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Original Article

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VARIABILITY INFLUENCE OF THE VOLATILE COMPOUNDS OF THREE ALGERIAN DATE CULTIVARS (*PHOENIX DACTYLIFERA* L.) ON INFESTATION RATES OF THE DATE MOTH [(*ECTOMYELOIS CERATONIAE* ZELL. (LEPIDOPTERA: PYRALIDAE)]

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ABSTRACT. The date moth *Ectomyelois ceratoniae* Zeller (Lepidoptera; Pyralidae) is a serious pest for the dates production in Algerian oasis. Its dangerousness resides in its wide geographic distribution on various bioclimatics stages and his polyphagia on various hosts. In this context, to find out the impact of the dates volatile compounds on the date moth oviposition behavior. To do this, we conducted the following study, which is divided into two parts, one in the field and the other in the laboratory. This study investigated the effect of the biochemical profiles of three Algerian date cultivars (Deglet-Nour, Ghars and Degla-Beidha) on the infestation rates of the date moth. The monitoring infection rates in the field produced the following results: during the campaigns from 2011/2012 to 2014/2015 at the INRAA Sidi Mahdi-Touggourt station (Algeria), revealed that the cultivar Deglet-Nour is the most affected with a rate of 18.84%, followed by Ghars with 10.28% then Degla-Beidha with 6.66%. As for the extracts analysis of the three date cultivars with hexane were identified and quantifie *via* coupling gas chromatography / mass spectrometry (GC/MS). The analysis of the volatile compounds of the cultivars studied allowed to identify 110 compounds distributed in eight chemical classes (hydrocarbons (saturated aliphatic hydrocarbons, unsaturated aliphatic hydrocarbons, unsaturated monocyclic hydrocarbons, saturated monocyclic hydrocarbons, aromatic hydrocarbons, terpene hydrocarbons), alcohols, aldehydes, esters, ketones, amides, phenols and carboxylic acids), whose compounds are distributed as follows: 72 compounds for the Deglet-Nour, 38 compounds for the cultivar Ghars and 29 compounds for Degla-Beidha.

Keywords: date moth; infestation; *Phoenix dactylifera* L.; allelochemical compound; extraction; Lepidoptera, Pyralidae.

INTRODUCTION

Date palm cultivation is among the millennial activities that man has

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known over the centuries by defying victoriously the rigor of nature. His culture began simultaneously and according to several writings in Mesopotamia at 4000 BC. J.-C. (Al-Bakr, 1972), and in the Nile Valley in Egypt about 3200 BC. J.-C. (Djerbi, 1992). In fact, it has been propagated according to a typological dynamic peculiar to sociological mutations (Ouennoughi and Dubost, 2005). Currently, date palm cultivation is practiced across the five continents in arid and semi-arid areas.

Hence, the cultivated area is estimated at 385 322 ha in Africa, 682 709 ha in Asia, 3581 ha in America and more than 4100 ha in Europe (Spain and Albania) (FAO, 2013) and 300 ha in Australia (Djerbi, 1992). The world date palm cultivation area is estimated at 1 075 712 ha with a production of 7 189 789 tons (FAO, 2013).

The Algerian date palm heritage is estimated at more than 19 million trees (M.A.D.R., 2013); the average annual production was estimated at 848199 tons (FAO, 2013). Currently, the date palm cultivation is economically important for Algeria, as it is considered a second source of currency after oil. However, this sector is confronted with several constraints, among others, the date moth [(*Ectomyelois ceratoniae* (Zeller, 1839) (Lepidoptera: Pyralidae)], which is considered as the most formidable date pest and as the main constraint to the export (Doumandji, 1981). *E. ceratoniae* is a cosmopolitan pest that can be found anywhere in the world. Its range is therefore very large ranging from 50°N - 30°S (Balachowsky, 1972). The date moth is an extremely polyphagous pest; the damage is caused by its caterpillars. A multitude of crops and spontaneous plants are the target of its attacks in very different bioclimatic stages (Arif, 2011). Indeed, a wide range of host plants has been reported around the world, estimated at about 49 species, including 32 in Algeria. However, the greatest damage in Algeria occurs on the date palm (*P. dactylifera* L.), the orange tree (*Citrus sinensis*), the almond tree (*Prunus amygdalus*), the fig tree (*Ficus carica*), the pomegranate tree (*Punica granatum*), the carob tree (*Ceratoniae siliqua* L.), the loquat tree (*Eriobotrya japonica*) and the tamarind tree (*Tamarindus indica*) (Doumandji, 1981). Indeed, in the Algerian palm groves, it has been found that *E. ceratoniae* attack some cultivars than others. According to Cossé *et al*. (1994), the females of this moth, in oviposition phase, are attracted by substances emitted by some date cultivars. To better understand this aspect, we conducted this study on three date cultivars to determine its varietal preferences at the time of oviposition and to explore the causes of these trends. Understanding this behavior can help to control this pest in perspective, in different date palm cultivation areas around the world.

