Original Research Article

Sap beetles (Nitidulidae) of date palms of the Deglet Nour variety in the Ziban region (Algeria): distribution patterns and effectiveness of date bunch bagging

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Abstract

This study aims to update the list of Nitidulidae species observed on date palms in Algeria (Ziban region), their spatial dynamics according to the development stages (larva, pupa, adult), and the effectiveness of the bagging operation. In 2020, we sampled and examined 1800 dates of the Deglet Nour variety from three palm groves managed with different protection modes: yellow bagging, white bagging, and no bagging. The results obtained mention the presence of nine species of Nitidulidae with five species reported for the first time on dates in Algeria. The highest relative abundance (RA) of Nitidulidae beetles was noted in the southern (28%) direction. However, the variation of infestation rate (IR) according to the direction was not very accentuated. The GLM analysis showed that, except for the adult stage, the direction presented a highly significant effect on the RA variation of the total Nitudilidae, the larva and pupa stages ($p < 0.0001$), but there was no significant effect of direction on the IR in all studied cases. The highest RA of total Nitidulidae was found on the white plastic-protected dates (RA = 42%), the IR of the total Nitidulidae was higher on dates protected by yellow plastic (IR = 38%). The unprotected dates recorded the lowest RA and IR for all studied cases and the effect of bagging type on the RA variation of Nitidulidae, in all studied cases, was statistically highly significant ($p < 0.0001$). This effect on the IR was very highly significant only for total Nitudilidae, larvae, and adults ($p < 0.0001$). So, the southern direction presents the best conditions for sheltering the largest numbers of Nitidulidae. The latter also has a marked preference for bunches covered by plastic bags rather than for those left uncovered. This implies the ineffectiveness of the operation of protecting dates with plastic bags, especially the yellow-coloured ones.

Keywords: infestation rate; relative abundance; spatial dynamics; stages of development; date palm

INTRODUCTION

The date palm is one of the oldest cultivated plant species (Sedra 2003; Sedra 2012). In the Algerian Sahara, the Date palm (*Phœnix dactylifera* L.) is the mainstay of oasis ecosystems (Bouguedoura et al. 2010), it plays a very important role in the socio-economic balance of this vast region (Rahmania and Huon 1997). The Ziban region (northeast Algeria) occupies the first place in terms of number of palm trees and production. It is also known for the production of its Deglet Nour variety,

the noblest, the most valuable, and the most marketed (FAOSTAT 2020).

Pests are the main factors influencing date production and quality; the species found on date palms are acclimatised to this biotope and no other (Munier 1973). About fifty species are known to attack date palms and their products, mostly belonging to the insect class (Jerraya 1993). El-Shafie et al. (2017) listed 132 species of insect and mite pests associated with date palms. In the United Arab Emirates, Kaakeh et al. (2018) identified 41 pest species of date palms. In Algeria, according to Dakhia et al. (2013), the phoeniculture is seriously threatened and/or damaged by various pests, including the Date moth (*Ectomyelois ceratoniae,* Lepidoptera), the Boufaroua (*Oligonychus afrasiasticus,* Acarina), the White mealybug (*Parlatoria blanchardi,* Coccoidea), and the Palm borer (*Apate monachus,* Coleoptera). The infestation rate of dates by *Ectomyelois ceratoniae* is among the highest ones, reaching 10–20% and sometimes 29–30% (Zouioueche 2012; Ouamane et al. 2017). Several other studies have been highlighting important damages by the White scale (Allam 2008; Nadji 2011; Achoura 2013; Mehaoua 2014; Allam 2016; Chebaani et al. 2021) and the Date moth (Doumandji-Mitiche et al. 1993; Idder-Ighili 2008; Zouioueche 2012; Boulanouar et al. 2018; Roumani 2020).

Despite the importance of date cultivation, very little work was done on knowledge and estimate Nitidulidae damage to dates in its vast cultivation areas, while they show an important upsurge in recent years with the appearance of several invasive species (Roumani 2020). These last are considered of major concern globally because they affect human health and food security (Cornelissen and Neumann 2022). The Nitidulidae family presents diversified ecological habits and plays a fundamental role in the environment (Fernandes et al. 2018). In stored foodstuffs, they often infest the product as it begins to dry, but disappear when the humidity level decreases. Only a limited number of species can grow in a perfectly dry product. The harmful nature of the Nitidulidae is generally linked more to the role they play in the dissemination of various moulds than to their capacity for proliferation (Delobel and Tran 1993).

