Food and Agriculture Organization of the United Nations

STATUS OF COCHINEAL AND OPUNTIA SPP. PRODUCTION IN THE NEAR EAST AND NORTH AFRICA REGION 2022

A perspective from Jordan, Lebanon, Morocco, the Syrian Arab Republic and Tunisia

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ACRONYMS AND ABBREVIATIONS

AFSED	Arab Fund for Economic and Social Development
AARINENA	Association of Agricultural Research Institutions in the Near East and North Africa
CGIAR	Consultative Group on International Agricultural Research
D. *opuntiae*	Dactylopius *opuntiae* (a.k.a. cochineal)
FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information systems
GPS	global positioning systems
ICARDA	International Center for Agriculture Research in the Dry Areas
IFAD	International Fund for Agricultural Development
INRA	National Institute of Agronomic Research (Morocco)
INRAT	Tunisia National Agronomic Research Institute
IRDC	International Research Development Centre
IRESA	Tunisia Institution of Agricultural Research and Higher Education
IPPC	International Plant Protection Convention
IPM	integrated pest management
LARI	Lebanese Agricultural Research Institute
MCGP	Morocco Collaborative Grant Program
NARC	Jordan National Center for Agriculture Research
NEFRC	Near East Forestry and Range Commission
NENA	Near East North Africa
O.	*Opuntia* genus + specific species name (as in *O. ficus-indica*)
ONSSA	National Plant Protection Organization and Phytosanitary Authority in Morocco
RS	remote sensing
sp.	species
spp.	several species within a genus
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

The multispecies (spp.) plant genus *Opuntia* (commonly referred to as cactus pear) plays a significant socioeconomic, environmental and nutritional role for many countries in the Near East and North Africa (NENA) region, which comprises 18 member countries of the Food and Agriculture Organization of the United Nations (FAO). *Opuntia* spp. are mainly used here for their fruit (human consumption as well as cosmetic and pharmaceutical applications), land rehabilitation, and fodder for livestock. While cactus pear has been cultivated for thousands of years in North and South America, *Opuntia* spp. is relatively new to NENA. Its earliest recorded history of cultivation in the region is 1770 in Morocco, followed by Tunisia from 1920–1930. Countries such as Jordan, the Syrian Arab Republic and Lebanon have been cultivating it for only about 60 years. Cactus production is becoming an increasingly popular source of livelihoods in the drylands.

When a foreign plant species is introduced into a new environment, pests and diseases are relatively few. This has been the case for cactus pear in the NENA region until recently. One of the major pests that threaten *Opuntia* spp. worldwide is *Dactylopius opuntiae* (*D. opuntiae*), commonly known as prickly pear cochineal. The pest is a red scale insect that originated in Central and South America. Some countries in South America grow other species of cochineals (*D. coccus*) for economic reasons, e.g. their bright red carmine dye, though this is decreasing due to limited market demand. The presence of cochineal is most noticeable on the plant when the nymphs secrete a white wax over their bodies, turning the cactus white in colour. For most cactus pear producers, this pest is a significant threat to their production if the infestation is not properly treated and controlled. Outbreaks can decimate orchards, destroying them completely in only a matter of months, devastating the livelihoods that depend on them.

Presence of this pest in the NENA region was first recorded in Lebanon in 2012. Since then, rapid cochineal spread has been officially documented in Jordan, Lebanon, the Syrian Arab Republic and Morocco with differing levels of significance. This report details that most countries were unprepared for the outbreak. Lack of knowledge of the pest and slow action to establish quarantine areas led to its rapid spread. Cochineal is thought to have spread in the region through the trading of cactus cladodes (pads) and fruits. Management and containment of outbreaks also differs on a country-by-country basis, with many farmers resorting to experimenting with different treatments. A lack of national urgency and planning in most countries has led to unsustainable and unhealthy practices, such as an over-dependency on chemical sprays and the use of fire.

This report emphasizes the need for greater agroecological alternatives to contain the cochineal spread in NENA. Greater research and implementation of integrated pest management (IPM) strategies are needed with broader promotion and adoption of the pest's natural enemies. Current practices of managing infested plants include burial or fire pits. These practices must be closely monitored with necessary risk assessments. Neglecting infested cactus without

treatment will only escalate the problem. Most orchards were densely planted. So, proper orchard management is necessary, including pruning orchards and adequate spacing between plants to allow greater exposure to direct sun and air circulation. Monoculture plantations have also accelerated the spread of cochineal. So, using different varieties of *Opuntia* spp., especially those more resistant to cochineal, will help minimize spread of the pest. This report recognizes that countries contain outbreaks to differing degrees and recommends greater collaboration and integration among stakeholders. Without proper management of cochineal, the *Opuntia* industry in NENA and surrounding regions (i.e. the Mediterranean and sub-Saharan Africa) will be threatened. Greater multinational approaches ought to be considered with clear and instructive action plans put in place.

INTRODUCTION

Cactus pear (*Opuntia* spp.) originated in Mexico, where it has been used since 6500 BCE. It was introduced to the Near East and North Africa (NENA) in the eighteenth century. Since its arrival here, the cactus pear has gradually become an important food and feed crop for smallholder farmers, improving rural livelihoods. It is planted as hedges around farmlands to protect field crops, secure ownership rights over the lands, and protect soil from erosion. The plant is also grown in orchards or plantations where fruits and young pads are harvested for human consumption as food, and for medicinal and cosmetic uses.

In some NENA countries, the spineless cactus pear was introduced for rangeland rehabilitation, where productivity depended on the level of rangeland degradation. The plant has been beneficial as livestock forage, particularly in drought, providing digestible energy, water, and vitamins. Despite *Opuntia* spp. usage in the region, there remains limited information on the total areas of hectares (ha) planted. Likewise, research on the plant's contribution to animal production, livestock feed, household income and livelihoods needs further investigation.

In recent years, several NENA countries have reported the spread of *Dactylopius opuntiae*, an invasive insect pest commonly known as prickly pear cochineal. The pest attacks cactus pear (*Opuntia* spp.), causing significant damage to established plantations in the region. *D. opuntiae* is native to the Americas, where *Opuntia* spp. originated. The insect is considered one of the most significant insect pests for cactus orchards, where it can infest large areas limiting cactus forage and fruit production. On the other hand, another species of cochineal, *D. coccus* has been used for centuries to produce a natural pigment called carmine. Although the carmine natural dye industry has decreased in recent decades due to the use of synthetic dyes, carmine has seen a resurgence in recent years for its health properties. Hence, as the adoption of cactus pear has increased, so too has cochineal infestation, making *D. opuntiae* a significant threat for *Opuntia* spp. development and production worldwide.

At the request of the 24th session of the Near East Forestry and Range Commission (NEFRC), FAO commissioned a 2020 study to assess the extent of cochineal spread and its effects on cactus pear orchards in the NENA countries. Due to the multifunctional nature of the plant, the assessment is carried out within FAO by a joint team from the FAO Regional Office for Near East and North Africa, FAO Subregional Office for North Africa, the Plant Production and Protection Division, the Forestry Division, and FAO-ICARDA CactusNet. Five pilot countries where the presence of cochineal was already confirmed or it is likely to be present were chosen to undertake a regional assessment: Jordan, Lebanon, Morocco, the Syrian Arab Republic and Tunisia. The countries were asked to investigate three core areas:

i. Assess current production areas of cactus pear in the country by reviewing available information and reports.

ii. Assess the occurrence of cactus cochineal pest across the country, the extent of damage and loss it has caused so far, control measures taken by stakeholders and gaps in the country's capacities to curb its spread.

iii. Assess current and potential damage and loss in livestock feed and its overall effect on livestock production.

In 2020, a national consultant in each pilot country was tasked with preparing a country report on the current status of cochineal and *Opuntia* spp. Each consultant collected data in the field, conducted interviews, and implemented a questionnaire (Annex 2). Each consultant analysed the data and delivered their individual country reports (Bouharroud, 2021; Boufaoor, 2021; Hayder, 2021; Katbeh, 2021; Moussa, 2021) to the FAO Regional Office for NENA as the basis for this regional publication.


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CACTUS PRODUCTION IN NENA

AREA AND SCALE OF *OPUNTIA* SPP. PRODUCTION

Cactus cultivation for food and fodder in Morocco, Libya, Egypt, Jordan, the Syrian Arab Republic and Lebanon has been estimated at a combined total of roughly 300 000 ha, while Tunisia recorded the largest cultivated land at 500 000 ha, bringing the total estimated cultivation area of *Opuntia* spp. in seven NENA countries to 950 000 ha (Nobel, 2002). The five country reports of 2021 in which information on prickly pear cochineal was presented recorded an estimated total area of 808 225 ha of cultivated cactus prior to the appearance of pest insect in the NENA region (Table 1).

Table 1. Estimated area of cultivated land used for *Opuntia* spp. in the five countries

	Cultivated (ha) as reported in secondary sources	Cultivated (ha) as reported in country reports
Morocco	120 000 (Inglese *et al.*, 2017)	~ 158 000
Tunisia	600 000 (Inglese *et al.*, 2017)	~ 650 000
Jordan	300 (Nasr, 2015)	>30
Syrian Arab Republic	100 (Inglese *et al.*, 2017)	>84.5
Lebanon	n/a	>110
Total	**~ 720 400**	**~ 808 225**

The data show an increase of nearly 90 000 ha. However, most of these figures are estimates and all reports acknowledge the need for further assessment of actual hectares cultivated. One of the difficulties in obtaining more accurate data is the fact that cactus distribution is sporadic; i.e. it is found in home gardens, used as farm fences, and scattered in the wild. Only a few countries plant cactus as a conventional crop in the form of plantations. Technologies such as geographic information systems (GIS), remote sensing (RS), and global positioning systems (GPS) should be adopted to assist in using satellite data to investigate the true distribution of *Opuntia* spp. in NENA and globally.

RECORDED SPECIES AND CULTIVARS

All five countries reported the presence of the *Opuntia ficus-indica* (*O. ficus-indica*) species, cultivated to differing capacities (Table 1). Eight species of the *Opuntia* family were identified in Morocco, more than any other country in the study (Figure 1).

