

Red Palm Weevil *Rhynchophorus ferrugineus* in Tunisia: Current Status, Distribution Patterns, and Management Implications

Saida Slimane Kharrat¹, Hamadttu Abdel Farag El-Shafie^{2*}, Jose Romeno Faleiro³

¹Dep. of Life Sciences, University of Carthage, Faculty of Sciences Bizerte, 7021 Tunisia.

²International Center for Agricultural Research in the Dry Areas (ICARDA), Dubai, UAE

³Arlem-Raia, Salcette, Goa, India

ABSTRACT: The red palm weevil, *Rhynchophorus ferrugineus* (Olivier) was first reported in Carthage, Tunisia in 2011 on Canary Islands palm *Phoenix canariensis*. Since this initial discovery, the adults of this pest started to spread, invading greater Tunis, La Marsa, La Guoulette, El Kram, Tunis city downtown. By the end of 2014, all the canary palms located in the regions of Greater Tunis were highly infested. From 2011 to 2023 RPW has invaded the Northeast region of Tunisia. Tunis, Ariana, Ben Arous, Manouba, Nabeul, Bizerte and Zaghouan. In 2024 RPW has invaded the Central East region of Tunisia, Bouficha, Sousse. In 2024, RPW has invaded the Northwest region of Tunisia, Mejez El Bab and Guebollat, Beja, Tunisia. The RPW is still confined to Canary Island palms and has not been reported on the date palm oases in the south. This article highlights the current situation of RPW in Tunisia. The origin of the RPW population in Tunisia, the evolution of infestation on the Canary Islands palms, the impact of indigenous entomopathogenic fungi on the population development, and future management strategy are discussed.

KEYWORDS: *Phoenix canariensis*, red palm weevil, entomopathogenic fungi, mass trapping, management

INTRODUCTION

Globally, the red palm weevil (RPW), *Rhynchophorus ferrugineus* (Olivier) invaded over 60 countries with Bulgaria, Republic of Georgia, Djibouti and Uruguay recently been invaded (Faleiro and El-Shafie, 2024). RPW is an oligophagous pest with more than 40 hosts, mostly palms and a few other plant species such as sugar cane. Out of these 40 hosts, date palm *Phoenix dactylifera*, coconut palm *Cocos nucifera*, oil palm *Elaeis guineensis*, and Canary Islands palm *Phoenix canariensis* are the most infested by the RPW with Canary Island palm and date palm preferable than other palms (Rugman-Jones et al., 2017). In coconut and date palm, infestation usually occurs in young palms less than 20 years old. In the Canary Island palm, infestation occurs in the crown of both young and old palms. The RPW was first discovered in Tunisia in 2011 on an imported *P. canariensis* palms in Carthage (Chebbi, 2011). And within only 4 years after the initial invasion, RPW has destroyed about 35000 Canary Island date palms which is about one third of palms in Tunis area (Rugman-Jones et al., 2017). This ornamental palm is well known for its environmental, ecological, and aesthetic values worldwide (Ijaz and Babar, 2020; Guerfali et al 2024). In Tunisia, this palm is extensively planted in landscape including parks, roadsides, and recreation sites. The RPW is only threatening the existence of Canary Islands palm, but the date palm which contribute largely the livelihood of large numbers of small farmers (~50,000) in southern region of Tunisia in oases such as Gafsa, Tozeur, Gabès and Kébili (Faleiro et al., 2012). The data on the estimation of damage on *P. canariensis* is scant. The ecological, environmental, aesthetic, and heritage values are difficult to quantify in monetary term. Adding to this damage, the costs of management operations, insecticides, replacement of felled palms may exceed millions of Dollars (Oehlschlager, 2016; Milosavljevic, 2018; Hoddle et al., 2024). The costs for transplanting mature *P. canariensis* to replace palms killed by *R. palmarum* in California may exceed US\$5,000 per palm (Hoddle and Hoddle, 2017). Palm trees, particularly *Phoenix canariensis*, are part of the landscape heritage of many Tunisian cities including greater Tunis, Carthage, El Kram, La Soukra, La Guoulette, Ariana, Manouba, Ben Arous, Bizerte, Nabeul, Zaghouan, etc., and Sousse (Guerfali et al., 2024). The Date palms in the oases are at high risk of being invaded by the RPW, unless strict enforcement of quarantine regulations is put in place. Many reports state that the RPW infestation is only confined to northern and Northwest of Tunisia, where infestation was discovered, and the date palm oases are still free of any infestation. Since the detection of RPW in Tunis during 2011, Tunisian authorities have been concerned and implemented several initiatives involving national and international organizations. The first FAO mission on RPW visited Tunis during February, 2012 to assess the situation, propose a control strategy and build national capacities. This was followed by a FAO regional Technical Cooperation Program (TCP) for the control of RPW in North Africa. The International

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Conference on RPW organized in Tunis in May 2017 recommended the introduction of new techniques that could make RPW management more effective. Techniques like attract and kill, RPW repellents (push-pull), service-less and smart traps, and GIS based management programs if efficacious and cost effective under Tunisian conditions, should be adopted by the Tunisian RPW containment and eradication program.

This article aims to give insights into the current situation of RPW infestation in Tunisia, fourteen years after the first invasion in 2011, and the possible reasons behind the confinement of infestation predominantly on *P. canariensis*.

POPULATIONS ORIGIN OF RPW AND INVASION HISTORY

Many sites in the big Tunisian cities are threatened with sudden extinction of palms caused by the red palm weevil (RPW), *Rhynchophorus ferrugineus*, a pest that was discovered in Canary palms in Carthage in 2011 from imported palm trees (Kharat et al., 2018). Uncertainty over the identity of the weevil population in Tunisia led to conflicting speculation that the source populations emerged from infested palms illegally imported from either the USA or Italy. Mitochondrial haplotypes of specimens collected at multiple sites around Tunis were compared with haplotypes from global populations of *R. ferrugineus* and *R. vulneratus*, confirming that the Tunisian populations were *R. ferrugineus*. Moreover, the Tunisian populations had the same fixed mitochondrial haplotype ubiquitous in invasive populations throughout the Mediterranean Basin, and Rugman-Jones et al (2017) concluded that the Tunisian populations most likely originated from infested palms imported from Europe, and not from palms imported from the USA.

