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Characterization of gypsy moth *Lymantria dispar* (Linnaeus, 1758) (Lepidoptera Lymantriidae) eggs in Cork oak forests of the Kabylie region (Jijel-Algeria)

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ABSTRACT Algerian oak forests, extending over the entire northern littoral region, are attacked episodically by many defoliating Lepidoptera, of which *Lymantria dispar* (Linnaeus, 1758) (Lepidoptera Limantriidae) is the most widespread. In our study we aim to highlight the action of the changes of trophic factors on the dynamics of the population of *Lymantria dispar* through field inventory methods. Namely: the eggs counting by the line-transect method, picking of the eggs, control of eggs quality. Carried out on two stations in the Kabylie region (Jijel), in the forest of Béni Ider El M'sid (Taher) and that of the Ouled Djendjen Canton Boudouda (Texanna). The obtained results show that Texanna station is distinguished by a very high non-viable egg rate compared to Taher station, this is caused by the difference between the phenology of *Lymantria dispar* and the host tree which is affected in its foliage by various factors whose altitude is one of these factors.

KEY WORDS Algeria; defoliation; egg mass; Jijel; *Lymantria dispar*; Oak cork.

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INTRODUCTION

Forests are the main shelter for terrestrial biodiversity, as they represent an important link for the successful integration of biodiversity conservation and socio-economic development (Liang et al., 2016). The Mediterranean forests are considered as biodiversity hotspots (Myers et al., 2000; Quézel & Médail 2003; Mendoza-Fernández et al., 2010; Vessella et al., 2017; Tabet et al., 2018) , which is of major interest in the context of biodiversity conservation (Quézel et al., 1980). Forest dieback is becoming increasingly important due to long and intense periods of drought (Camarero et al., 2015; Lloret & Kitzberger, 2018). The cork oak is an endemic species which characterizes the western Mediterranean zone, from the economic point of view it is the most important forest essence in North Africa, and it has important interests for the ecological and socio-economic balance (Piazzetta, 2006).

Cork forests in Algeria suffered a severe degradation which was the cause of a loss of almost half of the original surface of 450,000 Ha (Chenel, 1951) and only 229,000 Ha remain that are considered productive (Aouadi et al., 2010). Consequently, the strong degradation of this forest species has affected its productive capacity, which constitutes a significant economic potential, and which has greatly reduced in recent years (see Musset, 1954 and Roula & Chouial, 2005).

Among biotic Enemies, which may be a cause of degradation of Mediterranean forests, *Lymantria dispar* (Linnaeus, 1758) (Tae Hwa Kang et al., 2017) is a butterfly of the Lymantriidae family (Nierhaus-Wunderwald & Wermlinger, 2001). This gypsy moth is a pest of forest species (Gray, 2010), polyphagous and phyllophagous that lives on more than 300 species of trees and shrubs (Duan et al., 2011); prefers oak leaves (Nierhaus-Wunderwald & Wermlinger, 2001). The geographical distribution of *L. dispar* is remarkable: the Gypsy Moth, originates from Korea and Japan (Sparks et al., 2013; Contarini et al., 2016), has reached Scandinavia and the Mediterranean area passing through several countries including, among others, China, Afghanistan and Iran and Spain in Europe (Mecellem & Chakali, 2016). Fagaceae are widely threatened by this insect in Algeria, Morocco and Tunisia (Fraval, 1989; Villemant, 2006).

The very first observation of *L. dispar* infestations was recorded in the Edough Forest in the nineteenth century (Mecellem & Chakali, 2016). Since then, it has spread over all the oak forests of northern Algeria, particularly in the oak forests of Babors, in the forest of Blida and the forests of Kabylie. It is also present in the majority of West-northern oak forests (Laaribya et al., 2010; Mecellem & Chakali, 2016).

This insect is the origin of the disturbances of the pollination of the oak species, which endangered its production of the glands and the regeneration (Zeraia, 1988). The immediate nuisance of *Lymantria dispar* is the weakening of the tree which becomes vulnerable to the attack of xylophagous insects and lignivorous fungi (Fraval, 1989).

The forestry services pointed out that in 1977, *Lymantria dispar* invaded a very large forest area affecting the whole of Jijel wilaya, between 1984 and 1989 a second major infestation was recorded in the region, during which cork oak suffered significant defoliation (Villemant, 2006).

The present study is based on the effect and action of the trophic factor on the population dynamics of *Lymantria dispar*. The interest of the current research aims at the enumeration and characterization of the insect's eggs in its natural environment, whose main objective is to try to deduce the infested zones.

This study constitutes a support for the decision for a more rational management of infested species in the Jijel region and to know the priority areas for interventions.

