Actions protocol to face cactus cochineal in non-native regions

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Abstract

After attending several projects on cactus pear in America and Africa, the experiences and gathered information on its biotic and abiotic factors allowed us to conclude that some identified abiotic factors interact with cactus pear, mainly in America where its native origin is located. In Mexico one of these biotic factors (cactus cochineal) has several natural enemies that serve as an effective autonomous control for cactus cochineal, however in other areas with the lack of this element, the situation results quite different, since cactus cochineal tends to proliferate in huge populations that even surpass the hosts development. This manuscript presents an actions protocol to face this insect in non-native regions where cactus pear plantations are established as regular crops.

Keywords: *Opuntia ficus-indica*, *Dactylopius opuntiae*, pest management, Mediterranean basin

INTRODUCTION

Cactus pear plant when outside Mexico becomes an exotic element, however, it has been accepted as a regular crop to obtain fruit for human consumption, to feed animals, among other uses. As a non-native resource (it is originally from Mesoamerica) (Griffith, 2004), any disease or plague could easily fall out of control, mainly due to the absence of biotic factors present in their natural areas of distribution that equilibrate their environment.

The thorny or thornless cactus pear cultivars used for commercial purposes in the Mediterranean basin belong to the species *Opuntia ficus-indica* (L.) Miller; however, it is susceptible to cactus cochineal *Dactylopius opuntiae* (Cockerell) (Portillo and Vigueras, 2017). This insect is also native to Mexico as *D. coccus* (Van Dam et al., 2015); the information in the previous lines is of particular interest, since both, cactus pear and cactus cochineal, are alien factors now present in some areas of this region.

The aim of this contribution is to present an actions protocol to face cactus cochineal (*D. opuntiae*) in non-native regions.

MATERIALS AND METHODS

A series of projects carried out in different cactus pear populations in Mexico, South America, and Africa (Portillo and Vigueras, 2006; Suassuna et al., 2008; RE-ETI, 2015; TCP/TUN/4001, 2024; Inglese et al., 2017) allowed us to understand the interactions of their biotic and abiotic factors, as well importance of the human influence. These factors were used to compare their behavior with cactus pear populations in Mexico, Argentina, Bolivia, Brazil, Peru, Ethiopia, Morocco, and Tunez, permitting to structure protocols of how the ecology around cactus pear and biotic factors (main aspects), should be managed in plantations to avoid affectation beyond marked thresholds.

RESULTS AND DISCUSSION

Because in Mexico and Argentina there are several biotic factors that control *Dactylopius* species (Portillo and Vigueras, 1998; Ochoa et al., 2015), the cactus pear management tends to be quite different from other regions. Until now *D. opuntiae* is not

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present in Argentina, however, in Mexico, recently the control of this insect is managed with help of natural enemies (Cruz-Rodríguez et al., 2016). For other regions the management of cactus cochineal presents a different challenge, the next lines summarize the current protocol that we consider should be applied.

Action areas to face cactus cochineal in non-native regions

It is necessary to recognize three action areas where cactus pear grows: 1) free of cactus cochineal infestation, 2) recently infested zones, and 3) devastated zones. The first one must be considered as a reservoir of healthy plant material, and thus we shall call it the prevention area (before infestation). Due to the recent arrival of the cactus cochineal in the second area, it shall be named as the emergency area (during infestation). The third area should be contemplated as the recovery area (after infestation) given it suffered a long period of infestation that caused severe damage to the cactus pear plants. All the activities to be carried out in each one of the three previous areas must be based on considering risk management. Therefore, all procedures should consider every involved human resource (farmers, technicians, those from any organizations, etc.) to allow information to be shared and the plans designed contemplate every important aspect for pest management.

The following steps need to be taken to avoid and minimize the effects of the cactus cochineal infestation in the three different areas.

1. Prevention area (before infestation).

The plants found in this zone are free of infestation, thus, we need to anticipate the arrival of cactus cochineal that eventually will happen. This area can be considered an important reservoir of clean plant material and should be the source to establish new cactus pear plantations in other areas, not only susceptible cultivars but tolerant and resistant ones. Surveillance is the first activity to be implemented, and must be carried at all times in the whole surface of the prevention area, since cochineal can be dispersed by wind, birds (phoresy), and other biotic and abiotic factors; thus, not only the neighboring places to infested areas will be susceptible for a new colony of cochineal to be established, remote areas can be infested, so prospection is an important process to be performed continuously. To strengthen prevention, no material (instruments, tools, boxes, etc.) or animals from infested areas can be introduced into the prevention area. If introducing material from the infested areas, then a 100% secure area cannot be ensured, a quarantine zone for cleaning and disinfection activities should be implemented outside the prevention area. Another point to take into consideration is good agricultural practices (GAP), to be observed (annex 1) and put into practice at every step of the present plan. In case a new colony of cactus cochineal is detected, it must be removed and eliminated by pruning the affected cladodes or whole plants and dispose of them by burying. Surveillance must be more intense around the area where the colony was found to ensure no other colony settles further. In parallel, resistant cultivars of *Opuntia* should be planted. This will not only decrease the amount of work dedicated to surveillance, but it will also help significantly when cochineal eventually appears.