The present study investigates the field infestation rate of *E. ceratoniae*, followed by volatile compounds analysis of three dates cultivars via GC-MS technical.

MATERIALS AND METHODS

Insects

The species that is the subject of this study is *Ectomyelois ceratoniae* Zeller (Lepidoptera; Pyralidae).

Vegetal

The fresh dates of three date palm cultivars (*Phoenix dactylifera* L.) (Deglet-Nour, Ghars and Degla-Beidha) were analyzed.

They were collected during the month of November 2016 from the palm grove of the National Institute of Agronomic Research of Algeria (NIARA), experimental station Sidi-Mahdi Touggourt. The dates collected are stored under cryogenic conditions (-15°C).

Monitoring infestation rates

To highlight the varietal effect on the egg-laying behavior of *E. ceratoniae* Zeller in the field, the infestation rate of three date cultivars (Deglet-Nour, Ghars and Degla-Beidha) was monitored during the cropping seasons from 2011/2012 to 2015/2016.

We opted for Warner's (1988) method, which consists of a weekly sampling of 100 dates taken at random from each cultivar.

From the different bunches, five dates were collected from each palm tree, so be it 100 dates for the 20 palms representing each cultivar. In the laboratory, the samples were examined by a binocular loupe to detect all forms of *E. ceratoniae* (eggs, larvae).

Volatile compounds analysis

A 50 g sample of fresh date pulp from each cultivar was finely grinded by a pestle in a ceramic mortar. The pulp grinded was placed into a 250 ml glass flask in the presence of 100 ml of hexane, followed by agitation in an ultrasonic bath for 3 h. After agitation, the resulting solution was filtered by PVDF 0.45 µm filter. Then he concentrated to 0.3 mL by Rotavap apparatus. A volume of 4 µl of the extract obtained was injected into the column of the gas chromatograph coupled to a mass spectrometer (GC-MS) in Splitless mode for 3 min.

The analysis was carried out at the research and development center, EPE ALPHYT (Dar El-Beida, Algiers (Algeria). The chromatograph is a model material (Hewlett Packard; Agilent 6890N), controlled by ChemStation (NIST002), with flame ionization detector (FID), equipped with a column (DB5-MS) 30 m long, 0.25 mm of diameter and 0.25µm thick. The flow rate of the carrier gas (helium) was 1 ml min^{-1}. The oven was programmed at a temperature of 50°C for 2 min; then the temperature has increased at 3°C / min until reaching 250°C. The injector was heated to 250°C. The mass spectrometer model used was Agilent 5973, working in electronic impact at 70 eV; temperatures: interface (280°C), source (230°C), quadrupole (150°C). The identification of the compounds by mass spectral analysis was carried out using the database NIST002 (ed.), 2002, and the data acquisition software (Data analysis, MSD ChemStation G1701DA D-02.00. 275).

Statistical analysis

An ascending hierarchical classification of the three date cultivars was carried out based on the number of volatile compounds contained in each cultivar. It involves statistically treating the presence or absence of each volatile compound in each cultivar by coding them respectively by the values 1 and 0, respectively. We have matched the value 1 if the compound is present in the cultivar and 0 if the compound is absent. These data were then submitted to a principal component analysis (PCA) using the XLSTAT 2016 software; Publisher: Addinsoft; Version: (XLSTAT-Premium 2016.02.28451).

