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Abdelhadi AJERRAR[1,2], Redouan QESSAOUI[1], Hind LAHMYED[1,2], Rachid BOUHARROUD[*1], Bouchra CHEBLI[2], Mina ZAAFRANI[2], El Hassan MAYAD[3]

SEASONAL OCCURRENCE OF CERATITIS CAPITATA (DIPTERA: TEPHRITIDAE) ON ARGAN TREES (ARGANIA SPINOSE, SAPOTACEAE) IN MOROCCO

SUMMARY

The main objectives of this study are the assessment of *Ceratitis capitata* infestation level on Argan fruits, and monitoring of its seasonal dynamics, as well as the assessment of parasitism rate by its parasitoid *Psyttalia concolor* in Argan orchard. To study Argan fruit infestation level and the parasitism rate, infested Argan fruit were sampled and transferred immediately to laboratory. Sampled fruits were screened to determine the number of medfly punctures. Other sampled fruits were incubated in aerated plastic containers containing sterilized sand. *C. capitata* dynamics was monitored by using male attracted pheromones traps during 2018 and 2019. The obtained results show a current activity flight of *C. capitata* over the two studied years and dynamics variation between the two sampled years and between months. The peak of the *C. capitata* dynamics was recorded during May and June for 2018 and 2019 respectively. Low Argan infestation level was recorded during two periods: January and August-September. However, the peak of infestation was recorded during May (95%). *P. concolor* parasitism rate was relatively low. No significant effect of fruit origin on *P.concolor* parasitism rate ($P>0.05$) was found. Yet, the sampling period had a significant effect on parasitism rate ($p<0.05$). Argan tree is a suitable host plant

[1]Abdelhadi Ajerrar, Redouan Qessaoui, Hind Lahmyed, Rachid Bouharroud (corresponding author: rachid.bouharroud@inra.ma), Regional Center of Agricultural Research of Agadir, National Institute of Agricultural Research (INRA), Avenue Ennasr, B.P. 415 Rabat Principale, Rabat 10090, MOROCCO;

[2]Abdelhadi Ajerrar, Hind Lahmyed, Bouchra Chebli, Mina Zaafrani, Biotechnology and Environmental Engineering Unit, National School of Applied Sciences, Ibn Zohr University, MOROCCO;

[3]El Hassan Mayad, Laboratory of Biotechnology and Valorization of Natural Resources, Faculty of Science Agadir, Ibn Zohr University, PoB 8106, 80000 Agadir, MOROCCO.

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promoting *C. capitata* development with a permanent flight dynamics year-round. Despite the mediocre and variable parasitism rate of *P. concolor*, this parasitoid can be a very important tool together with the other protective measures to reduce infestation rate of *C. capitataand* to decrease its population size.

Keywords : *Argania spinosa, Ceratitis capitata*, Infestation, Parasitism, *Psyttalia concolor*

INTRODUCTION

The Mediterranean fruit fly (medfly), *Ceratitis capitata* (Wiedemann, 1924) is the most fruits fly damaging in the world. It's a polyphagous pest which infest a range wide of plants including horticultural and wild plants (Liquido *et al*., 1990; Liquido *et al.*, 1991; Morales *et al*., 2004; Copeland *et al*., 2003; Weldon *et al*., 2018). In Morocco, medfly is among major crop pests (FAOL/IAEA, 1995; Mazih, 2008). Citrus is the most important horticultural tree cultivated in Morocco with a total area of 129,000 ha and a total production of more than 2 million tons (Maroc citrus, 2022). About 50% of production is for export as fresh fruits. The current value of economic losses caused by *C. capitata* is not available. A survey carried out in 1995 in Morocco estimated the cost of loss at 53,422,200 DH based on annually losses on citrus fruits and other fruits such as Apples, Apricots, Peaches and Plums (FAO/IAEA, 1995). In addition, it is considered as quarantine pest for some countries (medfly free), such as Japan, USA, Russia and China, the exportation of fruits and vegetables to these countries requires adequate pest management in fields and cold treatment in post harvest, which raises production cost (Mazih, 2008). Host fruits of medfly in the citrus surrounding area were reported as a source of infestation (Alemany *et al.*, 2004; Martínez-Ferrer *et al.*, 2006; Ben yazid *et al*., 2020) and complicate their pest management.

