General Review of *Opuntias* in India♦

Gurbachan Singh
Assistant Director General (Agro.)
Indian Council of Agricultural Research
Krishi Bhavan, New Delhi-110001

INTRODUCTION

Cactus (*Opuntia ficus-indica*), commonly known as prickly pear, belongs to the family Cactaceae. In local parlence, cactus is called *nagphani* or *danda thohar*. In Tamil nadu, it is commonly known as *chapathi balli*. Family Cactaceae is reported to contain about 130 genera and nearly 1500 species, which were originally native to the New World. Cacti have a special carbon dioxide fixation pathway, known as Crassulacean acid metabolism (CAM) and are ideally suited to water-scarce dry zones of the world as an alternate source of food and fodder (Wessels, 1988; Mizrahi et al., 1997; Singh and Felker, 1998; Han and Felker, 1997). Being so water-use efficient, they are highly useful in arid and semiarid environments, particularly during prolonged dry spells or failure of the monsoon. However, incredible as it may sound, the cactus is not merely a hardy ornamental plant, as is commonly believed; it is a storehouse of virtues that have been commercially unexploited so far in India. In addition, certain genera, such as *Optuntia* and *Nopalea* have economically useful plant parts. Different parts of the cactus can be used as fruit and vegetable for human consumption, fodder for cattle, and raw material for various industries to prepare plywood, soap, dyes, adhesives and glue, pharmaceutical products for treating blood sugar and various other disorders, and cosmetics such as shampoo, cream, and body lotions, etc. (Barbera et al., 1995; Pimienta, 1994). The fruits of domesticated *Opuntia* cultivars are being sold as a desert fruit in markets of the USA, Chile, Mexico, Brazil, North Africa, Spain, Italy, and Greece. Similarly, the tender young pads of *Optunia* and *Nopalea* species, known as *nopalitos,* are extensively used as a fresh green vegetable in Mexico and Texas. Even its seeds can be used as flavouring agents. Use of cactus pear as a waterproof paint for homes is also reported (*The Hindu*, June 27, 2002).

Many species of cactus are found growing either as wild plants in arid and semiarid regions of India or as an ornamental plant in urban homes and gardens. Generally, these species are used as live fences to protect agricultural fields from human and animal encroachments. With few exceptions, there has, so far, been no attempt to cultivate this plant as a horticultural or fodder crop in India. In countries such as Mexico, USA, Spain, Italy, and in northern Africa, where the crop is commonly known, it already forms an integral part of the people's dietary requirement. In addition to the excellent quality and flavour of the fresh fruit, the young leaves serve both as a vegetable and salad dish and the immature fruit is used to make mock gherkins.

Opuntia Germplasm Introduction in India

As a part of an Indo-US collaborative research program on *Opuntia* in India initiated by Dr. Peter Felker, Texas, USA, 33 *Opuntia* clones were introduced at the Nimbkar Agricultural Research Institute at Phalton, India, in 1987. All these clones grew well under the semiarid agroclimate of western Maharashtra and it is reported that some clones also produced fruits. In 1991, Central Soil Salinity Research Institute, Karnal obtained five fruit, forage, and vegetable clones from Dr. Peter Felker's collection in Texas. The author of this paper worked with Dr. Felker in Texas for four months as a FAO fellow. As a followup of this programme, this germplasm exchange occurred. Again, in January 1997, 51 additional *Opuntia* clones were introduced from Texas A&M University-Kingsville at the National

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Research Centre for Arid Horticulture in Bikaner. The last germplasm exchange contained thorny and thornless varieties of red, orange, yellow, and lime-green fruits that ranged up to 200 g in fruit size.

