Good Agricultural Practices In Cactus Pear Crop

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Orchard planting and management of cactus pear production

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Introduction

Opuntia is cultivated on over 100,000 ha for fruit production and more than a million ha are devoted to obtain forage and fodder for cattle, sheep and goat production in main cactus pear producer countries (Inglese, 2010). Other products from cactus pear are nopalitos. In Mexico more than 15,000 ha are used to cultivate nopalitos. Cochineal production in Ethiopia, Chile, Mexico, Peru and other countries is an important resource obtained from more than 35,000 ha.

Opuntia plants are native to different environments, so they would be aninteresting genetic resource for diverse ecological regions. However, the high environmental disturbance in many of these areas, results in low harvests in cactus pear production systems. The main factors inducing this situation are the weak social and economic conditions, inadequate cultivars and predominant bad management of crop. This manual aims to provide a basic guide of management in different productive Sistem on cactus pear production.

Pre-planting operations

The soil should be ploughed to a depth of 60-80 cm, in order to ensure good drainage. As an alternative to this the soil can be be cross-ripped with a chisel to improve drainage and avoid alteration of soil profile (Figure 1). In sandy soils and soils free from weeds, pre-planting operations can be restricted to single holes in the rows.

Figure 1: Soil ploughed 60-80 cm depth with cow manure

Pre-planting cladodes management

Before planting cladodes must be dried for 24 h in a partially shaded location. It is recommended to use bordeaux paste or copper oxichloride (1 g L^{-1}) to reduce infestation before planting (Figure 2).

Figure 2: Cladodes at shade, ready for planting.

Planting time

It is recommended to plant after risk of frost in the sprint or from August to September. Late spring is the period for planting in the Mediterranean area, soil water content in late spring is high enough to allow root development in areas with winter rainfall. In the Mediterranean, root and cladodes reach their highest growth rate during late spring and early summer. Planting at the end of the summer slows down the development of the root system and the canopy, due to low winter temperatures and reduced daylight.

Planting material

To establish an orchard there are multiple recommended practices that can enhance the quality, productivity, and overall success of the orchard. Cladodes should come from nurseries or from controlled and healthy orchards. Single or multiple cladode cuttings are commercially utilised for orchard establishment. Single cuttings can be one or two-years-old, and their surface area and dry mass have a significant influence on successful field rooting and subsequent budding. Surface areas of 500 cm^2 or a dry mass of 70-100 g allow a good plant growth. A multiple cutting is made of a 2-year-old cladode bearing, on its crown-edge, one or two 1-year-old daughter cladodes. The advantage associated with the multiple cladode cutting is the rapid formation of plant structure, which results in early fruiting after planting, however it requires more planting material that increases planting costs. (referring plantation)

- The rows should be oriented north-south to maximize PAR (Photosynthetically Active Radiation) interception and cladodes face perpendicular to the rows.

- Depth of the hole in the row: 50 cm; eventually the hole should be filled with cow manure or hand fresh soil with 30 g of N.

  Cladodes should be planted upright with the cut end on the ground, it is recommended to plant half of the cladode underground.

- One-year-old single cladode or 2-years-old multiple cladode cuttings, cladode surface and dry matter content affects rooting. (Figures 3a and b).

- 2 parallel cladodes spaced 30-40 cm or 3-4 cladodes spaced 30 cm. (Fig. 3 c)

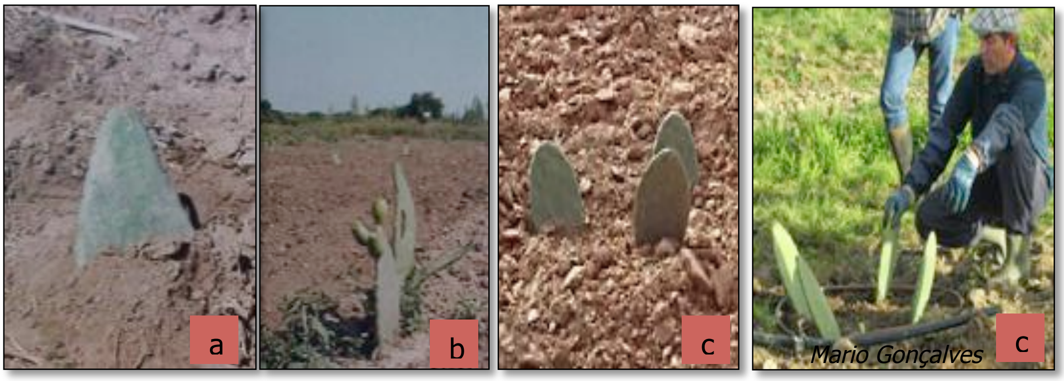

Figure 3: a-one year old single cladode; b: two years old multiple cladodes; c: two parallel cladodes spaced 30-40 cm.

Orchard design

Orchard desing depends on field size, environmental conditions, cultivar growth, orchard management and *Cactoblastis cactorum* presence. Hedgerow systems are common with plants placed closely within the row.The layout can be either square or rectangle with plants pruned to a globe shape that are well separated from each other.

- Modern, hedgerow, plantations utilize 2 m within the row and 6 m in between. (835 plants ha^{-1})

- Such a close spacing increases the number of fertile cladodes per hectare in the early stages of orchard life and results in continuous canopies which require high pruning. Clippings from pruning are usually left on the ground in the alley and eventually chopped mechanically.

 

Figure 4: Italy plantation, hedgerow.

- If trees are spaced in a rectangular or squared layout, plants are usually pruned to a bushy globe shape. In Italy plant spacing ranges from 4 x 6 m (416 plants ha $^{-1}$) to 5x 7 m (290 plants ha^{-1}) (Figure 4).

- In Argentina, normally, plant spacing ranges from 3x4 m to 4x6 m (Figure 5)

Figure 5: Cactus pear plantation, six-month-old Tucumán province, Argentina.

The crop yield is a function of site specific environmental factors, such as: solar radiation incidence (RFAinc.), solar radiation interception efficiency (IRFA), the efficiency with which the intercepted radiation is converted to dry matter (ec), and finally the partition efficiency (ep) which is the efficiency of total dry matter partitioning between fruiting organs and the other plant organs.The identified components can be summarized in the following equation:

Crop yield: RFA inc. * IRFA * ec * ep

However, this equation must be added to a final component to get a marketable yield, which is the fruit quality. This is a high impact factor in the profitability of the crop. Thus, the aim of pruning is to expose the cladodes to greater uptake of solar radiation; those developed in the shaGarded parts of the plant are less productive than those well exposed on the outside (García de Cortazar and Nobel 1992). As a result pruning in high density orchards is a very important a tool to maintain the productivity of the plantation as shade can reduce productivity. Most of the reproductive buds are located on 1-year-old cladodes, and then an adequate production of these cladodes every year is required (Nerd *et al.*, 1993).

