

**AFPP – PALM PEST MEDITERRANEAN CONFERENCE  
NICE – 16, 17 AND 18 JANUARY 2013**

**FEASIBILITY OF MICROWAVES FOR THE SANITATION OF PALMS ATTACKED BY  
*RHYNCHOPHORUS FERRUGINEUS* OLIVIER**

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## **SUMMARY**

Thermal effects induced by high power microwave applications have been evaluated for suppression of larvae and adults of red palm weevil (RPW), *Rhynchophorus ferrugineus* Olivier hosted in *Phoenix canariensis* palm. Dielectric spectroscopy was used to analyse the electromagnetic behaviour of palm tissues (both healthy and rotten) and insects (larvae and adults) in order to elucidate the internal heating mechanisms and provide the basis for further development, improvement, and scale-up of appropriate protocols for the use of microwave treatment for pest control. Preliminary results have shown that microwaves can be proposed as environment-friendly alternative, or cooperative, method for management of the RPW.

Key words: Microwaves, thermal effect, *Rhynchophorus ferrugineus*, *Phoenix canariensis*, palm.

## **RÉSUMÉ**

Les effets thermiques induits par des applications de micro-ondes à haute puissance ont été évalués pour éliminer larves et adultes de charançon rouge du palmier (CRP), *Rhynchophorus ferrugineus* Olivier vivant dans le palmier *Phoenix canariensis*. Une spectroscopie diélectrique a été utilisée pour analyser le comportement électromagnétique des tissus de palmier (sain ou pourri) et des insectes (larves et adultes) dans le but d'élucider les mécanismes d'échauffement interne et de fournir une base pour le développement, l'amélioration et l'intensification des protocoles pour une utilisation des micro-ondes en traitement antiparasitaire. Les résultats préliminaires ont montré que les micro-ondes peuvent être proposées comme une méthode alternative écologique, ou complémentaire, pour la gestion du CRP.

Mots-clés : Micro-ondes, effets thermique, *Rhynchophorus ferrugineus*, *Phoenix canariensis*, palmier.

## INTRODUCTION

RPW is widely considered to be the most damaging insect pest of palms in the world. It is native to Southeast Asia and is reported to attack 17 palm species worldwide, actually it is known from the following regions:

- Asia: RPW has been recorded in Bangladesh, Cambodia, China (Guangdong, Taiwan), Pakistan, India, Indonesia, Japan, Laos, Malaysia (Sabah, Sarawak), Myanmar, Philippines, Singapore, Sri Lanka, Thailand, and Vietnam.
- Africa: Algeria, Egypt, Libya, Madagascar, Malta, Morocco.
- Middle East: Bahrain, Syria, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.
- Europe: Cyprus, France, Greece, Italy, Spain, Portugal, and Turkey.
- Oceania: Australia, Papua New Guinea, Samoa, and the Solomon Islands.
- The Caribbean: Aruba.
- USA: Laguna Beach, Orange County, California

In the Mediterranean basin it has moved to Africa and Europe, mainly due to the movement of infested planting material. As concerns Italy, RPW severely damages overall *Phoenix (P.) canariensis*; the first time it was found in 2004 on some plants of *P. canariensis* located in a nursery in Tuscany. At the end of 2005, the insect was reported in Sicily and in Campania. Since then it has quickly spread in almost all areas where *P. Canariensis* was present, resulting in rapid death of thousands of plants.

Several control methods have been applied against this pest, among them we recall phytosanitation, which involves felling and burning infested palms, the use of insecticides, attractants or pheromone traps for adult monitoring and mass trapping, the development of biocontrol strategies for RPW adopting fungi or entomopathogenic nematodes or the employment of physical methods (preventing entry of weevils through cut ends of petioles and wounds).

Electromagnetic heat treatment is a thermal method proposed for post-harvest treatment of agricultural commodities. This method leaves no chemical residue on the commodities, ensures acceptable quality of the commodities, and causes minimal impact on the environment (NELSON, 1996).

In this work we present the results of a research intended to see whether microwave (MW) treatment could be an alternative or cooperative method to effectively control the pest. The research is actually supported by Regione Campania and, due to the inter-disciplinarity of the object, several competences are required, thus agronomists, physicists, engineers and entomologists are involved in the team.

As a first step of the investigation on the feasibility of MW for RPW control we have established the electromagnetic properties of the tissues under test (healthy and rotten palm tissues, insects at different stage levels), then the energy necessary for ensuring a high probability of a lethal treatment. Finally some MW treatments of palms opportunely infested by RPW larvae showed encouraging results MASSA *et al.* (2011).

