Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(4): 305-310

Received: 12-05-2018
Accepted: 13-06-2018

**M hammed Ehsine**
Institute of Arid Regions – kebili, BP 32, 4200, Kebili, Tunisia

**Mohamed Sadok Belkadhi**
Institute of Arid Regions – Kebili, BP 32, 4200, Kebili, Tunisia

**Mohamed Chaieb**
University of Sfax; faculty of Science, BP 802, 3018. Tunisia

**Correspondence**
**M hammed Ehsine**
Institute of Arid Regions – Kebili, BP 32, 4200, Kebili, Tunisia

# Spatial distribution of the rhinoceros beetle on a north African date palm oases, case of Rjim Maatoug south west of Tunisia

**M hammed Ehsine, Mohamed Sadok Belkadhi and Mohamed Chaieb**

**Abstract**
Date palm (*Phoenix dactylifera* L.) is attacked by many insect pests including species of rhinoceros beetles (Coleoptera: Scarabaeidae). Among rhinoceros beetles, the genus *Oryctes* is associated with palm trees and is severe pests of date palm. The rhinoceros beetle, *Oryctes agamemnon* Burmeister (Coleoptera, Scarabaeidae) was accidentally introduced in the southwestern oases of Tunisia where it becomes a serious pest. In the present study, the spatial distribution of *Oryctes agamemnon* in the oases of Rjim Maatoug was examined. Data showed that all these oases are infested by this insect but with a percentage of infestation which varies from 20% to 100%. The oases Rjiim1 and Rjiim2 are the least affected by the *Oryctes*, with 40% and 20% respectively. The others oases showed that all the prospected plots are infested by the pest. The percentage of infested plots by oasis varied between 35 to 100 %. The rates of infected feet and the number of different stadiums by date palm in the plots vary from a geographical location to another inside the oases and from an oasis to another without following a well defined rule. It seems that the average of population per palm tree is not strongly linked to the place of the plots inside the oases.

**Keywords:** *Oryctes agamemnon*, spatial distribution**,** date palm, oasis, percentage of infestation

## Introduction
The date palm (*Phoenix dactylifera* L.) belongs to Arecaceae family and it is considered a symbol of life and agrosystems in the desert, because it tolerates high temperatures, drought and salinity more than many other fruit crops [1]. It is a tree that can grow under conditions of temperature ranging from 12 to 50 °C and can be irrigated with very alkaline water. It has long been one of the most important fruit crops in the arid regions of the Arabian Peninsula, North Africa, and the Middle East [2, 3].

In Tunisia, date palms occur in the southern part of the country (North latitude 34°25`), where the conditions are most favourable for the oasis production. Tunisian date palm plantations are characterized by the prevalence of the variety Deglet Noor in spite of their large phytogenetic diversity valued at 250 different varieties [4]. This variety accounts for 60% of the total production [5]. It regarded as the engine of local and the national economy. Especially that comes in third place at its domestic farm product exports, after olive oil and seafood products [6], allowing the living of about 10% of the population [7]. In addition Palm dates play an important role in the struggle against desertification and it is also a shelter for many indigenous plant and animal species.

Although the effort, to optimize production, date palms are still facing many problems and constraints, that have without any doubt negative impacts on its normal growth and production. Problems such as water stress, excess of salinity, drainage and many diseases and pests. In Tunisia, however, some major pests of date palms are present which are considered serious pests to palm, that have without any doubt negative impacts on their normal growth and production [8]. The mite *Oligonychus afrasiaticus* McGregor. (Acarina: Tetranychidae) affects essentially the fruit [9, 10]. The white scale, *Parlatoria blanchardi* Targ. (Hemiptera : Diaspididae ) colonizes all parts of the tree with the heaviest infestation at the base of the leaves and crown [11]. The larva of the moth, *Ectomyelois ceratoniae* Zeller. (Lepidoptera: Pyralidae) infests the dates internally [8]. Several fungal diseases of date palms are known in Tunisia. *Mycosphaerella tassiana* causes brown spots on midribs, leaflets and thorns. *Diplodia phoenicecum* affects essentially leaves of offshoots and the lethal disease: “Brittle leaf disease” or, in French, “Maladie des feuilles cassantes” (MFC) that affected or killed up to 40,000 date

palm trees in the Djerid region of Southern Tunisia since the 1980s [5].