RESULTS AND DISCUSSION

The study carried out in the palm grove of the NIARA, Touggourt Station, during the cropping seasons from 2011-2012 to 2015-2016, recorded fluctuating infestation rates of dates by *E. ceratoniae*, depending on the cultivars. In fact, global infestation rates have been recorded of the order of 18.84, 10.28 and 6.66% for Deglet-Nour, Ghars and Degla-Beidha cultivars, respectively.

Changes in infestation levels during five consecutive cropping seasons (2011/ 012-2015/2016) showed that Deglet-Nour is the most affected cultivar, followed by the Ghars cultivar (except in 2014/2015), then followed by Degla-Beidha cultivar (*Table 1* and *Fig.1*).

Indeed, very fluctuating levels of attacks were recorded according to the cropping seasons and the cultivars; this is the case of the 2011/2012, where Deglet-Nour recorded an infestation rate of 22.4%, compared to 11.6% for Ghars and 3.2% for Degla-Beidha. In addition, the 2012/2013 campaign recorded the highest and most alarming infestation rates for all cultivars, particularly for Deglet-Nour and Ghars, with rates of 28.2 and 24%, respectively, and a rate of 15.6% for the Degla-Beidha cultivar. However, the 2013/2014 campaign was marked by the lowest attack levels with rates of 5.6% for Deglet-Nour, 0.8% for Ghars and 3.5% for Degla-Beidha (*Table 1* and *Fig. 1*). In light of these results, Deglet-Nour is proven to be the most infested cultivar, with very high infestation rates, that have an economic impact on the overall production of this cultivar; conversely to Degla-Beidha, which is the least affected.

The attack rate can go up to 96% in the palm groves of southern Algeria (personal unpublished data). Indeed, in 1985, the damage caused by this pest were of the order of 42.5% of fruits attacked on the ground and which has increased at the level of the places of storage and that up to 64.7% (Doumandji - Mitiche (1983), cited by Hadjeb (2012).

Moreover, depending on the cultivars, similar results were recorded by Arif (2011), through the study conducted on the same cultivars, during the 2007-2008 cropping year. The works of Mehrnejad (2001), Kishani Farahani and Goldansaz (2013), Doumandji (1981) and Doumandji and Doumandji-Mitiche (1976) indicated that climatic conditions, varietal physiological state of the host plant, the conduct of the culture and others are determining factors of the proliferation of *E. ceratoniae*.

Table 1 - Infestation rates evolution of three date cultivars (Deglet-Nour, Ghars and Degla-Beidha) by *E. ceratoniae* during the cropping seasons from 2011/2012 to 2014/2015 in the NIARA experimental station of Touggourt (Algeria)

Cropping years	Sample size*			Infestation rates (%)		
	D.Nour	Ghars	D.Beidha	D.Nour	Ghars	D.Beidha
2011/2012	500	500	500	22.4	11.6	3.2
2012/2013	500	500	500	28.2	24	15.6
2013/2014	500	500	500	5.6	0.8	3.5
2014/2015	500	500	500	26	6	5
2015/2016	500	500	500	12	9	6