MATERIAL AND METHODS

Study area

In the sub-humid bioclimatic domain of the Jijel region, two stations were chosen, the first being the Ouleds Djendjen forest, Boudouda (Texanna), a *Quercus suber* forest on a siliceous substratum, and at an altitude of 850 m south of the wilaya of Jijel and the second is the forest of Beni Ider, El M'sid (Taher), a high forest *Quercus suber* anchored in a shallow schistose substrate at an altitude of 570 m, south-west of Jijel.

The methodology followed is classic and is divided into three main phases which are detailed below, after choosing 15 trees as samples for each of the stations.

Phase of egg masses counting

The line-transect method has been adopted in this work, it consists of randomly establishing at the center of the sampling plot a series of fixed routes, the latter is located in the middle of the plot along these routes by moving at a regular interval to count all egg masses. The entire tree is taken as a sampling unit, the count of the egg masses is performed on 15 selected trees on a systemic linear altitudinal transect, the objective is to avoid edge effects (Chakali & Ghelem, 2008). Once spotted, the clutches are dated and marked with numbered tags.

Practically, we proceed to the counting of the egg masses visually, from the ground. For each sample tree, we do counting on the first meter of the trunk, , and one meter around the tree. After exploring the trunk and its crevices, the observer looks through the scaffold branches and shoots, choosing systematically the branch whose diameter is the smallest at each junction (Fraval, 1981; Zeraia, 1988; Laaribya et al., 2010).

For each tree two counts are made by two people in order to better quantify and confirm the number of lepidopteran egg masses. The majority of females lay their eggs on the lower parts of the branches to better protect themselves against natural enemies, including birds.

Egg masses collection

We measure the diameters of the clutches masses using a vernier caliper. These egg masses are collected and put into perforated bags to ensure aeration of the eggs. In the laboratory, with a binocular loupe, the eggs counting is done for each mass of eggs. The technique used in the counting of nonviable eggs (unhatched, flattened and parasitized) as well as the removal of eggs from their fluff is that proposed by Fraval (1989).

Control of **Lymantria dispar** *eggs*

After a first check (removal of fluff, counting of unhatched eggs, hatched, parasitized, dry, and broken eggs), we were able to determine the different states of lepidopteran eggs at the two study stations.

RESULT AND DISCUSSION

The analysis results of the collected data are organized in four steps, namely:

1) comparison of the number of eggs and the diameter of the egg masses between the two stations,

2) relationship between the number of eggs and the diameter of the egg masses of the two sites,

3) the results relating to the quality of the eggs of *Lymantria dispar*,

4) place of preference for laying eggs.

Number of eggs and diameter of egg masses

Statistical analysis showed no significant difference in the number of eggs for the two stations studied (P> 0.05, F3.92 = 2.367). On the other hand, a significant difference is recorded for the diameter of the clutches (P = 0.039, F3.92 = 4.363). The average diameter of lepidopteran clutches at the Taher station is larger than that of the Texanna station (Table 1).

Relationship between the number of eggs and the diameter of the egg masses

A partial correlation model was adopted to highlight the nature of the link between the two parameters number of eggs and the egg masses diameter for each station. These are positive and significant correlations but are considered average (Table 2).

Quality of the Lymantria dispar's eggs

At the two stations selected, the percentage of different categories of nonviable eggs (flattened, dry and parasitized) compared to viable categories is very important (Fig. 1).

Clutches are more exposed to the oophagous parasite, *Ooencyrtus kuvanae* (Howard, 1910) (Hymenoptera Encyrtidae) and predator-dismantlers such as *Dermestes lardarius* Linnaeus, 1758 (Coleoptera Dermestidae). The action of this predator is limited to 2 to 3 weeks after the laying period of *Lymantria dispar* (Luciano & Prota, 1984).

The results revealed a significant difference (P <0.001, χ216.27 = 53.589) between different types of eggs (Table 3). The rate of viable eggs is higher (73.23%) at the Texanna station compared to Taher station (57.95%). The rate of parasitized eggs, unlike viable eggs, is higher in the Taher station (27.64%) than in the Texanna station (18.53%). The remaining eggs (unhatched and flattened) accounted for only 8.24% and 14.4% at both Texanna and Taher stations, respectively (Fig. 2).

Place of preference for laying eggs

Statistical analysis showed no significant difference in the preference for laying eggs (P> 0.05, χ23.84 = 0.633) (Table 4). The female has no preference with regard to the place of deposit of her eggs on the tree.

The same observations can be noted for the two Taher and Texanna study areas, and despite the difference in certain factors, in particular altitude, the variation in environmental conditions is little.

