Biodiversity Journal, 2019, 10 (4): 577–588 https://doi.org/10.31396/Biodiv.Jour.2019.10.4.577.588

Bioecological study of parasitic complexes of aphids in North-West Algeria

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ABSTRACT

Myzus persicae (Sulzer, 1776) (Hemiptera Aphididae) is the most significant aphid pest of peach trees. Chemical control of this species is a quick and simple method to prevent the development of this pest, however, the massive use of these chemicals poses potential health and environmental risks. This study proposes an alternative biological control approach based on the use of parasitoids to reduce aphidian populations. The study, which we undertook over the course of three years, allowed us to observe almost the same species of parasitoid (Hymenoptera Braconidae) on the vegetable crops taken into exam in the study. However, some species were considered to be absent in the region. Others appeared only during the second and last year of study as *Aphidius funebris* Mackauer, 1961, *Trioxys angelicae* Haliday, 1833 and *Praon exsoletum* Nees, 1811. This study showed total dominance of *A. matricarae* Haliday, 1834 with very high parasitism (values of 61%, 54% and 78% during 2012, 2013 and 2014, respectively) followed by *Lysephlebus testaceipes* Cresson, 1880.

KEY WORDS *Myzus persicae*; biological control; dominance; parasitoids; aphidian populations.

Received 26.08.2019; accepted 25.10.2019; published online 30.12.2019

INTRODUCTION

In Algeria, market gardening is the second crop after that of cereals. It occupies an area of more than 330,000 Ha with an estimated production of 8.5 million tons in 2013 (F.A.O, 2013). As with most crops, vegetables are confronted with various phytosanitary problems, leading to economic losses of up to 100%.

Nowadays, in addition to the phytophagous insects known for the importance of their damage to vegetable crops, especially under greenhouse shelters such as whiteflies, moths and thrips, we find other pests more dreadful on these crops and especially on the greenhouse pepper, in this case, the aphids (Blancard, 1988; Gillespie et al., 2002).

Aphids are more than ever a concerning pest for many crops. They affect vegetable crops as well as field crops, orchards or floral crops (Norozou, 2013). These aphids, which settle early on crops, have an exceptional multiplication rate. Their biological characteristics make them formidable pests and they are the cause of numerous damage, at all stages of the cultures (Bouhroua, 1987).

Particularly, *Myzus persicae* (Sulzer, 1776) (Hemiptera Aphididae) is the most significant aphid pest of peach trees and it is also a vector for the transport of plant viruses.

Control of these aphids is more feasible through the application of synthetic insecticides that can limit their populations to a tolerable threshold (Lopez et al., 2012). This means of control can lead to several harmful effects such as the reduction of natural enemies, the appearance of resistant strains in pests, etc. Aphids have developed resistance to chemical pesticides (Riba & Silvy 1989; Foster et al., 2003; Wang et al., 2007). However, many studies aimed at biological control aim at exploiting and valuing the action of many natural enemies. This method implies a perfect knowledge of the biology of the pest in question and that of its natural enemies (Estevez et al., 2000).

Thus, the agricultural world has been pushed to adapt chemical control to minimize the number of chemical treatments. Significant development of biological control is currently the most advocated. This method of control aims at the effective use of the potentialities of auxiliary fauna, whether they are predators or parasitoids against aphids.

The growing interest in conservation biological control measures underscores the need to study the diversity and phenology of populations of aphidiphagous helper insects (Bouhroua, 1991).

Biological control in greenhouses is rapidly growing worldwide because of the advantage that a closed environment has for applying biocontrol agents (Boissard et al., 2008; Driesche et al., 2008; Lopes et al., 2009; van Lenteren, 2000a cited by Norouzi, 2011). In some systems, biological control has good potential for replacing chemical methods of arthropod pest control (Gillespie et al., 2002; van Lenteren, 2000b cited by Norouzi, 2011).

Several families of insect predators and parasitoids can control aphid populations, mainly ladybugs (Coleoptera Coccinellidae), syrphids (Diptera Syrphidae), chrysopes (Neuroptera Chrysopidae) and micro-Hymenoptera belonging to the family Braconidae and Aphelinidae (Lyon, 1983; Boivin, 2012; Lopes et al., 2012). The latter restrict aphid populations (Laamari et al., 2011). Parasitoids include the Hymenoptera of the family Braconidae and the subfamily Aphidinae. It encompasses about 400 species worldwide (Laamari et al., 2011). Some of these species are solitary and aphid-specific parasitoids (Kavallieratos et al., 2001; Aslan et al., 2004).

The Aphidiidae family is the most represented among the parasitic activity of aphid parasitoid species (Darsouei et al., 2011; Hemidi et al., 2013). Most of these species belonging to this family are koinobiont endoparasitoids of aphids (Kavallieratos et al., 2001; Aslan et al., 2004; Boivin et al., 2012). According to Akhtar et al. (2011), these Aphidiidae are known from all major habitats in the world, especially in the temperate and subtropical zones of the northern hemisphere.

According to Bouhraoua (1991), numerous authors throughout the world confirm that aphids are attacked in the field and in the greenhouse by a very large number of entomophagous species. They often succeed in completely eliminating the colonies of these aphids on cultivated plants. At present, in our country, the list of Aphidinae Hymenoptera has reached 32 species (Ghelamallah, 2016, 2018).

Indeed, it is very important to apply integrated pest management strategies in our pest management strategies that promote the exploitation of the action of many natural enemies and the use of selective chemicals, without eliminating the action of the auxiliary fauna. This approach should be based on a thorough knowledge of the population dynamics of the pest in question and of its parasitoid fauna (Ghelamallah, 2016).

