Another Conception of the "Preventive" and "Curative" Treatments to Control the Red Palm Weevil

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Abstract

The usual conception of "preventive" and "curative" treatments leads to extremely rare assessment of these treatments as components of IPM strategy although this strategy is systematically recommended as the right one to control the Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* (Olivier). In addition to the lack of scientific results on the efficiency of these treatments in real field conditions, the usual way to assess this efficiency does not integrate the fact that it depends on the efficiency of each component of the strategy (strong interdependence). Furthermore, it presents the risk to miss out the essentials to assess the efficiency of the RPW control programmes and even to misconceive what should be the objective of these programmess.

The objective of the RPW control programmes, as in fact of any IPM programme when the economic threshold is exceeded should be to obtain the quick decline of the pest. In case of RPW it is largely exceeded everywhere in the world. Two indicators allow perfectly to determine if this decline is or not strongly represented *viz*. the evolution of the number of new infested palms and of RPW captures in the traps during successive periods of time.

Monitoring carefully and permanently these indicators is indispensable to assess if globally all the components of the integrated strategy are efficient. This information is especially indispensable at the local level where action takes place. It should be easily accessible to each group of neighboring palms owners. It would facilitate their participation to RPW control programme. A greater contribution of their part in the

implementation of the various components of the strategy would considerably increase its technical and economic efficiency. For this purpose, a version of the *SusaHamra* system, developed by FAO and simplified for an exploitation focused to the registration and easy analysis by the local field actors, especially the farmers groups, of the two indicators mentioned above would be of great help.

To contribute to the shift of conception of the "preventive" treatment and the "curative" treatment, I propose, for a better evaluation of these two components of the integrated strategy of the RPW control programmes, to call them respectively "reproduction preventive" treatments (prevention of oviposition) and "sanitation" treatments (eradication of RPW in infested palms, including when necessary palm eradication). Presently, data are totally missing to evaluate the contribution of each component of the integrated strategy to the reduction of the RPW population (represented by the reduction of the number of new infested palms in successive periods of time). It would be very useful that, at least at experimental field level, studies on that issue be engaged.

Key words: *Rhynchophorus ferrugineus*, Integrated Pest Management, Red Palm Weevil control programme, farmers participation, economic threshold, sustainability, treatment efficiency, treatment persistency, quarantine pest, GIS, eradication.

Introduction

Within the last 35 years, the Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) has been introduced, due to palms trade, in a considerable number of countries, especially in all the Near East and North Africa countries, except Sudan and Algeria, and in all the countries of the Southern Europe and of the Eastern Mediterranean region.

In the infested countries, it has also been spread rapidly everywhere within the country, essentially as a consequence of the trade of palms or offshoots but also ornamental palms, initially infested by the imported palms (Ferry, 2019a). At its origin, this catastrophe is the consequence of the absence or the deficiency of quarantine measures, including the

production of phytosanitary certificates and implementation of inspections deficient for technical value (Ferry and Gomez, 2013).

In very few infested countries, the RPW control programmes have allowed to eradicate the pest (Fajardo *et al.*, 2019). In some oasis, eradication or important reduction of the pest has been obtained but re-introduction of new infested palms has reduced to zero these successes (Ferry, 2019a). Presently, in most of the countries, the natural spread of RPW to the palms around the infested palms is very active, in addition to the occurrence of new spots of infestation due to the internal trade of palms and sometimes to the continuation of palms imports from infested countries. In some countries, it is considered that the prevalence of infested palms is low but this statement is not well founded and this result is obtained thanks to high public resources, in unsustainable conditions in the medium and long term (Ferry, 2019a), both for economic reasons (high endless cost) and for environmental/health reasons (Abbassy *et al.*, 2017).

Nevertheless, since 1998, the strategy and the techniques to control this pest on date palm in oasis was established (Abraham *et al.,* 1998) and confirmed (Faleiro, 2006). The situation is similar regarding the control of the RPW on ornamental palms in urban environment (Ferry and Gomez, 2008).

