Pakistan J. Zool., pp 1-8, 2022. **DOI**: https://dx.doi.org/10.17582/journal.pjz/20230103190145

Influence of the Nutritional Quality of Three Date Varieties on the Biological Parameters of the Date Moth, *Ectomyelois ceratoniae* Zeller

Ayoub Hadjeb[1,2]*, Ismahane Lebbouz[3] and Yasmine Adjami[4]

[1]*Department of Agronomy, Mohamed Khider University, BP 145 RP Biskra 07000, Algeria.*
[2]*Laboratory DEDSPAZA, Mohamed Khider University, BP 145 RP Biskra 07000, Algeria.*
[3]*Department of Biology, Mohamed Khider University, BP 145 RP Biskra 07000, Algeria.*
[4]*Applied Neuro-endocrinology Laboratory, Department of Biology, Faculty of Sciences, Badji, Mokhtar University, BP 12 23000 Annaba, Algeria.*

Article Information
Received 03 January 2023
Revised 22 January 2023
Accepted 15 February 2023
Available online 14 April 2023
(early access)

Authors' Contribution
HA was responsible of conductedthe experimentsand wrote the paper. LS performed and, analyzed and interpreted the data. YA verified the experiments, contributed to statistical analysis. IM contributed to sampling. MSM contributed to sampling. All authors have read and approved the manuscript.

Key words
Date varieties, *Ectomyelois ceratoniae*, gravimetric index, Biological parameters, Allelochemical

ABSTRACT

The nutritional and allelochemical quality of the host plant plays an important role in the population dynamics of insects. The dates moth *Ectomyelois ceratoniae* is considered one of the most dangerous pests threatening date production in Algeria. Our results show that the highest relative rate of intake (RRI) and relative growth rate (RGR) were observed in larvae fed by Deglet Nour variety just as The efficiency of biomass conversion of digested food (ECD) and ingested food conversion efficiency (ICE) in Ghars and approximate digestibility (AD) in Mech Degla. The calculation of gravimetric index (nutritional) consumption and utilization of food showed a very highly significant difference (RRI,RGR, ECD and ICE: P <0.0001; AD: P <0.0004) between larvae fed by the dates of the three varieties of dates (Deglet Nour, Mech Dagla and Ghars).We have determined the influence of different food substrates on biological parameters of dates moth. While the nutritional quality of the three varieties of dates has no effect on the fertility of females and eggs. The control of this pest requires knowledge of the bio-ecology under the effect of various biotic and abiotic factors. This results will represent a fundamental data in mechanisms interpretation of variation in abundance of this pest.

INTRODUCTION

In general, nutrition provides organisms the chemical compounds necessary for their growth, development, reproduction, defense and survival (Slansky and Rodriguez, 1987). Insects like other animals need roughly the same basic nutritional compounds (Dadd, 1985) that come from food or can be synthesized by the insect (Dadd, 1977). The use of nutriments by the insect makes it better to understand their interaction with the ecosystem and thus be better able to control its populations through direct and/ or indirect intervention when it conflicts with the economic interests (Watt *et al*., 1990; Beauce *et al*, 2001). Moreover, the host plant, as a food source plays a decisive role in the insect population dynamics with its nutritive components (carbohydrates, lipids, proteins, amino acids, vitamins, minerals and water) and its non-nutritional components (phenols, polyphenols, allelochemical compounds, monoterpenes, glucosinolates and alkaloids) (Ogushi, 1992). According to Kennedy (1965) and Nay and Perring (2006), the selection of the host plant by an insects is determined by the active host plant volatiles, Repellent semiochemicals.which may have an attractive or repulsive effects. In Algeria.dateshave long been a very important element and valuable export product. but high carob moth infestation rates are known to cause heavy economic losses (Hadjeb et al., 2017). Dates are fruits rich in many nutrients and provide a good source of fast energy due to their high carbohydrate content (70-80%) (Al-Farsi *et al*., 2007). They contain proteins (2.30- 5.60%), dietary fiber (6.40-11.50%), fats (0.20-0.50%), minerals (0.10- 916 mg/100 g dry weight) and vitamins (C. B1.B2. B3 and A) with very little or no starch (Al-Shahib and Marshall, 2003). The chemical composition of the dates varies with

* Corresponding author: ayoub.hadjeb@univ-biskra.dz
0030-9923/2022/0001-0001 $ 9.00/0

the cultivar, soil conditions, agronomic practices and the fruit ripening stage (Ismail *et al*., 2006; Al-Farsi *et al*., 2007).