It is with this vision that our research work focuses on the knowledge of the bioecological parameters intervening in the regulation of the aphidian populations by using auxiliary fauna in order to preserve the balance of the agro-systems, thereby minimizing the use of insecticides.

Research carried out in the Mostaganem region deals with the monitoring of the population dynamics of *Myzus persicae* over a period of three years (2012–2014). They also make it possible to develop an exhaustive inventory of their natural enemies with an assessment of the impact of different abiotic factors (temperature in this case) on the biotic regulation of aphid populations (parasitoids and predators). This work also made it possible to study the dynamics of the populations of this auxiliary fauna over the same period of 3 years (2012–2014).

The main objective is to collect the information needed to develop biological control techniques, based in particular on parasitoid fauna. As a result, several parameters of the biology of the aphids, especially of *M. persicae* and its antagonists, have been studied.

MATERIAL AND METHODS

In this context, the auxiliary fauna of greenflies, an inventory of natural enemies of aphides was pursued, from 2011 to 2014, fot the experimental studies of the Department of Agricultural Sciences at the Mostaganem University, Algeria. As far as our study was enlarged to different farming sites in many localities in the province of Mostaganem in the north-western part of Mostaganem. All material has been collected by the first author.

For four consecutive years, from early January to early July, 300 leaves contain larvae of devastators that have been collected each weekto make an inventory of hymenopterous parasitoid species. To each sample, all the mommies found within the colonies of the studied green flies are collected and driven to the laboratory, then are separated and placed in labelled tubes and followed until the emergence of adult parasitoids. Once the emergence is obtained, these adults are conserved individually in micro-tubes containing a 90% of ethanol for a further identification.

The species mentioned in this study (Hymenoptara Braconidae) are: *Aphidius colemani* Viereck, 1912, *A. ervi* Haliday, 1834, *A. funebris* Mackauer, 1961, *A. matricariae* Haliday, 1834, *A. platensis* Brèthes, 1913, *A. transcaspicus* Telenga, 1958, *Binodoxysc angelicae* Haliday, 1833, *Diartiella rapae* M'Intosh, 1855, *Lysephlebus fabarum* Marshall, 1836, *L. testaceipes* Cresson, 1880, *Praon volucre* Haliday, 1833, *P. exsoletum* Nees, 1811, *Trioxys angelicae* Haliday, 1833.

Calculation formulas used rate of parasitism:

Tp = (Number of parasitized individuals / Σ of enumerated individuals) × 100.

RESULTS

The results obtained are statistically treated by the STATBOX PRO software and a comparison of the averages is performed on the Newman and Keuls test at 5%.

A factorial correspondence analysis (CFA) is performed using the Minitab 14 software. It is used to identify the effects of different months and years on relative abundances, parasitism and insect distribution in the foliar stage. Diagrams were also constructed to assess insect-specific abundance and years and months.

Relative abundance of inventoried parasitoids

In 2012, 8 species of Hymenoptera including seven parasitoids and one hyperparasitoids have been found. In contrast to the first year, we recorded new species during this period. These species are: *A. platensis*, *L. testaceipes*, *D. rapae*, and *L. fabarum*. On the other hand, we noticed the absence of two species *A. colemani*, *A. transcaspicus* during all the years of study. This absence can be explained by competition between species.

The differences revealed the presence of a newly established species in the study area. This is *A. platensis* with a relative abundance of 2% (Fig. 1).

In the first samplings, coinciding with February, the abundance of parasitoids recorded was very low except for the two species *A. matricariae* and *L. fabarum*. These two parasitoids are the most dominant with a rate of 61% for *A. matricariae* followed by *L. fabarum* with a relative abundance of 8%.

Comparatively, the other species identified, such as *A. platensis*, *A. ervi*, *L. testaceipes* and *D. rapae*, have values oscillating between 2% and 4%.

On the other hand, hyperparasitoids showed a presence at the end of the sampling period in May and early June with a rate of around 15%.

According to the factorial correspondence analysis, *A. matricariae* is very present during the three months of 2012 (Fig. 2) followed by *L. fabarum*, *D. rapae* and finally *L. testaceipes*.

The analysis reveals that the number of insects is very high in April compared to March and May respectively (Fig. 2).

During 2013, compared to 2012, we have identified two new species that appeared for the first time in our experimental site. These are *P. volucre* and *B. angelica*. Thus, we observed the disappearance of the species *A. platensis*, and this is due to the predominance of certain species that settled in the site of the study (Fig. 3).

Relative abundances in 2013 were highly variable across species. The highest value was recorded in *A. matricariae* (54%) followed by *L. testaceipes* with 22%. The other parasitoids participate with relatively low abundances ranging from 5% in *L. fabarum* and *A. ervi* to 2% in *P. volucre* to 1% for *B. angelicae*. These values are relatively similar to those observed in the previous year, except for *B. angelicae* and *P. volucre*, where abundance appears to be lower (Fig. 4). For hyperparasitoids, we noticed a decrease of 8%.

From our results, we note that the number of *A. matricariae* is considerably higher than the other species (about 51% of the total).

Our observations show that the species *L. testaceipes* is present at 22% in relation to all the insects.

Factor analysis shows that the number of species recorded during the month of May is significantly higher than in April and June (Fig. 4).

