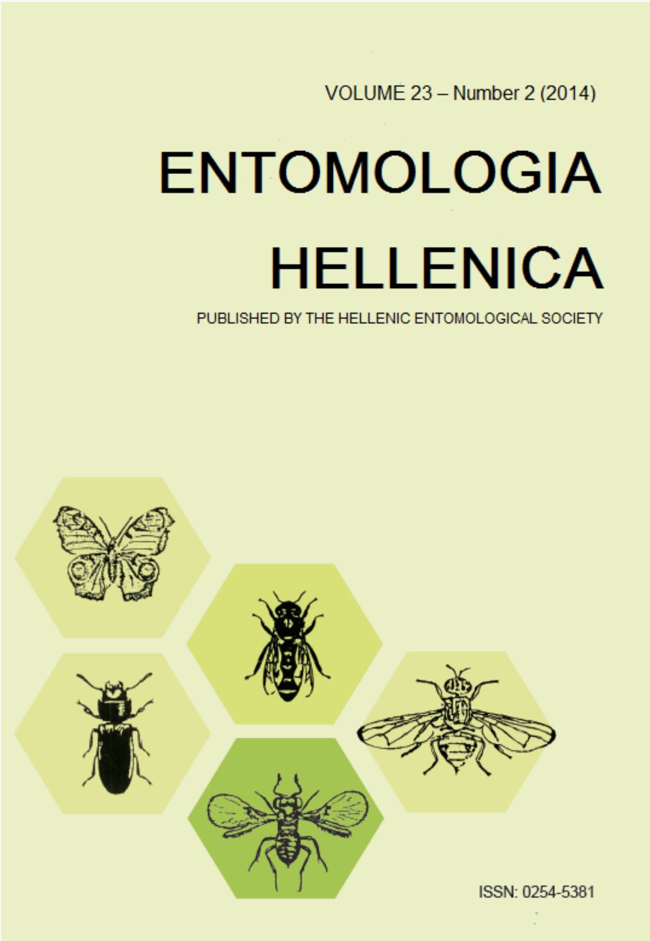
ENTOMOLOGIA HELLENICA

Vol 23, No 2 (2014)



Preliminary study in the use of electric current for the control of Rhynchophorus ferrugineus

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doi: [10.12681/eh.11536](https://doi.org/10.12681/eh.11536)

ENTOMOLOGIA HELLENICA **23** (2014): 52-58

SHORT COMMUNICATION

Preliminary study in the use of electric current for the control of *Rhynchophorus ferrugineus*

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ABSTRACT

The use of electric current is being studied as a method to control *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). The infested palm trees were pruned according to the severity of the infestation (heavy infestation requires more intense pruning). Then, electrolytes were injected into the palm trees to elevate conductivity. Electric current of specific voltage and amperage was coursed through the palm trees, using specifically designed electrodes; Electric current was applied for 20 min to 1 hour depending on the severity of the infestation and the size of the palm tree. A small number of palm trees were shocked, some of which were monitored for side effects due to the shock while others were cut down to monitor pest mortality rates. Larvae were collected and placed in entomological cages. A large percentage of larvae were killed after the shock, while the others showed difficulties in their movement. Six days later 84.78 % of larvae and 96.48 % of pupae were killed but practically all of the adults survived. Electric current has never been used in this way to control insects before.

KEY WORDS: Electric current, Palm trees, *Rhynchophorus ferrugineus.*

Introduction

Rhynchophorus ferrugineus (Olivier 1790) (Coleoptera: Curculionidae) was first recorded in Greece in 2005 in Hersonissos Crete in *Washingtonia* sp. (Kontodimas et al. 2005). In a short period of time *R. ferrugineus* spread throughout the country causing major damages to palm trees, especially *Phoenix canariensis* (Kontodimas et al. 2006). The insect has four stages (egg, larva, pupa and adult) with larvae damaging the infested palm tree. The insect produces 3-4 generations annually (EPPO 2008). In *Ph. canariensis* the female lays the eggs in the base of the leaves close to the stem. The young larvae start feeding on the tissue by burrowing tunnels into the stem creating cavities where all of the stages of the insect can be found. Inside the cavities there is a large amount of dead tissue, insect frass and various fungi. As the infestation proceeds the stem is completely destroyed leading to the death of the palm tree (Faleiro 2003). Up until now the use of pesticides is the most common method to control the insect and prevent new infestations. Other means include the use of microwaves, nematodes and tree surgery in a form of extensive pruning used in heavily infested palm trees. All leaves and pieces of infested stem are removed leaving exposed the healthy part of

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the palm tree underneath.