Treatments that are named “preventive” and “curative” constitute two components of this strategy. The knowledge about the efficiency of these treatments, especially regarding the preventive ones for date palms and in hot arid environment, is still insufficient in real field conditions and even in field experimental conditions. However, there is no doubt that these treatments when well applied and for which enough experimental rigorous field results are available, present a certain interest. It justifies their use as long as they are applied as components of an IPM strategy whose objectives are clearly established and as long as they are not proposed to be applied indefinitely.

These treatments are usually only conceived, implemented and assessed for their efficiency to protect the palms or to cure the infested ones. They are not evaluated for

their conformity with the principles of IPM. More globally, they are not evaluated as components whose usefulness depends strongly of the implementation and efficiency of the other components of RPW integrated control strategy. The "preventive" and "curative" treatments, as each component of such strategy, should be conceived, implemented and evaluated taking into consideration that the strategy has to be implemented in the whole infested area with the objective to reduce the pest population in a sustainable way, which means rapidly and strongly.

To integrate these aspects, I propose in this paper another conception of the "preventive" and "curative" treatments, different to the usual one and that should allow to better conceive and monitor the RPW control programmes. In order to better mark this difference in conception and objective of these treatments, I have called in this paper the "preventive" and "curative" treatments respectively "preventive reproduction treatment" (prevention of oviposition) and "sanitation treatment" (eradication of all forms of RPW in infested palm, including when necessary palm eradication).

Assessment of the usual conception of the "preventive" treatments

General assessment

Preventive treatments are often recommended without being based on results of rigorous experimental field work to evaluate their efficiency and the duration of their residual effect (persistency).

Regarding experimentation results, most papers published on these treatments consists of evaluating the effect of insecticides on adults or larvae in laboratory conditions. The corresponding results are useful but not sufficient to evaluate the efficiency of such treatments in field conditions.

Papers in small number have also been published where these treatments, especially for date palms and in hot arid conditions, were tested in field experimental conditions. In that case, most of the protocols used to evaluate the efficiency were based on active substance residue analysis. However, it has been established that this kind of protocol can lead to

erroneous conclusions as the active substance can be metabolized in another molecule as active or even more active than the original active substance against the pest. This result was clearly demonstrated especially with thiametoxam (Gómez *et al.*, 2011). For many insecticides, the metabolites of original active substance are even unknown. To evaluate the efficiency of treatments, protocols based on bioassays with larvae allow avoiding this problem (Ferry and Gomez, 2014) but very few papers are based on such protocols.

One of the reasons why experimentally robust results on the efficiency of spraying or soaking treatments in experimental field conditions are not numerous is that the protocols are complex and difficult to implement because it is usually not possible to dispose of homogeneous infested plots and it is of course not possible to release adults. For "preventive" treatments by injection, the experimentation is much easier and part of the available results is based on robust experimentation protocols.

Finally, to my knowledge, in only one paper, this type of treatments has been evaluated in real field conditions as a component of IPM strategy and for their contribution to control the pest inside an integrated control programme aimed to obtain the RPW regression. (Ferry *et al.*, 2019).

The main problem regarding preventive treatments is not the lack of efficient insecticides but the implementation of right application methods to reach the adults, the cost of treatments and the health and environment risks (Ferry, 2019b).

Soaking versus Spraying

It is not rare to see that today the classical way to apply phytosanitary treatments by spraying the insecticide solution is still used in the case of RPW. The efficiency of such mode of application is low because it does not answer the objectives of such treatments: to reach the adults and to extend as much as possible the effect of the treatment to protect the palms from new infestation.

The adults spend most of their life hidden at the petioles and leaves bases where they feed (mainly drink) by digging small holes and that constitutes also the main site of

oviposition of the females. It is in that region that the insecticide solution must reach. It is useless to treat the whole foliage or trunks of old palms (except when fresh wounds or aerial roots are present).

In palms, the base of each frond petiole is covered by fibrous leaf sheath (fibrillum / lif) of various other leaves. This fibrous matting corresponds to the dry part of leaf sheaths and constitutes a tissue that will absorb the insecticide solution. In addition, the very shape of the petiole base creates a small reservoir where insecticide solution can be retained and will pass from petioles bases to lower ones as the reservoirs are filled. These two advantages will be much better exploited if the insecticide solution is applied by soaking the petioles bases, instead of being sprayed. Even if soaking is well applied it requires a bit more time than spraying, this disadvantage is largely compensated by the treatment efficiency, especially for its extended effect and also its capacity to reach through the oviposition holes the eggs and the early stage larvae. To soak correctly with classical spraying equipment, the nozzle of the sprayers must be removed.

