

Original Research Article

Effect of Shade Levels on Growth, and Biomass Production of Cactus (*Opuntia ficus-indica* (L.) Mill.)

Rahul Dev^{1*}, J. P. Singh², Traloki Singh¹ and Devi Dayal¹

¹ICAR-Central Arid Zone Research Institute, Regional Research Station, Kukma, Bhuj, Gujarat 370105, India

²ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan 342003, India

*Corresponding author

ABSTRACT

An experiment was conducted during 2016-17 in the shade house to study the effect of different shade levels on the growth and biomass production potential of Cactus (*Opuntia ficus-indica* (L.) Mill.) under the arid Kachchh, Gujarat. Cactus in pots were grown for twelve months under 25, 50 and 75% shade; along with under full sun control. Shade level significantly affected plant response; the shading improved plant characters like height, number of leaves, leaf area, and overall plant weight. However, plant survival decreases at under high shade level (75%), mainly due to rotting. The plants grown in 25% and 50% shade levels produced the highest leaf area, no. of leaves and biomass than plants subjected to 75% shade and control. Plants grown under 75% shade level were taller, due to more longitudinal and less wide leaves (cladodes) along with more root length. Overall, up to 50% shading was found best for horti-based or agroforestry based cactus pear cultivation or intercropping.

Keywords

Opuntia ficus-indica, Shade level, Biomass, Cladode

Introduction

Cactus pear is an important species commercially cultivated in more than 20 countries. *Opuntias* meet the most important criteria for fodder crops in drought prone regions like Thar Desert, arid and semiarid Kachchhand other similar regions of India. Cactus pear (*Opuntia ficus-indica*) can tolerate water-limited conditions, high temperatures and poor soils (Singh 2003). *Opuntia* species possess crassulacean acid metabolism (CAM) pathways and hence capable of converting water to biomass fourfold more efficiently than either C4 or C3 plants (Han and Felker, 1997). They can be a source of water and dry matter in water-limited areas when fed to animals as green

feed. It is a multi-purpose plant since it can be used for direct human consumption (fruit and vegetable) and raw material for various industries to prepare plywood, soap, dyes, adhesives, glue, serve as medicines and cosmetics such as shampoo, cream, body lotions. Cactus belong the family Cactaceae, having 1600 species. The genus *Opuntia* contains 180 species, mostly consisting of platyopuntias with their stems occurring as flattened segments termed as cladodes (Roy. Cactus provides live green fodder which can be cut and fed to livestock along with other recommended fodder additives during drought. Nutritive values of cladodes vary with species, cladode age, growing season,

soil fertility and management practices. Cactus can be planted on communal rangelands and grazing lands. Cactus goes well with existing cropping systems. Due to shallow root system, there will not be any competition to the deep rooted plants. Studies at Bikaner also showed that cactus can be cultivated along with agroforestry trees such as *Tecomella undulata* and *Prosopis cineraria* (Yadava *et al.*, 2017). Suitability of cactus in different cropping and farming system models such as silvi-pasture and agro forestry systems need to be assessed for different agro-climatic regions of country.

There is no study conducted in the past in India to access the shade tolerance limit of cactus pear, this is the novel attempt aimed to evaluate the effect of shade levels on growth and yield of Cactus pear, in order to provide suitable cultivation practices with maximum yield.

Materials and Methods

Site characteristics

The present investigation was conducted at horticulture nursery of Central Arid Zone Research Institute, Regional Research Station Kukma, Bhuj- Gujarat (latitude 23.212°N, longitude 69.79°E) from March 2016- June 2017 under net house conditions as well as open condition. The climate of the region is hot arid to semi-arid with a maximum temperature range from 39 to 45° C during May - June and minimum from 1 to 8° C during December- January (Mangalassery *et al.*, 2017). The average rainfall of Kachchh is 385 mm (average of 1998 to 2016) with 71.25% of coefficient of variation and most of rainy days occur during July to September with high evapotranspiration that ranges from 1500 to 2000 mm per year.

Planting materials

Uniform sized mature cladodes (one year old) of CAZRI Botanical Garden accession of *Opuntia ficus-indica* were selected and separated from 4 year old mother plants situated at farm of CAZRI RRS Bhuj. The daughter cladodes were left for suberization under shade condition for one week to minimize the microbial infection during planting.

The planting was done in the month of March, 2016 in the plastic pots (20 × 20 cm) under green coloured plastic shade net with three different shade levels (25%, 50%, and 75%). Radiation under shade net with different shading levels was found to be lower as compared to full sun condition. Plastic nets alter the spectrum of the filtered light thereby lower the transmittance level and enrich the content of scattered light (Oren-Shamir *et al.*, 2001). PAR levels were also reduced under shade nets of different shade levels (Gaurav *et al.*, 2015). The cactus growth and production under these shade levels were compared with the open field cactus growth and production (without shade nets). The bottom of pots (approx. 5 cm) filled with concrete materials to facilitate drainage. The remaining part filled with mixture of sand, soil and FYM (2:2:1). The suberized cactus cladodes were planted in the pots, for planting one third portion of cladode was inserted in the pot mixture. The 10 cladodes of cactus pear were planted in each treatment with three replication. The cut portion of cladodes was treated with Carbendizam fungicide @ 2 g lit⁻¹ solution to check the rotting and fungal infection. Different plant characteristics like plant height (cm), cladode length (cm), cladode width (cm), cladode thickness (mm), No. of daughter cladodes/ mother cladodes, were measured during different growth stages. The cladodes thickness was estimated

through digital vernier caliper at top, middle and bottom and averaged. Leaf area (cm^2), plant fresh weight, plant dry weight etc. were recorded at the end of experiment. Due to thickness of cactus cladode, the direct measurement of cactus leaf area was not possible using the leaf area meter. Therefore, the leaf area of cladode was determined by tracing the actual area on the colored paper. The leaf area was measured using Leaf area meter (Licor-3100). The leaf area measurement is a determining factor in crop mechanisms such as radiation interception and water and energy exchange (Peksen, 2007).