Actually, a relatively new pest, is assuming alarming proportions: the rhinoceros beetle, root borer, *Oryctes agamemnon* Burm. (Coleoptera: Scarabaeidae) weakens the root system, and renders the trees susceptible to fall off [12-15]. *Oryctes agamemnon* was accidentally introduced in the south-western oases of Tunisia, it was identified for the first time in 1995 in Tozeur [12], and introduced to Rjim Maatoug region after the creation of a new oasis [16, 14]. *Oryctes agamemnon*, also, occurs in several countries, including Egypt, the United Arab Emirates (UAE), Oman, Saudi Arabia and the Persian Gulf of Iran [17-20].

In Tunisia, the important damage of the genus is due to the grubs, mainly the third larval instars [13, 14]. Which feed on the roots, and bore into the underground bases and the trunks. Severe damage is inflicted particularly to offshoots and young palms, in which the mortality rates may be very high [14]. In addition, the insect is a univoltine species in this region, their activity starts from late May to early June until the first 10 d of November and the populations peaked once each year generally between the last week of July and the first week of August [15].

Understanding such spatial patterns in agriculture fields can be important for developing effective management programs for insect pests [21, 22]. In this study, the spatial distribution of *O. agamemnon* in the main oasis of Rjim Maatoug was investigated. The primary objective of this study was to determine the infestation state of different oases and whether the infestation and density of different instars of this insect changed from the geographical location of the plots within the oasis and geographical location palm tree within plots.

## Materials and methods

### Study area

This work was completed in the oases of Rjim Maatoug. It is an area which is with 120 kilometers in the south western of kebili city in the south-west of Tunisia (Figure1). It is characterized by a Saharan continental climate, a pluviometry annual average lower than 100 mm, an average temperature of 21 °C with extremes of +55° in summer in the shade and -7 °C in winter, ETP = 2200 to 4300 mm and a very filter sandy soil. Our study concerns all the older oases in this area. They consist of 6 different oases (Table 1), occupying a total surface area of 1452 ha. They are created on both sides along the road connecting Rjim Maatoug to Elmatrouha directed of the East to the West according to the following order: Rjiim1, Rjiim2, Ferdaous1, Ferdaous2, Nasr1 and Nasr 2. Each oasis is divided into parcels or plots.

The creation of this project was started at the beginning with the establishment of two oases which are Rjim1 and Rjim2 by the service of development. The discovery of great potentialities of underground water for irrigation in this zone on the level of the final complex, and the need for development of this area to make settle the population, encouraged the Government to create other oases. It is within this framework that the Office of Development of Rjim Maatoug (ODRM) was created for the management of 2500 ha. It currently manages to create 1152 ha of oases in production which are allotted to the beneficiaries at a rate of 1.5 ha per farmer with a rural housing. The farmers of Rjiim1 and Rjiim2 only profit each one of a plot of 1 ha. The oases were created successively since 1984 while going from the east towards the west as indicated in table 1.

The creation of new oases to achieve the objective of development in this area is under development by the ODRM.

### Study of the rhinoceros beetle infestation of Rjim Maatoug oases

The objective of this study is to comprehend the distribution of infestation by *Oryctes* in the different oases of Rjim Maatoug western south of Tunisia and to determine if the repartition of this attack is influenced by the geographical location of palm date in the parcels or else by the locality of parcels inside the oasis.

To achieve this object, work was based on a weekly prospecting to search the different instars of *oryctes* on palm trees in the oases $R_1$, $R_2$, $F_1$, $F_2$, $N_1$ and $N_2$. The oasis $F_1$ was divided into two entities (Figure1), therefore in this work each entity was regarded as an oasis. The entity which is close to the road in Figure1 was called $F_{1\text{-}1}$. The other entity was called $F_{1\text{-}2}$.