Opuntia Introduction in Karnal

Keeping in view the potential uses of cactus and its low water requirement, five promising clones (1270, 1271, 1280, 1287, and 1308) from Texas A&M University(see Parish and Felker, 1997) were introduced at Karnal. The salient characteristics of the five introduced clones are: 1270, high-protein forage and fairly sweet pale-green fruits originally from Dr. Severino Gonzaga Albuquerque in Petrolina, Brazil, where this forage variety was known as Palma redonda; 1271, fast growing and fairly sweet fruits originally from Dr. Severino Gonzaga Albuquerque in Petrolina, Brazil, where this forage variety was known as Palma giganta; 1280, thornless with pretty good yellow fruits obtained by C. Russell in 1983 from the Universidad Autonoma de Chapingo, Mexico; 1287, thorny, but best fruit variety, collected by C. Russell in Agua Prieta, Mexquite, San Luis Potosi, Mexico; 1308, very fast growing vegetable variety; *O. cochinillifera*, collected by C. Russell in Tamazunchale, San Luis Potosi, Mexico where it was growing in association with fruits and vegetables (beans, mangos, bananas, etc.) on steep slopes in a tropical environment. The clones were planted in ceramic pots having 20 kg soil blended with 1 kg of farmyard manure (FYM) in 1991 for germplasm evaluation and multiplication (Figure 1). The vegetable clone 1308 took nearly 57 days for sprouting, while the fruit clone 1287 took 85 days and was last to sprout (Table 1).

Table 1. Days Taken for Growth Initiation and Number of Cladodes Formed by Different Cactus Clones

Clone and Characteristic*	Days for Sprouting	Cladodes Per Plant
1308 (V)	57	6
1270 (FF)	68	4
1271 (F)	91	3
1280 (F)	98	2
1287 (F)	100	1

* V = vegetable; FF = forage and fruit; F = fruit

Sodicity Tolerance

Cactus performance was evaluated in different pH soil (pH_2 8.1, 8.4, 8.7, 9.4, and 10.0) in pots (Plate 2). Growth initiation was affected markedly by the pH levels of the medium. At pH 8.1, growth started 54 days after planting, whereas at pH 10.0, sprouting took about 90 days. The number of cladodes formed per plant were significantly less above pH 8.7. The plant formed cladodes even at pH 10.0, identifying it as a very useful plant which can grow even under high pH levels. This study showed that owing to its low water requirement and moderate tolerance for salt stress it can be grown as a companion crop with low-water-demanding and highly salt-tolerant trees of the genus *Prosopis* to augment fuelwood, forage, fruit, and vegetable needs of inhabitants in arid environments.

Planting in Field

In February 1993, these clones were planted in the field for large-scale germplasm multiplication (Plate 3). Cladodes of five clones dried for one month under shade before planting were planted on ridges (40-cm height) keeping one-third portion of the cladode under the soil and two-thirds above the soil surface. The row-to-row and plant-to-plant distances were 4 m and 2m, respectively. Before planting, about 5 kg of well rotted farmyard manure (FYM) per plant was added. Immediately after planting, 5 liters of water was applied to each plant. All clones have been raised successfully, without supplemental irrigation, even

under the field conditions. This orchard served as a major germplasm source for introduction in other places: Jodhpur, Bikaner, Agra and Jhansi (Plate 4). Dr. Enrique Aries, FAO Cactus Net Coordinator, visited our field plantations in 1998 (Plate 5).

Flowering and Fruiting

In April 1995 (nearly 3½ years after planting) flower initiation took place in all the clones (which later developed into fruits). The fruits started ripening by the first fortnight of June and all fruits were harvested by July 20, 1995 (Plate 6). Maximum fruiting took place in clone 1270 and minimum in clone 1287. The fruits were oval shaped, pale green in colour and the weight of each fruit ranged from 50 to 100 grams (Plate 7). Each cladode of clone 1270 bore 8 to 15 fruits (nearly 1 kg fruit per pad). Total fruit yield from 20 plants of clone 1270 planted in the pots was nearly 40 kg. This could be much higher when planted under field conditions. The potted plants were given no other inputs except nutrient solution of 2% cent urea, 0.5% super phosphate and 0.2% zinc sulphate annually. Ripened fruits packed in two trays (normally used for packing eggs) were sent to Delhi through Dr. N.K. Tyagi, Director of CSSRI, Karnal, for taste demonstration in the ICAR Director's Conference, which was presided over by Dr. R.S. Paroda, Director General, ICAR, New Delhi. As a followup, Dr. Paroda wrote to the Director, Central Institute on Arid Horticulture (CIAH), Bikaner, and Director, CAZRI, Jodhpur, for introduction of this material in Rajasthan. On Dr. Paroda's personal initiative, the material could be introduced in many places located in different parts of the country.