Lower planting distance requires high pruning intensity and frequency. The reduced density makes cultural practices (fruit thinning, spraying for *Cactoblastis* and harvest) easier and helps to improve fruit quality.Table 1 shows the increase in total dry matter, interception of photosynthetically active radiation and conversion efficiency of a plantation, for two seasons with different levels of nitrogen, where deficiencies of N reduced the accumulation of dry matter during the first year, with no significant differences between treatments during the second season. This effect (N deficiency) was mainly due to lower light interception by the crop and the conversion efficiency of radiation, with greater weight for the first variable. During the second season both components of the total dry matter showed a balanced contribution, no difference between treatments in the percentage of N increments the first cycle.

Table 1: Relative increases of total dry matter (TDM), Intercept radiation (IRFA) and efficient use of solar radiation (ECR) computed as values at the end of the campaign year 1 and the start of the trial, and as values at the end of year 2 as securities at the end of the cycle.

Campaing	∆ year1/init	∆ year1/init	∆ end/year1	∆ end/year1	∆ end/year1	∆end/year1
Treatment	∆ TDM [1]	∆ IRFA[2]	∆ ECR	∆ TDM	∆ IRFA	∆ ECR
	-----------------------------------%--------------------------------------					
N_{low}	36 b[3]	26 b	10 b	47 a	28 a	20 a
N_{medio}	66 a	43 a	23 a	51 a	23 a	28 a
N_{high}	64 a	40 a	24 a	51 a	26 a	25 a

[1] Values of dry matter at the beginning of treatment includes only cladodes, while the values for 1-2 and 2-end year of the assay include the total above ground dry matter.
[2] Increments IRFA were computed from the average of estimates, with k = 0.2 and 0.4.
[3] Mean followed by the same character did not differ between them (LSD, 5% significance)

Pruning recommendations:

Leave no more than two daughters cladodes on a parent cladode (Figures 6a and b).

Pruning system.

In productive plants 80-90% of 1-year-old cladodes should produce fruit one year after its formation. Two-year-old cladodes can be fruitful, but its contribution to the fertility of the plant is limited. Most plants reduce their productive potential 20-25 years after planting. The rejuvenation of these plants can be considered as alternative. This can be done by cutting 5-6-years-old cladodes. Pruned plants could produce two years after pruning depending on its intensity.

Figure 6a and b: Pruning in a 2-year-old plantation, Cochabamba, Bolivia.

Nutrition and Fertilization

Soil management

Soil cultivation should be restricted to a minimum, in order to avoid damaging the superficial root system of the cactus pear.

Mechanical control: to avoid any damage to the roots and to preserve soil structure, weeds can be mowed and left as mulch in the soil cover. This method reduces weed growth and retains soil moisture.

Chemical control: paraquat and glyphosate (20 g/L) (Sobrero, pers. com.) can be successfully used; care must be taken to avoid drift, as cladodes are extremely sensitive to weed killers.

Irrigation

In Argentina, 80% of cactus pear orchards are in arid areas that are without irrigation.

Cactus pear needs an annual amount of water estimated at 600 mm. Depending on the environmental conditions, plants may need up to 150-200 mm during the development of the fruit. Irrigation water should not exceed 25 mol m^{-3} NaCl (Nerd *et al.*, 1991). Cactus pear is a drought resistant crop and its water-use efficiency is among the highest.

In areas where the fruit develops during the dry season irrigation is required to obtain a commercially accettablefruit size (Barbera, 1984)

The suspension of the irrigation in the winter can reduce the fruiting potential due to the reduction of the induction and formation of flower buds.

Therefore irrigation is required:

- At planting time
- The floral induction period (30-60 days before sprouting)
- During early stages of fruit development (2-3 irrigations after flowering to 4-5 weeks after fruit set) (Nerd *et al.*, 1993).

Watering must be moderated in the last stages of fruit development.

Drip irrigation (two lines to a row) or localised micro-sprinklers, which cover a relatively large soil surface area with small volumes, meet the characteristics of *Opuntia* shallow root system. (Figure 7)

Figure 7: Drip irrigation in Sicily

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Major diseases and pests in America

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Introduction

In spite of the social and economic importance of cactus pear culture, worldwide scientific investigations regarding biotic factors have been reduced (Ochoa *et al*., 2015) This has been a problem since the 90s .As a result, the knowledge and available literature on diseases is limited (Osorio and Grove, 1994). As in other crops, cactus pear has complex sanitary issues, which may vary depending on each region. Regardless, biotic factors (pests and diseases) are considered of major economic importance. As a result, this work aima to call attention to the major biotic factors impacting cactus pear plantations. (Ochoa *et al.,* 2015).

Cactus pear black spot (*Pseudocercospora opuntiae*)

Black spot is a disease that causes a severe reduction of the photosynthetic area and eventually the total or partial fall of the plants (Ochoa, 2013). The productive life of a plantation can be diminished by 50% or more. According to Méndez Gallegos *et al*. (2008), some of the principal reasons for which the diseases have proliferated in this genus are: the method of propagation and multiplication of cactus pear, reduced genetic diversity from which the expansion of the culture began, scarce agronomic managing of plantations, ignorance of symptoms (confusion of damage, synonymies and causal agents) and inadequate strategies of control.

Importance and Evolution

This disease was first detected in 1990 on cactus pear plantations of Western Mexico. The causal agent (*Pseudocercospora opuntiae*) was determined in 2006 (Quezada-Salinas et al., 2006). Five years ago in Bolivia, Perú and Mexico, it achieved 100% of infection in commercial areas.

Causal Agent

Quezada-Salinas *et al*. (2006) determined that *Pseudocercospora opuntiae* is the causal agent of black spot of cactus pear and *Colletotrichum gloeosporoides* is associated as a saprophyte.

Symptomatology

The process starts with discoloration of a small location on the cuticle that will turn transparent with white small olive-colored specks. Then it will turn dark brown with a yellow contour and it will became larger (3-4 cm) and perforate the cladode (Ochoa, 2013) (Fig. 8).

Figure 8: Developmental stages of cactus pear black spot (*Pseudocercospora opuntiae*) after 90 days of infection. A) Symptom 1, B) symptom 2, C) symptom 3, D) symptom 4, E) symptom 5, F) symptom 6, and G) symptom 7.

To determine the damage in cactus pear productivity systems a severity scale is used (Figure 9).

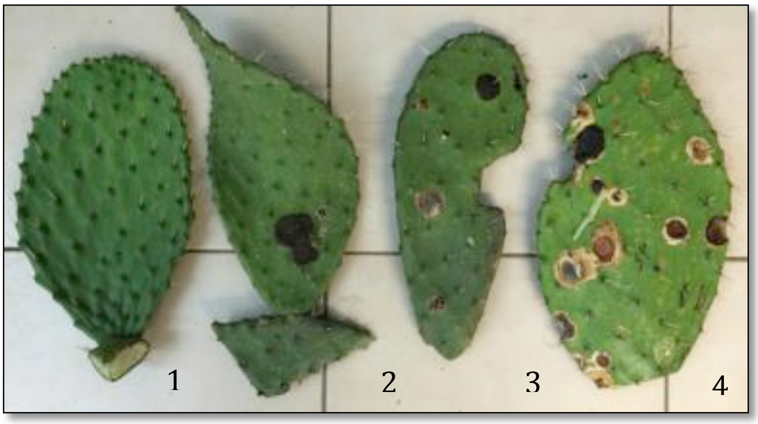

Figura 9: Nominal damage scale in cladodes: 1- healthy cladode, 2- initial damage, 3-4- lost cladode.

