



Egg-laying preference in *Lobesia botrana* (Denis & Schiffermuller, 1776) (Lepidoptera: Tortricidae) in a mitidja vineyard

Kaddouri M A¹, Abdelhamid D², Bissaad F Z³, Bounaceur F^{2*}

¹ Department of Natural and Life Sciences, Faculty of Science, University of Laghouat, Laghouat, Algeria

² Department of Natural and Life Sciences, Faculty of Science, University of Tissemsilt, Tissemsilt, Algeria

³ Research Laboratory of Bioinformatics Applied Microbiology, Faculty of Sciences, University of Boumerdès, Boumerdes, Algeria

Abstract

The vine eudemis (*Lobesia botrana*) is the main pest responsible for a considerable loss in the genus *Vitis* worldwide. The egg-laying behavior in the female is oriented on the fruiting organs on this basis our work is oriented in order to determine the preferences of laying.

This study provides information necessary for egg-laying behavior in a potential pest of the vine, our objective is to determine the egg-laying preferences in this insect in order to master future blooms to develop relevant management measures for this insect.

The study was approached by two different samples: destructive sampling and visual sampling.

The results have made it possible to deduce that the number of eggs present on clusters varies significantly according to the years, the grape varieties studied and the different generations of the eudemis. The microdistribution of the eggs was studied according to the high or low position on the berries.

Significant variability in the presence of eggs on clusters and the number of *L. botrana* eggs per cluster were observed between generations, years and grape varieties. Egg-laying preference varies according to grape varieties, generations and years.

Keywords: *Lobesia botrana*, preference, egg-laying, distribution, grape varieties, vines

Introduction

The vine is a crop susceptible to a large number of pathogens and pests. In Algeria, the losses generated cost viticulture billions of dinars each year for an area of 94,025 ha of vines. In the vineyards, more than 45 different viruses and a dozen viral diseases whose transmission takes place through vegetative propagation routes (cuttings and grafting) or by vectors such as nematodes and mealybugs, have been characterized and cause significant problems [1, 2]. In addition to these pathogens, fungal and bacterial diseases, the most important of which are late blight, *Plasmopara viticola*, powdery mildew *Uncinula necator* and *Botrytis cinerea* cause significant damage [3].

Vine pests are the other main causes responsible for losses in vineyards. Among these we can distinguish nematodes, mites, lepidoptera, mealybugs and leafhoppers. Most of these pests have been introduced in Algeria where several of them are likely in some years to cause considerable damage in certain wine regions as was the case of the broiler leafhopper in 2004, 2005 and 2007 in the vineyards of Mitidja and Oranais [4].

Among the pests of the vine, the eudemic of the vine (*Lobesia botrana* Den & Schiff, 1776), the African leafhopper (*Jacobiasca lybica* Bergevin & Zanon, 1922) and the mealybug (*Planococcus ficus* Signoret, 1875), are species responsible for significant qualitative and quantitative losses within the Algerian vineyard [4].

The eudemic of the vine, *Lobesia botrana* is the main pest responsible for a considerable loss of yield and quality of the grape in many wine regions around the world [5]. Its larvae are polyphagous, feeding on a wide range of several

cultivated grape varieties [6, 7, 8]. Females lay their eggs almost exclusively on fruiting organs (i.e., flower buds, berry development and ripening; unlike several other fruit tortricids such as codling moth, *Cydia pomonella*, which deposits these eggs either on leaves, stems, or fruits [9].

In Algeria, Eudemis was first reported in 1904 by Vermiel. Its distribution was noted only in 1930 and 1931, during these years the Eudemis wreaked havoc in most of the Mitidja (Bourkika, Ahmeur-El-Ain... etc) and the Sahel [10]. Data on vine pests and more particularly on *Lobesia botrana* are almost absent in Algeria apart from that of Bounaceur [4], Bissaad *et al.* [10] and Bounaceur *et al.* [11].

The control of these pests involves the application of insecticide products periodically, from spring to late summer. However, the winegrower must have reliable information to avoid unnecessary phytosanitary interventions. In-depth knowledge of pest bioecology, behaviour, distribution, egg-laying preferences and knowledge of the dynamics of these populations are essential today for better management of potential vineyard pests.

In this reasoning of the fight, it is necessary to foresee the risk incurred which is a component of the number of insects and the tolerance threshold of the vineyard. Such a forecast will require the development of a reliable monitoring and surveillance system, aimed at detecting pests at the right time in order to fully understand their ethologies according to the phenological stages of the host plant "vine" and their spatio-temporal distributions, through mapping analysis

tools, with a view to adopting the best strategies for reasoned control.

With this objective that we propose in this work, to establish the egg-laying preferences of *Lobesia botrana* in order to clarify the laying choices in this insect in a context of better management of this pest in the context of sustainable viticulture.

Material and methods

1. Characteristics and description of the chosen study station

The study was conducted on a large winery in western Mitidja, the latter extends over an area of more than 145 ha, the Eurl Semiani, located 80 km from Algiers on the national road 42 (Fig. 1).

