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# Cactus pear (*Opuntia ficus indica* Mill.) as an emerging fruit crop for arid and semi-arid regions of India

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## ABSTRACT

Cactus pear (*Opuntia ficus indica* Mill.) is gradually gaining popularity as fruit and vegetable crop in hot arid regions of the world. In Mexico, it plays a strategic role in subsistence agriculture from the semi-arid lands. In India also, cactus pear is spreading fast owing to its nutritious and sweet fruits, tender cladodes as vegetable and digestible fodder. Spiny and spineless cultivars are available in Mexcio but most of the Indian genotypes are thorny which are used for live fencing around field boundaries. Visualizing its importance as fruit, vegetable, animal feed and industrial raw material and its suitability to Indian desertic climate, cactus pear can be a potential crop of these regions. Efforts are now on war footings to exploit the potential of this crop in the most neglected arid and semi-arid regions of the country where most of the crops are rainfed and less productive. Works related to propagation, planting techniques, water and nutrient management, canopy management, flowering, fruiting and harvesting of cactus pear in India and abroad have been reviewed in this paper.

## INTRODUCTION

Scientists with far reaching vision consider that the future of arid and semi-arid lands in entire world largely depends on the sustainable farming system using most suitable crops (Barbera *et al.*, 1995). In India, 12 per cent of geographical area comes under such arid and 27.7 per cent under semi-arid zone where extremes of temperatures, high wind velocity and solar radiation, poor rainfall and moisture holding capacity of soil makes the crop production much difficult. The most suitable crops under such hostile climate and edaphic conditions are those that successfully copes with water shortage, high temperature and poor soils and requires low energy inputs to provide food and forage for the subsistence agriculture. Cactus pear (*Opuntia ficus indica* Mill.), a zerophytic plant of Mexican origin have been identified and established as fruit, vegetable and fodder crop (Pimienta, 1994; Kaidanu, 1995; Barbera *et al.*, 1995). Owing to presence of pricks on its body cactus pear is commonly known as prickly pear while its edible fruit is called "tuna". Tender and often spineless cladodes of "nopalea" (*Opuntia cochenilifera*) are used as vegetable and salad while mature cladodes of both the types can be used as nutritive fodder for animals.

### *Origin and History of Cultivation*

Prickly pear is native of Central American and Mexican region (Pareek *et al.*, 1998). The earliest known record of this context is available in oldest edition of *oviedo-y-valdes, La historia general* published in 1535, which is based on the plants growing in America only (Barbera, 1995). Although, introduction of plants to Europe and other parts of the world has not been properly documented, however, from the scanty literature it is evident that the introduction of plants in Europe did take place before 1552 when *Lapec de Gomara* wrote about *Nopals*, a well known plant in Spain at that time (Donkin, 1977). The

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plants of genus *Opuntia* were reported and have been presented in Italy around 1560, in Germany and Netherland in 1583, and in England around 1556. Since the climatic conditions of Mediterranean region exceptionally suitable for *Opuntias* therefore, the species ingressed in the countries around this region very soon. Consequently, it become the most common element of the flora in these countries. Plants of genus *Opuntia* have also been reported in Philippines (1695), China (1700) South Africa (1772), India (1780) and south-east Asia (1790), however, there are probabilities that the plants were introduced in these countries at an earlier dates (Donkin, 1977). At the moment, *Opuntias* are the integral part of the farming system and natural landscape in several regions of the world. Some species are even naturalised as weeds in certain countries (Wessels, 1988). In India, prickly pear is in wild state and thorny species are being planted as livefence to protect field crops in arid and semi-arid regions from antiquity.