Preventive Measures

It is highly recommended to survey the cactus pear plantations after the rainy season to detect and eliminate the plants with the first disease symptoms and to mark healthy ones to be selected for new plantations (Ochoa *et al.*, 2015). Preventive pruning is also a way to allow for good ventilation (Figure 10). Systemic and contact action fungicides should be applied just before the rainy season.

Figure 10: Sanitary pruning in a cactus pear plantation in Jalisco, Mexico.

Mechanical Control

It is necessary to clean and disinfect with 1 L water with a spoon ful of commercial chlorine, all the equipment and tools after every culture labor, and to avoid going from plantations with the disease to those healthy ones.

Cactus moth (Cactoblastis cactorum)

Cactus moth is an insect plague that must be controlled in anticipation of damage to the plant structure (Ochoa *et al.,* 2005). It can kill cladodes and young cactus pear plantations. The main characteristics to consider in the measures of control are: a) cactus moth has a long embryonal period reaching 45 days in the first generation and is completed in approximately three weeks in the third and last summer generation, b) the larvae, after emerged from egg, penetrate the cladode for only one orifice during the first 24-36 hrs, c) the larvae develop inside the cladode; they go out only to defecate or at the end of the larval period to climb down the plant to pupate in the soil, protected by detritus, lumps of soil or fallen cladodes, d) the communication between adults is realized across a sexual pheromone issued by the female.

Some procedures toward its prevention and suppression have been developed, based on the bioecology and behavior of this plague.

Cultural Labors

Elimination of damaged cladodes is an important task, to generate a stronger structure of the plant. This operation must be done before the end of winter and after the detection of any new attacks. It is highly recommended to eliminate the ovipositions (eggstick) (Figure 11). They are easy to recognize and eliminate manually or with a brush of branches. During the first generation, the ovipostures must be eliminated surveying the plantation 2-3 times every 15 days in spring and every 10 days in autumn. In the last generation at the end of summer. Removing the eggsticks is a highly effective practice in small and medium size plantations. The start of flights can be detected with traps baited with pheromones of *C. cactorum.*

Figure 11: Eggstick of cactus moth.

Chemical Control

There are not any insecticides registered for the protection against cactus moth. In order to develop one, there have been different insecticides evaluated One had a very good level of efficiency, with the following dose and moments of application; 100 g/hl SEVIN 85% WP (Carbaril), 30 cc/hl Tracer 48% SC (Spinosad), and 10 cc/hl DECIS 10% EC (Deltametrina)(Figure 11). This may be used to control the arrival of new larvae and those that entered the cladode at least ten days after birth (Lobos et al., 2000, 2007). It is fundamental to add a surfactant to the insecticide to improve the wetting of the waxen surface of the cladode, this will also optimize the quantity of product deposited on the plant. Siliconed or alcohol-based products can also be added to improve the sparying efficiencies of insecticides. This technique is suitable for large areas and plants in compact areas with difficult access for manual control. Two or three sprays are needed to prevent and control larvae every generation.

Etologic Control

The pheromone of the cactus moth is 54% of (Z, E)-9,12 tetradecadie-1-ol acetate, 42% of (Z, E)-9,12 tetradecadien-1-ol and 4% (Z, E)-9,12 tetradecen-1-ol acetate. It is only available for experimental purposes or official monitoring in North America (Figura 12).
From a practical point of view, the pheromones can be used to determine the adult flights in different generations. This can help decide when to initiate the elimination of ovipostures and the application of insecticides (Ochoa *et al.*, 2015). Preliminary tests allow informed decisions of whento carry out an effective control of the plague by interfering the mating with massivel adult trapping. With the distribution of 20-pheromone traps/ha, the number of damaged cladodes significantly diminished in a plantation located in Pampa Muyoj (Santiago del Estero, Argentina). Currently this control technology is being studied to select the most efficient trap as well as the suitable number of traps for the best performance.

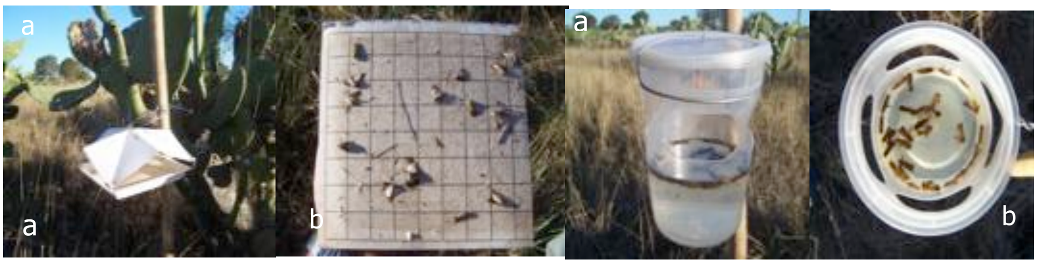

Figure 12: Tramps with pheromone for ethologic control. a) Outside view, b) inside view with trapped cactus moth adult males.

Biological Control

Normally parasitism or depredation is not enough to avoid the damage by plagues, and there are not known experiences on the utilization of biological control.

Himenopteran parasitoids have been found in ovipostures and on larvae-pupae as well. Tachinidae dipteran was found emerging from pupae. Some ants were observed predating ovispotures (Ochoa *et al.,* 2015).Biological control could be suitable forcases of difficult access and plants for disposal of spawning (eggsticks).

Conclusions

Countries growing *Opuntia* species with presence of pests and diseases should alert to plant sanitary institutions for regulations of adequate management (Ochoa *et al.*, 2015). If importing cactus material It is necessary to ask places free of pests and diseases, or use plants micropropagated to get plant material free of biotic factors.

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Management of postharvest disorders and diseases of cactus pears

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Introduction

Cactus pear fruit are very perishable, susceptible to physical and mechanical stress as well as to microbiological spoilage due to various pathogens. For many fruit species, postharvest losses can vary greatly according to producing areas, cultural practices and available postharvest facilities, Cactus pears susceptibility to mechanical damages, bruises and microbiological spoilage may be considerably higher than other species in frequency and intensity, due to their high succulence and presence of glochids..