Souss region is one of the most important area of citrus fruit production in Morocco. In this region, the Argan tree is the main host for medfly. Argan is an endemic tree in west-central of Morocco which covering over 821,800 ha (M'Hirit *et al.*, 1998) and playing an important socioeconomic and ecological role (Ait Aabd *et al*., 2019). The edible oil extracted from their seeds has a multiple use as food, cosmetic, and as a source of medicine. To meet the strong international demand of Argan oil, the new Argan orchards have been created. Further, a planting program of 50.000 ha was also developed and initiated as part of the new Moroccan agricultural strategy (Ait Aabd *et al*., 2022). These new established Argan orchards and Argan forest are favorable hosts for *C. capitata* which ensuring the continuity of their generations (Naamani, 2004). The Arganeraie is considered as a huge reservoir of medfly in the world (Bodenheimer, 1951; Sacantanis, 1957; Debouzie and Mazih, 1999). The ripe and ripening Argan fruits seem as a large olive fruit favorable to medfly larval development (Balachowsky, 1950; Mazih and Debouzie, 1996) which when completed is followed by pupation in the soil and then emergence of a new generation.

The main objectives of this study were the assessment of *C. capitata* infestation level on Argan fruits, the monitoring of its seasonal dynamics, and the assessment of parasitism rate of its parasitoid *Psyttalia concolor* in Moroccan Argan plantation.

MATERIAL AND METHODS

Study sites

This study has been conducted in an Argan orchard located at Belfaa (30.0434N, -9.55635W) about 50 km from Agadir city, central-west of Morocco. This Argan orchard is located in experimental farm of National Institute of Agronomic Research (INRA) in Belfaa (Figure 1). It has been planted in 2010 as an experiment of Argan breeding on a sandy soil at a density of 150 trees per hectare. The height of Argan trees is ranged from 3 to 5 meters. The drip irrigation and organic manures were applied as needed.

Figure 1. Map of studied site

Climatic data

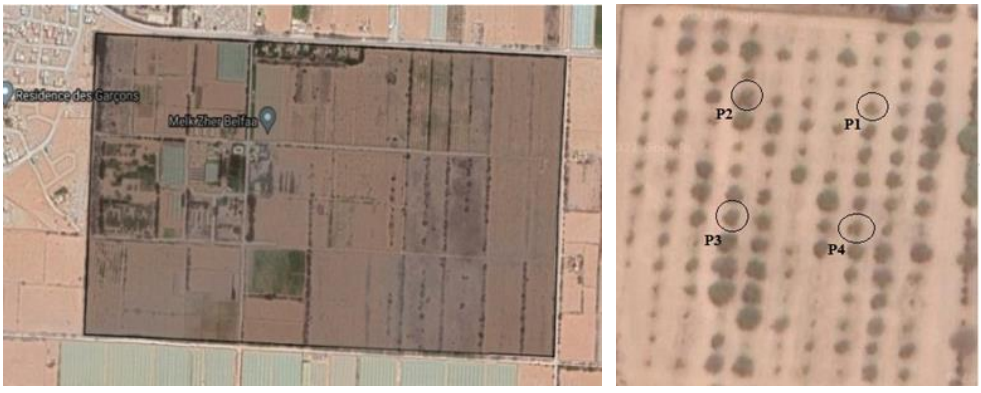
The farm is equipped by its own meteorological station, which recorded the weather parameters. Therefore, monthly temperature, rainfall and relative humidity are recorded. The Table 1 presents the average climatic data of rainfall, temperature and humidity (H) recorded monthly in Belfaa for a period of 16 years (between 1999 and 2014).

