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Diversity of entomofauna associated with greenhouse-grown tomatoes in Algiers (North Algeria)

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SUMMARY. Tomato is an important economic crop worldwide. Many insect pests are cause both quality and quantity yearly decrease on greenhouse-grown tomatoes. Thus, diversity and relative abundance of both harmful and useful insects were investigated in greenhouse-grown tomatoes in Algiers coastal area. The inventory was realized in 2014 by using yellow sticky platelets traps. The information obtained allowed us to elaborate an inventory with no less than 1449 individuals belonging to 46 different taxons, distributed among eight orders and 26 families. Useful entomofauna is very rich and represented around 32% of the total population with five predators and a dozen of Hymenoptera parasites. Presence ofa significant predatory parasite complex may contribute to the regulation of pests in tomatoes greenhouse and carry out control programs against the main harmful pest of this crop. This assessment of the entomofauna will make it possible to carry out control programs against the main pests of this culture. The results of this study will contribute to finding mechanisms and conditions for reducing the negative impacts of the bio-aggressors of tomato.

Keywords: Algeria, diversity, entomofauna, greenhouse, tomato.

Introduction

Tomato (*Solanum lycopersicon* Mill.) is one of the most important vegetable crops in the world, consumed both fresh or processed form (Blancard *et al.*, 2009). It originated as wild from South America and supposed to be domesticated in Central and Latin America (Kolev, 1976). Tomato was first introduced into Europe by the Spanish conquerors in the sixteenth century and was mostly cultivated in the Sevillian region (Vernouillet, 2007).

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According to the latest statistics (FAO, 2015) the world production of tomatoes is increasing 161,326,827 tons produced in 2012. The world's leading producers of tomatoes areChina with 22 million tons, followed by the European Union with 15 million tons, and the United States of America producing 10 million tons, Turkey is the 4th world producer, with more than 8 million tons (Desneux *et al.*, 2010). Tomato is an important vegetable crop in Algeria (Nechadi *et al.*, 2001), the annual production in 2013 was 975,075 tons (FAO, 2015), however the production does not meet the needs of the population. Algerians are large consumers of tomatoes and prefer the processed tomato with a consumption close to 4 kg / person / year (Baci, 1993).

Tomato is prone to numerous attacks of diseases caused mainly by fungi, bacteria, viruses, viroids and phytoplasmas. It is also threatened by several pests like *Tetranychus mites,* whiteflies, aphids, thrips, leaf miners and greenhouse moths (Vernouillet, 2007). *Tuta absoluta* leaf miner is a microlepidoptera a new pest of tomatoes in the Mediterranean regions (Desneux *et al.*, 2010). It is a microlepidoptera of the family Gelechiidae, originating in Latin America. Its mining caterpillars can cause damages up to 80% and even 100% losses of the crop (Desneux *et al.*, 2010). In Algeria, these biological aggressors were reported for the first time in early spring 2008 in the northwestern region of the country (Mostaganem and Oran), and then spread through all the country reaching south Algeria. Since, several researches on this pest have been carried out in order to evaluate its impact on the tomato crop, such as the studies carried out by Idrenmouche (2011), Mahdi (2011) and Selmane (2011).

The little work about the pest of tomato are published in Algeria, this study is new information about entomofauna of Solanaceae. The aim of this paper is inventoried the entomofauna associated with tomato under greenhouse cultivation system in the western Algerian coastal region, by using conventional survey of both harmful insects and their natural enemies. The approach used in this study is to provide a database of harmful and useful entomofauna diversity and to establish a general state of the main pests and their natural enemies. This assessment of the entomofauna will lead to control programs of the main pests. We will also qualitatively and quantitatively evaluate the main pests of greenhouse tomatoes.

Materials and methods

Study sites

Data collection was conducted ingreenhouses settled in the domain Kheloufi el Djillali in Zeralda (2°49'45" E, 36° 41' 15" N, altitude: 120 MASL), this farm located 40 km west of Algiers (Fig. 1).