Introduction in Bikaner

Because cactus pear has several uses and can grow well with low inputs even under wasteland conditions, great potential was recognized for its adoption as a commercial crop in arid regions of India. Forty-one clones of cactus pear (39 exotic and 2 local collections) from Dr. Felker's collections in Texas were introduced in 1987 at Nimbakar Agricultural Research Institute, Phalton (Maharashtra), and 5 exotic clones introduced in 1991 at Central Soil Salinity Research Institute, Karnal, were planted at Bikaner during 1996. The recent information is that these clones have established well and have started growing. It is reported that, in general, fruiting-type clones were slower growing compared to vegetable and fodder types. Of the 51 clones obtained from Texas A&M University, Kingsville, in January 1997, 48 have survived under Bikaner conditions. Some local clones were also collected and planted in the field to have information on comparative performance of the introduced and indigenously collected germplasm.

Introduction at Agra

As a part of his Ph.D. dissertation research, Mr. R.S. Singh, scientist horticulture, working at CIAH, Bikaner, introduced four exotic varieties of cactus-pear fruiting types (1271, 1280), and vegetable type (1308 and *Nopalea*). Vegetative performance of these clones in a sandy loam soil adequate in nutrient status was evaluated in spring (February through March) and monsoon (September through October) planting seasons. Nearly 12-month-old cladodes collected from CSSRI, Karnal and Bikaner, were planted using the upright planting method facing the east-west direction, keeping a distance of 3 m between rows and 1 m between the plants. The experiment was conducted in randomized-block design (RBD) with six replications. The cladodes were blended with Baviston (0.2%) before planting to check cladode rotting. Singh and Singh recorded observations for two years on days taken to sprout after planting; cladodes formed per plant; length, width, and weight of cladodes at harvest; moisture (%); titrable acidity; ascorbic acid (vitamin C); total sugars; reducing sugars; and nonreducing sugars in fresh cladodes of the four clones planted at Agra. Results of their experimentation are given in Table 2 and Table 3.

Table 2. Comparative Performance of Cactus Clones at Agra

Cactus Types or Varieties	Spring Season (February-March)				
	Days Taken To Sprout	Size of Cladodes		Cladodes Per Plant	Average Weight Per Cladode (g)
		Length (cm)	Width (cm)		
1271 (F)	37.5	21.61	10.24	3.84	209.18
1280 (F)	35.8	20.17	8.89	3.34	211.15
1308 (V)	23.6	13.66	6.84	6.20	88.90
Nopalea (V)	26.0	13.15	7.04	6.10	81.10
C.D. at 5%	**7.15**	**1.83**	**0.61**	**0.33**	**4.72**
Cactus Types or Varieties	**Monsoon Season (September-October)**				
	Days Taken To Sprout	Size of Cladodes		Cladodes Per Plant	Average Weight Per Cladode (g)
Cactus Types or Varieties		Length (cm)	Width (cm)		
1271 (F)	80.0	19.06	8.30	3.15	148.75
1280 (F)	56.6	18.16	7.58	3.00	140.83
1308 (V)	53.3	13.05	5.80	6.13	67.50
Nopalea (V)	51.6	12.55	6.16	6.17	58.67
C.D. at 5%	**14.11**	**2.05**	**0.95**	**0.41**	**9.15**

Source: Singh and Singh, 2000 (Unpublished)

Table 3. Chemical Composition of Prickly-Pear Cladodes Planted at Agra.