Since at least 1998 (Abraham *et al.*, 1998), the interest of applying soaking treatments instead of spraying treatments was recommended.

Another great advantage of such way to apply the treatments is also to prevent or reduce greatly the dispersion of insecticides in the environment and consequently to reduce health risk for the workers and soil and water contamination.

Targeting the treatments to the oviposition sites

Because of persistent and surprising misconception, it is still often stated that wounds are necessary for RPW oviposition. However, since at least 1911 (Gosh, 1911), it was established that previous wounds were not necessary for oviposition and that female dig holes in which they lay their eggs. Various authors have confirmed this information (Wattanapongsiri, 1966; Ferry and Gomez 2011; Ince *et al.*, 2011). The extraordinary ballet that female realize to lay their eggs have also been described (Ferry and Gomez, 2015).

The behavior of the female for oviposition has fundamental consequences. The depth of oviposition holes is strictly limited to the length of the rostrum till the antennae. As the eggs must be imperatively placed in living tissues for their survival as well as for the survival of the first instars stages and as the female realizes oviposition in hidden places (except in the presence of fresh wounds), the sites of oviposition are very specific (Ferry, 2019). These sites must be the targeted sites of the treatments.

Unfortunately, because this behavior for oviposition is still ignored, it is frequent to find, even in recent scientific papers, that the sites of oviposition are: wounds, cracks and crevices, wound pruned rachis, junction between mother palm and offshoots, places like the trunk base (where in fact they just hide) or old remaining petioles where the superficial tissue is necrotic at a depth much superior to the rostrum length, etc. Only fresh wounds and of sufficient size constitute possible oviposition sites. Otherwise females can be attracted by volatiles resulting of a wound but the wound by itself, if its size is not sufficient for the oviposition ballet to take place, will not constitute oviposition site. For oviposition, females don't need previous wound. Females dig exploratory holes before oviposition; they will not lay their eggs in drying or dry wounds. In addition, for date palm, at the difference of what occurs for coconut or *Phoenix canariensis* for example, palms of more than 2-3 meters trunk height and without offshoots are rarely infested (excepted when they present a wound of sufficient size or live aerial roots). When infestation occurs in a date palm of more than 3 meters, it is usually with male palm and infestation takes place at the crown level like with coconut and *Phoenix canariensis*.

Because of the misconception on oviposition, the right way to apply "preventive" treatments is still often misunderstood. Preventive treatments should be applied essentially on date palms of less than 2-3 meters trunk height and targeted to the sites of infestation that are also the places where the adults are hiding most of the time: the offshoots, the trunk to soak the base and the remaining petioles and the crown fronds bases.

Persistency of the efficiency

In very few experimental papers, the persistency of action of «preventive» treatments by spraying or soaking has been established. The situation is similar for chemical and biological treatments.

For spraying or soaking treatments, a certain efficacy can be obtained if the formulation is liquid and the application is repeated each 2 to 4 weeks and well targeted to the base of the petioles where chemical insecticides or biological agents are protected from the direct sun effects.

Systemic insecticides for soaking treatment

Amongst the insecticides that are used for spraying or soaking treatments, some of them are recommended because they are known to be systemic. This reason is not valid because the leaves of the palms are covered by a thick cuticle that prevents nearly totally the absorption of the insecticide. A bioassay with imidacloprid and thiametoxam allowed to confirm this point (Gómez *et al.*, 2011). The systemic insecticides act essentially by contact in the case of these treatments.

Injection

Preventive treatments by injection have been used at large scale on *Phoenix canariensis* in Europe. In contrast with the soaking treatments, strong experimental protocols based on bioassays can be used to assess the efficiency and the persistency of such treatments in the field. Very low cost, easy to use and safe techniques, especially when injection is based on infusion mechanism, are available.

One of the main problems of this technique is the production of wounds resulting of the hole done to inject the insecticide. To limit the mechanical and physiological risks that can result from the production of numerous injections, these must be well separated and also be as shallow as possible (15 cm depth maximum in the trunk after passing the remaining petioles).