On the trees, the majority of the clutches are deposited on the trunks where population density of the insect is low. However, during outbreaks, the number of laying increases, and the insect lays and places its eggs all over the tree.

Parameters / Station	Number of eggs	diameter of laying-eggs (mm)
Taher	302.72 ± 24.84a	16.16 ± 041a
Texanna	362.03 ± 29.49a	14.43 ± 0.72b
$F_{3.92}$	2.367	4.363
P	0.127	0.039*
d. d. l.	1 / 118	1 / 118
n	60	60

Table 1: Number and diameter of laying-eggs in both Taher and Texanna stations (Mean ± ES). The averages followed by different letters in the columns are significantly different (ANOVA; * P <0.05). F: calculated factor. P: probability, d.d.l .: degrees of freedom. v1 = 1, v2 = 118. n: number of repetitions.

Parameters		**Number of eggs**	
	Stations	***Taher***	***Texanna***
Diameter of egg masses	***Taher***	r = 0.32 (P = 0.013)*	
	Texanna		r = 0.335 (P = 0.009)**

Table 2. Correlation coefficients (r) between the number of eggs and the diameter of the egg. * P < 0.05. ** P < 0.01.

Parameters / **Stations**	Viable eggs	Unhatched eggs	Flattened eggs	Parasited eggs	**Total number of eggs**	Chi-square test (χ2)
Taher	499	70	54	238	861	$\chi^2 = 53.589$
Texanna	818	60	32	207	1117	$v = 3$
Total number of eggs	1317	130	86	445	1978	P = 0.000*

Table 3. Statistical analysis of egg quality. (v: degrees of freedom, *P < 0.001).

Parameters / Stations	Number of egg masses on trunk	Number of egg masses on main branches	Total	Chi-square test (χ2)
Taher	37	59	96	$\chi^2 = 0.633$
Texanna	42	53	95	$v = 1$
Total	79	112	191	P = 0.426

Table 4. Place of preference for depositing the egg masses. (v: degrees of freedom).

DISCUSSION

The issues addressed in this study provide additional information on the behavior of *L. dispar* in its natural environment.

The abundance of the clutches observed during our census shows the females' high reproductive success of *L. dispar*. The presence of unfertilized eggs in large numbers in the egg-laying and eggs undergoing high mortality is probably due to poor trophic conditions (Fraval, 1989), the environmental conditions affect the periods and durations of *L. dispar* development phases in its natural environment (Hlasny et al., 2015). This desynchronism between the phenology of the *L. dispar* and the host tree is undoubtedly the determining factor of the presence of unfertilized eggs, since the larval development phase is more sensitive to sudden environmental changes, which may have a spreading of the infestation period of 3 to 4 years in the case of coastal werate trees (Fraval, 1989; Khous & Demolin, 1997; Mecellem & Chakali, 2016).

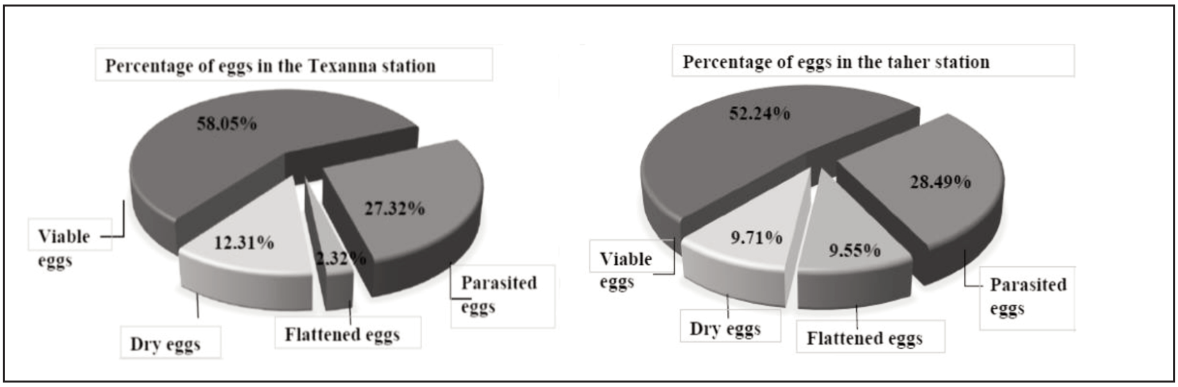

Figure 1. Percentage of different eggs categories at both stations (Taher and Texanna).