This work focuses on determining the impact of the variations in the diet and nutritional performance of the carob moth using the differences in the biochemical composition between three-date varieties (Deglet Nour, Mech Dagla and Ghars). The study of the trophic relationships between the carob moth *E. ceratoniae* and its host plant the date palm *Phoenix dactylifera* seems to be very interesting to reveal more details on the mechanisms responsible for these interactions.

MATERIALS AND METHODS

Biochemical analysis of dates

The dates samples used were collected on November 2019 from the palm grove of Biskra in the south-east of Algeria (34° 43′ 0″ North, 5° 22′ 0″ East and 147 m of altitude). These dates varieties were represented in three categories: the soft dates (Ghars), the semi-soft dates (Deglet Nour) and the dry dates (Mech Degla).

Insect rearing

The varietie used was obtained from the virgin dates collected in November 2019 in the Biskra area during the trial period.Virgin females were placed together with fertile males in locally constructed spawning cages (dimensions 65 cm (diameter) x 65 cm (height). After mating.the eggs were collected and placed in a natural diet (70% date flour, 30% wheat bran. and drops of water) to continue their larval development. The adults obtained were supplied with a solution of sugar on wet rolls of cotton wool. A series of these cages are kept in a controlled room (temperature of 28 ± 1°C, with a photoperiod of 16: 8 (L: D) and 65±5% relative humidity (RH)). Insect breeding remains for three generations until a stable generation. Larvae of the first stage L1 were collected and used for bioassays. the insect breeding procedure was carried out in the zoology laboratory at the department of agronomic sciences, University of Biskra.

Gravimetric indices or nutritional indices

Each egg freshly laid was put inside the three dates varieties (Deglet Nour, Mech Degla and Ghars) whose initial weight is calculated. We closed the dates which will be placed in a small box on which one indicates the date of setting up and the number of the box. After hatching.theneonate larvae are weighed then theywere allowed to feed inside the dates until they reach the 5th stage. Development time is noted.and feces produced by each larva during this period are collected and weighed to determine the quantity of food ingested by each larva. All the tests have been repeated three times.We used the Waldbauer indices (Waldbauer, 1968).

Relative rate of intake (the amount of food eaten as a function of time):

$$RRI = \frac{NI}{P \times T}$$

Relative growth rate (the growth of the insect as a function of time):

$$RGR = \frac{GP}{P \times T}$$

Approximate digestibility (the proportion of ingested food that has been assimilated or absorbed by the body):

$$DA = \left[\frac{NI - FP}{NI}\right] \times 100$$

The efficiency of biomass conversion of digested food (the ability of the insect to convert digested food into biomass):

$$ECD = \left[\frac{GP}{NI - FP}\right] \times 100$$

Ingested food conversion efficiency (the insect's ability to convert ingested food into biomass):

$$ICE = \left[\frac{GP}{NI}\right] \times 100$$

GP is gain in weight; P is average weight (GP / log GP); NI is the amount of food ingested; FP is quantity of feces produced; T is development time.

Determing biological parameters of Ectomyelois ceratoniae *on the three dates varieties*

To determine the life table parameters of *E. ceratoniae*. A date moth is reared on dates of the Deglet Nour, Mech Degla and Ghars varieties (Fig. 1). To facilitate the observation of each larval stage, we introduced freshly laid eggs (same age) inside the dates, one egg for each date, after having cut them into two parts using pruning shears and removed the pit. The dates are then closed and placed separately in small plastic boxes on which is indicated the date of placement, the number of the individual and the name of the variety.

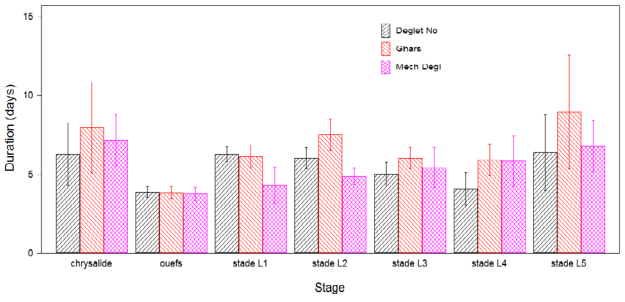

Fig. 1. Duration of stages of the three varieties (Deglet Nour, Ghars and Mech Degla).

