

# Growth and Development Influenced by Size, Age, and Planting Methods of Cladodes in Cactus Pear (*Opuntia ficus-indica* (L.) Mill.)<sup>♦</sup>

R.S. Singh and Vijai Singh\*

Central Institute for Arid Horticulture, Bikaner-334 006 India

\* Head, Department of Horticulture, R.B.S. College, Bichpuri, Agra - 283 105, India

## ABSTRACT

An experiment was conducted to study the effect of size, age, and planting methods of cladodes on relative growth rate and production of cladodes in cactus pear (Clone 1271). The upright planting of full-size cladodes (12 months old, 8 to 15 cm width) significantly influenced the relative growth rate (RGR) and dry weight at 2, 4, and 6 months during *monsoon* (September) and spring (February) seasons. Higher cladode yield was also recorded from planting 12-month-old cladodes as compared to 6-month-old cladodes. Spring (February) planting gave better plant growth.

**Keywords:** cactus pear, cladodes, relative growth rate

## INTRODUCTION

Cactus pear (*Opuntia ficus-indica* (L.) Mill.), also known as prickly pear, is a suitable crop for water-scarcity regions. It is a succulent, xerophytic, spiny or spineless plant of multiple uses (Felker *et al.*, 1997). It requires low inputs to provide food and fodder for sustainable development in arid and semiarid regions. It is being grown worldwide for its delicious sweet fruits, vegetable, nutritive forage, and for several other medicinal as well as industrial uses (Shanker and Saxena, 1976; Mizrahi *et al.*, 1997; Singh and Felker, 1998). In cacti, areoles, which function like meristemic buds, are solely responsible for development of shoot and roots (Buxbaum, 1950). Being a drought-hardy plant, there is tremendous scope of cactus pear production in Indian arid regions. Considering its importance, it was introduced in India from Texas, USA (Pareek *et al.*, 2001). It is propagated by cladodes/stems, or even by their pieces. Variability in growth habit and biomass production has been reported by Carneiro *et al.* (1989) and Scheinvar (1995) in different *Opuntia* spp. However, growth habit in cactus pear varies with type and place of cultivation. The cladode production depends on the environment and genotypes (Anonymous, 1993; Pareek *et al.*, 2001). The role of season and methods of planting also affect productivity. Subsequently, size and age of cladodes also influence growth and development. The information on growth behaviour in cactus pear is very limited. Keeping in view, the investigation was planned to study the effect of size, age of cladode and different methods of planting on growth and cladodes production.

## MATERIAL AND METHODS

The present studies were undertaken at the Department of Horticulture, R.B.S. College, Bichpuri, Agra (U.P.), India, in two seasons, i.e., spring (February) and *monsoon* (September) of 1998-1999 and 1999-2000 using Factorial Randomized Block Design with four replications. The soil of the experimental site was fertile sandy loam. The annual average rainfall is 700 mm in the Agra region. During summer, temperature goes as high as 48°C in May and June. The winter season is very cold and temperature goes as low as 0°C in December and January, with occasional rains. The planting material was obtained from

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Central Soil Salinity Research Institute, Karnal, and Central Institute for Arid Horticulture, Bikaner, India. For the study, cactus-pear clone Texas A&M University-Kingsville accession 1271, originally provided by Dr. Severino Gonzaga Albuquerque in Petrolina, Brazil, where this forage variety was known as *Palma gigantea*, was used which produces abundant fruits at a young age. The cladodes of this strain are spineless, vigorous, erect, and fast growing. The height of plants is 1.5 to 2.5 m. Production of fruit starts 3 to 4 years after planting on 1- to 2-year-old cladodes. Fruits are large in size (average weight of 150 g). The flesh is light yellow in colour, sweet in taste (TSS 14.0°Brix). According to age, the cladodes were separated into two groups: 6 months old and 12 months old. In each age group, they were further subdivided by size of cladodes into 10- to 15-cm, 10- to 12-cm, and 8- to 10-cm widths (all whole cladodes) and into 6- to 8-cm, 4- to 6-cm and 2- to 4-cm widths of cut pieces. All these cladodes were planted by five methods: upright, flat, at a 30-degree angle in flat beds, upright planting on ridges, and at a 30-degree angle on ridges at 100-cm x 50-cm spacing. For ridge planting, 15- to 20-cm-high ridges were prepared. Five cladodes or pieces as per treatment, excluding border plants, were planted. The orientation of cladode at planting was kept in east-west direction. The common cultural operations such as irrigation, hoeing, weeding, plant protection, etc., were followed during the study. Fresh and dry weights of cladodes in each treatment were recorded before planting in each season. The cladodes were dipped in Bavistin (Carbendazim) solution (0.2%) for 5 minutes at the time of planting to check disease infection. The relative growth rate (RGR) of plants was measured at intervals of 2, 4, and 6 months after planting during both the seasons. One plant from each replication per treatment at every stage was uprooted carefully and washed with water to record observations. Fresh and dry (oven dry) weights of plants were recorded and RGR in milligrams per month was calculated by using the formula described by Noggle and Fritz (1986).