The climate of these regions characterised by wet winters, dry and hot summers (Table 1). The site is surrounded by stateforests and is based on a loamclay soil with a neutral pH and low levels of organic matter (0.57%), with a total limestone of 2.25%. The domain specializes in viticulture, citrus and greenhouse vegetable crops, where the main crops are tomatoes and pepper.

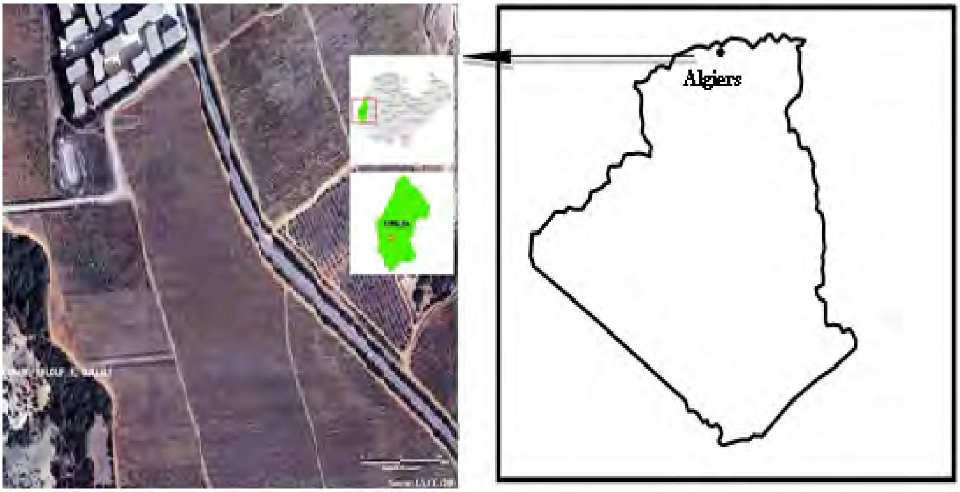

Figure 1. Location of the study area.

Sampling

After the installation of the crop on October 24th, 2014, yellow-glue pads were installed at the entrances and in the middle of each of the two selected greenhouses.The cultivated tomato variety was Agora and no chemical treatment was applied.

Table 1.

Monthly climatic parameters for the study area in north Algeria, between October 2014 to April 2015

Climatic parameters	Oct.	Nov.	Dec.	Jan.	Fev.	Mar.	Apr.
Maximum temperature (°C)	26.9	18.0	17.0	17.9	18.2	18.5	23.5
Minimum temperature (°C)	19.9	12.0	10.0	11.4	11.8	09.4	13.0
Maximum air humidity (%)	87.1	87.9	88.7	86.9	-	-	-
Minimum air humidity (%)	52.5	59.3	62.7	57.2	-	-	-
Wind speed [km/h]	14.0	24.0	13.2	24.0	27.2	4.0	4.0
Evaporation (mm/day)	108.6	89.4	69.0	110.5	75.6	64.8	110.1
Precipitation (mm)	21.3	236.6	99.2	54.8	22.7	49.5	3.2

The yellow sticky traps were replaced by new ones twice a month and brought back to the laboratory for analysis. The traps are cut in three parts before their observation under the magnifying glass. The identification of captured individuals is performed by using determination keys or by the help of the Department of Agricultural and Forestry Zoology (National Higher School of Agronomy, El Harrach). Traps installations startedwith tomato transplantation and lasted until the harvest on April 7th, 2015.

Data analysis

To calculate the species abundance, species diversity and the differences in community composition and structure at each month, data were analyzed using PAST software (Paleontological Statistics; Version 2.17). The indexes used to examine insects community were: species richness (S), Frequency of occurrence (F %), Shannon diversity index (H), and equitability (E), where these indices are useful for a comparison between populations at monthly catch. The non-parametric Kruskal-Wallis test (χ^2) was applied to test the variation in species abundances between the months of greenhouse-grown tomatos. The relationships between insect diversity parameters were verified using Pearson correlation tests for each month.