After removing infertile eggs, measurements were made on only 25 individuals of each developmental stage, from egg incubation to adult emergence.

The stages of development were checked daily with a binocular loupe and the periods of development, mortality of eggs, larvae, pupae and adults were recorded. The larval stages were identified by the exuvia produced by the moult. This experiment was continued until the death of all the individuals of the cohort.

In order to calculate the reproductive parameters of the date moth, the same number of males and females was chosen at random among the newly emerged adults (less than 24 h old) respectively of the Deglet Nour; Mech Degla and Ghars varieties, for placed them in separate pairs in Petri dishes, in the rearing room. The number of eggs laid by each female and the number of fertile eggs were recorded daily until the death of the last female. Eggs were removed after counting.

The developmental parameters studied for the date moth were egg incubation time, larval development time (duration of each larval stage), pupa stage time.adult longevity and life cycle time.

The reproductive parameters calculated for *E. ceratoniae* by daily egg counts were crude fecundity rate, crude fertility rate, net fecundity rate, net fertility rate, eggs laid per female per day and daily fertile eggs per female on different varieties were estimated using Carey's equations (Carey, 1993).

Statistical analysis

All data were examined for normality using Kolmogorov–Smirnov test by SPSS v. 16.0 statistical programs (SPSS, 2007). The developmental time, weights of fifth instar larvae and pupae, nutritional indices, energy reserves, and biochemical traits of the three dates were analyzed by one-way ANOVA with mean separation at 5% level of significance by Tukey test (SAS, 2002). The Newman–Keuls test was applied by SPSS (2007).

RESULTS

Gravimetric indices

Table I presented the results of the statistical analysis of the different gravimetric indices which showed a highly significant difference.

The different letters in the rows indicate significant differences ($P < 0.05$) within the different date varieties.

The variance analysis of the means of relative rate intake (RRI) of the larvae showed a very highly significant difference between the three varieties studied with $P<0.0001$ (Table I). The highest relative intake rate was observed in larvae fed by Deglet Nour variety (0.024 ± 0.017).while the lowest RRI was recorded in the Ghars variety (0.007 ± 0.0021) and a RRI average for the Mech Degla variety (0.023 ± 0.009). According to the Newman and Keuls test at the 5% threshold, there is a very highly significant difference in the approximate digestibility DA ($P < 0.0004$). The larvae that used the biggest quantity of food were fed by the variety Mech Degla with an average of 71.48±12.46%, while the smallest digestibility was observed in the Deglet Nour variety (49.39±19.61%). The relative growth rate (RGR) of *E. ceratoniae* larvae showed a very highly significant difference between the three varieties studied with $F = 42.9$ and $P < 0.0001$ (Table I). The highest relative growth rate was observed in larvae fed the Deglet Nour variety (0.004 ± 0.0001) while the lowest RGR was recorded in the Ghars and Mech Degla varieties with (0.003±0.0001) and (0.003±0.0001). Table I showed that larvae fed on the Ghars variety significantly converted the digested food into biomass at an average rate of 64.13±18.49.while the efficiency of biomass conversion in the Mech Degla variety is lower. The statistical analysis shows a very highly significant difference with $F= 19.51$; $P < 0.0001$.

Effect of the nutritional quality on development duration and life table of E. ceratoniae

Observing of the development cycle of *E. ceratoniae* from laying until the emergence of adults in dates of

Table I. The averages of the different gravimetric indices.

	Mech Degla	Deglet Nour	Ghars	Valeur de F	Valeur de P
RRI	0.023±0.0091 b	0.024±0.017 a	0.007±0.0021 c	11.13	0.0001
AD	71.48±12.46a	49.39±19.61 c	65.86±7.11 b	6. 698	0.0004
ECD	22.06±10.57 c	38.09±15.47 b	64.13±18.49 a	19.514	0.0001
ICE	14.73±5.26 c	17.33±6.51 b	42.73±15.59 a	22.96	0.0001
RGR	0.003±0.0001 b	0.004±0.0001 a	0.003±0.0001 b	42.92	0.0001

RRI, relative rate of intake; RGR, relative growth rate; ECD, efficiency of biomass conversion of digested food; ICE, ingested food conversion efficiency; AD, approximate digestibility.