$$\text{RGR} = \frac{2.303 (\log_{10} W_2 - \log_{10} W_1)}{t_2 - t_1}$$

Where  $W_2$  and  $W_1$  are the dry weights of the plant at final ( $t_2$ ) and initial ( $t_1$ ) times, respectively.

The relative growth rate was calculated on the basis of increase in dry weight at successive stages of growth in milligrams per month. The number of cladodes per plant and dry weight (in grams) of plants were recorded 6 months after planting during both the seasons. The pooled data were subjected to statistical analysis.

## RESULTS AND DISCUSSION

### Relative Growth Rate

The RGR in cactus pear was calculated on the basis of increase in dry weight at intervals of 2, 4, and 6 months after planting. The final-stage data on Relative Growth Rate values are presented in Table 1. The data revealed that size, age, and planting methods of cladodes significantly affected RGR values during both the seasons. Plantings of 12-month-old cladodes exhibited significantly higher relative growth rates than the plantings of 6-month-old cladodes in both the seasons. The higher relative growth rate obtained in 1-year-old planted cladodes possibly may be due to its appropriate age and a larger number of active areoles having more accumulated food material at planting time, which was further utilized for root and shoot growth after planting. The results agree with those of Nobel (1988) and Mizrahi *et al.* (1997). The maximum relative growth rate was observed in upright, at 30-degree-angle planting in flat beds, and upright planting on ridges compared to other methods of planting. However, variations in RGR values due to different planting methods (upright, planting at a 30-degree angle in flat beds, as well as planting on ridges) were statistically similar during both the seasons of planting. The values of RGR at 2, 4, and 6 months after planting in upright, at a 30-degree angle in flat beds, as well as on ridges, might be due to

interception of more light (photoperiod) and temperature in these methods of planting, which, in turn, influenced the relative growth rate. Similar results also have been reported by Nobel (1988) and Mora and Palmela (1996). Cladodes of all the sizes differed significantly among themselves with respect to relative growth rate. It is noteworthy that the RGR values (in milligrams per month) recorded during the spring season were remarkably higher than those of the *monsoon* (September) season. It possibly may be due to vigorous growth in the warmer season. The treatment combinations between size, age, and planting methods of cladodes also influenced the relative growth rate significantly during both the seasons after 6 months of growth.

With the decrease in width of planted cladodes from 10-15 cm to 2-4 cm, there was a noticeable decrease in RGR values during both the seasons. The higher RGR value, in terms of dry weight increase in cladodes obtained by planting a full size cladode of 10-15 cm width followed by 10-12 cm and 8-10 cm, was probably be due to vigorous root and shoot growth. Further, it also might be due to accumulation of relatively more photosynthates. Similar results have been reported by Anonymous (1993) while working on evaluation of cactus pear genotypes under semiarid conditions of Phaltan, Maharashtra, India.

A similar pattern of effect of size of cladodes on RGR was also recorded at 2 and 4 months after planting. The variation in RGR values at 2, 4, and 6 months revealed that faster growth of the plants occurred between 2- to 4-month intervals. Luo and Nobel (1993) found that the growth rate in cacti (*Opuntia* sp.) increased rapidly within the first 30 days after planting; afterward, the increase was more or less linear.