Results and discussion

Taxonomic list and abundances of insect species

The inventory of the entomofauna associated with greenhouse tomato allowed us to capture no less than 1449 individuals belonging to 46 species belonging to 8 orders and 26 families (Table 2). The order of the Homoptera is the most dominant with 13 species, followed by Hymenoptera with 12 species. Diptera are in third position with 8 species, followed by Thysanoptera with 4 species. Coleoptera and Hemiptera contain only 4 species each. Finally, the Neuroptera and Lepidoptera are the least represented with one species each. The Kruskal-Wallis test showed a significant relationship between insect abundances of the six months (χ^2=17.84, P<0.05). Comparing these results with those of other inventories in Algeria and other countries, we can say that they have a relatively important. (Mahdi, 2011) used the same trapping technique and reported the presence of 3.908 individuals distributed among 295 species with 2817 individuals trapped in the field and 1093 caught on greenhouse tomatoes. Species trapped were belonging to the classes of Gastropoda, Arachnida, Crustacea, Chilopoda, Diplopoda, Collembola and Insecta. Clere and Bretagnolle (2001) reported that 4,863 individuals belonging to 35 taxa of arthropods were caught in the Barber pots in the Niort-Brioux (France) cereal plains. Roth (1965) reported 8,222 individuals trapped in yellow insect plates which were distributed among 12 families. Similarly, with the same technique, Chauvin *et al.* (1966) captured 11454 insects in an alfalfa plot during 13 days of collection. Lahmar (2008) trapped no fewer than 62 taxa in a tomato greenhouse in Ouargla (south-east of Algeria).

The constancy classes of the trapped species determined in relation to the occurrence frequencies, according to the Sturge rule, are 11 with an interval equal to 8.75%.The frequency analysis of occurrences shows that among the 45 species trapped, three species are omnipresent (FO% = 100%), namely *A. gossypii*, *M destructor* and *Calliphora* sp. Thirteen taxa are regular with frequencies ranging from 50.0% to 66.7%, among which we can mention aphids: *A. frangulae*, *A. craccivora*, *B. cardui*, *B.*

helychrysi and *M. persicae,* thrips: *F. occidentalis* and the predatory *N. tenuis*stink bug *T. absoluta*. Five species are very constant (FO between 75% and 83.3%), they include the species: *Diglyphus sp, Agromyzidae sp, M. domestica, Chrysocharis sp* and *T. tabaci*. Twelve taxa are accessory or very accessory with frequencies varying between 33.3% and 41.7%, among which we cite *A. nasturkii aphids, T. triffoli, M. euphorbiae, M. viciae, B. tabaci, M. pallidior, Anthocoridae sp., E. fabae* and *C. carnea*. Unintentional species (FO = 25%) have only two species while there are five others with a frequency of 8.3%. This parasite-predator complex can play a key role in limiting the main pests of the tomato by also ensuring a biological balance in the tomato plot. In order to achieve this goal, it is necessary to use modern tools of comparative analysis.

The different species that can potentially be used in a biological control program must be described and compared taking into account their phylogenetic links (Harvey and Pagel, 1991). The species *N. tenuis* will certainly contribute to the regulation of populations of the species *T. absoluta*, a key pest of tomato in Algeria. Among the predators identified, the ladybug *C. arcuatus* may also limit populations of whitefly *B. tabaci*a well as the aphidiphagous predators *H. variegata, C. carnea* and *E. balteatus* in association with the listed Hymenoptera parasites, because no less than 11 species of aphids live on tomato. The idea of looking for an ideal environment (hedges and floral strips) allowing the installation of useful insects: mirids, micro-hymenoptera in order to promote biological control by conservation remains the most promising alternative (Mazollier *et al*., 2005). The *A. craccivora* and *B. tabaci*, have been recognized to be serious pests of tomatoes worldwide (Lange and Bronson, 1988).

Table 2.