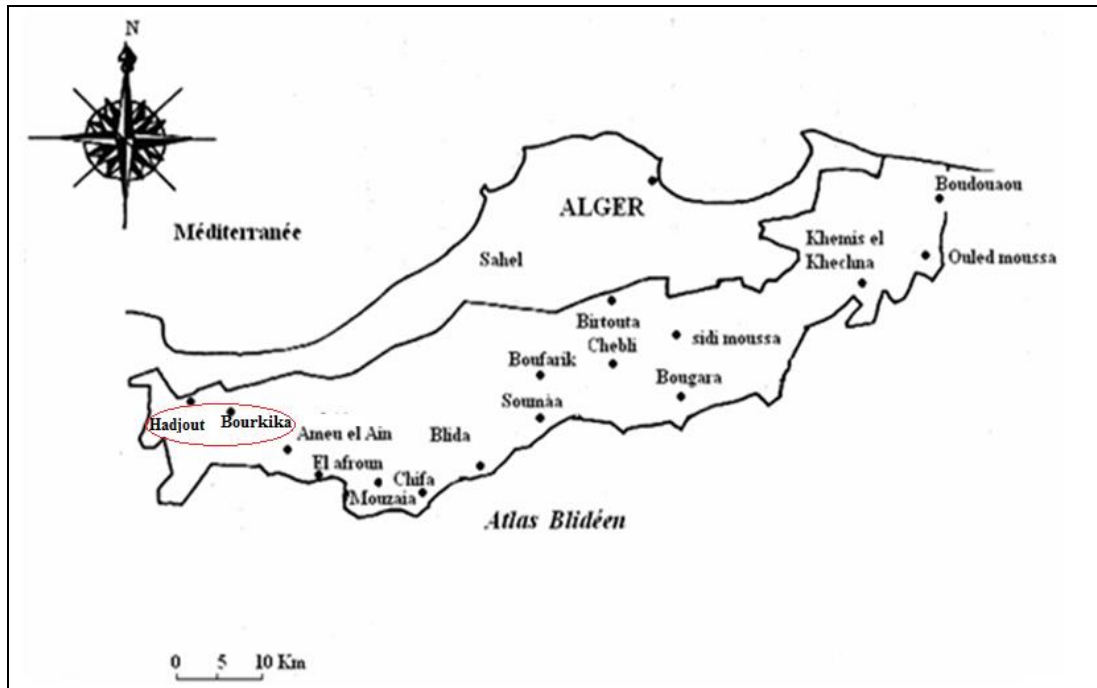


Fig 1: Location and limit of the study station in the Mitidja (Mutin, 1969) ^[12]

The samples were taken in a vineyard of vat grafted on rootstocks 41B and SO4, three grape varieties were followed Cinsault, Carignan and Grenache, (classic reference grape varieties). The latter are planted in the majority of wine-growing areas in Algeria.

As for the table vineyard, it is composed of three grape varieties; represented by the Muscat of Alexandria, the Date Palm of Beirut and the Cardinal, all are grafted welded onto rootstock 41B (Table 1). These vineyards are conducted in trellising on three iron wires, cut in simple guyot at a planting density of 3300 plants per hectare and according to a north-south orientation.

Fungicide treatments based on Anvil, Ridomil, Bordeaux porridge and copper sulfate against cryptogamic diseases have been conducted over the years of follow-up with two insecticide applications based on Decis and Karate.

Table 1: Characteristics of the grape varieties used to monitor egg-laying preference at *Lobesia botrana*

Grape varieties	Plot area	Age of vineyard	Rootstock
Cinsault	3,33 ha	6 years	41 B
Carignan	3,33 ha	6 years	41 B
Grenache	3,33 ha	6 years	41 B
Muscat of Alexandria	3,33 ha	15 years	41 B
Beirut date tree	3,33 ha	15 years	41 B
Cardinal	3,33 ha	10 years	41 B

2. Egg-laying preference

The egg-laying preference of *Lobesia botrana* was followed on the 6 plots during the 2006, 2007 and 2008 wine seasons. The scales of time and space concerned are variable according to the parameters studied, namely the parcel

dynamics and the distribution of egg-laying. Two different samplings, destructive sampling and visual sampling were used to describe egg-laying preference in the 6 plots described above at the two stations.

The dynamics of egg-laying were carried out on 50 sample stocks, distributed uniformly throughout the plot, according to a grid of 10 vines per row over 5 rows (Barnay, 1999) ^[13]. One cluster per plant is taken at each sampling date in a random manner. Each cluster is coded by a number of plant, row, plot and date of collection. At each sampling date, the grid is advanced by 1 plant on the row in order to distribute the samples evenly on all the plants of the plot and thus not to weaken the production of certain plants. This sampling is carried out as soon as the first eggs appear in the plots and is interrupted in the absence of laying. These samples are taken 2 times a week throughout the laying period of *Lobesia botrana*, in the first, second and third generation.

All the clusters are brought back to the laboratory, observed under binocular magnifying glass to count the eggs of *Lobesia botrana*. The parameter position of the eggs on the bunch was noted during each sampling. The differentiation of the positions of the eggs on the bunch is carried out by dividing it into three equal parts: a high position of the eggs (upper part of the cluster near the peduncle), a medium position and finally a low position.

3. Statistical Analysis

It was carried out using the "PAST" software. Microrepair of the egg-laying was treated by the "One-Factor Anova" analysis of variance. For the dynamics of egg-laying we used the global linear model (G.L.M.) at the threshold 0.05%.

Results

1. Interpretative cycle *Lobesia botrana* on *Vitis vinifera* en Mitidja

In Mitidja *Lobesia botrana* Den & Schiff, is a holometabolic insect presenting four annual generations.

From spring the wintering females of *Lobesia botrana* come out of their diapauses. The latter are attracted by the inflorescences of young green berry clusters on which they lay their eggs.

The first generation is generated by the first flight of butterflies whose activity threshold is in mid-spring (Fig. 2). Adults emerge with protandria of about one to two days. Females lay their eggs near the food source of future caterpillars, on the bracts of flower buds. The second generation is attracted to the young green berries on which they lay their eggs. Caterpillars will penetrate below the

surface of the bay and settle there. Caterpillars go through several larval stages. Their coloration varies from greenish yellow to light brown. At the end of their development, they leave the cluster to pupate; under the bark, on the edge of the leaves and on the ground.