In Australia, the Nitidulidae are considered the main pests of stone fruits (Baig et al. 2023). According to Wakil et al. (2015), Nitidulidae beetles are found worldwide on a variety of plants whose fruits contain a significant amount of carbohydrates. They are mainly found in decaying and fermenting fruits and are therefore considered secondary pests of date palms. Several new pest species of Nitidulidae were reported worldwide (Avgin et al. 2015, Parmain et al. 2016; Audisio et al. 2017; Powell and Duffy 2017; Kirejtshuk et al. 2018; Lee et al. 2020; Sparacio et al. 2020).

In the genus *Carpophilus,* several invasive species can swarm in the heaps of damaged grain near silos or deposited on game feeders (Callot and Brua 2013). In the Ziban region, the Nitudilidae *C. hemipterus* is the most common species of the family and was often considered a secondary pest of fermented fruits and attacks only soft dates (Doumandji-Mitiche 1977).

However, in recent years, climatic variations have been observed in the Ziban region which modifies the behaviour of pests and their distribution, and several new techniques are used to minimise the negative effects of pests and autumn rains, such as localised irrigation; chasing inflorescences, and bagging of bunches (Acourene and Benchabane 2001).

In this context, we proposed this study to support this hypothesis according to which climatic variations as well as the actions carried out by farmers to protect their crops, impact in one way or another the pests frequenting the date palm in the Ziban region. It mainly involves describing the community structure of Nitudilidae beetles attacking the date palm in the Ziban region; highlighting the modalities, abundances, and infestation rates of Nitidulidae in palm groves according to their development stages and the cardinal directions of the trees. Furthermore, we evaluated the effectiveness of bagging the bunches in plastic film, an operation used for pest protection, on the abundance and infestation rate of dates by Nitidulidae.

MATERIALS AND METHODS

Description of the study area and sampling sites

The study was carried out in the Ziban region, located in north-eastern Algeria, more precisely at the foot of the southern slope of the Saharan Atlas mountain range. It forms the boundary between northern and southern Algeria (Berlan-Darque et al. 2007). Biskra is the capital town of the Ziban region which represents a prosperous agricultural region, particularly for the dates culture. The Ziban region is characterised by an arid climate with a very hot, dry summer and a mild winter. According to National Meteorological Office data from 2011 to 2020, the region is characterised by low and irregular rainfall: the average annual rainfall over the last 10 years was 11.36 ± 7.35 mm. In addition, for the same previous period, the mean annual temperature was 28.89 ± 7.84 °C, the average relative humidity of 42.87 ± 9.92%; and the average wind speed of 4.6 ± 1.03 km/h.