List of greenhouse Tomato Entomofauna at Zeralda station (Ni: number of individuals, Ar %: Relative abundance, FO%: Frequencies of occurrence, P*: Presence) (SR: Slightly regular, OP: Omnipresent, VA:Very accessory, VR: Very regular, A: Accessory, SF: Slightly frequent, R: Rare, AC: Accidental, C:Constant, RE: Regular, Very consistent: VC)

Order	**Families**	**Species**	**Ni**	**Ar %**	**FO %**	**P***
Homoptera	Aphididae	*Aphis craccivora*	20	1.4	50	SR
		Aphis frangulae	43	3.0	50	SR
		Aphis gossypii	163	11.2	100	OP
		Aphis nasturtii	23	1.6	41.67	VA
		Brachycaudus cardui	20	1.4	66.6	VR
		Brachycaudus helychrysi	18	1.2	66.6	VR
		Therioaphis triffoli	20	1.4	33.3	A
		Lypaphis erysimi	4	0.3	16.67	SF
		Macrosiphum euphorbiae	29	2.0	41.7	VA
		Megoura viciae	58	4.0	33.3	A
		Myzus persicae	19	1.3	50	SR
	Aleurodidae	*Bemisia tabaci*	49	3.4	41.7	VA
	Psyllidae	Psyllidae sp.	1	0.1	8.3	R

Order	Families	Species	Ni	Ar %	FO %	P*
Thysanoptera	Thripidae	*Aeolothrips fasciatus*	8	0.6	25	AC
		Melanthrips pallidior	9	0.6	41.7	VA
		Frankliniella occidentalis	53	3.7	66.7	VR
		Thrips tabaci	100	6.9	75	C
Nevroptera	Chrysopidae	*Chrysoperla carnea*	7	0.5	33.3	A
Hemiptera	Cicadellidae	*Empoasca fabae*	16	1.1	33.3	A
	Miridae	*Nesidiocoris tenuis*	47	3.2	66.7	VR
	Anthocoridae	*Anthocoris* sp.	7	0.5	41.7	VA
Lepidoptera	Gelechiidae	*Tutaabsoluta*	3	0.2	16.7	SF
Diptera	Syrphidae	*Episyrphus balteatus*	9	0.6	41.7	VA
	Cecidomyiidae	*Mayetiola destructor*	96	6.6	100	OP
	Agromizidae	*Liriomyza brioniae*	37	2.6	58.3	RE
		Agromyzidae *sp.*	109	7.5	83.3	VC
	Muscidae	*Musca domistica*	35	2.4	83.3	VC
	Calliphoridae	*Lucilia* sp.	20	1.4	66.7	VR
		Calliphora sp.	218	15.0	100	OP
	Tephritidae	*Dacus oleae*	1	0.1	8.3	R
Coleoptera	Coccinellidae	*Clitostethus arcuatus*	3	0.2	25	AC
		Hippodamia variegata	2	0.1	16.7	SF
	Bruchidae	*Bruchus* sp.	2	0.1	16.7	SF
	Curculionidae	*Otiorhynchus* sp.	2	0.1	16.7	SF
Hymenoptera	Apidae	*Apis mellifera*	2	0.1	16.7	SF
	Cephidae	*Cephus spinipes*	35	2.4	58.3	RE
	Braconidae	*Aphidius ervi*	34	2.3	50	SF
		Apanteles glomeratus	2	0.1	8.3	R
	Eulophidae	*Tetrastichus* sp.	3	0.2	8.3	R
		Diglyphus sp.	36	2.5	83.3	VC
		Chrysocharis sp.	39	2.7	75	C
	Aphelinidae	*Aphytis* sp.	10	0.7	41.7	VA
		Aphelinus sp.	15	1.0	50	SF
	Sphecidae	*Pemphredon* sp.	6	0.4	8.3	R
	Ichnomonidae	Ichnomonidae sp.	8	0.6	33.3	A
	Aphidiidae	*Lysiphlebus* sp.	8	0.6	50	SF

Variation of insect diversity parameters

The monthly values of diversity and equitability calculated for the entomofauna trapped with yellow sticky pads are shown in Table 3. Shannon monthly diversity values range from 2.26 bits in October to 3.1 bits in March. Similarly, the equitability (E) values obtained for the captured species are maintained above 0.76. It was in March that E reached its highest level of 0.90. These are values that tend towards 1. As a result, the numbers of species captured tend to be in equilibrium with each other. The differences of species richness, composition and insect diversity parameters between the sampling months can be explained by the variability of seasons.The climatic factors determine trends of population number of generations of many pest insects of agricultural importance (Chafaa *et al.*, 2013).