The third generation G3 generally took place in the phase of mid-veraison or even early veraison first half of July. A month later, slightly more than 3 to 4 days begins the fourth generation which takes place just before the start of the harvest until the end of this operation. Eggs are laid on the ripe grapes. Larvae develop on mature clusters and can cause considerable damage. The latter open many gateways to *Botrytis cinerea* spores. The caterpillars pupate in September and give chrysalises that will pass the winter and emerge the following spring.

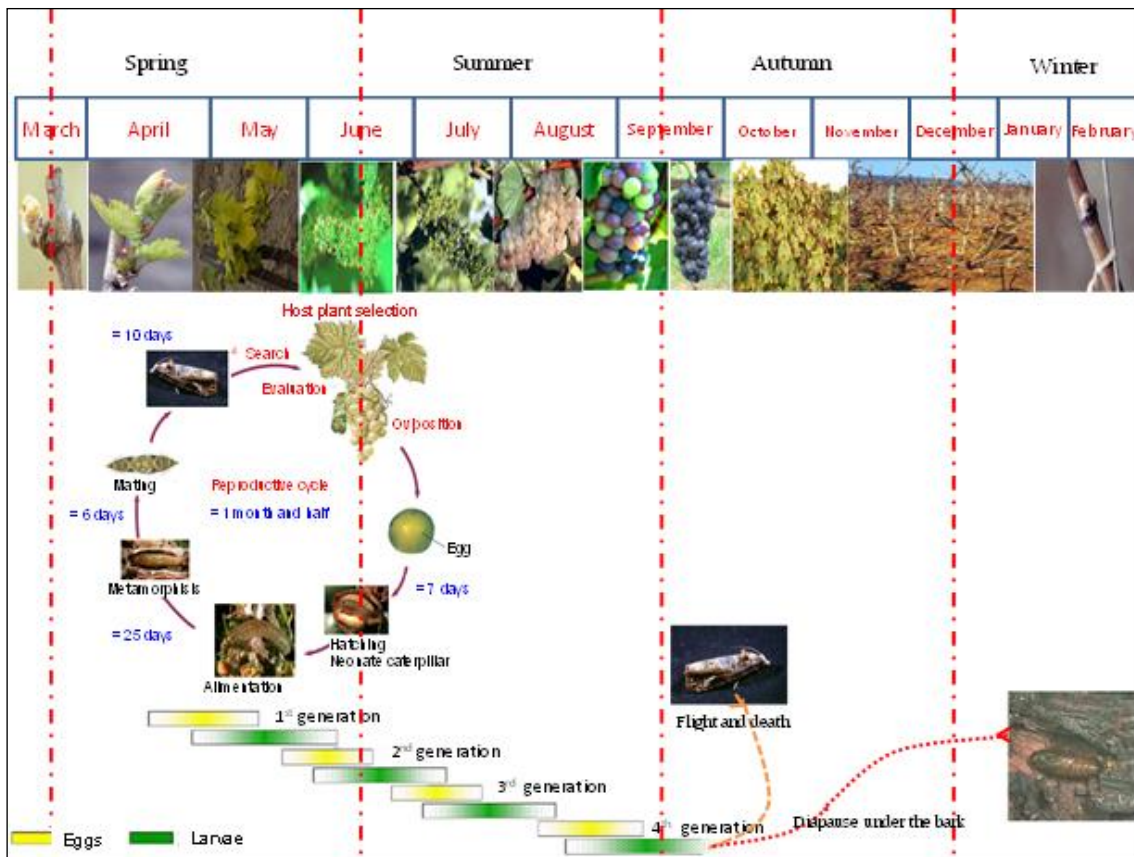
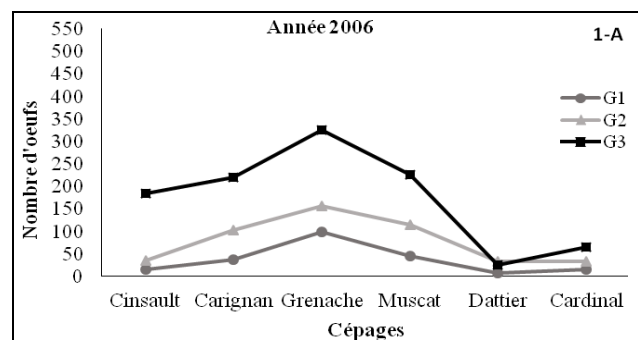


Fig 2: Interpretative cycle of *Lobesia botrana* on *Vitis vinifera* in Mitidja [4]

2. Egg-laying preference

The fluctuations in the egg-laying of *Lobesia botrana* on the six grape varieties during the years 2006, 2007 and 2008 are shown in Figure 3. Analysis of the dynamics of egg-laying in this species over three consecutive years reveals relatively similar trends according to the six grape varieties studied. Indeed, the number of eggs is important in the grape varieties of vats, it is of the order of 185, 111 and 145 eggs for the Cinsault and 220, 250 to 320 eggs for the Carignan respectively for the years 2006, 2007 and 2008. It reaches a peak of laying for the Grenache grape variety with 325 eggs (1A), 402 eggs (1B) and 510 eggs (1C) respectively for the years 2006, 2007 and 2008. Unlike table varieties, this egg-laying seems to be very limited or absent in the Beirut Date palm grape variety, compared to the Muscat of Alexandria and Cardinal. The Egg-laying of *L. botrana* observed at the level of this grape variety increases

with the number of generations: it is low during the 1st, average during the 2nd and high during the 3rd generation.



