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CONTRIBUTION TO THE KNOWLEDGE OF MEDIUM AND LONG TERM DAMAGE CAUSED BY TRUNK INJECTIONS IN THE CONTROL OF RED PALM WEEVIL, *RHYNCHOPHORUS FERRUGINEUS* OLIVIER (COLEOPTERA: CURCULIONIDAE)

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SUMMARY
With the recent introduction of the red palm weevil in Italy a prestigious environmental and cultural heritage is under serious threat. Thousands of trees have died and the control of this insect has obtained results below expectations. Furthermore, the use of chemical products in an urban environment requires searching for combating techniques that respect as much as possible the public health. The trunk injection is a technique that meets this requirements as it limits the dispersion of chemicals in the environment. However, it is necessary to analyze the different aspects associated with this technique, the consequences on the stability of the palm trees as a result of perforation of the trunk. Studies on the subject have been undertaken and an experimental protocol is being defined.

Key words: red palm weevil, trunk injection, biomechanics, evaluation of stability, palms.

RESUME
Avec l'introduction récente du charançon rouge du palmier, en Italie un patrimoine prestigieux environnemental et culturel est sérieusement menacé. Des milliers d'arbres sont morts et la lutte contre cet insecte a obtenu des résultats inférieurs aux attentes. En outre, l'utilisation de produits chimiques en milieu urbain nécessite la recherche de techniques qui respectent autant que possible la santé publique. Les techniques d'injection répondent à ces exigences car elles limitent la dispersion de produits chimiques dans l'environnement. Cependant, il est nécessaire d'analyser les différents aspects liés à cette technique, les conséquences sur la stabilité des palmiers à la suite de la perforation des troncs. Les études sur le sujet ont été entreprises et un protocole expérimental est en cours de définition.

Mots-clés: charançon rouge du palmier, techniques d'injection, biomécanique, évaluation de la stabilité, palmiers.

In Italy there are numerous works of art, literature and botany that over the centuries have witnessed the presence of exotic palm trees in parks, gardens, botanical gardens and villas. Acclimation of different species, the result of scientific work and a great passion by botanists and enthusiasts, has allowed, in particular since the nineteenth century, an extraordinary spread of these as a decorative element dominant in public and private parks. Among the palm trees, the species within the genus *Butia*, *Brahea*, *Jubaea*, *Livistona*, *Phoenix*, *Sabal*, *Trachycarpus* and *Washingtonia* have been widely used for ornamental purposes, but *Phoenix canariensis*, introduced in 1864, is the one that has had the greatest distribution, probably for its particular adaptability to different environmental conditions. Within the Italian territory, the palm trees are mostly found in central and southern regions, Sicily, Sardinia and Liguria. All species mentioned above, together with *Chamerops humilis*, the only endemic palm, are susceptible to the attack of the red palm weevil (LONGO *et al.*, 2011); the majority of reports of infestations in Italy, where they now took the characteristics of phytosanitary emergency and where there is a decree of mandatory control (Decree 11.9.2007), refer however to specimens of *P. canariensis*.

In Italy, the first report of the presence of the red weevil, a native of Southeast Asia and Melanesia (MURPHY & BRISCOE, 1999), took place in 2004 in a nursery in Tuscany (SACCHETTI *et al*., 2005). Within a few years it has been firmly in place in Sicily, Campania, Puglia, Lazio, Marche, Abruzzo, Sardinia, Liguria, Calabria, Molise (LONGO, 2009), and finally, in 2010 in Basilicata. The number of infested trees indicated by the Italian Phytosanitary Services, in early 2010, was about 40.000 (GRIFFO, 2010); today the number is difficult to quantify.

In Liguria, the palm trees characterize all the coastal cities from Ventimiglia to La Spezia. To date, western areas of infestation have been confirmed in the municipalities of Bordighera, Sanremo and Ospedaletti. In the province of Savona significant outbreaks are reported in the towns of Alassio and Laigueglia; no report has, however, come from the provinces of Genoa and La Spezia. Currently infestations are therefore confined in the west, but given the significant presence of palm trees in the whole coast, a further expansion could be expected.

The prevention and control of infestations of this pest, about 10 years after its introduction in Europe (BARRANCO & DE LA PEÑA, 1996), still need to be optimized. The larvae, the endophitic activity of which originates damage, live well protected inside the plant and only at maturity they move outward to pupate; this, together with the considerable dimensions and the particular physiology of the palms, makes ineffective the most common means of chemical control.

In an urban environment, moreover, there are only few chemical molecules currently authorized in Italy against the red palm weevil. In view of the spread of infestations and the limited effectiveness of the insecticides used in this context, the Italian Ministry of Health, since 2008, has allowed, with a series of decrees with a temporary duration of 120 days, the use of certain products, not used before. In 2012 it was finally approved the use of chlorpyrifos-methyl to treat hair, abamectin to be administered by trunk injections (natural absorption or pressure) and, finally, imidacloprid + cyfluthrin by both sprinkling and trunk injections.

