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Research Article

Diversity of fruit fly species in agricultural area Chott Zahrez Chergui (Djelfa): First record of *Trupanea amoena* (Diptera: Tephritidae) in Algeria

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Abstract

Fruit flies (Diptera: Tephritidae) are cosmopolitan, species-rich, and yet poorly studied in Algeria, particularly in the agro area of Djelfa. We sampled fruit flies in orchard containing three types of trees apricot, fig and grapes at each site, using the yellow traps. Results show that the orchard differed significantly in species richness, abundance, diversity and evenness. A total of 956 individuals distributed by nine species of Diptera, including four species of fruit flies are collected. The results revealed that most abundant species are *Drosophila melanogaster* at the apricot fruit site (RA%=28.32%), *Zaprionus indianus* at fig fruit site (RA%=34.74 %) and *Tephritis praecox* at the grapes fruit site with (RA%= 51.61 %). The orchard selected a greater number of species and individuals, and higher diversity indices H′=2.40 bits; 2.32 bits and 2.02 bits. Statistically, the result of stepwise multiple regressions revealed a very strong correlation between the number of fruit fly species and the temperatures with (r=93.1%) and (Sig .000**). Thus, fruit flies appear to have rather arrow with the host plant requirements and their phenology was correlated with environmental differences. Our study highlighted for; the first time; the presence of *Trupanea amoena* in Algeria. This important and substantial preliminary work on this new species in Algeria provides a solid basis for future research and extension of the study in particular for monitoring and control of this dreaded agricultural pest.

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1. Introduction

Fruit flies are one of the main threats to the agricultural sector worldwide due to the direct damage to 400 different vegetables and fruits (Ganie et al., 2022). They are currently responsible for high production losses up to 80% (Kibira et al., 2015). These Tephridae (Insecta, Diptera) belong to a large group counting more than 500 genera and 5000 species (Scolari et al., 2021). These flies are expanding and causing serious damage not only to hosts but also to the development of related industries and economic income (Deguine et al., 2015; Kibira et al., 2015; Mwatawala et al., 2009). Most stages development of fruit fly species are phytophagous, attacking the tissues of a variety of hosts, particularly fruits and flowers, and significantly reducing crop production (Díaz-Fleischer et al., 1999). The attack is done by puncturing the fruit, after the larval stage developing inside (Cai et al., 2020). These invasive species are gaining significant interest in the domains of plant protection, plant quarantine, bio-security, and invasive biology due to their economic value. In North African countries, fruit flies are a major concern, and destructive pests, but the most damaged host-plants are not the same in each country depending on the fly species present (Bayoumy et al., 2021; Boulahia-Kheder, 2021; El Harym & Belqat, 2017; Mohamed, 2015). In Algeria, except for a few species described, in some Northern regions; such as the peach fruit fly *Bactrocera zonata* Saund. (1841), the olive fruit fly *B. oleae* Ross. (1790) and the greater melon fly *Dacus frontalis* Becker, 1922 (Oukil et al., 2002; Settaoui et al., 2017), in other agricultural regions such as Djelfa, where the arboriculture sector has been expanding in recent years, no studies have being conducted to identify existing present fruit fly species, at-risk fruits and the targeted fruits. To this end, the primary goal of the present study is to monitor the seasonality of the fruit fly species in this area. This study is the first of its kind in which the fruit flies diversity is identified in agricultural areas near to Chott Zahrez Chergui. So, the research is the first in which the fruit fly species and the varieties of the host-plants are both recognized in this important agricultural areas. We trying to establish the importance of different host fruits for the development of populations and to compare fly populations in the orchard prospected with different availability of host fruits. Furthermore; we seek to understand how knowledge of seasonality and hosts can help in planning an effective control strategy against these fearsome pests, in order to curb their development in neighbouring regions of the Algerian arid agroecosystem.

2. Materials and Methods

2.1 Field sites

The field work was performed in an agricultural zone near to Chott Zahrez Chergui one of the large RAMSAR sites in Algeria. It is a flat basin formed of a sandy-clay substrate. The orchard surveyed (3°31’25’’E; 35°00’52’’N) is located in the agricultural region of Djelfa. It covers an area of 1 ha, at an altitude of 1110 m, has a total of 30 apricot trees of 15 years old, 25 fig trees of 30 years old, and 15 grapes trees of 15 years old. The orchard is a private pilot project within the development framework; the goal is to develop it to 12 hectares and 500 trees of each of the three fruit varieties (Figure 1). The area is semi-arid with cold winters. Precipitation is variable; the heaviest rainfall is recorded during the period from October to January and from April to May, with a mean of 290.1mm per year. The dry period starts from June with a maximum of drought in July and August. Annual mean temperatures are 15.9°C. Winds are intense and frequent; the most frequent winds are those of North-East and North-West orientations. However, the main characteristic of the prevailing winds in the region is materialized by the frequency of Sirocco, of desert origin lasting from20 to 30 days per year. The orchard complied with all organic agricultural standards, which mean no pesticides, fungicides or herbicides are applied. Trees were regularly watered during dry periods by drip irrigation, with a water tank and artesian well nearby.