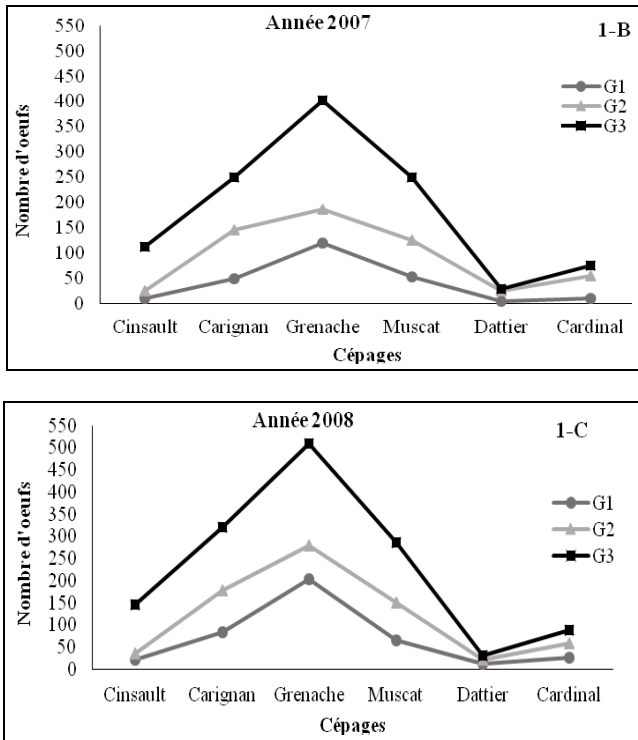


Fig 3: Fluctuations in the total laying of *Lobesia botrana* on six grape varieties in Mitidja during the years 2006 (A), 2007 (B) and 2008

The application of the G.L.M. model for the 54 cumulative data (Table 2 and Fig. 4), allows us to deduce that the number of eggs present on clusters varies significantly according to the years, the grape varieties studied and the

different generations of eudemis. We note very large variations in the maximum average number of eggs laid per cluster.

This number increases significantly with years ($P=0.033$) (Table 2). It is of the order of 98 for the year 2006, 102 for the year 2007 and 140 for the year 2008 for 50 clusters (Fig. 3). As for the analysis of the number of eggs per grape variety, the G.L.M model shows highly significant differences ($P<0.001$), (table, 2). The figure makes it possible to classify the Grenache grape variety as the most sought-after variety when selecting the spawning site for this pest, followed by the Carignan and Muscat d'Alexandrie grape variety, the Cinsault and the Cardinal have practically similar egg-laying. On the other hand, Beirut Date palm ranks as the least sought-after grape variety for the laying of eudemis females. Analysis of spawning dynamics by generation reveals very significant differences ($P<0.001$) (Table 2). Indeed the number of eggs increases significantly according to the generations. This egg-laying reaches its maximum in the 3rd generation, while it is reduced to its half during the 2nd generation. That of the 1st generation remains relatively the least important (Fig. 4).

Table 2: G.L.M. model applied for the study of egg-laying dynamics in the Eudemis of the vine

Facteurs	Somme des carrés	d.d.l.	Carrés moyens	F-ratio	P
Années	18041.148	2	9020.574	3.687	0.033
Cépages	338683.426	5	67736.685	27.684	0.000
Génération	205293.593	2	102646.796	41.952	0.000
Var. intra	107657.704	44	2446.766	-	-

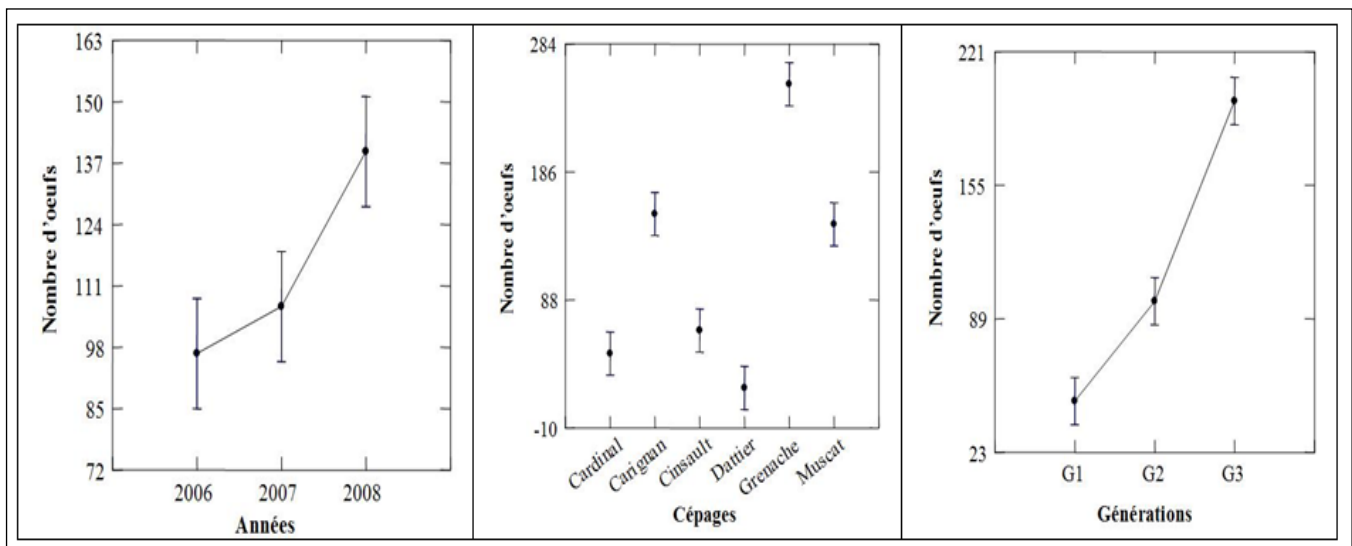


Fig 4: Egg-laying preferences in the Eudemis of the vine during the 2006, 2007 and 2008 wine seasons in the Mitidja vineyards

3. Distribution of the laying of *Lobesia botrana* eggs on clusters

The distribution of the laying position of *Lobesia botrana* of the three generations on the six vine varieties studied during the years 2006, 2007 and 2008 in the mitidja region is shown in Table 2. We found that the laying of the 1st generation is oriented on a high position while in the 2nd and 3rd generation it has an average position.