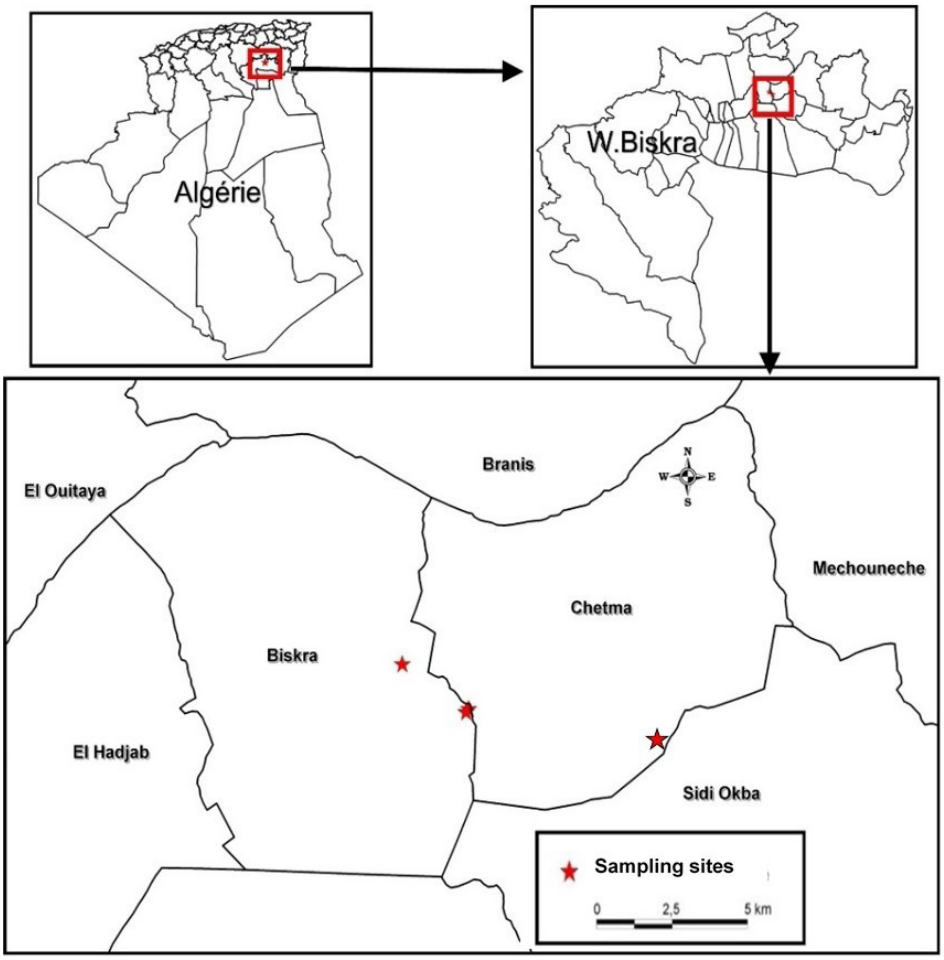

Figure 1. Location of sampling palm groves in Biskra province

To eliminate the effect of climate variation, the study was conducted in three palm groves of the Deglet Nour variety in the neighboring localities of Biskra and Chetma. The central coordinates of the three sites are 34° 50′ 44.82″ N and 05° 47′ 24.68″ E; and the distance between the three groves does not exceed 5 km as the crow flies (Figure 1).

Sampling methods

Sampling was carried out in the three palm groves in October 2020, at harvest time, and when the damage of the Nitidulidae was the most considerable.

Our sampling scheme consists of dividing each palm grove into five identical blocks. In each block, we chose a median line of the palm from which we randomly sampled six palms in such a way as to cover all areas of the palm grove. Thus, the border palms are excluded to have more representative samples of the study palm grove with a total of 30 trees for each grove and a total of 90 palms for the three groves.

For each palm sampled, we manually took five dates from the bunches at random for the four cardinal orientations of the palm (north, south, west, and east), and placed them in plastic bags with all the necessary sampled information: name of the palm grove, block number, palm number, and tree orientation. A total of 20 dates for each palm, 600 dates for each palm grove, and 1800 dates for the three palm groves.

In the laboratory, each date sampled was examined by binocular observation after their longitudinal cutting. Careful examination of date flesh by two entomological forceps allowed us to collect the Nitidulidae specimens and define the individual numbers of larvae, pupae, and adults.

Data treatment and statistical analysis

The relative abundance of Nitidulidae beetles (%) was calculated for each of the three development stages considered (larva, pupa, and adult) using the following formula: Relative abundance (RA in %) of a "development stage" considered = (individuals number of considered development stage/total number of Nitidulidae)×100. The infestation rate (IR in %) by Nitidulidae beetles on the date at the larval, pupal, and

Table 1. Nitidulidae species reported in the Ziban region (Biskra, northeast Algeria) and elsewhere in the world. (*) species reported for the first time on date palm in Algeria