Cactus Types Or Varieties	Spring season (February-March)					
	Moisture Content (%)	Titrable Acidity (%)	Ascorbic Acid (mg/100g)	Total Sugar	Reducing Sugar (mg/g fresh weight)	Nonreducing Sugar (mg/g fresh weight)
1271 (F)	93.58	0.821	5.33	2.17	1.39	0.78
1280 (F)	93.07	0.491	9.33	4.29	2.70	1.58
1308 (V)	92.78	0.459	11.33	3.08	2.33	0.75
Nopalea (V)	92.70	0.672	11.92	4.23	3.19	1.07
C.D. at 5%	**0.49**	**0.052**	**0.76**	**1.07**	**0.15**	**0.17**
Cactus Types Or Varieties	**Monsoon season (September-October)**					
	Moisture Content (%)	**Titrable Acidity (%)**	**Ascorbic Acid (mg/100g)**	**Total Sugar**	**Reducing Sugar (mg/g fresh weight)**	**Nonreducing Sugar (mg/g fresh weight)**
1271 (F)	93.61	0..917	4.92	2.20	1.38	0.81
1280 (F)	92.41	0.661	8.92	4.25	2.25	2.00
1308 (V)	91.16	0.437	11.25	3.10	2.30	0.80
Nopalea (V)	90.41	0.747	12.00	4.35	3.14	1.20
C.D. at 5%	**1.37**	**0.066**	**0.66**	**0.13**	**0.10**	**0.14**

Source : Singh and Singh, 2000 (Unpublished)

Introduction in Bundhelkhand Region, Jhansi (Central India)

Elite cactus material from CSSRI, Karnal, was introduced at National Research Centre for Agroforestry (NRCAF), Jhansi, in 1998 and planted under a rainfed situation on raised bunds in red soils of Bundelkhand (Plate 8). Soils of Bundelkhand are coarse textured, shallow, low in water retention, and deficient in organic carbon, usually found at higher elevations with rocky terrain and face serious moisture stress for a major part (October to June) of the year. The idea to introduce edible cactus in rainfed Bundelkhand region (Central India) was to exploit its potential as an alternate source of forage, as a biofence, and as a source of food for the economically disadvantaged human and animal population settled in this ecologically disadvantaged environment. Establishment performance of this new crop in this region was evaluated and monitored for three years (Singh, et al., 2001). Cladodes of each type were detached from the mother plants in October 1998, stored for one month at ambient temperature, and planted in November 1998 on raised beds at 4 m by 2 m spacing. Two methods of planting viz., erect and flat planting were attempted. In erect planting, one-third portion of the cladode remained in the soil layer. In flat planting, the whole cladode was kept flat and covered with a 2.5-cm-thick layer of soil. The experiment was laid out in a RBD with three replications and eight plants per treatment. Five liters of water was given to each plant just after planting. No irrigation was applied later throughout the study

period. About 5 kg FYM was mixed in the soil where each cladode was planted. The field was maintained almost weed free by periodic cleaning or cultivation. One earthing-up was done after withdrawal of rains in 1999. Observations were recorded on survival, cladodes formed per plant, size of cladodes, sprouting pattern, biomass per plant, fruit yield, and its chemical composition in October 2000.

Method of Planting

Establishment and survival of transplanted cladodes (unrooted) recorded 6 and 12 months after planting is presented in Table 4. It is apparent that erect planting gave 100% survival of plants after one year for clones 1270, 1271, and 1280. Clones 1308 and 1287 recorded 83% and 75% success, respectively. Flat planting showed poor establishment for all clones. This may be because flat-planted cladodes were completely covered by a 2.5-cm-thick layer of soil, while erect-planted cladodes were partially buried in soil. In the latter case, sprouting took place from above ground parts of cladode. Rotting of cladodes was markedly higher when they were completely buried in the soil.

Table 4. Percent Survival of Cladodes 6 and 12 months After Flat and Erect Planting

Type	After 6 Months		After 12 Months	
	Flat	Erect	Flat	Erect
1270	83	100	17	100
1271	50	100	33	100
1280	33	66	17	100
1287	50	92	42	75
1308	17	100	--	83

Number of Cladodes per Plant

Clone1271 produced the maximum (18.42) cladodes per plant at 2 years of age (Table 5), closely followed by 1270 type (18.09). The number of cladodes was minimum in clone 1308 (9.14), followed by 1287. Both were significantly at par but lower than others. Singh and Solanki (1999) reported that in arid zones of India, clone1308 grows profusely when provided with sufficient water and fertilization during early stages of growth. However, under present site conditions sufficiently large damage by rabbits in clone 1308 was noticed, and growth was affected adversely. The fleshy nature of cladodes due to higher moisture content in this clone, encouraged damage by wild animals.