In the use of this technique for ornamental palms, long persistency insecticides are preferable to limit the number of injection and to reduce the cost. For palms cultivated for fruit production, injection can also be done but taking into account a delay before harvest (variable with insecticide type) to prevent the presence of insecticide residues in the fruits.

Conclusion

The knowledge on the effectiveness in the field of the «preventive» treatments by soaking chemical or biological products as well as the duration of their residual effect is still insufficient. Nevertheless, it can be concluded from the available experimental data that, even if their effectiveness, especially in the case of date palms and in dry arid environment present certain limits (short persistency), they can play a role as a component of an IPM approach if they are well applied as described above and repeated frequently.

Assessment of the usual conception of the "curative" treatments

Curative treatments by heavy soaking the infested zone with chemical insecticides or nematodes can be effective if they are applied frequently and during sufficient time to prevent the reproduction of the weevil (by killing the RPW in cocoons that are in contact with the outside). Curative treatments with *Beauveria bassiana* strains that have been tested cannot work because endophytic migration that in addition requires previous injection, is limited to a very small zone (Gómez *et al.*, 2009).

Curative treatments are done by injection of chemical insecticides for many years and their efficiency is high when well applied (Abraham *et al.,* 1998). As already mentioned very simple and low-cost methods (a simple syringe or tube can be sufficient if the insecticide can be injected a little or no diluted) can be used.

Nevertheless, alternative mechanical sanitation methods exist. They can be easily applied by the farmers themselves (Ferry, 2020).

Fumigation with phosphine although it is applied in some places is a risky technique that should be applied only by specialized staff. The use of such technique in the field is forbidden in many countries. It is only authorized in special chambers. For these reasons and because alternatives exist, the interest of this technique is very limited.

Another conception of the "preventive" and "curative" treatments

In this conception, «preventive» and "curative" treatments are conceived, implemented and assessed as inseparable components of IPM programmes to control a quarantine pest. The objective of such programmes in the case of the RPW that is a deadly quarantine pest is to obtain quickly the decline of the pest and possibly its eradication.

In this framework, the objective of the «preventive» and «curative» treatments is much more ambitious than those addressed in the usual conception of these treatments.

The objective of the «preventive» treatments is not to protect the palms but to kill the adults and to prevent oviposition or even to kill eggs and larvae at the first stage when they are still close to the surface. The objective of the «curative» treatments is not to cure the palms but to eradicate all the weevils present in the infested palms (when possible by preserving the infested palm) and consequently to eradicate spots of RPW reproduction and spreading.

In the framework of this conception, the objective of the «preventive» and «curative» treatments is to contribute in strong interrelation with other components of an integrated strategy to obtain the quick reduction of the RPW population. Consequently, it will be in view of this objective that they will have to be conceived, implemented and assessed. I would like to underline that this conception presents the great advantage to conceive and assess the treatments not individually as it is done in the usual conception but as components which efficiency depends of the effectiveness of each of the other components.

To contribute to the shift of conception of the "preventive" treatment and "curative" treatment, I propose, for a better evaluation of these two components of the integrated

strategy of the RPW control programmes, to call them respectively “reproduction preventive” treatments (prevention of oviposition) and “sanitation” treatments (eradication of RPW in infested palms, including when necessary palm eradication).

Conception based on IPM approach principles

The two fundamental pillars of the IPM approach are:

- to avoid or to limit as much as possible the use of synthetic chemical products, because of the risks that they could present for environment and health, by implementing other methods of control (including, as a priority, the prevention of the pest introduction). Nevertheless, as the RPW is a quarantine pest, it may be considered acceptable to qualify this principle if the effectiveness of a chemical “preventive reproduction treatment” is much greater than that of the other components of the IPM strategy and its use would result in a rapid decline of the RPW. In this case, it would be legitimate to give preference to a chemical treatment, taking into account that its use would be limited to a short period of time. Unfortunately, chemical “preventive” and «curative» treatments have been applied in many places for tens of year resulting in hazards for health and environment.