Table II. Average development time (in days) of *E. ceratoniae* in the fruits of the three date varieties tested.

Stages of development	Average duration ± Standard deviation (days)			F	P
	Deglet Nour	Mech Degla	Ghars		
Egg incubation time	3.88 ± 0.33 a	3.76 ± 0.44 a	3.84 ± 0.37 a	0.636	0.5322
1st instar stage	6.28 ± 0.46 a	4.32 ± 1.15 b	6.12 ± 0.73 a	43.407	< 0.0001
2nd instar stage	6.04 ± 0.68 b	4.88 ± 0.53 c	7.52 ± 1.01 a	75.327	< 0.0001
3rd instar stage	5.04 ± 0.74 b	5.44 ± 1.29 b	6.04 ± 0.68 a	7.116	0.0015
4th instar stage	4.08 ± 1.04 b	5.84 ± 1.60 a	5.92 ± 1.00 a	17.533	< 0.0001
5th instar stage	6.40 ± 2.42 b	6.80 ± 1.63 b	8.96 ± 3.60 a	6.629	0.0023
Larval devlopment	31.72 ± 3.12 b	31.04 ± 3.01 b	38.40 ± 4.13 a	34.624	< 0.0001
Chrysalis	6.28 ± 1.95 b	7.16 ± 1.63 ab	7.96 ± 2.87 a	3.617	0.0318
Preimaginaldevelopment	38.00 ± 3.52 b	38.20 ± 3.58 b	46.36 ± 4.85 a	35.011	< 0.0001
AdultLongevity	4.30 ± 1.13 a	3.40± 0.69 b	4.65 ± 1.23 a	4.305	0.0192
Life cycle	41.88 ± 3.64b	41.96 ± 3.65 b	50.20 ± 4.80a	21.351	< 0.0001

Table III. The reproductive parameters of *E. ceratoniae*in the three date varieties fruits.

Parameters	Varieties			F	P
	Deglet Nour	Mech Degla	Ghars		
Crude fertility rate	129.70 ± 9.66 a	128.80 ± 12.65 a	112.80± 14.75 a	0.584	0.5658
Crude fecundity rate	111.90 ± 10.13 a	101.00± 7.35 a	91.70 ± 14.39 a	0.776	0.4726
Net fertility rate	51.88 ± 3.86 a	41.22± 4.05 a	45.12± 5.90 a	1.009	0.3807
Net fecundity rate	44.76 ± 4.05 a	32.32± 2.35 a	36.68 ± 5.76 a	1.464	0.2530
Mean number of eggs laid per female per day	27.76 ± 2.09 ab	36.41± 6.82 a	21.99 ± 2.95 b	3.638	0.0432
Mean number of fertile eggs laid per female per day	23.83 ± 2.15 a	28.04± 4.19 a	17.91 ± 2.77 a	2.876	0.0777

The different letters in the rows indicate significant differences (P <0.05) within the different date varieties.

the Ghars, Deglet Nour and Mech Degla varieties, allowed us to measure the average duration of incubation of the eggs which is almost the same for the three varieties.

Further more the average duration of larval development was longer in the Ghars variety (L1-L5: 38.40±4.13 days) and shorter in the Deglet Nour (31.72±3.12 days) and Mech Degla varieties. with (31.04 ± 3.01 days), likewise, the longest average duration of the chrysalis stage and the imaginal phase were recorded on the dates of the ghars variety with respectively 7.96±2.87 days and 4 .65 ± 1.23 days compared to the other varieties (Table II).

The different letters in the rows indicate significant differences (P <0.05) within the different date varieties, we were able to notice that the average duration of the life cycle of *E. ceratoniae* sur in the three varieties is longer on the Ghars dates with 50.20±4.80 days and shorter on the Mech Degla variety with 41.96±3.65 days which is very close to the Deglet Nour variety with 41.88±3.64 days (Table II).