Figure 1. Diversity of *Opuntia* spp. in Morocco: a) *O. leucotricha*; b) *O. dillenii*; c) *O. engelmannii var linguiformis*; d) *O. cochenillifera*; e) *O. megacantha*; f) *O. engelmannii*; g) *O. robusta*; h) *O. engelmannii*

a.

b.

c.

d.

e.

f.

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g.

h.

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All country reports noted the need for more detailed monitoring of species and varieties. Table 2 presents the species recorded in each of the five countries, but there are also other species present in NENA that are as yet unidentified. Proper taxonomy and up-to-date recording need to be more mainstreamed throughout NENA. With an increase of *Opuntia* spp. in the region, it could be problematic if unrecorded species grow out of control and threaten local and native ecosystems. Lebanon reported 43 accessions – previously unidentified varieties – of *O. ficus-indica* (Chalak *et al*, 2012).

Table 2. Recorded *Opuntia* species and cultivars in the five countries

	Morocco	Tunisia	Jordan	Syrian Arab Republic	Lebanon
Species	*O. ficus indica, O. megacantha, O. dillenii, O. robusta, O. aequatorialis, O. cochenillifera, O. stricta, O. Argentina, O. schumannii*	*O. ficus-indica f. inermis, O. ficus-indica*	*O. ficus-indica* (L.) Mill	*O. ficus-indica* (L.) Mill	*O. ficus-indica* (L.) Mill

USES OF CACTUS

Opuntia spp. has multiple uses and each country utilizes the crop in different ways: human food consumption, conservation, medicine, cosmetic, and fodder. In all five countries, the fruit itself, rather than the cladodes, was reported to be the major source of economic benefits, though even this differed from country to country. A more detailed summary of utilization of cactus is discussed below.

Jordan, Lebanon and the Syrian Arab Republic

Cactus pear is cultivated mainly for fresh fruit consumption, and a small proportion is used for pharmaceuticals (cladode and flower). The cactus is planted at the boundaries of farms and gardens as a fence, and used to a lesser extent as animal feed.

Morocco

Cactus pear is used in Morocco for food, cosmetics, traditional medicine, feed, and most commonly as boundary fencing. *Opuntia* spp. are also utilized for ecosystem services such as preventing erosion, protecting terraces in mountain areas, and as a firebreak. From an ecological view, the cactus also provides habitat for squirrels (*Atlantoxerus getulus*) and nectar for pollinators like honey bees (Figure 2.b).

Tunisia

Cactus pear is used as protective hedges surrounding rural houses, stabilizing erosion control structures, and for extensive and intensive fruit production. The plants are processed and sold in both local and export markets as dried cladode powder, jam, juice, cactus oil, dietary supplements, mucilage, honey, and cosmetic oil (when seeds are processed) (Figure 2.c.)

Figure 2. Various cactus utilization: a) bowl of peeled fruit; b) honey production in Tunisia; c) cosmetic and medical products in Tunisia; d) landscape and terrace conservation in Morocco

a.

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b.

© FAO/M. Hayder

c.

© FAO/M. Hayder

d.

© FAO/R. Bouharroud

AGRONOMICAL SYSTEMS OF PRODUCTION

Just as cactus farming in NENA was introduced at different periods, so cactus utilization differs from country to country. As illustrated in Figure 3, the country reports show three common types of *Opuntia* spp. production. The cactus pear is cultivated in Lebanon at a wide range of agroclimatic regions, ranging from coastal to inland and adapted to conditions of 900 m in altitude (Chalak *et al*., 2012). Three systems are found throughout NENA:

- Wild: *found in the wild with no human intervention.*
- Semi-domesticated: *used as boundary fencing or rehabilitation of landscapes with little maintenance or human intervention*.
- Domesticated: *intensively farmed in orchards or paddocks with inputs (irrigation, pesticides, fertilizer) for harvest and selling*.

Figure 3. Three agronomy cactus production systems as reported in Morocco: a) in the wild; b) planted for conservation; c) intensive farming with inputs

a. **b.** **c.**

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When the cactus pear is not planted as a fence, it is used as a crop to produce fruits or cladodes for animal feed. Most densities adapted for fruit production in NENA were spaced at 6 m * 3 m (inter-row * inter-plant). For the production of cladodes, the density could be up to 40 000 plants/ha. Irrigation and fertilization were adopted by some farmers, but most used minimal inputs. Based on the country surveys, limited irrigation was used, and orchards primarily were rainfed. Cactus pear were planted in small water catchments to maximize water retention to take full advantage of the rain.

Vegetative propagation of cactus pear was most commonly used for its cost effectiveness through the use of plant cuttings. Only a few farmers reported using organic manures to fertilize their cactus orchards, mainly using common nitrogen, phosphorus, and potassium mineral fertilizers. Pruning and thinning of plantations were conducted by removing cladodes for new plantations or animal feed. Currently, in most cases, the entire cladode is used for propagation after drying in the shade. The cladodes are planted vertically by covering a third to a half of the cladode in the soil. Farmers reported that the cladode age is essential: they

should be at least one year old for good results. The lines of the plantation are oriented north–south for cactus orchards and follow the contour lines in mountains. Nurseries that produce cladodes use a rooting hormone to promote healthy root development.

Before cochineal was introduced, the main pests and diseases in cactus were snails (Figure 4.a) and rot caused by fungi (Figure 4.b). Less significant pests and diseases on cactus pear included swelling cladode (Figure 4.c) and cactus scale (known as *Diaspisechino cacti*) (Figure 4.d). No pesticides were sprayed to control these pests and diseases.

Figure 4. Pests and disease on cactus in Morocco: a) snail damage; b) rot caused by fungal infection; c) swelling cladodes; d) scale on cladodes (*Diaspis echinocacti*)

a.

b.

c.

d.

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SOCIOECONOMIC IMPORTANCE FOR RURAL DEVELOPMENT

Cactus pear plays a vital role in rural regions and contributes to the income of vulnerable communities. Cactus pear plantations are mainly managed by men and women between the ages of 30–60, but also by young people. Jordan reported the lowest price of cactus fruit at USD 0.35 –2/kg. In Lebanon, cactus fruit prices were reported between USD 1.6 –6.6/kg; the local price is less (USD 1.6 –3.3/kg) compared to supermarkets (USD 5 –6.6/kg). Tunisia reports the price of cactus pear during the summer season at around USD 0.6/kg, but it can reach USD 2.5/kg in other seasons. In Morocco, for the last decade, prices generally ranged from USD 0.15 to 2/kg depending on the quality and size. In Lebanon, the income from 1 ha of cactus pear ranged from USD 16 000 to USD 66 00 per year. All these figures are only based on the market value of fruit; however, additional income may come from selling cladodes as fodder and the oil extracted from the seeds as cosmetics. The gross price for 1 litre of cactus seed oil in Morocco ranges from USD 780 to USD 1120.

The main problems faced by farmers were pests and diseases, lack of trained workers for the harvest, and low marketing prices. Cactus pear offers socioeconomic incentives and ecosystem services such as soil conservation and combating desertification, which has not yet been accounted for.


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COCHINEAL PRESENCE IN THE NENA REGION

In the last decade, invasive cochineal *Dactylopius opuntiae* (*Hemiptera: Dactylopiidae*) in NENA has left a trail of destruction to rural livelihoods and farms. *Dactylopius,* is the only genus in the family of Dactylopiidae, which includes 11 species of cochineal insects: *D. opuntiae, D. coccus* (true cochineal)*, D. bassi, D. ceylonicus, D. austrinus, D. confertus, D. confusus, D. gracilipilus, D. salmianus, D. tomentosus and D. zimmermanni,* (Guerra, 1991; Mazzeo *et al.,* 2019). The pest goes by numerous common names: vermilion cochineal scale, prickly pear cochineal, and false carmine cochineal scale (Mazzeo *et al.,* 2019).

D. opuntiae is the primary pest of *O. ficus-indica* in many regions of the Mediterranean basin and countries of South and Central America (Vanegas-Rico *et al*., 2017). It was first described in 1896 by entomologist Theodore Dru Alison Cockerell in Mexico, the original home of the cactus pear. Since then, the insect has been used for biological control of *Opuntia* spp. in countries where the plant is exotic, such as Australia and South Africa (Mazzeo *et al*., 2019; Volchansky *et al*., 1999). The pest was registered in 22 countries, including Brazil, Mexico, and the Mediterranean basin countries (Mazzeo *et al*., 2019; Inglese *et al*., 2017), in addition to its recently reported presence in the Syrian Arab Republic, Jordan, Algeria and Tunisia.

The insect spreads through the wingless nymphs of the second life cycle stage, which climb to the tops of the infested cactus plants. They are carried to far distances by the wind, human activities (e.g. transport) and animals (Mazzeo *et al*., 2019; Fitiwy *et al*., 2016; Mathenge *et al*., 2009).

COCHINEAL SCALE INSECT *DACTYLOPIUS OPUNTIAE*

D. opuntiae colonies live in aggregations on fruits and cladodes of *Opuntia* spp., usually at the base of the spines (Figure 5.a-b), where they feed on sap. Like other scale insects, *Dactylopius* produces toxic substances through their mouth part inside the plant, causing chlorosis. With increasing pest populations, fruits drop, and cladodes dry out and fall off. In addition, *Dactylopius* bodies produce a red substance known as carminic acid to protect themselves from predators (Eisner *et al*., 1994). The red substance has caused fear and confusion among local farmers, who considered it a skin disease agent due to the red dye that appeared on their hands after touching the insect (Figure 5.c). *Dactylopius* has a sexual dimorphism where females are wingless and immobile (Figure 5.a), and males are winged and have no mouth parts (Figure 5.d). Only the first instars known as 'crawlers' (Figure 5.e) are mobile and can disperse to other cactus plants by wind (Mow *et al.,* 1982). Since adult males do not feed on the host, nymphs and adult females are responsible for the damages caused to cactus plants in the region.