To determine the percentage of the infested parcel in each oasis, we proceeded by a representative sampling of the parcels in each oasis (table 2). To determine the percentage of infestation in each oasis we divided the number of parcels infested in the oasis by all the prospected parcels in the same oasis multiplied by 100. To determine the location of damage in function of the geographical direction of oasis and parcels the sampling was carried in this way. The same number of pieces was randomly selected in each geographical direction (northern, southern, eastern, and western) and in the middle, of each oasis. In each parcel, 20 palm trees were randomly selected at a rate of four date palm in the middle and four feet of each geographical direction of the plot. So, 2300 palm trees were investigated. The Work was completed at the court of the period of June 2006 until August 2007.

### Statistical data processing

Statistical analysis was performed using SPSS 16.0 for Windows. The level of significance alpha set for all tests is 5%. A comparison test of averages two to two (procedure on SPSS: DUNCAN), has been done to make groups within the parameters studied.

## Results and Discussion

### The infestation of Rjim Maatoug oases by *Oryctes*

Investigation in different oases of Rjim Maatoug, ($R_1$, $R_2$, $F_1$, $F_2$, $N_1$ and $N_2$) showed that all these oases were infested by *Oryctes* but with a percentage of infestation which varies from 20% to 100%. The results obtained represented in table 2, show that $R_1$ and $R_2$ were the least affected by the *Oryctes* with an infection rate of 20% and 40% with respectively 3 and 6 parcels infested. The overall number of individual per foot in both oases is respectively 0.04 and 0.0773 individuals. This relatively low infestation in the tow oases could be explained by the fact why, that these two oases were unscathed at the beginning and that the insect was introduced unconsciously by the farmers from the other parcels by the means of the offshoots. Indeed these two oases were the first plantation in this region and created at 1984-1985, before that the problem of infestation by the pest was announced by Khoualdia *et al.* (1997) in the oasis of Mrah Lahouar Governorate of Tozeur. Moreover, the offshoots used to create this two oasis had as origin the oases of Kébili, where the presence of *Oryctes* did not declare until now. Pasek (1988) announced that Insect dispersal is affected by the wind and, influence insect distribution in sheltered areas, or these oases are in a geographical position which disadvantages their infestation by *Oryctes*. They are located at a distance of about

5 km from infested oasis in North East side. Thus, the movement of adults from infested plots to these oases was hampered by the prevailing winds. The other oases ($F_1$, $F_2$, $N_1$ and $N_2$) are infested by *O. agamemnon* with a rate of infestation of 100% (all the prospected parcels are infested by *Oryctes*). So in the follow work we will compare only between the four oases.

The monitoring in different oases showed that the percentage of infestation vary within the same oasis and among the oases. Figure 2 recapitalize the percentage of date palm infestation by *Oryctes* in the different prospected plots by oasis. The smallest rate of infestation was unregistered in the oasis $F_{1\text{-}1}$ with 35% and the highest rate of infestation was 100 % at the level of the oasis $N_1$.

The comparison between percentages of plants infestation by *Oryctes* in the various oases (table 2) showed that there is a significant difference between the degrees of infestation. It make possible to distinguish two groups of oasis from which the rates of infestation are statistically different. A first group more infested formed by the oases $N_1$ and $F_2$ and a second group less infested represented by the oasis $F_{1\text{-}1}$. The oases $N_2$ and $F_{1\text{-}2}$ set up an intermediate group. Data (table 2) showed that the percentages of the infested feet increase by an oasis to another in accordance with the arrangement of oasis (Figure1), from East to West except for the Oasis Nasr 2, which is at the Western end, but it reveals a percentage of infested feet (74,333%) higher than the oasis which is located in the East edge (66%). The highest percentage of the infested plants by *Oryctes* in the various oases was recorded in the $N_1$ with a rate of 80, 75%, whereas the lowest percentage of the infested plants was recorded on the level of entity $F_{1\text{-}1}$ with a rate of 66%. It remarked that the middle oases $N_1$ and $F_2$ were more infested then the oasies in the edge (table 2). Winder *et al.* (1999), Olson et Andow (2008), Luna et Xue (2009) [21, 24, 25], announced that edge effects may exist for insect populations in agricultural fields. In insects, these edge effects could be caused by a variety of factors including host plant distributions, oviposition sites, predator or natural enemy distributions, microclimates, and windbreaks [26, 22, 25]. In this area, the wind prevailing comes from the direction North-East, it seems that the gradient of infestation which increases through an oasis to another from the East towards the West is in close relationship to a flow movement of the adults under the action of the wind.