Table 3.

Monthly values of species richness (S), Number of individuals (Ni) and diversity indices of insect communities subservient to greenhouse-grown tomatos in Zeralda (Algeria) between October 2014 to April 2015

	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**
S	17	27	27	17	24	32	25
Ni	87	307	183	135	203	316	218
Shannon_*H (Bit)*	2.26	2.50	2.85	2.30	2.73	3.10	2.80
Equitability_*E*	0.80	0.76	0.87	0.81	0.86	0.90	0.87

Relationships between diversity parameters

All insect diversity parameters were positively correlated regardless of sampling month in greenhouse-grown tomatos. The species richness were positively correlated with number of individuals and Shannon index respectively (r=0.89, P<0.05; r= 0.9, P<0.05). The Equitability positively correlated with Shannon index (r=0.84, P<0.05) (Table 4). The diversity indices provide more information than simply the number of species present (Drouai *et al.*, 2018).

Table 4.

Correlation matrices displaying correlations between diversity parameters of insects subservient to greenhouse-grown tomatos in Zeralda (Algeria). Pearson correlation tests are given as correlation coefficients (shown by white case) and P-values (grey case).

	S	Ni	Shannon_H	Equitability_E
S	1	**0.007**	**0.006**	0.229
Ni	**0.89**	1	0.105	0.664
Shannon_H	**0.90**	0.66	1	**0.017**
Equitability_E	0.52	0.20	**0.84**	1

Entomofauna composition

Overall population by order

The histograms (Fig. 2) show a high predominance of the order of the Diptera followed by Homoptera, totaling 525 and 467 individuals and representing 36.21% and 32.21% of the total population respectively. The order of the Diptera is more particularly represented by Syrphidae, Ceccidomyiidae, Agromizidae and Calliphoridae. In Homoptera it is mainly the aphids that predominate with no less than eleven species, then come the Psyllidae and Aleurodidae with only one species each. Hymenoptera come in third with 198 individuals (13.66%), mostly represented by parasites, belonging to the Braconidae, Eulophidae, Aphelinidae, Sphecidae and Ichnomonidae families. Thysanoptera totaling 170 individuals include four species of Thrips from vegetable crops*:* *A. fasciatus*, *M. pallidior*, *F. occidentalis* and *T. tabaci*. Finally, the orders of the Coleoptera, the Hemiptera, the Neuroptera and the Lepidoptera their presence in greenhouse tomato is insignificant, their number does not exceed 70 individuals.The Kruskal-Wallis test showed a no significant relationship between ordersabundances of the six months (P>0.05).

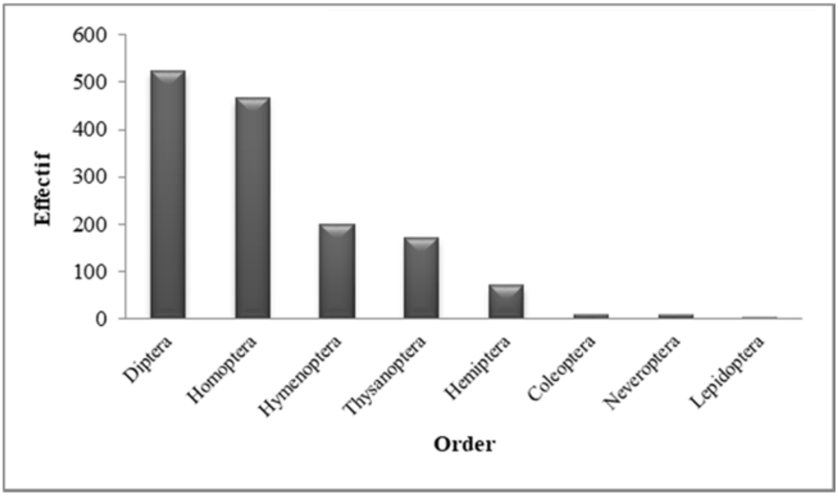

Figure 2. Importance of the entomofauna by orders.