Figure 5. Cochineal in Lebanon: a) adult female *D. opuntiae* on the base of spine; b) colony of *D. opuntiae* on fruits and cladodes in Aaba; c) red dye on the hand caused by *D. opuntiae*; d) adult male *D. opuntiae*; e) *D. opuntiae* crawlers on cladode

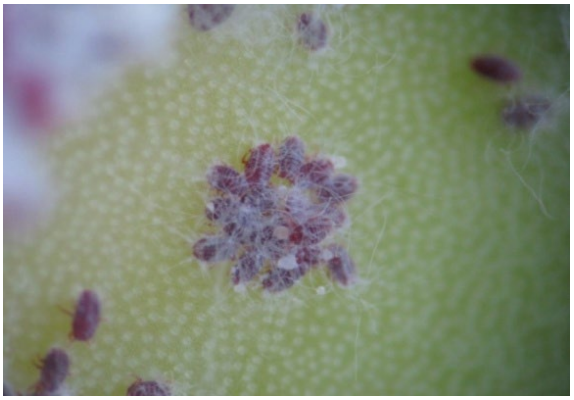
a.

b.

c.

d.

e.



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REPORTED CASES OF COCHINEAL

Of the five countries studied, the presence of *D. opuntiae* was first documented in 2012 in Lebanon (Table 3). Though the Syrian Arab Republic dates the pest's presence to 2018, farmers there say they were witnessing the insect earlier than official reports. While Tunisia reported no official outbreak, video shows a recent infestation of cochineal in the Mahdia Governorate (Aithamou, 2021). All five country reports show the accounts of infestation are becoming more significant.

Table 3. Officially confirmed detection of *D. opuntiae* in the five countries

	Morocco	Tunisia	Jordan	Syrian Arab Republic	Lebanon
Date and location first detected	2014 Sidi Bennour	*n/a*	2018 northern part of ArRafid	2018 western countryside of Al-Sweida	2012 Nabatiyeh

In Lebanon, orchards were classified into four categories according to the percentage of infestation in both the planted area and the individual plant pad surface of *Opuntia* (Figure 6).

- Low infestation: less than 25 percent of the pad surface and plants in the field are infested.
- Medium infestation: from 25 percent to 50 percent of the pad surface and plants in the field are infested.
- High infestation: from 50 percent to 90 percent of the pad surface and plants in the field are infested.
- Very high infestation: more than 90 percent of the pad surface and plants in the field are infested.

Figure 6. Levels of infestation of cladodes by cochineal: a) less than 25 percent; b) 25–50 percent; c) 50–90 percent; d) more than 90 percent

a. b. c. d.

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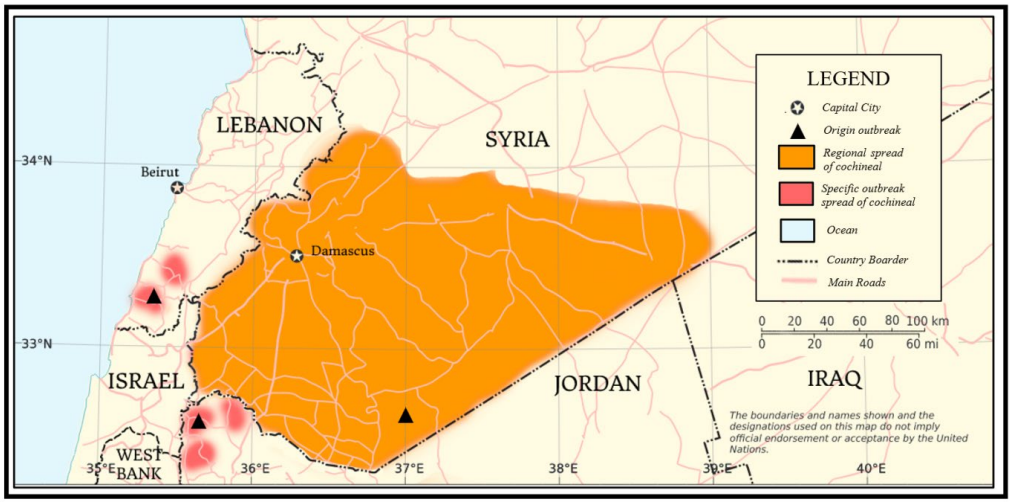
Figure 7 shows the area of original outbreak of *D. opuntiae* in four NENA countries; Tunisia had no official records of infestation at the time this report was prepared. The mode of cochineal spread is thought to be through transport and the trade of goods and services. Most outbreaks occurred in cities that are connected by major roads. It is worth noting that, because cochineal spread is so rapid, surrounding areas are quickly infested after the first outbreak spot is detected. Further assessment of specific outbreaks in the southern part of the Syrian Arab Republic is needed to confirm impacts there.

Figure 7. Spread of cochineal infestation throughout the Syrian Arab Republic, Jordan, Lebanon



Source: UN. 2021. General Maps. In: *United Nations Geospatial*. New York, USA. Cited 10 October 2022; https://www.un.org/geospatial/mapsgeo. modified by the authors

DAMAGE OF COCHINEAL ON *OPUNTIA* SPP.

Nymphs and adult females feed on host plant tissues and cause damage by sucking the sap. Clear yellowish areas appear on the feeding point, followed by the cladode's collapse, which drops off later. Most of the outer parts of the plant fall, leaving only the hard woody stem, which may take about six months to die, depending on the variety, age, and size of the plant (Palafox-Luna *et al.*, 2018; Inglese *et al.*, 2017). In Brazil, the insect infected 100 000 ha of cactus pear grown as livestock feed and reduced productivity by 80 percent, causing losses of USD 100 million and economic and social problems for rural communities (Mazzeo *et al.*, 2019). While the economic damage in NENA remains limited so far, farmers reported that a loss in harvest increased the selling price of cactus pear.

Figure 8. Damage of cochineal on *Opuntia* spp.: a) damage caused by *D. opuntiae* in Nabatieh, Lebanon; b) infestation on cladodes in Morocco; c) field of cactus destroyed by cochineal in Lebanon

a.

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b.

© FAO/R. Bouharroud

c.

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PEST MANAGEMENT OF COCHINEAL

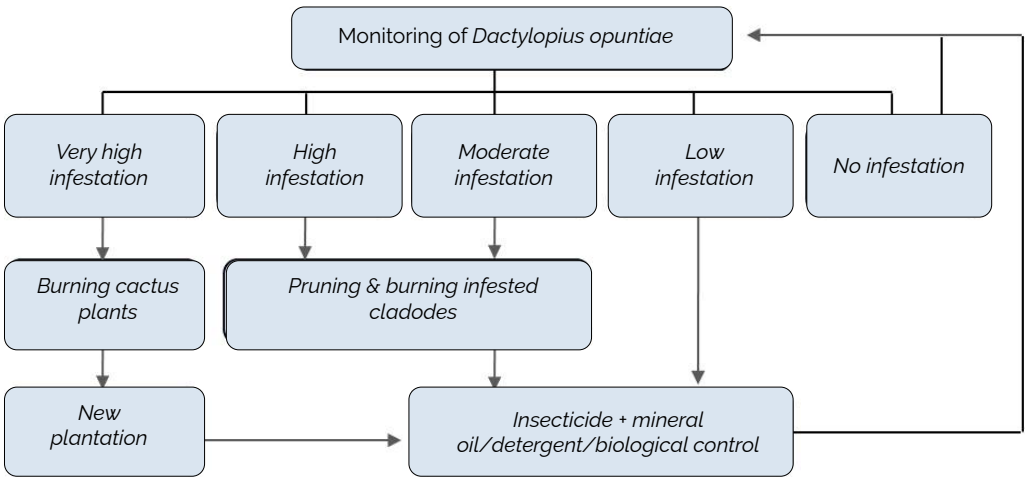
Cochineal is a difficult pest to control due to its complex protection system; the body is covered with a thick waxy coating. The defensive mechanisms impede access into it by demand pesticides and vital natural enemies (Eisner *et al.*, 1994; Mow *et al.*, 1982). The mechanical control can be effective at the beginning of the infestation when the first colonies appear. Infected plants are collected and either burnt or buried. This is ineffective if the infection spreads over large areas.

Several predators have been recorded feeding on the scales of the cactus, including Coleoptera and Coccinellidae family: *Hyperaspis trifurcata,* L. *Chilocorus cacti* Schaeffer. *Leucopisbellula* is one of the two-winged order (*Diptera: Chamaemyiidae*), the brown lace wing *Sympherobius barberi*, *Sympherobius angustus* (*Neuroptera: Hemerobiidae*), *Salpingogaster cochenillivorus* (Diptera: Syrphidae) and *Laetilia coccidivora* (*Lepidoptera: Pyralidae*) (Vanegas-Rico *et al.*, 2010). In fields of cactus in Mexico, the predatory beetle *H. trifurcata* (*Coccinellidae: Coleoptera*) was the most abundant predator of the cochineal cactus insect *D. opuntiae* (Vanegas-Rico *et al.*, 2017). In Israel, the predator *Cryptolaemus montrouzieri* (*Coccinellidae: Coleoptera*) was successfully reared in the laboratory, but when released in the field with 100 000 predators, it was not sufficient to stop the spread of cochineal (Protasov *et al.,* 2017). In Morocco, *C. montrouzieri* were released at a ratio of 30 individuals per square metre of the soil surface, which reduced the cochineal infestation up to 92 percent within 77 days of release (Bouharroud *et al.,* 2018).

The pathogenic fungi *Beauveria bassiana*, *Metarhizium anisopliae,* and *Fusarium incarnatum* delivered encouraging results in controlling the cochineal *D. opuntiae*. However, the fungi could be negatively affected by environmental factors such as high temperature, low relative humidity, and direct sunlight (Reis *et al.*, 2005). In Brazil, a mixture of isolates was used: *Fusarium incarnatum Desm* from cochineal *D. opuntiae*, aqueous extracts from castor bean *Ricinus communis* L., and the plant *Poincianella pyramidalis* Tul. The effectiveness of the combination ranged between 61 and 100 percent (Santos *et al.*, 2016). In the Syrian Arab Republic, tests have been conducted on the effect of the raw enzyme produced by the Syrian isolate SY134D from the bacterium *Bacillus subtilis* on nymphs and adults of cochineal. The experiment used concentrations of 35 percent, 65 percent and 100 percent, which resulted in efficacy rates of 58 percent, 69 percent and 95 percent on nymphs, and 49 percent, 68 percent and 84 percent on adult insects (females). This led to a significant decrease in the insect's wax cover, causing death of nymphs and mature females. When three sprays were carried out at concentrations of 35 percent, 65 percent, and 100 percent, the efficacy was 98 percent, 100 percent and 100 percent on nymphs, and 91 percent, 100 percent and 100 percent on adult insects respectively (Idris *et al.*, 2019).