In the fourth year of inventory (2014), only 9 species were observed, of which three species are listed for the first time: *T. angelicae*, *P. exsoletum* and *A. funebris*. The latter has marked its presence with a fairly appreciable rate of around 5% and will perhaps be the most dominant over time.

For relative abundance, we noticed a rather impressive increase in *A. matricariae* with a dominance which reached a maximum threshold of 78% (Fig. 5). For the remainder of the inventoried species, namely *A. funebris*, *L. testaceipes*, *D. rapae*, *A. ervi*, *P. volucre*, *T. angelicae* and *P. exsoletum*, their abundance is very low, ranging from 1 to 5% only.

Concerning hyperparasitoid, we observed that the rate remains almost identical to that of the previous year (10%).

During the year 2014, the number of *A. matricariae* is significantly higher than the other species with an estimated 78%.

The factor analysis of the correspondences shows that the month of April records a large number of individuals compared to the other months of the same year. This same analysis reveals that there is a close relationship between the number of *A. matricariae* and the month of April (Fig. 6).

It should be noted that the number of hyperparasitoid in 2014 is estimated to be 10% of the total number of insects surveyed.

Monthly relative abundance of different inventoried parasitoid species.

In 2012, according to figure 10, we note that April is the most favorable month for the development of parasitoids. This could be explained by the climatic conditions favorable to their development. We recorded an average temperature of 22 °C, which increases gradually to an average between 27 and 30 °C during the months of May and June. The density of aphid populations was high during this period.

The monthly proportions of each species showed a regular presence of *A. matricariae* during the various months of study and reached the maximum threshold during the month of April when the temperature inside the greenhouse is adequate to the reproduction of this species.

Aphidius ervi, *D. rapae* and *L. testaceipes* were observed only once during the study period. Thus, we observed that *A. platensis* appeared only during the month of May (Fig. 7), whereas certain species appeared only during the month of March, such as *L. testaceipes*.

Subsequently, a decrease in the level of parasitoid hymenoptera was recorded towards the end of April (Fig. 8).

The factorial analysis of the correspondences shows a positive correlation between the development of *A. matricariae* and the month of April (Fig. 8). However, the analysis also reveals a positive relationship between March and the same species. Our results also show that April is the right month for the development of all forms of insects. The number of insects in the month of May is smaller than in April when, apart from the *A. matricariae*, virtually no insects have been recorded.

In 2013, the monthly presence of the parasitoid species inventoried allowed to highlight their regular activity during the different months. We note in particular the predominance of *A. matricariae* in April and May, with the exception of the previous year where we noticed its presence during the month of June.

The monthly proportions from March to July of each species showed a regular presence of five species, *L. testaceipes*, *L. fabarum*, *A. ervi*, *P. volucre* and *B. angelicae*, with a clear predominance of *L. testaceipes* from April to June (Fig. 9). Some species continue to appear until July. This presence during the summer can be explained by the temperatures favorable to the development of these parasitoid species.

Regarding the monthly relative abundance of hyperparasitoids, we recorded a significant presence of some species during May and June.

During 2013, the abundance of hymenoptera species is relative to the different months. Their factor analysis reveals that April is the ideal month for the development of *A. matricariae* and *L. fabarum* while the climatic conditions of June contribute to the growth of the number of individuals of *L. testaceipes* and *A. ervi* (Fig. 10).

During 2014, the monthly presence of the listed species revealed a constant activity of *T. angelica*, *A. funebris*, *L. testaceipes*, *P. exsoletum*, *D. rapae*, *A. ervi* and *P. volucre* during April. However, between February and June, we record the dominance of *A. matricariae* (Fig. 11). This high abundance of this parasitoid during the sampling period may be due to the favorable temperature, from 20 to 28 °C. It was in these thermal conditions that we recorded a relationship between the highest abundance of the insect during April and the average temperature of 24 °C.

The monthly proportions of hyperparasitoids showed a regular presence but earlier than those of last year. During this year, the appearance is more contrasted during April and May (Fig. 11).

During 2014, there was a significant decrease in the number of individuals of all species of hymenopterans recorded mainly during May and June. However, it is important to note that relative abundance is very high during April especially for *A. matricariae* (Fig. 12).

DISCUSSION

The relative abundance of aphidian parasitoids would differ from one year to the next (Kavallieratos et al., 2005). According to Andrade (2013), the different species of parasitoids can be influenced unequally by climatic variables. Depending on the year, the community may be dominated by one species or another. These very large fluctuations in abundance indicate the existence of an annual factor structuring these communities, possibly associated with climate variations and the host resource.

These biotic and abiotic variations have favored the appearance of certain species during each year at different rates of abundance: for example, the species *L. testaceipes* and *A. ervi*, are in total dominance of *A. matricariae*.

These results observed on the expansion and increasing predominance of this parasitoid are similar to those already observed by other authors, in particular Laamari et al. (2011) and Acheampong et al. (2012). Currently, we can consider that this species (*A. matricariae*) is one of the most efficient auxiliaries against the aphids in Algeria.

Aphidius matricariae is an important parasite of the green peach aphid, *Myzus persicae*, and 40 species of aphids belonging to 20 genera have been recognized as hosts (Rashki et al., 2009).

Throughout Algeria, Laamari & Stary (2013) mentioned that the parasitoid *L. testaceipes* occupies the second position after *A. matricariae*. It was able to develop 74 tritrophic associations. After being introduced to the South of France in 1973-1974 (Starý et al., 1988), it was introduced also in Spain (Baixeras & Michelena, 1983), Portugal (Cecilio, 1994) and, finally, north Africa, probably through the Straits of Gibraltar.