Table 1. Climatic data recorded in the studied site (Belfaa).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmax (°C)	21.3	22	24	24	24.6	26.4	28.5	29.1	27.7	27.3	24.4	22.3
Tmin (°C)	5.4	7.1	9.9	12	13.8	16.4	17.7	18.3	17	14.7	10.1	7.4
Tmean (°C)	13.4	14.5	16.9	18	19.2	21.4	23.1	23.7	22.3	21	17.3	14.8
Rainfall (mm)	20	25.1	26.3	11.9	4.6	0.2	0.1	1.9	4.8	13.3	22.3	28.4
Humidity (%)	63	62.9	63.1	67.5	70.1	71.7	71.9	71.2	69.8	65.6	64.2	65.4

Monitoring of *C. capitata* population

Four Argan trees were chosen for the traps installation. *C. capitata* population monitoring was designed to avoid the effect of the hedging; therefore, the four selected trees were as far away as possible from the hedge forming a square in the middle of orchard as shown in the figure 2. *C. capitata* population monitoring was performed using sticky yellow traps with a male specific pheromone (IPM Russell, UK). The traps were suspended at 1.5-2 m from the ground on the southeast side sheltered from the prevailing wind in the canopy. The pheromone was changed every four weeks and the traps were checked every two weeks during two years (2018 and 2019) to record the number of trapped males and to change the sticky yellow traps whenever necessary (De Villiers *et al*., 2013).



a **b**

Figure 2. (a) Argan orchard localization and (b) sampling design showing the four Argan trees selected for monitoring the dynamic of *C. capitata* population.

Infestation level

C. capitata infestation on Argan fruits was assessed monthly during 2018 from January to December by screening 10 fruits per tree randomly picked from the four central trees. Infested fruits were ranked according to scale adopted by Calabuig (2015) was used: 0=0 punctures; 1=1-3 punctures; 2=4-10 punctures; 3=11-30 punctures.

The infestation level was evaluated using the Townsend and Heuberger (1943) formula as showed below:

$$\boldsymbol{I}(\%) = \frac{\sum(\boldsymbol{nv})}{\boldsymbol{NV}} \times \mathbf{100}$$

n-levels of infestation according to the scale; v-number of fruits at each level of infestation; V-the total number of fruits screened; N- the highest level of the scale infestation (3 in our case)

Parasitism rate

To assess the number of *C. capitata* emerged from Argan fruits and the parasitism rate of their endoparasite P. concolor, recently fallen Argan fruits were collected every month down the four selected trees. The collected fruits were transferred immediately to the laboratory where, 10 Argan fruits per container, were placed in aerated plastic containers containing sterilized sand then incubated at temperature of 25±2°C and 70% ±5% of relative humidity (Ajerrar *et al.*, 2017). To assess the eventual difference of *C. capitata* emerged per fruits and the parasitism rate of *P. concolor* between the fallen fruits and the fruit picked from the trees, we randomly picked 10 ripe fruits in each selected trees then incubated as previously.

Data analysis

Studied parameters are the number of *C. capitata* trapped per two weeks, the mean number of *C. capitata* emerged per Argan 10 fruits and the parasitism rate of *P. concolor*. Statistical analysis was performed using Statistica software (V6, StatSoft, USA). One way and two-way ANOVA test at $p<0.05$ followed by Tukey test if significant difference was found (Ajerrar *et al*., 2020).

RESULTS AND DISCUSSION

Dynamic of Ceratitis capitate

The figure 3 shows the results of the dynamic of *C. capitata* population during the two successive years (2018 and 2019). The result shows an intra and interannual variation. Therefore, the dynamic of *C. capitata* population fluctuated between the months of the same year as well as the same months of the two sampled years. During 2018, a low dynamic between January and mid-April was registered; the mean number of males trapped during this period did not exceed 6 adults/trap days during the four surveys carried out between mid-February and mid-April. A slight increase was recorded during the second half of April where the mean number of trapped male exceeds 20 adults/trap. A significant increase of *C. capitata* dynamic was recorded during May when population reach the peak of dynamic. Therefore, more than 290 adults/trap on average was trapped. Compared to May, a slight decrease of *C. capitata* dynamic was observed during June. However, a strong decrease of the *C. capitata* dynamics was recorded from July. This decrease was progressively maintained during August and September. From the beginning of October, progressive increase of population dynamic was

shown, and consequently the mean of trapped male reached 88.5 male/trap. This increasing dynamic was maintained progressively until the end of December when the number of trapped males has exceeded 310 male/trap (Figure 3).