2. Emergency area (during infestation).

It is possible to manage a cactus pear plantation with the presence of cactus cochineal if regular agronomic practices (annex 2) are performed throughout the year just as with any regular crop. However, it should be taken into consideration that implementing agronomic practices will increase production costs. Since infestation would decrease the yield of the plantation, careful cost/benefit planning should be carried out to keep the cactus pear plantation profitable. When the level of infestation of cactus cochineal is light (just a few colonies observed in the plantation), pruning and burying is the most common option to reduce the incidence of cochineal. However, if the infestation is severe (a considerable number of plants already dead), the elimination of the whole lot in the plantation is recommended. The use of pesticides (chemical or natural) should be suggested only in those plantations with regular agronomic practices and is not recommended in neglected areas where cactus pear grows without human attention as re-infestation will occur as soon as the pesticide effect

disappears. All the zones where cactus cochineal is already settled must be indicated with visible signs as part of an awareness program for farmers and the general population (annex 3). An integrated pest management (IPM) program describing into detail must be launched by several institutions in each country. The activities to be contemplated in such a program should include prophylactic measures, agronomic practices, genotypes selection, chemical treatments, biological control, and beyond holistic concepts. Particularly for this IPM, the strongest tool to face the situation will be the use of tolerant and resistant *Opuntia* plants to cactus cochineal.

3. Recovery area (after infestation).

An area subject to recovery measures fulfills several characteristics. Cactus pear plants suffer chlorosis, numerous abscission zones with branches falling apart is observed; a substantial part of the plant wilted and dried up; cochineal colonies have specimens in all developmental stages, indicating the colonies are well settled and thus mitigation efforts will be useless most of the time. At this stage, the cactus pear plants need to be removed and buried, just like the emergency areas, but at a much larger scale, and new cactus pear plantations must be established. Crucial for the success of the new plantations are *Opuntia* species resistant to cactus cochineal. Some resistance or tolerance in local plants can be already present in the non-native areas, but more cultivars may be introduced. Every new cultivar should be tested under controlled conditions to confirm its possible tolerances or resistance to the cochineal biotype present in every region. Propagation of new plant material can be started with cactus pear cladodes which can be cut into minimal fractions (small cuttings) (annex 4). Alternatively, its micropropagation (Gutiérrez-Quintana et al., 2018) can be carried out in available in vitro laboratories or biofactories. Currently there are several regional research centers with expertise working in several areas on cactus pear, I recommend considering those institutions as part of the projects on selection and propagation of tolerant and resistant cactus pear cultivars to cactus cochineal. The substitution of damaged plants with new tolerant cultivars should be performed gradually and involve farmers and any other people benefit from it, so they can adopt the new ways to manage cactus pear as a regular crop. One important reminder is that all commercial *O. ficus-indica* cultivars (thorny or thornless) existing in the Mediterranean basin are susceptible to cactus cochineal. We expect that eventually the insect will arrive at all cactus pear populations in this region, therefore, changing the plantations to resistant or tolerant cultivars should become part of a permanent program to allow the continuity of the advantages of *Opuntia* uses. Due to each area having its own biotic and abiotic characteristics, there are and will be several recommendations (annex 5) that would arise for local areas of a particular region once the actions protocol be applied.

Annexes

1. Good agricultural practices (GAP) for cactus pear (Annex 1).

The following points are a series of GAP principles that here are adapted for cactus pear plantations:

1. The selection of cladodes to establish a cactus pear plantation, or just to be transported, must ensure that they are healthy and have no diseases or plagues. Disinfection is a good option; a sodium hypochlorite solution (50% commercial bleach plus 0.1% liquid detergent) rinsed three times with running water should be enough. For material being transported between different countries, it is highly suggested to use tissue culture explants to have pathogen-free plants or to use material from certified collections. The idea is to avoid the further use of pesticides;
2. Contrary to a common misconception that *Opuntia* plants grow without any care, regular checks are important to eliminate or diminish further problems. Continuous visits can help to detect biotic and abiotic issues, which will facilitate their control;
3. All organic manure to be added to the plantation must be composted. Raw organic material may introduce pathogens that develop further into sanitary issues. The application of biofertilizers, which are microbial inoculants, is preferred to organic

fertilizers like manure;

4. To have superior quality plant material, the isolation of the plantation must be observed all the time;
5. It is important to implement a system to reduce the risks of contamination, which must be observed for all involved people (owner, manager, workers, suppliers, clients, and any visitor);
6. Cochineal farmers must be aware of the phytosanitary risks in the area. Since cochineal itself is a plant parasite, it is important as well to be aware of the risks that cochineal itself can impose on neighboring cactus pear plantations.