- to take into consideration two economic thresholds in order to establish from which level of pest population, control programme has to be implemented and from which level the cost of damages becomes superior to the cost of control. In the case of the RPW, that is a pest that first kills very quickly and unavoidably the palms that it has infested if nothing is done to prevent it and, secondly, reproduces rapidly and intensively in the infested palms, it must be considered that the economic threshold is reached as soon as one infested palm is detected and even before if a pest free area is located closed to an infested one. Regarding the economic injury level (EIL), data are missing to establish it. The situation is especially problematic in the places where the cost of the control is entirely funded by of the State and/or where the date palm cultivation is now much more

based on cultural than economic reasons. In these places, the incidence of infestation is far beyond the EIL for many years.

In view of the two principles of IPM mentioned above should lead to reconsider in many places the conception of RPW control programmes and of the "preventive" and "curative" treatments in these programmes.

An IPM programme targeting the quick decline of the RPW

The different components of an IPM programme targeting the quick decline of the RPW and their interrelation are schematized in figure 1.

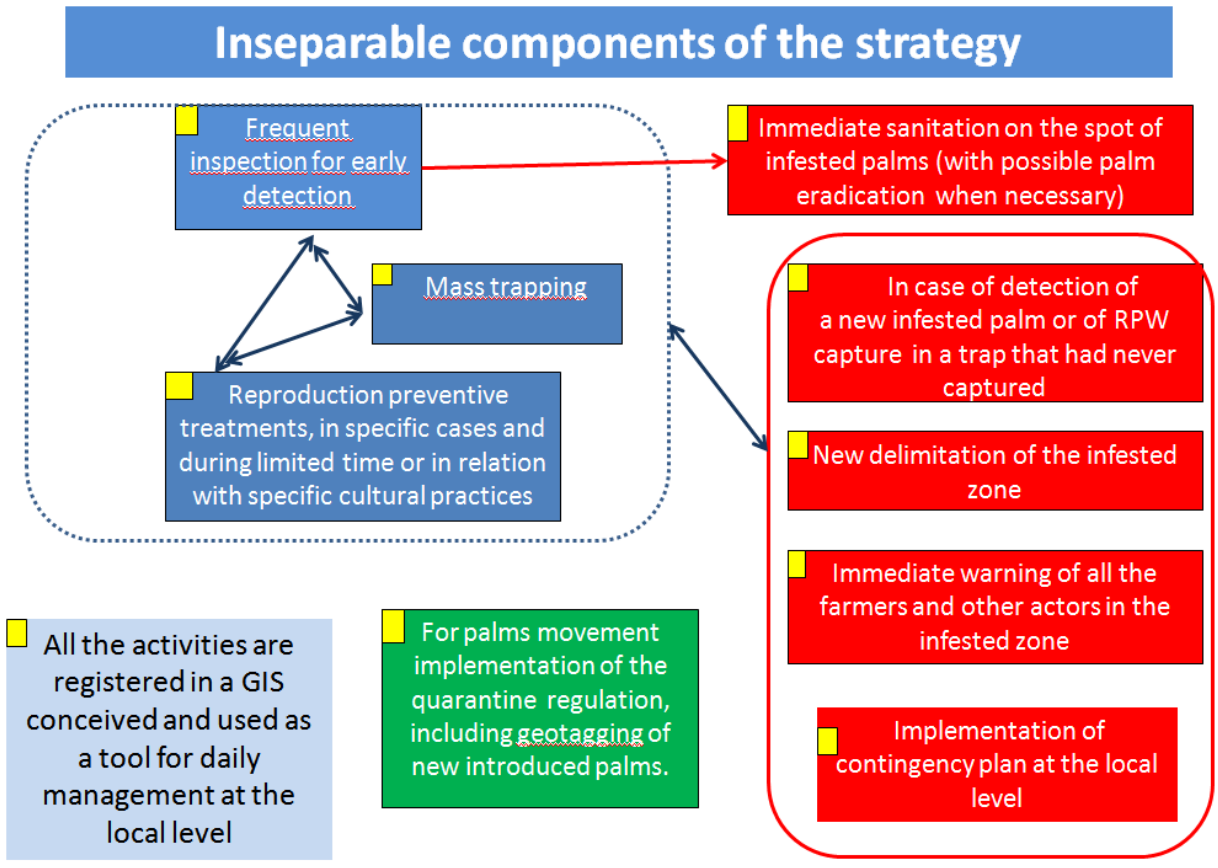

Figure 1. Integrated strategy to obtain the quick decline of the RPW

Two conditions are necessary to assure the success of such strategy:

- it must be implemented in the entire potentially infested area, considered as the zone where RPW is present at a given time, including the infested palms and the not yet detected infested palms. The exact limits of this zone are of course is impossible to establish. For practical and economic reasons and because the natural spread of RPW is aggregative/clumped around the infested palms, the potentially infested area corresponds to the zone where at a given time are present the infested palms and the traps that capture, increased by a strip of few hundred meters. Implementing the strategy only in some places of this zone is doomed to fail because the control of the pest in these places become rapidly unsustainable if RPW continue to reproduce in uncontrolled infested palms located around these places.

- all the activities and the results must be registered (with their geo-tagging) and updated permanently (GIS) to monitor the right implementation of the strategy and to react rapidly if the results don't correspond to what was expected. This tool is also indispensable for the exchanges with and between the palms owners and for early warning.

Reproduction preventive and sanitation treatments integrated inside a global strategy

The different components of the strategy must be applied in a very complementary way to assure the best efficiency of each of them and of the global strategy. It must be noted that no data so far have been published to establish the contribution of each component of the strategy in the efficiency of the global strategy. It is not easy to address this question but it would be very interesting that it is studied, at least at an experimental scale.

Although theoretically, the different components of this strategy or at least some of them could allow when applied alone to control the pest, such result would be difficult to obtain in real field conditions at the scale of a large potentially infested area.

Sanitation treatments usefulness depends of the inspection efficiency

Sanitation treatments if applied before new adults emerge and spread would allow as unique component of a strategy prevent the reproduction of the RPW and would lead rapidly to the eradication of the pest. However, although visual and by touch inspections when they are realized frequently allow to detect infestation early, the efficiency of inspections will not be sufficient in real field conditions and at a large scale to detect on time all the infested palms and so sanitation treatment alone cannot permit to control the pest. Nevertheless, inspection followed by immediate sanitation when an infested palm is detected contributes undoubtedly to the efficiency of the global strategy. Leaving infested palms without acting for months or even till they dry makes much more difficult to obtain the quick regression of the pest. Much more difficult but not impossible because it is important to repeat, that when a palm is finally killed by the RPW, it ceases to be a problem.

Furthermore, it is important to underline that in the framework of the conception of the sanitation treatments proposed in this paper, their efficiency, even if sanitation (RPW eradication in an infested palms) can perfectly be efficient at 100%, depends very much of the efficiency of the inspection component of the global strategy. When detected and sanitized late, an infested palm will have released part of the RPW population that it contained. In that case, the usefulness of the sanitation will be inferior.

It must be added that inspection and sanitation, especially if it is mechanical, could be perfectly implemented by the farmers themselves after training.

Reproduction preventive treatments usefulness and complementarily with the other components of the strategy

At a small scale, “reproduction preventive” treatments applied rigorously (mode of application, frequency) could allow as unique component of a strategy to obtain the rapid decline of the pest and finally its eradication. Modelling and results obtained at a medium scale have even allowed to establish that if only 75% of the palms of an infested zone

were treated with a technique, at the same time, very efficient and affordable for the majority of the palms owners, the quick decline of the RPW population could be obtained in four years (Ferry *et al.*, 2019).

Nevertheless, such results could most probably not be obtained at a large scale in palms plantation for fruit production because, first, the technique mentioned above is only acceptable for ornamental palms (no problem of residue in fruits) and, secondly, the implementation at a large scale of soaking treatments that have to be repeated each 3-4 weeks to be efficient seems unrealistic even if applied during only few years. However, reproduction preventive treatments can contribute to the decline of the RPW population and consequently to the success of the global strategy if they are applied in specific cases and for a short period of time: new or small spot of infestation, hot spot of infestation (traps capturing a lot, infested palms detected late), on the palms in the vicinity of traps, after offshoots removal, pruning or mechanical sanitation.