2.2 Trapping methods:

Sampling is carried out using yellow traps in the crop's fruiting zone. The yellow traps are plastic pots that have been set down on the ground for the purpose of catching of the winged entomofauna (Figure 2). All traps are arranged in a row spaced five meters and filled up to a third of water to which we add a detergent to keep trapped insects from escaping. The traps are left in the field for 24h. The applied work extended over a period of a full year from February 2021 to February 2022. Sampling was done at three locations inside the orchard; the apricot fruit site, the fig fruit site, and the grapes fruit one.

2.3 Morphological identification

The whole samples were observed using Stereo Optical Microscope. In order to verify the specimen's diagnose is based solely on morphological identification. The photos of detained samples, especially for the wings were captured using camera of OPPO 13MB/ f2/2. The samples were identified using taxonomical keys of Jaber & Najim (2022), of MacAlpine et al. (1987), and of Séguy (1983). Microscopic observations of samples showing morphological characteristics were harmonized with the diagnosis of *Trupanea amoena*. The dimensions of adults were obtained by direct measurements of the specimens.

2.4 Exploitation of results

We utilized species richness (S), relative abundance (RA %), occurrence frequency (OF %), Shannon's diversity index (H'), and evenness index (E) to analyse the data in order to determine the species diversity and abundance at each site. For statistical analysis tools, we used Multiple linear regressions (MLR). MLR it is one of linear regression analyses applied to analyse the relationship between dependent variable (number of fruit flies) with two or more independent variables (temperature, precipitation and humidity). There are three methods in MLR which are forward selection, backward elimination and stepwise regression. Building a forecasting model for fruit flies boarding in MLR involved four general processes, the first by checking presumptions, choosing appropriate MLR methods, interpreting the output. For the current investigation climate data (temperature, precipitation and humidity) were obtained from the website recognized of meteorology (historical-weather.net). All statistical treatments were performed using the free statistics program IBM SPSS Statistics 22.

3. Results

3.1 Fruit flies diversity and richness

The study of diversity of fruit flies species in agricultural area of Chott Zahrez Chergui allowed us to identify the major species connected to the fruit in this area. Good diversity of Diptera species is indicated by the diversity parameters for the three study sites (Table 1). The total number of individuals is 956 with a maximum number of 452 noted at apricot fruit site. The Shannon index measures the degree of dispersion of individuals within the current taxa. The values obtained range from 2.02 bits to 2.40 bits. The three sites' Evenness (E) values show that there is a high degree of regularity and that the species are distributed fairly. The values obtained for this index are ranging from 0.76 to 0.82.

In total, 9 pest species including 4 fruit flies species were found in the surveyed orchard (Table 2). Among these species, *Drosophila melanogaster* Meig. (1830) (Figure 3a) dominates in apricot fruit site with a rate of 28.32%. It is followed by *Zaprionus indianus* Gup. (1970) (Figure 3b) with a rate of 16.81%. The latter is at the top of the list in fig fruit site with a rate of 34.74%. It is followed by *Thaumatomyia* sp. 26.84% and by *Tephritis praecox* Loe. (1844) (Figure 4a) 18.95%. This species is the most dominant pest found in grapes fruits site with a rate exceeding 50% of the population infesting this site. Other pests are found in the orchard with low percentages including the dreaded *Trupanea amoena* with a rate of 1.55% and 2.37% in apricot fruit site and fig fruit site, this species recorded the first time in Algeria.

The occurrence of different fruit flies species varies according to the type of fruit crop. The occurrence of *Zaprionus indianus* is 61.5% in the two sites of apricot and fig. It is a regular species in both sites. *Zaprionus indianus* begins to appear from March to November with a maximum in June. *Drosophila melanogaster* is between regular and accessory, with OF%=53.85% and 30.77%. This species begins its activity from the month of April until October; same for *Tephritis praecox* which changes its appearance depending on the associated plant. *Trupanea amoenais* accessory in the apricot fruit site OF %=30.77% and in fig fruit site OF %=38.5%. This species is seen from April to September. As we noted above, this pest is not previously reported in Algeria. The male specimens found in the present study are identified through morphological characterization. In what follows we present a brief overview of the morphological characteristics of this species (Figure 4b):

Body: plump; length 4mm, black with yellowish legs and with large, rounded green eyes.