The aim of this study is to test the use of electric current as a method to control the insect without the use of pesticides. The main idea is to take advantage of the humidity in the infested part of the stem and channel electric current in order to kill all the stages of the insect. Voltage, when applied to a material with various degrees of conductivity, will create electric current. The greatest amount of that energy will pass through the least resistant part of the material. The cavities where the insects live have much greater humidity than the healthy part of the stem and thus greater conductivity. As a result the majority of the energy from the electric current will pass through the infested areas killing the insects.

Materials and Methods

Iron galvanized electrodes were used. The electrodes were hollow and drilled in one end (4-6 small holes, 2 mm in diameter each hole) in order to enable pumping water with electrolytes in the stem of the palm tree without dowsing the entire palm tree. A petrol generator (220 V, 50 – 60 Hz, 0 -12 Amp) was used. Also a “distributor” was constructed to enable monitoring the electric current flowing in each of the electrodes used in the palm tree and choosing different combinations of electrodes. Statistical analysis was carried out using One-Way ANOVA.

The experiment took place in November 2012. Four to six holes were drilled in each palm (15 mm in diameter and 20 – 30 cm in depth) and one electrode was placed in each hole. Water was pumped through each electrode to elevate conductivity using a 5 lit knapsack sprayer, approximately 5-10 liters were used in each palm tree (Fig. 1). The electrodes were then connected to the ‘distributor’ of electric current and in turn the ‘distributor’ was connected to the petrol generator (Fig. 2). Each palm was shocked for 60 minutes with various combinations of the electrodes.

Two experiments were conducted, to assess the use of electric current to control insects that infest palm trees:

Experiment No 1
The first experiment was aimed to search the side-effects of the procedure on a palm tree In total, 20 infested palm trees were shocked (Table 1). These palm trees were monitored for almost a whole year after the shock to see how they would respond to the treatment.

TABLE 1. Number of treated palms that were monitored for side effects.

Palms	Number
Pruned *Ph. canariensis*	10
Ph. canariensis with tree surgery	3
Chamaerops humilis	5
Phoenix dactylifera	2

FIG. 1. Water injected inside the palm tree through the electrode.

Experiment No 2
Aim of this study was to test the efficiency of electricity as a method for controlling insects that live and feed inside palm trees. Seven infested date palms (*Ph. canariensis*) were selected for the experiment. Their height ranged from 1 to 1.5m.

TABLE 2: Number of *R. ferrugineus* larvae, pupae and adults collected from 6 palm trees after treated with the method and from the control (a single palm tree).

	***R. ferrugineus* stage**		
	Larva	**Pupa**	**Adult**
Control	**22**	**10**	**8**
Palm Nº 1	30	7	13
Palm Nº 2	27	12	7
Palm Nº 3	20	6	8
Palm Nº 4	17	9	14
Palm Nº 5	18	10	6
Palm Nº 6	26	8	14
Total	**138**	**52**	**62**

All of them were infested but the degree of severity varied. The palm trees were located close to each other; they were planted in a row 1.5 m apart and had not been treated with any pesticide or other method to control the pest for more than six months. One palm tree was left as control for the experiment, six were shocked, as described earlier (220V, 0-12 Amp, 60 min approximately, 50 – 60 Hz using various combinations of the electrodes). After the shock the palm trees were dissected to collect the insects. All larvae of 3 cm or more in length were collected, smaller ones were discarded. Some larvae were destroyed by the chainsaw and were also not collected. Pupae and adults were also collected. The insects were placed in insect cages, one for each palm tree (Table 2). In all of the cages pieces of palm were placed to ensure adequate feeding of the insects. All of the cages were placed under room conditions and enough ventilation. Insects from the control were also placed in the same room but in a separate insect cage. Each day, for the next six days, dead insects were counted and removed from the cages.

RESULTS

Experiment No 1

Half of the *Ph. canariensis* died after the shock (five out of ten). This seems to be due to the water used into the palm tree. Although similar quantities are used in pesticide applications, in this case the water is also heated by the flow of electricity leading probably to the destruction in some cases of the stem. *Chamaerops humilis* and *Phoenix dactylifera* showed no negative side effects from the treatment. The same happened in *Ph. Canariensis* where tree surgery had been performed. In the case of *Ph. Canariensis* where tree surgery was not performed half of them did not survive (Table 3). This could be happening because the water used for the treatment may be responsible for the destruction of the stem. The fact that the water is also heated from the electric current seems to only worsen the problem. In the case of *Chamaerops humilis* and *Phoenix dactylifera* where the tissue is much more dry and cohesive less water is held in the palm tree. In *Ph. canariensis* where tree surgery was performed the excess water that is used for the shock dries up faster than on a palm tree were normal pruning is used. The last two theories are currently under research by the team.