Tests have been conducted using neem leaf extract *Azadiracta indica* L., *Nicotiana glauca* G., liquid soap, Dimethoate, and Lambda-cyhalothrin in controlling *D. coccus* in the field. After spraying for three days the results found that *N. glauca* leaf extract and the pesticide Dimethoate gave the best results with a death rate of 88 percent and 70 percent respectively. Neem leaf extract, soap, and the pesticide Lambda-cyhalothrin showed an efficacy rate of 73 percent, 58 percent and 63 percent respectively. After spraying for 15 days, the tobacco leaf extract and the pesticide Dimethoate gave an efficacy rate of 94 percent and 84 percent, while neem leaf extract, soap and pesticide Lambda-cyhalothrin gave respective efficacy rates of 51 percent, 74 percent and 73 percent (Fitiwy *et al.,* 2016). In Morocco, a group of compounds were tested under semi field conditions – d-limonene (C10H16 the main compound of orange peel oil), mineral oil, malathion (organophosphorus) and the pesticide alpha-cypermethrin (Pyrethroid) – in controlling the scales of cochineal and studying the effect of these compounds on the predator *C. montrouzieri*. The results showed that d-limonene gave the highest efficacy on the second instar nymphs after 24 hours of spraying with an efficacy rate of 99 percent. Limonene and mineral oil gave the highest efficacy on the mature females with an efficiency reaching 99 percent after 120 hours of spraying. On the other hand, limonene and mineral oil had the least effect on the predator *C. montrouzieri*, causing a death rate of larva and adults of the predator of 11–15 percent (El Aalaoui *et al.*, 2019).

Figure 9. Lebanon's strategy for monitoring cochineal



Source: Moussa, Z. 2021. Assessment of the spread and effects of cactus cochineal in Lebanon. Cairo, FAO (unpublished).

Lebanon developed a pest protection plan that helps decision-makers decide what treatment to apply (Figure 9). Such strategies remain limited in the NENA region (Table 4). There is a noticeable variation in treatments and procedures to control cochineal in the four studied countries (no outbreaks reported in Tunisia).

Table 4. Pest management strategies to control cochineal in the five countries

	National action plan	IPM	Chemical treatment	Agronomical practices	Other alternatives
Jordan	n/a	*H. trifurcata* was released	10 days apart	n/a	ICARDA cactus germplasm collection
Lebanon	Yes	Predator found in 2015 and bugs released at 4 sites but effectiveness was low	Every 15–20 days	Removal & burning	Traditional soap
Morocco	Yes	11 local predators were reported, and *C. montrouzieri* chosen for release. 8 resistant cultivars were identified, registered, and multiplied. Plantation at large scale is underway	Yes	Removal	Use of plastic boxes for transport; traditional soap
Syrian Arab Republic	n/a	*C. montrouzeiri* was released	Every 15 days or 20 times a year	Removal & burning	n/a
Tunisia	In progress	n/a	n/a	n//a	n/a

PESTICIDE/CHEMICAL USE

Pesticide use is the most common form of protection from and control of cochineal globally, and has also been adopted in NENA countries. A list of pesticides used in the region is shown in Annex 3 and Annex 4. The mode of action of these pesticides is exclusively by contact, which needs 100 percent cover spray to reach cochineal. Although chemical treatment is common, the usefulness in treating outbreaks is determined by the degree of infestation. In Jordan, the National Agriculture Research Centre (NARC) demonstrated chemical sprays using the active ingredients Chlorpyrifos 50 percent and Cypermethrin 5 percent mixed with summer oil. A total of 30 ha was sprayed in which 169 farmers benefited from this spraying

activity. The spraying was reported effective, especially when combined with summer oil and when the mixture was applied more than once. The farmers were advised to prune the cactus plants to make space between them, and they were instructed to plant resistant varieties.

Figure 10. Chemical control of *D. opuntiae* by a Moroccan farmer

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farmers began to adopt pruning as cultural practices to reduce cladodes from cactus pests. In Morocco, farmers used two active ingredients at the beginning of a cochineal infestation: Chlorpyrifos-ethyl (before it was banned) and Pyriproxyfen. Traditional soaps were also widely used. Some When the infestation is very low, farmers removed the infested cladodes manually. Morocco's National Plant Protection Organization and Phytosanitary Authority (ONSSA), is responsible for managing outbreaks including chemical control, uprooting and providing technical assistance including the distribution of chemicals and spraying equipment. Before 2020, there were no direct subsidies for farmers to control *D. opuntiae*.

INTEGRATED PEST MANAGEMENT

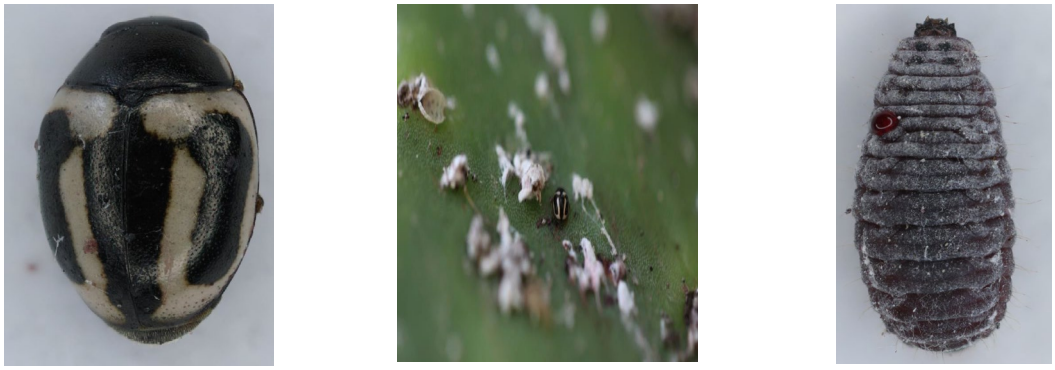
National IPM strategies throughout NENA are limited in controlling the spread of cochineal. IPM uses a combination of strategies to decrease pests, disease, and weeds. One plan includes the use of beneficiary insects or natural enemies to biologically control pest infestation. Most of the biological control work is still at the research level, and it is not yet a practical tool to be used to control the pest in the field (Table 4).

In Morocco, for instance, eight cultivars of cactus resistant to *D. opuntiae* were identified and registered in the official plant variety catalogue. Currently, the resistant cultivars are under mass propagation *in situ* in many regions of Morocco in order to supply farmers with sufficient plant material. Promising signs of natural enemies were reported in Jordan where larvae and adults of the *Hyperaspis trifurcata* (*Coleoptera: Coccinellidae*) were feeding on the cochineal scale (Figure 11). Few Coccinellids of the *Cryptolaemus montrouzieri* beetles were observed. In Morocco, a few individuals of the 12 local predators were collected from infested

cladodes (*Hyperaspis campestris, Hyperaspis notata, Scymnus interruptus, Scymnus loewii, Scymnus latemaculatus, Scymnus guttulatus, Nephus redtenbacheri, Hippodamia convergens, Exochomus nigripennis, Chilocorus bipustulatus, Chilocorus politus, Leucopis bellula*). However, these are preliminary observations and further investigations regarding their distribution, efficacy, and densities are required.

Figure 11. Cochineal's natural enemy – *Hyperaspis trifurcata* – in Jordan: a) adult of *Hyperaspis trifurcata* (*Coleoptera: Coccinellidae*); b) adult of *Hyperaspis trifurcata* among the cochineal scale individuals; c) dorsal view of *Hyperaspis trifurcata Larva*