Average weight of cladodes

The average weight of cladodes (Table 5) was a maximum of 555 g, and was significantly higher than other types in the case of clone 1271, followed by 1280 (460 g/cladode). Clones 1270 and 1287 recorded 340 g and 360 g average weight and both were at par, while 1308 type recorded a significantly lower average weight (95 g/cladode). Biomass production 2 years after plantation was significantly higher in clone 1271 (Table 5).

Table 5. Average Number of Cladodes per Plant, Weight of Cladode, and Biomass Yield

Type	Cladodes Per Plant	Average Weight of Cladode (g)	Biomass (kg/plant)
1270	18.09	340	18.56
1271	18.42	555	30.61
1280	13.38	460	18.14
1287	10.34	360	11.15
1308	9.14	95	2.61
CD at 5%	**2.41**	**75.18**	**1.57**

Loss of Weight During Storage

Loss of weight during storage of cladodes at ambient temperature for one month also was recorded. Clone 1308 incurred maximum (23.68%) loss in weight, while all others showed losses of 12.39% to 13.66% (Table 6), indicating that the clone for vegetable use has more moisture than the cladodes of forage and fruit varieties. Four cladodes of each type were also observed for sprouting during storage. Clones 1270, 1271, and 1280 showed sprouts just after 20 days. The sprouting pattern also differed in different clones (Table 6). Type 1287 produced maximum-size cladodes closely followed by 1271 (Table 7).

Table 6. Weight Loss, Sprouting, and Sprouting Patterns of Cladodes During Storage Between September 25 to October 25

Particulars	Type				
	1270	**1271**	**1280**	**1287**	**1308**
Weight loss (%)	13.60	12.39	13.66	13.10	23.68
Sprouting (%)	50	100	50	--	--
Sprouting pattern	Terminal only	Terminal and dorsal	Dorsal only	--	--

Table7. Size and shape of cladodes

Type	Length (cm)	Width (cm)	Length to Width Ratio	Shape
1270	25.14	18.71	1.34	Round
1271	30.29	15.57	1.95	Elliptical
1280	26.57	12.86	2.07	Elliptical
1287	31.63	15.25	2.07	Elliptical
1308	21.14	6.71	3.15	Elliptical

Fruit Yield and Quality

Fruiting was observed in clones 1270 and 1287 two years after planting. Each plant produced 2 to 4 fruits in both types. Similarly, clone 1270 yielded nearly 1 kg to 2 kg fruit per plant three years after planting at Karnal (Felker et al., 1997, Singh and Felker, 1998). Fruit characteristics are given in Table 8. It is obvious that 1287 produced bigger fruits and, as such, higher fruit yield. Both the types showed 13^{o} brix TSS. Flesh colour of 1287 was yellow, while 1271 was orange, with fewer small seeds. However, type 1271 was more juicy than 1287, which has tough texture, hence better transportability. The ripe fruits of clone 1270 and 1287 were given to 25 persons for taste analysis based upon sweetness. Each individual was asked to give a score on a 0 to 10 scale. The scores given by 25 individuals varying in age from 28 to 50 years are reported in Table 9. Six persons gave a score of 8, or more; whereas two persons did not like the taste and gave a score less than 6. Most of the people suggested to improve it further for seedless character and more sweetness. The taste evaluation group comprised doctors, scientists, advocates, students, technicians, and farmers.

Table 8: Fruit Characteristics of Cactus Clones Planted in Red Soils of Bundelkhand

Characteristic	1287	1270
Fruit length (cm)	7.55	5.50
Fruit width (cm)	4.6	3.30
Fruit weight (g)	74.13	29.29
TSS (obrix)	13	13
Colour of flesh	Yellow	Orange
Texture	Tough	Soft

Table 9: Rating of Cactus Fruit Based on Sweetness and Taste on 0 to 10 Scale By 25 Respondents

Score	Number	General Remarks
8 and above	06	i. Needs improvement for less seeds and more sugar ii. It is juicy and tasty
6 to 8	17	--
Less than 6	02	--

Present Status of Clones Planted at Jhansi

The cactus is being further planted on rocky hillocks as a rehabilitation option. The germplasm multiplication studies using 1/8 piece of cladode after one month of suberization proved highly successful (Plate 9). This technique of raising eight plants from single cactus cladode proved highly helpful in reducing bulk of transport of material. *Senna* (*Cassia augustifolia*), was planted between two plants of prickly pear on ridges and lemon grass (*Cymbopogon flexuosus*) planted in beds (between ridges) at 75-cm spacing (rows and plants). The system is well established and performing well. However, *Senna* has shown widespread mortality due to scarcity of moisture in red soils. Fruiting in year 2002 was negligible due to extreme drought conditions. However, plants survived the drought.