Overall population by family

The entomofauna recorded during our experimentation is distributed in no less than 26 families. The most dominant is the Aphididae (417 individuals), or 28.78% of the total population. They are followed by Calliphoridae (Diptera) with 238 individuals (16.43%). Thripidae and Agromizidae come in third with 170 and 146 individuals respectively, ie 11.73% and 10.08%. Holophidae (Hymenoptera), Ceccidomyiidae (Diptera), Miridae (Hemiptera) and Aleurodidae (Homoptera)with respectively 71, 66, 40 and 39 individuals. Finally, the other families are insignificant, not more than 25 individuals (Fig. 3). The Kruskal-Wallis test showed a no significant relationship between orders abundances of the six months (P>0.05).

The family Aphididae (Fig. 4) occupies the first place in the greenhouse tomato inventoried entomofauna. 11 species have been identified in this study. The species *A. gos*sypii predominates with 163 individuals (39.09%) of the overall aphid population. *Megoura vicia* is the second species with 58 individuals (13.91%), followed by the tomato aphids *A. frangulae* and *M. euphorbiae* with 10.31% and 6.95% respectively. The other species,from the most important to the less important are *A.*

nasturkii (5.52%), *A. craccivora* (4.80%), *T. trifolii* (4.80%), *B. cardui* (4.80%), *M. persicae* (4.56%) and *B. hel*ychrysi (4.32%). Only four isolated individuals of *L.erysimi* were trapped.