In recent years, interest in *Opuntia* species especially for fruit, vegetable and fodder types has remarkably increased, particularly in arid and semi-arid regions. Few years back, concentrated efforts have been made on horticultural aspect of this genus which has taken a shape of Cactus Network all over the world in recent years. As a result, cultivation and commercial exploitation of cactus pear has been done by a number of countries (Pimienta *et al.*, 1993; Barbera *et al.*, 1995). With the advancement in scientific knowledge, cactus pear area is increasing day by day and now its various products are available in International Market. Owing to greater conversion of water to dry matter (than either $C_3$ or $C_4$ plants) through specialised photosynthetic mechanisms, known as Crassulacean Acid Metabolism (CAM) (Felker *et al.* 1997) and its remarkable ability to bind soil particles through fibrous roots, cactus pear is well suited crop for Indian arid and semi-arid zone where low moisture index and sandy soils are the characteristic features. Visualising the importance of crop, Indian Council of Agricultural Research had sanctioned an A P Cess fund scheme to establish cactus pear germplasm at Nimbkar Agricultural Research Institute (NARI) Phaltan (MS) where 61 genotypes, including 39 from Texas A & M University, Kingsville, Texas have been maintained (Anon., 1993). Five genotypes at Central Soil Salinity Research Institute (CSSRI), Karnal, three at Indo-Italian Project, Dhakrani, Dehradun, have also been maintained. During 1996-97, 51 genotypes have been introduced from Texas A & M University, Kingsville, Texas at National Research Centre for Arid Horticulture (NRCAH), Bikaner. At present the centre has a total collection of 109 genotypes.

| Place of collection | Number collected | Genotypes |
|---|---|---|
| NARI, Phaltan (MS) | 41 | Fruit, vegetable, fodder type |
| Texas A & M University, Texas (USA) | 51 | Fruit, vegetable, fodder type |
| CSSRI, Karnal (Haryana) | 5 | Fruit, vegetable, fodder type |
| Indo-Italian Project, Dehradun | 3 | Fruiting type |
| CAZRI, Jodhpur, Rajasthan | 1 | Fruiting type |
| B.G.U., Beersheva, Israel | 3 | Fruit and vegetable |
| Regional Plant Centre, Bhubneshwar | 1 | Fruiting type |
| Fatehpur Shekhawati, Rajasthan | 1 | Fruiting type |
| Rahuri (Local), Maharashtra | 1 | Fruiting type |
| Jodhpur (Local), Rajasthan | 1 | Fruiting type |
| Jhunjhunu (Local), Rajasthan | 1 | Fruiting type |

### *Botanical Description*

Genus *Opuntia* belongs to family Cactaceae, has nearly 1600 species. These species have been categorised under 11 sub-genera : *Opuntia, Gnsolea, Austrocylindropuntia, Brasiliopuntia, Corynopuntia,*

*Cylindropuntia, Grusonia, Marenopuntia, Nopalea, Stenopuntia* and *Tephrocactus*. Out of 1600 species, about twenty species are being grown for fruits, vegetables and fodder in which *Opuntia ficus indica* is of prime importance. The prickly pear has the highest chromosome number (2n=66, 2n=44) found in cultivated conditions and changes in ploidy levels are commonly expressed by an increase in vegetative (Cladode size) and reproductive (fruit size) vigour which perhaps played an important role in domestication of this crop (Pimienta, 1994).

Taxonomy of *Opuntia* sp. varies according to ecological conditions and level of polyploidy that exists in great number of population regenerated through vegetative and sexual means (Leuenberger, 1991; Scheinvar, 1995). Generally, the Opuntia plant has thick succulent, spiny or spineless leaves called 'cladodes'. These cladodes have numerous areoles which functions like meristematic buds. These buds develop into new cladodes and fruits (from areal portion) and roots (from under ground parts) with the passage of time. Plants are glabrous, joints obovate, 30-60 cm long, 20-40 cm wide and 19-28 mm thick with dark green colour which are covered by layers of wax. Areoles disposed in 8-9 spiral series, pyriform, 2-4.5 mm long and approximately 3 mm. wide; 1-2 mm long caducus, light brown or yellow glochids are arranged in the middle of areole (Leuenberger, 1991).

The flowers are 7-9 cm long; orange, yellow or red in colour; pericarple 2-2.5 times longer than the perianth and tuberculated with approximately eight spiral series of aeroles. Fruits (5-10 cm long and 4-8 cm wide) are sweet; juicy; edible; pyriform; yellow, orange, red or purple in colour with abundant fleshy pulp are commonly called as Tuna. Tuna is very rich in sugars, minerals and vitamins.