Recently, a project called MIPALM (Microwaves for PALM sanitation), specifically aimed to the development, improvement, and scale-up of appropriate protocols for the use of microwave treatment for pest control, has started.

## MICROWAVE HEATING PRINCIPLES

Microwaves are electromagnetic fields oscillating at high frequencies (300 MHz – 100 GHz). Their thermal effect induced when they interact with a material is well known and largely employed for the heating and processing of food and in production of industrial materials.

The mechanisms involved in the process are due to the nature of the molecules constituting the materials. Briefly, molecules exposed to the electromagnetic field move following its oscillations and the heat is generated by the frictional forces occurring in their motion. Polar molecules are particularly involved in the phenomenon, thus biological tissues, that are rich of water, can show a high coupling with the electromagnetic field and consequently an increase of temperature in all the volume where the wave propagates. Thus, differently from the conventional heating where the heat is transferred from the surface to the interior of the material, microwaves induce a volumetric heating, referred also as dielectric heating, strongly depending on the dielectric behaviour of the material. Microwave heating evolved after World War II, as magnetrons and other microwave sources became available and affordable. Actually, with the development of commercial microwave oven, magnetrons working at 2.45 GHz are very cheap sources, consequently this frequency is particularly interesting for large scale microwave applicators design.

In this work we evaluated the possibility of inducing the thermal increase in the pest, heating the insects to a lethal temperature without harming the tissues of *Phoenix canariensis*. The major advantages of this technique are:

- the temperature reached on the surface of the material is less than that required by conventional heating in order to attempt the same effect inside the body;
- the heating is more uniform for large bodies too;
- it could be possible to operate selectively by focussing microwave beam or by exploiting the different behaviour of the pest respectively the host;
- once the source is switched off, the heating immediately stops.

As already mentioned, microwave heating is a dielectric heating and the efficacy of the treatment depends on the dielectric behaviour of the material, that is described by the dielectric constant and the loss factor (both included in the permittivity). The dielectric constant of a material is associated with the energy storage capability in the electric field in the material and the loss factor is associated with the energy dissipation, conversion of electric energy to heat energy in the material. In this article, the latter is interpreted to include the energy losses in the dielectric due to all operating dielectric relaxation mechanisms and ionic conduction. These terms depend on many parameters as frequency, temperature, moist level, and their knowledge is fundamental in order to understand the feasibility of the treatment.

## **MATERIAL AND METHODS**

Permittivity measurements were carried out by means of the open-ended coaxial cable technique, that is widely employed for the dielectric characterization of agricultural products (WANG & TANG, 2001). Palm tissues, both healthy and rotten, with different values of moist content were adopted. Due to the inhomogeneities of the samples several measurements in different place of the material were considered and average values were determined. With respect to the insects the probe was placed in strict contact with larvae of average dimensions or adults.

Once known the permittivity values of interest, numerical simulations, with a dedicated code, were carried out in order to have preliminary information about the power loss distribution into the palm.

Thermal limits of survival of the pests were found estimating the lethal temperature and time of permanence in hot air inserting larvae (2-6 g) and/or adults (weighting about 1 g) in an electrical heated incubator.

Semi-field tests were carried out treating some artificially infested plants with microwaves in a controlled ambient. Four *P. canariensis* (stipe diameter about 20 cm) were exposed with a magnetron source (2.45 GHz, 1 kW) 20 day after a controlled infection performed with four young larvae per plant. Three non-infested palms were adopted as control. Thermal increase was monitored by an infrared thermocamera.

## RESULTS

Concerning the dielectric properties of *P. canariensis* plant, in contrast with other kind of trunks of plants, high loss factor was found in both healthy and tissues damaged by the insects. This is due to the high water content in this kind of plants. Accordingly, the loss factor diminished with the reduction of the moist content. A high loss factor implies high power loss and a low penetration depth of the microwaves into the trunk, because most of the energy is dissipated in the first layer of the trunk. As a consequence high efficiency of the treatment can be expected in the regions of the palm where RPW attack and/or larvae emerge for building the pupal case with fibers extracted from the galleries inside the trunk. Numerical simulation [Fig.1] and in field measurements [Fig.2] confirmed these results.

Lethal temperature estimation results showed that lethal time for the larvae varies with weight. Adults and young larvae (2-4 g) are killed after about 20 min at 50°C while all insects (larvae and adults) do not survive after 5 min at 80°C. Treatments for more than 30 min at 50°C should be able to strongly affect all population. Considering that a temperature of about 30°C can be supposed to be present into the palm, due to infestation, an increase of 20°C can be sufficient for contrasting the larvae development. These additional results suggest that the inner zone of the palm, eventually not reached by microwaves, can achieve lethal temperature by exploiting the thermal conduction from the surrounding environment at higher temperatures.