Species	References reporting the presence on date palms in the world
Epuraea luteola Erichson, 1843 *	Iraq, USA (California), Israel, Libya, and India (Ahmed, 1978; Wakil et al., 2015).
Carpophilus mutilatus Erichson, 1843 *	Iraq, Israel, USA (California) Australia, and Libya (Wakil et al., 2015).
Carpophilus truncatus Murray1864 *	France, Germany, Iran, Austria, China, Croatia, Czech Republic, Greece, Italy, Japan, Poland, Slovakia, Slovenia, Taiwan, Turkey; Egypt, Morocco (Lasoń and Ghahari, 2013).
Carpophilus nepos Murray1864 *	Libya (Wakil et al., 2015).
Carpophilus hemipterus (Linnaeus 1758)	Iraq, USA (California), Israel, Iran, Indonesia, Algeria, Libya, and tropical Africa (Doumandji-Mitiche, 1977; Wakil et al., 2015; Ahmad Salah and Thamer, 2020) Cosmopolite species: Delobel et Tran (1993)
Urophorus humeralis (Fabricius 1798)	Iraq, Libya, Egypt, Somalia, Palestine, Oman, Algeria (Doumandji-Mitiche, 1977; Wakil et al., 2015; Ahmad Salah and Thamer, 2020; Khaldi et al., 2021)
Carpophilus marginellus Motschulsky, 1858	Algeria (Torki, 2022)
Carpophilus obsolelus Erichson, 1843*	Cosmopolite species: Delobel et Tran (1993)
Carpophilus zeaphilus (Dobson, 1969)	Algeria (Torki, 2022)

adult stages, for each palm grove, is evaluated by the following formula: Infestation rate of a "development stage" = (number of dates infested by the considered development stage/total number of dates collected from bunches) × 100.

During the statistical processing of data, the effect of the four cardinal directions on the variation of the relative abundance and the infestation rate of dates by Nitidulidae beetles, at the different stages; and the effect of the plastic film used for the operation of bunches bagging according to its colour (white or yellow), were processed by the generalised linear model (GLM) (Poisson-distribution, log-link function). Statistical tests were performed using the R software (R Development Core Team 2014).

RESULTS

Update of Nitidulidae beetles collected on date palm

The microscopic observation of the dates sampled allows us to describe nine species of pests belonging to the family of Nitidulidae, seven of which belong to the genus *Carpophilus*, a species of the genus *Urophorus* and one *Epuraea* (Table 1).

Five Nitidulidae species are reported here for the first time on date palms in Algeria (*Epuraea luteola*, *Carpophilus mutilatus*, *C. truncatus, C. nepos,* and *C. obsolelus)*, but have already been reported elsewhere in several regions of the world. To our knowledge, the two species *C. marginellus* and *C. zeaphilus* are reported only in Algeria on date palms and not elsewhere in the world (Table 1).

Abundance and infestation rate of Nitidulidae beetles according to direction

Considering the three studied groves, the highest relative abundance (RA) of total Nitidulidae beetles is noted in the southern direction (28%), but it is different from one development stage to another. The highest RA of the larvae was noticed in the southern direction (28%), while we recorded the highest values of RA for pupae and adults in the northern direction with 51% and 28%, respectively (Fig 2A). The GLM analysis showed that, except for the adult stage, the direction presents a highly significant effect on the variation of RA of the total Nitudilidae, the larva and pupa stages ($p < 0.0001$) (Table 2).

According to the four cardinal orientations, the IR varies between the total Nitudilidae IR and the IR of each development stage. This variation is not very

Table 2. Results of GLM testing the effect of direction on the variation of relative abundance the infestation rate of date palm by the different stages of Nitudilidae

Relative abundance (RA)			
Development stages	**LR Chisq**	**Df**	**Pr (>Chisq)**
Total	80.320	3	<2.2e-16
Larvae	34.141	3	0.000000185
Pupae	64.215	3	7.39e-14
Adults	4.813	3	0.186
Infestation rate (IR)			
Total	3.865	3	0.2764
Larvae	3.911	3	0.2712
Pupae	6.3475	3	0.09587
Adults	3.4347	3	0.3293