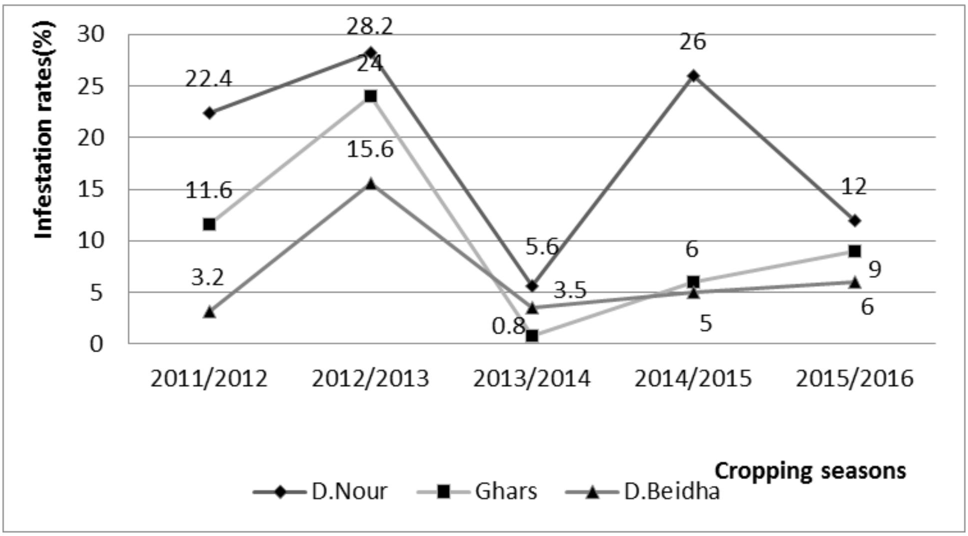

Figure 1- Infestation rates evolution of three date cultivars (Deglet-Nour, Ghars and Degla-Beidha) by *E. ceratoniae* during the cropping seasons from 2011/2012 to 2014/2015 in the NIARA experimental station of Touggourt (Algeria)

However, Lebrun *et al.* (2007) report that the higher infestation rate of some date cultivars may be due to a variability of the volatile substances emitted, exerting more or less accentuated effects of attractiveness or repulsion. Indeed, to analyze the world around them, all animals have sensory faculties that allow them to communicate with him (Picimbon, 2002). In insects, olfaction is a crucial sensory modality for controlling many aspects of behavior. They resort to chemical signals in the detection of food and oviposition sites, in the establishment of interindividual, social, sexual relations, and in the apprehension of the danger. All these aspects are related to the functioning of smell and taste (Hildebrand, 1995 and Picimbon, 2002).

According to Arif and Lombarkia (2015), the female body of the *E. ceratoniae* is endowed with sensilla of different functions; structures specialized in the perception of information signals (chemical or mechanical), which proves that the laying behavior of the date moth is largely guided by the volatile (phytochemical) substances of its host plants.

The analysis of the volatile compounds of three date cultivars, namely Deglet-Nour, Degla-Beidha and Ghars, by GC-MS technical allowed us to find a total of 234 volatile compounds, including 151 compounds in the Deglet-Nour cultivar, 51 compounds in the Ghars cultivar and 32 compounds in the Degla-Beidha cultivar (*Table 2*). However, only 110 compounds (not counting the compounds in common) were identified among the 234 compounds found and distributed as follows: 72 compounds for Deglet-Nour, 38 compounds for cultivar Ghars and 29 compounds for Degla-Beidha.

In addition, the identified compounds are divided into eight chemical classes, forming the 110 volatile compounds identified in this study, these are hydrocarbons (saturated aliphatic hydrocarbons (alkanes), unsaturated aliphatic hydrocarbons (alkenes/alkynes), hydrocarbons unsaturated cyclic, saturated cyclic hydrocarbons, aromatic hydrocarbons, terpene hydrocarbons, alcohols, aldehydes, esters, ketones, amides, phenols and carboxylic acids.

Indeed, from the results obtained (*Table 2*) and the dendrogram established on the basis of the number of volatile compounds of each chemical class (*Fig. 2*), we found that the group (Ghars/Degla-Beidha) has a profile biochemical close, which is relatively very rich in hydrocarbons (29 and 17 compounds, respectively), richer in esters with five compounds for each, and less rich in aldehydes and phenols with one compound for each cultivar. As for the ketone compounds, we recorded two compounds for the Degla-Beidha cultivar against one compound for the Ghars cultivar; the latter presented a richness in amides (one compound), whereas the cultivar Degla-Beidha denotes the lack of these compounds. It is reported that only the Degla-Beidha cultivar among the three cultivars studied is provided with carboxylic acids (one compound).

In addition, all chemical classes identified in the three cultivars are represented in the Deglet-Nour cultivar (with the exception of the carboxylic acid class), with a relatively high number of compounds, compared to the other cultivars. Indeed, Deglet-Nour is characterized by a high hydrocarbons content. Among the 72 compounds, there are 32 compounds of saturated aliphatic hydrocarbons (alkanes), three compounds of cyclic hydrocarbons, 13 compounds of aromatic hydrocarbons, seven compounds of unsaturated aliphatic hydrocarbons (alkenes/alkynes) and one hydrocarbon compound terpene, eight compounds of esters and two compounds of ketones. In contrast to Ghars and D. Beidha, D. Nour is rich in aldehydes and alcohols, with three compounds for the first and one for the latter. The cultivar is also characterized by the presence of one compound of amides. As for phenols, the three cultivars have a relatively small number one compound/cultivar) (*Tables 2* and *3*).