Regarding these three last cases, I would like to insist of the importance to change the perspective: the implementation of these cultural practices, that anyway are indispensable, has usually perceived as problematic because they lead to the production of wounds kairomones that could attract RPW and facilitate the female oviposition. First of all, no data (at the contrary it is well established that the largest part of adults remains in the infested palms as long as possible) demonstrate that wound kairomone could contribute to increase the number of RPW that will leave an infested palm. The main effect of wound kairomone will be that the wounded palms will be more attractive than the no wounded palms. Secondly, wounds to become a favourable oviposition site needs to be of a sufficient size. Consequently, wound kairomone emission (that is, in addition, of short duration) is not so problematic and on the contrary the attraction that they produced should be used as deadly traps for the RPW thanks to the implementation of "reproduction preventive" treatments on wounded palms.

Mass trapping and interconnection with the other components of the strategy

At the difference of the two other components, it is known that mass trapping as unique component of a strategy will not be sufficient to control the RPW. The increase of the number of traps, even if it was practically and economically feasible, present limits as traps interference would lead to counterproductive effects. In real field condition and even in experimental field condition, the percentage of RPW population that the best trapping system can capture has not been established. Nevertheless, it is estimated not to be more than 50%. A recent result (El-Shafie and Faleiro, 2017), although obtained in specific laboratory conditions, gives even a lower figure.

Nevertheless, mass trapping constitutes an essential component, complementary of the other components of the global strategy not only for its contribution to reduce the RPW moving adults population, especially the female one, but also for its monitoring role. The evolution of the captures in the traps will help to improve or to modify the implementation of the other components: intensification of the inspections around traps where captures do not decrease and reproduction preventive treatments around traps that capture a lot besides, increasing the number of traps in hot spots of infestation.

The advantage of mass trapping, in addition to be an ecological technique of control, is that low cost traps can be perfectly manufactured and managed by the palm owners themselves.

Assessment of the usefulness of different components of the global strategy, including the reproduction preventive and «sanitation» treatments

As already mentioned, the contribution of each component of the global strategy, including «reproduction preventive» and sanitation treatment, to the efficiency of the strategy is not easy to establish.

Nevertheless, this contribution can be assessed qualitatively. For example: inspection is not well done if infested palms are detected late or if traps capture and infested palms are not found in the vicinity of the traps; when reproduction preventive treatments have no effect on traps captures reduction or decrease of new infested palms, it can mean that they are not well applied; etc.

In addition, two excellent indicators allow assessing the efficient of the global strategy and at least the jointed efficiency of its components: the evolution of the number of new infested palms and of traps captures during successive periods of time.

I would like to emphasize one fundamental point regarding the indicator on infested palms. In reports and papers, it is not rare to find data concerning infested palms without any reference to period of time, as if an infested palm remained infested indefinitely. An infested palm will be sanitized, eradicated or will die rapidly. At that moment, it can no longer be considered as infested palm and consequently as a focus of RPW reproduction and spread. So it is absolutely indispensable to associate the number of infested palms to a period of time (as well as with the indicator "incidence" or with the "reproduction number"). To avoid any confusion, it is better to use the expression 'new infested palms' because it leads automatically to complete with a period of time. In addition, what matters is the evolution of this number in successive periods of time and it is not this number by itself.

If the different components of the strategy including the reproduction preventive and sanitation treatments are well applied, the number of new infested palms and traps captures must decrease rapidly during successive periods of time. As illustrated in the following figures, the quick decline has been perfectly obtained in the framework of the RPW control in the Canary Islands.