We compared the distribution of egg-laying according to generations according to the position of the cluster of the six grape varieties described above. For each generation, an ANOVA was carried out on two positions at the level of the bunches of each grape variety. All results are summarized in Table 3.

Table 3: Distribution of the position of *Lobesia botrana* eggs on six grape varieties of vine in the Mitidja region during the years 2006, 2007 and 2008.

Cépages	Génération	2006		2007		2008	
		Nombre d'œufs	Position de l'œuf sur la grappe	Nombre d'œufs	Position de l'œuf sur la grappe	Nombre d'œufs	Position de l'œuf sur la grappe
Cardinal	G1	15	H	10	H	25	H
	G2	34	M	54	M	58	M
	G3	65	M	75	M	87	M
Carignan	G1	38	H	48	H	84	H
	G2	102	M	145	M	178	M
	G3	220	M	250	M	320	M
Cinsault	G1	15	H	10	H	21	H
	G2	35	M	25	M	35	M
	G3	185	M	111	M	145	M
Dattier	G1	8	H	4	H	11	H
	G2	25	M	24	M	22	M
	G3	34	M	28	M	30	M
Grenache	G1	98	H	120	H	202	H
	G2	156	M	186	M	280	M
	G3	325	M	402	M	510	M
Muscat	G1	45	H	52	H	65	H
	G2	115	M	125	M	150	M
	G3	225	M	250	M	287	M

Légende: M: position moyenne H: Position haute

The distribution of eggs is significantly influenced by the same types of variables (high, medium and low position), (P=0.000) (Table 4). Thus at the level of the cluster in the first generation (G1), we observe more eggs at the top than in the middle of the bunch and this for all the grape varieties studied (figure, 4). Compared to the 1st generation, greater heterogeneity is observed during the sampling of the 2nd generation and, of the 3rd generation, the average position seems to influence the latter two.

Table 4: ANOVA of the micro-distribution of egg-laying in the Eudemis of the vine

Facteurs	Somme des carrés	d.d.l.	Carrés moyens	F-ratio	P
Ponte*position	205293.593	2	102646.796	11.273	0.000
Var. intra	464382.278	51	9105.535	-	-

The distribution of eggs is significantly influenced by the same types of variables (high, medium and low position), (P<0.001) Thus at the level of the cluster in the first generation (G1), more eggs are observed at the top than in the middle of the bunch for all the grape varieties studied (Fig. 5). Compared to the 1st generation, greater heterogeneity is observed during the sampling of the 2nd and, of the 3rd generation the average position seems to influence the latter two. We observe more eggs in the middle positions or in the center of the cluster. Overall, we can estimate that a maximum of eggs are deposited in the middle of the cluster and in smaller numbers at the bottom of the cluster.

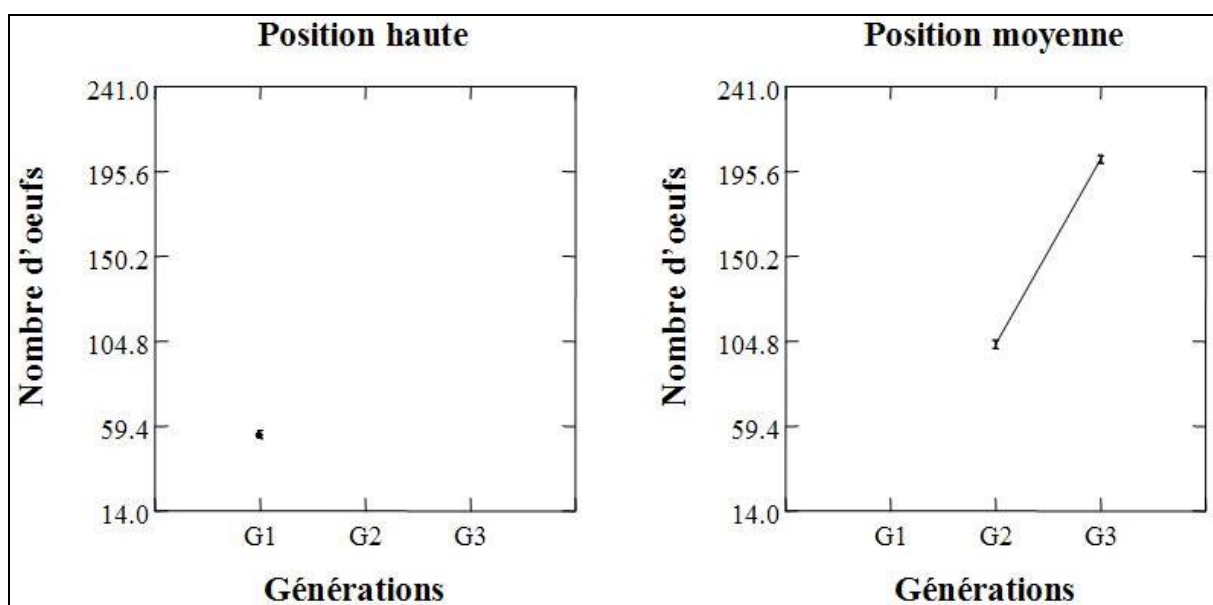


Fig 5: Distribution of egg-laying by cluster position and generation of *Lobesia botrana* during the 2006, 2007 and 2008 wine seasons in the Mitidja vineyards