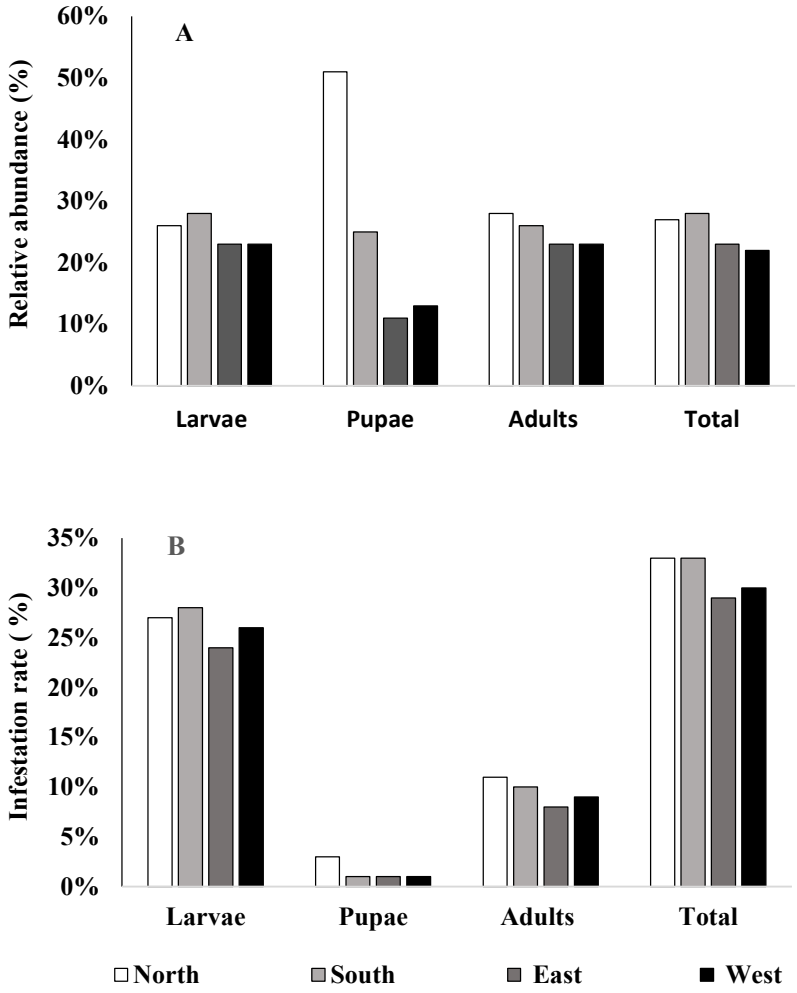

Figure 2. Variation in relative abundance and infestation rate of Nitidulidae as a function of direction and development stages of Nitidulidae

accentuated within the total Nitidulidae (IR: 29–33%) and the IR of each of the development stages (larvae: 24–28%, pupae: 1–3%, and adults: 8–11%) (Fig 2B). The GLM analysis indicates no significant effect of direction on the total Nitudilidae and the IR of the three development stages (Table 2).

Abundance and infestation rate of Nitidulidae beetles according to the type of bunches bagging

According to the type of bunch bagging, the highest RA was represented by dates protected by white bags, both for the total Nitudilidae (RA = 42%), the larva (RA = 43%), and the pupa (RA = 59%). However, the highest RA of adults (RA = 48%) was recorded on the bunches protected by yellow bags. For all developmental stages (larva, pupa, adult) and the

Table 3. Results of GLM testing the effect of the type of bunches bagging on the variation of the relative abundance and infestation rate of date palm by the different stages of Nitudilidae

Relative abundance (RA)			
Development stages	**LR Chisq**	**Df**	**Pr (>Chisq)**
Total	316.84	2	<2.2e-16
Larvae	216.198	2	<2.2e-16
Pupae	61.388	2	4.67e-14
Adults	89.242	2	<2e-16
Infestation rate (IR)			
Total	56.735	2	4.79e-13
Larvae	42.896	2	4.84e-10
Pupae	5.3982	2	0.06727
Adults	31.4792	2	0.000000146

