of specimens	(%)	
F. occidentalis	30	34.09	33	27.5	30.79
P. kellyanus	13	14.77	45	37.5	26.13
T. tabaci	11	12.5	15	12.5	12.5
T. major	19	21.59	5	4.16	12.87
M. fuscus	15	17.04	22	18.33	17.68
Total	88		120		

Table 4. Host-plant range of Thysanoptera species collected in citrus orchards from 2015 to 2017.

Thrips species	Plant family	Plant species	Number of localities
F. occidentalis	Asteraceae	*Calendula bicolor*	4
	Asteraceae	*Glebionis coronaria*	6
	Brassicaceae	*Diplotaxis erucoides*	6
	Brassicaceae	*Diplotaxis muralis*	6
	Brassicaceae	*Sinapis arvensis*	6
	Rutaceae	*Citrus* sp.	6
T. major	Brassicaceae	*D. erucoides*	4
	Convolvulaceae	*Convolvulus arvensis*	3
	Rutaceae	*Citrus* sp.	6
P. kellyanus	Apiaceae	*Bunium pachypodum*	1
	Brassicaceae	*D. erucoides*	1
	Oleaceae	*Jasmimum officinalis*	2
	Rutaceae	*Citrus* sp.	6
T. tabaci	Apiaceae	*B. pachypodum*	1
	Asteraceae	*C. bicolor*	3
	Asteraceae	*G. coronaria*	3
	Asteraceae	*Chrysanthemum coronarium*	6
	Brassicaceae	*S. arvensis*	4
	Fabaceae	*Medicago sativa*	3
	Malvaceae	*Malva parviflora*	2
	Poaceae	*Triticum aestivum*	3
	Rutaceae	*Citrus* sp.	6
A. collaris	Asteraceae	*C. coronarium*	4
	Asteraceae	*G. coronaria*	2
	Brassicaceae	*D. erucoides*	5
	Rutaceae	*Citrus* sp.	2
A. intermedius	Apiaceae	*Daucus carota*	3
	Brassicaceae	*D. erucoides*	3
	Brassicaceae	*D. muralis*	1
	Brassicaceae	*S. arvensis*	4
	Fabaceae	*M. sativa*	3
	Rutaceae	*Citrus* sp.	2
M. pallidior	Brassicaceae	*D. erucoides*	1
	Rutaceae	*Citrus* sp.	1
S. longicornis	Rutaceae	*Citrus* sp.	3
F. vespiformis	Rutaceae	*Citrus* sp.	1
F. megalops	Rutaceae	*Citrus* sp.	3

from citrus trees, however *Aeolothrips intermedius* Bagnall, *Aeolothrips collaris* Priesner and *Melanthrips pallidior* Priesner were collected from both orange trees and some herbaceous plants (table 4). These latter may play the role of potential reservoirs for thrips natural enemies.

Surprisingly no thrips species has been found in *Oxalis pes-caprae* (Oxalidaceae), *Urtica dioica* (Urticaceae) and *Legousia hybrida* (Campanulaceae) although they are very common in Tunisian citrus orchards.

In order to facilitate identification of the thrips species that are likely to be encountered in citrus orchards of Tunisia, we have developed the simplified key (see next page).

Identification key to Thysanoptera species of citrus orchards in Tunisia

1 - Abdominal segment X tube-shaped in both sexes; forewings when present, lacking veins and microtrichia . . . . Tubulifera, Phlaeothripidae . . 19

-- - Abdominal segment X cone-shaped, in females pointed with a saw-shaped ovipositor; forewings with veins and microtrichia . . . . Terebrantia . . 2

2 - Antennae 9-segmented, segments III-IV with elongated and linear or transverse linear sensoria; forewings broad with cross-veins . . . . Aeolothripidae . . 3

-- - Antennae 7-8 segmented, segments III-IV with simple or forked sense cones; forewings narrow without cross-veins . . . . Thripidae . . 9

3 - Antennal segments III and IV very long, segment III about 15 times as long as broad, with distinctive sensory areas; tergites I-IV constricted . . . . *Franklinothrips* . . 8

-- - Antennal segments III-IV about 3-4 times as long as broad; tergites I-IV not constricted 4

4 - Head with anterior interocular area prolonged and blunt; antennal segment II with a ventral-lateral bulge . . . . *Ankothrips niezabitowskii*

-- - Head without anterior prolonged interocular area; antennal segment II without a ventral-lateral protuberance 5

5 - Antennal segments V-IX fused; claw-like tooth present on tarsal segment II; sternite VII with two pairs of submarginal accessory setae . . . . *Aeolothrips* . . 6