Discussion

The laying preference in *Lobesia botrana* was studied by the G.L.M model according to explanatory variables that significantly influence the number of eggs present on the clusters during destructive sampling. Indeed the number of eggs present on a bunch varies significantly according to the years, grape varieties and generations. We observe significant variations in the maximum number of eggs per bunch and per grape variety. The year 2008 recorded the highest number of clutches on Grenache grape varieties for the wine varieties and the Muscat d'Alexandrie for the table varieties, in the third generation. In 2006 and 2007 almost similar egg-laying could be observed. These infestations were very important in 2008 compared to 2006 and 2007, this can be explained by a behavior of *Lobesia botrana* which in low population density for 2006 and 2007, would tend to distribute its egg-laying over a greater number of clusters looking for clusters without egg-laying, while in high population density (case of 2008), laying is carried out on already infested clusters (presence of eggs on clusters). These latter results are in agreement with those of [12], which considers that the females of *Lobesia botrana* have the ability to assess the density of their population at the time of their laying and can thus detect the presence of the laying of another female, either directly or indirectly, or at the level of the cluster [14]. These differences in egg population densities indicate that *Lobesia botrana* tends to lay eggs in order to reduce the phenomena of competition between future caterpillars [11].

The grape variety factor being considered as an essential criterion for the selection of the laying site, it appears that the grape varieties of vats are much more subject to attacks of *Lobesia botrana*, compared to the varieties of tables. Thus, Grenache is the most infested followed by Carignan and Muscat of Alexandria. As for the other grape varieties, we note almost similar infestation rates. In this context, several hypotheses can be evoked, we can suggest that this increase in infestations between grape varieties is the result of two complementary behaviors: either the insect evaluates the size of the cluster or its volume and deposits a precise number of eggs according to this size, or the voluminous clusters offer sufficient space between the clutches and thus allow several clutches of females on a single cluster. These two behaviors reflect that the laying of eudemis is carried out in such a way as to reduce competition between future caterpillars by distributing it according to the characteristics of the clusters of the six grape varieties studied, this is in line with the work of Barney [13], Thiery [15] and Thiery *et al* [16].

During egg-laying, the female of *Lobesia botrana* polyphagous insect, may be brought to meet in the wild several of its host plants, one after the other. It is likely to compare them sequentially by involving some form of short-term memory [17, 18]. Several authors (Wiklund [19], Thompson & Pellmyr [20] and Singer & Lee [21]) consider that a hierarchical egg-laying preference exists between the different species composing the range of host plants of an insect. According to Maher [6], it turns out that under ideal conditions, many eggs are laid on the preferred species, then fewer eggs on the less preferred species, and even fewer eggs on the species that occupy a lower rank of preference. As part of a study on the behavior of egg-laying choices in *Lobesia botrana*, was able to establish a range of preferences between berries of different plants, he also

showed that the sensory equipment of the eudemic female has sensory receptors that intervene in the role of gustation and mechanical reception in the choice of the spawning site in this insect. Indeed, this variation between grape varieties can be attributed to other criteria such as the compactness of the bunches [5], this is in line with our results. The preferred grape varieties Grenache and Carignan have very compact clusters, therefore susceptible to infestation [22]. Parallel to what has been cited in the bibliography, it would seem that eudemic females are attracted by volatile odorous substances that are very characteristic and vary from one grape variety to another [23, 24]. On the other hand, eudemic females seek a much more adequate nutritional quality for their offspring in order to ensure better fitness and competitiveness [25].

Egg-laying preference also appears to vary significantly between generations. In our case, the latter is much more important in the third generation compared to the first two, this is due to the consequence of the abundance of nutritional substrates highly sought after by *Lobesia botrana* in this period that coincides with the ripening of the grapes therefore a high sugar content. Our data seem to be comparable to those of Maher *et al.* [26], who show a very strong influence of sugars in particular, glucose, fructose and sucrose on the selection of the ovipositor site in the female eudemis; the latter has a relatively high sensitivity, particularly to the fructose that is the main constituent of grape juice [27].

This particular preference in favor of some grape varieties over others can be attributed to the role of fructose, glucose and sucrose in stimulating egg-laying, the latter are known to be the dominant sugars in the ripe fruits of different plants, especially the berries of grapes from *V. vinifera* are no exception [28]. In this context, Varandas [29] shows that fructose and glucose are present and increase with the maturity of the grapes on the surface of the fruit, as well as in content. Dreier *et al.* [30] investigated the relative concentrations of fructose and glucose during the ripening of grape berries in *V. vinifera* L. cv. Sultanina. Indeed, a relatively high concentration of fructose characterizes mature berries, which are preferential sites for the oviposition of females of *L. botrana*. This is in line with the behavior of the species supported by research in applied electrophysiology showing that fructose, as opposed to glucose, is the most important element for the stimulation of egg-laying. Fructose is not present in the stems and leaves of vines [30] and it is possible that females use fructose, as well as other unknown molecules, for the distinction between leaves or stems and berries for oviposition. In the same vein, Lombarkia and Derridj [31] found that fructose is an important egg-laying component in *Cydia pomonella*.

However, it should be noted that *V. vinifera* is not the original or unique host of *L. botrana* [7; 24] and that the sugar content may vary depending on the host plants that are accepted by *L. botrana*. Thus, studies conducted on the distribution of fructose in different host plants could produce additional indications about the reasons for egg-laying as well as the receptor neurons that appear to be most sensitive to fructose.

Indeed, Hansen & Wiczorek [32] and Shimada [33] concluded through previous work concerning the sugar receptor of insect neurons with multiple receptor sites for different sugar molecules as well as their fragments using a pharmacological approach.

Ovipositor contact chemoreceptors have neurons that are specifically sensitive to fructose. Bernays *et al.* [34] and Bernays & Chapman [35] found that the sensilla styloconica of the lateral maxilla of the Arctic caterpillar, *Grammia geneura*, has a neuron responding to fructose but much less to sucrose and glucose. Apparently, fructose is an important stimulant for some phytophagous insects, and is probably a clue for plant tissues with high photosynthetic or storage activity.