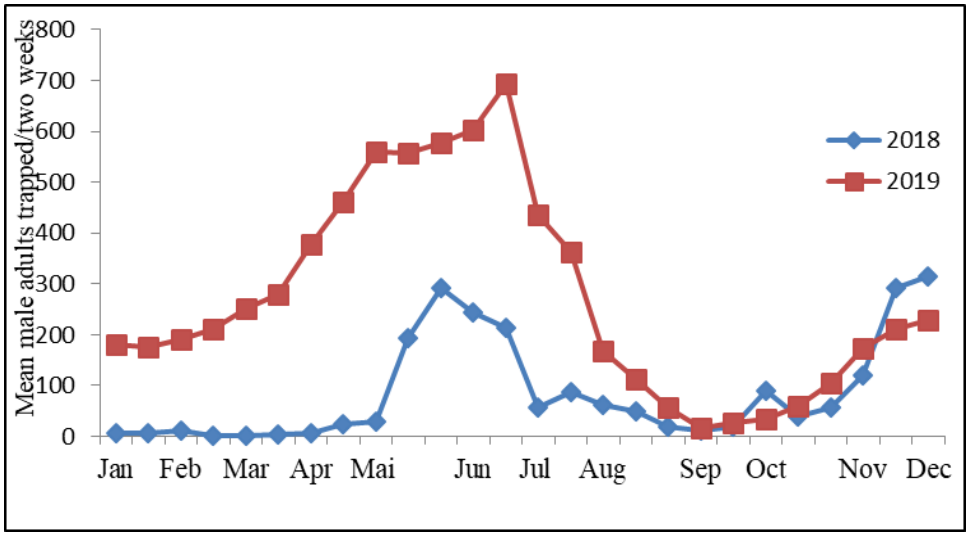


Figure 3. Population Dynamic Of *Ceratitis Capitata* During 2018 And 2019.

Compared to *C. capitata* dynamics recorded during 2018, a highly significant dynamic was recorded during 2019. Med fly dynamic was progressively increasing between January and June with a high number of male adults trapped, ranged from180 adult/trap to 280 adults/trap between January and March. After the second half of April, mean trapped male exceed 450 adult/trap and the peak of dynamic was recorded during June by 692 adult/trap. After the peak a sharp decrease was recorded during July, August and September. Therefore, 363 adult/trap was recorded in July, 57 adult/trap and 16 adult/trap during August and September respectively (Figure 3).

Infestation level of Argan fruits

A low Argan infestation level was recorded during January 2018 (7%). A progressive increase of infestation level was observed from January to March where over 50% of Argan fruits was infested; slight decrease was recorded during April (47%). Between April and May, a highly infestation level was observed; the peak of infestation was recorded during May reaching over 95% of infested fruits. A slight decrease was recorded between May and July (87%). Low infestation level was recorded during August and September which was normally characterized by the lack of Argan fruits. A sharp increase of infestation level was recorded during October (62%) with the same level during December. Significant decrease was registered during November (34%) (Figure 4).