-- - Antennal segments V-IX separated; claw-like tooth not present on tarsal segment II; sternite VII with a pair of posteromarginal lobes . . . . *Melanthrips* . . 7

6 - Distance of median setae on male's tergite IX longer than length; pronotum almost yellow . . . . *Aeolothrips collaris*

-- - Distance of median setae on male's tergite IX shorter than length; pronotum dark brown . . . . . *Aeolothrips intermedius*

7 - Sternites V and VI with 1-4 accessory setae . . . . *Melanthrips fuscus*

-- - Sternites V-VI without accessory setae, sternite IV with 2-4 discal setae; sensory area on antennal segment IV parallel to the apical margin of the following antennals segments V-IX . . . . *Melanthrips pallidior*

8 - Body dark brown, tergites II, III and X whitish yellow or yellow, hind margin of tergites II-III or tergite III with a transverse brown band, tergite IX setae dark brown . . . . *Franklinothrips vespiformis*

-- - Body bicoloured, tergites I-IV pale yellow, tergites V-VIII dark brown or black, IX-X orange or reddish-yellow; grey patches on tergites I-II, a transverse brown band on hind margin of tergites III-IV, tergite IX setae pale yellow . . . . *Franklinothrips megalops*

9 - Pronotum with 6 pairs of long and stout setae . . . . *Scolothrips longicornis*

-- - Pronotum with 0-5 pairs of long setae 10

10 - Pronotum trapezoidal with 2 pairs of long posteroangular setae; antennal segment II strongly asymmetric . . . . *Chirothrips manicatus*

-- - Pronotum broadly rectangular 11

11 - Pronotum with one pair of long posteroangular setae; tergite IX with stout thorn-like setae (spines) . . . . *Limothrips cerealium*

-- - Pronotum with 1 or 2 pairs of long posteroangular setae; tergite IX without stout setae 12

12 - Tergite VIII with a pair of well-developed ctenidia 13

-- - Tergite VIII without ctenidia or with an irregular group of microtrichia 14

13 - Ctenidia on tergite VIII anterolateral to spiracle; antenna 8-segmented; forewing with 2 complete rows of setae . . . . *Frankliniella occidentalis*

-- - Ctenidia on tergite VIII posterolateral to spiracle; antenna 7-8 segmented 15

14 - Male sternites without glandular areas; tergite VIII with posteromarginal comb interrupted medially . . . . *Megalurothrips sjostedti*

-- - Male sternites with several glandular areas; tergite VIII posteromarginal comb with 10-20 fine microtrichia laterally and a large gap medially . . . . *Pezothrips kellyanus*

15 - Head elongated; pronotum with long transverse lines of sculpture . . . . *Stenothrips graminum*

-- - Head not elongated; pronotum with interrupted transverse lines of sculpture 16

16 - Antenna 8-segmented; metanotum with a linear striate sculpture . . . . *Thrips meridionalis*

-- - Antenna 7-segmented 17

17 - Sternites III-VII with 10-15 discal setae in irregular double row; forewing first vein with 6-7 setae on distal half . . . . *Thrips angusticeps*

-- - Sternites without discal setae; forewing with 2, 3 or 4 setae on distal half of first vein 18

18 - Pleurotergites with rows of ciliated microtrichia; forewings with 4 setae on distal half of first vein; tergite VIII with a complete comb of fine microtrichia . . . . *Thrips tabaci*

-- - Pleurotergites without microtrichia; forewings with 3 setae on distal half of first vein; tergite VIII without a marginal comb . . . . *Thrips major*

19 - Forewings constricted medially; maxillary bridge present; maxillary stylets well retracted into the head not close together; antennal segment IV with 4 sense cones; basantra (praepectal plates) broader than long . . . . *Haplothrips* . . 20

-- - Forewings parallel sided; maxillary bridge absent; maxillary stylets well retracted into the head and lying close together; antennal segment IV with 2 sense cones; pronotum with 5 pairs of well-developed setae; basantra not developed; mid and hind legs dark . . . . *Liothrips oleae*

20 - Antennal segment III without sense cones . . . . *Haplothrips minutus*

-- - Antennal segment III with 2 sense cones . . . . *Haplothrips tritici*

Discussion and conclusions

This investigation showed that twenty-one thrips species was sampled from Navel oranges trees in citrus orchards of North Tunisia belonging to Thripidae, Aeolothripidae and Phlaeothripidae. Thripidae is the most represented family with eleven species distributed in eight genera including *T. major*, *T. tabaci*, *T. angusticeps*, *T. meridionalis*, *F. occidentalis*, *P. kellyanus*, *Megalurothrips sjostedti* Trybom, *Limothrips cerealium* Haliday, *Stenothrips graminum* Uzel, *Chirothrips manicatus* Haliday and *S. longicornis*. These species were also found in other varieties of citrus present in the same orchards such as Lemon, Bergamot and Clementine.