Head: Length, 0.98 mm, number of frontal bristles three pairs, number of orbital bristles two pairs. Anterior orbital bristle of male normal, unmodified; predominantly arista long with short pubescence black. Proboscis short;

Thorax: Length1.45 mm, slightly shorter than abdomen (1.57 mm), black with yellow and pale yellow thick hair; notopleural area normally yellow; small scutellum, almost triangular, convex, its ground colour almost black.

Abdomen: Length 1.57 mm, black with some yellowish colouration, abdominal sternite 5, posterior margin with deep V-shaped posterior concavity.

Wings: Length, 4.59 mm, longer than body (4 mm). It is distinguished by the star-shaped mark on the wing, which is typically related to cell sc; brown spot on vein CuA1; first ray faint, incomplete, extending from stigma to vein M; second ray beginning at the costal margin, extending up to the cross vein r-m, united with star in cell r 2+3; subapical spot with 3 rays up to the posterior margin in cell m; posterior cubital cell with very short extension. We should note that this is the main characteristic that helped us to confirm the species (Figure 5).

3.2 Statistical Analysis

Firstly, the normality can be check using two tests which are by Kolmogorov-Smirnov (if sample size is more than 50) and Shapiro-Wilk (if sample size is less than 50). Since the sample size in this research ($n = 10 < 50$), so we need to use Shapiro-Wilk which gives a Sig. value equal to 0.200. It shows that the number of fruit flies is normally distributed (Sig = $0.200 > 0.05$), in this study; we used stepwise regression method to forecast number of fruit flies boarding. From the Table 3, that represents the correlations between response variable (number of fruit flies) and variables independent using Pearson Correlation (Figure 6), we note that the weak correlation between the numbers of fruit files and the precipitation(r=.072). While the very strong correlation shows between the number of fruit files and the temperatures (r=93.1%). Therefore, the one relationship significant is with the temperature (T) because Sig. < .05, and the strength correlation. By contrast, the correlation shows between the number of fruit flies and humidity is strong inverse relationship (r= -91.6%); This makes humidity a limiting factor because it means that the number of people decreases as humidity increases. The stepwise regression method removes the variables (precipitation and humidity) as needed for each step and add the temperature the one variable with significance statistic (p=.000). The value of $R2$ is 0.867 shows that there are 86.7% changes in number of fruit flies. From the ANOVA results we found that F= 45.637 with p=.000. These data indicate that the only statistically significant variable is temperature only, as is evident from the level of significance (Table 4).

For seasonality in fruit flies' communities, the high species richness values were noted in spring and summer (May, June, July and August, S=4). While the lowest values were in March and November (S = 1). The appearance of species begins in the spring. This coincides with the increase in average temperatures and the flowering and fruiting season of certain trees in spring and summer. The study of the structure and seasonality of flies mainly depends on the phenology of the fruit tree. Consideration of all sampling months together, the highest abundance values were observed in July and August at the apricot site and June, July at the fig and grapes sites. In contrast, the lowest abundance values in the introduced varieties were in March, October and November. In apricot and fig fruit, its appearance coincided with the mid- and late-flowering periods (April, May and June) and with the development of the fruit during the long, hot days of summer (July, August and September) (Figure 7).