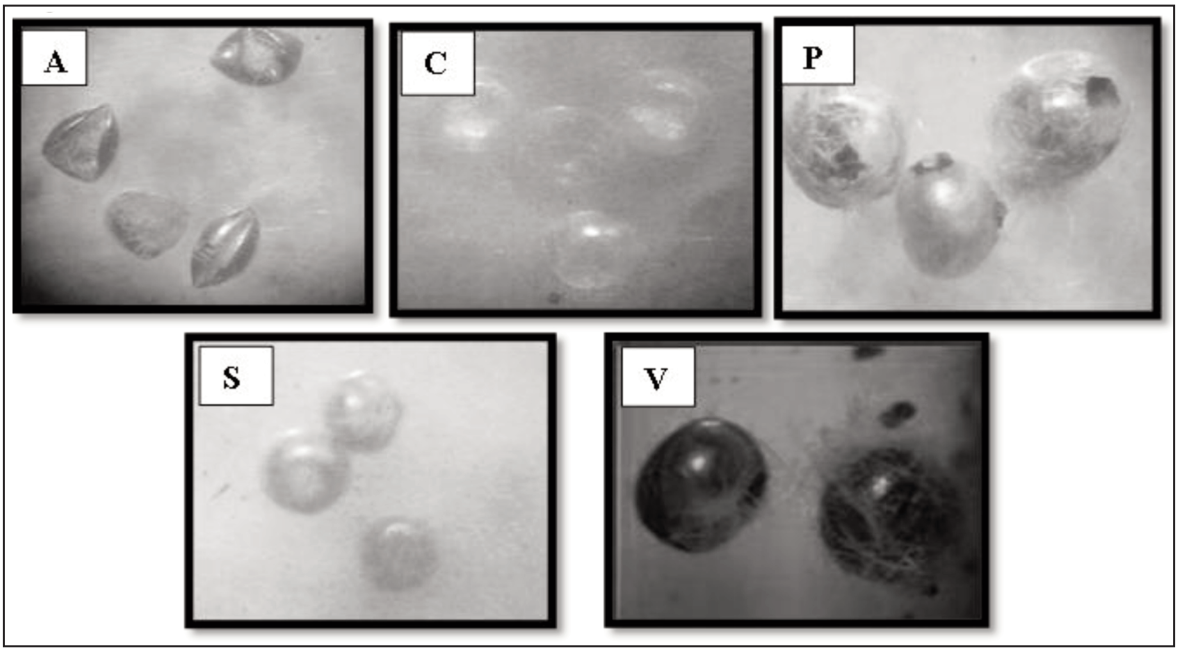

Figure 2. Categories of *Lymantria dispar* eggs providing information on the causes of death. (V: viable, P: parasited, C: broken, A: flattened (not fertilized), S: dry (dead embryo).

In most cases, it should be assumed that natural enemies are sufficient to reduce defoliator populations. *Ooencyrtus kuvanae* is the only oophagous parasite of *Lymantria dispar* recorded at the level of the two stations but also the predators-deniers such as *Dermestes lardarius*, among others, were present and did important damage to the bombyx's eggs. This result is confirmed by the work of Morsli (2008) and also by those of Basir et al. (2005).

Large foci have been localized at medium altitude (570 m) at the level of El M'Sid (Taher) cork oak. Defoliation at the level of the plains is characterized by their extension on large surfaces contrary to high altitudes as in the case Boudouda (Texanna 850 m), at the level of high altitudes the defoliation affects the forest massifs successively during considerable periods of time (Zamoum et al., 2014).

Lymantria dispar is a very dynamic species, able to live at the expense of forests and very varied species (Duan et al., 2011) under very different climatic conditions (Mecellem & Chakali, 2016). In eastern Algeria, in the case of delayed budding of the cork oak or when the clutches are distant from the host plant, the larvae can continue a part of their development on some tree species (Stoyenoff et al., 1994; Ouakid et al., 2001; Morsli, 2008). The other cause that facilitates the frequent attack and the installation of this pest on the forests of the study area is their weakening by the human intervention and consequently the frequent fires (Zamoum et al., 2014).

The vast operations of struggle put into action today do not prevent the increase of the areas subjected to the defoliation of this lepidoptere. The action of this gypsy moth can result in the weakening of the attacked tree subjects, the latter being subjected to a strong attack of xylophagous and lignivorous insects and parasites which can in their turn weaken the affected stands.

Lymantria dispar is the best-known defoliator and the most widespread defoliator in cork oak forests, causing spectacular defoliation periodically, its attack is made according to an altitudinal gradient where the infested species are more and more green with late growth, suitable for the completion of its development cycle and to ensure its sustainability.

Apart from any parasitic causes of this defoliator, the latter showed a good dynamism which is proved by the good progress of the laying on the majority of the compartments of the tree. This translates the preference of the gypsy moth of this species cork oak which offered him optimal development.

Actions to control this type of insect pest have priority and urgency for affected stands, especially forests with high susceptibility to caterpillar attack.

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