Table 2 - Volatile compounds number in each chemical class identified in three date cultivars (Deglet-Nour, Ghars and Degla-Beidha) *via* GC-MS

Chimical classes	D. Nour	Ghars	D. Beidha
Alkanes	32	18	10
Alkenes/Alkynes	07	04	04
Unsaturated cyclic hydrocarbons	00	00	01
Saturated cyclic hydrocarbons	03	03	01
Aromatic hydrocarbons	13	04	00
Terpenic hydrocarbons	01	00	01
Alcohols	01	00	01
Aldehydes	03	01	01
Esters	08	05	05
Ketones	02	01	02
Amides	01	01	00
Phenols	01	01	01
Carboxylic acids	00	00	02
Total	**72**	**38**	**29**

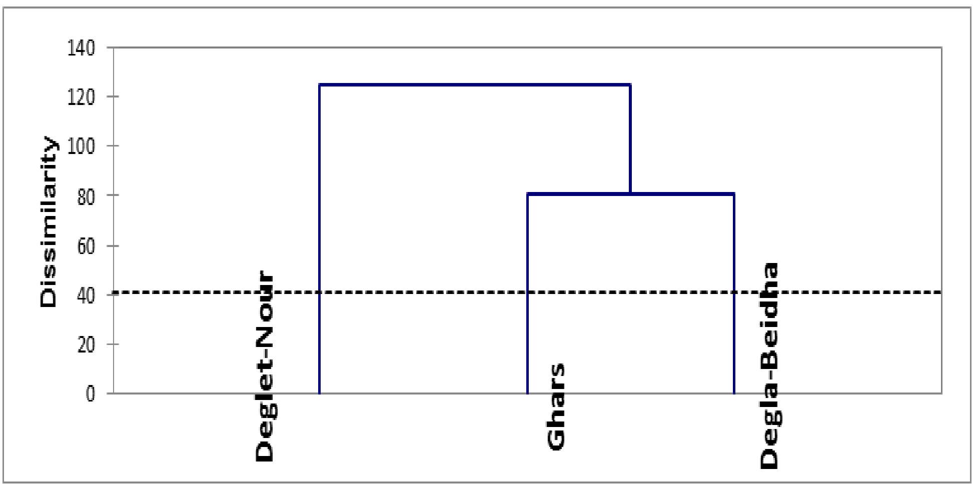

Figure 2 - Classification dendrogram of three Algerian date cultivars (Deglet-Nour, Ghars and Degla-Beidha), obtained by an ascending hierarchical classification (AHC) based on the number of volatile compounds of each chemical class identified in each cultivar

Compared to previous studies, Jaddou *et al.* (1984) identified 38 volatile compounds, divided into six chemical classes in the Iraqi variety Zahdi. In turn, Harrak *et al.* (2005) identified 47 compounds in dates of eight Moroccan date varieties belonging to nine chemical classes. In Tunisia, El Arem *et al.* (2011) identified 80 volatile compounds, classified in eight chemical classes in five date cultivars. It should be noted that, these works have given especially importance to organoleptic aspects, including aromas. In addition, most of the work undertaken on *E. ceratoniae* has addressed the eco-biological aspects, very little work has treated the allelochemical effect between the date and its pests, especially *E. ceratoniae*. Thus, the studies undertaken by Cossé *et al.* (1994) and Gothilf (1964), cited by Gothilf *et al.* (1975) on *E. ceratoniae* claimed that the females respond to chemical stimuli, represented by volatile compounds emitted by dates or carob infested by the fungus *Phomopsis* sp.

However, from the chemical nature of the substances, it is obvious that the cultivars studied, in particular Deglet-Nour, present high hydrocarbons content, especially alkanes (32 compounds). According to Benchabane (2007), the stored dates show a more pronounced oxidation, a high reactivity of the polyunsaturated fatty acids, favoring the formation of hydroperoxides and thus accelerating the reaction towards the production of carbonyl and hydroxyl compounds, such as hydrocarbons, compounds come from a degradation of polyunsaturated fatty acids of type C18: 2, responsible for the rancid taste (Berset and Cuvelier, 1996).