**The geographical distribution of the infestation**

The Statistical analysis carried out on percentages of the infested feet by *Oryctes* in the various prospected parcels according to their implantation in different geographical directions of the oases (table 3) shows that for the oasis Nasr 1 the highest percentage of infected feet has been recorded in the parcels of the western side with 93.75%, while the lowest percentage of infected feet was recorded in plots of north side. This distribution may be influenced by the starting state of infestation or by introducing a population of *Oryctes* which is dragged by the wind blowing in the direction of that side. In addition, the low percentage recorded on the north side would be the result of a problem of hydromorphy and salinity prevailing in the plots on this side. Indeed, it was found that the rate of infection generally decreases in the presence of these problems in most cases. This concurs with the studies of Turner (1989) [27], who announced that landscape structure and dynamics influence ecological processes (e.g., population dynamics, spatial distribution) of the organisms living in the landscape.

In the case of the oasis Nasr 2 we note that the East and the North directions represented the higher rate of infestation presenting significant differences with the other groups. The difference between the rates of infestation may be due to the starting state of infestation. For the other oases, we note that the infestation by *Oryctes* is homogenous in the different parcels of each oasis.

Concerning the average of *Oryctes* population per feet in function of the location of parcels inside the oasis (table 4) we discern that in the case of the oases $F_{1\text{-}1}$and $N_2$, statistical analysis shows that the average of population per palm tree in the various pieces is not influenced by the geographical position of the parcels inside the oasis. Whereas in the other oases; $N_1$, $F_{1\text{-}2}$ and $F_2$, the average of the populations per feet varies according to the place of the parcels on the level of the oasis. For the oasis $N_1$, the feet of the pieces of the medium are populated by *Oryctes* with a median number of 2,775 individuals per feet. The least infested feet are located in the pieces of with dimensions North. In the case of the oases $F_{1\text{-}2}$ and $F_2$, the feet of the medium parcels are more infest. We note; also; that the higher average of *Oryctes* individuals per foot was recorded at the level of the different parcels of $F_2$ in the different direction inside the oasis.

Caughley (1979) [28] announced that the distribution patterns of species are rarely uniform and continuous in space and time. A wide range of factors influence the distribution of plants and animals and many of these operate at different spatial and temporal scales. They include abiotic processes, biologically mediated processes, and processes dominated by biotic interactions [29]. In this study it seemed that the average of population per palm tree is not strongly linked to the place of the pieces inside the oases. Even the differences recorded in oases do not follow a well defined general rule. Thus, it is probable that these differences are rather related on the starting state of infestation and the operations of maintenance undertaken by the farmer in their farm.

The comparison of the population averages of *Oryctes* per feet in the various prospected parcels in different oases (Table 5) showed that there is a significant effect between the oases. Indeed the oasis $F_2$ is distinguished from the other oases by the highest average of individuals by plant. The comparisons of the averages explain a significant difference between that of this oasis and those of the others with an average value which slightly exceeds the double of the other oases. This difference between the average of individuals per feet between $F_2$ and the other oases can be explained by the existence of the partners of manual collection of various biological stages of the insect which are refunded by the interprofessional grouping of vegetables. This oasis was indeed prospected before the starting of the operation of the manual collection of different instars *Oryctes* (operation organized and financed by the Interprofessional Grouping of the Fruits). Thus we can deduce from this result the importance of the manual collection in the reduction of the populations of this pest in the palm plantations. This showed that the manual collection contributes in the reduction of *Oryctes* population of more than 50% and thus will be able to constitute a principal component in any program of fight integrated against this pest.