This species has been introduced into biological control against various aphid species in many parts of the world such as Australia (Carver, 1984) or the Mediterranean basin (Lopez, 2007). As well as *L. testaceipes*, which has parasitized 20 species of aphids predominantly harmful to crops, it can be used in biological control programs against these phytophagous plants (Laamari et al., 2011). According to Ouadah (2009), among the natural enemies of *Aphis gossypii* Glover 1877, the parasitoid *L. fabarum* plays an important role in limiting populations of this aphid on the cultivation of greenhouse bell peppers.

However, *A. matricariae* was the most dominant species, having already formed 57 tritrophic associations with 23 species of aphids found on 38 plant species (Laamari et al., 2011; Laamari & Stary, 2013).

The numerical importance of *Aphidius* and *Lysiphlebus* species can be attributed to their ability to adapt to different climatic conditions. According to Stary et al. (1975), species belonging to these genera are not very demanding from a climatic point of view. This is certainly what explains their

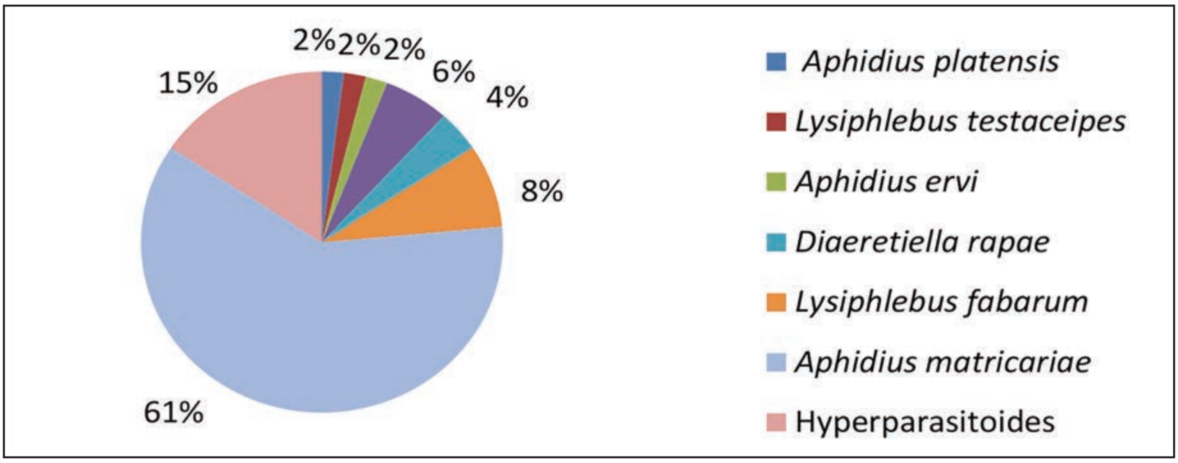

Figure 1. Relative abundance (%) of parasitoids taken during 2012.

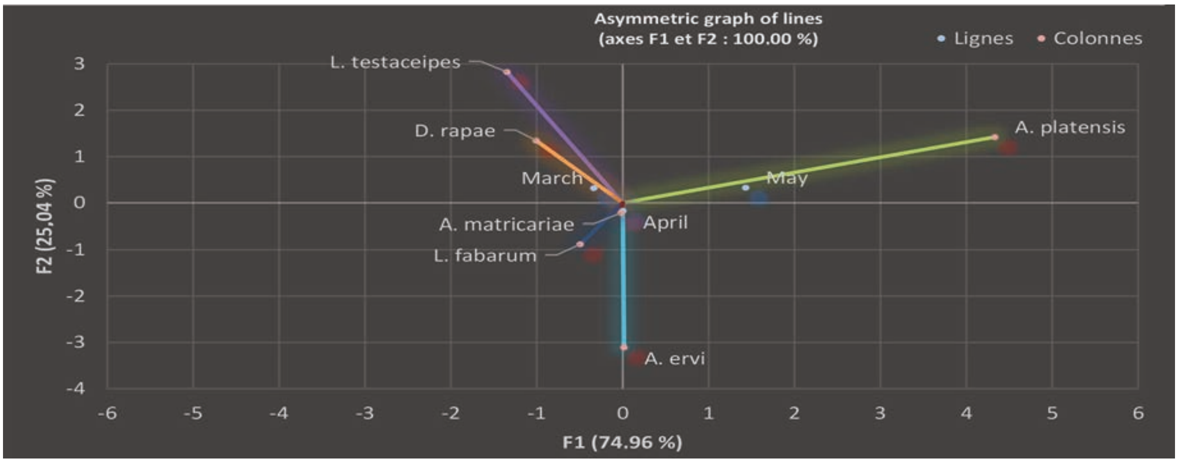

Figure 2. Representation of species inventoried in the A.F.C plan during 2012.