Preharvest conditions and the degree of maturity at harvest significantly affect fruit quality after harvest. Much care must be paid at harvesting operations to reduce bruises and wounds, which can significantly increase susceptibility to microbiological spoilage. The potential postharvest span life of cactus pears is markedly affected by fruit respiration; the higher its activity, the shorter the postharvest lifeNevertheless, factors other than respiration, both biotic and abiotic, may markedly anticipate the end of the postharvest life. In this chapter the main biotic and abiotic factors, which may bring to an end or reduce the commercial life span of cactus pears will be briefly described, along with the more common postharvest handling practices and treatments.

Abiotic factors

Glochids and spines cause frequent damages in the form of pitting (Cantwell, 1995). The punctured tissues die and dry up forming characteristic punctate staining (Figure 13, left). When the density of punctures is high, individual stains tend to coalesce into large and irregular spots (Figure 13, right). Superficial damages turn to a reddish-brown color, while deeper wounds evolve in brown-black pits surrounded by a rusted aloe. Fruit susceptibility increases with maturity and most of damages are inflicted during harvest, transport and handling in the packing-house.

Superficial damages only alter fruit appearance, while deeper wounds can markedly increase fruit susceptibility to wound-pathogens, like *Penicillium* spp., especially in fruit harvested in wet conditions. Weight loss and susceptibility to chilling injury may increase dramatically in severely affected fruit during storage.

Figure 13 Tiny pitting due to glochids (left) can increase in size during storage (right) because of the high transpiration occurring in pitted areas, especially when the environmental humidity is quite low.

Mature fruit are also susceptible to bruises (Cantwell, 2004), which generally involve the parenchymatous cells underneath the cuticle and epidermis. Injured areas appear depressed as a consequence of the citoplasmatic material release from the broken cells in the intercellular space, but the fruit surface shows no damage.

Parenchymatous tissue breakdown (Figure 14 left) is another physiological disorder consisting in suberification of the parenchymatoues tissue underneath the glochids and occurs in fruit at advanced stage of maturity in the field as well as during storage.

Figure 14: Parenchymatous tissue breakdown (left) occurs in over-ripe fruit where tissue underneath collapses giving rise to depressed areas on fruit surface. Wilting and shriveling (right) appear on the fruit surface as a consequence of excessive water loss.

Wilting and shriveling are consequences of excessive water loss. Transpiration in cactus pears does not occur evenly throughout the fruit surface; tissues surrounding the stem end, and the stem scar loses water at higher rates than other part of the fruit (D'Aquino et al., 2012). This causes wilting and shriveling of the fruit starting from the ends. When shriveling of the peel is severe, affected tissues turn to a brownish-black deep color and market quality is noticeably reduced (Figure 15, right), although the eating traits may not be affected.

Water imbalance or marked fluctuations in soil moisture and temperature can cause fruit splitting (Figure 15, left). This disorder is more likely to occur in the fruit of the second crop, when the first autumn rains may cause strong hydrostatic pressure from inside the fruit that are not sustainable by the outer external tissues of the peel that eventually break. When splitting is severe and visible, fruit are left in the field or discarded in the packing house. When the hydrostatic pressure is not strong enough micro-cracks may form on the peel, which can cause splitting when fruit are moved to a cold temperature and high humidity (Figure 15, right). The split areas can become infection sites for conidia of wound-pathogens. Conditioning the fruit at room temperature before storage may reduce this disorder.

Figure 15: Water imbalance leading to high hydrostatic pressure can cause fruit splitting both in the field (left) and during storage (right).

Chilling injury, which occurs when fruit are stored at temperatures below 10-12 ° C for extended periods, is the most important physiological disorder of cactus pear (Inglese *et al*., 2002). Indeed, chilling injury is a generic term, which includes all physiological unbalances of various metabolic pathways caused by exposure to low temperatures. These alterations may involve membrane permeability and lead to increased ion leakage, a decrease in the scavenging cells' activity of free radicals. It can also stimulate the synthesis of toxic metabolites or undesirable volatiles (acetaldehyde, ethanol) that can alter specific metabolic pathways or fruit nutrition and taste properties. Visible symptoms of chilling injury that affect fruit appearance develop in the form of a scalded area (Figure 16, left), black pits and sunken brown-black spots on the peel (Figure 16, right). Most of these visible symptoms are thaught to be induced by excessive localized transpiration rates that initially cause cells dehydration andeventually lead to their death rather than a result of metabolic imbalances.

Postharvest treatments that reduce transpiration rate or make the transpiration process more even on fruit surface may reduce the severity of chilling injury and make the fruit more tolerant to low storage temperatures (D'Aquino *et al*., 2014; Piga *et al*., 1997; Schirra *et al*., 1996, 1997, 2002). The following postharvest practices have been identified to reduce transpiration rates:

- storage at high relative humidity,
- film wrapping,
- hot water dips,
- high temperature conditioning)
- intermittent warming (lets the tissue metabolize to get rid of toxic compounds)

Figure 16: Chilling injury as brownish depressed spots of epidermal cells (left) or wilted-blackish leathery and depressed pits or stains, worsened by severe weight loss (right).

Microbiological spoilage

The succulence of cactus pears tissues together with the relatively high juice pH, make the fruit susceptible to a large number of pathogens, including fungi, bacteria and yeasts (Inglese *et al.*, 2002).
There are several factors that markedly affect fruit predisposition to postharvest decay: the type of crop (first crop or scozzolati), weather conditions at harvest time, the care put in picking, transport and handling, as well the procedures followed in the packing house to prepare the fruit for fresh market or for storage. The practice of picking the fruit in the morning when dew is present on the peel and humidity in the air is high, favors micro-wounds and mechanical damages which are conducive to wound-pathogens' infections (Figure 17, left). While picking fruit in the mornding with dew can be conducive to wound pathogen infections, it can prevent the release of glochids, which present a serious hazard for the pickers.
The stem end or the little piece of cladode left at harvest are sites of infections by fungi and yeast that gradually invade peel tissues and the flesh causing soft rot (Fig. 17, right). Decay incidence incited by different species of *Penicillium* is markedly reduced by accurate care paid to prevent any mechanical damage to the fruit.

Figure 17: Soft-rot incidence induced by wound-pathogens like Penicillium spp. (left) or infections inflicted by other microorganisms (right) can be significantly reduced by minimizing mechanical damages during harvesting and packinghouse operations.

Dry rot in the form of black necrotic spots develop as pitted areas that eventually overlap to form deep-black, and sometime depressed blemishes that can be extended necrotic and leathery. These blemished patches generally affect the first layers of peel cells (Figure 18, right). This alteration is likely incited by latent infections of *Alternari*spp. . The infection starts from the glochids (Fig. 18, left), from the calix scar, or by conidia present on fruit surface that initiate the infection from injured sites during storage. The disease, which grows slowly in cold stored fruit, can be confused with physiological disorders induced by low temperatures. Susceptibility to chilling injury can be increased in diseased tissues. Despite the downgrade of commercial value, when symptoms are slight or moderate the eating quality is not affected.

Figure 18: Dry rot caused by Alternaria spp. usually starts from the glochids (left) as necrotic black depressed pits that gradually coalesceand increase in size during storage (right).