**Table 1:** Creation dates, surfaces and coordinates of the studied oases.

| Oases | codes | Year of creation | surface (ha) and coordinates |
|---|---|---|---|
| Rijim1 | $R_1$ | 1984-1985 | **96** (33° 19' 508'' N and 8° 01' 828'' E) |
| Rijim2 | $R_2$ | 1984-1985 | 104 (33° 20' 103'' N and 8° 01' 153'' E) |
| Ferdaous1 | $F_1$ | 1993 | 360 (33° 17' 982'' N and 8° 00' 672'' E) |
| Ferdaous2 | $F_2$ | 1994 | 360 (33° 19' 321'' N and 7° 57' 309'' E) |
| Nasr1 | $N_1$ | 1990-1991-1992-1993 | 288 (33° 19' 232'' N and 7° 55' 784'' E) |
| Nasr2 | $N_2$ | 1995 | 144 (33° 19' 34'' N and 7° 54' 174'' E) |

**Table 2:** Percentage of infested plots and trees in different oases.

| Oases prospected plots | | % of infestation plots comparison of % of infested plants | |
|---|---|---|---|
| $R_1$ | 15 | 40% | - |
| $R_2$ | 15 | 20% | - |
| $F_{1.1}$ | 15 | 100% | 66,000 b |
| $F_{1.2}$ | 15 | 100% | 72,666 ab |
| $F_2$ | 20 | 100% | 76,500 a |
| $N_1$ | 20 | 100% | 80,750 a |
| $N_2$ | 15 | 100% | 74,333 ab |
| In a column, number followed by common letter(s) is not significantly different at the 5% levels | | | |

**Table 3:** Comparison of percentages of infested feet by *Oryctes* per parcel in function of geographical direction within various oases.

| | $N_1$ | $N_2$ | $F_{1-1}$ | $F_{1-2}$ | $F_2$ |
|---|---|---|---|---|---|
| South | 78,75ab | 75ab | 63,33a | 73,33a | 71.25a |
| North | 67,5b | 85a | 70a | 70a | 73.55a |
| East | 77,5ab | 83,33a | 60a | 83,33a | 77.5a |
| West | 93,75a | 68,33ab | 73,33a | 68,33a | 78.75a |
| Middle | 86,25ab | 60b | 63,33a | 68.33a | 81.25a |
| In a column, number followed by common letter(s) is not significantly different at the 5% levels | | | | | |

**Table 4:** comparison of population means of *Oryctes* per foot per parcels according to the direction inside the various oases

| | $N_1$ | $N_2$ | $F_{1-1}$ | $F_{1-2}$ | $F_2$ |
|---|---|---|---|---|---|
| Sud | 1,850b | 2,133a | 1,750a | 2,13b | 3,275b |
| Nord | 1,550b | 1,833a | 1,683a | 2,08b | 5,125ab |
| Est | 1,887b | 2,100a | 2,450a | 4,01a | 6,987a |
| Ouest | 2,112b | 1,700a | 2,566a | 2,08b | 3,237b |
| Milieu | 2,775a | 1,366a | 2,566a | 2,08b | 4,112b |
| In a column, number followed by common letter(s) is not significantly different at the 5% levels | | | | | |

**Table 5:** comparison of population means of *Oryctes* by foot in the various parcels surveyed by Oasis

| | Nombre moyen d'individus |
|---|---|
| $N_1$ | 2,0525b |
| $N_2$ | 1,8267b |
| $F_{1-1}$ | 2,103b |
| $F_{1-2}$ | 2,406b |
| $F_2$ | 4,552a |
| In a column, number followed by common letter(s) is not significantly different at the 5% levels | |