Table 3 - Volatile compounds identified in three Algerian date cultivars (Deglet-Nour, Ghars and Degla-Beidha) through gas chromatography-mass spectrometry (GC-MS)

Chimical Classes	Compounds	D. Nour	Ghars	D. Beidha
Alkanes	Octane, 4-methyl-	+		
	"Octane, 2,6-dimethyl-"	+		
	"Heptane, 3-ethyl-2-methyl-"	+		
	"Nonane, 3-methyl-"	+		
	"Decane"	+		
	"Decane, 3-methyl-"	+		
	"Undecane"	+		
	"Dodecane, 4,6-dimethyl-"	+		
	"Undecane, 2,6-dimethyl-"	+		
	"Tridecane"	+	+	+
	"Tetradecane, 1-bromo-"	+		
	"Tridecane, 2-methyl-"	+		
	"Hexadecane, 2,6,10,14-tetramethyl-"	+		
	"Dodecane, 2,6,10-trimethyl-"	+		
	"Tetradecane"	+		
	"Decane, 4-cyclohexyl-"	+		

	"Tetradecane, 5-methyl-"	+		
	"Tridecane, 7-hexyl-"	+		
	"Tetradecane, 2-methyl-"	+		
	"Tetradecane, 3-methyl-"	+		
	"Pentadecane"	+	+	
	"Hexadecane"	+	+	
	"Heptadecane"	+	+	+
	"Octadecane"	+		
	"Nonadecane"	+	+	+
	"Eicosane"	+	+	+
	"Heneicosane"	+	+	
	"Octadecane, 1-chloro-"	+		
	"Docosane"	+		
	"Tetracosane"	+	+	+
	"Nonacosane"	+	+	
	"Hexacosane"	+		+
	"Dodecane, 2,6,10-trimethyl-"		+	
	"Tetradecane"		+	
	"2-Bromo dodecane"		+	
	"Heptacosane"		+	
	"Octadecane"		+	
	"Tetratriacontane"		+	
	"Octacosane"		+	
	"1-Diphenylsilyloxyheptane"		+	
	"Z-14-Nonacosane"		+	
	"Tetradecane"			+
	"Octadecane"			+
	"Octacosane"			+
	"Triacontane"			+

Chimical classes	Compounds	D. Nour	Ghars	D. Beidha
Alkenes / Alkynes	"Octadecane"	+	+	
	"1-Pentadecene"	+		
	"1-Hexacosene"	+	+	
	"1-Hexadecene"	+		
	"3-Hexene, 3-ethyl-2,5-dimethyl-"	+		
	"17-Pentatriacontene"	+		
	"2,6,10,14,18,22-Tetracosahexaene, 2,6,10,15,19,23-hexamethyl-, (all-E)-"	+		
	"1-Decene"		+	
	"Z-8-Hexadecene"		+	
	"9-Tricosene, (Z)-"			+
	"1-Docosene"			+
	"9-Hexacosene"			+
	"2,6,10,14,18,22-Tetracosahexaene, 2,6,10,15,19,23-hexamethyl-,(all-E)-"			+
	"Cyclopentane, 1-pentyl-2-propyl-"	+		
	"Cyclododecane, ethyl-"	+		

Saturated cyclic hydrocarbons	"Cyclopentadecane"	+		
	"Cyclopentane, nonyl-"		+	
	"Cyclohexadecane"		+	
	"Cyclobutane, 1,2-diphenyl-"		+	
	"Cyclotetracosane"			+
	"Bicyclo[4.2.0]octa-1,3,5-triene"			+
Aromatic hydrocarbons	"p-Xylene"	+		
	"Naphthalene, 1-methyl-"	+		
	"Benzene, 1,2,4,5-tetramethyl-"	+		
	"Styrene"	+	+	
	"Benzene, 1,2,3-trimethyl-"	+		
	"3-Methyl-2-(2-oxopropyl)furan"	+		
	"Naphthalene, decahydro-, trans-"	+		
	"trans-Decalin, 2-methyl-"	+		
	"Naphthalene, 1,2,3,4-tetrahydro-1,6,8-trimethyl-"	+		
	"Naphthalene, 1,4-dimethyl-"	+		
	"Naphthalene, 2,7-dimethyl-"	+		
	"Naphthalene, 1,6,7-trimethyl-"	+		
	"Naphthalene, 2,3,6-trimethyl-"	+		
	"Benzene, 1,1'-(1,3-propanediyl)bis-"		+	
	"Benzene, 1,1'-(1,2-cyclobutanediyl)bis-, trans-"		+	
	"Naphthalene, 1,2,3,4-tetrahydro-1-phenyl-"		+	
Terpenic hydrocarbons	"Limonene"	+		+
Alcohols	"1-Decanol, 2-hexyl-"	+		
	"1,22-Docosanediol"			+
Carboxylics acids	"n-Hexadecanoicacid"			+
	"9,12-Octadecadienoic acid (Z,Z)-"			+