.a **.b** **.c**



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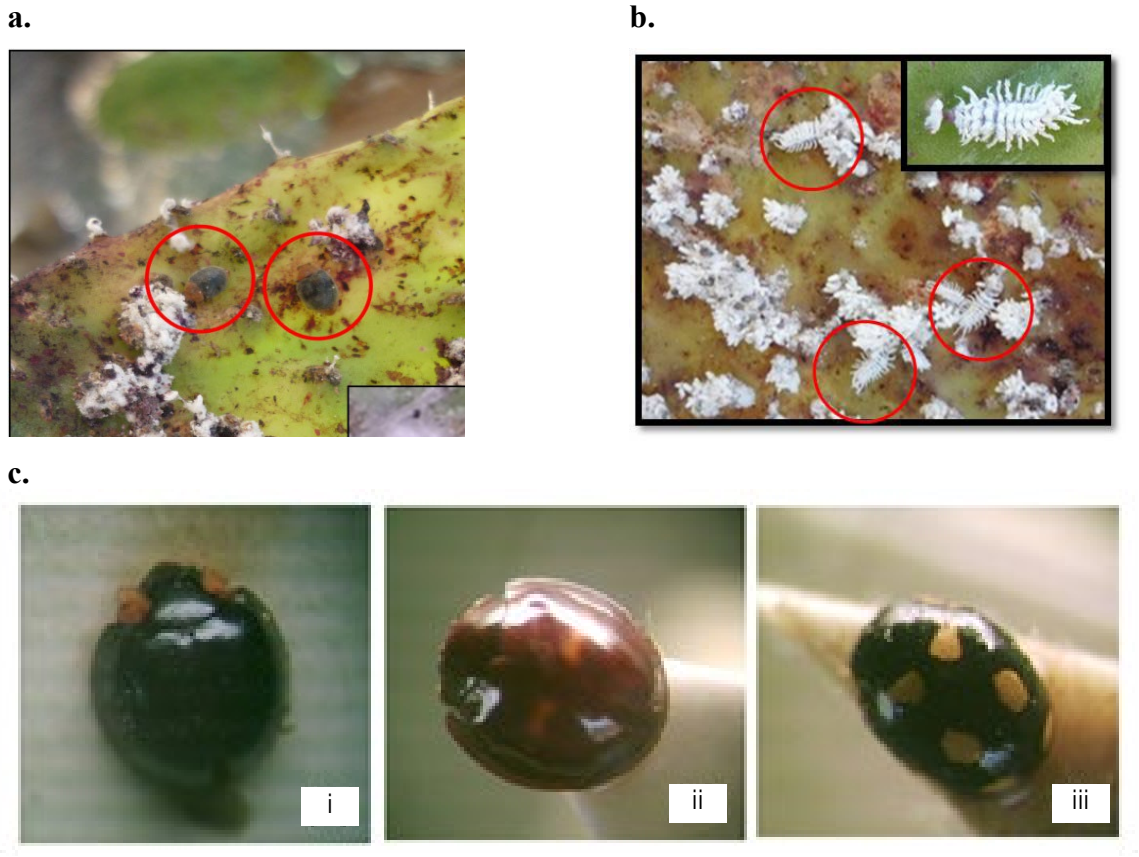
In Lebanon a few numbers of adults and larva of the predator *C. montrouzieri* Mulsant (*Coleoptera, Coccinellidae*) were observed in association with the population of *Dactylopius* in the districts of Tyre, Bint Jbeil, Chouf, Aley and Matn (Figure 12.a-b). Farmers did not know about the behaviour of this predator. During a 2015 field visit by experts from the Lebanese Agricultural Research Institute (LARI), only one site at Kfardounin (District of Bint Jbeil) in southern Lebanon showed a high population of *C. montrouzieri* aggregated on one giant cactus (Figure 12.a-b) (Moussa *et al*., 2017). This high population could be associated with the inundated releases of this predator in Israel in the same year. Once informed about this predator by LARI, farmers collected adults and released them in other sites. Three other predators belonging to the family of Coccinellidae were also spotted in very low numbers within the colonies of *D. opuntiae* during a 2014 survey: *Exochomus flavipes* (Thunberg); *Chilocorus* sp. (Leach) and *Hyperaspis* sp. (Pettey) (Figure 12.c) (Moussa, 2015).

Figure 12. Other natural enemies of cochineal found in Lebanon: a) adults of C. montrouzieri in Kfardounin 2015; b) Larvae of C. montrouzieri in Kfardounin 2015; c) adult lady beetles: (i) Exochomus sp., (ii) Chilocorus sp., (iii) Hyperaspis sp.



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AGRONOMIC PRACTICES

To control an infestation, many farmers uproot their orchards either manually (Figure 13.a) or mechanically (Figure 13.b). Proper monitoring and evaluation of orchards is also important. When an outbreak begins and infestation spread is low, farmers must treat the problem at the site-specific area by pruning cladodes, brushing/wiping cochineal off cladodes, or washing with traditional soaps. Proper pruning and thinning are needed to make sure the crop density maintains sufficient light and air, as proved useful in Morocco and Jordan. If the infestation is high, burning, uprooting, and burial are commonly practiced. The burial process is shown in Figure 13.c. First, uprooted plants are sprayed with authorized pesticides before being buried *in situ* to prevent the pest from spreading. The removed infested cladodes are also covered with plastic and placed under the sun until they wilt completely. Because the mucilage in the cladode tissues stops fire, burning infested cladodes was found to be impractical in the Syrian Arab Republic and Lebanon, even when using gasoline. Replanting orchards with more resistant varieties was noted as one of the most effective methods. However, replanting orchards can pose significant economic cost for farmers, especially when their livelihoods are dependent on the plant.

Figure 13. Uprooting and destruction *in situ* of infested cactus plants in Morocco: a) uprooting orchards; b) mechanically moving infested crops; c) spraying pesticide and burial of infested cladodes

a. b. c.

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OTHER ALTERNATIVES

Other alternatives that can be implemented to mitigate the spread and control outbreaks of cochineal infestations include the use of more resistant varieties of cladodes, capacity building, and training of local farmers through awareness campaigns. Country reports suggested developing a communication strategy to provide and share technical posters, leaflets, and advertisements via local and national broadcasting agencies. In addition, plastic boxes were promoted in Morocco to transport fruits and cladodesis instead of wooden boxes (Figure 14).

Figure 14. Transporting fruits in plastic boxes in Morocco

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INTERNATIONAL PLANT PROTECTION CONVENTION

The International Plant Protection Convention (IPPC) is an intergovernmental treaty signed by over 180 countries (FAO, 2014). The treaty aims to protect international plant resources from the spread and introduction of pests such as cochineal, while promoting safe trade. The IPPC Secretariat established an information exchange platform called the International Phytosanitary Portal. The portal encourages NENA countries to login into their country page and regularly update pest reports of cochineal to help monitor the situation. IPPC also introduced International Standards for Phytosanitary Measures as one of its main tools to achieve its aims, making it the sole global standard-setting organization for plant health. These phytosanitary measures from IPPC can assist member countries to set standards, facilitate trade and reduce the risk of cochineal spread.


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FUTURE CHALLENGES

In the future, greater attention is needed for improved systems on contact tracing of cochineal. This will be important in NENA to contain the pest outbreaks and make sure transport of material is not spreading cochineal further. The country reports recognize that there is a lack of knowledge as well as misconceptions among farmers and extension officers about the pest and how to manage its outbreaks. Further regulatory monitoring of chemical treatments, pesticide registration and research on biopesticides and natural enemies is to be encouraged.

STAKEHOLDER ENGAGEMENT IN NENA

We have summarized the institutions currently working on *Opuntia* spp. and the cochineal threat throughout the five NENA countries (Table 5).

Table 5. Stakeholders and bodies providing institutional support for *Opuntia* spp. and cochineal

Intergovernmental & international organizations	Ministries	National research & scientific agencies	Universities	NGOs & associations
Food and Agriculture Organization (FAO) InternationalCenter for Agricultural Research in the Dry Areas (ICARDA) United States Agency for International Development (USAID) International Fund for Agricultural Development (IFAD) Consultative Group on International Agricultural Research (CGIAR)	Jordan Ministry of Agriculture Syrian Ministry of Agriculture and Agrarian Reform (Plant Production, Forestry and Livestock Development Department) Syrian Forestry department of General Commission for Agricultural Research Moroccan Ministry of Agriculture and Forestry Moroccan Ministry of Interior Lebanon Ministry of Agriculture Tunisia Ministry of Agriculture and Environment and Territorial Management	Jordan National Agriculture Research Centre (NARC) Jordan Marw Agricultural Field Station Lebanon Agricultural Research Institute (LARI) Tunisia National Agronomic Research Institute (INRAT) Tunisia Institution of Agricultural Research and Higher Education (IRESA) Morocco National Plant Protection Organization and Phytosanitary Authority in Morocco (ONSSA) National Institute of Agronomic Research (INRA-Morocco) Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA)	Al-Baath University Faculty of Agriculture at Tishreen University Lebanese University Faculty of Agricultural Engineering and Veterinary Medicine University of Saint Esprit of Kaslik	Arab Society for Plant Protection Arab Fund for Economic and Social Development (AFSED)

These research and development projects in NENA pertain to cochineal and *Opuntia* spp.:

- Tunisia is implementing a four-year national project (2021–2025) with a total budget of USD 28 000 – "The preventive measures against cactus cochineal in Tunisia" – which aims to develop phytosanitary measures and an emergency action plan for monitoring and management of cactus cochineal in Tunisia.
- In Morocco, USD 1.1 million is being allocated over a three-year period (2021–2024) to a national research programme for the development of IPM, using resistant cactus cultivars while improving their cropping system, breeding of new resistant varieties and development of *in vitro* propagation schemes.
- In 2021, ICARDA conducted a global survey including Jordan and Tunisia to characterize cactus pear production systems and assess its economic valuation. The study benefited from funding from the CGIAR Research Program on Livestock.
- In 2021, ICARDA, in collaboration with the Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA), implemented an online webinar on cactus pear importance and challenges.
- In 2020, the Arab Society for Plant Protection, in collaboration with Tishreen University, organized in a one-day workshop on detection, spread and management of invasive or newly emerging pests (including cochineal) in the Syrian Arab Republic and neighboring countries.
- In 2020, ICARDA and NARC hosted an online expert meeting in Jordan involving several national and international institutions from Jordan, Morocco and ICARDA to increase awareness and develop a strategy to minimize risk of cochineal scale on cactus.
- Algeria developed with FAO support (2019–2021) a strategy for the prickly pear *Opuntia ficus-indica* (L.) sector.
- In 2019, Morocco funded the project "Assistance d'urgence pour l'éradication de la cochenille du cactus au Maroc" with a total budget USD 417 000. The project supported the installation of 1.2 ha of greenhouse on an experimental farm at INRA-Agadir to serve as an *in-situ* gene bank for further uses in breeding programme; in the greenhouse are all accessions of cactus planted to prevent from cochineal. Training and workshops were carried out.
- In 2019, ICARDA and NARC organized a five-day group training course in Jordan on "Cactus Pear Evaluation & Best-Agronomic Practices" attended by 28 experts.
- With support from ICARDA, INRA-Morocco developed a two-year research programme (2017–2019) to control cactus cochineal through a Collaborative Grant Program (MCGP) project.
- Jordan National Research Council initiated, with ICARDA support, a two-phase research programme (2016–2021) to promote cactus pear to improve provisioning of ecosystem services. The programme is funded by AFSED.
- In 2016, through an IFAD-funded project, the Ministry of Agriculture in the Syrian Arab Republic distributed 11 000 cladodes across its lower socioeconomic areas. Since then, the Ministry of Agriculture indicated that this project offers annually more than 48 000 cladodes of smooth cactus to breeders in targeted areas.