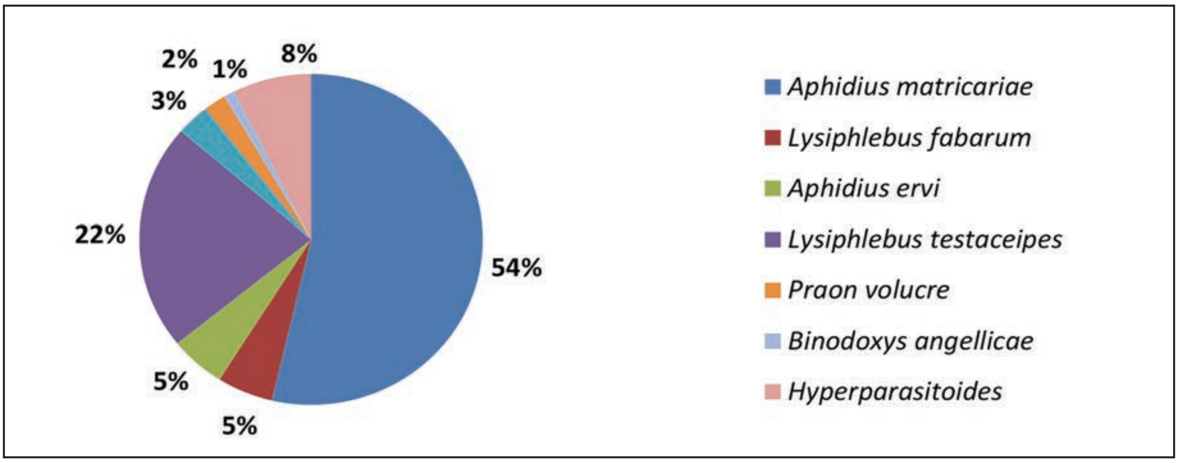

Figure 3. Relative abundance (%) of parasitoids collected during 2013.

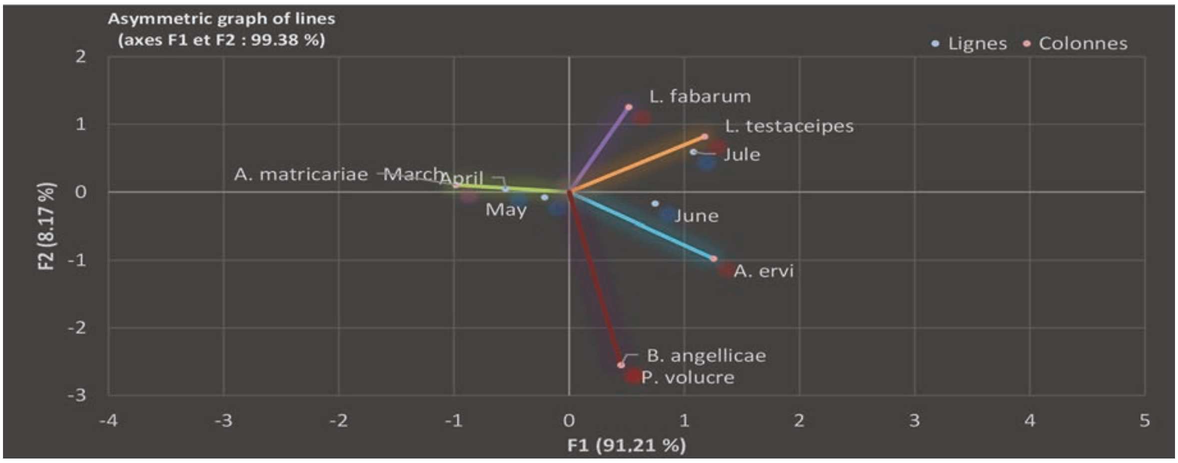

Figure 4. Representation of species inventoried in the A.F.C plan during 2013.

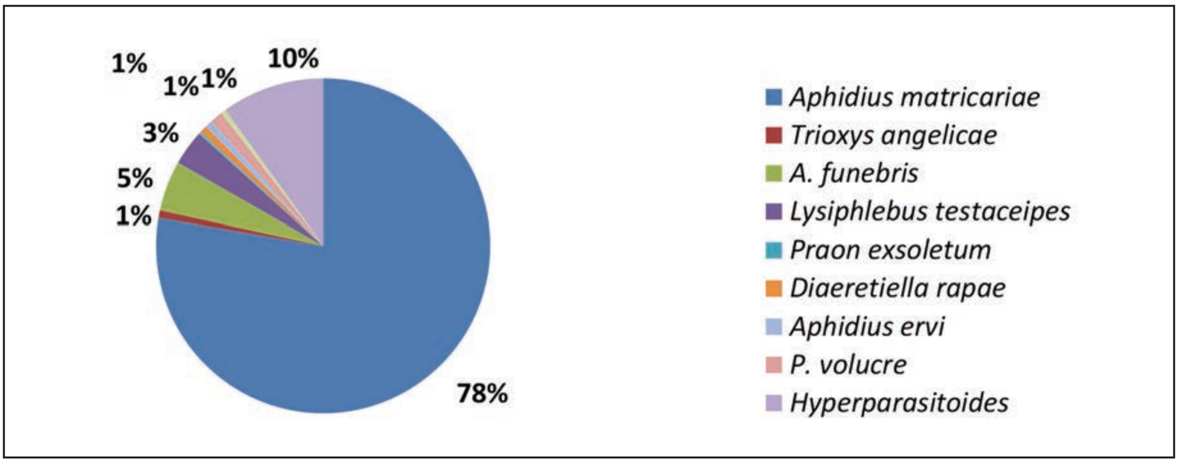

Figure 5. Relative abundance (%) of species of parasitoids identified during the 2014 study period.