The species has been domesticated since prehistoric times (Scheinvar, 1995). In Mexico, the tender stems are used as a vegetable (*nopalitos*) and sweet fruits are in very much demand in international market. Joints are also used as forage or to propogate new plants. The species is now being cultivated in many parts of world.

### *Area and Distribution*

*Opuntia* has highest degree of genetic diversity in Mexico and hence these are being utilised by the mankind in larger amount than anywhere else (Pimienta, 1993). The most common species of *Opuntia* i.e., *O. ficus indica* (Cactus pear) and its hybrids are distributed widely from North and South American continent to South-East Asia encompassing several regions of Europe, Africa and Asia. At present, commercial cultivation of Cactus pear is being done world wide for fruit, vegetable and fodder (Reese *et al.*, 1995). Today, this crop covers around 50,000 ha area in Mexico and 1000 ha in Chile. In USA, cactus pear is cultivated for fruit production in state of California where it covers around 120 ha (Russel and Felker, 1987). Peru is the largest producer of Carmine dye (a product of *Opuntia* sp.). In Peru, wild plantation of *Opuntia* covers about 35,000 ha which provide 80% of natural yield. Intensive plantations of the species have recently been set up along the coasts. In Brazil, 40,000 ha is under wild and intensive plantation of the species and here, it serve as an important source of fodder. In Bolavia, approximately 630 ha is under this crop. *Opuntia*, especially *O. ficus indica* are the commercial fruit crop in Argentina and Colombia (Ochoa de corneli, 1993).

In Sicily province of Italy, *O. ficus indica* has been widely grown since eighteenth century (Barbera *et al.*, 1992) which accounts for 90% of the total production of the country. At the moment, there are 2500 ha of specialised orchards and 25000 ha of mixed plantations in Sicily (Basile *et al.*, 1996). Cactus pear is also grown in Spain, Portugal and Turkey but only on limited scale for domestic consumption.

Systematic plantation of cactus pear covers around 1500 ha area in South Africa. Once upon a time, wild *Opuntia* species had around 90,000 ha area in South Africa but now they have almost been eliminated with biological cowlort through an act applied to the spiny forms, prohibiting the uncontrolled diffusion of the plant. The spineless *O. ficus indica* was not subjected to this regulation (Brutsch and Zimmermann, 1993). In place of wild plantations, specialised plantations are gradually coming up (Brutsch, 1984). *O. ficus indica* has spread over an area of 2,00,000 ha in North Africa as whole and 60,000 to 80,000 ha in Tunisia alone. Besides, the species are also distributed and/or cultivated in Algeria, Ethiopia, Morocco and Egypt (Pimienta, 1994). In Middle East Asia, specialised plantations of the cactus pear are spread over an area of 400 ha. Out of which Israel alone has about 200 ha area with an estimated fruit yield of 18 t/ha (Nerd *et al.*, 1993). In India, cactus pear has been introduced from Texas, USA only in late eighties and thus, at present, the area under cultivation is negligible. The crop is now gradually becoming popular in arid and semi-arid regions, because of its high yield and export potential from these fragile regions.

### *Importance and Uses*

Cactus pear has great adaptability to various soil and climatic conditions and can produce economical yield under fragile environmental conditions of arid and semi- arid region in India. All parts of the plant has great industrial and commercial importance.

As fodder and feed : Cactus pear grows abundantly in western prairies of USA and is becoming a valuable livestock feed (Felker, 1995). In South Africa, spineless cacti was introduced for livestock feeding (De Kock, 1990). Similarly 3,00,000 ha spineless cacti is being grown in north-eastern Brazil for livestock feeding (Domingues, 1963). Nutritional quality of *Opuntia* forage used in animal diet has been evaluated by number of workers time to time (Griffiths and Hare, 1906; Shoop *et al.*, 1977; Meyer and Brown, 1985; Ritamal *et al.*, 1987). In general, *Opuntia* fodder have 85 per cent moisture, 5-12 per cent crude protein and good amount of minerals (P, K, Ca and Mg). *In vitro* dry matter digestibility of cactus fodder is around 75 per cent (Felker, 1995). Under drought situation, cactus cladodes are an excellent feed for cattle and goat (Hansclka and Paschal, 1990). In India, Sirohi *et al.*, (1997) reported that cactus cladodes are highly palatable and can be used as nutritive feed in comparison with conventional material for cattle and sheep.