Cactus Day Celebration

During fruiting season, a cactus day was celebrated in the cactus field at Jhansi. All scientists, technicals, and supporting staff of NRCAF participated in this event and tasted the fruit of this newly introduced crop (Plate 10). All people liked the fruit taste and sweetness (Plate 11).

The preliminary investigations carried out for two years with five clones of edible cactus in shallow-depth red soils of the rainfed Bundelkhand region clearly showed that edible cactus can be established successfully under these situations as an alternate source of forage, fruit, and vegetable during lean periods. Cactus cladodes remain green, even during May and June, when no other green fodder is available for milk cattle under Bundelkhand climatic situations. This characteristic makes this plant highly relevant for planting in fodder-scarce areas, particularly to supplement forage requirements during drought. Under the World Bank aided National Agricultural Technology Project, a project on developing live fencing practices with a budget of about US$400,000 is in operation at seven locations in India. In this project, edible cactus is being exploited as a successful live fence to protect agricultural fields from wild animals, particularly blue bulls and other stray animals. An average yield of 30-kg green biomass per plant in two years in the case of clone 1271, with no irrigation and fertilization showed that nearly 37.5 t/ha of green fodder could be produced from soils that normally are considered unsuitable for other crops. Furthermore, there is a need to study the compatibility of cactus under agroforestry systems in this region. Since consumption of cactus-pear fruits and *nopalitos* is almost unknown in this region, a strong extension service effort would be necessary to create awareness regarding nutritive value and different

methods of utilization. A good extension service must also take into account not only the need for multiplication and supply of planting material but also popularization of the package of practices for cultivation.

Cactus in National Drought Management Planning

The Indian Council of Agricultural Research, New Delhi, an apex research, education, and extension organization of the country has recently prepared a document on National Drought Management. Short-term and long-term strategies for moderating the present drought impact and drought proofing for the future have been suggested. In the long term planning, planting of cactus on all kinds of wastelands, on field boundaries, roadsides, etc. in all the drought prone areas of the country has been strongly emphasized.

On account of multipurpose uses of cactus, a cactus crop may prove a boon for the rehabilitation of degraded sites including wastelands. The low cost of establishing and producing the crop, as well as its tolerance to drought, make cactus imminently suited to becoming a viable future industry in India. The Thar desert in Rajasthan, Rann of Kutch in Gujarat, southwestern parts of Haryana, Bundelkhand, and other similar rainfed areas prone to severe drought would be very productive. Since cactus has good potential for the arid and semiarid India, it would be helpful if we could produce a research and development plan involving people having similar interests to import and exchange *Opuntia* germplasm. To start with, a centre for germplasm collection and its maintenance should be identified. Possibilities must be explored for international collaboration involving people from those countries where the crop is commercially cultivated and has already become a part of their dietary requirements. Also, there is a need for a coordinated effort within the country to promote cactus and its linking with the already existing international network on cactus.

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Figure 1. Multiplication of Cactus Germplasm in Pots Introduced From Texas A&M University-Kingsville

Figure 2. Establishment Performance of Cactus in Different pH Soils

Figure 3. A View of Cactus Growth Under Field Conditions at CSSRI, Karnal

Figure 4. A View of Cactus Orchard at Karnal Four Years After Planting

Figure 5. Dr. Enrique Aries, FAO Cactus Net Coordinator, Discussing Cactus Programme During His Visit to Karnal in 1998