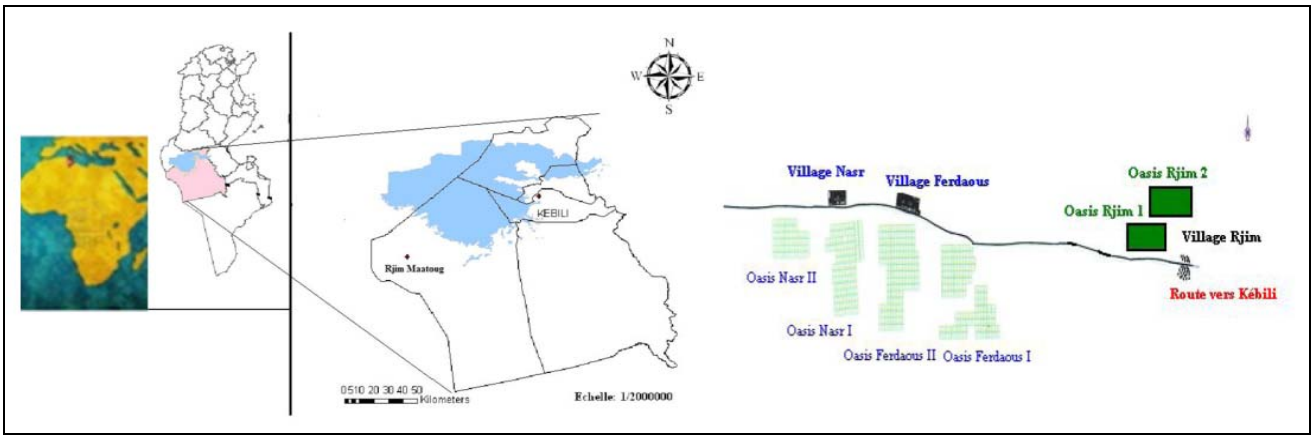
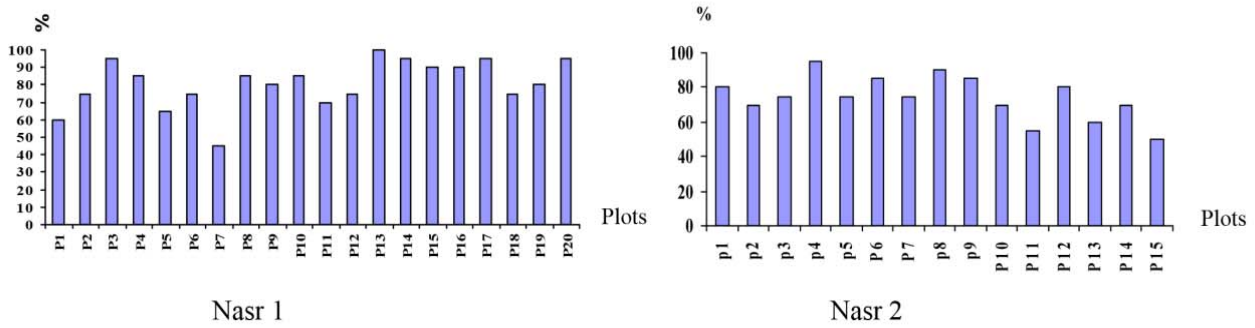