3.3 Discussion

Insect pests are the forcing barrier for crop production worldwide (Yadav et al., 2022). Among these insects; fruit flies are one of the world's most destructive and the most economically damaging pests of fruits especially in the European and African mainland's (Gutierrez et al., 2021; Mutamiswa et al., 2021; Nanga Nanga et al., 2022). Several fruit flies attack diverse species of fruit (El-Heneidy et al., 2019; Food and Agriculture Organization, 2015; Łabanowska & Piotrowski, 2015; Mahmoud et al., 2019; Nebie et al., 2021; Orhan et al., 2016). In Algeria, fruit fly pose a risk to most commercial fruit; some species of the Tephritidae family are introduced pests and are very common in Mitidja and in many regions where fruit production is intense (Chergui et al., 2020; Laamari et al., 2022; Mostefaoui et al., 2020; Settaoui et al., 2017). The dense vegetation cover of the steppes near the Chotts, particularly in Djelfa, provides a favourable environment for the development of arthropods harmful to agriculture and humans (Khadoumi, et al., 2022; Messaoudene et al., 2023). In the region of Djelfa, four species of fruit flies were inventoried during this study. Among which, *Drosophila melanogaster* and *Zaprionus indianus* are the dominant species in the investigated orchard. These two Drosophilidae species that damage small fruit have invaded the Neotropics in recent decades (Valadão et al., 2019). The predominance of fruit flies in agroecosystems has been highlighted in African continent from their introduction into certain countries in and since that they had rapidly spread and established successfully across the continent (Mutamiswa et al., 2021). Like most fruit flies; species belonging to the Drosophila genus in family Drosophilidae have different host preferences (Kim et al., 2023). *Drosophila* is polyphagous pests attacking a wide range of fruits, which may have facilitated their spread in different regions (Boughdad et al., 2021; Cini et al., 2014; Pfeiffer et al., 2019; Zanuncio-Junior et al., 2018). In Algeria, *Drosophila* are known for their pests of different types of fruit tree in particularapple fruit tree *Malus domestica* at Annaba (northeast of Algeria) and pomegranate fruit tree *Punica granatum* at M'sila (The central part of Algeria) (Khaldi et al., 2021; Rahat et al., 2021). In this study, we found that they attack the apricot, fig and grapes fruits.

Furthermore, the presence of *Trupanea amoena* is very interesting because the species has been never reported in Algeria before; the low percentage of T. *amoena* is certainly an underestimate of the reality. The parameters studied do not necessarily reflect the density of the fly. We suggest that it is an introduced species. In fact, long-distance migration could be the cause, given the potential for the spread of Tephritidae species. The detection of *Trupanea amoena* in temperate regions confirms the ability to adapt to conditions outside of its original tropical environment. We must note that several species of Tephritidae have a greater impact on global agricultural horticulture trade than almost any other pest; their introduction poses a major risk to horticulture in affected countries (Food and Agriculture Organization, 2015). Previously, *Trupanea amoena* is recorded in Middle Asia, India, Iran, Pakistan, Iraq, Turkey, Saudi Arabia, in Middle and North Europe, Spain, Poland and North Africa Morocco, Tunisia and Egypt (El Harym & Belqat, 2017; Fazel et al., 2011; Görmez & Kütük, 2019; Jaber & Najim, 2022; Kapoor, 2002; Klasa et al., 2011; Merz & Blasco-Zumeta, 1995; Norfolk & Dathe, 2019; Riaz & Sarwar, 2013). The implementation of a control strategy against this species is much recommended, early in the phenological cycle on the three types of fruit, in order to limit its spread in neighbouring agroecosystems.

Likewise, our study confirmed that there is a clear coexistence between the two fruit fly species *Z. Indianus* and *D. melanogaster.* According to Simão et al. (2018), *Zaprionus* genus shares evolutionary features with the *melanogaster* subgroup, such as space and time of origin. Previous studies highlight the coexistence de *Z. Indianus* with species of the genus *Drosophilis* (Van Der Linde et al., 2006; De Paiva Mendonça et al. 2023). *Z. Indianus* has been recorded as a pest on oranges, peaches, and figs in Brazil (Van Der Linde et al., 2006), and fig fruits in Mexico by (Martínez et al., 2017).

3.4 Statistic treatment

Like many crop pests in Mediterranean regions, fruit flies species growing is hampered by climatic factors such as high temperatures and rainfall (Fernandez et al., 2023; Hill et al., 2016; Mutamiswa et al., 2021). Our findings support that high temperature affected significantly the abundance of the fruit flies species. Using multiple linear regressions MLR to built forecasting model for fruit flies boarding in MLR, we found that only the temperature is the factor to the fruit flies boarding. Based on the output from SPSS, there are one model was built, the value of R2 and adjusted R2 in Model is ($R2 = .867;\ R2 - adj\ = .848$). The result obtained in this study is in agreement with that of Duyck et al. (2006), who found that the temperature affected significantly the abundance of adults of the three species of *Ceratitis* spp. Further, the species are found mainly on lowlands, where temperatures are high, which means that the presence of the fruit flies is most common in warm and dry areas. Earlier studies have shown a positive correlation between high temperatures in spring and increase the number of fruit flies, as well as a positive relationship between rising temperatures and the incidence and severity of pests in walnut orchards in a Mediterranean climate (Freitas et al., 2023; Moral et al., 2019). The concerns raised by temperate fruit experts stress the urgent need for developing and implementing measures to secure the future production of temperate fruits in the Mediterranean basin. Generally, variations in the abundance of fauna and flora is from the climate change and the external conditions, by the occurrence of heat waves and other unusual climatic events during the growing season, extended periods, of drought and increasing pressure of pests (Lim et al., 2013).

