The use of trunk injection in *Rhynchophorus ferrugineus* control (Olivier).

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Introduction

This work aims at summarizing the state of the art knowledge acquired on trunk injection methods applied to palms and on the correct procedures to obtain the best results in red palm weevil control.

State of the Art

Red palm weevil comes from South Asia where it originated and quickly moved westward, being facilitated by exports of infested vegetables. Since 1994 it has struck European coastlines (Ferry e Gomez, 2002). This insect has the characteristic of being lethal for palms. The phytophagous can attack several species of palms (EPPO, RHYCFE; Esteban-Duran, 1998), showing however, as in the Italian case, food preference for the *Phoenix* species. In Europe the difficulty in red palm weevil control is mainly due to the fact that most plants are situated in urban areas with a consequent loss of their productive functions, which is the basis of all work so far published internationally. Pest control within the urban environment is based on pesticides with active ingredients with a low environmental impact and on administering techniques which imply no contact between pesticides and urban plant users. This implication means that researchers and technicians must explore methods and molecules which, though effective in red palm weevil control, mainly safeguard human health. Trunk injection is a method which meets most requirements mentioned above and is therefore of great interest for the development of *ad hoc* research of red palm weevil control. On the other hand it must be said that this method does not allow an effective control at the pupa and adult stages of the insect. These stages must be controlled by employing other applied methods. The main reservations on the use of this methodology on monocotyledon plants like palms, rest on the idea of the difficulty in reaching the vascular bundle of the plant in order to spread the injected active ingredients. Palms, indeed, have no vascular cambium and, unlike dicotyledon plants, do not grow secondary with yearly rings.

The mere placing of injections within the trunk of dicotyledon plants with the immediate location of vascular areas of activity, the little information on the anatomy of the vascular area in monocotyledon plants and the small amount of news on chemical and botanical research on the actual possibility of translocation of substances within palm trees through xylem tissue, have supported the idea that trunk injection is not a viable strategy against endophytic insects on these plants. A better understanding of the vascular anatomy of these monocotyledon plants, the study of the red palm weevil life cycle and the understanding of the different development stages when the action of highly systemic pesticides is most effective, led us to research the actual capacity of trunk injection pest control systems in red palm weevil.

Doubts on the transmission of substances injected in the vascular system of palm trees have already been discussed and mainly rest on the type of molecule injected. Transmission, however, has been highlighted in several papers. It has been noted that the use of Dimethoate as an active principle in trunk injection shows its presence in fruit from fifteen days after treatment up to the 60th day, finally disappearing around the 75th day from treatment (Khan et al., 2001). During trial

treatments with ground irrigation of the active ingredient Imidacloprid, it has been noted that has been transmitted up to the preimaginal stages of the red palm weevil causing its death (Kaakeh, 2006). Hernandez-Marante and his colleagues (2003), moreover, have shown the transmission of the products used in trunk injection thanks to an *ad hoc* test which made use of safranine (1%) during injections, as per the Navarro protocol (Navarro et al., 1992). Considering the peculiar anatomy of the palm vascular system, they have highlighted, thanks to a section at the crown level, that the dying product caused a widespread cloud of red dots in connection with the vascular bundles. Finally, cutting leaves at their bases, the spreading of the product has been confirmed (Hernandez-Marante, et al., 2003). Alvarez and his colleagues (2003) showed that the transmission of inducers resistance used for fungus control *Elaeis guineensis*, is by all mean similar if these are inserted into the plant either from the trunk injection or through root absorption. Moreover, tests of iron fertilization through trunk injection treatment have shown transmission of the product to the leaves (Abo-Rady et al., 2007). It is believed that some problems during trunk injection treatments could be linked to the peculiar anatomy of the vascular system of the palm tree resulting in embolisms. The presence of cavitations due to emboli, as an ordinary consequence after water stress periods in palm trees, is a fact that remains to be confirmed. Sperry (1986) showed that these forms of embolism can be reversed in palm trees, during rainy periods. It must also be taken into account that there are many anastomosis in palm vascular vessels and that excessive liquid in the xylem area causes the opening of anastomosis with phloematic areas at night-time increasing its descending flow, which is restored during day time (Fisher et al., 2002; Zimmermann et al., 2002) .