We stress the importance of GAP since remarks from our field work revealed GAP is poorly observed by cactus pear growers. It is crucial that new farmers start any agricultural activity in an informed way and that the growers that have grown cactus pear already for a long time adopt GAP principles.

FAO has published a series of manuals on GAP. These manuals are available for all NGOs, producer associations, and government technical groups on arid land crops. We hope the implementation of GAP principles on cactus pear plantations diminishes the number of future cochineal infestations. Specialized literature available on this topic from ICARDA and FAO can be obtained on request.

2. Regular agronomic practices for cactus pear (Annex 2).

Agronomic practices may change from one cactus pear plantation to another, mainly depending on the product exploited (fruit, forage, vegetable, etc.). The most common agronomic practices are weed management, pruning, fertilization, irrigation, orchard sanitation (waste disposal), pests and diseases management, as well as harvesting protocols. The idea is not to allow the existence of neglected cactus pear populations.

3. Nationwide awareness program (Annex 3).

One recommendation from the present project is to launch a local awareness program focused on farmers and general population, about the sensitization of a code of conduct for cactus cochineal movement. This nationwide program must consider not only media communications, but also sanitary borders inside the country and even with neighboring countries. In addition, permanent prospection and "training of trainers" on the subject will help to reinforce this program.

4. Minimal fractions protocol (Annex 4).

Small cuttings from mature cactus pear cladodes can be used to propagate a bigger number of plants from a single cladode (around eight fractions). The protocol is very simple; it consists in dividing the cladode into small cuttings. It must be made sure that every fraction of the cladode contains at least five areoles (meristems) for the proliferation to be successful. Allow one week after the cutting process for the healing of edges to be dried and place them in pots with substrate (sand:peat moss:composted manure, 6:3:1 v/v, respectively) at field capacity and keep regular horticultural cares. After six months, the small cuttings with the new shoots and roots may be moved to soil in nurseries or regular plantations.

5. Some recommendations (Annex 5).

Protocols to introduce tolerant and resistant plants.

It is a strong observation to do these procedures by tissue culture since the plant material is in aseptic conditions without any possible source of infestation or infection. The risk of introducing new pests or diseases always will be latent with fresh plant material delivery even with sanitary control. Besides, several biotic factors in cactus pear native areas are arising as primary pests as *Cylindrocopturus biradiatus* in Mexico. It is important to bear in mind that any organism is in balance with those factors prevailing in its native environment; however, if it is moved to a new range (particularly to non-native areas), this condition may be broken with several consequences, even if it becomes invasive. Cactus pear cultivars have

been introduced to many countries beyond Mexico, so ecologically it is a foreign biotic factor in a non-native area, sometimes considered invasive but now became a useful element well known for the local inhabitants and utilized to a suggestive level, that deep ethnobotany relations can be observed in many communities around the world. However, it is necessary to address that new biotic factors eventually may be established; for cactus pear there are more threats such as cactus moth insect (*Cactoblastis cactorum*) and black spot disease (*Pseudocercospora opuntiae*) (Ochoa et al., 2015); so, the plant sanitary controls must be stricter.

Biological control program.

This activity must be developed by several institutions, anyway, the selection of natural enemies will be an important decision, since introducing alien biotic factors in non-native areas always represents a challenge. The best option is to contemplate non-generalist biological controllers, for *D. opuntiae* there is a coleopteran, the coccinellid *Hyperaspis trifurcate* which has been used in several countries with different levels of success to control the cactus cochineal. However, previously it will be necessary to perform some experimentation to test its fitness by controlling the biotype of cactus cochineal present in each area of a given region.

Visit a country affected with cactus cochineal.

One recommendation is to visit a country, as Morocco, where the region has been affected by the cactus cochineal and already had implemented a biological control with an integrated pest management to gain knowledge with previous experiences. A second recommendation is to visit Mexico, the best time to do it is in spring, just before summer to avoid rainy season; the idea is to see in native areas the interaction of cactus pear with the cactus cochineal and other biotic factors. It is possible to visit Mexico in summer to witness the harvest of cactus pear fruit production, but cochineal population diminishes with the rain.

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