About the phenology of fruit fly populations, this is closely related to climate factors. The most abundant are during the hot season, regardless of the type of fruits trees (apricot, fig or grapes). Generally, the seasonal abundance of the fruit fly species of economic importance depended on climatic factors and the availability of host fruits in the plant formations (Zida et al., 2020). According to Boulahia-Kheder (2021), species of Tephritidae family are characterized by high population levels in summer and low levels in winter. In the Comoros archipelago, high densities of fruit fly populations were observed during the hot season, compared with the cold season (Mze Hassani et al., 2016). In contrast, the phenological synchronicity of a high fly pest population and fruit maturity is critical for the fruiting season and hence for growers (Anderson et al., 2021), as indicated by Mwatawala et al. (2006) in fruit orchards in Morogoro Region (Tanzania, East of Africa). These authors mention that the fruit flies populations present high numbers of flies coinciding with their fruiting season.

Indeed, we have seen that fruit flies invades was most abundant during the whole summer season exploiting the different cultivars at their respective ripening times especially in May and June, are the two important months of the fruit fruiting season. According to Ekesi et al. (2016), the highest numbers of *Ceratitis cosyra* Walk. (1849) counts are highest during the maturity and pre-maturity period, followed by the fruit growth period and then flowering periods. Like those of extant in the Southern Sudan zone (East of Africa), *Ceratitis cosyra* populations are present during all reproductive developments of the mango tree. It is noteworthy that mango flowers can be attractive for *Ceratitis* adults, as already recorded for other fly species (Rwomushana & Tanga, 2016). Finally, the coincidence of these two favourable events, the maturity period (biotic factor) and the hot season (abiotic factor) has made the big outbreak of fruit flies possible.

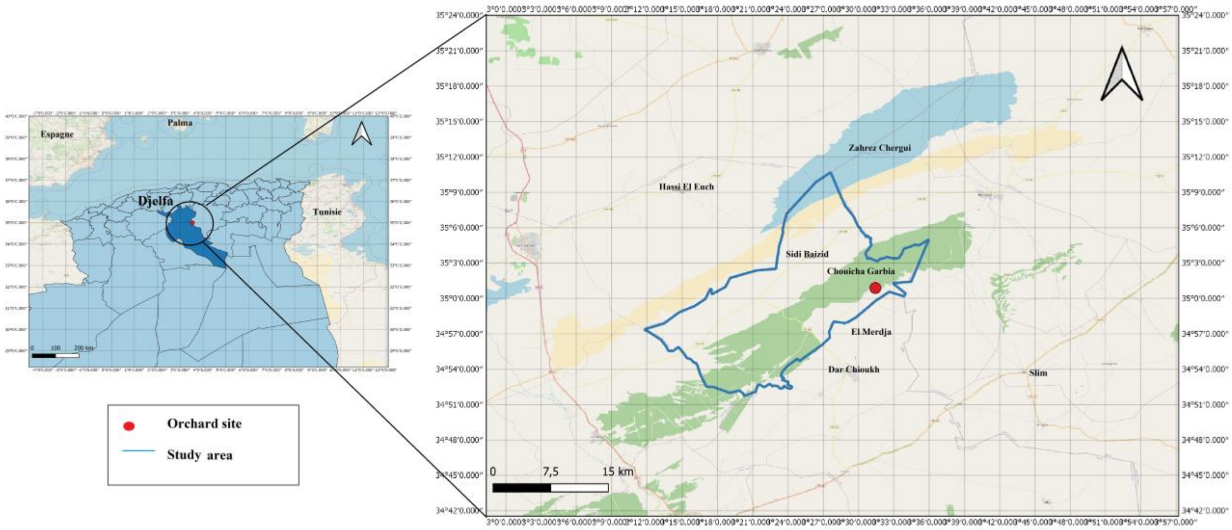

Figure 1. Geographic position of Djelfa and the sampling orchard (Algeria)