Postharvest losses can increase dramatically if attacks by medfly (*Ceratitis capitata* Wideman) (Figure 19 left) are not adequately controlled. When ovipositon precedesa few days harvest, fruit apparently are sound, but the eggs will hatch within a few days and larvae may develop during storage or distribution (Figure 19, right). Even in cases when larvae do not survive low temperature storage, the ovipositon wounds will increase pathogen infections.

Figure 19: Fruit damaged by medfly infestation in the field (left). When medfly oviposition precedes a few days harvest, fruit apparently are sound, but larvae continue to grow even when fruit are cold stored and eventually fruit decay (right).

Postharvest handling

Procedures and the duration of use of packing houses often vary by size and the location. In Sicily the harvesting season covers a 4-month period, starting with the first crop (agostani) in August and ending with the second crop (scozzolati) in November (Inglese *et al.*, 2002). Fruit are generally transported to the packing houses in plastic boxes containing 15-20 kg of fruit.

In large packinghouses, processing lines are those used for citrus fruit adapted to handle cactus pears (Figure 20, right). In small-scale packing houses built within farm buildings, it is popular for a few growers to combine their harvest.. The simplest packing line design consists of a sloped ramp onto which fruit are dry-dumped, followed by moving conveyor belts along which workers do a pre-selection. Fruit then pass through a series of brushes to remove the glochids and increase peel shinnyness. They are then conveyed to a rotating sorting table (Figure 20, left) where workers sort and grade before packing the fruit in retail units or in plastic crates placed inside plastic or carton trays. Fruit are generally not washed or treated with sanitizing agents or fungicides and are destined to direct consumption. Refrigeration is only limited to transportation or to brief periods between processing and shipping. Under these conditions the development of physiological disorders or rot is rare and of little practical relevance.

Figure 20: Sorting table at the end of a small and simple packing line (left). Processing lines used for citrus fruit are adapted to also process cactus pears, this occurs frequently in large packinghouses (right).

However, the growing market demands for fresh product and the need to extend the marketing period well beyond that of harvest time requires cold storage. Export of fruit in countries where medfly is not present involves cold quarantine treatments.

To prolong the postharvest life of 1-2 months fruit need to be stored at 6-8 °C with a relative humidity of 95 %. To achieve cold quarantine requirements fruit must be held at 0-2° C for 2-3 weeks.Some pre-storage treatments, although still rarely applied at commercial scale, have proven to increase fruit tolerance to chilling injury while reducing microbiological spoilage and decay.

High temperature conditioning consisting in exposing the fruit for 12-48 h at 33-36 °C and 80-95 % RH ameliorates storability by lowering fruit susceptibility to low temperatures. The reduced physiological disorders induced by chilling temperatures maintain cellular integrity and as a result, also make the tissue more resistant to pathogen attacks (D'Aquino *et al.*, 2014; Schirra *et al.*, 1997). Moreover, the melting effect of high temperatures on epicuticular waxes reduces cuticular cracks and consequently overall transpiration rates and weight losses.

Hot water dips for 2-3 min. at 48-50 °C (Schirra *et al*., 1996; 1999) can directly reduce decay incidence by partially killing conidia of pathogens on fruit surface and increasing endurance to chilling temperatures by rearranging wax structure. Although the partial removal of waxes can lead to higher weight losses.

Hot water brushing, consisting of spraying water heated at 60-70 °C for 10-30 seconds while brushing for glochids removal along the processing line, can also lessen physiological disorders caused by prolonged exposure to chilling temperatures and lower losses for decay (Dimitris *et al*., 2005). This treatment could be easily integrated in most existing processing lines andwould prevent any waste of time as compared to high temperature conditioning and hot water dip treatments

A relative humidity of 90-95 % is highly recommended during storage to minimize weight losses, preserve visual appearance and decrease injuries from chilling. Damages from chilling may be more severe when low temperatures are associated with dry conditions. High humidity is recommended despite the fact that it can stimulate the growth of pathogens.

Figure 21: Cactus pears in nest trays (left) or plastic lidded punnets (right) inside corrugated board carton ready to market.

Dry dumping and harvesting are often the source of fruit damages. Much care should be paid when unloading fruit in the processing line. Dry dumping, which is the most popular, can induce mechanical damages, such as bruises and micro-wounds in the peel. Such damages can often easily heal if left at room temperature before being delivered to the fresh market. .In contrast, in fruit cold stored for a long time with lesions do not heal so easily and may be the avenue of entry for decay-causing pathogens.Wounds at the stem ends inflicted by the harvesting operations can favor infections and contribute significantly to rot incidence, especially if fruit are not properly cured before storage.

Many preventative measures can be taken to reduce dumping and harvesting damages. To reduce the risk of decay the edges and rails of the line should be padded. Canvas curtains should be mounted along the line to reduce fruit speed or to break the fall when fruit drops to a lower plane. When long-term cold storage periods are planned, wet dumping, together with a sanitizing treatment with sodium hypochlorite and a wide spectrum registered fungicide, may be preferred to dry dumping. If the packing line is provided with a large tank, an immersion of the fruit in hot water at 48-50 °C alone or in combination with sanitizing agents, may improve the treatments' fungicidal effectiveness and tissue tolerance to chilling injury. The following sanitizing agents are recommended; sodium bicarbonate (1-3%) and/or 500-1000 mg/L of thiabendazole, imazalil or other fungicides (D'Aquino *et al*., 2012; 2015). Combining sanitizers or fungicides with hot water brushing may further reduce fruit susceptibility to chilling injury and microbiological spoilage.

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Good agricultural practices for fine cochineal production

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Introduction

Good agricultural practices (GAP) are a compilation of principles to be applied in any farm during its production and post-production processes. The goal is to achieve safe and healthy food and non-food agricultural products with sustainability; taking in consideration the economical, social and other important factors. GAP is part of and contributes to SARD (Sustainable Agriculture and Rural Development), which also supportseconomic, environmental, and social elements. Since GAP are becoming an increasingly important issue for many developing countries (Poisot and Casey, 2004), its philosophy is applicable in many cactus pear plantations. GAPs are mose applicable in areas that are regularly dry and the crop is an option to produce forage, fruit, nopalitos, or even cochineal insect for carmine pigment. However to accomplish this task, it is necessary to meet some inherent points that sometimes are not clear to understand, which include; good handling practices, good manufacturing practices, quality control standards and others.

In order to facilitate the acceptance of GAP, it is necessary to have some incentives for farmers. One of the main incentrives is economic (Hobbs, 2003), which helps to avoid the exclusion of small farmers in developing countries. The strategies must provide ample education and training to over-come human capital constraints and increase the development of necessary infrastructure to support GAP in such environments. The aim of this paper is to highlight the importance of GAP for carmine cochineal production.