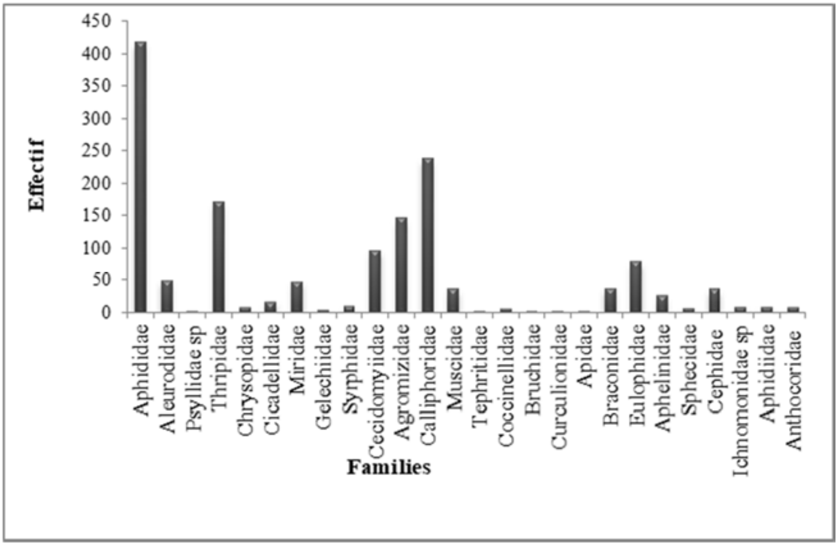

Figure 3. Importance of the entomofauna by families

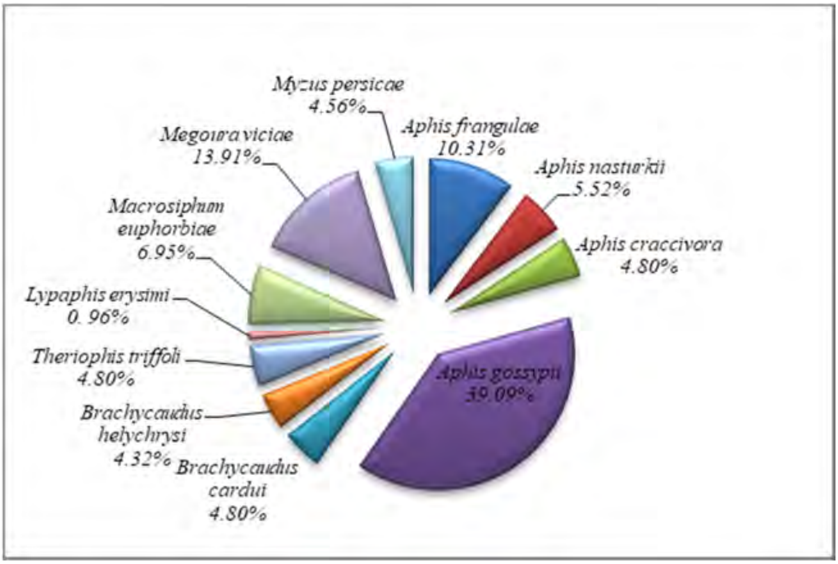

Figure 4. Abundance of species of Aphidofauna

The second family Thrips, represent the order of the Thysanoptera in the inventory. Possessing buccal parts of the picker-sucker type, they cause enormous damage to the crops. On tomato, thrips attack much more young leaves. Among the four taxa listed *T. tabaci* is the most dominant, it accounts for 58.82% with 100 individuals. It is followed by *F. occidentalis* with 53 individuals ie 31.18%. The other two species are *M. pallidor* and *A. fasci*atus their presence is insignificant with only 9 individuals (Fig. 5).

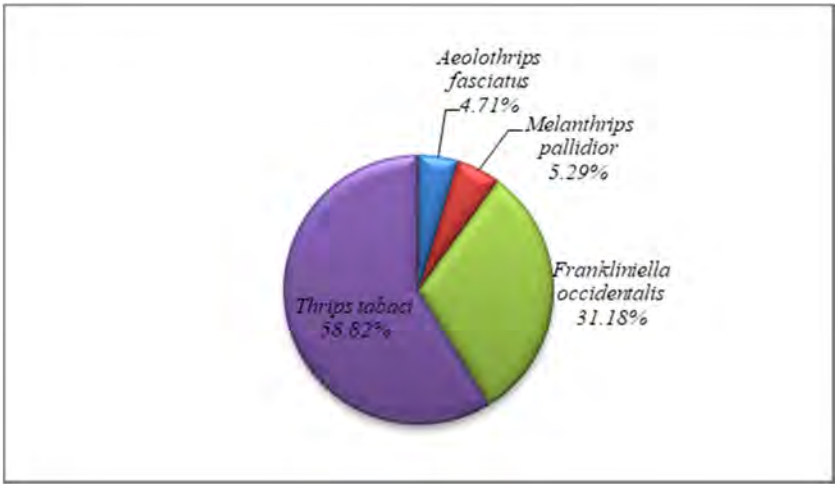

Figure 5. Abundance of species of Thrips

The family of the ordre Diptera are the most important group of trapped entomofauna, with 525 individuals representing 36.21% of the total trapped population. The genus Calliphora predominates with 218 individuals (41.52%) of the total Diptera population. The Agromizidae come in second with 109 individuals ie 20.76%. In the leafminers, the Hessian Fly (*M. destructor*), which is considered to be a key pest of tomato in recent years, totals 96 individuals (18.29%), while the other miner, *L. brioniae*, represents 7.05% of the total population (37 individuals). It is followed by *M. domestica* with 35 individuals. The only inventoried insect predator is the Syrphe *E. balteatus*, its presence is insignificant with only (09) individuals (Fig. 6).

Finally, the Hymenoptera are the richest species group in which 11taxons have been identified. This order comprises ten parasites representing 81.31% of the total trapped Hymenoptera (Fig. 7). These parasites can play an important role in regulating the populations of certain pests such as aphids and leaf miners. The rest consists of a pest*: C. spinipes*and a Hymenoptera poliniser *A. mellifera*. In the parasites group the species *Chrysocharis* sp. predominates with 39 individuals

(19.70%) of the total population. It is followed by: *Diglyphus* sp., *A. ervi* and *Aphelinus* sp. with 36, 34 and 15 individuals, respectively. Finally, parasites as *A. glomeratus, Tetrastichus* sp., *Aphytis* sp., *Pemphredon* sp. and Ichnomonidae species had an insignificant presence, their number does not exceed 8 individuals. As for the pest *C. spinipes* and the bee *A. mellifera*, they total 35 and 2 individuals respectively.