Our results are consistent with observations of egg-laying behaviour in other microlepidopteran insects, including *Ostrinia nubilalis*. Derridj *et al.* [36] show a correlation between the concentration of fructose on the leaf surface of different phenological stages of three plants (*Zea mays*, *Helianthus annuus* and *Phaseolus vulgaris*) and the preference of oviposition in moths. In addition, Derridj *et al.* [37] reported that sensilla ovipositorial neurons are selectively sensitive to fructose which induces the ultimate importance in the final stimulation of egg-laying in *L. botrana*. Recent studies have shown that volatile odorous compounds can attract pregnant females and stimulate egg-laying on vegetation [38]. Ripe berries are known to release both volatile substances different from those of unripe plant clusters [39]. In particular, the release of these compounds such as terpenoids and methyl salicylate, have been identified as egg-laying stimulants by Anfora *et al.* [38]. In previous studies, volatile substances from host plants not only affect egg-laying but may also attract *L. botrana* [40, 41]. Similar results have also been reported in another moth [42]. The distribution of egg-laying is significantly influenced by two types of variables, cluster position and generation. Regardless of the sampling technique, it turns out that the high position is preferred for laying eggs of the first generations, which seems obvious at this phenological stage, since, the cluster is small in size, which leaves no other choices. While in the second and third generation the average position is preferred. Barney [13] reports almost similar observations, with a preference in the first generation for the low and high position, on the other hand in the second generation the intermediate position seems to be preferred for egg-laying.

Conclusion

The studies conducted revealed significant variability in the presence of eggs on the bunches and the number of *Lobesia botrana* eggs per cluster between generations, years and grape varieties. The difference in parcel infestation is probably due to surrounding conditions such as adjacent botanical diversity, cultivation techniques and/or plot history, which are parameters that we have not assessed.

The preference of the laying of *Lobesia botrana* varies according to the grape varieties, generations and years. Micro-distribution of eggs at the cluster level can help avoid competition between future caterpillars. It has been dismantled that the high position is preferred for the laying of the first generations, that in the second and third generation the medium position is the preferred. This approach can be applied and adapted to different pests on different crops. It provides a better understanding of the relationship between the pest and the crop and, as a result, adapts control methods.

References

1. Esmanjeaud D. Les nématodes de la vigne. 17-34. In Les ravageurs de la vigne. J. Stockel, ed. Editions Féret. Bordeaux, France, 2000, 231.
2. Sforza R. Cochenilles sur la vigne: Bio-éthologie, impact agronomique, lutte et prophylaxie. Pages 130-147. In: Les ravageurs de la vigne. J. Stockel. Editions Féret. Bordeaux. France, 2000, 231.
3. Dubos B. Maladies cryptogamiques de la vigne: champignons parasites des organes herbacés et du bois de la vigne [rev. et augm.], Bordeaux: Éd. Féret, 2002, (2).
4. Bounaceur F. Dynamique Spatio-temporelle et Dégâts de *Lobesia botrana* (Denis & Schiffermuller, 1776) (Lepidoptera: Tortricidae), *Jacobiasca lybica* (Bergevin & Zanon, 1922), (Homoptera: Jassidae) et *Planococcus ficus* (Signoret, 1875) (Homoptera: Pseudococcidae) dans les Vignobles de la Mitidja. Thèse de Doctorat. ENSA, Alger, 2010, 151.
5. Stockel J. L'eudémis. Lépidoptères (du groupe des Tordeuses). In: Les Ravageurs de la vigne (J. Stockel ed): Editions Féret. Bordeaux, 2000, 151-176.
6. Maher N. Sélection du site de ponte chez *Lobesia botrana* (Lepidoptera, Tortricidae): Influence de l'information chimique non volatile présente sur les fruits des plantes hôtes. Thèse de Doctorat. Œnologie et Ampélogie Université Bordeaux II, 2002, 107.
7. Thiéry D. Les vers de la grappe. Guide Pratique. Publishers Vigne et Vins Intl., Bordeaux, France, 2005, 58.
8. Thiéry D, Moreau J. Relative performance of European grape berry moth (*Lobesia botrana*) on grapes or other hosts. *Oecologia*, 2005;143:548-557.
9. Thiéry D, Gabel B, Farkas P, Jarry M. Egg dispersion in codling moth: influence of egg extract and of its fatty acid constituents. *Journal of Chemical Ecology*, 1995;21:2015-26.
10. Bissaad F, Bounaceur F, Doumandji-Mitiche B. Dynamique spatio-temporelle de *Planococcus ficus* (Signoret, 1875) dans les vignobles de la Mitidja (Algeria). *Lebanese Science Journal*, 2017;18(1):26-46.
11. Bounaceur F, Bissaad FZ, Doumandji-mitiche B. Etude de la biocénose viticole du nord algérien. *Lebanese Science Journal*, 2018;19(2):150-176.
12. Mutin G. L'Algérie et ses Agrumes. Extrait de la revue de géographie., Lyon, 1969:441:36.
13. Barnay O. Dynamique des populations et relations hôtes-parasitoïdes chez le couple *Lobesia botrana* Den & Schiff. - *Trichogramma cacoeciae* Marshal, dans le cadre de la lutte biologique en vignoble. Thèse de Doctorat Université Paris, 1999:6:188.
14. Gabel B, Thiéry D. Biological evidence of an oviposition-detering pheromone in *Lobesia botrana* Den. et Schiff. (Lepidoptera: Tortricidae). *Journal of Chemical Ecology*, 1992;18:353-358.
15. Thiéry D. Les tordeuses nuisibles à la vigne. In: Ravageurs de la vigne, Féret Publication, Bordeaux, 2008, 214-246.
16. Thiéry D, Monceau K, Moreau J. Different emergence phenology of European grapevine moth (*Lobesia botrana*, Lepidoptera: Tortricidae) on six varieties of grapes. *Bulletin of Entomological Research*, 2014;104:277-287.