Carmine cochineals

Carmine cochineals are parasitic insects thriving on *Opuntia* cactus pear plants, belonging to the monogeneric familiy Dactylopiidae (order Hemiptera), genus *Dactylopius* with eleven species. They are indigenous to America with a distribution from the southern United States to northern Argentina. The following insects are considered carmine cochineals: *D. austrinus* De Lotto, *D. confertus* De Lotto, *D. zimmermanni* De Lotto, *D. salmianus* De Lotto, and *D. ceylonicus* Green are native to South America; meanwhile *D. bassi* (Targioni Tozzetti), *D. coccus* Costa, *D. confusus* (Cockerell), *D. gracilipilus* Van Dam and May, *D. opuntiae* (Cockerell), and *D. tomentosus* Lamarck which are all from North America (Vigueras and Portillo, 2014). This group of insects are of particular interest, mainly for two important uses. Firstly, they present carminic acid in their bodies, which is used worldwide as a pigment due to its high quality colorings properties for food, drugs, cosmetics and other applications. *Dactylopius coccus* Costa (cultivated or fine cochineal) (Figure 22a) is the commercially species reared to produce the pigment. Secondly, cochineals may be used as a biological control agent against invasive cactus (Table 2). Sometimes a particular biotype of cochineal has its own host species (Githure *et al.*, 1999). Vigueras and

Portillo (2014) described more than 70 *Opuntia* species as host of *Dactylopius* species, which indicates the great potential of this insect group to be used for biological purposes.

Table 2. Cochineal species (*Dactylopius* spp.) used to control invasive *Opuntia* species in the world.

***Dactylopius* species**	***Opuntia* species**	**Place and year**	**Reference**
D. austrinus De Lotto	*O. aurantiaca* Guilles *ex* Lindley	Australia 1970 South Africa 1979	Moran and Cabby, 1979
D. ceylonicus (Green)	*O. vulgaris* Miller	Sri Lanka 1863	Volchansky *et al.*, 1999
D. opuntiae (Cockerell)	*O. ficus-indica* (L.) Mill.	Sudáfrica 1938	Moran and Zimmermann, 1984
D. opuntiae (Cockerell)	*O. stricta* Haworth	Australia 1921	Hoffmann *et al.*, 2002
D. opuntiae (Cockerell)	*O. ficus-indica*	Brasil 2001*	Batista *et al.*, 2009

*In Brazil, wild cochineal *D. opuntiae* was not introduced for biological control, but now is a destructive pest in cactus pear plantations.

Fine cochineal and good agricultural practices

According to the GAP statements, for fine cochineal production, there are some points that must be taken into account during all plant production processes, from the plantation of host plants to insect post-harvest handling:

1. To establish a cactus pear plantation for fine cochineal rearing, cladodes must be selected from healthy plants (without presence of diseases and plagues), disinfected with a chlorine solution (50% of commercial bleach plus 1 mL of liquid detergent) and rinsed three times to avoid possible damage for subsequently oxidation. If the material must be introduced from abroad, it is highly suggested to do it from certifiied plantations, or preferibly by tissue culture allowing an aseptic delivery of micropropagated plant material. This latter technique is now available practically in all developing countries from governmental sanitary institutions or universities. The protocols for vitro plants establishment in *ex vitro* conditions are simple, cheap and available from a lot of web sites or through request to diverse authors of the theme. BIOMTCO is one tissue culture laboratory of Michael Technology (www.mtco.org) based in Fresco, California; this charitable organization offers the necessary information as well *in situ* training activities for all those interested on this subject.

2. Plantation care need to be observed carefully, contrary to the common concepts that *Opuntia* species grow without any care. Prevision is the better option, since further problems can be eliminated or diminished. Continuous visits to check for any biotic factor, will allow controlling it easily, since the presence of localized plagues or diseases can be sometimes be punctually eliminated without posterior necessity of chemical products.

All organic manure to be added to the plantation must be composted. Raw organic material may introduce some biotic factors that could develop further sanitary issues. The application of biofertilizers, which are microbial inoculants, is preferred to organic fertilizers like manure.

In order to have superior quality plant material, the isolation of the plantation must be observed all the time. The presence of animals, such pets or cows, horses etc., should be limited to the minimum possible, since their excretions are a source of microorganisms. These microorganisms can contaminate the host plants. as has been showed for *Salmonella* (Hernández-Anguiano, 2014). To obtain superior quality plant material it is important to have a system to reduce the risks of contamination, which must be observed for all involved people (owner, manager, workers, suppliers, clients, and any visitor).

3. The fine cochineal production process (insect rearing, harvest, and postharvest) is recommended inside greenhouses (Figure 22c), however coccidoculture (cochineal rearing) can be done in the open (Figure 22d), particularly in those areas where the insect does not represent a real threat of infestation for cactus pear plantations devoted to other purposes.

4. Harvest and postharvest (dried, selection and qualification of fine cochineal) are activities to be performed with clean utensils, inside a dry and isolated room to avoid wind streams. To keep the insect until its use or sale, it's necessary to maintain it dried, away from dust, humidity, animals, and in closed containers.

The recommendation is to start any agricultural activity with a solid base, and GAP offer by simple using of common sense, a concrete guidance to be applied in any protocol. The former points have to meet the emerging challenge to make agricultural systems more sustainable in a world where food supply chains are increasingly globalized and complex, and pressure on farmers livelihoods is high (FAO, 2014).

Wild cochineal

Wild cochineal (*D. opuntiae* (Cockerell)) is the most used species for biological control, due to its aggressive behavior against many *Opuntia* species. It is most known, particularly to its common host *O. ficus-indica*, which is the most cultivated cactus worldwide. Its waxy coating (Figure 22b) prevents effectiveness of contact insecticides, causing it to be the most insidious pest in cactus pear plantations. There is not a specific insecticide for this pest, which is belived to increases the indiscriminate use of insecticides such as Malathion, Parathion and others pesticides that are highly toxic. This is problematic because it also eliminates the natural enemies of this pest as well other beneficial insects.

The different wild cochineal developmental stages cause severe damage to the cactus pear. The most common symptoms are;as chlorosis (yellowing), dehydration, and weakening of the plant (Figure 22e).In a short time (six to ten months) the plants may die (Figure 22f). This insect is of gregarious habits, and is located around the thorns in small colonies (Figure 22e); when the temperature rises in spring, the population increases considerably and its biological cycle time is reduced. Once wild cochineal is settled on the cactus pear plantations, it is very difficult to eradicate it. During the winter the insect is protected in the root area and stem bark of the plant, where it will emerge again to the surface the next spring.

Wild cochineal has a wide dispersal capacity, which makes it a plague of imminent danger to countries where cactus pear represents an important resource. Its control protocols are still under development; there are few papers dealing with this subject (Vigueras *et al.*, 2009; Palacios-Mendoza *et* al., 2004). Biotic factors must be taken into account in cactus pear plantations, since they impact directly the production system (Ochoa *et al.*, 2015), and attending GAP may help to reduce and thus control sanitary problems as wild cochineal.