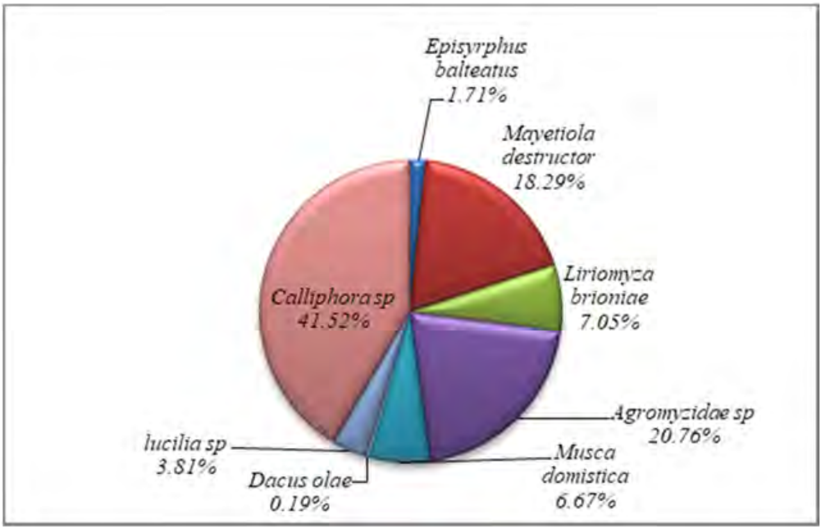

Figure 6. Abundance of species of Diptera

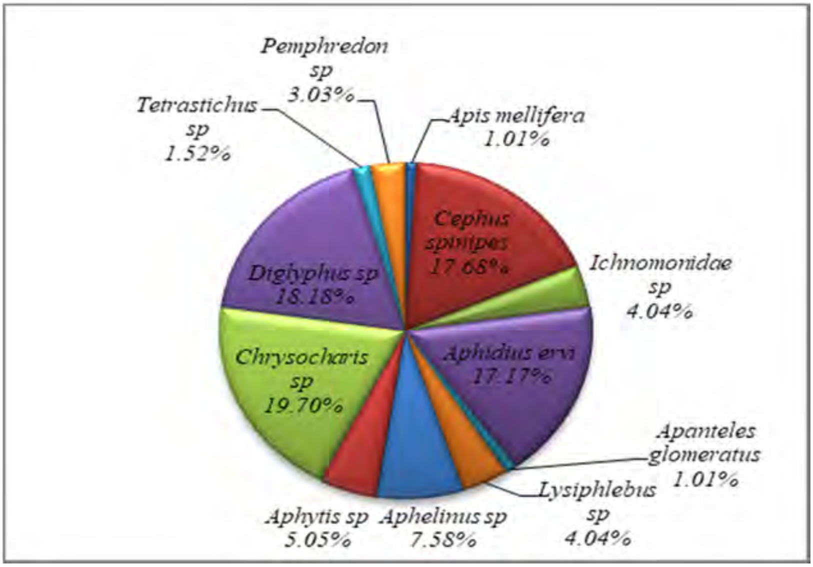

Figure 7. Abundance of species of Hymenoptera

Conclusions

At the end of this work on the diversity of the entomofauna associated with the tomato under shelters, 46 species distributed in eight orders and 26 families have been recorded.

The order of the homoptera is the most dominant with 13 species, followed by that of the hymenoptera with 12 species.

Three taxa are ubiquitous: the *Aphis gossypii* aphid, the *Mayetiola destructor* and *Calliphora* sp.

The useful entomofauna is very rich, accounting for 32.61% of the total population. Five predators: *Chrysoperla carnea*, *Nesidiocoris tenuis*, *Episyrphus balteatus*, *Hippodamia variegata* and *Clitostethus arcuatus*, and about ten parasites. Hymenoptera: *Aphidius ervi*, *Apanteles glomeratus*, *Tetrastichus* sp., *Diglyphus* sp., *Chrysocharis* sp., *Aphytis* sp., *Aphelinus* sp., *Pemphredon* sp., Ichnomonidae species and *Lysiphlebus* sp. were identified. This predatory parasite complex can contribute to the regulation of tomato pests under shelter.

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