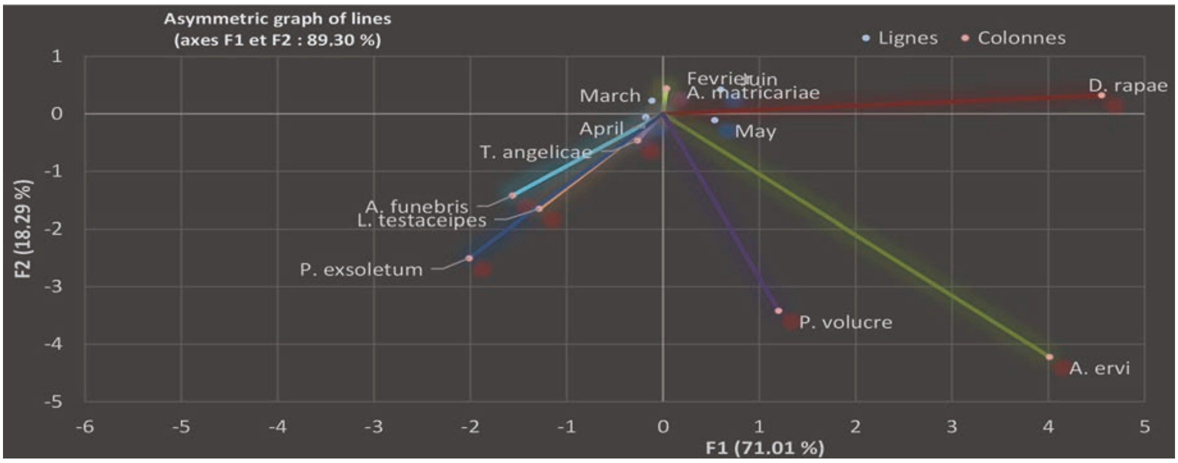

Figure 6. Representation of species inventoried in the A.F.C plan during 2014.

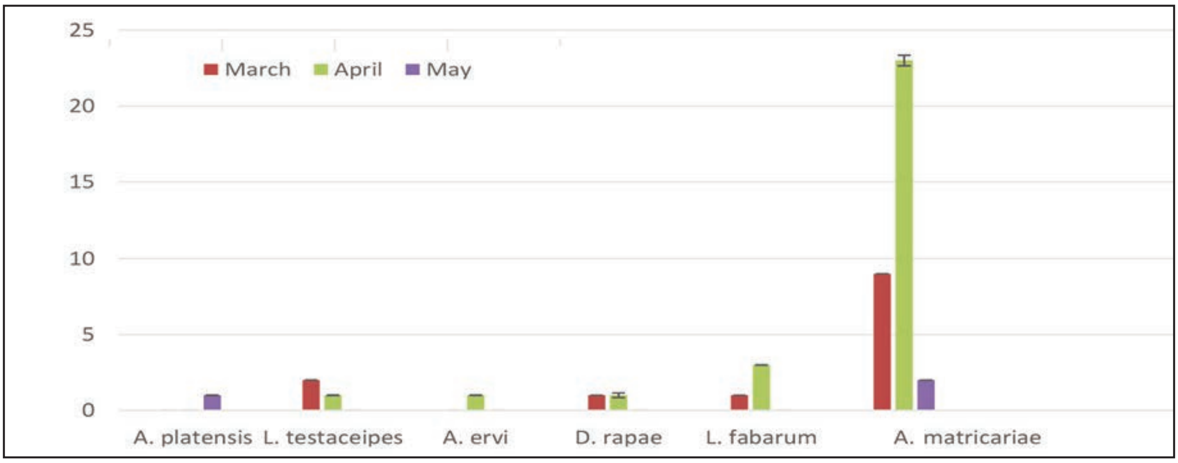

Figure 7. Monthly relative abundance of the various species of parasitoids inventoried during 2012.

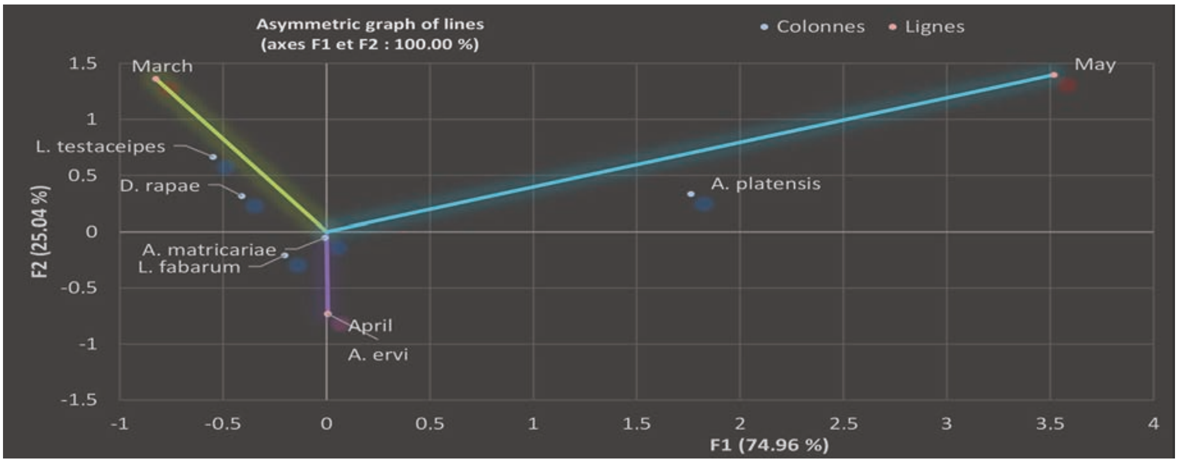

Figure 8. Monthly representation of the abundance of species inventoried in the A.F.C plan during 2012 (effect of months).