Following a complaint received in December 2011 at the Carthage Town Hall in Tunis, the competent services of the General Directorate for the Protection and Quality Control of Agricultural Products, namely the Quarantine specialists, went to the site, investigated the issue, and established a diagnosis process. Their initial observations among the hundreds of ornamental palm trees were as follows: 40 Canary palms *Phoenix canariensis* had dried out and the tops of these declining trees had been seriously affected by RPW. Since this initial discovery of the RPW infestation in Carthage, the adults of these pests started to spread, invading greater Tunis, La Marsa, La Guoulette, El Kram, Tunis city downtown. Since the internal quarantine of this species was not strictly enforced and given the high-flying capacity of adults, RPW continued its invasion. The weevil was able to quickly adapt to the local climatic conditions and continued to spread its infestation in the Canary palm trees in the governorate of Ariana, followed by the governorates of Manouba, Ben Arous, Bizerte, Nabeul, Zaghuan and recently Sousse and Beja (Fig.1 and Fig. 2). As a result, by the end of 2014, all the canary palms located in the regions of Greater Tunis were highly infested. More specifically:

- 2015 the RPW attacked the Canary Island palm trees in Bizerte in the Utica region.
- 2016 the RPW invaded Menzel Bourguiba and Tinja.
- 2017 RPW attacked Jarzouna and Northern Bizerte.
- 2019 the RPW arrived at the Cap Bon of Tunisia to infest canariensis palms located in all the regions of Nabeul governorate.
- 2023 The RPW arrived at Zaghuan governorate to attack canary palms in different regions,
- In January 2024 the RPW infested canary palms located in the region of Bouficha, governorate of Sousse located 140 km south of the capital Tunis, it is beside the eastern coast of the country.
- In October 2024 the RPW arrived at Beja Governorate located in Northwest Tunisia and was detected in the Delegation of Mejez Elbab and in the Delegation of Guebollat, in December 2024 fifty canary Palms were dead and cut from the Guebollat region and two dead palms were removed from Mejez ElBab.