As edible fruit : Cactus produces fruits of 100-200 g weight which are highly priced in various developed countries. These fruits, after ripening, can be used as fresh as well as for processing. Fruits are being processed into jam, syrup, juices, etc. in Mexico, Chile, Agrentina, Brazil, South Africa, Israel, Italy and USA. Various workers have analysed the nutritive value of cactus fruits. In general, a ripe fruit contains moisture (85%), carbohydrates (11%), crude fibre (1.8%), protein (0.5%), lipid (0.1%), acidity (0.18%), calcium (60 mg/100 mg), vitamin C (300 mg/100 g) and vitamin A (50 IU) (Hernandez *et al.*, 1980, Askar and El-Samahy, 1981 and Sawaya *et al.*, 1983).

As vegetable : The young tender cladodes of vegetable type cactus (*Nopalea*) are being used for culinary and salad purposes. Felker *et al.* (1997) noted the taste of prepared *nopalea* vegetable like okra. Due to its excellent nutritional qualities (Russel and Felker, 1987) and therapeutic properties against hyperglycaeamia, hypercholesterolasmia and many other ailment (Hegwood, 1990; Mulas *et al.*, 1993), this type has high demand in International Market for human consumption. Wessels (1994) mentioned that *nopalea* is a traditional vegetable in many parts of Mexico and some Latin American countries. The

young *nopalea* cladode, in general contains 3.7 per cent carbohydrates, 1.0 per cent protein, 1.3 per cent mineral, 1.0 per cent fibre, 18-23 mg/100 g ß-carotene and 10-18 mg/100 g vitamin C except moisture to the tune of 90 per cent (Cantwell *et al.*, 1992).

Industrial and other Uses : *Opuntia* species are commercially used in cosmetic and dye industry. Shampoo, cream, body lotions, moisturizing agents, etc. are some commercial products prepared from its various parts. *Opuntia* is one of the best rearing source of the Cochineal insect at mass scale. This insect is used for the prodcution of red dye (Carminic acid) (Brutsch and Zimmermann, 1993). Cactus plant parts have been found cheap and economical source to generate non-conventional energy like biogas (Uribe *et al.*, 1992; Anon., 1993).

Visualising the horticultural, industrial and commercial potential of cactus pear, Food and Agricultural Organisation (FAO) has establish a "Cactus pear Network" with the aim to promote cactus pear as an important fruit crop world wide (Pimienta *et al.*, 1993).

### *Environmental Suitability and Adoptive Mechanisms*

Being xerophytic nature of plant, arid and semi-arid conditions are very much suitable for cactus pear. It can tolerate as high as 50-55°C temperature (Mizrahi *et al.*, 1997). Owing to CAM path way, cactus pear can withstand with high degree of moisture stress. Cactus pear put forth new flush (both vegetative and reproductive) during March-April and produces yield during hottest season in aerid and semi-arid zone. Besides, poor soils (sandy, gravely and stony) are not coming in the way of cactus pear production in these regions. Ferroyra *et al.* (1997) reported that cactus pear can do better even when they are irrigated with saline (8.2 dsm) and boron rich (17 mg/lit) water available in plenty in arid region.

Cactus pear has deep, fibres root system which absorbs the moisture available in the lower strata of the soil. Thorny, wax coated cladodes and fruits allowing least moisture evaporation through aerial portion. Under sandy soil conditions, cactus pear roots binds the soil particles and minimises their dispersal by wind forces on one hand and on the other hand keep the plant standing well under high wind velocity situation. Thus, under fragile environmental conditions of Indian arid zone cactus pear is a potential fruit crop which can bring revolution in years ahead.

### *Cultivars*

Cactus pear has wide range of cultivars. Depending upon the agroclimatic adaptability, the cultivars can be classified into Mexican or American group, Italian group and Argentinean group apart from some cultivars from South Africa, Israel and Malta. The important cultivars are Amarilla Montesa, Fafayuco, Roja Pilona, Copena Cardona, Burrona, Cristallina (Mexico); Bianca, Gialla, Rossa (Italy); Algerian, Direkteur, Fusicaulis, Nudosa, Roly Poly (South Africa) and Ofer, B S-1 (Israel). In India, however the performance evaluation of these cultivars is under progress.