Figure 1 : Results of numerical simulation reproducing an infested palm irradiated with a waveguide at 2.45 GHz. The power loss distribution shows penetration depth of few centimeters.

Résultats de la simulation numérique reproduisant un palmier infesté, irradié à 2,45 GHz. La distribution de la perte de puissance montre que la pénétration est de quelques centimètres.

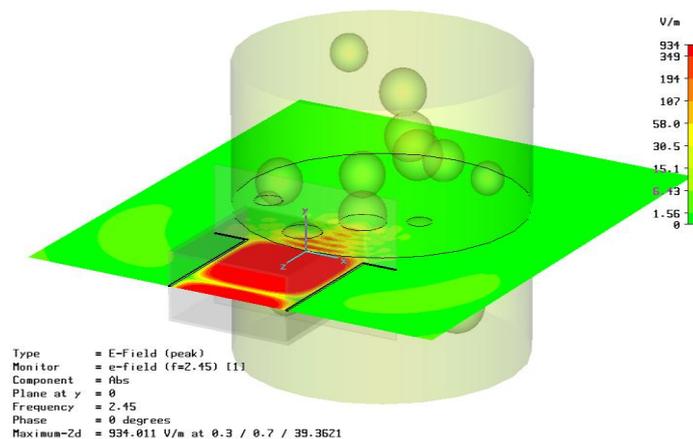
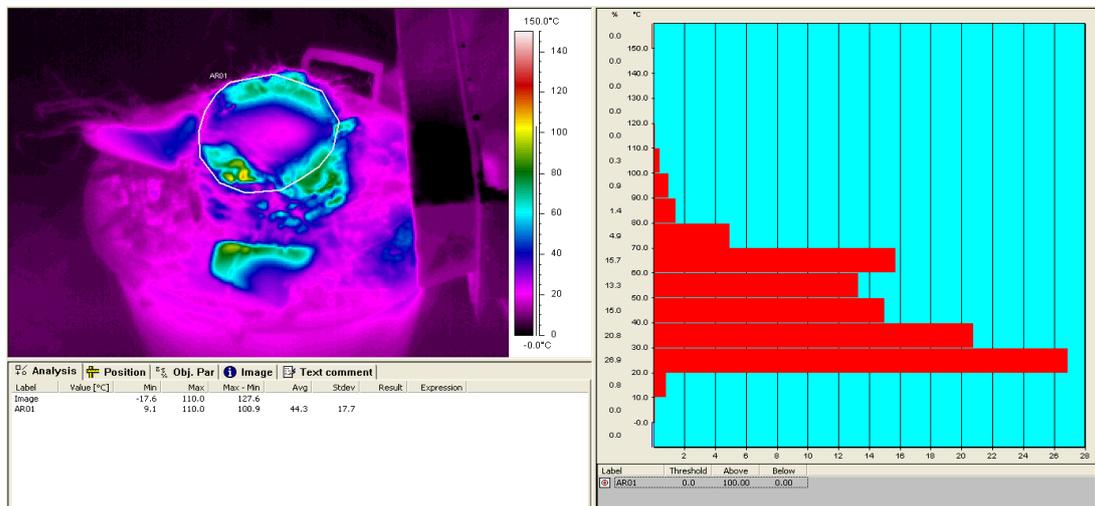


Figure 2: Thermogram detected after microwave exposure of a *P. canariensis* palm. The inner section is not involved by the thermal effect induced by microwaves.

Thermogramme obtenu d'un palmier *P. canariensis* après exposition à des micro-ondes. La section interne n'est pas touchée par l'effet thermique induit par les micro-ondes.



## DISCUSSION

Microwave heating applications are increasingly proposed in environmental engineering. This non ionizing radiation could be a potential candidate for limiting the spread of RPW as well as the environmental pollution caused by pesticides. Thermal effect could be used both as curative treatment and/or preventive treatment, as well as for disposal of unrecoverable palm trees. No single technique developed up to now seems able to eradicate this pest; however the possibility of combining the proposed methods with other pest control technique should be considered in order to strongly contrast it. In this context, MIPALM project aim is the development, improvement, and scale-up of appropriate protocols that can be applied by non-expert technicians; an additional goal of the study is the evaluation of long term effects on the palms, that are still unknown.

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## ACKNOWLEDGEMENTS

The authors would like to thank Regione Campania for supporting their research.