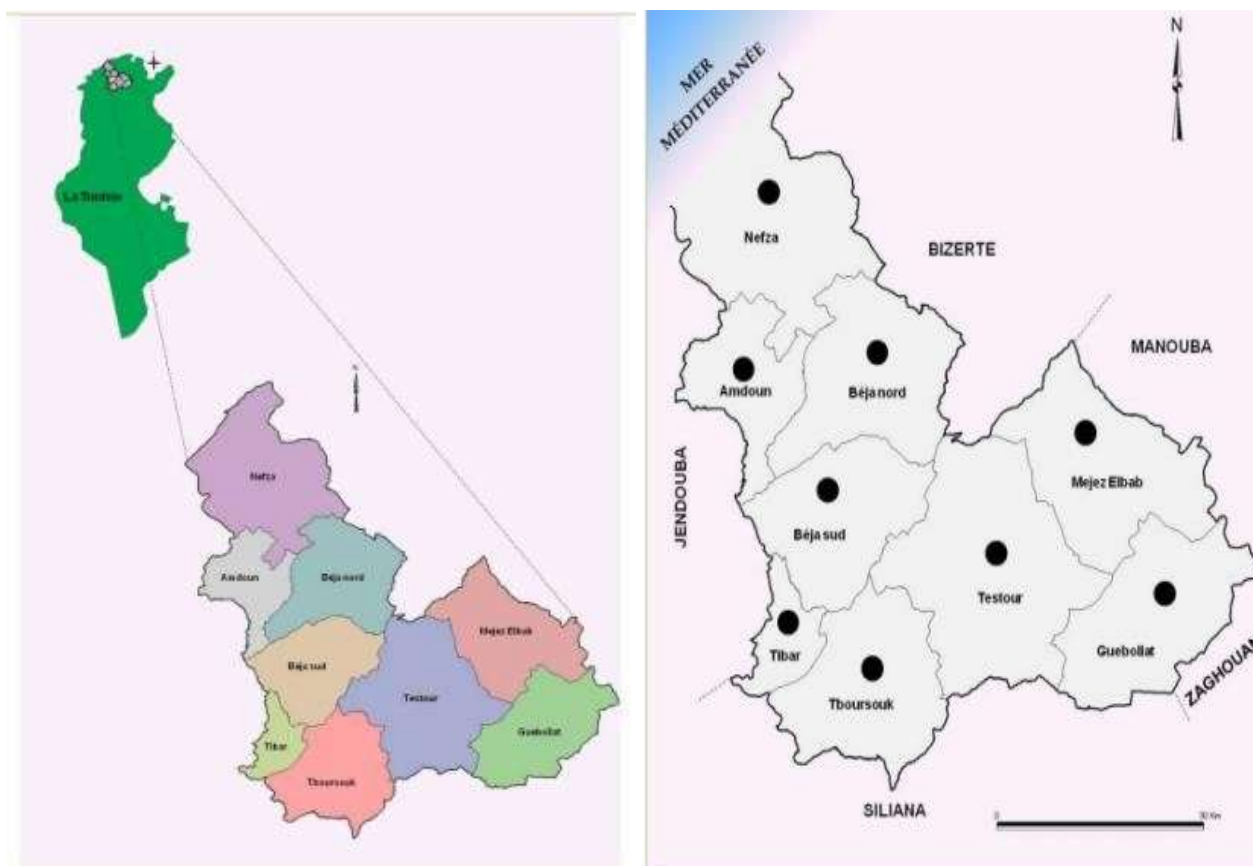


Fig. 1. Location and boundaries of Beja delegations on the map of Tunisia

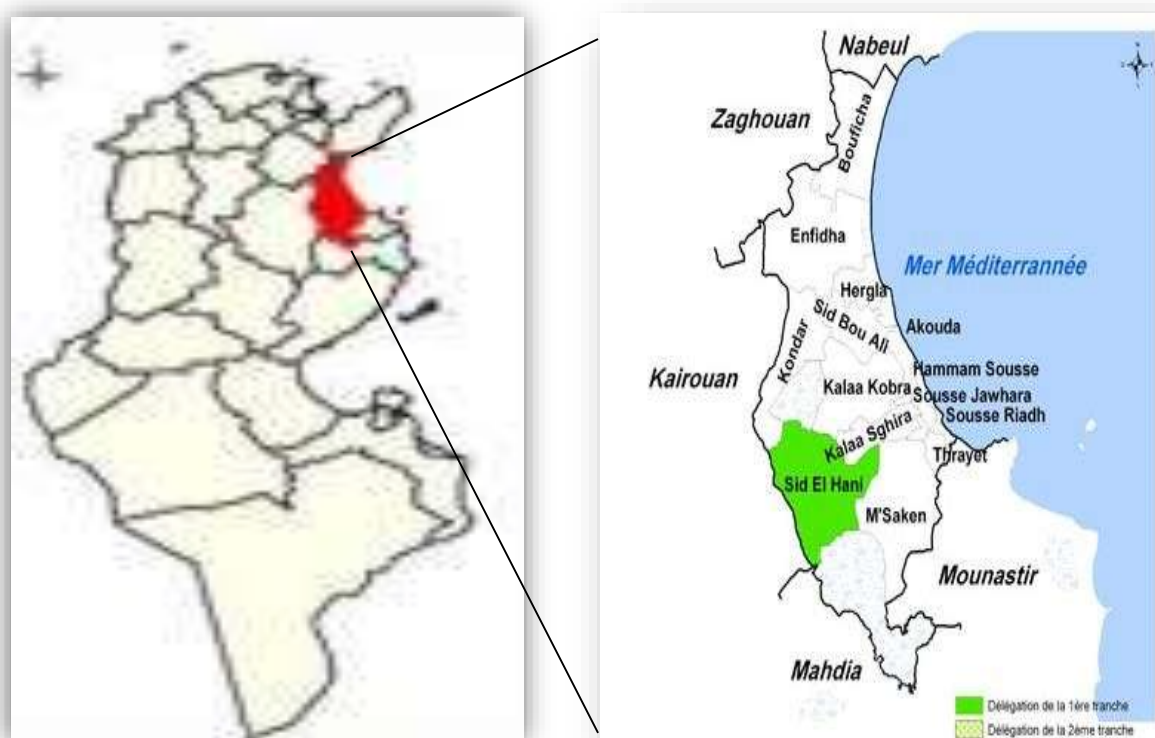


Fig. 2. Location and boundaries of Sousse delegations on the map of Tunisia

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From 2011 to 2023 RPW has invaded the Northeast region of Tunisia. Tunis, Ariana, Ben Arous, Manouba, Nabeul, Bizerte and Zaghouan. The infestation was confined in the Northeast region of Tunisia only, however, in 2024 RPW has invaded the Central East region, Bouficha, Sousse and the Northwest region of Mejez El Bab and Guebollat, Beja (Fig. 3).