Chimical classes	Compounds	Deglet-Nour	Ghars	Degla-Beidha
Aldehydes	"Benzaldehyde, 3-phenoxy-"	+		
	"3,5-di-tert-Butyl-4-hydroxybenzaldehyde"	+		
	"Octadecanal"	+		
	"Benzaldehyde, 3-phenoxy-"		+	
	"Vanillin"			+
Esters	"Heptafluorobutanoic acid, heptadecyl ester"	+		
	"Isopropyl Myristate"	+	+	+
	"1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester"	+	+	
	"Dibutyl phthalate"	+	+	+
	"1,2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester"	+		
	"Hexanedioic acid, bis(2-ethylhexyl) ester"	+		
	"1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester"	+		+

	"Cyclopropanecarboxylic acid, 3-(2,2-dichloroethenyl)-2,2-dimethyl-, cyano(3-phenoxyphenyl)methyl ester, (.+/-.)-"	+	+	+
	"Hexadecanoicacid, methyl ester"		+	
	"1,2-Benzenedicarboxylic acid, diisooctyl ester"		+	
	"8,11-Octadecadienoic acid, methyl ester"			+
Ketones	"2-Piperidinone, N-[4-bromo-n-butyl]-"	+		
	"3,8,8'-Trihydroxy-6,6'-dimethyl-2,2'-binaphthalene-1,1',4,4'-tetrone"	+		+
	"2-Pentadecanone, 6,10,14-trimethyl-"			+
	"2,5-Cyclohexadiene-1,4-dione, 2,6-bis(1,1-dimethylethyl)-"		+	
Amides	"13-Docosenamide, (Z)-"	+	+	
Phenols	"Phenol, 2,2'-methylenebis[6-(1,1-dimethylethyl)-4-methyl-"	+		+
	"Phenol, 2,5-bis(1,1-dimethylethyl)-"		+	

+ Presence of the compound in the designated cultivar

The principal correspondence analysis (PCA) shows several correlations between the infestation rate and the chemical composition of the cultivars studied (number of compounds that each chemical family contains). Indeed, positive correlations mark the relationships of the rate of infestation and saturated aliphatic hydrocarbons (alkanes) (0.997), unsaturated aliphatic hydrocarbons (alkenes) (0.957), saturated cyclic hydrocarbons (0.729), aromatic hydrocarbons (1) (perfectly correlated), aldehydes (0.957), esters (0.957) and amides (0.729). In addition, negative correlations characterize the relationship between infestation rate and unsaturated cyclic hydrocarbons (-0.729) and carboxylic acids (-0.729).

However, by their central position, the phenols are significantly uncorrelated; similarly for terpene hydrocarbons, alcohols and ketones, which have an orthogonal position (*Table 4* and *Fig. 3*).

Simultaneous representation of cultivars and variables on a two-dimensional map identified trends (*Fig. 3*). Indeed, we noticed that based on the variables of the chemical composition and the infestation rate that we have; the cultivar Deglet-Nour is rather particular, it seems that the infestation rate in this cultivar is significantly correlated with saturated aliphatic hydrocarbons (alkanes), unsaturated aliphatic hydrocarbons (alkenes), aldehydes, esters and in particular aromatic hydrocarbons. Similarly, for the Ghars cultivar, it appears that the infestation rate is positively correlated with saturated cyclic hydrocarbon variables and amides. As for the Degla-Beidha cultivar, the infestation rate is negatively correlated with unsaturated cyclic hydrocarbon variables and with carboxylic acids.