### *Agrotechniques*

Cactus pear is an emerging fruit crop particularly in the most neglected and resource poor regions of the country. Visualising the importance of the crop in Indian context, agrotechniques for raising saplings for commercial plantation, planting techniques, water and nutrient management, plant architecture and canopy management and produce handling methods have been reviewed in this paper.

Propagation: Cactus pear can be propagated through sexual and asexual means. Owing to hard, lignified seed coat which though protects the seeds from adverse environmental conditions, prohibits the

germination. Consequently, seed takes longer period to germinate. Being heterogeneity in seed lot the resulted seedlings are not true to type which is a limiting factor for commercial cultivation of the crop. Seed propagation also takes long time to select desirable plants. In view of these negative aspects of sexual propagation, vegetative propagation through cladodes have been attempted and found suitable for raising true to type cactus pear orchard (Pimienta, 1990).

Though, much literature is not available on vegetative propagation of cactus pear but for deciding suitable propagating material, cladode size appears to be an important factor (Barbera *et al.* 1988; Wessels, 1988). An unit of two to three leaves were found to be highly suitable cladode size for planting (Wessels, 1988). Mondragon (1992) and Mondragon and Pimienta (1995) observed that clodode size is the most important factor for selecting planting material because it affects the number and size of shoots produced during the first year of growth in the field and inferred that bigger cladodes could be divided into two or even four pieces and smaller cladodes should be planted whole as planting material. Wessels *et al.* (1997) has also emphasized that cladode size has positive correlation with growth of the plant.

The age of cladode is another important factor to decide the planting material as it is very much associated with the survival and growth of plants in field. Barbera *et al.* (1988) observed that 2-3 one year old cladode, attached to a two year old cladode are successfully used in Multiple Cladode Cutting (MCC) method of planting by Italian, Mexican and Chilean growers since last four years. Mondragon and Pimienta (1995) reported that optimum age of cladode for planting is one year but two year old cladodes can also be planted successfully. Plant growth regulators (PGR) particularly auxins have been found to improve the rooting in cactus pear (Mulas *et al.*, 1992). Mulas *et al.* (1992 a) reported that young cladodes of cultivar Gialla treated with 1000 ppm Naphthalene Acetic Acid (NAA) for 15 minutes showed the best performance in terms of number and weight of root per cladode.

Planting : Workers have contradictory opinion regarding the time of planting in cactus pear. Bonifacio (1961) mentioned that autumn or spring is the appropriate time for planting of cladodes whereas Damigella (1958) considered autumn to be the best season. According to Barbera *et al.* (1992), late spring is the best time for planting in Italy. However, in South African conditions, August-September is considered to be the best time for planting of cladodes (Wessels, 1988). Recently, Inglese (1995) observed that late spring is the best time for planting of cladodes.

Orientation of cladodes during planting is another important aspect for successful production of cactus pear. To recieve optimum photosynthetically active radiation (PAR) correct row orientation is necessary for better growth and production (Nobel, 1982). At around 27° latitude, east-west face of cladodes gave better results in terms of survival, growth and production of cactus pear orchards. However, with change in latitude and topographical features as well, the orientation of cladode can be changed. According to Mondragon and Pimienta (1995), cladodes placed facing east-west improves the productivity. In semi-arid region of India, cladodes when planted on ridges under ridge-furrow system, exhibited appreciably better growth and production (Anon., 1993). Inglese (1995) observed that planting of cladodes at an angle of 30° resulted in better growth and production but flat planting by placing planner surface of cladode on ground is also practised in many European countries because it saves the cost of pit digging.