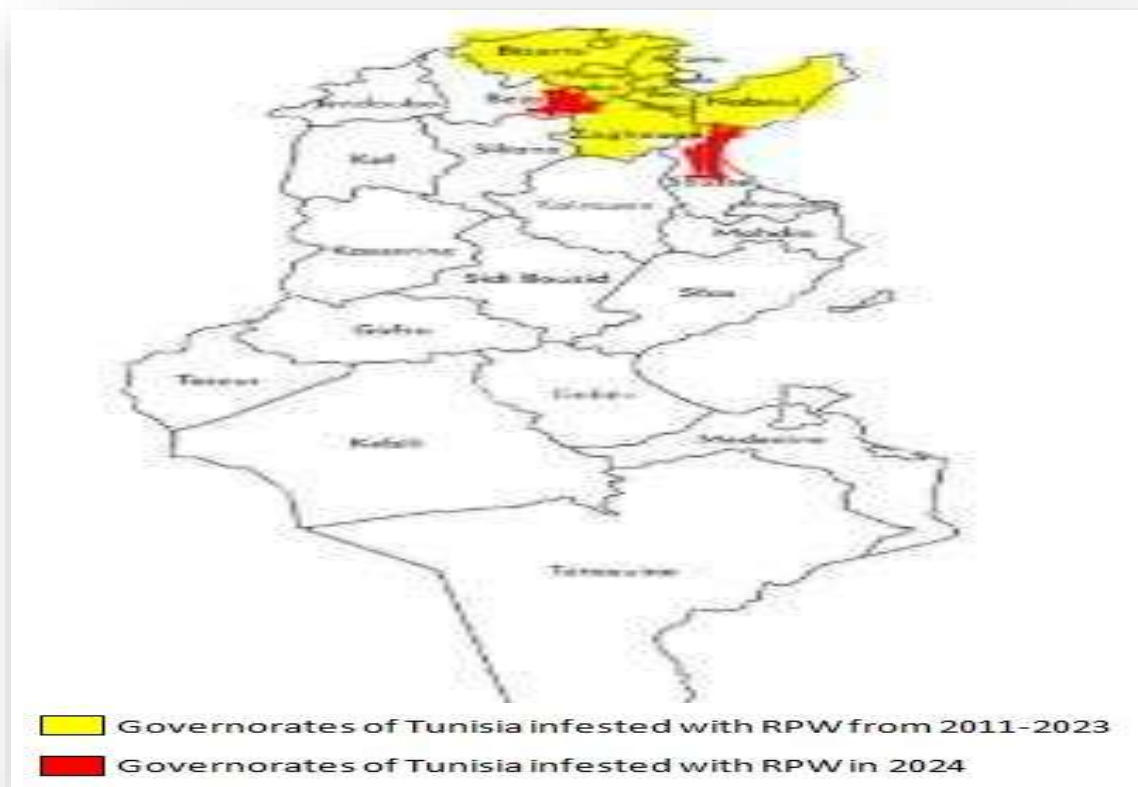


Fig. 3. Dispersal of RPW during the years 2011-2023 and 2024 in Tunisia

DISPERSAL OF RPW FROM THE INITIAL SPOT OF INVASION TO DIFFERENT GOVERNORATES OF TUNISIA

The weevil moved from Carthage to Tunis (11km away) and Ariana (21.4 km) and from Tunis to Ben Arous. The populations found in Manouba and Bizerte came from Ariana. From Ben Arous the weevil moved to Nabeul and Zaghouan. The weevil then invaded Mejez Elbab, Beja in the Northwest of Tunisia. From Nabeul the weevil invaded Bouficha, Sousse which is in the center East region of Tunisia. The distance from Carthage (spot of initial invasion) to Manouba, Ben Arous, Nabeul, and Utique, Bizerte is 28.3, 26.8, 58, and 45 km, respectively. While the distance from Carthage to Hammamet is 82 Km and to Bouficha is 92 km. The distance from the city of Tunis to Guebollat is 68.36 km. From 2011 to 2023 RPW has invaded the Northeast region of Tunisia. Tunis, Ariana, Ben Arous, Manouba, Nabeul, Bizerte and Zaghouan. In 2024 RPW has invaded the Central East region of Tunisia, Bouficha, Sousse. In 2024, RPW has invaded the Northwest region of Tunisia, Mejez El Bab and Guebollat, Beja, Tunisia. The weevil spent 13 years reaching Bouficha which is 92 km far from Carthage, which the weevil was first reported. This means that the annual rate of dispersal was 7 km/year. On the other hand, the rate of dispersal of the weevil to reach Mejez and Guebollat was 4.46 km and 6.10 km, respectively. The average annual dispersal rate of the RPW in Tunisia is 5.85 km. The dispersal rate of the weevil in Saudi Arabia is about 40 km/year (Abdel-Banat and El-Shafie, 2023) suggesting that the anthropogenic activity of moving infested date palm from one place to another is responsible for his high rate compared with natural movement of the weevil. The sequence of RPW movement from Carthage to other governorates of Tunisia is shown in Fig. 4.

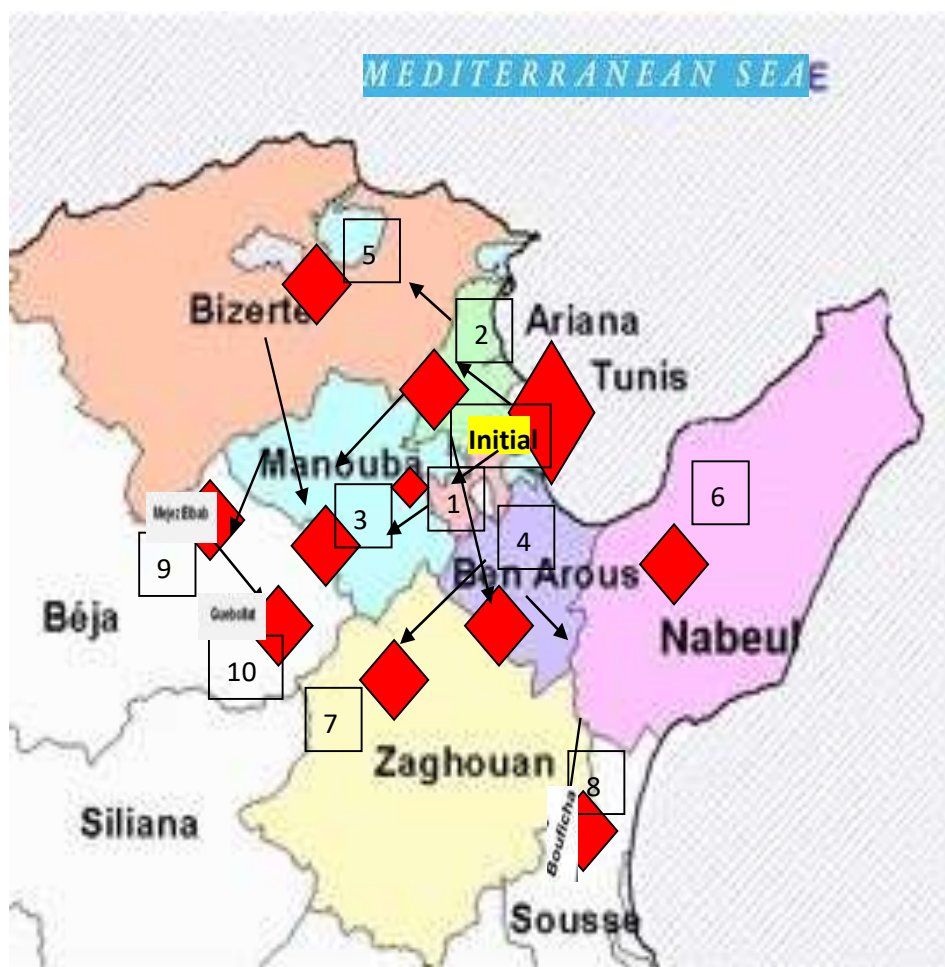


Fig. 4. Sequence of RPW dispersal in the different governorates of Tunisia (2011-2024)

SURVEY AND EVOLUTION OF RPW INFESTATION IN MOHAMED V AVENUE, TUNIS AND JEANNE D ARC PLACE, TUNIS FROM 2016 TO 2025.

The Avenue Mohammed V is one of the most important avenues of Tunis, capital of Tunisia, Named Mohammed V, King of Morocco and measuring about 1.5 km. GPS coordinates:

36.812079°N 10.184429°E. Mohamed V stretches from the Plaza 14 January 2011 to the Plaza Pasteur and contains four lanes, sidewalks, palm rows. The total number of *Phoenix canariensis* palms is 841.

The first red palm weevil infestation appeared in this avenue in February 2016. As immediate action, all the palms were treated with endotherapy twice a year. The first endotherapy with imidacloprid 200 g/l at a rate of 30 g/palm, this application was from March to April 2016 and after six months, the second application with emamectin benzoate 50 g/l at a rate of 60 g/palm was made from September to October.

A survey was conducted to monitor and evaluate the establishment of the infestation in this avenue from February 2016 to April 2025. The survey was made by walking once a month, on the left side of the avenue, from Place Pasteur to Plaza14 January and back on the right side, from Plaza 14 January to Place Pasteur. Palms were visually searched for signs of RPW infestation. The damage to each palm was rated during these inspections. The total number of infested palms is shown in Fig. 5.