17. Singer MC. The definition and measurement of oviposition preference in plant feeding insects. In: *Insect Plant Interactions*. (J.R. Miller & T.A. Miller ed: 65-94. New York (USA): Springer-Verlag, 1986, 315.
18. Courtney SP, Chen GK, Gardner A. A general model for individual host selection. *Oikos*,1989;55:55-65.
19. Wilklund C. Generalist vs. specialist oviposition behavior in *Papilio machaon* (Lepidoptera) and functional aspects on the hierarchy of oviposition preference. *Oikos*,1981;36:163-170.
20. Thompson JN, Pellmyr O. Evolution of oviposition behavior and host preference in Lepidoptera. *Annual Review of Entomology*,1991;36:65-89.
21. Singer MC, Lee JR. Discrimination within and between host species by a butterfly: implications for design of preference experiments. *Ecology Letters*,2000;3:101-105.
22. Reynier A. *Manuel de viticulture*. 8ème Edition. Tec et Doc. Lavoisier, Paris, 2000, 512.
23. Richard E, Couranjon C, Arruego X, Jolivet J, Thiery D. Influence de l'alimentation larvaire de la vigne sur *Lobesia botrana* (Lepidoptera, Tortricidae). *Integrated Control in Viticulture*. IOBC. Bulletin,2000;23(4):139-143.
24. Maher N, Thiéry DA bioassay to evaluate the activity of chemical stimuli from grape berries on the oviposition of *Lobesia botrana* (Lepidoptera: Tortricidae). *Bull Entomol Res.*,2004;94(1):27-33.
25. Moreau J, Arruego X, Benrey B, Thiery D. Differences in nutritional quality of parts of *Vitis vinefera* berries affect fitness of the European grapevine moth. *Entomologia Experimentalis et Applicata*,2006;119:93-99.
26. Maher N, Thiery D, Stadler E. Oviposition by *Lobesia botrana* is stimulated by sugars detected by contact chemoreceptors. *Physiological Entomology*,2006;31:14-22.
27. Riberau-Gayon P, Dubourdieu D, Donèche B, Lonvaud A. *Traité d'œnologie*. Tome 1. Microbiologie du vin. Vinifications. Ed Dunod, Paris, 1998, 600.
28. Coombe BG. Research on development and ripening of the grape berry. *American Journal of Enology and Viticulture*,1992;43:101-110.
29. Varandas S, Teixeira MJ, Marques JC. Glucose and fructose levels on grape skin: Interference in *Lobesia botrana* behaviour. *Analytica Chimica Acta*,2004;513:351-355.
30. Dreier LP, Hunter JJ, Ruffner HP. Invertase activity, grape berry development and cell compartmentation. *Plant Physiology and Biochemistry*,1998;36:865-872.
31. Lombarkia N, Derridj S. Incidence of apple fruit and leaf surface metabolites on *Cydia pomonella* oviposition. *Entomologia Experimentalis et Applicata*,2002;104:79-87.
32. Hansen K, Wiczorek H. Biochemical aspects of sugar reception in insects. *Biochemistry of Taste and Olfaction* (ed. by R. H. Cagan and M. R. Kare), Academic Press, New York, New York, 1981, 139-162.
33. Shimada I. Stereospecificity of the multiple receptor sites in the sugar taste receptor cell of the fleshfly. *Chemical Senses*,1987;12:235-244.
34. Bernays EA, Chapman RF, Singer MS. Sensitivity to chemically diverse phagostimulants in a single gustatory neuron of a polyphagous caterpillar. *Journal of Comparative Physiology A*,2000;186:13-19.
35. Bernays EA, Chapman RF. Taste cell responses in the polyphagous arctiid, *Grammia geneura*: towards a general pat-tern for caterpillars. *Journal of Insect Physiology*,2001;47:1029-1043.
36. Derridj S, Gregoire V, Boutin JP, Fiala V. Plant growth stages in the interspecific oviposition preference of the European corn borer and relations with chemicals present on the leaf sur-faces. *Entomologia Experimentalis et Applicata*,1989;53:267-276.
37. Derridj S, Fiala V, Barry P. Role of nutrients found in the phylloplane, in the insect host plant selection for oviposition. *Proceedings of the Eight International Symposium on Insect-Plant Relationships* (ed. by S. B. J. Menjken, J. H. Visserand P. Harrewyn), Kluwer Academic Publishers, The Netherlands, 1992, 139-140.
38. Anfora G, Tasin M, De Cristofaro A, Ioriatti C, Lucchi A. Synthetic grape volatiles attract mated *Lobesia botrana* females in laboratory and field bioassays. *J Chem Ecol.*,2009;35(9):1054-1062.
39. Tasin M, Anfora G, Ioriatti C, Carlin S, De Cristofaro A, Schmidt S, *et al.* Antennal and behavioral responses of grapevine moth *Lobesia botrana* females to volatiles from grapevine. *J Chem Ecol.*,2005;31(1):77-87.
40. Masante-Roca I, Anton S, Delbac L, Dufour MC, Gadenne C. Attraction of the grapevine moth to host and non-host plant parts in the wind tunnel: effects of plant phenology, sex, and mating status. *Entomol Exp Appl.*,2007;122(3):239-245.
41. Tasin M, Baickman AC, Anfora G, Carlin S, Ioriatti C, Witzgall P. Attraction of female grapevine moth to common and specific olfactory cues from two host plants. *Chem Senses.*,2010;35:57-64.
42. Rojas JC, Virgen A, Cruz-Lopez, L. Chemical and tactile cues influencing oviposition of a generalist moth, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Environ Entomol.*,2003;32(6):1386-139.