Figure 6. Clone 1270 in Fruiting Nearly 42 Months After Planting

Figure 7. A Closeup of 1270 Cladode Supporting a Large Number of Fruits

Figure 8. Field View of Cactus Plantation at Jhansi

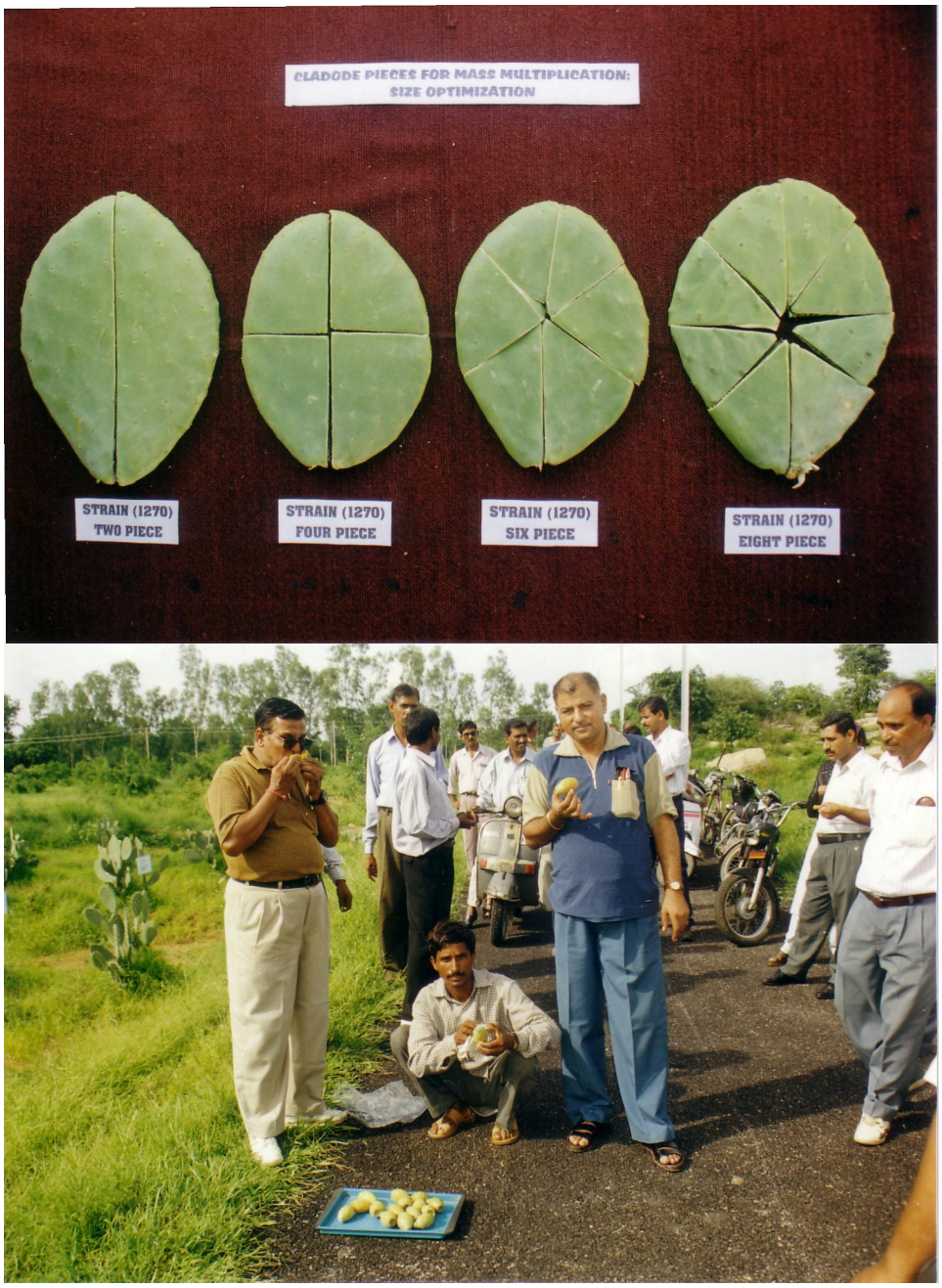

Figure 9. A View of Quicker Germplasm Multiplication of Cactus at Jhansi. Each segment of cactus cladode was able to generate one plant when planted in the field

Figure 10. Cactus Day Celebration During Fruiting Season

Figure 11. Freshly Picked Fruits of Clone 1270 From Cactus Planted at Jhansi