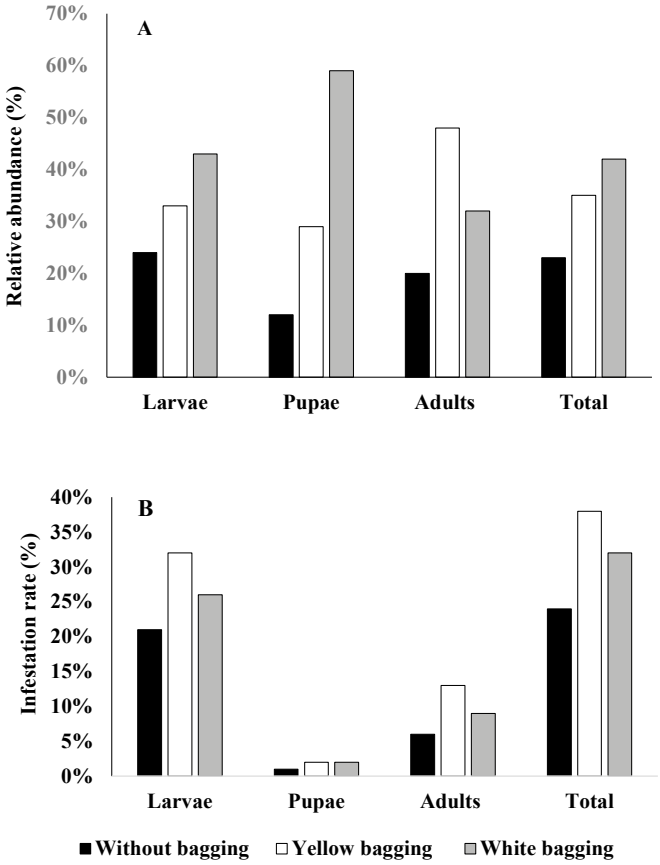

Figure 3. Variation in relative abundance and infestation rate of Nitidulidae beetles according to the type of bunches bagging

total Nitidulidae, the lowest RA was noted in the dates without bagging (Fig 3A). The effect of bagging type on the variation of RA of Nitidulidae, in all studied cases (total Nitudilidae, larvae, pupae, and adults), was statistically highly significant ($p < 0.0001$) (Table 3).

For the total Nitidulidae (IR = 38%), as well as for each of the development stages (larvae: IR = 32%, and adults: IR = 13%), the IR is highest in dates protected by yellow bags, followed by protection by white bags. The dates that are not protected by bags show the lowest levels of IR in all studied cases. Only the pupae IR does not show any notable variation for all bagging types (IR = 1 to 2%) (Fig 3 B). The statistical analysis showed that the effect of the type of bagging on the variation of the IR is very highly significant for the total of Nitudilidae, for the larvae and the adults ($p < 0.0001$). The effect of the bagging type on the IR of the pupal stage is not significant (Table 3).

DISCUSSION

The study allowed us to describe nine pest species of sap beetles (Nitidulidae, tribe Carpophilinae) of which five species are reported for the first time on date palms in Algeria. According to the literature consulted it should be noted that *Carpophilus marginellus* and *C. zeaphilus* are reported only in Algeria on date palms and not elsewhere in the world. *C. marginellus* is from paleotropical and has been introduced in the Mediterranean area (Europe, including Fennoscandia and Ireland) since the years 1800–1900. This species grows especially on ripening and rotten fruits. *C. zeaphilus* is from East Africa and reported in the Mediterranean region since the 1980s (Portugal; Spain; Monaco; Italy; Albania; near East) causing damage to ripening and rotten fruits, dried fruits, and flowers of rosaceae (Jelinek et al. 2016). The appearance of these new species on date in Algeria is probably due to climate change which influences the microclimate inside the palm groves or the cultivation

work carried out. According to Fernandes et al. (2018), climate change alters pest behaviour and distribution. The risks of increased phytosanitary pressure due to disturbances of the environment and agrosystems are real and worry all agricultural stakeholders, particularly in temperate countries where the introduction of new pests, diseases, and weeds is legion. In our study, the nine species reported feeding on the flesh of the date between the epicarp and the endocarp of the fruit and thus affect the quality of date by the presence of larvae, pupae, and the gap left between the mesocarp and the endocarp of the date.

The Nitidulidae family includes some 4500 species, and 350 genera, and is divided into ten subfamilies, making it the most species-rich family of Cucujoidea (Lee et al. 2020). The present work confirms again the invasive trend of representatives of the Nitudilidae family which increasingly attack various fruit crops during the last decades, outside of its known preferred habitats, namely storage areas. (Avgin et al. 2015; Parmain et al. 2016; Audisio et al. 2017; Powell and Duffy 2017; Kirejtshuk et al. 2018; Lee et al. 2020; Sparacio et al. 2020; Ahmad Salah and Thamer 2020; Khaldi et al. 2021).

Overall, the distribution of Nitidulidae according to the tree direction shows higher total relative abundances (RA) and infestation rates (IR) in the southern and northern directions, even if their variations are not statistically significant. This is probably due to the conditions of temperature and humidity favourable to the development and proliferation of Nitidulidae beetles in oasis environments. According to Wakil et al. (2015), the optimum temperatures for egg production of Nitidulidae are 22.5 to 25 °C, with higher fecundity to 70% at relative humidity than 50%. Fecundity is reduced at higher (30 °C) and lower (20 °C) temperatures, or lower relative humidity (50%).