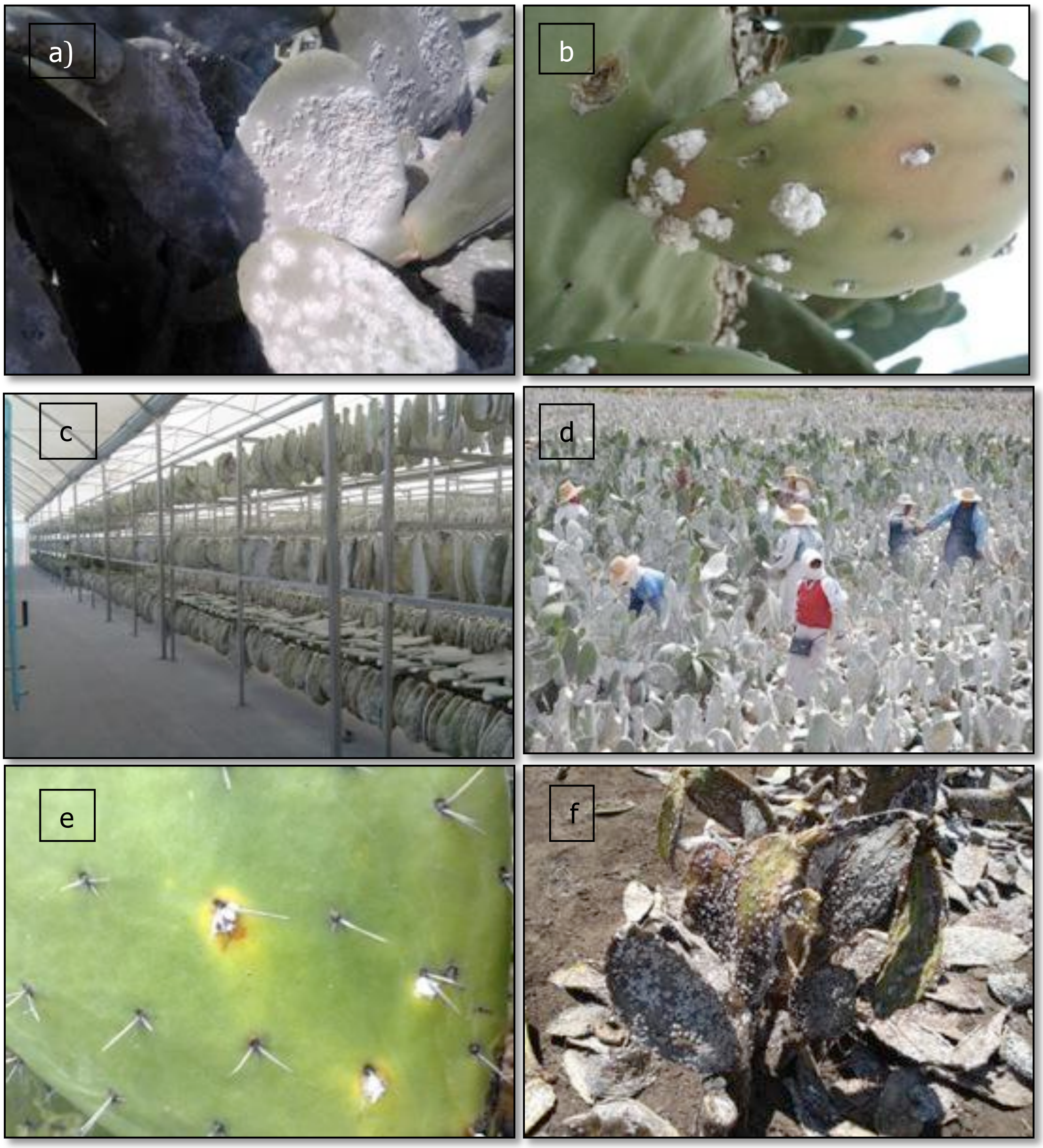

Figure 22: Carmine cochineals. a) *Dactylopius coccus* Costa (fine cochineal), b) *D. opuntiae* (Cockerell) (wild cochineal), c) *D. coccus* production in greenhouse, d) *D. coccus* production in field, e) and f) Chlorosis in cactus pear cladodes and cactus pear destroyed by wild cochineal, respectively.

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Good agricultural practices for forage

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Introduction

The spineless cactus (*Opuntia* and *Nopalea*) are native from Mexico, these plants have the crassulacean acid metabolism (CAM), with efficient use of water. The spineless cactus has multiples uses in agriculture, and is mainly utilized as a forage in the semiarid region of Brazil.

Opuntia and *Nopalea* are the main feed source for thedairy farms. They play an important role in ruminant feeding in this region, mostly in the dry season, when forage availability from others sources are reduced drastically.

The high moisture content present in the spineless cactus (90% on average) helps meet the water demands of animals. For several decades farmers from semiarid region of Brazil, had cultivated spineless cactus without appropriate agronomic practices, and as a result had low dry matter (DM) productivity rates. Currently, a set of technological practices that allowhigher production of DM per area for spineless cactus are available. To cultivate more dry matter it is important to; use the properplant density per area (spacing), maintenane low weeds, use chemical and organic fertilization, and use high productive cultivars with resistance to certain pests and diseases, Some factors may limit their cultivation, such as: high nocturnal temperatures (above 25 °C), too shallow or saturated soils, and the presence of pests, such as cochineal carmine [*Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopiidae)]. Management practices in Brazil have advanced the cultivation of *O. ficus indica* as a forage and further information on improve practices is provided in this section.

Key factors for cultivation and productivity of the spineless cactus

Climate

Despite the fact that spineless cactus is considered to be well adapted to semiarid conditions, to express their agronomic potential, these plants needs altitudes above 600 meters from sea level, an average annual rainfall between 400 and 800 mm, relative humidity above 40% (Viana, 1969), and average temperatures for the day and night of 25-15 °C, respectively (Nobel, 1995). This is important becauselow relative humidity and high temperatures at night, found in some regions of the semiarid from Brazil, often justify some lower yields or even death of some cultivars. Under these conditions, irrigation has shown a high potential for being used, in order to repair water losses from transpiration (Lima *et al.*, 2013 a, b).

Soil and Fertilization

The spineless cactus has low demands related to the physical and chemical characteristics of the soil. It is most fertile in areas with sandy or clays soils that are well drained.

In relation to the soil fertility, the spineless cactus has responded well to mineral and organic fertilization. Organic fertilization can be used from many sources, such as, manure from cattle, sheep and goats. Commonly organic fertilization is applied in the minimum quantities of 10 t/ha at the time of planting, this application is repeated every two years near the beginning of the rainy season. However, positive responses have been already dated under organic fertilization up to 80 t/ha. However, the use of high amounts of organic fertilizer can to create a favorable environment for the development of pathogens that cause rot in the planted cladodes.