Table II, shows that the development duration of the larval period (L1-L5) of *E. ceratoniae* of the three varieties of dates was significantly different (L1: P< 0.0001, L2: P< 0.0001, L3: P= 0.0015, L4: P<0.0001 and L5: P=0.0023).

The longest duration of the L1 stage was recorded for the Ghars variety (6.12 ± 0.73 days) and Deglet Nour (6.28±0.46 days). while it is short for the Mech Degla variety (4.32±1.15 days) (Fig. 1).

The L2 larval stage also marks a longer development with 7.52 ± 1.01 days on Ghars dates compared to Deglet Nour dates (6.04 ± 0.68 days) and Mech Degla (4.88 ± 0.53 days). A longer growth of L3 larvae was observed in Ghars dates (6.04 ± 0.68 days) on the other hand the shortest duration was reported for the varieties Deglet Nour (5.04 ± 0.74 days) and Mech Degla (5.44 ± 1.29 days) .On the latter and for the Ghars variety, a longer duration of the L4 stage was recorded with respectively 5.84 ± 1.60 and 5.92 ± 1.00 days compared to Deglet Nour. The duration of the fifth larval stage was also longer for Ghar dates (8.96 ± 3.60 days) compared to the other two

varieties (Fig. 1). Conversely no significant difference was observed between egg incubation period (P = 0.5322).

The significant differences were noted between the development time of the chrysalis (P= 0.0318) and adult (P= 0.0192) stage on the fruits of the three varieties, with a longer duration for the pupae of Ghars dates (7.96 ± 2.87 days) and a short duration for that of Deglet Nour dates (6.28 ± 1.95 days), adults emerged from Ghars and Deglet *Nour* dates showed longer longevity with respectively 4.65 ± 1.23 and 4.30 ± 1.13 days compared to adults from Mech Degla dates with 3.40 ± 0.69 days (Table II). A highly significant difference was also recorded between the life cycle of the date moth accomplished on the dates of the three varieties (P < 0.0001), it is completed in a long period of 50 days in the Ghars variety compared to the other two varieties (Fig. 1).

Effect of the nutritional quality on reproduction parameters

The gross fertility rate of date moth females is high in emerged females of Deglet Nour dates (129.70 eggs) followed by females of Mech Degla dates (128.80 eggs). while it is low in emerged females of the Ghars variety with 112.80 eggs (Table III).The highest value of the crude fertility rate was observed on Deglet Nour (111.90 ± 10.13 eggs) followed by Mech Degla (101.00 ± 7.35 eggs) and Ghars (91.70 ± 14.39 eggs) (Table III). Net fertility and fertility rates are lower on the Mech Degla dates (respectively, 41.22± 4.05 and 32.32± 2.35) compared to the other varieties. However, the analysis of the variance (ANOVA) of the gross and net rates of fecundity and fertility of *E. ceratoniae* of the three varieties revealed no significant difference (respectively. P = 0.5658; P = 0.4726; P = 0.3807 and P = 0.2530).

The mean number of eggs per female and per day of the emerged females of the different dates was significantly different (P = 0.0432). This parameter is higher on Mech Degla (36.41 ± 6.82 eggs) and lower on Ghars (21.99 ± 2.95 eggs) (Table III). Furthermore, the number of fertile eggs per female per day was not significantly influenced by the different date varieties (p <0.0777).

DISCUSSION

The study of the relationship between the insect and its host plant using general biological parameters such as development time, weight, and survival is sometimes insufficient. Only the results of a process are observed, depending on the nature of the input: food (Kumbasli, 2005). One of the most important criteria of fruit quality is flavor. The formation of flavor and aroma compounds in fruit is a dynamic process that depends on the volatile substances with continuously synthesized and developed during fruit growth so that the volatile composition changes both qualitatively and quantitatively (Jaddou *et al*., 1984; Reynes *et al*., 1996; Torres *et al*., 1996).

Maier and Metzler (1965) indicated in their study that the various fitness parameters measured provided insights into the biology of immature carob moth development in the various fruit stages present through the growing season in southern California. Compared with field-collected fruit, the artificial diet supported the most rapid development. This diet may have had high amino acid content compared with date fruit or it may lack carob moth growth inhibitors such as simple polyphenols and soluble and insoluble tannins which have been identified in small quantities in Deglet Nour dates.