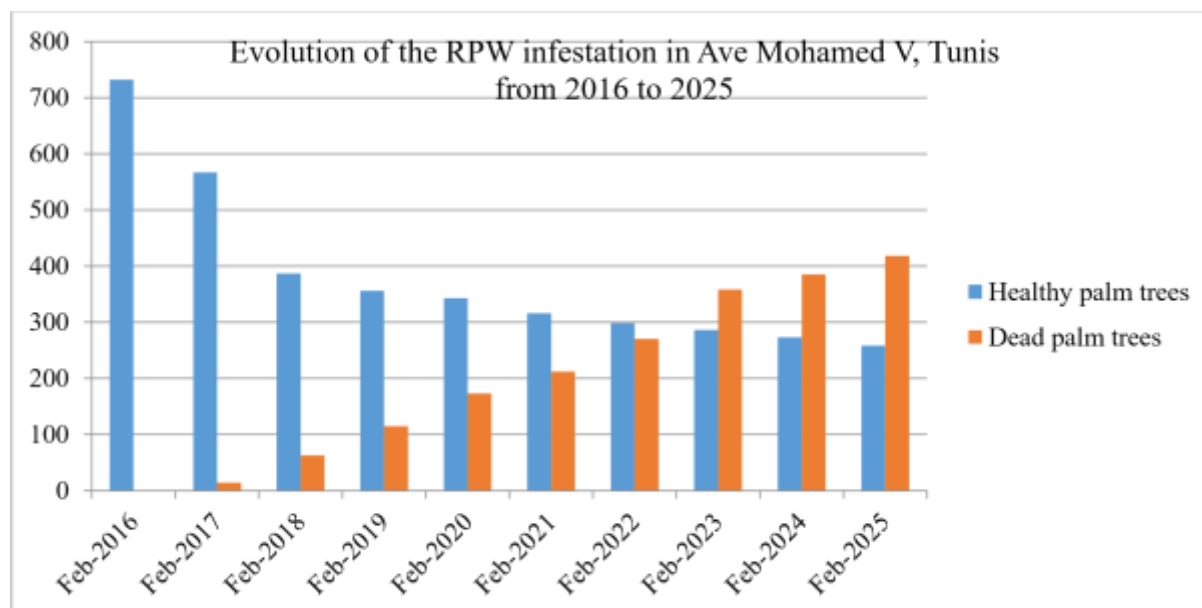


Fig. 5. Total number of Canary Island date palms infested by the red palm weevil in Avenue Mohamed V, Tunis between Feb 2016 and Feb 2025

The Jeanne d Arc place is located about 500 m from Mohamed V. Currently this place is named place martyr Mohamed Brahmi, planted with a total number of 87 *Phoenix canariensis* palms GPS coordinates (36.8182 °N,10.17977°E) (Fig. 6)



Fig. 6. The Jeanne d Arc place showing Canary Island date palms killed by the red palm weevil The first red palm weevil infestation appeared in this place in May 2016. All the palms were treated with endotherapy twice a year, the first endotherapy date was in May 2016 where the insecticide imidacloprid 200 g/l was used at a rate of 30 g/palm and after six months, the second application was made by November 2016, where the emamectin benzoate 50 g/l was used at a rate of 60 g/palm.

A survey was conducted to estimate the percentage of the infestation in this place during the last 9 years from May 2016 to April 2025. A monthly survey was conducted by walking and the damage to each palm was rated during these visual inspections. Figure 7 shows the evolution of infestation in the Jeanne d Arc place.

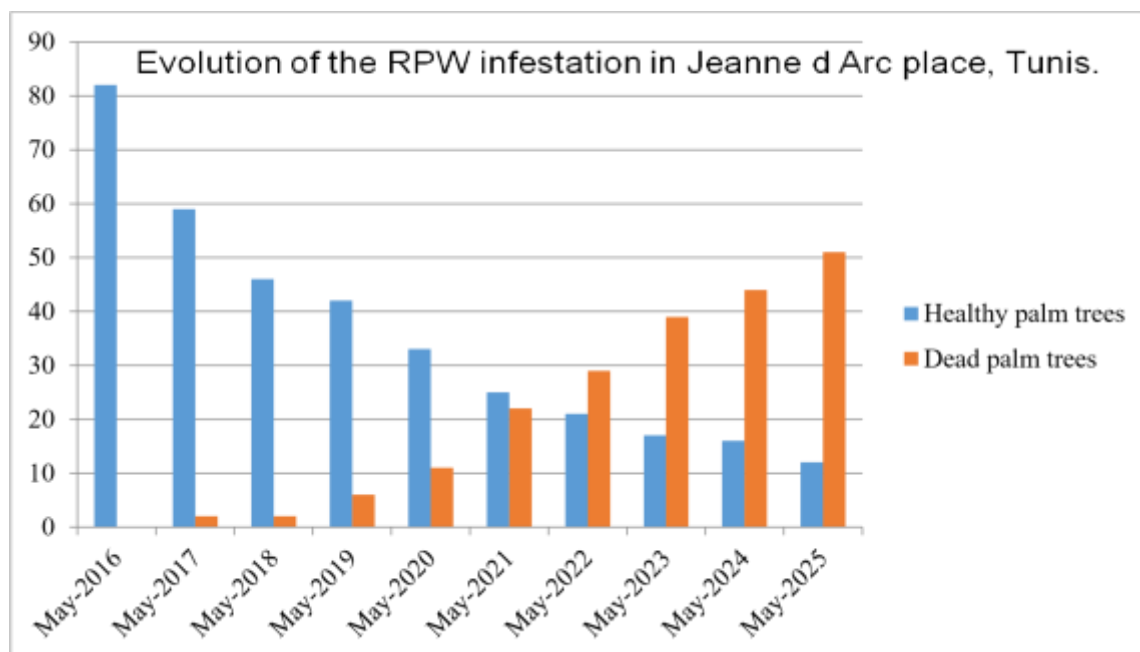


Fig. 7. Total number of Canary Island date palms infested by the red palm weevil in Jeanne d Arc place, Tunis between May 2016 and May 2025

In *Phoenix canariensis*, the male palm was found to be more infested by RPW as compared with the female (Fig. 8). This is in contrast with date palm *Phoenix dactylifera*, where infestation is more concentrated on the female palms.

