

CACTUS PEAR (*Opuntia ficus-indica* L. Mill.) INTENSIVE PRODUCTION IN ITALY: AN OVERVIEW

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Abstract

Modern specialized plantations of cactus pear (*Opuntia ficus-indica* Mill.) in Sicily are located in three main areas characterized by different environmental conditions. In Santa Margherita area about 300 ha are cultivated on Lithosols and Mediterranean Red soils; in San Cono area about 1,300 ha are cultivated on Euthrich Fluvisols and Chromic and/or Pellic Luvisols on sandy or conglomerate soils; in the area surrounding the Etna Volcano about 400 ha are located on Volcanic soils. The climate is typical Mediterranean with the dry season occurring from May to September. Three main cultivars are grown, differentiated by the peel color at harvest: Bianca (2%), Rossa (8%) and Gialla (90%). The latter has the best reflowering habit and fruits are well suited to be manipulated. Nevertheless, the genetic background of the cactus pear industry has never been investigated and it is quite possible that different clones are present among the three populations. The whole industry in Sicily is based on "scozzolatura" in order to get late ripening and high-quality fruits. The plants are usually spaced in rows 5-7 m apart and 4-5 m within the row. The plants are trained either as a globe (San Cono) or vase (Santa Margherita). The main pest is the Mediterranean fruit fly which affects fruit during ripening. The main disease is the scabies caused by bacteria and yeasts.

Geographical Distribution

In Italy, cactus pear is naturalized in the southern regions and in the islands, while cultivation, even if without economic purposes, reaches northern regions, such as Liguria. Modern specialized cactus pear plantations (*Opuntia ficus-indica* L. Miller) grow mostly in Sicily. Ninety percent of the whole industry is on this island. In some other Italian southern regions, cactus pear grows in private gardens or is used as a hedge between the fields or the orchards. According to Basile (1990), Sicily has 2,500 hectares of specialized plantations and 25,000 hectares of secondary ones. San Cono (CT) is the most important area (1,250 ha), followed by the Etna area, where 400 ha of cactus pear are widespread on the foothills of the volcano, and, finally, Santa Margherita Belice (AG) with 280 ha of specialized plantations (Table 1). The latter area is where modern specialized plantations first appeared during the fifties. Regional fruit production amounts to 48,000 T, based on 1987-1990 average production (Basile, 1990).

Table 1. Main Sicilian Productive Areas and Yield

	Area (ha)		Yield (t)	
	1988	1976	1988	2000
Colline di S. Cono	1250	9000	18000	36000
Sudovest etneo	400	17000	16000	15000
Valle del Belice	350	2000	3000	4500
Others	500	12000	11000	9500
Total	2500	40000	48000	65000

Source: Basile, 1990

A brief analysis of specialized cactus pear cultivated areas enables us to verify the presence of common characteristics, such as lack of water resources, length of the dry season as defined by the Bagnouls-Gaussen ombrotermic diagram, high thermic regime during flowering, and mild fall season when fruit ripening takes place. Similar marginal social and economic framework characterize the areas where cactus pear has been taking the place of other crops, such as almonds and grapes, whose growing systems became, under the prevailing conditions, unable to ensure satisfactory incomes. The reason for cactus pear success can be found in the interaction between biological features of this species and environmental conditions, which allows an extraordinary genotype performance. As a result, we have a growing system that, by maintaining its own characteristics of specialized and intensive plantation, lives in perfect accordance with the scarce available resources, proving effectiveness from the economic and energetic point of view (Barbera et al., 1991).

Physical Setting

In Sicily, the highest altitude in which the cactus pear grows is 700-800 m. Specialized plantations are mostly located at 400-500 m. The Mediterranean climate, with short-day, damp, cold winters and long-day, very hot summers, limits the natural propagation of the species, so that cactus pear has never become a weed, as happened in Australia and South Africa. The annual rainfall in the cultivated area is about 550 mm; the annual average temperature is just above 16 °C. Comparing Italian with Mexican situations, it is clear that fruit development and ripening takes place under very different climatic conditions: in Italy at the end of a very hot and dry season, in Mexico after summer rains. As far as the soil characteristics (Fierotti, 1988) are concerned, in Sicily, cactus pear grows mostly on Andosols on the Mt. Etna foothills and in the

majority of the little islands surrounding Sicily where it plays a pioneristic role in soil formation. This is obviously the case of naturalized plantations.

In the Santa Margherita area, we find soil associations defined as Chromic Luvisols - Calcic Cambisols, and Lithosols which form the typical "Mediterranean red soils." They are very shallow soils, poor in organic matter and nutrients and with very low water-storage capacity.