The management strategy of public parks, regardless of the legal aspects, however, should be addressed to activate the use of insecticides with low environmental impact and methods of administration that have as their premise the impossibility of contact with the user audience. The trunk injection is a technique that responds to this request, since it consists of a direct entering of the formulations into the palm tissues, although this does not make an effective control of the pupa and adult insect possible, stages that must be controlled by means of the interaction with other application methods.

In this context, pursuing the goal of reducing the number of foliar applications, as well as to obtain a prolonged persistence of action of the molecules used, an intensive research started, aimed to evaluate the effectiveness of trunk injections. This technique was most widely tested in the case of dicotyledonous trees, while in the case of palm trees, monocots and therefore with a different system of water and nutrient transport, there are still many aspects which need to be investigated.

The trunk injections has a number of advantages over more traditional methods of spraying or fogging, but like all the chemical treatments, of whatever nature, causes a disturbance of the biological equilibrium inside and outside the plant.
This application method, being devoid of dispersion, may be considered of low environmental impact, allowing to perform targeted chemical treatments and reducing pollution and risks to human health; at the same time, the amount of used formulated can be reduced. From the economic point of view, the higher cost of single treatment, is compensated by the number of treatments (1-2 per year, while with the traditional methods it is necessary to intervene 2-3 times in a season) and by the lower amount of product used; consequently it can be assumed also a lower treatment cost.
Although the humidity and low solar light slow down the process of absorption of plant protection products within the plant, the weather conditions, such as rain and wind, do not diminish the effectiveness of endotherapeutic treatments. In the absence of washout or aerial drift, one should get a higher absorption, favoring a longer period of protection, regardless of the weather conditions.
In contrast, plant protection products for endotherapeutic use may have a very low pH, for which if not properly diluted may cause localized phytotoxicity. On the other hand excessive dilution may induce precipitation of the product which, by blocking the conductive vessels, reduces its absorption capacity. Furthermore, as demonstrated for other plant species physiological responses, such as discoloration of the tissues and formations of tires, may occur in reaction to the introduction of foreign substances (NICOLOTTI *et al.,* 2006). Little is known about the effects of endotherapy against the microflora and microfauna of the palms. We know that some products may preferentially accumulate on flowers, fruits or leaves, threatening insect fauna and microflora. Another aspect not negligible are the phenomena related to the penetration of air bubbles inside the vessels during the perforations in the trunk. The air pockets cause interruptions that break the flow of xylem and interrupt the delivery of the injected product. Internal cavities near to the perforations or in a higher position may take place, in which case the product may not continue its path. Same phenomenon occurs in the vicinity of areas inside the conducting system which is damaged by the activity of the larvae of the weevil. The problem of internal occult cavities is not negligible, since the palm damaged tissues do not build reaction wood and the only visual investigation can hardly detect the damage.
Another aspect to be considered is related to drilling practiced on the palms for trunk injections and the consequences they may have in the medium or long term stability of the plant. In fact, it is possible that several holes in the radial plane of the trunk, to a depth of 20-30 cm, damaging the tissue, may alter the normal function of support. In this regard, it is worth repeating that the palm can not build new tissues through the cambial activity to partition the wounds, and the hole remains for as long as the life of the plant. It is appropriate, therefore, the study of the influence that the trunk injections can have on the propensity to failure of the palms.
This type of study must be supported by knowledge of the biomechanical mechanisms upon which relies the stability of the palms. To meet this need, a research was undertaken aimed at the definition of these matters. The first observations suggest that is of fundamental importance the anatomical configuration of the palms, that contributes to stability by a dissipative process of wind energy captured from the stalk (RAIMBAULT *et al*., 2010). In this way, even a lesion apparently marginal in the tissues of the trunk disrupts the chain of translocation of forces. Building on the findings of an initial experimental phase, the project is trying to develop a protocol for the evaluation of the structural short-term endotherapeutic interventions on *Phoenix spp.*
The study conducted so far has been articulated through next logical and consequential procedural steps:
1) definition of a theoretical model of stability of the palm (*Phoenix spp*.);
2) identification of the energy chain (capture, translocation, dissipation and dispersion) in relation to morpho-physiological aspects of palms;
3) application of controlled tension to evaluate the deformation of the trunks under load;

4) evaluation of the compressive load and traction palm wood to acquire further information on the biomechanical and structural evaluation of the propensity to failure;
5) use of sonic tomography to study the structural aspects of palm wood;
6) comparison of the results of the points 3 to 6 with the mechanical model referred to in point 1;
7) development of a code of reading mechanical anatomy of the palms as a function of their stability;
8) possible applications of instrumental assessment of stability of the palms (VPA, Visual Palms Assessment).
The research was undertaken as part of the project "PALM I.S. ", funded by the Centro Studi e Ricerche per le Palme (Sanremo) in 2012. Waiting for a critical analysis of the results already obtained and the research plan for the years 2012-2015, it is desirable to adopt the principle of prudence in the application of the endotherapeutic techniques repeated on the palms which could further aggravate an environmental heritage already widely threatened by the red palm weevil.

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