- In 2014, ICARDA sent 66 varieties of *Opuntia* to the Syrian Arab Republic. More than 17 000 cladodes of smooth cactus were planted as fodder in the form of a fence for families. A total of 228 breeders were trained and an estimated 4306 ha were planted.
- In Lebanon, LARI conducted in four surveys (2012–2020) for monitoring and evaluation of the spread of cochineal.
- In 2012, Lebanon planted local cactus in the region of Qaa in the District of Baalback under the frame of LARI/USAID/ICARDA Water Livelihoods Initiatives.
- During the 2002–2011 period, the Tunisian Ministry of Agriculture and Environment and Territorial Management planted around 165 000 ha of cactus (mainly *Opuntia ficus-indica f. inermis*) in private rangelands as part of a national reforestation plan.
- In Jordan in 1993, ICARDA – in collaboration with NARC and with financial support from AFSED – established the Cactus Germ Plasm Collection at the ICARDA Marw Agricultural Field Station. Today, the collection contains 120 different accessions from North America, South America, North Africa, Europe and the NENA region.

RESEARCH GAPS

Although the body of literature in the NENA is growing, there still remains significant data gaps to make precise judgements or decisions in relation to cactus cochineal. Further research is needed to:

- Provide satisfactory data about the efficiency of each of the various control methods.
- Generate GIS mapping of the extent of *Opuntia* spp.in the NENA region.
- Determine the efficacy of the cochineal's natural enemies and inventory the presence of indigenous natural enemies in the region.
- Develop a socioeconomic assessment on the contribution of *Opuntia* spp. to rural people's income and livelihoods.
- Research livestock feed potentials of *Opuntia* spp. in NENA region.
- Research on the valuation of ecosystem services provided by *Opuntia* spp, *inter alia* soil erosion control, sand dune fixation, pollination.


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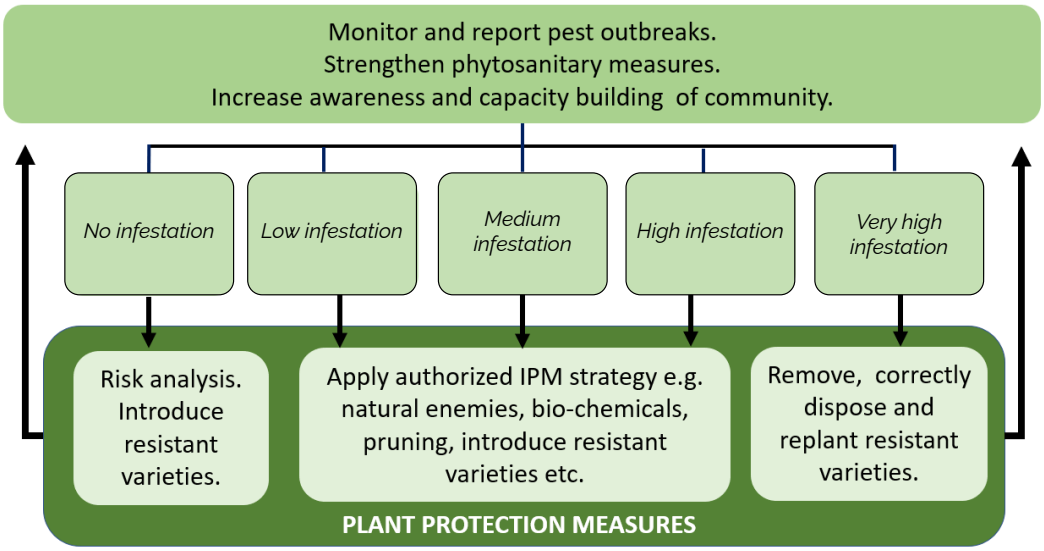
RECOMMENDATIONS AND CONCLUSIONS

With the growing threat of cochineal in the NENA, greater collaboration is needed to combat and contain spread of the pest. This report summarizes the solutions and concerns for the cactus pear industry reported by all five countries. For future research and investigation in NENA, greater standardization of data collection is recommended to allow for greater consensus and comparative analysis of the pest's status. Cochineal poses a significant threat to livelihoods in NENA; hence addressing data gaps and raising their importance at the decision-making level must occur if the cactus pear industry is to thrive. Due to the multipurpose use of cactus, particularly fodder for livestock, it is essential to build a sustainable and resilient future for the *Opuntia* spp. industry. Based on recommendations outlined in the five country reports, a NENA strategy has been developed to tackle future outbreaks (Figure 15). A road map for next steps and an outline of a control protocol for the prickly pear cochineal (*Dactylopius opuntiae)* are presented at the end of this report and Annex 1.

Figure 15. Recommended NENA strategy for cochineal management



NENA COCHINEAL RECOMMENDATIONS

- Promote IPM approaches within the region; share research on and upscale implementation and adoption of natural enemies and new varieties/tolerant cladodes.
- Routinely update country-level pest reports of cochineal and submit to the IPPC International Phytosanitary Portal.
- Develop, with the IPPC, national and regional phytosanitary and eradication strategies to control cochineal in affected countries.
- Provide more supervision and regulation of the application of authorized pesticides.
- Establish demonstration farms for stakeholders' awareness and disseminate information about best pest management practices among farmers.

NENA *OPUNTIA* SPP. RECOMMENDATIONS

- Greater consensus and empirical data on *Opuntia* spp. taxonomy and cactus production hectares using new technologies and participatory approaches.
- Establish cactus pear germplasm (field gene bank) per country or per agroecological system and submit to the ICARDA gene bank to conserve NENA cactus accessions.
- Extend this assessment to cover other NENA countries: Algeria, Palestine, Egypt, Libya, Iraq, and Türkiye.
- Campaign to promote the multiple uses and benefits of cactus in NENA, especially for fodder, ecosystem restoration, and human health.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ROAD MAP FOR NEXT STEPS

Based on the national reports (Jordan, Lebanon, the Syrian Arab Republic, Tunisia and Morocco) and the validation workshop of 4 July 2022, a road map was elaborated focusing on the following measures: cactus germplasm conservation, adoption of appropriate regulations, internationally funded collaboration, farmers involvement, applied research plan, alternative species of cactus pear and experience-sharing among NENA countries.

1. CACTUS GERMPLASM CONSERVATION

The diversity of cactus species in the NENA region is relatively low compared to its centre of origin. In order to obtain the maximum diversity, the conservation programme depends largely on propagation methods. All cactaceae species are relatively easy to propagate by vegetative methods using cladodes in whole or in part. Meaning that a 'copy' is made from original plant accessions with the whole genetic characteristics being preserved. Cactus species are well adapted to NENA's climate. The plant is drought tolerant and does not need specific cultural care. Morocco, as example, started the programme of cactus ecotypes collection in 1999 from all regional sites of cactus plantations in the country with other accessions introduced by FAO/ICARDA CactusNet in 2009 from the centre of origin of cactus in Latin America where the diversity is very high. It is the first NENA country that has created an official register of cactus varieties. Eight accessions resistant to D. *opuntiae* were registered and propagated in the most infested areas of the country. These eight accessions were taken from the cactus collection orchard established in 1999 at INRA experimental farm in Agadir. Currently, more than 400 accessions are preserved under the screenhouse at the INRA experimental farm with FAO support. The collected germplasm will serve as parents for future breeding programs. It is important that each country in the NENA region begin collecting and preserving all accessions of cactus in its territories in anticipation of future diseases and pests that may damage cactus plantations.

2. ADOPTION OF APPROPRIATE PHYTOSANITARY REGULATIONS

Following the first detection of *D. opuntiae* in a country, the pest should be declared by the national phytosanitary authority as a quarantine pest. Quarantine regulations must be established, published and strictly respected. Quarantine measures should be fully described and properly communicated through appropriate communication channels in the local languages and dialects. At field level, first-detected plants should be uprooted and buried in the ground at the same site. Inspection and spraying of the buffer zone is to be enforced by law.

In countries where the prickly pear cochineal has not yet been reported, rigorous regulations and inspection measures must be established at the custom borders to check for any infested material or equipment.

3. INTERNATIONALLY FUNDED COLLABORATION

Compared to other pest outbreaks, *D. opuntiae* occurrence received relatively less attention and interests and limited funding from both national and international funding sources. Funds are needed for monitoring pest occurrence and spread, for research and development actions and technology transfer, regardless of whether *D. opuntiae* is reported or not. Assistance could be sought from technical and financial agencies such FAO, CGIAR, European Union, World bank, IFAD, United Nations Development Programme (UNDP), International Research Development Centre (IRDC), United Nations Industrial Development Organization (UNIDO) and from cactus fruits importing countries.

4. FARMER INVOLVEMENT

Farmers' involvement in the operations undertaken at field level is a keystone of success for any form of agricultural development. The awareness of cactus farmers is essential at many stages:

- Early detection: farmers should be trained on how, where and when to detect infested cladodes in their own fields.
- Removal and burial of infested plant material and spraying surrounding areas.
- Monitoring all transport materials and equipment (boxes, trucks, animals, etc.) coming from infested areas to ensure they are pest-free.

It is important to organize farmers as professional associations or cooperatives to facilitate government and non-government support and subsidies in the form of equipment, plant materials, chemicals and training (Farmer field school).

5. EXCHANGE EXPERIENCES AMONG NENA COUNTRIES

NENA countries need to strengthen regional and interregional collaboration and benefit from the experience of countries where cactus pear is considered by policymakers and farmers as priority production crop. The experiences accumulated on cultural practices, biological control (Jordan, Lebanon, the Syrian Arab Republic and Morocco), chemical control, policy strategies should be exchanged within the NENA countries. The availability of natural enemies such as *Cryptolaemus montrouzieri*, *Hyperaspis trifurcata* (*Coccinellidae: Coleoptera*) and *Leucopis bellula* (*Diptera: Chamaemyiidae*) in countries such as the Syrian Arab Republic, Lebanon and Jordan can benefit other countries. Countries can also share the resistant cultivars from Morocco to preemptively prepare for eventual infestation, saving time and money. Other cultural practices aimed at reducing the damage of *D. opuntiae* on cactus plantations (e.g.

spacing, pruning, fertilization, etc.), could be shared within research and extension services in the region. National research institutes could also share the list of conventional chemicals and natural pesticides used as well as data on their efficacy. Appropriate and optimized methodology of spraying – already developed in some countries for black soap and plant extracts – could be described and translated to local languages and disseminated to farmers as needed.