**Fig 1:** The geographic location study area and the arrangement of the oases in this area



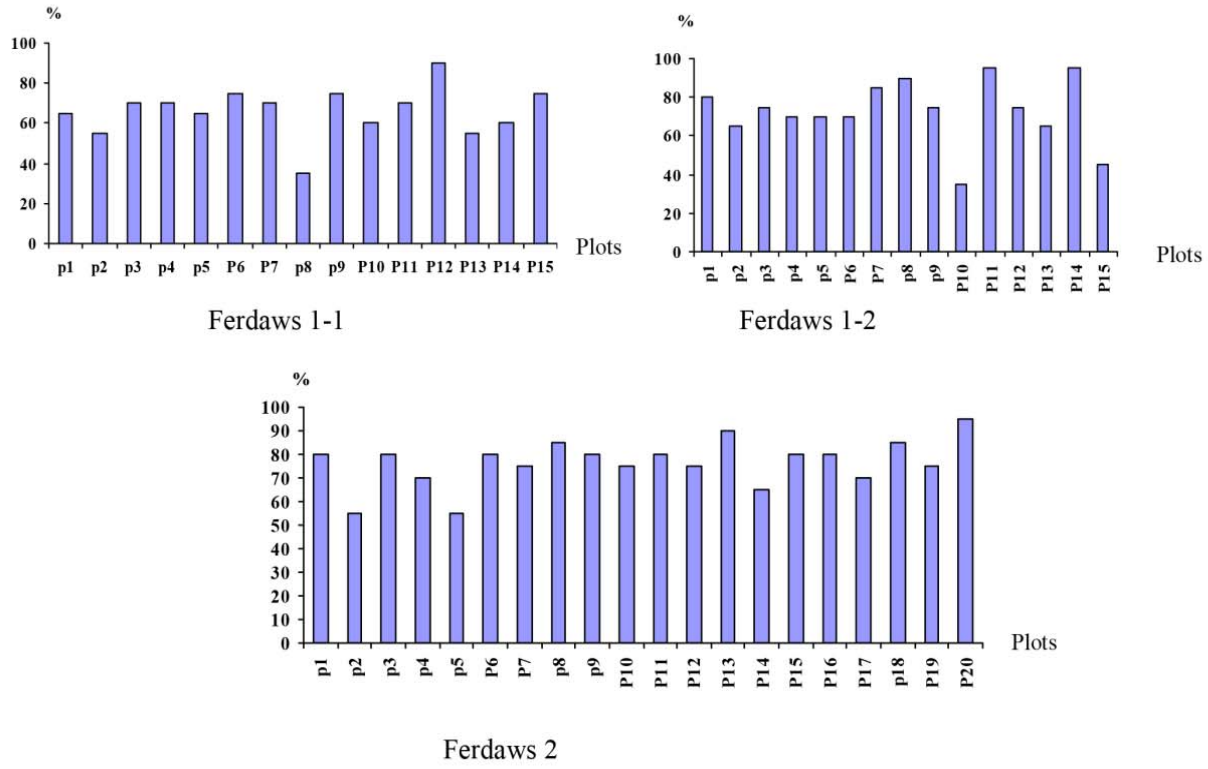



**Fig 2:** the percentage of plants in festation in different prospected plots

## Conclusion

It may be concluded from the present study that the different oases of Rjim Maatoug are infested by *Oryctes* but with a percentage of infestation which varies from 20% to 100% with the least percentage at the level of Rjiim2 and Rjim 1 with respectively 20 and 40%. Whereas, other oases are 100 % infested. It seems that the average of population per palm tree is not strongly linked to the place of the pieces inside the oases. Even the differences recorded in oases do not follow a well-defined general rule. The spatial pattern of *Oryctes* in the oasis of Rjm Maatoug was affected by environmental characteristics, such as the presence of hydromorphy, the starting state of infestation and also by the operations of maintenance undertaken by the farmer in their plots.

The monitoring shows that manual collection of various biological stages of the insect helps in reducing the population of the pest and it can constitute a major component in any Integrated Pest Management programs against this pest.

## References

1. Lunde P. A History of Dates. Saudi Aramco World. 1978; 29(2):176-179.
2. Chao CCT, Krueger RR. The date palm (*Phoenix dactylifera* L.): Overview of biology, uses and cultivation. Horticulture Science. 2007; 42:1077-1082.
3. El Hadrami A, Al-Khayri JM. Socioeconomic and traditional importance of date palm. Emirates Journal of Food and Agriculture. 2012; 24(5):371-385.
4. Hammadi H, Vendramin GG, Ali F. Microsatellite diversity among tunisian date palm (*Phoenix dactylifera* L.) subpopulations. Pakistan Journal of Botany. 2011; 43(2):1257-1264.
5. Triki MA, Zouba A, Khoualdia O, Ben Mahamoud O, Takrouni ML, Garnier M *et al* "Maladie des Feuilles Cassantes" or Brittle Leaf Disease of Date Palms in Tunisia: biotic or abiotic disease? Journal of Plant Pathology. 2003; 85:71-79.
6. El-Juhany LI. Degradation of date palm trees and date production in Arab countries: causes and potential rehabilitation. Australian Journal of Basic and Applied Sciences. 2010; 4(8):3998-4010.
7. Karim K, Chokri B, Amel S, Wafa H, Rachid H, Nouredine D. Genetic diversity of Tunisian germplasm using ISSR markers. International Journal of Botany. 2010; 6(2):182-186.
8. Haouel S, Mediouni-Ben Jemâa J, Khouja ML. Postharvest control of the date moth *Ectomyelois ceratoniae* using eucalyptus essential oil fumigation. Tunisian Journal of Plant Protection. 2010; 5:201-212.
9. Ben Chaabene S, Chermiti B. *Oligonychus afrasiaticus*. Seasonal abundance and life history of the old world mite in various date palm cultivars in Segdoud Oasis, south Tunisia. African Journal of Plant Science and Biotechnology. 2010; 4:59-63.
10. Chaaban SB, Chermiti B, Kreiter S. Comparative demography of the spider mite, *Oligonychus afrasiaticus*, on four date palm varieties in southwestern Tunisia. Journal of Insect Science. 2011; 11:136 (www.insectscience.org/11.136).
11. Khoualdia O, Rhouma A, Hmidi MS. Contribution to the bioecological study of the white scale Parlatoria blanchardi. Targ (Homoptera: Diaspididae) of date palm in Djerid (southern Tunisia). Annales de l'Institut National de la Recherche Agronomique de Tunisie. 1993; 66:89-108.
12. Khoualdia O, Rhouma A, Marro JP, Brun J. Premières observations sur *Oryctes agamemnon*, ravageur du palmier dattier en Tunisie. Fruits. 1997; 52(2):111-115.
13. Soltani R, Ikbel C, Ben Hamouda M. Descriptive study of damage caused by the rhinoceros beetle, Oryctes