FIG 2: Electric voltage applied to the palm tree through electrodes.

TABLE 3. Number of treated palms that survived.

Palms	Number of treated palms	Number of palms that survived
Pruned *Ph. canariensis*	10	5
***Ph. canariensis* with tree surgery**	3	3
Chamaerops humilis	5	5
Phoenix dactylifera	2	2

Experiment No 2

In the second experiment all of the palm trees were destroyed in order to collect the insects. Almost no adult died from the use of electricity (Table 4). In the 6th day only 3.57% mortality rate was recorded. In the control 8 adults were collected and all of them survived.

The mortality rate of larvae was 32.49% in the first day (Table 5). Some of the larvae who died immediately after the shock showed extensive burns in their body while others that survived the initial shock showed a change in their color and behavior. In the following 6 days the larvae that had different color and acted differently died. In total the experiment produced 84.78% mortality rate to larvae. In the control a total of 22 larvae were collected and after 7 days all of them survived. Statistical analysis showed that there is a significant difference ($P< 0.001$).

Similar results were produced in pupae (Table 6). Many of the pupae that were extracted from the palm trees were already dead (palm trees number 3 and 6). Some pupae literally burst open from the electricity. In 7 days almost all of them died, giving almost 100% mortality rate. In the control 10 were collected and one died in the fourth day. Statistical analysis showed that there is a significant difference with confidence level 99% for the last day of the experiment ($P<0.001$).

DISCUSSION

This project is the beginning of standardization of an innovative method never tested again in a similar way for the control of *R. ferrugineus* and other insects that live and feed inside palm trees. This is the first time electric current is tested in date palms as a method to control an insect.

TABLE 4: Average adult mortality rate extracted from the six *Ph. Canariensis* and the control in experiment 2 in the course of seven days.

Date	**Control**	**Palm tree No 1**	**Palm tree No 2**	**Palm tree No 3**	**Palm tree No 4**	**Palm tree No 5**	**Palm tree No 6**	**AVG**
13/11/2012	0.00	0.00	0.00	0.00	0.00	7.14	0.00	1.19
14/11/2012	0.00	0.00	0.00	0.00	0.00	7.14	0.00	1.19
15/11/2012	0.00	0.00	0.00	0.00	0.00	7.14	0.00	1.19
16/11/2012	0.00	0.00	0.00	0.00	0.00	7.14	0.00	1.19
17/11/2012	0.00	0.00	0.00	0.00	0.00	7.14	0.00	1.19
18/11/2012	0.00	0.00	0.00	0.00	0.00	7.14	0.00	1.19
19/11/2012	0.00	0.00	0.00	14.29	0.00	7.14	0.00	3.57

TABLE 5. Average larvae mortality rate extracted from the six *Ph. Canariensis* and the control in experiment 2 in the course of seven days.

Date	**Control**	**Palm tree No 1**	**Palm tree No 2**	**Palm tree No 3**	**Palm tree No 4**	**Palm tree No 5**	**Palm tree No 6**	**AVG**
13/11/2012	0.00	23.33	33.33	25.00	47.06	27.78	38.46	32.49
14/11/2012	0.00	30.00	40.74	35.00	47.06	44.44	46.15	40.57
15/11/2012	0.00	33.33	70.37	50.00	58.82	61.11	57.69	55.22
16/11/2012	0.00	66.67	74.07	65.00	70.59	66.67	69.23	68.70
17/11/2012	0.00	76.67	74.07	75.00	70.59	88.89	69.23	75.74
18/11/2012	0.00	90.00	74.07	75.00	88.24	94.44	76.92	83.11
19/11/2012	0.00	100.00	74.07	75.00	88.24	94.44	76.92	84.78

TABLE 6. Average pupae mortality rate extracted from the six *Ph. canariensis* and the control in experiment 2 in the course of seven days.

Date	**Control**	**Palm tree No 1**	**Palm tree No 2**	**Palm tree No 3**	**Palm tree No 4**	**Palm tree No 5**	**Palm tree No 6**	**AVG**
13/11/2012	0.00	57.14	16.67	100.00	66.67	70.00	100.00	68.41
14/11/2012	0.00	85.71	58.33	100.00	88.89	90.00	100.00	87.16
15/11/2012	0.00	100.00	83.33	100.00	88.89	90.00	100.00	93.70
16/11/2012	10.00	100.00	100.00	100.00	88.89	90.00	100.00	96.48
17/11/2012	10.00	100.00	100.00	100.00	88.89	90.00	100.00	96.48
18/11/2012	10.00	100.00	100.00	100.00	88.89	90.00	100.00	96.48
19/11/2012	10.00	100.00	100.00	100.00	88.89	90.00	100.00	96.48

A few other cases exist where electricity is used as a method to control insects but vary significantly from the method described:

a) A high frequency and voltage device which uses a lot less amperage to control termites in houses and buildings. (http://www.electro-guntermitecontrol.com/).

b) Four patented methods on controlling insects with electricity 1) US3826035 2) KR20100138535 3) JP2004141127 4) JPS53127173. All of the above have major differences with the method described earlier in the paper and to our knowledge have not yielded any fruitful results (www.obi.gr).