### **Number of Cladodes per Plant**

The cladodes produced per plant were harvested 6 months after planting and mean values were analysed statistically for both the seasons. Data presented in Table 2 revealed that the planting of 12-month-old cladodes produced more cladodes compared to the planting of 6-month-old cladodes during the spring season. However, the differences were not statistically significant. To the contrary, the difference due to planting of 12-month-old and 6-month-old cladodes was significant in the *monsoon* season.

The upright planting of cladodes in flat beds produced the maximum number of cladodes per plant (1.56 and 1.57) during the *monsoon* and spring seasons, respectively (Table 2). However, upright planting of cladodes on ridges was equally good and superior to the other methods tried in this study with respect to cladodes-per-plant production.

The size of planted cladodes affected significantly the number of cladodes formed per plant during both the seasons. The results of planting full-size cladodes of 10-15 cm, 10-12 cm, 8-10 cm width were similar for the production of new cladodes 6 months after planting. Moreover, these treatments were significantly superior to other treatments. The interactions between size, age, and methods of planting cladodes also influenced the production of cladodes per plant (Table 2). The formation of more cladodes per plant possibly may be due to the presence of a larger number of active areoles, i.e., meristemic buds, which are solely responsible for cladode production. Further, more reserve food material in a full-size cladodes and favourable climatic conditions also may be responsible for the formation of a larger number of new cladodes. Similar opinions regarding formation of cladodes in cactus also have been expressed by Buxbaum (1950), Gathaara *et al.* (1987), Anonymous (1993), and Mizrahi *et al.* (1997).

### **Dry Weight of Cladodes**

Data presented in Table 3 showed that dry-matter production of cladodes at harvest was influenced significantly by all the treatments during both the seasons. The planting of 12-month-old cladodes was significantly superior to planting 6-month-old cladodes with respect to the dry weight of cladodes per plant during the *monsoon* and spring seasons. The findings broadly concur with the results of Gathaara *et al.* (1987) and Anonymous (1993) who reported higher values due to planting older material (1-2 years

old). The minimum dry weight was recorded by planting 12-month-old full-size cladodes on ridges. The maximum dry weight of cladodes was observed in the upright planting method during the monsoon season and in upright planting on ridges during the spring season. These treatments were statistically superior to the other methods of planting. The data presented in Table 3 revealed that the dry weight of cladodes was maximum in full-size cladodes (10-15 cm width) viz. 10.24 g in monsoon and 9.46 g in spring season. The reduction in size of planted cladodes from 10-15 cm to 10-12 cm caused significant reduction in dry-matter content of cladodes during both the seasons. The treatment combinations also affected this characteristic significantly during both the seasons. The gain in fresh and dry weight is basically the function of overall biomass production. The results showed a good response of treatments on dry weight of cladodes, and it was higher during *monsoon* than the spring season of planting. It indicates that the season factor also dominated the treatments. Such findings in the case of prickly pear are not uncommon (Russells and Felker, 1987; Gathaara *et al*, 1987).

Thus, it can be concluded that upright planting of 1-year-old full-size cladodes of 8 to 15 cm width was found suitable for obtaining a higher rate of plant growth and dry weight, as well as a larger number of cladodes per plant in cactus pear.

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Table 1. Effect of Size, Age, and Methods of Planting Cladodes and Their Interactions on Relative Growth Rate (mg/month) Months After Planting