Water Management : Cactus pear is a drought hardy fruit crop however, it responds to irrigation. Singh and Felkar, (1998) mentioned that 2-3 irrigation at 20-25 days interval during fruit formation and development enhances the yield and checks fruit cracking. Since the root system in cactus pear is fibrous and confined to upper 20-30 cm layer of soil, light irrigation is most beneficial. Under semi-arid conditions

of Maharashtra, irrigation at monthly interval except during monsoon was found most useful for plant growth and production (Anon., 1993). Barbera (1984) reported that 2-3 irrigations during fruit development stage increases yield, fruit size and flesh percentage. Areas receiving little higher rainfall (400-600 cm), can produce cactus pear under rainfed condition. Wessels (1988) considered that 300-600 cm well distributed rainfall is sufficient to ensure good yield, however, light irrigation during fruit swelling is essential particularly in light soils to regulate the soil moisture balance and ultimate fruit cracking. Rainfed production can be more profitable through mositure management techniques such as *in situ* and *ex situ* water harvesting and mulching. At critical stage of fruit development, light irrigation can be provided from *ex situ* stored water whereas soil moisture status can be improved by providing 5 per cent slope towards plant from all the direction and provision of organic (local weed, crop wastes, etc.) and inorganic (black polythene) mulching. For *nopalea* production, however, assured irrigation facility is essential particularly during summer months.

For efficient use of irrigation water and to minimise the cost of water application, suitable method of irrigation should be followed in cactus pear. Traditional basin system is consuming a lot of labour therefore, for better establishment of plants in arid region furrow system is an easy and economical method of irrigation during initial year. Once the plant established, drip system has been found much effective. For establishment of cactus pear in hyper arid situation at Bikaner, Pitcher system has been found much useful. Pareek *et al.* (1998) reported that by fixing an earthen pitcher of 10-12 lit capacity to each plant improves the initial cladode development by 2-3 times in fruiting type cactus as compared to basin system. They further suggested that by mixing inorganic fertilizer in pitcher water, an effective integration of water and nutrient application can be done.

Nutrient Management : Although manures and fertilizes are frequently used in cactus pear (Russel and Felker, 1987) but the doses of nutrients, their time of application in different soil and climatic conditions has not been clearly delineated. Application of 10 kg manure alongwith 250 g ammonium sulphate, 200 g single super phosphate and 100 g potassium sulphate per plant per year during winter is a common practice in Chile. It was observed that nutrients applied during this period improved fruit yield and quality. Further, Nerd *et al.* (1989) found that any interruption in fertilizer application during winter reduced the number of flower buds and delayed their emergence. Nerd *et al.* (1991) further clarified that continuous fertigation reduces the flower bud in winter than in summer crop. They found that increase in flower bud production in fertigated plants were associated with the increase of $NO_3$ content in the cladodes. In semi-arid condition of India, application of 200 g poultry manure/plant at the time of planting with the provision of sufficient moisture produced good vegetative growth (Anon., 1993) whereas Nerd *et al.* (1993) reported that NPK fertigated young plantation of *Opuntia ficus indica* produced 18 ton/ha fruits after 2.5 years of planting in Negev desert of Israel.

Influence of nitrogen and phosphorus on biomass productivity, fruiting and crude protein have been examined by Gathaara et al. (1989). Results reveal that the highest dry fruit production (734 kg/ha/year) was obtained by the application of 0 kg nitrogen and 80 kg phosphorus/ha. Further, it was pointed out that soil application of N and P has significant correlation with fruiting whereas total biomass productivity for 3 years growth does not have any correlation with soil application of nitrogenous and phosphatic fertilizers.

Canopy Management : Cactus pear is a typical plant which produces number of cladodes from the mother cladode. These initial cladodes make the branches in long run. Therefore, to develop a well

spaced branches and ultimately the strong frame of a plant, initial training of cladodes is very muc essential. To develop a strong frame, 2-3 cladoeds ore allowed to develop on each of which 2-3 ne cladodes are permitted. In this way, the plant is trained. Besides strong frame, the main objective c training is to allow more penetration of light in plant canopy and to ease plant protection, pruning an harvesting operations.