The majority of thrips species identified are polyphagous, such as *F. occidentalis* and those belonging to the genus *Thrips* that makes them able to live on citrus as well as on a wide host-plant range. Weeds growing in citrus orchards determined in this study include 23 botanical species hosting all the thrips collected. Among these plants, *D. erucoides* (white wall-rocket), very common and abundant in citrus orchards year-round and especially in spring, hosted the largest number of thrips species including major species. These latter are *F. occidentalis*, *P. kellyanus*, *T. tabaci* and *T. major*, collected also from citrus trees and soil. However only larvae of *F. occidentalis* and *P. kellyanus* were recovered from citrus trees suggesting that these last species reproduce on citrus while adults of *T. tabaci* and *T. major* may migrate to citrus flowers in spring using citrus as an incidental host.

The species *F. occidentalis*, a very polyphagous thrips infesting many crops and wild plants worldwide (González-Zamora and Garcia-Mari, 2003; Atakan *et al.*, 2016), was the most dominant species on citrus as well as on Brassicaceae and Fabaceae wild plants associated with the crop. In Tunisia, western flower thrips is commonly recorded as a pest on some ornamentals and vegetable plants (Elimem *et al.*, 2011) and recently it was found on citrus flowers (Belaam-Kort and Boulahia-Kheder, 2017a), but it has not been reported before as a main pest on citrus, comparing to other species such as *P. kellyanus* (Belaam-Kort and Boulahia-Kheder, 2017b). Our results showed also that the density of *F. occidentalis* increased dramatically in 2017 compared to previous years and also to the other species. Some studies in the Mediterranean region (Spain, Turkey, Cyprus and Italy) stated that *F. occidentalis* is able to spread and to colonize citrus crops and to compete with native thrips species resulting in a decrease of infestation by these latter (Navarro *et al.*, 2008; Vassiliou, 2010; Teksam and Tunc, 2009; De Grazia and Marullo, 2013). This thrips has not been reported to scar citrus fruits so far in the Mediterranean Region (Marullo, 2001) but was recorded as a pest of citrus in Korea and Japan for heavy damage to fruits (Donghwang *et al.*, 2000; Tsuchiya and Furuhashi, 1993).

The four identified *Thrips* species: *T. major*, *T. tabaci*, *T. angusticeps* and *T. meridionalis* were abundant on citrus trees and herbaceous wild plants. *T. major* was the most abundant species with an average of 23.5% of the total of thrips collected between 2015-2017. This species is known for its polyphagy and reproduction on cultivated and spontaneous plants (Marullo, 2003). It was the dominant species in the fauna of citrus thrips in Turkey with 84% on average on sampled species (Teksam and Tunç, 2009) and in Tunisia with 90% of the thrips fauna in a previous inventory (Belaam-Kort and Boulahia-Kheder, 2012). However, *T. major* is not regarded as a citrus pest. Nevertheless, Bournier (1963) reported the harmfulness of *T. major* to citrus in North Africa as necrosis of the tender fruits around the insertion of the floral peduncle, forming a smaller crown.