6. ALTERNATIVE SPECIES OF CACTUS *OPUNTIA FICUS INDICA*

Resistant species such as *Opuntia robusta* and *Opuntia dillenii* could replace *Opuntia ficus indica*, especially for erosion and desertification prevention and as a hedge on land boundaries. These species can serve as a source of nectar for beekeeping and other income-generating activities, such as seed oils for cosmetic uses.

7. APPLIED RESEARCH PLAN

Research priorities should be identified and actions planned in consultation with all stakeholders including farmers' professional associations. Morocco's short-, mid- and long-term research programme can provide inspiration for other NENA countries in shaping their cochineal research programme. The main elements of the Moroccan emergency plan are:

- identify prickly pear cochineal and its possible biotypes;
- establish a research programme on the development of cultivar resistance to *D. opuntiae*;
- study the biology and ecology of *D. opuntiae* at regional conditions;
- develop natural biopesticides to preserve the organic label of cactus fruits;
- study all aspects of biological control strategies (local and introduced exotic natural enemies).

REFERENCES

Aithamou, A. 2021. *Cochineal in Tunisia (24 September 2021)* [video]. Mahdia Governorate, Tunisia. Cited 21 September 2022. https://www.youtube.com/watch?v=WQKNVhwOVgc

Boujghagh, M. 2011. *Le cactus (Opuntia spp.): Guide pratique de conduite technique de la culture*. Agadir, Morocco, Institut National de la Recherche Agronomique. https://www.inra.org.ma/fr/content/le-cactus-*opuntia*-spp-guide-pratique-de-conduite-technique-de-la-culture-0

Bouharroud, R., Amarraque, A. & Qessaoui, R. 2016. First report of the *Opuntia* cochineal scale *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) in Morocco. *EPPO Bulletin,* 46(2): 308–310. https://doi.org/10.1111/epp.12298

Bouharroud, R. 2021. *Assessment of the spread and effects of cactus cochineal in the Near East &North Africa region: Morocco*. Cairo, FAO (unpublished).

Boufaoor, M. 2021. *Assessment of the spread and effects of cactus cochineal in Syria.* Cairo, FAO (unpublished).

Bufaur, M., & Bohamdan, R. 2020. First record of *Opuntia* cochineal *Dactylopius opuntiae* (Cockerell, 1896) in Syria. *Arab Journal of Plant Protection (AJPP)*, 38(1): 59–63. https://www.cabdirect.org/cabdirect/abstract/20203315133

Chalak, L. Younes, J. Rouphael, S. & Hamadeh, B. 2012. Morphological characterization of prickly pears (*Opuntia ficus indica* (L.) Mill.) cultivated in Lebanon. *International Journal of Science and Research (IJSR)*, 3(6): 2541–2553. https://www.ijsr.net/archive/v3i6/MjQwNjE0MDU=.pdf

De Lotto, G. 1974. On the status and identity of the cochineal insects (Homoptera: Coccoidea: Dactylopiidae). *Journal of the Entomological Society of Southern Africa*, 37(1): 167–193. https://journals.co.za/doi/epdf/10.10520/AJA00128789_2848

Eisner, T., Ziegler, R., McCormick, M., Eisner, J. L., Hoebeke, E. R. & Meinwald J. 1994. Defensive use of an acquired substance (carminic acid) by predaceous insect larvae. *Experientia*, 50(1): 610–615. https://link.springer.com/article/10.1007/BF01921733

El Aalaoui M., Bouharroud R., Sbaghi M., El Bouhssini M., Hilali, L. & Dari, K. 2019. Comparative toxicity of different chemical and biological insecticides against the scale insect *Dactylopius opuntiae* and their side effects on the predator *Cryptolaemus montrouzieri*. *Archives of Phytopathology and Plant Protection*, 52(1): 155–169. https://doi.org/10.1080/03235408.2019.1589909

European Commission. 2022. European Union Pesticide Database. In: *European Commission*. Brussels. Cited 22 September 2022. https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/mrls/?event=search.pr

Fitiwy, I., Gebretsadkan, A. & Araya, A. 2016. Management of cochineal (*Dactylopius coccus* Costa) insect pest through botanical extraction in Tigray, in North Ethiopia. *Journal of the Drylands*, 6(2): 499–505. https://www.researchgate.net/publication/313862365

FAO. 2014. IPPC Factsheet. Rome, FAO and the International Plant Protection Convention. https://www.ippc.int/static/media/files/mediakit/IPPC_GenericFactSheet_e_variation_en_20140305.pdf

Guerra, P. G. 1991. Biosystematics of the family Dactylopiidae (Homoptera; Coccinea) with emphasis on life cycle of *Dactylopius coccus* costa. Blacksburg, Virgina, USA, Virginia Polytechnic Institute and State University, PhD dissertation. https://vtechworks.lib.vt.edu/handle/10919/29024

Hayder, M. 2021. *Assessment of the spread and effects of cactus cochineal in the Near East &North Africa region: Tunisia*. Cairo, FAO (unpublished).

Idris, I., Elkhouri, S., Bakri, Y. 2019. Evaluation of crude enzyme produced by Bacillus subtilis SY134D culture as a biocontrol agent against *Dactylopius opuntiae* (Dactylopiidae: Hemiptera) on cactus pear. *Journal of Bio Innovation* 8(3): 289-300. https://www.jbino.com/docs/Issue03_07_2019.pdf

Inglese, P., Mondragon, C., Nefzaoui, A., & Saenz, C. 2017. *Crop ecology, cultivation and uses of cactus pear*. Rome, FAO and ICARDA. https://www.fao.org/3/i7012e/i7012e.pdf

Katbeh, A. 2021. *Report on the current status of the cochineal scale, Dactylopius opuntiae in Jordan.* Cairo, FAO. (unpublished).

Nobel, P. S. 2002. *Cacti: biology and uses*. Berkely and Los Angeles, California, USA, University of California Press.

Mathenge, C. W., Holford P., Hoffmann, J. H., Spooner-Hart, R., Beattie G. A. C. & Zimmermann, H. G. 2009. The biology of *Dactylopius tomentosus* (Hemiptera: Dactylopiidae). *Bulletin of Entomological Research*, 99(6): 551–559. https://pubmed.ncbi.nlm.nih.gov/19203403/

Mazzeo, G., Nucifora, S.,Russo,A. &Suma, P. 2019. *Dactylopius opuntiae*, a new prickly pear cactus pest in the Mediterranean: an overview. *Entomologia Experimentalis et Applicata*,167(1): 59–72. https://doi.org/10.1111/eea.12756

Mow, V. C., Gunn, B. H. & Walter, G. H. 1982. Wind dispersal and settling of first-instar crawlers of the cochineal insect *Dactylopius austrinus* (Homoptera: Coccoidea: Dactylopiidae). *Ecological Entomology*, 7(1): 409–419. https://doi.org/10.1111/j.1365-2311.1982.tb00683.x

Moussa, Z. 2015. *Managing Dactylopius opuntiae (Cockerell, 1929) (Hemiptera: Coccoidae: Dactylopiidae), a new invasive pest in South Lebanon*. Beirut, Lebanon, Lebanese University Faculty of Sciences, master thesis.

Moussa, Z. 2021. *Assessment of the spread and effects of cactus cochineal in Lebanon.* Cairo, FAO (unpublished).

Moussa, Z., Yammouni, D. & Azar, D. 2017. *Dactylopius opuntiae* (Cockerell, 1896), a new invasive pest of the cactus plants *Opuntia ficus-indica* in the South of Lebanon (Hemiptera, Coccoidea, Dactylopiidae). *Bulletin de la Société entomologique de France*, 122(2): 173–178.

Nasr, Y. 2015. Cactus pear in Jordan: current status, potential, and opportunities. I*Acta Horticulturae*, 1067(41): 299–303. https://doi.org/10.17660/ActaHortic.2015.1067.41

National Plant Protection Organization and Phytosanitary Authority of Morocco (ONSSA). 2022. In: *ONSSA*. Rabat. Cited 10 October 2021. http://www.onssa.gov.ma/fr/

Palafox-Luna, J., Rodríguez-Leyva, E., Lomeli-Flores, J. R., Vigueras-Guzmán A. L. & Vanegas-Rico, J. M. 2018. Life cycle and fecundity of *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) in *Opuntia ficus-indica. Agrociencia,* 52(1): 103–114. https://www.researchgate.net/publication/323127276

Protasov, A., Mendel, Z., Spodek, M. & Carvalho, C. J. 2017. Management of the *Opuntia* cochineal scale insect, *Dactylopius opuntiae* (Cockerell) in Israel. *Alon haNotea,* 71: 48–51. https://www.researchgate.net/publication/320583651

Reis, R. C. S., Melo, D. R., Perinotto, W. M., & Bittencourt, V. R. E. P. 2005. Patogenicidade in vitro de formulações fúngicas sobre ninfas e adultos de *Rhipicephalus sanguineus* (Latreile, 1806) (Acari: Ixodidae). *Revista Brasileira de Parasitologia Veterinária*, 14: 101–105.

UN. 2021. General Maps. In: *United Nations Geospatial*. New York, USA. Cited 10 October 2021. https://www.un.org/geospatial/mapsgeo

Vanegas-Rico, J. M., Lomeli-Flores, J. R., Rodríguez-Leyva, E., Mora-Aguilera, G., & Valdez, J. M. 2010. Enemigos naturales de *Dactylopius opuntiae* (Cockerell) en *Opuntia ficus-indica* (L.) Miller en el centro de México. *Acta zoológica mexicana*, 26(2): 415–433. https://doi.org/10.21829/azm.2010.262718

Vanegas-Rico, J. M., Pérez-Panduro A., Lomelí-Flores, J. R., Rodríguez-Leyva, E., Valdez-Carrasco, J. M. & Mora-Aguilera, G. 2017. *Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopiidae) population fluctuations and predators in Tlalnepantla, Morelos, Mexico. *Folia Entomológica Mexicana* 3: 23–31. http://revistas.acaentmex.org/index.php/folia/article/view/128/117

Volchansky, C. R., Hofmann, J. H. & Zimmermann, H. G. 1999. Host plant affinities of two biotypes of *Dactylopius opuntiae* (Homoptera: Dactylopiidae): enhanced prospects for biological control of *Opuntia stricta* (Cactaceae) in South Africa. *Journal of Applied Ecology,* 36(1): 85–91. https://doi.org/10.1046/j.1365-2664.1999.00381.x

ANNEXES

ANNEX 1. OUTLINE OF THE CONTROL PROTOCOL FOR COCHINEAL

- Plant resistant cultivars when available.
- Adopt pruning as a key practice in cactus orchards.
- Avoid high plantation density (unless for livestock feed cladode production).
- Promote classical biological control.
- Promote conservation biological control.
- Training and awareness for farmers.
- Promote the uses of ecofreindly pesticides.
- Promote mechanical control at low infestation.
- Adopt cultural practices to reduce dissemination.
  - bury infested plant material on site;
  - use plastic boxes;
  - washing equipment for transport vehicles.