agamemnon, and its influence on data palm oases of Rjim Maatoug, Tunisia. Journal of Insect Science. 2008a; 8(57):11.
14. Ehsine M, Belkadhi MS, Chaeib M. Bio-ecologic Observations on Rhinoceros Beetle *Oryctes agamemnon* (Burmeister 1847) on the palm Dates Oasis of rjim Maatoug in South-western Tunisia. Journal of arid Land Studies. 2009; 19(1):379-382.
15. Ehsine M, Belkadhi MS, Chaieb M. Seasonal and Nocturnal Activities of the Rhinoceros Borer (Coleoptera: Scarabaeidae) in the North Saharan Oases Ecosystems. Journal of Insect Science (Online). 2014; 14(1):5
16. Soltani R, Chaieb I, Ben Hamouda MH. Life cycle of the root borer, *Oryctes agamemnon*, under laboratory conditions. Journal of Insect Science. 2008b; 8(61):6.
17. Bedford GO. Biology, ecology and control of palm rhinoceros beetles. Annual Review of Entomology. 1980; 25:309-339.
18. Hallet RH, Perez AL, Gries G, Gries R, Pierce JrHD, Yue J *et al*. Aggregation pheromone of coconut rhinoceros beetle, *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae). Journal of Chemical Ecology. 1995; 21:1549-1570.
19. Rochat D, Mohammadpoor K, Malosse C, Avand-Faghih A, Lettere M, Beauhaire J *et al*. Male Aggregation Pheromone of Date Palm Fruit Stalk Borer *Oryctes elegans*. Journal of Chemical Ecology. 2004; 30:387-407.
20. Bedford GO. Biology and management of palm dynastid beetles: recent advances. Annual Review of Entomology. 2013; 58:353-372.
21. Winder L, Perry JN, Holland JM. The spatial and temporal distribution of the grain aphid *Sitobion avenae* in winter wheat. Entomologia Experimentalis et Applicata.1999; 93:277-290.
22. Thomas CFG, Parkinson L, Griffiths GJK, Garcia AF, Marshall EJP. Aggregation and temporal stability of carabid beetle distributions in field and hedgerow habitats. Journal of Applied Ecology.2001; 38:100-116.
23. Pasek JE. Influence of wind and windbreaks on local dispersal of insects. Agriculture, Ecosystems & Environment. 1988; 22-23:539-554
24. Olson D, Andow D. Patch edges and insect populations. Oecologia. 2008; 155:549-558.
25. Luna JM, Xue L. Aggregation behaviour of western spotted cucumber beetle (Coleoptera: Chrysomelidae) in vegetable cropping systems. Environmental Entomology. 2009; 38:809-814.
26. McKone MJ, McLauchlan KK, Lebrun EG, McCall AC. An edge effect caused by adult corn-rootworm beetles on sunflowers in tallgrass prairie remnants. Conservation Biology. 2001; 15:1315-1324.
27. Turner MG. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics. 1989; 20:171-197.
28. Caughley G. The analysis of vertebrate populations. John Wiley and Sons, London.1979, 234.
29. Mackey BG, Lindenmayer DB. Towards a hierarchical framework for modelling the spatial distribution of animals. Journal of Biogeography. 2001; 28(9):1147-1166.