It is important to note that the abundant populations of *F. occidentalis* and *T. major* on citrus trees might be related to herbaceous host plants or cultivated plants close to citrus fields. *F. occidentalis* has been found commonly at high densities on herbaceous Brassicaceae and Fabaceae plants. Instead, populations of *T. major* have been observed mainly on *D. erucoides*. The survival of some herbaceous plants throughout the year in citrus orchards as well as the lemon re-flowering, is very likely to favour the migration of thrips from plant to others. Also, the abundance of *F. occidentalis* and *T. major* on orange crops possibly results from diversity in the surrounding crops and wild flora. During spring, adults of these species may diffuse from wild host plants which flower earlier to the crop. Chellemi *et al*. (1994) and Northfield *et al*. (2008) have studied the migration of polyphagous thrips from non-crop surrounding hosts into cultivated area. Thus to keep lower the field abundance of thrips on citrus and to prevent damage, farmers need to consider the cultural practices in each control program. In particular, weeds that grow around citrus plants including *D. erucoides* should be removed once citrus fruits are not yet susceptible that means until they reach about four centimetres diameter. Before that period weeds may harbour either a proportion of thrips population or natural enemies, hence balancing the number of thrips that can attack citrus. The most economically important species *P. kellyanus* was recovered at both larvae and adult stages on citrus with a percentage of 22.69% of the total thrips collected between 2015-2017. These results are similar to those reported from Turkey where Kelly's citrus thrips represents 10% of thrips species found on citrus fruits (Teksam and Tunç, 2009). In a more recent study (Belaam-Kort and Boulahia-Kheder, 2019), the population of *P. kellyanus* seems to develop between the different citrus varieties such as bergamot and lemon varieties. In the present contribution, 2 non-citrus host-plant species on which *P. kellyanus* breeds and develops were identified: *Jasminum officinalis* (jasmine) and *Bunium pachypodium* (Bunium heavy foot) where larvae and adults were found in very high numbers. *J. officinalis* is a common plant growing in different regions of Tunisia; however, in citrus orchards it is quite rare. Likewise *B. pachypodium* is a rare wild plant in citrus orchards and has been collected only from the locality of el Alia in Bizerte, during spring. On the plant *D. erucoides*, characterized by white flowers, an attractive colour for *P.kellyanus* (Navarro *et al.*, 2013), only one adult was identified and no larvae were found. The absence of alternative host-plants for *P. kellyanus* could be one of the factors that prevent the accomplishment of many generations through the year. It could then explain the relatively low populations of *P. kellyanus* in citrus orchards. In other countries such as Australia and Spain where *P. kellyanus* is an important pest of citrus, many breeding hosts grow in citrus orchards, with white and sweetly scented flowers such as *Jasminum* spp., *Lonicera* spp., *Gardenia jasminoides* and *Araujia sericifera* (Kirk, 1987; Mound and Jackman, 1998; Froud *et al*., 2001; Marullo, 2004; Navarro *et al*., 2013). Regarding *D. erucoides*, Navarro *et al*. (2013) found the same result; so this plant should be considered as incidental rather than a breeding host for *P. kellyanus*.

About predaceous thrips, the Thripidae species *S. longicornis* and the predaceous species of the Aeolothripidae family are important predatory species of thrips and mites (Trdan *et al.*, 2005; 2012; Conti, 2009; Masarovic *et al*., 2013). *S. longicornis*, *F. megalops* and *F. vespiformis* were collected only from citrus tree whereas *M. pallidior*, *A. intermedius* and *A. collaris* were collected both from citrus and wild plants. Apart from on citrus, they were present mostly on Asteraceae, Fabaceae and Brassicaceae families. This result shows that these herbaceous plants maintain thrips predators and parasitoids. This brings up the thought that the preservation of these plants may be exploited in the conservation biological control practices.

Regarding *M. sjostedti*, the African bean flower thrips, it is noteworthy to mention that this species, well known as pest of cowpeas in sub-Saharan Africa region (Tamo *et al*., 1993) is a new record for North Africa. At this time, only two adults were collected from oranges trees in Khlidia (Mornag region) but the species as well as others that can be potential pests for citrus such as *C. orchidii* (Goane *et al*., 2013) must be closely followed.

Based on results obtained, it could be asserted that the Thysanoptera fauna in citrus orchards of Tunisia is diverse. Indeed, more than 40 thrips species were identified in association with citrus in the world (Longo, 1986). In Florida, for example, 36 species of thrips were collected from citrus orchards with and without use of synthetic pesticides (Childers and Nakahara, 2006). Yet, the diversity of thrips fauna in citrus orchards does not mean that all thrips species represent serious pests for citrus production. Only the detection of key species known as pests of citrus such as *P. kellyanus* needs close monitoring to avoid severe damage.

This research has drafted the main host range of thrips species living in citrus orchards, providing some basic knowledge about thrips damaging citrus, predaceous thrips and the main plants hosting them which are citrus and weeds. The diversity of secondary vegetation in citrus orchards may play two opposing functions: to maintain pest thrips and to conserve and enhance naturally occurring populations of predatory thrips and others possible beneficial entomophages (Loomans and van Lenteren, 1995). These data should be more developed for future conservation biological control strategies.

Acknowledgements

The authors thank the research group of Zeineb Ghrabi from the Department of Agronomy and Plant Biotechnology of INAT for identification of herbaceous plants. They are also grateful to the farmers visited for allowing us to survey their orchards. Finally, they owe deep thanks to the anonymous reviewers of the manuscript for their comments.

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Authors' addresses: Imen BELAAM-KORT (corresponding author: imenebelaamkort@gmail.com), Sabrine ATTIA, Synda BOULAHIA-KHEDER, Laboratory of Bio-aggressors and Integrated Pest Management in Agriculture, National Agronomic Institute of Tunisia (INAT), University of Carthage, Tunisia; Rita MARULLO, Department of Agriculture, Mediterranean University of Reggio Calabria, località Feo di Vito, I-89060 Reggio Calabria, Italy.

Received July 5, 2019. Accepted September 30, 2019.