Table 4 - Correlation matrix (Pearson (n)) between infestation rate and number of volatile compounds in each chemical classe

	Infest
H,al,sat	**0,997**
H,al,ins	**0,957**
H,cy,ins	**-0,729**
H,cy,sat	**0,729**
H,arom	**1,000**
H,terp	0,228
Alco	0,228
Ald	**0,957**
Est	**0,957**
Céto	0,228
Amid	**0,729**
Phén	
Ac,car	**-0,729**
Infest	**1**

Legend:

H, al, sat: Saturated aliphatic hydrocarbons (Alkanes); **H, al, ins:** Unsaturated aliphatic hydrocarbons;H, cy, ins: Unsaturated cyclic hydrocarbons; **H, cy, sat:** Saturated cyclic hydrocarbons; **H, arom:** Aromatic hydrocarbons; **H, terp:** terpenic hydrocarbons; **Alco:** Alcohols; **Phen:** Phenols, **Ald:** Aldehydes; **Est**: Esters; **Céto:** Ketones; **Amid:** Amides; **Ac, car:** Carboxylic acids, **Infest:** Infestation.

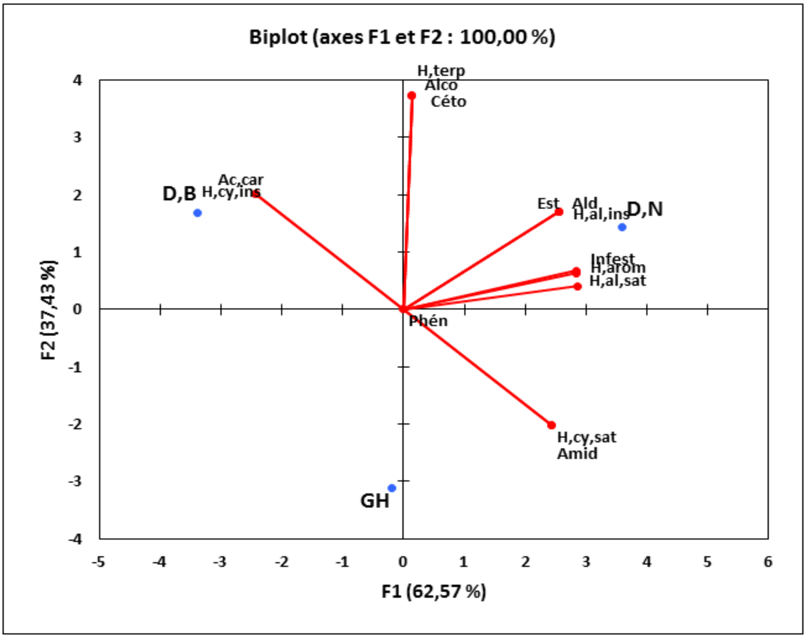

Figure 3 - Simultaneous representation of cultivars (observations) and variables in a principal correspondence analysis (PCA)

According to Cossé *et al.* (1994), esters, alcohols and aldehydes in particular, ethyl hexanoate, ethanol and acetaldehyde are oviposition stimulants of *E. ceratoniae*. While, Gothilf *et al*. (1975) noted that simple chain alcohols, in particular ethanol, the two isomers 1-propanol, 2-propanol and 1-butanol are also compounds that activate the oviposition function of this moth.

As a result, the composition of the volatile compounds of the studied cultivars shows a significant richness of Dglet-Nour in esters (eight compounds), in aldehydes (five compounds) and in degree less in alcohols (one compound).

On the other hand, the cultivar Ghars shows a poverty in alcohols, but a richness in aldehydes (five compounds) and ester (one compound). As for the cultivar Degla-Beidha, it noted the presence of five aldehyde compounds and one compound for each class of alcohols and esters (*Table 2*).

CONCLUSION

From the results obtained in this study, it can be concluded that the fluctuations of infestation rates of *E. ceratoniae*, according to date cultivars, are related to the chemical composition in volatile compounds of each cultivar.

Hence, it isnecessary to take these aspects into varietal choice during cultivation and in the control programs of this pest.

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