Al-Izzi and Al-Maliky (1996) found that high levels of tannic acid influenced carob moth larval developmental time, as well as, Al-Izzi *et al*. (1988) discovered that high levels of lysine increased developmental time by as much as 15 d. Nay and Perring (2006) showed a prolonged development, increased mortality, and reduced fitness of carob moth when reared on dehydrated fruit. However, our results show that the larvae fed by Deglet Nour and *MechDegla* dates have higher relative intake rates than those fed on Ghars dates. This is mainly due to the amount of food consumed and the duration development cycle that seems longer in larvae fed by dates Ghars. Thus, the ingestion rate decreases as the duration of the development cycle increases (Gremare and Amouroux, 1988). Also, Guidi (1986) reported that the decrease in ingestion rates with the duration of the experiments can be caused either by intermittent nutrition or by a depletion of the food source. The weight of the feces of the larvae fed on the Ghars and Mech Degla varieties is less important than that of the Deglet Nour variety. This difference was related to the high digestibility rate (DA) in Ghars and Mech Degla varieties compared to the Deglet Nour variety. The low conversion efficiency of ingested food (ECI) and digested food (ECD) in larvae fedonDeglet Nour and Mech Degla varieties compared to those grown on the Ghars variety can be explained by the low water content of dates.

Abedi *et al*. (2019) mentioned that insects fed on the Shahvare-Danesefid pomegranate cultivar as host plant were displayed the fastest development and immature survival rate and nutritional performance that appears as a consequence of the higher richness of the cultivar studied bybiochemical metabolite.

The influence of the nutritive quality of the host plant on the demographic parameters and certain biological aspects characteristic of *E. ceratoniae* have been demonstrated by several studies carried out on dates, pomegranates, pistachios and figs (Norouzi *et al*., 2008), in maize as artificial feed and almond (Navarro *et al*.,

1986; Hung *et al*., 2003; Ghavami, 2006), the date (Nay and Perring, 2006) and the pomegranate (Yousefi and Ghanbari, 2002).

The low weight of L2, L3, L4 larvae on Ghars can be explained by the consistency very soft fruit which does not allow sufficient food intake for the larvae which induces a weak development, on the other hand the dates of the variety Mech Degla and Deglet Nour, which are dry and semi-soft in consistency, have a high weight of larvae. The reduction in weight of the adults on the three varieties is mainly due to a larval transformation to give new adults, the decrease in weight allows the stolen power adult.

The results of the present study show the obvious effects of different diets on the development time, survival, fecundity and growth of the date moth.

Regarding the duration of development of the different stages.we found no significant difference in the egg incubation period (3.76 to 3.88 days) between the three varieties. These results,are in part, in agreement with Norouzi *et al*. (2008) (3.05 days on date) and Alrubeai (1987) (3.6 days on artificial feeding at 27 ºC). The duration of larval development of the date moth obtained in our study on dates is shorter than that recorded by Norouzi *et al*. (2008) (72.9 days on the Zahedi date).

The duration of the pupal stage of *E. ceratoniae* on different varieties of dates is similar to that observed by Norouzi *et al*. (2008); Also, adults emerged from Deglet Nour and Ghars dates showed a longevity close to that observed by Norouzi *et al*. (2008) on the Zahedi date (dry date).

All the biological parameters that we have studied tell us about the survival and reproductive potential of *E. ceratoniae* which form the basis of population growth (Mehaoua, 2015). Thanks to this study, we are able to determine the population dynamics of the pest insect on different host varieties and use this information to manage the pest population below the level of economic harm.

CONCLUSION

Regarding the study of nutritional gravitational indices of the date moth.the quantity of food ingested as a function of the most important time is recorded in the larvae fed by the two Deglet Nour and Mech Degla varieties compared to those fed by the variety of Ghars. On the other hand, the larvae fed by the two varieties Mech Degla and Ghars have assimilated a larger portion of food than the ones fed by the variety Deglet Nour. Regarding the index of the conversion efficiency of the digested and ingested food was always higher for the larvae fed by the variety Ghars and lower for the variety Mech Degla. However.the highest relative rate of growth as a function of time was recorded for larvae fed on the Deglet Nour variety.