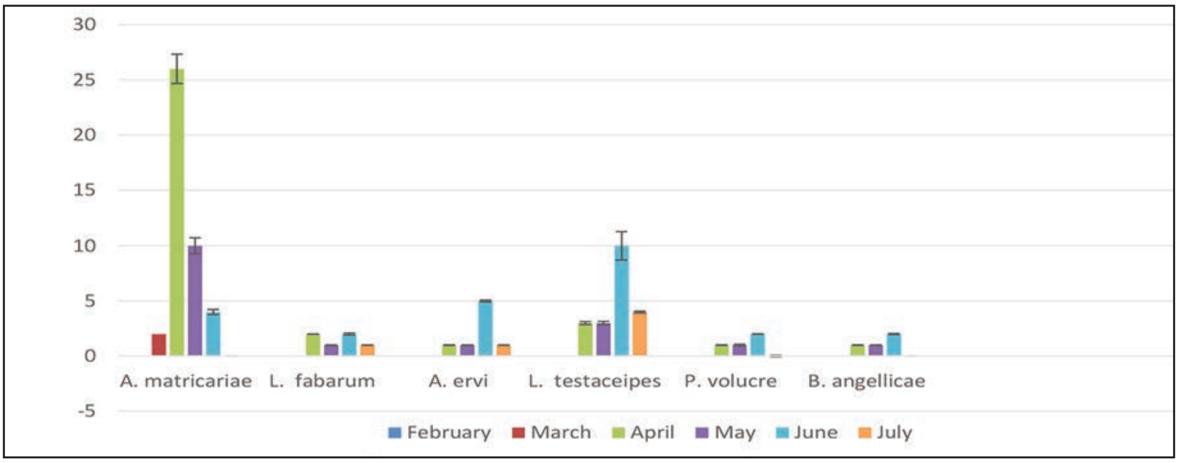

Figure 9. Monthly relative abundance of the various species of parasitoids inventoried during 2013.

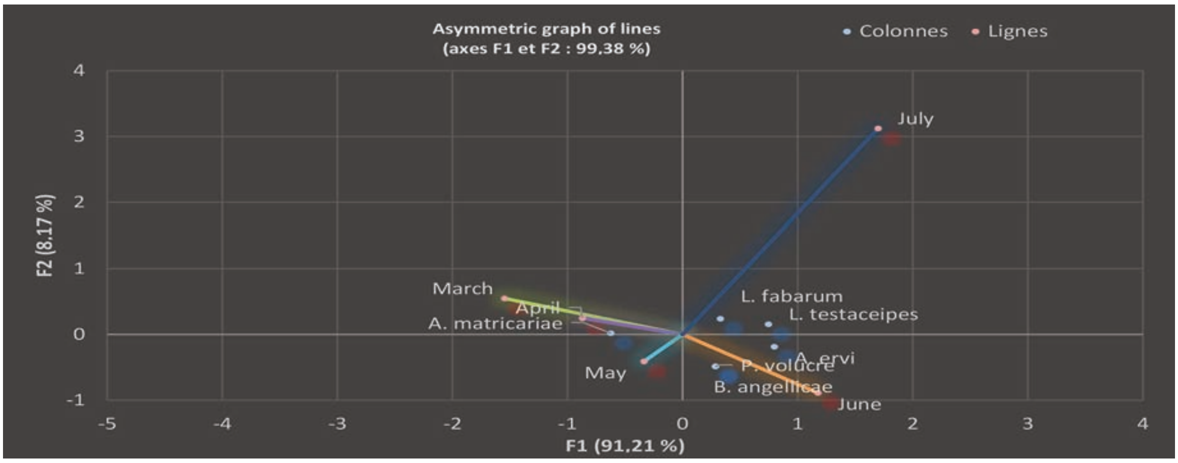

Figure 10. Monthly representation of the abundance of species inventoried in the A.F.C plan during 2013 (effect of the months).

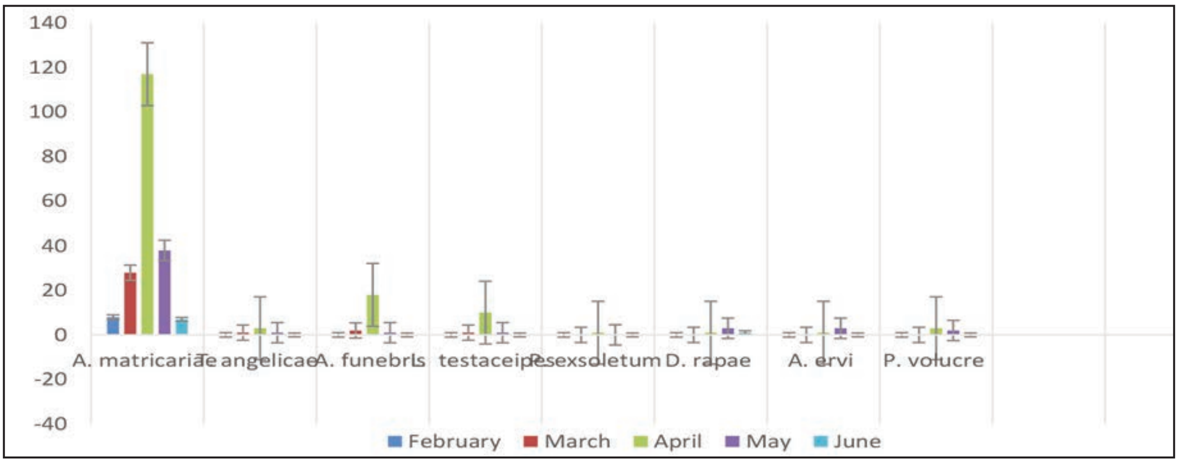

Figure 11. Monthly relative abundance of the various species of parasitoids inventoried during 2014.