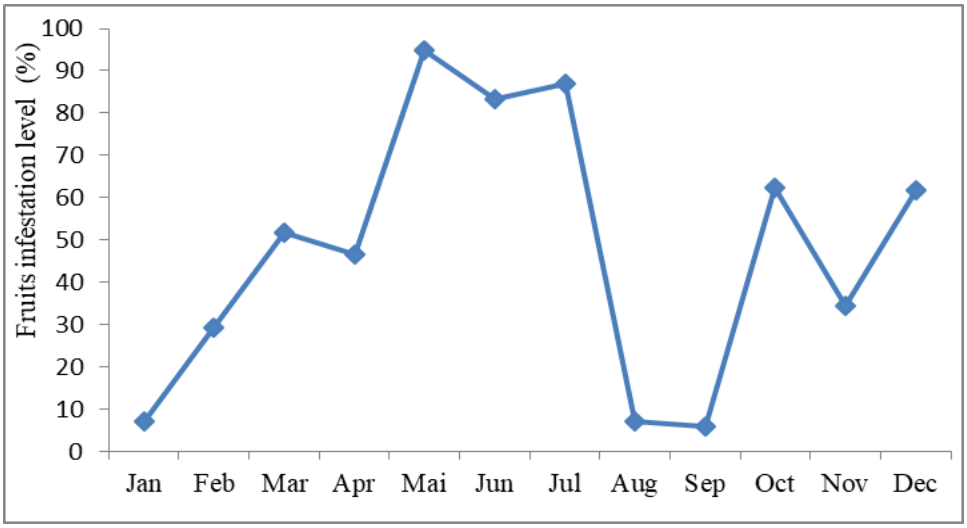


Figure 4. Argan fruits infestation level during 2018.

Results of emerged medfly per 10 Argan fruits among months during 2018 are subjected to one-way ANOVA test ($P<0.05$). No significant difference was observed on the number of emerged *C. capitata* among sampling periods (months) ($p>0.05$). Nevertheless, a high emerged medfly was observed in June 2018 with 31.7±4.44 adults per 10 fruits and a low emerged medfly was recorded during January 2018 5±6.6 (Figure 5). Also, no significant difference was recorded between the number of medfly emerged from Argan fruits collected in soil and picked ones ($p>0.05$). In addition, no significant difference was observed for interaction between sampling period and fruits origin (fallen and picked) (Table 2).

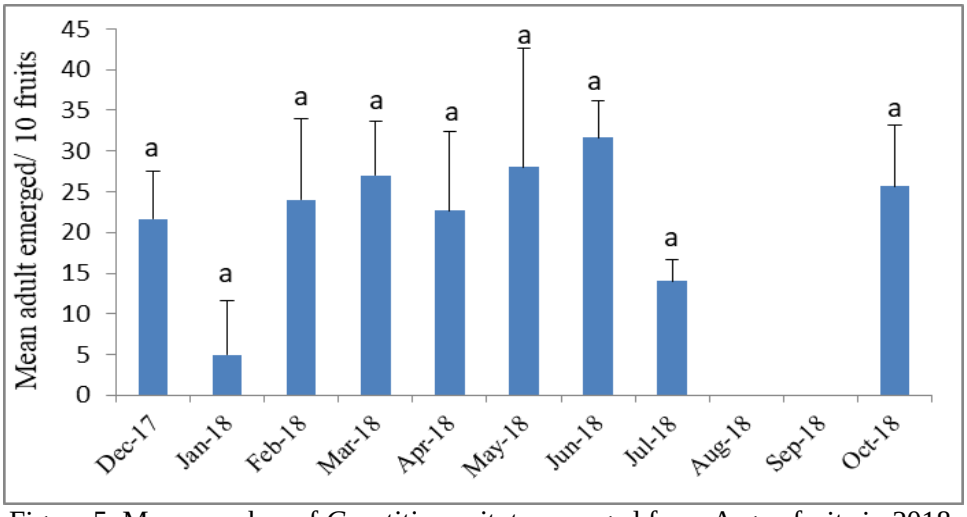


Figure 5. Mean number of *Ceratitis capitata* emerged from Argan fruits in 2018.

Table 2. Summary of ANOVA test for the effect of fruits origin (fallen /picked) and sampling period and their interaction on the number of emerged *Ceratitis capitata*.

	fd	*F*	*P*
Fruits origin	1	0.656731267	0.427254458
Sampling period	4	2.085221266	0.120781095
Interaction	4	0.176422427	0.947923237

***Psyttalia concolor* parasitism rate**

The obtained results of *Psyttalia concolor* parasitism rate are subjected to ANOVA test (P<0.05). The statistical analysis shows no significant effect of fruit origin (fallen/ picked) on parasitism rate (P>0.05). However, *Psyttalia concolor* parasitism rate shows a significant difference between the sampling periods (p<0.05). No significant impact of interaction between the fruits origin and the sampling periods on the parasitism rate was observed (P>0.05) (Table 3). A highly significant parasitism rate was recorded on fallen Argan fruit (11.85%±6.38) during May 2018. However, the low parasitism rate was reported during April and June 2018 for both fallen and picked Argan fruits with a parasitism rate less than 1% (Figure 6).