Understanding the life history of the population of *E. ceratoniae* requires obtaining reliable estimates of the main demographic parameters on these main host plants in the Biskra region. With this in mind, we have highlighted the influence of the nutritional quality of dates from three date palm cultivars (Deglet Nour. Mech Degla and Ghars) on the biological parameters of the date moth. We measured the average incubation time of the eggs and calculated the fecundity and fertility rates which do not seem to be affected by the nutritional quality of the dates of the three varieties. While the average length of the life cycle, is shorter in Deglet Nour and Mech Degla dates.

ACKNOWLEDGEMENT

The authors gratefully thank the Department of Agriculture Science, the University of Biskra, Algeria for suporting the research project.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

IRB approval

The scientific committee at the Department of Nature and Life Sciences of the University of Biskra has approved that all efforts were taken to minimize pain and discomfort to the animal while conducting these experiments.

Availability of data and materials

All data generated or analyzed during this study are included in thispublished article.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFRENCES

Abedi, Z., Golizadeh, A., Soufbaf, M., Hassanpour, M., Jafari-Nodoushan, A., and Akhavan, H.R., 2019. Relationship between performance of carob moth, *Ectomyelois ceratoniae* Zeller (Lepidoptera: Pyralidae) and phytochemical metabolites in various pomegranate cultivars. *Front. Physiol.,* **10**: 1425. https://doi.org/10.3389/fphys.2019.01425

Al-Farsi, M., Alasalvar, C., Al-Abid, M., Al-Shoaily, K., Al-Amry, M., and Al-Rawahy, F., 2007. Compositional and functional characteristics of dates, syrups, and their by-products. *Fd.*

Chem., **104**: 943-947. https://doi.org/10.1016/j.foodchem.2006.12.051

Al-Izzi, M.A., Al-Mallky, S.K., and Jabbo, N., 1988. Effect of supplemental dietary l-lysine and soybean flour on growth and fertility of *Ectomyelois ceratoniae* Zeller (Lepidoptera: Pyralidae). *J. econ. Ent.,* **81**: 970-972. https://doi.org/10.1093/jee/81.3.970

Al-Izzi, M.A., and Al-Maliky, S.K., 1996. Action of tannic acid on consumption and utilisation of food by *Ectomyelois ceratoniae* Zeller (Lepidoptera: Pyralidae). *J. Stored Prod. Res.,* **32**: 195-199. https://doi.org/10.1016/S0022-474X(96)00025-2

Alrubeai, H.F., 1987. Growth and development of Ectomyelois ceratoniae (Lepidoptera: Pyralidae) under laboratory mass-rearing conditions. *J. Stored Prod. Res.,* **23**: 133-135. https://doi.org/10.1016/0022-474X(87)90039-7

Al-Shahib, W., and Marshall, R.J., 2003. The fruit of the date palm: Its possible use as the best food for the future? *Int. J. Fd. Sci. Nutr.,* **54**: 247-259. https://doi.org/10.1080/09637480120091982

Bauce, É., Bérubé, R., Carisey, N., and Charest, M., 2001. *La tordeuse des bourgeons de l'épinette*. Acquisition et transfert de connaissances au laboratoire d'entomologie forestière de l'Université Laval, pp. 176.

Carey, J.R., 1993. *Applied demography for biologists with special emphasis on insects*. Oxford University Press.

Dadd, R., 1977. *Qualitative requirements and utilization of nutrients: Insects nutritional requirements* (USA).

Dadd, R., 1985. Nutrition: Organisms. *Compr. Insect Physiol. Biochem. Pharmacol.,* **4**: 313-390. https://doi.org/10.1016/B978-0-08-030805-0.50014-6

Ghavami, S., 2006. Effects of three artificial diets on biological characteristics of the carob moth, *Ectomyelois ceratoniae* (Lep.: Pyralidae). *J. entomol. Soc. Iran,* **25**: 63-76.

Gremare, A., and Amouroux, J., 1988. Etude expérimentale des taux d'ingestion et de métabolisme de Eupolymnia nebulosa: Influence de l'état de maturation sexuelle. *Oceanol. Acta,* **11**: 299-305.