In the San Cono area, soils belong to the soil associations defined as Brown soils - Leached Brown soils - Regosols and/or Lithosols; Brown soils - Vertic Brown soils - Vertisols; Regosols - Brown soils - Lighty Leached Brown soils - Alluvial soils - Vertisols; Euthrich Fluvisols and Chromic and/or Pellic Luvisols on sandy and conglomerate mother rock. They have a sandy loam texture with a neutral or subalkaline pH and a sufficient level of organic matter and nutrients.

However, no difference in fruit production has been demonstrated, either in terms of yield potential or fruit quality, as related to different pedologic and climatic conditions. Available empiric information shows that an average daily temperature less than 20 °C in June can be considered as a limiting factor for the reflowering induced by the scozzolatura. It is commonly known that in the hilly area of Sicily and in northern Italian regions cactus pear reflowering does not occur often.

Cultivar

Opuntia ficus-indica apparently has a low variability in Sicily, even if in the region five other *Opuntia* species are widespread (Mazzola et al., 1988). Nevertheless, a deeper knowledge of the Sicilian population is desirable. Definitely, in Sicily, a crude distinction is based on the color of fruit flesh and peel (Table 2). From fruit color, it is possible to distinguish three cultivars or, better, three groups (Barbera, Inglese, 1992). Another cultivar "Apirena" (seedless) should be mentioned as well as other cultivars of minor importance. In commercial plantations, we generally find different cultivars according to a constant, predominant presence of Gialla (85%-90%) which is the only one adopted in specialized, monovarietal plantations. Rossa (8%-15%) and Bianca (2%) play only a marginal role. Unfortunately, information on market preference and tendencies about fruit color is not available even though it would be of a great importance for the growers. The leading role of Gialla is due to its higher productivity and reflowering aptitude and to the good resistance of its fruits to processing (brushing to remove glochids) and transportation. Furthermore, the limited distribution of Rossa and Bianca itself becomes a limiting factor in their spread if we take into consideration the methods used in Sicily to propagate cactus pear, which need a great number of mother plants. In any case, fruits of the three cultivars can be arranged to produce an attractive multicolored display.

Gialla ripe epicarp appears as yellow-orange, shaded on the edges, while flesh is a less intense yellow. Peel thickness varies according to different environmental and growing conditions, and is higher than in Bianca but similar to Rossa. Gialla late fruits ripen a couple of days earlier than those of the other two cultivars. Rossa has a lower productivity than Gialla and its fruits are frequently damaged by cracking after October rains. Among the three cultivars Rossa is the latest to ripen; its late fruits ripen between the end of November and the beginning of December. Ripe fruits are red-violet colored, more intense in the sun-exposed parts, and sometimes green at the

fruit's edge with flesh being red-purple colored. Late fruits can be very large (250-280 g), but they are particularly spongy and the peel sticks tightly to the flesh. Barbera et al. (1991) have demonstrated its alternate bearing behavior. Bianca grows mostly in family orchards, rather than in specialized plantations. The reason is not the productivity of the plant but the very limited suitability of the fruit to be manipulated and transported. Its peel is thinner than the other two cultivars, making the fruits more sensitive to the Mediterranean fruit fly. However, Bianca fruits are highly appreciated by the local markets because of their taste and sweetness, even if sugar content is not significantly higher than in Gialla and Rossa. Ripe fruits are rose-orange colored while flesh is yellow-cream. Fruits begin to ripen earlier than in the other two cultivars. It should be emphasized that no difference occurs among the fruits of the three cultivars as far as seed number and the seed vs. flesh (number vs. g) ratios are concerned.

Finally, the Apirena, which was discovered in 1827 (Coppoler), has not been of commercial interest, although it has few seeds (60-70), because of its small fruits that do not grow even if over thinned.

Table 2. Fruit Parameters of the Sicilian Varieties

		Fruit Wt (g)	Peel (%)	Flesh (%)	Seeds (%)	Seeds/Flesh (n/g)
Gialla	1	79-100	34-43	54-61	2.2-4.3	6.9-8.1
	2	100-145	24-38	56-75	3.4-4.3	4.7-5.9
Rossa	1	77-82	33-48	51-62	4.5-4.6	7.3-8.8
	2	98-165	32-45	50-64	2.7-3.7	5.5-6.1
Bianca	1	87	33	62	4	6.2
	2	107-155	26-42	60-73	3.7-4.2	5.2-6.2
Apirena	1	48	52	48	--	--
	2	80	52-56	42-43	1.8-1.9	4.0-4.2