It is best to do a soil analysis for mineral fertilization, for a better guidance of the recommended nutrient levels. Increments in the dry matter production have been related to nitrogen inputs up to 600 kg/ha. These significant responses of the spineless cactus to fertilization are due to their ability to extract soil nutrients well (Table 3) (Santos *et al*., 1990). It is noteworthy that the best production results have been observed when combining the organic and mineral fertilizers.

Table 3. Nutrient uptake by *Opuntia ficus-indica* Mill cv. Gigante in the semiarid conditions of the Agreste region of Pernambuco state, Brazil

Yield (ton DM/ha/year)	Nutrient uptake (kg/ha)			
	N	P	K	Ca
10	90	16	258	235

According to spineless cactus contents (N, P, K and Ca) of 0.9%; 0.16%; 2.58% and 2.35%, respectively (Santos et al., 1990).

Cultivars

Since spineless cactus was first cultivated in Brazil, *Opuntia ficus indica* (cv. Gigante, Redonda, Clone IPA-20) and *Nopalea cochenillifera* (cv. Miúda or Doce) aremainly used. Dry Matter production per area, *N. cochenillifera* presents DM content of 40-50% higher than *O. ficus indica* cultivars, which presents a higher productivity of fresh biomass. An advantage of *N. cochenillifera* lies in the higher concentration of soluble carbohydrates than *Opuntia*.As a result, *N. cochenillifera* has better dry matter digestibility rates. It also has resistance to the cochineal carmine (*D. opuntiae*).

Several works carried out by the IPA/UFRPE partnership, have indicated resistant cultivars to cochineal: *N. cochenillifera* cv. (IPA-200021/F_{21}, IPA-10004/Miúda, IPA-200205//IPA Sertânia, IPA-200206//Orelha de Onça), *Opuntia robusta* cv. (IPA-200013/F_{13}, IPA-200015/F_{15}); *Opuntia instricta* Haw. cv. (IPA-200016/Orelha de elefante Mexicana); *Opuntia undulata* Griffiths. cv. (IPA-200174//Orelha de elefante Africana); *Opuntia atropes* Rose. cv. (IPA-200008/F_8, IPA-200024/F_{24}); and Algerian (*Opuntia* sp.).

Planting methods

Planting is usually done by the vegetative method (using the cladode pads as "seedlings"). Planting is normally in the last two months of the dry period, to reduce the risks of damage by attack of fungi and bacteria in the wounds that are created during the harvesting of the cladodes. It is important to carefully select the cladodes that will be used as seedlings. Ideally, the cladodes should have six months to two years of growth, and free of pests and diseases.

At planting, the cladodes position can be tilted or vertical within the pit (Mafra *et al.,* 1974). Costa *et al*. (1973) reparted that is is best to keep cladodes in the shade for aproximatley 10-15 days after cuttint to allow the wounds to dry before planting. . Treating the cladodes "pads" with copper-based fungicide, can be another way to avoid fungiafter planting. It is essential that the wounded side where the pad was cut is completely buried. The soil must cover until the middle of the cladode, approximately half of its length approximately half of its length according to the ground contours.

Regarding the number of planted cladodes, Mafra et al. (1974) reported that whentwo cladodes/pit were planted, an increase of 18% in the yieldwas observed. However, this duplicates the costs of the cladode pads for planting. To obtain a better soil conservation, another important practice is to plant the cladodes in the transversal direction of water runoff to avoide erosion.

The spacing between cladodes should be defined according to many factors, such as; the cultivar of spineless cactus selected, the costs of the cladodes "pads", future management practices (fertilization, weed control, harvesting), fertilization costs, and the production system adopted in the farm, among others.

Until the final third of the last century, farmersused densities of planting for the spineless cactus of 2 x 1m and 1 x 1 m, resulting in densities of 5,000 to 10,000 plants/ha. Santos *et al.* (2008) conducted experiments with high-density planting for *O. ficus indica* cv. IPA-20, in two locations of the semiarid region of Northeast-Brazil (Caruaru-PE and Arcoverde-PE), and linear increments for dry matter production were reported up to densities of 40,000-50,000 plants/ha. Planting densities above this range can cause problems, although dry matter productivity may increase at decreasing rates. High plant densitis can create problems in implementing most management practices. High densities also increase the costs of planting (seedlings acquisition), fertilization and the labor force necessary.

Management practices

Spineless cactus plantations respond well to weed control by mowing and hoeing. For high-density plantings, it is recommended to do at least three mowings in a year. In plantations with low-density plantings, usually one mowing at the end of the rainy season is enough for effective weed control. In high-density plantings, better control and efficiency are observed with the use of herbicides of pre and post-emergence when compared with mowing in the summerwithout control.

Due to the high costs of management practices and harvesting(mainly because they are done by manual work) it is recommended to choose low-densities of planting between the rows in the spineless cactus plantation. The spacing given must be enough to allow for the use of mechanization and animal traction through of the rows.

In general, harvesting every two years has provided increments in productivity and longevity of the spineless cactus plantations compared to annual harvestings (Farias *et al*., 2005). However, there are interactions among the harvesting frequency, cutting intensity and spacing. Inglese (1995) stated that, in high-density plantations (over 40,000 plants/ha), the annual harvesting is recommended, seeking to reduce self-shading, and infestations with cochineal carmine. Under these conditions of high-density planting, fertilizations are obligatory. In relation to the interaction between frequency of harvesting vs. the cutting intensity, it is known that, with increases in the frequency of harvestings, it is recommended preserve more cladodes on the plants that were cut, to allow a safe regrowth.

The spineless cactus has little losses in the nutritional value after harvesting compared to others forage plants.. If stored under shade, it can be kept for up to 16 days without significant losses in the chemical composition (Santos, 1989), without alterations on the dry matter intake, and milk production "in natura" 4% fat-corrected (Santos *et al.*, 1990). Changes in harvesting time also doe not effect the nutritional value. This allows for pads to be kept in the field, and reducted storage and production costs.

Figure 23: a-Soil preparation and planting b-2 month old c-four month old d- one year old harvest. Laguna Yema, Formosa, province, Argentina.

Finals considerations

Despite being extremely adapted to the semiarid conditions, it is important for farmer to know that spinelss cactus has some specific requirements in relation to soil and climate. When these conditions are met they can express all their productive potential.

There is no doubt about the potential of the spineless cactus as an excellent option for productions systems of ruminants in semiarid of Brazil, in both large and small farms. Until now, there are not any grasses or legumes that have adapted to the semiarid conditions, with higher productivity of dry matter than the spineless cactus.

The "good agricultural practices" in the spineless cactus plantations, are constituted by a main set of techniques, such as: use of cultivars adapted to the soil and climate conditions of each semiarid region(cultivars that combine high productivity and resistance to pests and diseases); choosing healthy cladodes "pads" for further plantings; correction and fertilization of soils; weed control; and proper management in harvesting (frequency x intensity) and in the post-harvesting.

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