Guidi, L., 1986. The feeding response of the epibenthic amphipod Siphonoecetes dellavallei Stebbing to varying food particle sizes and concentrations. *J. exp. Mar. Biol. Ecol.,* **98**: 51-63. https://doi.org/10.1016/0022-0981(86)90075-4

Hadjeb, A., Mehaoua, M.S., Bensalah, M.K., Lebbouz, I., and Ouakid, M.L., 2017. Effects of the allelochemical compounds of the deglet nour date on the attractiveness of the caterpillars of *Ectomyelois ceratoniae* (Lepidoptera: Pyralidae). *World J. environ. Biosci.,* **6**: 7-12.

Hung, C., Chiang, B., and Wang, W., 2003. Development and fecundity of the Carob moth, *Apomyelois ceratoniae*, reared on different foods and its eclosion, mating, and ovipositing behavior. *Pl. Prot. Bull. Taipei,* **45**: 185-198.

Ismail, B., Haffar, I., Baalbaki, R., Mechref, Y., and Henry, J., 2006. Physico chemical characteristics and total quality of five date varieties grown in the United Arab Emirates. *Int. J. Fd. Sci. Technol.,* **4** 919-926. https://doi.org/10.1111/j.1365-2621.2005.01143.x

Jaddou, H., Mhaisen, M., and Al-Hakim, M., 1984. Flavour volatile analysis of Zahdi dates by gas-liquid chromatography (in Iraq). *Date Palm J.*, **3**: 367-379.

Kennedy, J., 1965. Mechanisms of host plant selection. *Annls appl. Biol.,* **56**: 317-322. https://doi.org/10.1111/j.1744-7348.1965.tb01242.x

Kumbasli, M., 2005. *Études sur les composés polyphénoliques en relation avec l'alimentation de la tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana *(Clem.)*.

Maier, V., and Metzler, D., 1965. Quantitative changes in date polyphenols and their relation to browning. *J. Fd. Sci.,* **30**: 80-84. https://doi.org/10.1111/j.1365-2621.1965.tb00267.x

Mehaoua, M.S., 2015. *Abondance saisonnière de la pyrale des dattes (*Ectomyelois ceratoniae *Zeller., 1839), bioécologie, comportement et essai de lutte.* Université Mohamed Khider-Biskra.

Navarro, S., Donahaye, E., and Calderon, M., 1986. Development of the carob moth, *Spectrobates ceratoniae*, on stored almonds. *Phytoparasitica,* **14**: 177-186. https://doi.org/10.1007/BF02980485

Nay, J.E., and Perring, T.M., 2006. Effect of fruit moisture content on mortality, development, and fitness of the carob moth (Lepidoptera: Pyralidae). *Environ. Ent.,* **35**: 237-244. https://doi.org/10.1603/0046-225X-35.2.237

Norouzi, A., Talebi, A.A., and Fathipour, Y., 2008. Development and demographic parameters of the carob moth *Apomyelois ceratoniae* on four diet regimes. *Bull. Insectol.,* **61**: 291-297.

Ogushi, T., 1992. *Resource limitation on insect herbivore populations*. *Effects resource distribution on animal-plant interactions*, pp. 199-241. https://doi.org/10.1016/B978-0-08-091881-5.50011-6

Reynes, M., Lebrun, M., and Shaw, P., 1996.

Identification des arômes de trois variétés de dattes.

SAS, 2002. *The SAS system for Windows*. SAS Institute, Cary. NC.

Slansky, F., and Rodriguez, J.G., 1987. *Nutritional ecology of insects, mites, spiders and related invertebrates*. Wiley.

SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.

Torres, P., Reynes, M., Lebrun, M., and Ferry, M., 1996. *Volatile constituent of dates from* Phoenix dactylifera *grown in Elche*.

Waldbauer, G., 1968. The consumption and utilization of food by insects. *Adv. Insect Physiol.,* **5**: 229-288 Elsevier. https://doi.org/10.1016/S0065-2806(08)60230-1

Watt, A., Leather, S., Hunter, M., and Kidd, N., 1990. *Population dynamics of forest insects. Intercept.* Andover, Hampshire.

Yousefi, H.J., and Ghanbari, A.A., 2002. *Effect of different temperature on developmental stages of pomegranate neck worm moth* Spectrobates ceratoniae *on laboratory condition*. Proceedings of the 15th Iranian, Plant Protection Congress, pp. 171-172.