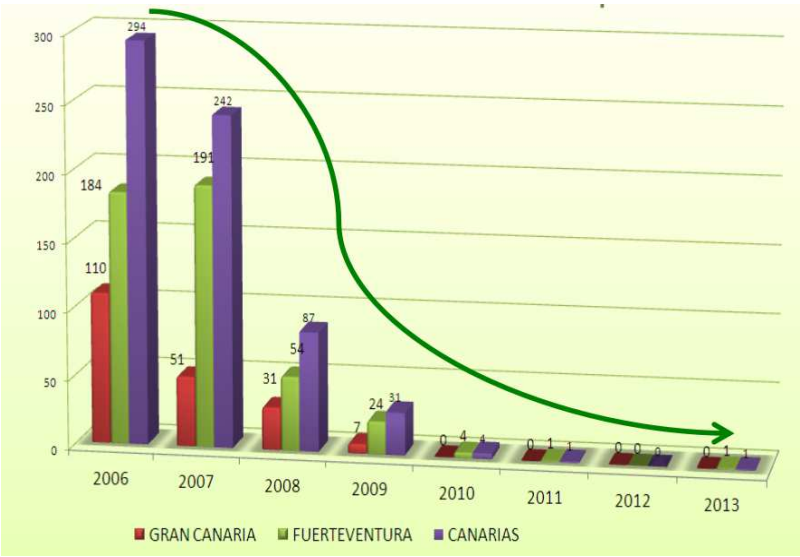

Figure 2: Evolution of the number of new infested palms per year in each island from 2006 to 2013 (Source: Fajardo *et al.*, 2019)

To assess the jointed efficiency the different components of the strategy, including the reproduction preventive and sanitation treatments, it is necessary to register the detection of each new infested palm and of the action that has been taken to sanitize it as well as the results of the periodic inspection of the traps. These data must be transmitted, computerized and integrated in a data base to be analyzed easily and at any moment with the help of a GIS programme. To have this information update permanently and easily available to all the actors at the local level, especially the farmers groups, is absolutely fundamental because it is at this level that action takes place (early warning, exchanges between palms owners, contingency plan implementation).

Unfortunately, in very few places, these data are available or exploitable in an easy way. Consequently, this essential tool to monitor permanently and easily the situation and the organization of the RPW control programmes at the local level is missing. This gap is probably one of the more serious one of the RPW control programmes worldwide. The persons in charge of the RPW control programme in Canary Islands consider that the management with the assistance of a GIS was a key element of the success of this programme (Fajardo *et al.*, 2019).

Recently FAO has developed a complete system, from data registration in the field with smartphone (*SusaHamra* app) to GIS-based online platform for data analysis and mapping (Cressman, 2019). A simplified version of this system that would include only the two main indicators that import for monitoring the implementing the RPW control programme, detection of new infested palms and captures in the trap, could be of enormous interest to improve the efficiency of these programmes at the local level. It could also greatly contribute to facilitate the participation of the farmers to the implementation of the different components of the RPW control programmes. Increasing this participation is absolutely essential as it was underlined during the Rome meeting in 2017 (Faleiro *et al.*, 2019).

Conclusions

The usual conception of "preventive" and "curative" treatments leads to extremely rare assessment of these treatments as components of IPM strategy although this strategy is systematically recommended as the right one to control the RPW. In addition to the lack of scientific results on the efficiency of these treatments in real field conditions, the usual way to assess this efficiency does not integrate the fact that it depends on the efficiency of each component of the strategy (strong interdependence). Furthermore, it presents the risk to miss out the essentials to assess the efficiency of the RPW control programmes and even to misconceive what should be the objective of these programmes.

The objective of the RPW control programmes, as in fact of any IPM programme when the economic threshold is exceeded should be to obtain the quick decline of the pest. In case of RPW it is largely exceeded everywhere in the world. Two indicators allow perfectly determining if this decline is or not strongly represented *viz.* the evolution of the number of new infested palms and of RPW captures in the traps during successive periods of time.

Monitoring carefully and permanently these indicators is indispensable to assess if globally all the components of the integrated strategy are efficient. This information is

especially indispensable at the local level where action takes place. It should be easily accessible to each group of neighboring palms owners. It would facilitate the participation of the local communities in the RPW control programme. A greater contribution on their part in the implementation of the various components of the strategy would considerably increase its technical and economic efficiency. For this purpose, a version of the *SusaHamra* system, developed by FAO, and simplified for exploitation focused to the registration and easy analysis by the local field actors, especially the farmers groups, of the two indicators mentioned above would be of great help.

To contribute to the shift of conception of the "preventive" treatment and "curative" treatment, I propose, for a better evaluation of these two components of the integrated strategy of the RPW control programmes, to call them respectively "reproduction preventive" treatments (prevention of oviposition) and "sanitation" treatments (eradication of RPW in infested palms, including when necessary palm eradication). Presently, data are totally missing to evaluate the contribution of each component of the integrated strategy to the reduction of the RPW population (represented by the reduction of the number of new infested palms in successive periods of time). It would be very useful that, at least at experimental field level, studies on that issue be engaged.

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