1 = First flush fruits 2 = Second flush fruits

Source: Different authors in Barbera and Inglese, 1992

Propagation and Planting

Technical evolution in cactus pear cultivation has not been accompanied by a rational nursery activity. Farmers have always taken cladodes from commercial orchards following pruning. Cactus pear can be easily propagated by cuttings, which could be a single cladode between six months and two or three years of age, or of multiple combined cladodes. Currently, growers use cuttings composed of a two-year-old cladode with two or three cladodes of one year growing on it. This method needs a great number of mother plants if we consider that only 8-10 cuttings can be taken from a very good, 8- to 10-year-old plant. Thus, to establish one hectare of cactus pear we need at least 28-40 mother plants. There is a strong need for propagation techniques that ensure that growers receive plants certified from a genetic and sanitary point of view. In that regard, the use of cladode fragments to produce potted plants could be of a great interest. First results obtained in Italy using cuttings of two or three areolas, or a quarter of a cladode, confirm that this method can provide one-year-old potted plants ready to be transplanted in the field (Barbera et al., 1992).

The suitable period to plant the cuttings in Sicilian environmental conditions is in May. As previously stated, commonly used cuttings are the result of a two-year-old cladode with two one-year-old cladodes growing on it. Cuttings of more than two items are more rarely used, together with those with a three-year-old basic cladode. A plantation can also be made by planting in each hole two parallel cuttings spaced 20 cm, or three or four cuttings placed in a triangle or square. This method, even if expensive because of the large number of cuttings, is still practiced because it allows an earlier development of the canopy and a higher production during the first years after planting. Plants are spaced 4-5 m within the row and 6-8 m between the rows. We are also working on dynamic rows with plants spaced 2-3 m within the row and 6-7 m between the rows. The aim is to have an early heavy crop. Every second plant along the row will probably be cut off five years after planting.

Pruning and Training Systems

The bush-type or "globe" trees, with the lower part of the canopy very close to the soil is the training system of San Cono area. It is typical of orchards realized by using more than one cutting per hole. In Santa Margherita Belice, cactus pear orchards are generally established with only one cutting per hole and the plant is trained as a vase with the main branches starting at an height of 40-60 cm from the soil. Plants trained as a globe reach a lower height (almost 2 m). This makes scozzolatura, pruning, and harvest easier. Weed control around and within the globe can be done only manually. Furthermore, many cladodes still remain shaded and the crop is mainly concentrated in the outer cladodes all around the tree. The higher number of pruning treatments required to form a vase-shaped tree induce a longer unproductive period. Pruning operations start the first year after planting to eliminate inner cladodes. In the following three or four years, when training pruning is terminated, it is important to eliminate inner cladodes and to leave no more than two good cladodes on every mother cladode. At maturity, 80 to 120 one-year-old cladodes are necessary to ensure a high plant yield. Pruning is done in April, just before spring burst. Two-year-old cladodes that have already produced are usually cut off if they do not have any vegetative production; inner or shaded one-year-old cladodes are also eliminated because they will produce only a few flower buds. A summer pruning is practiced along with

fruit thinning when the current-year second-flush cladodes are thinned. If the mother cladode produces both fruits and cladodes, the latter are eliminated.

Soil Management

The soil is worked four or five times a year. In December or January, fertilizers are plowed in. Sometimes the soil can be left untouched until March and manure applied early in spring when it is worked again to eliminate weeds and to plough in the results of pruning. In summer, the soil is worked lightly with a weeder. Weed removal in the bush-type trained plants should be manual because this training system makes it very difficult to work mechanically near the tree. Chemical weed control is becoming more and more widespread. Diquat and/or Paraquat are commonly used while Simazine is sometimes applied. Also, glyphosate compounds are being more widely used.

Fertilization

The importance of manure is greatly appreciated by Sicilian farmers. But the lack of easily available manure limits the supply at planting when 10-20 kg per plant is applied. In addition to manure, preplanting fertilization includes 300-400 kg/ha of P_2O_5 and 300-500 kg/ha of K_2O . This amount of fertilizer is usually applied in the San Cono area, while farmers in Santa Margherita usually employ 50% less. Ordinarily fertilization takes place in winter, between November and January. In Santa Margherita, 0.4-0.5 T/ha of 11-22-16 is used, while in the San Cono area at least 30 kg/ha of P as superphosphate and 120 kg/ha as K_2SO_4 is used. Nitrogen is supplied twice in spring: at spring burst (urea) and just before scozzolatura in May. Fertigation is practiced by giving KNO_3 in August to gain bigger fruits with a higher percentage of flesh.