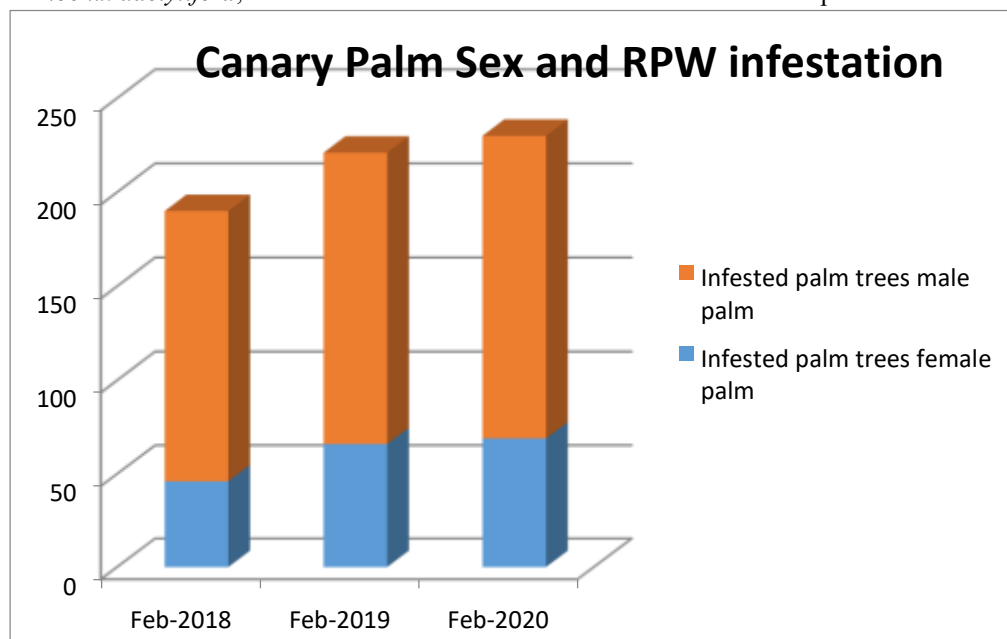


Fig. 8. *Rhynchophorus ferrugineus* infestation on male and female of Canary Island date palm *Phoenix canariensis* (2018-2020) .

SEASONAL ABUNDANCE OF RPW

To determine the seasonal abundance of the RPW population in Tunisia, from January 2017 to December 2019, ten standard bucket traps of five liters each and with four circular holes in the cover were installed. Traps were baited with RPW aggregation pheromone and ethyl acetate as kairomone, each trap contained three liters of water and 150 g of paste date. Traps were distributed in five localities as follows: 2 traps in Belvedere Garden in Tunis, 2 traps in private residency at La Soukra, 2 traps in the graveyard at ElKram, 2 traps in Carthage archeological site and 2 traps in la Guoulette private residency. In each area, the traps were placed in shade, 4 meters from the palm and 300 meters were maintained between the traps. From May to November and for the three consecutive years, the pheromone and the kairomone were replaced every 12 weeks from May to November and every 15 weeks

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during wintertime. Water and date were replaced every fifteen days. Traps were checked on a weekly basis and trapped adults' weevils were collected, counted, sexed and recorded. The daily minimum and maximum temperatures were, including time and date, obtained from Time and Date, the online climatological site; the mean weekly minimum and maximum temperatures were calculated and recorded. As it is clear from Fig.9 that the peaks of RPW populations occur during May-July, September-November.



Fig. 9. Seasonal abundance of *Rhynchophorus ferrugineus* in Tunisia during 2017-2019

IMPACT OF ENTOMOPATHOGENIC FUNGI ON RPW POPULATION DEVELOPMENT

The present work was carried out during March 2015 to April 2016 with the aim of determining the biotic factors that could affect the RPW population. RPW cocoons were collected from frond materials cut from twelve Canary palm trees showing late symptoms of infestation and were in final stage of collapse (Fig.10). These infested palms were located in various places: two palms in Carthage street, Governorate of Tunis, two palms in ElKram Cemetery, Governorate of Tunis, three palms in La Guoulette street, Governorate of Tunis, two palms in Raoued, Governorate of Ariana, and, three palms in private residency garden in La Soukra, Governorate of Ariana. From each of these infested *Phoenix* palms, non-empty cocoons were collected, placed in a labeled plastic box and brought to the laboratory, where they were kept at 4 °C. Each cocoon was manually dissected and healthy, predated or dead pupae infected with fungi were collected, counted and recorded. Initially, pupae covered with white mycellia were considered as infected with *Beauveria bassiana*, while those showed green colour infected with *Metarhizium anisopliae*. The impact of these entomopathogenic fungi is shown in Fig. 11. Further laboratory investigations were carried out to confirm the identity of the entomopathogenic isolated fungi.



Fig. 10. Canary Island date palm tree in final stage of collapse, El kram, Tunisia.