Treatments	Monsoon (September) Season						
	Method of Planting						
	Upright	Flat	At 30° angle	Upright on ridges	At 30° angle on ridges	Mean	
<b>Age of cladode</b>							
6 months old	407	293	380	388	369	<b>367.8</b>	
12 months old	430	384	390	386	401	<b>398.8</b>	
<b>Size of cladode</b>							
10-15 cm width	556	373	499	505	512	<b>490.0</b>	
10-12 cm width	485	412	481	525	496	<b>480.0</b>	
8-10 cm width	473	356	432	450	486	<b>440.0</b>	
6-8 cm width piece	413	341	330	326	337	<b>350.0</b>	
4-6 cm width piece	306	294	312	280	256	<b>289.9</b>	
2-4 cm width piece	277	254	258	237	222	<b>250.1</b>	
<b>Mean</b>	<b>418.9</b>	<b>339.2</b>	<b>385.7</b>	<b>387.5</b>	<b>385.3</b>	--	
	<b>Age</b>	<b>Method</b>	<b>Size</b>	<b>Age x Method</b>	<b>Age x size</b>	<b>Method x size</b>	<b>Age x method x size</b>
<b>SEM±</b>	1.24	1.96	2.15	2.77	3.04	4.81	6.80
<b>CD. at 5%</b>	3.44	5.44	5.96	7.70	8.43	13.34	18.86
Treatments	Spring (February) Season						
	Method of Planting						
	Upright	Flat	At 30° angle	Upright on ridges	At 30° angle on ridges	Mean	
<b>Age of cladode</b>							
6 months old	420	307	394	382	402	<b>381.3</b>	
12 months old	444	380	404	414	399	<b>412.2</b>	
<b>Size of cladode</b>							
10-15 cm width	586	406	529	542	535	<b>520.1</b>	
10-12 cm width	508	435	504	519	548	<b>503.3</b>	
8-10 cm width	479	362	438	493	456	<b>446.1</b>	
6-8 cm width piece	419	347	336	343	332	<b>355.8</b>	
4-6 cm width piece	312	299	318	262	286	<b>295.8</b>	
2-4 cm width piece	287	263	268	231	246	<b>259.6</b>	
<b>Mean</b>	<b>432.4</b>	<b>352.6</b>	<b>399.1</b>	<b>398.7</b>	<b>400.9</b>	--	
	<b>Age</b>	<b>Method</b>	<b>Size</b>	<b>Age x Method</b>	<b>Age x size</b>	<b>Method x size</b>	<b>Age x method x size</b>
<b>SEM±</b>	0.76	1.20	1.31	1.70	1.86	2.94	4.16
<b>CD. at 5%</b>	2.10	3.33	3.65	4.71	5.16	8.16	11.54

Table 2. Effect of Size, Age, and Methods of Planting Cladodes and Their Interactions on Number of Cladodes Produced Per Plant 6 Months After Planting

Treatments	Monsoon (September) Season						
	Method of Planting						
	Upright	Flat	At 30° angle	Upright on ridges	At 30° angle on ridges	Mean	
<b>Age of cladode</b>							
6 months old	1.38	1.19	1.08	1.40	1.35	<b>1.28</b>	
12 months old	1.75	1.27	1.04	1.48	1.25	<b>1.36</b>	
<b>Size of cladode</b>							
10-15 cm width	1.75	1.31	1.06	1.31	1.31	<b>1.35</b>	
10-12 cm width	2.13	1.44	1.00	1.56	1.38	<b>1.50</b>	
8-10 cm width	1.69	1.38	1.25	1.81	1.19	<b>1.46</b>	
6-8 cm width piece	1.75	0.94	1.00	1.75	1.19	<b>1.33</b>	
4-6 cm width piece	1.13	1.25	1.06	1.00	1.44	<b>1.18</b>	
2-4 cm width piece	0.94	1.06	1.00	1.19	1.31	<b>1.10</b>	
<b>Mean</b>	<b>1.56</b>	<b>1.23</b>	<b>1.06</b>	<b>1.44</b>	<b>1.30</b>	<b>--</b>	
	<b>Age</b>	<b>Method</b>	<b>Size</b>	<b>Age x Method</b>	<b>Age x size</b>	<b>Method x size</b>	<b>Age x method x size</b>
<b>SEm±</b>	0.02	0.03	0.04	0.05	0.06	0.09	0.01
<b>CD at 5%</b>	0.06	0.11	0.11	0.15	0.16	0.26	0.30
Treatments	Spring (February) Season						
	Method of Planting						
	Upright	Flat	At 30° angle	Upright on ridges	At 30° angle on ridges	Mean	
<b>Age of cladode</b>							
6 months old	1.35	1.25	1.15	1.42	1.40	<b>1.31</b>	
12 months old	1.79	1.33	1.08	1.54	1.27	<b>1.40</b>	
<b>Size of cladode</b>							
10-15 cm width	1.81	1.50	1.25	1.38	1.44	<b>1.48</b>	
10-12 cm width	2.19	1.50	1.13	1.75	1.50	<b>1.61</b>	
8-10 cm width	1.63	1.31	1.25	1.75	1.13	<b>1.41</b>	
6-8 cm width piece	1.75	1.00	1.00	1.63	1.25	<b>1.33</b>	
4-6 cm width piece	1.06	1.25	1.00	1.13	1.38	<b>1.16</b>	
2-4 cm width piece	1.00	1.19	1.06	1.25	1.31	<b>1.16</b>	
<b>Mean</b>	<b>1.57</b>	<b>1.29</b>	<b>1.11</b>	<b>1.48</b>	<b>1.33</b>	<b>--</b>	
	<b>Age</b>	<b>Method</b>	<b>Size</b>	<b>Age x Method</b>	<b>Age x size</b>	<b>Method x size</b>	<b>Age x method x size</b>
<b>SEm±</b>	0.04	0.06	0.06	0.08	0.09	0.15	0.21
<b>CD at 5%</b>	NS	0.17	0.19	0.25	0.27	0.43	0.61