Irrigation

Sicilian cactus pear, late-fruit production is dependent on irrigation. Irrigation can take place from one to four times, depending on soil characteristics and climatic seasonal conditions. So far, irrigation has been scheduled according to growers experience with no recourse to any physiological (plant water status, fruit growth) or physical (soil water content, evapotranspiration) index.

Comparing different irrigation schemes, Barbera (1984) has pointed out the effectiveness of two irrigations, the first after reflowering and another one 30 days later, when the flesh begins to grow intensively. A seasonal amount of 60-100 mm is usually given. The traditional basin irrigation method, largely practiced so far, is certainly not adequate from either a technical or bioagronomic point of view if we take into consideration cactus pear root system, which is a very shallow, and the high drainage capacity of the soils in which the cactus is usually grown. Recently, new irrigation methods (localized micro-sprinkler or drip irrigation) have been introduced.

Scozzolatura

In Sicily, cactus pear flowering season occurs once a year from the end of May to the beginning of July. In this respect the plant behaves differently than in Chile, USA, and Israel where a second fall flowering has been reported (Curtis, 1977; Gonzales, 1977; Nerd et al., 1991).

Sicilian cactus pear cultivation is based on late fruit production obtained by forcing the plant to produce a second bloom. By taking away flowers and cladodes of the spring flush at full bloom, the plant will reflower within 30-40 days to produce fruits that are bigger with a higher percentage flesh compared to the summer ones. These fruits will ripen the next fall, from the beginning of October to the end of November, depending on the spring flush removal date (Table 3). Removal time does affect reflowering rate, fruit development, and ripening time (Barbera et al., 1991).

Table 3. Flowering and Fruiting Behavior as Related to Removal Time (days after removal)

Removal Time	Bud Break			Bloom			Ripening		
	B	A	E	B	A	E	B	A	E
Preanthesis	10	16	32	45	55	65	127	145	156
Full bloom	10	16	25	40	50	58	130	147	156
Postanthesis	10	14	20	38	45	52	140	151	160

B = Beginning A = Average E = End

Source: Barbera, et al., 1991

A prebloom removal results in the highest reflowering rate, while removing the spring flush after petals are shed reduces reflowering up to 50%-70%. Prebloom fruits have the shortest fruit development period and ripen 15-20 days earlier than full-bloom ones and 30-40 days earlier than the postbloom ones. Furthermore, latest ripening fruits, even if bigger, will be spongy, cracked easily, and have a lower sugar content and poor coloration.

Sometimes fruits do not ripen until the next spring when their quality will be very poor. Even so, the fruit harvesting period could be extended from the end of September to the beginning of December by proper scheduling of spring flush removal. This could be useful in overcoming harvesting and marketing problems related to the poor storage performance of the fruit.

The number of cladodes produced after scozzolatura corresponds to the 60%-90% of the spring-flush number. Alternate bearing, which has been observed in Rossa more than in Gialla, seems to be related to reduced cladode fertility rather than to the lack of one-year-old cladodes. The spring flush removal takes place from the end of May to the last week of June when the main bloom occurs.

As previously stated, the reflowering rate will also depend on environmental conditions. In light soils having a low water content even in June, irrigation is applied at spring flush removal to allow good reflowering. The reflowering index, defined by the ratio of second- vs. first-flush flowers ($F_{II/I}$) is not constant (Table 4). As regard to full bloom removal, figures such as 0.7/1 are common in Sicily. The lowest values are typical of June cool areas or in the driest ones, if irrigation is not applied. The second-flush load of each cladode is related to that of the first one by a quadratic regression; cladodes bearing from 6 up to 13 flowers in the spring flush will provide most of the plant yield, having the best reflowering potential. No more than 25% of the current year cladodes produced in the spring flush can be left on the plant after scozzolatura. A higher percentage will result in a lower reflowering rate and in a sharp alternate-bearing behavior. Scozzolatura is never applied until 3-4 years after planting.

Table 4. Flowers per Cladode at the Second Flush and Relationship Between Second and First Flush According to the Variety and at Different Removal Dates

Treatment	Flowers 2nd Flush	$F_{II/I}$
Gialla	8.04	1.08
Rossa	4.97	0.75
	(*)	(*)
Preanthesis	8.44	1.25
Full bloom	6.85	0.85
Postanthesis	4.20	0.67
	(*)	(*)

(*) $P = 0.01$

Source: Barbera, et al., 1991

Fruit Thinning

Due to the typical flower and fruit development of cactus pear, both flower and fruit thinning are practiced. No more than five to seven flowers/fruits are left along the upper margin of each fertile cladode.