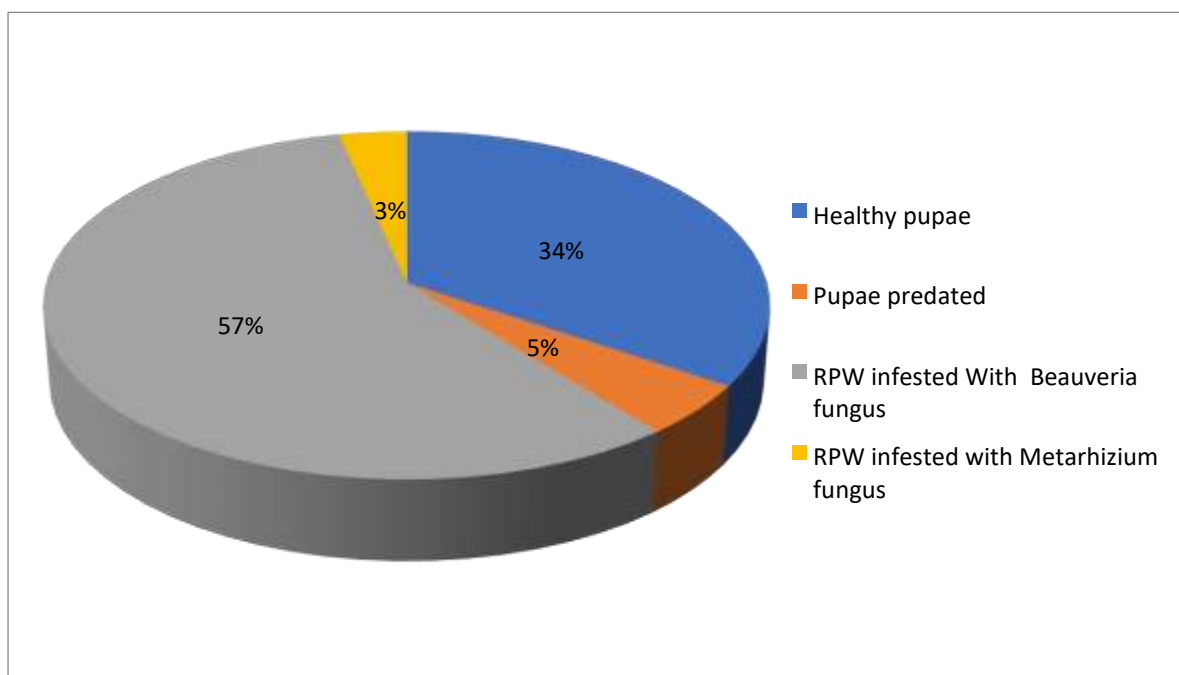


Fig. 11. Impact of entomopathogenic fungi on *Rhynchophorus ferrugineus* population in Tunisia

BENCHMARKING OF RPW INFESTATION IN TUNISIA AND CANARY ISLANDS

In the Canary Islands RPW was discovered in December 2005 and by September 2006 it was located on 4 islands. During the next 8 years; 706,081 palms were inspected (~441/working day @ 200 working days/yr for 8 years). About 209,547 were treated for infestation (~131/working day @ 200 working days/yr for 8 years), 659 palms were destroyed (~0.4/working day @ 200 working days/yr for 8 years). 681 RPW captured in traps (~0.4/working day @ 200 working days/yr for 8 years). The last weevil and the last infested palm were detected in 2013 and in September 2016 eradication was declared (Fajardo, et al., 2021).

The Canary Island Strategy for RPW eradication included Organizational Structure in which all responsibility for combatting RPW was given to one group within the government with the main goal of weevil eradication. The eradication strategy included consensus and inspections of palm trees, training of all stakeholders, raising public awareness, trading accreditation for transplantation and movement of palm trees, phytosanitary treatments, and elimination of palm trees infected by RPW. All susceptible palm trees in urban areas were geo- referenced. This is done by sending RPW Eradication teams to all parks, public buildings with surrounding

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palms, avenues and as many private locations as possible to invent susceptible palms. The geo-reference process required a worker with GIS transmitter in hand to stand by a susceptible palm and transmit or record data of the location of that palm. The coordinates of that palm are then recorded in a database with mapping capability. Several of these systems are commercially available. In the case of Tunisia, the coordinates and the state of the palm would need to be transmitted. Tunisian Canary palms are either live, dead, infested or recovering. The reason for the inventory is that when a newly infested palm was subsequently located the RPW Eradication team had a very good idea of the surroundings susceptible palms and could plan their containment action without needing to go to the location to do an onsite inspection of all palms in the containment area they defined. This made actions faster and more efficient.

Tunisia recorded its first RPW in 2011 and by 2017 an estimated 1,500 palms (1.25/day @ 200 d/yr for 6 years) have been killed. From the Canary Island experience, it can be concluded that inspection is the most intense control activity followed by treatment of infestation, removal of highly infested palms, and trapping which is high investment and necessary but numerically less rewarding. In the Canary Islands between 2006 and 2013, the strategy adopted by Moises Fajardo was to rapidly locate each infested palm, set up traps, remove each infested palm carefully and completely, inspect all palms in a defined radius around the infested palm, spray all palms in areas containing infested palms and move on the next infested palm. Within 4 years this protocol lowered infestations by 89% and eradication was achieved within 8 years of initiation of the program. During this program no palm was subjected to endotherapy or to complete pruning. When queried about the absence of these strategies in the Canary Islands protocol, Fajardo replied that the objective was to eradicate RPW not attempting to save palm trees that could act as inoculum for future infestations (Fig. 12).

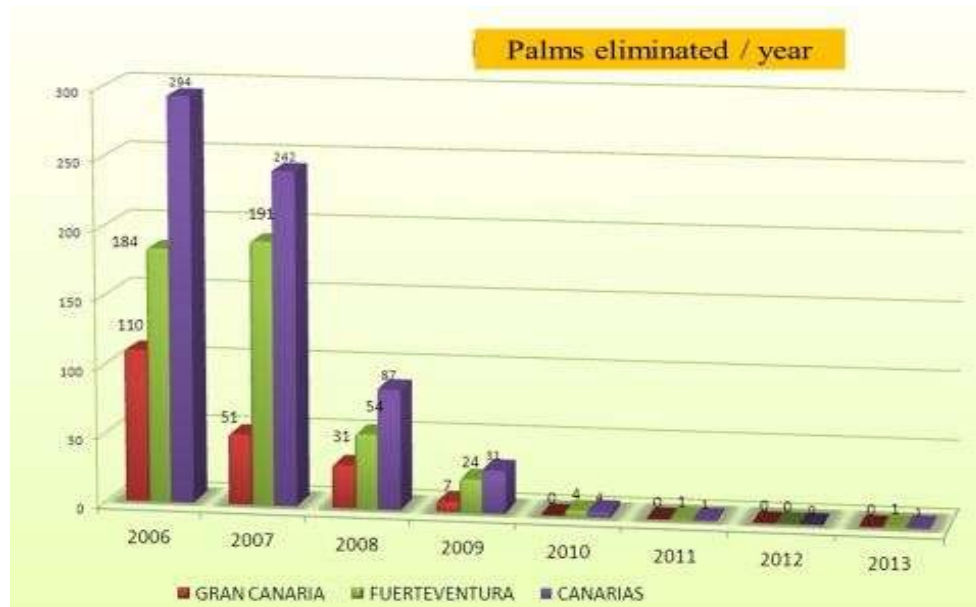


Fig. 12. Palms eliminated in Canary Islands during Eradication process (Moises Fajardo, Canary Islands SC HLM FAO Rome, 2017 with permission)