The main objective of pruning is to make a balance between the vegetative and reproductiv growth of plant which also facilitates the penetration of light and thus, improves the yield and quality o fruits. Pruned cladodes can also be used as source of planting material to establish new orchards. Mula and D'Hallewin (1992) found positive results of pruning in cactus pear cultivar Gialla. They reported tha pruning promotes the vigourous shoot growth. They also mentioned that during initial years, the yield ir terms of cladodes number per plant and cladode number/$m^3$ is reduced by pruning. Inglese *et al.* (1995a also emphasised that cladode load and time of thinning maximises the fruit size and flesh content ir *Opuntia ficus indica* cultivar Gialla. Singh and Felker (1998) suggested the best time of pruning und Indian condition. They emphasized that pruning should be done when the crop has been reaped and the plant is in non active growth stage. They further pointed out that never prune a cactus pear during active growth phase.

Flowering and Fruiting : Flowering in cactus pear is influenced by age of plant and environmental and nutritional factors. Fruiting generally starts after 3 years of planting but with better management practices (fertigation) it can be induced earlier also (Nerd *et al.*, 1993). Flowering generally takes place on terminal cladodes of one year age but subterminal cladodes can also produce flowers (Wessels, 1988). Flower bud initiation generally takes place on areoles located along the edges of cladode. Spring-summer is the peak time of flowering. Under Indian arid condition, early flower bud initiation have been observed in clones 1118, 1270 and 1271. Detailed study on flowering has also been conducted. Nieddu and Spano (1992) reported that flowering in cactus pear cultivar Gialla occurred mainly on one year old cladode. They found that 74 per cent flowers were arising from the upper margin and 17 per cent from the central part of the cladodes. Regarding the time, they found that the maximum flowers (76%) emerged during June while 23% appeared during May. The flowers took 25-37 days to come into full bloom whereas the fruit development period was 56-75 days. Similarly, Gutterman (1995) also reported that flowering, fruiting and yield in cactus pear is influenced by temperature not by light. They also mentioned that young cladodes show significantly lower fertility. Cactus pear blooms during day and most of the flowers open late in the morning and close by the evening. Perfect pollination is essential for fruit and seed se cactus pear. Number of seeds/fruit ranged from 80-300 (Wessels, 1988). After pollination, growth and development of fruit starts which take 80-90 days for ripening. Parthenocarpy has also been observed in cactus pear.

Harvesting and Yield : Harvesting time and yield in cactus pear vary according to purpose for which it is being grown. For vegetable purpose, Flores (1995) reported that when cladodes attain optimum size (12-15 cm) and remain tender, should be harvested preferably in morning hours. after sprouting, a cladode takes 30-60 days to attain vegetable maturity. A recent report from Israel suggested that marketable size (17-20 cm long) cladode is obtained within 20-30 days after sprouting and new vegetative buds start developing after cladode reaches to its maximum (130 $cm^2$) size (Anon., 1996).

Botanically, fruit of cactus pear is a berry in which exocarp and endocarp are not separable and thus, it has delicate skin therefore, during harvesting and handling it requires utmost care. Harvesting of

fruits should be done at proper maturity. Fruits have small pricks on its outer surface, therefore, these pricks should be removed by rubbing the fruit or by propane torches. Fruiting in cactus pear generally starts after 3-4 years of planting and 10-15 t/ha yield can be obtained from a well managed plantation. A yield of 80-90 t/ha immature cladodes can be harvested from vegetable types whereas fodder type yields 100-150 t/ha forage. Wessels (1994) reported that a yield of 21.35 t/ha immature cladode (fresh weight) has been obtained from ultra high density planting system (40,000 plants/ha) which could supply the annual protein requirement to 12.2 peoples.

## RESEARCH NEEDS AND FUTURE THRUST

In Indian arid and semi-arid region, cactus pear has immense potential. Research efforts are on but they needs to be more intensified in following areas:

1. Collection, conservation and screening of germplasm for Indian environmental condition.
2. Crop improvement programme to develop high yielding cutlivars having tolerance to biotic and abiotic stresses.
3. More attention is needed to standardise the agro-techniques particularly for time and methods of planting and water, nutrient, weed and canopy management.
4. Emphasis should also be given to develop maturity indices, harvesting time and techniques and handling of the produce.
5. Medicinal value of various parts of cactus pear needs to be examined in context to major human health hazards.
6. Plant protection measures needs to be developed.
7. Work should be undertaken to minimise the post harvest losses in fruit and vegetable type.
8. To popularise the crop and its importance in Indian farming community, extension programmes should also be under taken up at various levels.

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