Table 3. Effect of Size, Age, and Methods of Planting Cladodes and Their Interactions on Dry Weight of Cladodes Per Plant (g) 6 Months After Planting

Treatments	Monsoon (September) Season						
	Method of Planting						
	Upright	Flat	At 30° Angle	Upright on Ridges	At 30° Angle on Ridges	Mean	
<b>Age of cladode</b>							
6 months old	8.35	7.38	9.28	9.00	8.00	8.40	
12 months old	10.04	8.48	8.40	9.00	9.60	9.10	
<b>Size of cladode</b>							
10-15 cm width	11.19	10.19	10.13	8.00	11.69	10.24	
10-12 cm width	9.63	9.38	8.81	11.50	9.81	9.83	
8-10 cm width	9.94	8.44	9.88	10.50	8.94	9.40	
6-8 cm width piece	7.97	6.69	9.13	8.94	8.19	8.18	
4-6 cm width piece	8.00	6.88	8.19	8.44	7.44	7.79	
2-4 cm width piece	8.50	6.00	6.88	6.88	6.73	7.00	
<b>Mean</b>	<b>9.20</b>	<b>7.93</b>	<b>8.83</b>	<b>9.00</b>	<b>8.80</b>	-	
	<b>Age</b>	<b>Method</b>	<b>Size</b>	<b>Age x Method</b>	<b>Age X Size</b>	<b>Method X Size</b>	<b>Age X Method X Size</b>
<b>SEm±</b>	0.09	0.15	0.17	0.22	0.24	0.38	0.53
<b>CD at 5%</b>	0.27	0.43	0.47	0.61	0.66	1.05	1.49
Treatments	Spring (February) Season						
	Method of Planting						
	Upright	Flat	At 30° Angle	Upright on Ridges	At 30° Angle on Ridges	Mean	
<b>Age of cladode</b>							
6 months old	5.00	6.70	6.98	6.08	5.73	6.10	
12 months old	6.21	6.71	6.07	7.63	7.27	6.79	
<b>Size of cladode</b>							
10-15 cm width	9.41	7.20	9.37	10.38	10.36	9.46	
10-12 cm width	7.06	9.21	6.50	7.36	7.59	7.54	
8-10 cm width	6.10	7.88	7.51	7.56	6.56	7.12	
6-8 cm width piece	3.59	5.94	6.11	4.90	5.09	5.22	
4-6 cm width piece	4.36	5.89	5.61	5.48	4.93	5.25	
2-4 cm width piece	3.11	4.10	4.06	5.60	3.88	4.15	
<b>Mean</b>	<b>5.60</b>	<b>6.90</b>	<b>6.53</b>	<b>6.88</b>	<b>6.50</b>	-	
	<b>Age</b>	<b>Method</b>	<b>Size</b>	<b>Age X Method</b>	<b>Age X Size</b>	<b>Method X Size</b>	<b>Age X Method X Size</b>
<b>SEm±</b>	0.08	0.23	0.14	0.18	0.21	0.32	0.46
<b>CD at 5%</b>	0.13						