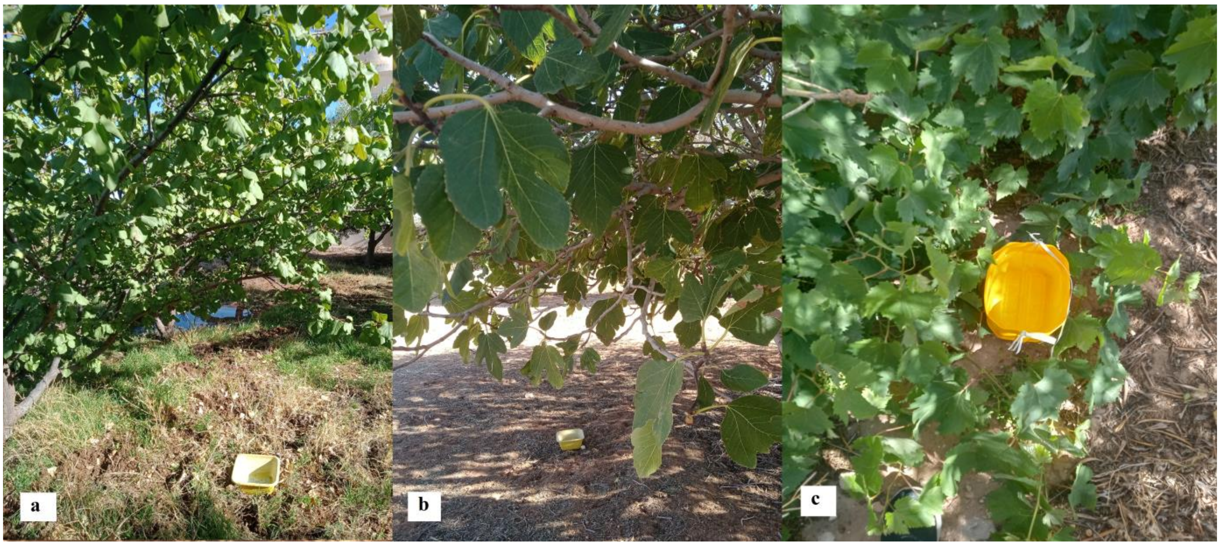

Figure 2. The sampling method yellow traps in Orchard (a: apricot fruit site; b: fig fruit site; c: grapes fruit site)

Figure 3. Drosophiliae species found in the surveyed orchardX4;
a: Drosophila melanogaster, b: Zaprionus indianus

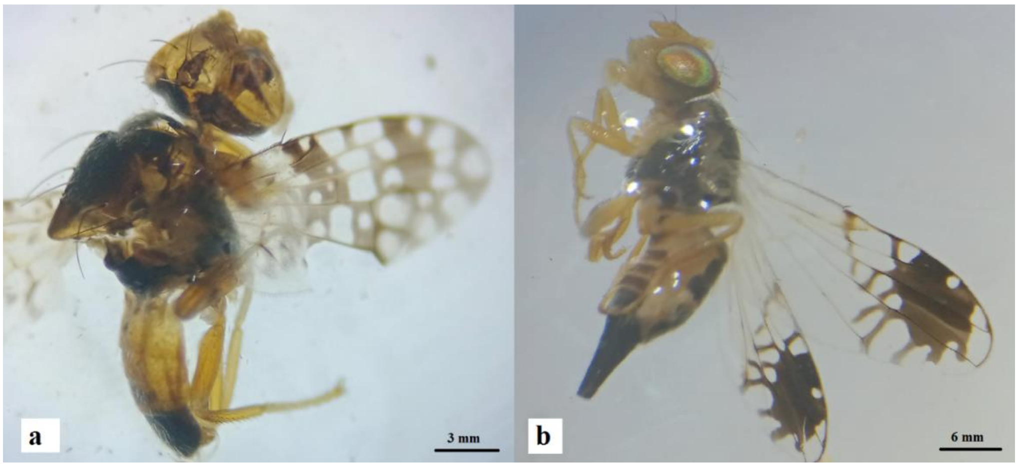

Figure 4. Tephritidae species found in the surveyed orchardX4;
a: Tephritis praecox, b: Trupanea amoena (First record in Algeria)