Moreover, the RA and IR of Nitidulidae vary depending on the colour of the bagging used for the protection of date bunches. White bagging was the most favourable environment for the larvae and pupae abundance. For the total Nitidulidae, as well as for each of the larvae and adults' development stages, the IR is highest in dates protected by yellow bags. For all studied cases (total Nitidulidae, larva, pupa and adult), the unprotected dates recorded the lowest RA and IR. The effect of the type of bagging on the variation of the RA, in all the cases studied, was statistically highly significant, but this effect on the IR was very highly significant only for the total Nitudilidae, larvae, and adults. According to Bouchekioua (2008), yellow plastic film accelerates the ripening of dates 15 to 20 days more than white plastic film without bagging. It is likely that yellow plastic film also accelerates the cycle of some larvae to the pupal stage before dropping to the ground. Acourene and Benchabane (2001) report that yellow bagging not only accelerates the ripening period but also considerably increases the ripening percentage at harvest to 97.7%. This effect is explained by an increase in temperatures within the bagged regime whose microclimate favors ripening.

The effect of bagging on the dynamics of Nitidulidae is probably due to the rigidity of the polyethylene with which the protective bags are made, and to the yellow colouring of the bags used, which is more attractive for adults than white colouring or unprotected bunches. Bagging provides likely favourable conditions in the bunches, such as temperature and humidity, inside the yellow and white plastic film that is more attractive than bunches not covered. Bouchekioua (2008) also mentioned that the infestation rate of dates by date worm is much higher in dates protected by yellow plastic film than those protected by white plastic film and unprotected bunches. We can explain this phenomenon by the attractiveness of the yellow colour which attracts adult Nitidulidae beetles to feed and lay their eggs. However, the high temperature inside the date bunch affects the larval rates.

In the Nitidulidae family, life cycles vary between species and depend on environmental conditions such as temperature and humidity. During the rainy seasons, sap beetles are more likely to build up high populations (Carpenter and Elmer 1978; Warner et al. 1990). Sap beetles develop and survive very well under the extreme climatic conditions (especially high temperatures) that prevail during the summer in date-growing areas. At 27 °C, development from egg to adult takes 16 to 21 days, while at 32 °C it only takes 12 to 15 mandatory days (Blumberg 2008). For example, the duration of larval and pupal development of *Urophorus humeralis* and *Carpophilus mutilatus* is similar at most temperatures between 20 and 40 °C (Stickney et al. 1950). According to James and Vogele (2000), the Nitidulidae survival was highest for all species at temperatures between 25 and 30 °C.

CONCLUSION

This study reported 9 species of beetles (Nitidulidae) developing on Deglet Nour dates in the Zibans region (Algeria). We have updated the systematic list of Nitidulidae by reporting certain species for the first time on palm groves in the study region (Zibans), in Algeria, and in the vast Mediterranean region. The study showed that these beetles were present in standing bunches

during the harvest period, thus affecting the quality of dates with a significant damage rate. This allowed us to demonstrate that Nitidulidae beetles are invasive and devastating species that could represent in the future one of the main pests of date palm cultivation.

Date palm growers in the Ziban region use plastic films of different colours as a means of protection against rain and date moths. The majority of farmers prefer the yellow colour which, it seems, improves the production of the date and accelerates its maturation. Our study shows that this operation has a secondary and negative effect since it contributes to the development and even to the proliferation of Nitidulidae beetles whose real damage remains to be estimated. We believe that the mosquito net is the right protective material against the proliferation of Nitidulidae, thus promoting date protection and bunch aeration.

To take the necessary prophylactic measures, it is important to avoid the proliferation of Nitidulidae, to preserve the quality of the Deglet Nour date. More data, hence more time, are needed to provide a stronger and more reliable answer to this challenging research question.

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CONFLICT OF INTEREST

The authors declared no conflicts of interest concerning research, authorship, and publication of this article.

ETHICAL COMPLIANCE

The authors have followed ethical standards in conducting the research and preparing the manuscript.

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