ANNEX 2. FAO QUESTIONNAIRE USED TO COLLECT COUNTRY DATA

Questionnaire

Assessment of the spread and effects of cactus cochineal in the Near East and North Africa region

Country:

Name of national consultant		**Name of respondent and affiliation**	

A- General information related to cactus

1. Is the introduction of cactus (*Opuntia* spp.) in the country known, if so please give the approximate year of first introduction:

2. Which government department(s) is/are managing cactus:

Agriculture	Forestry	Environment	Other

3. What is the number of administrative regions (governorates) in the country?

4. In how many regions/provinces is cactus planted?

5. What is the estimated area of cactus in each region/province?

6. What are the most common groups of cactus in the country?

Spiny	**Spineless**	**Both**

7. The cactus cropping system: Is the plantation of cactus considered as a conventional crop?

Yes		No	

(If 'No' go to part **II**.)

I- If 'Yes,' please answer the below follow up questions:

1- What is the density (plants/ha):

2- Are cactus plants irrigated?

Yes		No (rainfed)	

if 'Yes,' what is the amount of water used per crop cycle?

3- Are cactus plants fertilized?

Yes		No	

If 'Yes,' what are the main fertilizers used:

Organic manure		**Macronutrients (NPK)**		**Micronutrients**	

4- Is pruning practiced (including removing cladode for animal feed)?

Yes		No	

If 'Yes,' please indicate the period of pruning?

5- What is the main pest/disease damaging cactus?

6- What is the mode of seedlings production adopted?

Vegetative using cladode or part of cladode	**in-vitro plants**	**From seeds**	**Nursery**

7- What is the appropriate planting date/period adopted in the country?

8- What is the harvest period for fruits and/or fodder?

9- What is the yield for fruit and cladode?

Fruit yield/ha	Cladode yield/ha (feed production)

II- If no crop management is adopted

1- What is the purpose of cactus?

Hedge	Definition of land boundaries	Others

2- What are the uses of cactus crop?

Feed	Food (fresh fruit)	By-products	Bee keeping	Other

B- Uses of cactus pear products:

1- Where do harvested fresh fruits/cladodes of cactus go to?

Street vendor		Supermarket	
Local Market		Local Animal feed	

2- Is the cactus exported?

Yes		No	

If 'Yes:'

3- In what form is cactus exported?

Fresh fruits		By-products (after processing)	
Volume (Ton)		Volume	

4- What type of processing industry related to cactus exists in the country?

Fresh fruits packaging	Cosmetic oils (seeds extraction)	processed feed	Food byproducts

5- If cactus is processed as a food by-product, what is the final product(s)?

Dried cladode powder	Dried pulp	Juice	Jam	Dried fruits	Dietary supplement	Colourants/ dye	Mucilage	other

C- Socioeconomic aspects of cactus:

1- Farmer personal information managing cactus– Gender

Male		Female	

2- Average age?

<25	25<age<35	35<age<45	45<age<60	>60

3- In your opinion who are the main consumers/clients of cactus/by-products in the country?

Women	Men	Both

4- What is the lowest price of cactus fruit in 2019/2020 (local currency per kg or piece)?

5- What is the highest price of cactus fruit in 2019/2020 (local currency per kg or piece)?

6- Is cladode sold for animal feed?

Yes		No	

7- If 'Yes,' what is the latest average price per common unit in the country?

8- What is the estimated annual income received from all activities related to cactus? (per USD and area unit):

D- Cactus pear cochineal:

1- When was cochineal first detected in the country?

2- Please indicate the region where the cochineal was detected for the first time in your country?

3- What is the current infestation degree in that region?

Low (<25%)	**Medium (25–50%)**	**High (<50%)**

4- What is the estimated total area damaged (ha)?

5- What is the infestation degree per region where cactus is planted? (add more lines as needed)

	Low (<25%)	**Medium (25–50%)**	**High (<50%)**
Region 1(Name)			
Infestation degree			
Region 2 (Name)			
Infestation degree			
Region 3 (Name)			
Infestation degree			
Region 4 (Name)			
Infestation degree			
Region 5 (Name)			
Infestation degree			

6- Please indicate the cochineal species reported in the country based on research and/or official reports?

D. opuntiae	*D. coccus*	*D. tomentosus*	Other

7- Control management at farmer level:

i- From farmer side, is cochineal considered as a pest to be eradicated?

Yes		No	

ii- Which control method is adopted by farmers?

Chemical control	**Uprooting**	**Incineration**	**Biocontrol using natural enemies**	**Biocontrol using biopesticides**	**Resistant/ tolerant cultivars**	**Other (please specify)**
Active ingredients sprayed:			Species of natural enemies:	Composition/ Active extracts:	Cultivars names:	

8- Control management at national level (the control is supported and/or subsidized by government)

i- Is there an official document (e.g. Government order) considering cactus pear cochineal as a pest or quarantine pest?

Yes		No	

ii- Is there an official document (e.g. Government order) that require quarantine measures to eradicate/limit dissemination of cactus pear cochineal?

Yes		No	

iii- What are the authorized pesticides to control cactus pear cochineal?

iv- What is the list of authorized pesticides to control other pests and diseases on cactus crop? (if any)

v- Please indicate the complete name/code of the official document/website of National Plant Protection Organization (NPPO) listing authorized pesticides:

vi- Is there a control strategy undertaken by authorities (ministry of agriculture, NPPO …)?

Yes		No	

vii- Which control methods are adopted in your country?

Chemical control	**Uprooting**	**Incineration**	**Biocontrol using natural enemies**	**Biocontrol using biopesticides**	**Resistant/ tolerant cultivars**	**Other (please specify)**
Active ingredients sprayed:			Species of natural enemies:	Composition/ Active extracts:	Cultivars names:	

viii- Are there any subsidies to farmers to control cactus pear cochineal?

Yes		No	

If 'Yes,' please indicate the amount per area unit?

6- Is there any national research programme implemented in your country on cochineal control?

Yes		No	

7- Is there any national research programme implemented in your country related to cactus in general?

Yes		No	

i- If 'Yes,' what are the current, past and/or planned research activities?

Chemical control	Uprooting	Incineration	Biocontrol using natural enemies	Biocontrol using biopesticides	Resistant/ tolerant cultivars	Other

ii- What is the total budget allocated (current, past and planned in future) for cactus research programme?

iii- List of published papers (including the ones in Arabic/French):

iv- Is there any international collaboration on cactus with ICARDA?

Yes		No	

v- If 'Yes,' list of countries/organizations involved:

ANNEX 3. REGISTERED PESTICIDES ON PRICKLY PEAR CACTUS COCHINEAL IN MOROCCO

Pesticide trade name	Formulation	Active ingredient	A.I. content	Rate	PHI	Number of applications
ADMIRAL 10	EC	Pyriproxyfen	100 g/l	35 cc/ hl	7	
AGROIL	EC	Mineral oil	78%	2 l/hl	–	
CITROLE BM	EC	Mineral oil	97%	1.5 l/hl	Not required	
GENERAL 100	EC	Pyriproxyfen	100 g/l	35 cc/ hl	7	
MOSPILAN 20	SP	Acetamiprid	20%	20 g/hl	7	
MOVENTO 100	SC	Spirotetramat	100 g/l	1.5 l/ha	7	1
OVIPHYT	EC	Vaseline oil	817 g/l	2 l/hl	Not required	1
PROXIMO	EC	Pyriproxyfen	100 g/l	50 cc/ hl	7	1
SAF-T-SIDE	Emulsion, water in oil	Petroleum oil	80%	2 l/hl	Not required	
Many trade names	EC	Chlorpyrifos-ethyl	480 g/l	150 cc/ hl	Currently banned	

Source: National Plant Protection Organization and Phytosanitary Authority of Morocco (ONSSA). 2022. In: *ONSSA*. Rabat. http://www.onssa.gov.ma/fr/

ANNEX 4. PESTICIDES USED TO CONTROL DACTYLOPIUS *OPUNTIA*E IN LEBANON AND THEIR MAXIMUM RESIDUE LEVEL IN CACTUS FRUITS

Pesticide	Mode of action	Class	Approval expiry date in the European Union	MRL (mg/kg) *
Abamectin	Contact and ingestion	Avermectin	30 April 2021	0.01
Spirotetramat	Systemic	Ketoenols	30 April 30 2024	0.1
Acetamiprid	Systemic	Neonicotinoid	28 February 2033	0.01
Thiamethoxam	Systemic	Neonicotinoid	Not approved	
Chlorpyriphos	Contact	Organophosphate	Not approved	
Deltamethrin	Contact	Pyrethroid	31 October 2021	0.01
Cypermethrin	Contact	Pyrethroid	31 October 2021	0.05
Methomyl	Contact	Carbamate	Not approved	
Sulfoxaflor	Systemic	Sulfoximine	18 August 2025	0.01
Diflubenzuron	Insect Growth Regulator	Benzoylurea	31 December 2020	0.01

Source: European Commission. 2022. European Union Pesticide Database. In: *European Commission*. Brussels. Cited 22 September 2022. https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/mrls/?event=search.pr

STATUS OF COCHINEAL AND OPUNTIA SPP. PRODUCTION IN THE NEAR EAST AND NORTH AFRICA REGION 2022

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