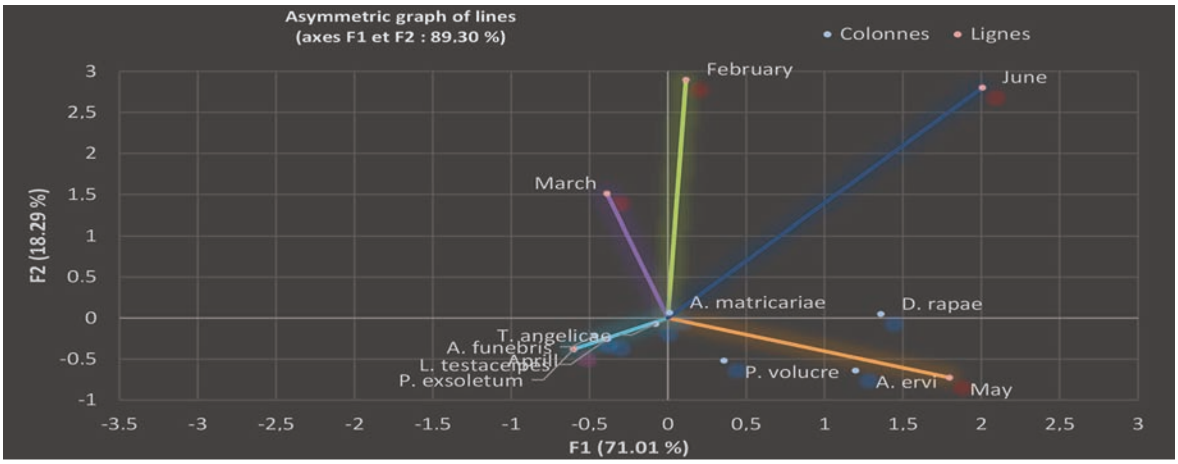

Figure 12. Monthly representation of the abundance of species inventoried in the A.F.C plan during 2014 (effect of the months).

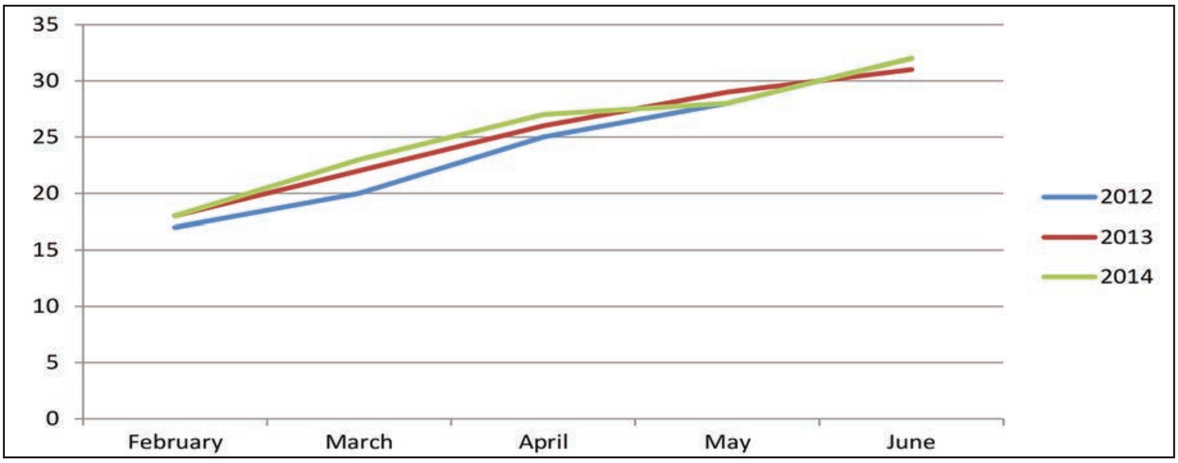

Figure 13. Temperature during the years 2012, 2013 and 2014.

wide distribution throughout the world.

It is important to understand the influence of climatic variations on the functioning of the communities of aphids and their parasitoids. It is also of fundamental importance for the biological control of pest populations (Hance et al., 2007).

Parasitoid performance can be influenced by interaction with other parasitoids, predators and entomopathogens (Rosenheim, 1998; Rashki et al., 2009).

In addition, the abundance and efficacy of primary parasitoids is limited by hyperparasitoid intervention (Darsouei et al., 2011).

Traditionally, hyperparasitoids have been designed to have a negative effect on primary parasitoid populations. There are several ways in which hyperparasitoids can influence primary parasitoid populations: directly by mortality, or indirectly by changing the behavior of parasitoids or the aphids (Buitenhuis, 2004).

In the literature, high rates of hyperparasitism have often been reported. In an agro-ecosystem, the mortality of parasitoids due to hyperparasitism can even reach 100% (Höller et al., 1993). Kanuck & Sullivan (1992) showed that female hyperparasitoids have a preference for the mummified aphid.

Finally, the absence of certain parasitoid species in the study region compared to other regions can be explained by the intensification of modern agriculture, notably by the use of fertilizers and pesticides. This has, of course, led to a decrease in the quantitative and qualitative richness of these parasitoids (Hemidi et al., 2013).

CONCLUSIONS

The populations of *A. matricariae* are the most frequent and have gradually increased to become the most dominant species among aphid parasitoids during the last year of the study, with proportions reaching 78%. The relative and monthly abundances showed us a dominance of *A. matricariae* throughout the study area.

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