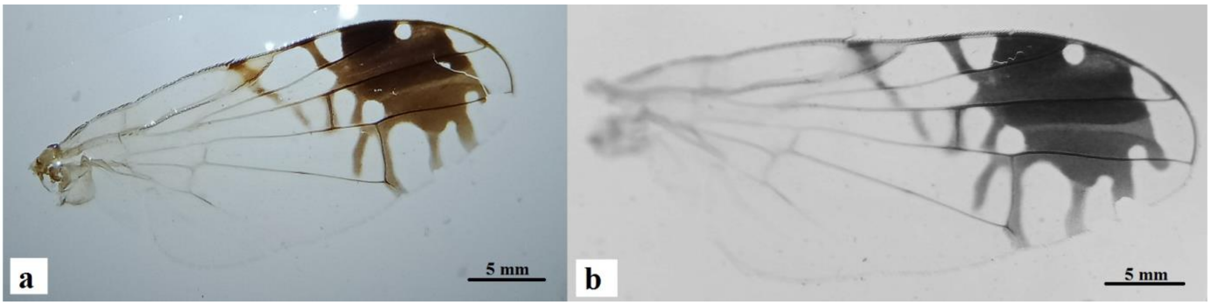

Figure 5. Trupanea amoena wing.
a: photo of the wing taken by camera of OPPO 13MB/ f2/2,
b: photo of the wing modified by CamScanner program

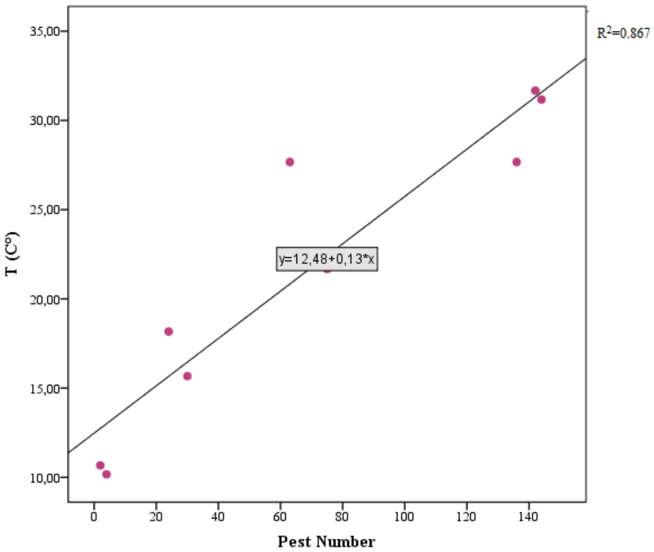

Figure 6. Scatter Plot of number of fruit flies and the temperature of the study region (Pearson Correlation Scatter Plot)