Table 3. Summary of two-way ANOVA for the effects of fruits origin (fallen /picked) and sampling periods and their interaction on parasitism rate of *P. concolor*.

	Df	*F*	*P*
Fruits origin	1	3.59424763	0.07252304
Sampling period	4	3.78994685	0.01883952
Interaction	4	0.93515119	0.46372775

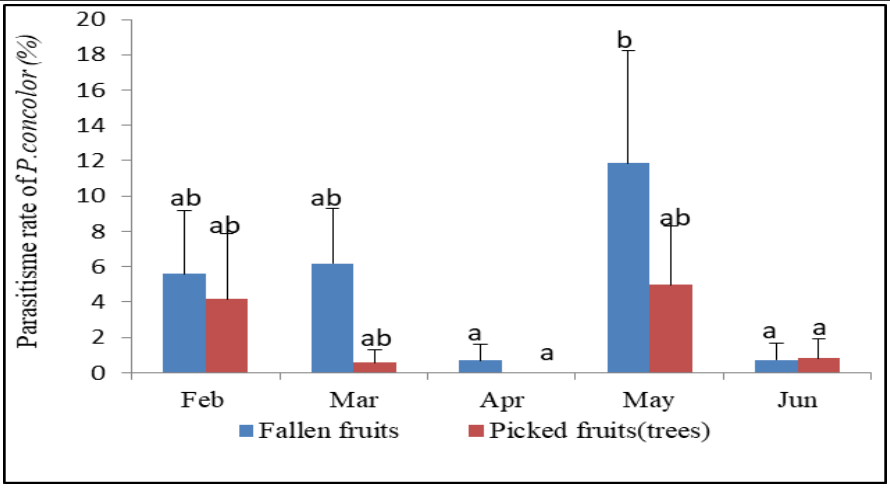


Figure 6. Parasitism rate of *P. concolor* recorded during different sampling periods. Means (±SE) with different letters indicate significant difference at P<0.05.

The monitoring of *C. capitata* dynamic allows showing the permanent activity of this pest during the whole year. This permanent dynamic can be explained by a perfect adaptation of *C. capitata* to the Argan fruits. In addition, many authors had considered Argan fruits as a perfect host of med fly (Sacantanis, 1957; Debouzie and Mazih, 1999). The results of med fly monitoring reveal a difference of mean adults trapped between the two studied years and between the different periods (months) of the same studied year. These differences may be explained by host fruits availability among the different periods. The fruiting process of Argan trees was not homogeneous during the two studied years, which leads to the time lag of availability of receptive fruits. During 2018, low dynamic was observed during two periods: between January and mid-April when receptive fruits were almost absent in the field and during August-September where receptive fruits were not available. The autumn fruiting during 2018 allows the emergence of a new generation of *C. capitata*, which in turn increased the population size during the following year. The relatively high number of trapped males between November 2018 and March 2019 can be explained by the availability of receptive fruits on some Argan trees during this period. The peak of *C. capitata* dynamics was recorded in May 2018 and June 2019. These two periods generally coincided with the peak of fruit ripening of most Argan trees in this orchard. Our results show that the number of *C. capitata* emerged per fruits was not impacted either by Argan fruits origin (fallen or picked) or by the sampling period. Moreover, no significant effect of fruits origin on *P. concolor* parasitism rate was registered. However, sampling periods had a significant effect on *P. concolor* parasitism rate. Therefore, the parasitism rate differed between periods with a high significant parasitism rate recorded during May 11.85%±6.38% and the lowest during April and June with less than 1%. This parasitism rate variation may relate with temperature difference among studied periods. Moreover, *P. concolor* development is very sensible to temperature fluctuation. According to Loni (1997), *P. concolor* development ranged between 15°C and 30°C, and no adult emergence was obtained at 13°C and 33°C. In addition, the same author state that optimal emergence rate was obtained at temperature interval ranged from 18°C to 25°C. Pearson correlation test showed that no significant relationship between the number of *C. capitata* emerged per fruit, the trapped adults (dynamic), the infestation level and the parasitism rate of *P. concolor* and the three climatic parameters recorded in Belfaa monthly (Figure 7). However, a significant relationship was observed between the infestation level and the *C. capitata* dynamics ($P<0.05$) (Figure 7). This pattern may be explained by *C. capitata* high tolerance. According to Nyamukondiwa and Terblanche (2009) *C. capitata* showed a greater thermal tolerance.