Trunk injection in Palm trees

Trunk injection in palm trees has been effectively used also for other pest control, such as some tettigonids defoliating the oil palm tree (Caudwell e Orrel, 1997), with the homopter *Asterolecanium phoenicis* Rao (Ahmed, 2007) and other pests (Dharmaraju, 1977; Nadarajan e Channa Basavanna 1981; Ooi *et al*., 1975; Singh 1986).

Trunk injection in palm trees to control the red palm weevil

In the past several authors have shown how various active ingredients injected directly into the palm tree have been effective in the preimaginal stages of the red palm weevil (Abad e Gallego, 1978; Abraham et al., 1975; Azam e Razvi, 2001; Dean, 1976; El Ezaby, 1997a; El Ezaby et al., 1998; Frohlich, 1970; Hernandez-Marante et al., 2003; Kitrhisinghe, 1966; Kurian e Mathen, 1971; Lakshmanan, et al., 1972; Lepesme, 1974; Mathen e Kurian, 1967, 1970; Muthuraman, 1984; Nirula, 1956; Rajmanickam et al., 1995; Rao, 1973; Vidyasagar et al., 2000). Moreover trunk injection tests have been carried out with entoparasite nematodes injections. These have shown high effectiveness in lab tests but not in open fields because of the difficulty these organisms have in reaching all development stages of the red palm weevil (Shamseldean, e Abd-Elgawad, 1994).

Best time for trunk injection treatments

Considering the close relationship between increase of light hours, increase of temperature, decrease of relative humidity and the immediate reduction of xylem pressure within negative values (Zimmermann et al., 2002), it is well acknowledged that trunk injection treatment should be carried out on sunny days, with little relative humidity and away from downpours.

Assessment of the infestation degree

Regarding the study of the effectiveness of trunk injection treatments, preliminary data obtained during tests carried out along the Latium coasts by the Plant Protection Department of the Tuscia

University (Viterbo, Italy) together with the Technogreen® firm from Cesena, show the importance of very early intervention, when the first symptoms of pest appear (publishing of data currently in progress). These data are in line with what Hernandez-Marante and his colleagues showed in 2003. In order to assess the infestation degree during preliminary tests, the method described by Hunsberger and colleagues in 2000 was applied against the *Rhynchophorus cruentatus*, assessing palm infestation with the use of nine classes of palm decline. It must be noted, however, that in 1997 El-Ezaby had already designed a five degree classification of the infestation level, which can also be used (El-Ezaby, 1997b).

Injection procedures

Place injections at least one metre from the base of the crown. Needles must reach down to the depth of the trunk ray at least. Trunk injection treatment is not advisable with *Phoenix canariensis* and *Phoenix dactylifera* and with a diameter below 30 cm. In case of 30-45 cm diameter three injections are recommended, with 45-60 cm diameter four injections, with diameters larger that 60 cm five injections are recommended. The number of injections can increase in case of exceptionally large diameters (Hernandez-Marante et al., 2003). Taking into account the lack of cicatrisation of the injection puncture (Howard, 2001), it is necessary to seal punctures with protective pruning cement .

Conclusions

From bibliographical data and from preliminary tests, currently under publication, carried out along Latium coasts, we can confirm that trunk injection is a feasible technique in red palm weevil pest control. On the basis of the results so far achieved, and along the lines of other authors (Faleiro, 2006; Rochat et al., 2006; Sacchetti et al., 2006), we must stress that preventive pest control rather than curative pest control treatments are more appropriate. However, these considerations must follow the assumption that in the case of this dangerous pest an integrated control plan is necessary. Along with other authors (Faleiro, 2006; Ferry e Gomez, 2002), this plan must include an agronomic phase for the well keeping of the plant, for the ridding of endangered palm tress, correct management of pruning practice, an indispensable and exact assessment of the presence and the degree of pests and an adequate chemical strategy, a preventive one if possible, which makes use of both trunk injection treatments as well as local treatments of the palm crown for adult pest control. On the other hand it must be said that foliage treatments cause products to drift and disperse with obvious negative side effects in urban areas. Moreover, the development of biological models able to predict the dynamics of pests would be desirable as a valid help to IPM programmes (Speranza et al., 2007). Bearing in mind that the main difficulty in this kind of pest control is related to the fact that palm trees are grown in urban areas, it would be desirable that these pest control methods be associated with products which have little or no environmental impact, such as organic active ingredients and organisms which are entoparasite and entomopathogen to the red palm weevil.

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