Based on the above it is suggested that Tunisia seriously consider rigorous implementation of a program to combat RPW that has the key elements of the RPW eradication program used in the Canary Islands. This may be a costly addition to current RPW management programs and should be trialed in a defined area to determine if it adds any benefit to the existing program. Tunisia has 3D google maps that allow street view, and these come with date of view which in the trial done by the author was July 2016 so some may be current. The central goal is for a manager to know as much as possible about the location of susceptible palms in the areas surrounding each newly reported infested palm so that planning can be rapid. In Tunisia infested palm pruning residue is left on site for some days before removal. This should not be done since there are pupae and adults in cocoons in the frond bases that can emerge and disperse. It is recommended to trial small chipper/shredders to be taken to the site where the pruning is being done. Shredded material should not be left on site but removed by shredding directly into a truck that transports shredded material to burial site. Burying shredded material should involve placing construction plastic (8 mm) over the buried material to further guard against emergence of any RPW life stages not killed by shredding (Fig. 13). In the Canary Islands pruned and infested fronds were wrapped on site and transported back to a medium-size regional shredder. Shredding of trunks requires a large shredder which, if available, would be preferable to burial of large trunks. Between 2011 and 2017 approximately 1,500 Tunisian Canary palms

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have been killed by RPW. This occurred over 6 years at 200 working days / year which allows one to calculate that approximately 1 palm per day would need to be shredded. If this approach is followed in Tunisia, large shredders are needed that can shred a single palm in less than 15 minutes (Fig. 14).



Fig. 13. Infested frond material not removed after palm pruning in Tunis and truck pulled shredder



Fig. 14. Removal, transportation and shredding of palms in Canary Islands

In the Canary Islands traps were moved from location to location as problems increased in one area and decreased in another area. Several invited speakers at the Tunis conference emphasized that the addition of pheromone trapping to RPW management systems has been crucial to their success. A trap that is installed on the ground and easy for RPW to enter and black or red colored captured more weevils than other colored ones (Al Saoud, 2013). A good pheromone lure is that it emits at least 2 mg of pheromone / day and probably no more than 10 mg / day (Vacas, et al., 2017). To ensure good trapping efficiency lures that are easily determined by inspection to have pheromone remaining are recommended over those that cannot be determined to still contain pheromone in attractive amounts. Tunisia uses lures for which it is difficult to judge effectiveness. They are used because they were the most effective of the 4 lures that were tested before the selection process. Since there are at least 15 companies that produce pheromone lures for RPW it would be a good idea to test additional lures for evaluation on maximum RPW capture and field longevity (Vacas, et al., 2017). Ethyl acetate and ethanol are additional trap additives that are used in Tunisia. These are available from several manufacturers and should be tested to select the most effective so that an economic judgement can be made on this component of the trap.

The most problematic component of the RPW trap is the food component. Tunisia was visited by at least two international experts in the last 5 years both of whom recommended the standard protocol of placing food bait in water to allow for fermentation (the fermentation organic volatiles are the synergistic odors that contribute to enhanced capture over pheromone, ethyl acetate and ethanol). Standard Tunisian RPW traps have four side entry holes and need servicing every two weeks. To extend the service period of these traps, we conducted trials from June 15-Aug 7, 2019 (9 weeks) to compare buried bucket traps with a hole or cone top entry. These traps were baited with membrane pheromone lures (Ferrolure+), a long-lasting membrane ethyl acetate lure (Weevil Magnet) and contained or did not contain, 150 g of dates and three liters of water, renewed every two weeks. We found that traps with only pheromone and ethyl acetate captured ~ 50% of those that additionally contained food replaced biweekly. We expect that there is an advantage to areawide management systems using traps that are less efficient compared with wet traps, but do not require

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servicing since lures can be designed for even longer release. Also, we found that in the top cone entry trap used with food the water evaporation rate is only 30% as high as with the current Tunisian palm weevil trap.

There is an additional technique that might add to the success of an RPW management strategy. In this technique, pheromone and contact insecticide are incorporated into emulsified wax at concentrations that allow for multi-months emission of pheromone and continuous killing action. Small (3 g) dollops of the pheromone/insecticide wax are placed on non-host plants in date palm plantations using calibrated caulking guns. Two groups have been tested; A&K for RPW produced by ISCA Technologies with a formulation named SPLAT Hook RPW (El-Shafie, et al., 2011) that is reapplied at 3-to-4-month intervals on non-host plants within infested stands. Another formulation called SMART Ferrolure produced by ChemTica Internacional has been tested in oil palm as well as Malaysian coconut (Faleiro, et al. 2016). In the latter two initial applications, the RPW population maintained at less than 5% of original levels for at least 9 months (Kharrat, et al., 2018).

CONCLUSION

Since the discovery of the Red Palm Weevil (RPW) in Carthage in 2011, the infestation has been limited to Canary Islands palms (*P. canariensis*), while date palm (*P. dactylifera*) oases in the south remain unaffected. To prevent the weevil from reaching date palm plantations, strict internal quarantine measures and containment efforts of the pest in Canary Islands palms coupled with robust monitoring and capacity building in the southern oases are essential. Mass trapping of adult weevils is a key component of Integrated Pest Management (IPM) for RPW that could be strengthened with new semiochemical mediated technologies like attract and kill. The new top cone entry trap is expected to be more cost-effective than current traps, as it can be used with or without food and has a lower water evaporation rate. Tunisia is encouraged to implement a rigorous RPW control program similar to the eradication efforts in the Canary Islands. For optimal results, management strategies should involve all stakeholders and adopt a coordinated, area-wide approach.

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