Therefore, climatic parameters recoded in Belfaa were suitable for *C. capitata* development. Moreover, the mean temperature recorded in Belfaa during the coldest month (January) and the hottest month (August) were 13.4°C and 23.7°C respectively. These values are far than critical thermal limits recorded for

C. capitata established by Nyamukondiwa and Terblanche (2009) which ranged from (5.4–6.6°C) to (42.4–43.0°C) as critical minimal and maximal temperature respectively. In addition, De Villiers *et al* (2013) study states that *C. capitata* may also be better adapted to arid climates.

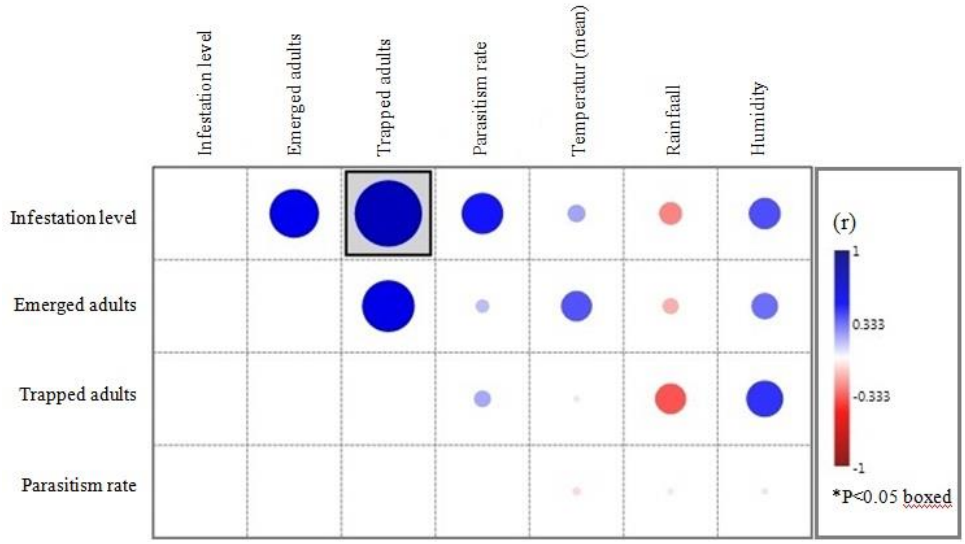


Figure 7.Summary of correlation test (Pearson) between studied parameters and the mean of climaticrecorded in Belfaa.

CONCLUSIONS

C. capitata occurrence and their flight dynamics in this Argan orchard are almost permanent. Low occurrence was recorded during a few months, mainly related to lack of ripe and ripening Argan fruits; but once the Argan fruits reach ripeness, a rapid increase in the population size was shown. This permanent occurrence is mainly explained by the favorable climatic conditions in Belfaa region, and presence of *C. capitata* in the neighboring orchards areas. Among these host plants the prickly pear and the different varieties of orange, whose ripeness period ranged from September to July, can replace the Argan fruits and thus allowing the relay of medfly generations. On the other hand, despite the mediocre and unstable parasitism rate of *P. concolor*, this parasitoid can be an important ally to other protective measures to reduce the rate of *C. capitata* infestation and to decrease the size of its population.

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