However, there are several aspects that should be studied further. The main problem that has to be solved is the apparent damage the use of water in conjunction with the electric current causes to *Ph. canariensis*. For this goal, many of the details of the procedure have to be studied, such as time length of the application and electric current characteristics (amperage, voltage and frequency). The whole methodology, although differs greatly from the original idea, which was the use of just two iron rods and a power source from the ground network, still has to be improved on many aspects. The effects of electricity in the biology of the palm tree have not been studied at all. Also neither the exact way electricity kills the insects has been studied, nor the fact that the adults are extremely tolerant to electricity. It is speculated that the chitin in the exoskeleton provides some sort of insulation against the electrical current. From the results so far, it seems to be a very promising method to control the insects than infest palm trees.

Acknowledgements

The Authors thank Dr Dimitris Kontodimas, Mr Antonis Aspradakis, Dr Manolis Lattos, Dr Eleftherios Goulielmakis and Mr Vasileios Vakrinos.

The above project was funded solely by the researchers and an application was filed to the Greek Industrial Property Organization with patent pending number 20130100279/10/05/2013, under the title “Device for Killing Insects that Infest Palm Trees Using Electric Current.

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Προκαταρκτική μελέτη για τη χρήση του ηλεκτρικού ρεύματος στην αντιμετώπιση του ρυγχοφόρου των φοινικοειδών (*Rhynchophorus ferrugineus*)

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ΠΕΡΙΛΗΨΗ

Μελετήθηκε η επίδραση του ηλεκτρικού ρεύματος στην αντιμετώπιση του ρυγχοφόρου των φοινικοειδών *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). Ανάλογα με το μέγεθος της προσβολής τα φοινικοειδή κλαδεύτηκαν ή καρατομήθηκαν. Ηλεκτρολύτες προστέθηκαν στο εσωτερικό τους για την αύξηση της αγωγιμότητας. Ηλεκτρικό ρεύμα συγκεκριμένων χαρακτηριστικών (220 V, 50- 60 Hz, 0 – 12 Amp) διοχετεύθηκε μέσω ηλεκτροδίων στο εσωτερικό του κάθε φοινικοειδούς για διάστημα 1 ώρας περίπου. Πραγματοποιήθηκε επέμβαση σε 27 προσβεβλημένα φοινικοειδή από τα οποία τα 20 παρακολουθήθηκαν για τυχόν αρνητικές επιπτώσεις του ηλεκτρικού ρεύματος και τα υπόλοιπα 7 τεμαχίστηκαν και τα έντομα (προνύμφες, πλαγγόνες και ενήλικα) τοποθετήθηκαν σε ξεχωριστούς κλωβούς με τροφή για τη μέτρηση της θνησιμότητας. Επτά ημέρες μετά, παρατηρήθηκε θνησιμότητα 84,78% στις προνύμφες, 96,48% στις πλαγγόνες αλλά πολύ μικρή θνησιμότητα στα ενήλικα (3,57%). Αναφορικά με τις επιπτώσεις του ηλεκτρικού ρεύματος στα φοινικοειδή φαίνεται ότι εμφανίζονται προβλήματα στους κανάριους φοίνικες πιθανώς λόγω της αύξησης της θερμοκρασίας στο εσωτερικό τους από τη διέλευση του ηλεκτρικού ρεύματος σε συνδυασμό με την ύπαρξη μεγάλης ποσότητας νερού. Παρατηρήθηκε ότι ένα ποσοστό της τάξης του 50 % των κανάριων φοινίκων που δεν είχαν υποστεί δενδροχειρουργική δεν επιβίωσε μετά την εφαρμογή του ηλεκτρικού ρεύματος. Τα προβλήματα αυτά πρόκειται να αντιμετωπιστούν με τη χρήση ηλεκτρικού ρεύματος διαφορετικών χαρακτηριστικών. Κατατέθηκε στον Οργανισμό Βιομηχανικής Ιδιοκτησίας αίτηση με αριθμό 20130100279/10/05/2013 για κατοχύρωση Διπλώματος Ευρεσιτεχνίας με τίτλο «Συσκευή Θανάτωσης Εντόμων που Προσβάλλουν τα Φοινικοειδή με Ηλεκτρικό Ρεύμα».