Pest and Disease Control

The recent spreading of cactus pear intensive cultivation on a large scale has prompted a stronger effort in pest and disease control. The Mediterranean fruit fly (*Ceratitis capitata* Wied.) is the only insect that causes serious damage (Longo, 1991). This fly attacks fruits in summer and autumn months when adults from the nearby orchards migrate into cactus pear orchards to reproduce. *Ceratitis* infestations can be controlled by monitoring adults' flights, determining the percentage of damaged fruits, and controlling both adults and grubs.

The most widespread disease among specialized plantations is, no doubt, the dry rot of the cladode or cladode scabies. The agent is the bacteria *Erwinia cactovora* (Granata and Varvaro, 1990; Magnano di San Lio, 1991). In spring, or at the beginning of summer, isolated white spots appear on the surface of the ill cladode, very soon forming large brown crusts. When the hot season arrives, the ill tissues dry out, the epidermis cracks and breaks away so that the cladode appears as being scabby.

Yeasts of the *Pichia* genus are responsible for the putrid rot of the cladode which is often associated with the scabies. The symptoms are dark spots which appear under the epidermis of the cladode. The epidermis remains safe and retains a bad-smelling liquid formed by the decomposition of the inner tissues which are completely destroyed by the fungus. In both diseases, the ill cladodes must be removed and destroyed far away. When cladodes are injured for any reason, e.g. hail, treatments with cupric salts are recommended. Root rot is much more rare. The agent is *Phytophthora nicotianae* (Cacciola and Magnano di San Lio, 1988). This alterations shows rotting with exudates at the base of the plant but rotting can rise up 20-30 cm from the soil. The inner tissues appear reddish; the plant becomes chlorotic with stunted growth; and, most of the time, it will die. Heavy soils, water clogging, and poor irrigation management promote development of this disease.

Harvest

Cactus pear summer fruits, derived from the spring bloom, will ripen from the second half of August to the last week of September. Even late fruit have a fairly scattered ripening period also at cladode level. Harvesting usually takes place at different times (2-3). Farmers are advised to collect the fruits at peel color breakage, 80-90 days after flowering, when TSS is around 13%, percent flesh 60%-65%, and flesh firmness 5-7 kg cm⁻¹ (Barbera et al, 1992). Fruits harvested when the peel is fully colored will be very easily damaged during harvest and glochid removal, while their storage ability will be very low. The highest yields are obtained in San Cono specialized area (14-16 T/ha, with peaks of 20-22 T/ha), while in Santa Margherita farmers never realize more than 15-16 T/ha, with average yield of 10-12 T/ha. Soon after harvesting fruits are washed and brushed to remove the glochids, then selected by size and packed in boxes of 4-10 kg each.

Outlook

The young age of most orchards, lets us predict that cactus pear fruit production will reach 65,000 T by the end of the century. Such an increase in production requires adequate enlargement of the markets to avoid a general collapse of the industry. This means that beside the ordinary cactus pear consumers who, in Europe, are natives or emigres from Mediterranean countries, new consumers should be reached both in northern Italy and Europe. Cactus pear export from Italy to EEC and North American (Canadian) markets has reached 2,000-3,000 T. To gain a larger market appreciation of this fruit with glochids and seeds, innovative marketing strategies should be carried out. Positive results come from a survey made in the Frankfurt market where 60% of the interviewees confirmed the great interest of the local consumers (Woirgardt, 1988). Consumers should be better informed about the good nutritional and organoleptic value of the fruit and how to handle and consume it.

Technologies for removing glochids should be improved to make the fruit easier to handle. Also, greater effort should be made to help the cactus pear fruit industry grow. So far, growers have been pushing cactus pear cultivation and development by themselves while the research activity on cactus pear in Italy has been poorly promoted. No more than 110 papers concerning cactus pear have been published in the last two centuries by Italian authors (Barbera et al, 1991). Since 1991, the government, through an EEC program, has begun to support cactus pear research in Sicily. Consequently, researchers from the University of Palermo (Reggio Calabria, Sassari, and Catania) are working on different topics for common strategies on reproductive biology, ecophysiology, propagation, orchard design and management, improvement of fruit quality, fruit storage, and marketing. Nevertheless, cooperation among researchers in Italy and abroad should be much better defined with specific tasks and goals. Accordingly, a network that we are promoting under the framework of FAO should improve relationships between scientists from all major cactus pear growing areas.

Finally, cooperation between Italian and Mexican universities is of great importance. Presently, we are developing research plans together with exchanges of farmers, students, and researchers.

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