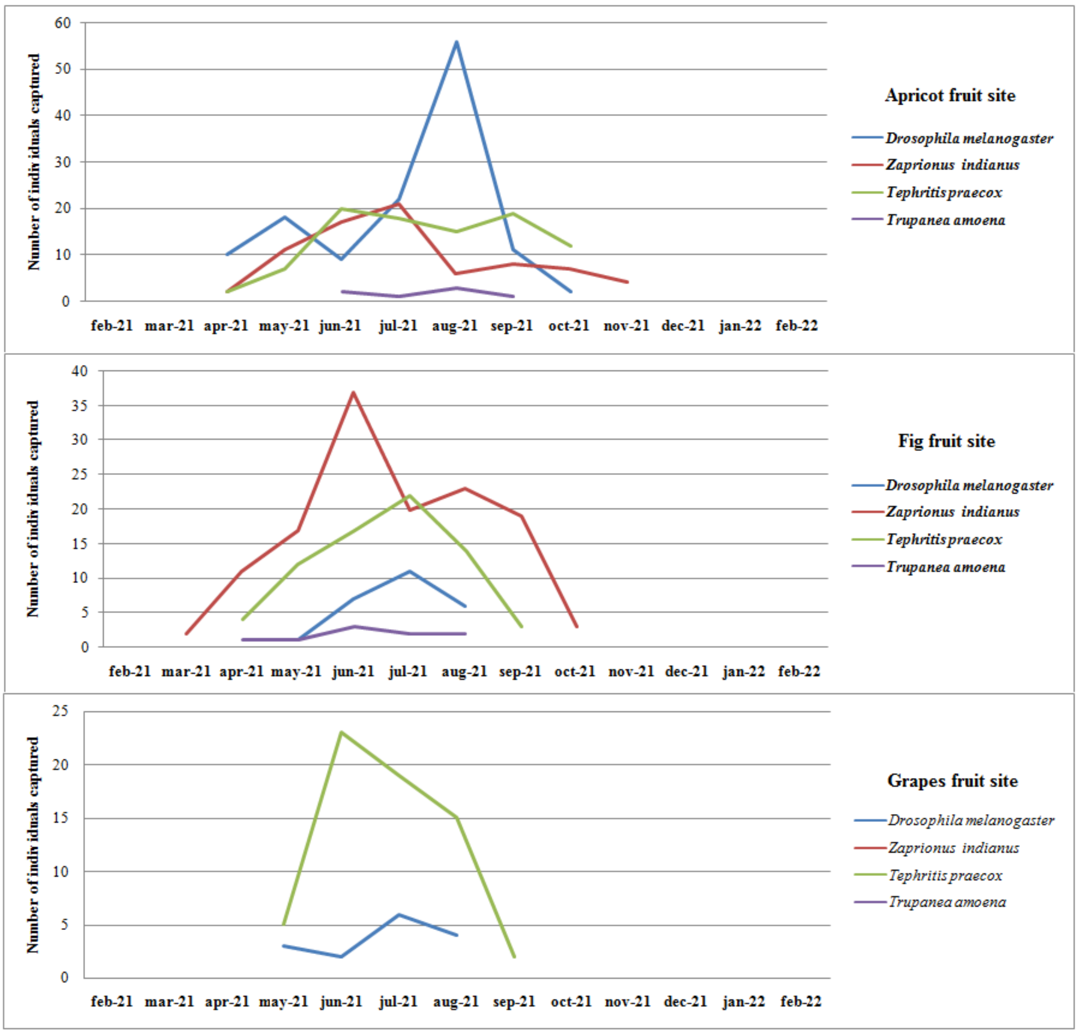

Figure 7. Seasonal fluctuations in the number of fruit fly species according to climatic factors variations (temperature, precipitation and humidity)

Table 1. Diversity indices for apricot, fig and grapes fruit sites

Ecological indices	Sampling sites		
	apricot fruit site	fig fruit site	grapes fruit site
Taxa (S)	9	7	6
Individuals	452	380	124
Shannon Weaver (H') bits	2.40	2.32	2.02
Evenness (E)	0.76	0.82	0.78

Table 2. Species inventory, relative abundance RA %and occurrence frequency OF% of different pest species recorded at the three sampling sites in Algeria

Pest species	Sampling sites					
	apricot fruit site		fig fruit site		grapes fruit site	
	RA %	OF%	RA%	OF%	RA%	OF%
Thaumatomyia sp. Zenker 1833	9.96	46.15	26.84	46.15	13.71	23.07
Sciapus sp. Zeller 1842	1.55	23.07	-	-	2.42	23.07
Drosophila melanogaster (Meig1830)	28.32	53.85	6.58	30.77	12.09	30.77
Zaprionus indianus (Gupta 1970)	16.81	61.54	34.74	61.54	-	-
Scatella sp. Robineau-Desvoidy 1830	7.96	46.15	7.63	30.77	-	-
Musca domestica Linnaeus 1758	1.99	46.15	2.89	30.77	14.52	38.46
Sepsis cynipsea (Linnaeus 1758)	11.28	61.54	-	-	5.65	23.07
Tephritis praecox (Loew 1844)	20.58	53.85	18.95	46.15	51.61	38.46
Trupanea amoena (Frauenfeld 1857)	1.55	30.77	2.37	38.46	-	-
Total	100	-	100	-	100	-

- Absence

Table 3. The correlation between the numbers of fruit flies species with temperature, precipitation and humidity

Response variable	Variables	R	Sig.
Constant (Pest Number)	T (C°)	.931	.000**
	P (mm)	.072	.427
	H (%)	-.916	.000**

Table 4. Stepwise regression results

	Result
Constant	-72.381
T (C°)	6.536
t-value	6.756
p-value	.000
S	22.971
R-Sq	.867
R-Sq(adj)	.848
F(ANOVA) sig. =.000	45.637

4. Conclusion

The present study confirms, for the first time, the dispersal of fruit flies inside the agroecosystem of Djelfa. Our findings revealed the co-occurring different fruit fly species in the same biotope. This may help to explain patterns of the interactions between pests and their hosts in order to develop an integrated pest management programme. This study should be pursued by exploring parameters certainly impacting the distribution of flies and by studying the cycle and the factors limiting the development of *Trupanea amoena*, reported for the first time in Algeria, as our knowledge of this species is still very marginal. Exploration effective and efficient biocontrol agents need to be developed to limit the spread of fruit fly species through commercial exchanges.

Author's declaration

The authors declare no conflict of interest. GA (Professor of Agronomy) managed and supervised the project. YSR (Post Graduate Student) carried out laboratory work, analysed data and manuscript proofreading before submission. MF (Professor of Agronomy) advised about the laboratory technique and assisted in species identification. SB (Doctor of Engineering) advised and assisted in the choice of sampling sites and ensured data collection. All authors read and approved the final version of the manuscript.

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