The plants were uprooted at the end of experiment for measurement of plant fresh weight and root parameters. Plant fresh weight and root fresh weight were noted in the field with the help of portable weighing balance. Root dry weight was recorded after drying of roots at 72°C for 48 hours. While, cladodes were dried at 100°C until no further weight change occurred before drying, 3-4 parallel cut was made with the help of sharp knife to facilitate quick and complete drying.

The treatments were arranged in a completely randomized design with three replications. Each replication contained thirty plants. Analysis of Variance was performed to determine significant differences among treatments ($P < 0.05$) using Statistical Software Package for Agricultural Research Workers (Sheoran *et al.*, 1998).

Results and Discussion

Plant survival

Plant survival of cactus pear was significantly ($p < 0.05$) influenced by different level of plant shading (Table 1). Up

to 50% shade was positive for increasing plant survival. However, shade of 75% had negative effect on plant establishment as cactus cladodes was susceptible to microbial rotting under this shading. Highest mean cladode survival was noted under 25% shade level ($91.66 \pm 4.41\%$), followed by open sun condition ($81.66 \pm 6.0\%$). While, minimum plant survival was noted under highest shade level (75%) *i.e.* $71.33 \pm 4.09\%$ at 12 months after planting (MAP). Plants grown under 25% and 50% shade levels showed good survival (91.66 ± 8.33 and $83.33 \pm 8.33\%$ respectively), upto 3 months of growth, however, afterward survival rate decreased to $76.66 \pm 1.66\%$ and $75.0 \pm 0.0\%$ respectively. Higher mortality was observed under 75% shade level than other shade treatments.

Plant height and No. of leaves (cladodes) plant⁻¹

Plant height was significantly influenced by shade treatment over the open sun condition. Reduced radiation level increased plant height due to increase in the cladode length, while it reduced the thickness and width of cactus cladode. Plants grown under 75% shade level was found to be tallest (117.33 ± 2.03 cm), followed by 50% shade level (100.94 ± 0.77 cm) and 25% shade (83.71 ± 1.73 cm). While, plants grown in open field (T4) were the shortest (50.72 ± 1.43 cm). It showed that shade had positive effect on plant height on cactus pear. The number of cladodes was found to be highest in plants grown in 50% shade (8.33 ± 0.67), and it was on par with 25% and 75% shade levels.

Cladode length (cm), width (cm), and thickness (mm)

Growth of cactus cladode was significantly influenced by the shade levels. Cactus

cladodes grew more longitudinally than those in the open field. Maximum cladode length was recorded under 75% shade level (27.33 ± 0.64 cm), followed by in plants grown under 50% shade level (22.40 ± 1.50 cm) and 25% shade level (21.57 ± 0.47 cm). However, minimum cladode length (20.83 ± 1.28 cm) was found in the plants received full sunlight (T4). As the radiation level reduced, the thickness and width of cladodes decreases. More thinner (13.57 ± 0.33 mm) and narrow (6.67 ± 0.51 cm) cladodes was reported under 75% shade level.

Among the shade treatments, maximum thickness (15.28 ± 1.44 cm) and width (7.42 ± 0.37 cm) of cladodes was recorded in the plants subjected to 25% shade level. However, the maximum thickness and width of cladodes reported in the plants grown under full sun (19.50 ± 1.80 mm and 8.58 ± 0.17 cm respectively).

Total Soluble Solids (T.S.S)

Although the content of TSS did not differ significantly due to shade treatment. Full sun exposer resulted highest TSS content in the cactus cladodes ($3.03 \pm 0.38^{\circ}$). Among the shade treatment, plants with 25% radiation provided better TSS ($2.90 \pm 0.34^{\circ}$). While, minimum ($2.30 \pm 0.36^{\circ}$) was noted under the higher shade treatment (75% shade) level.

Leaf Area per Plant

Cactus leaf area (LA) was enhanced by shade treatment (fig. 4). LA was the lowest under open condition and it was increased with increasing shade level upto 50% shade level afterword it declined. Maximum leaf area was recorded under 50% shade (116.68 cm²) than 25% shade (112.71 cm²) and 75% (109.80 cm²) shade levels. Plants grown in open field (T4) developed significantly

lowest leaf area (104.40 cm²). It showed that partial shade considerably increased leaf area in cactus plants.

Root length (cm)

The root length was measured at the end of experiment and it was found to be increasing with increase in shade levels as it was the highest under 75% shade level (44.25 cm) followed by 50% shade (39.33 cm), and 25% shade (29.46 cm). The root growth was also better (42.67) under without shade treatment. With respect to root volume and no. of roots, it was found better (data no presented) in the plant received full sun light compared to shade treatment. The shoot: root length ratio was measured at the end of experiment. It was found to be maximum (0.65) in plants grown in full sun condition followed by under 50% shade (0.38) and minimum in 75% shade level (0.32) (Fig 3).

Biomass production

The light availability strongly affected dry matter production of cactus plant (Fig. 1). Fresh weight of whole plant was found to be increased with increase in shade level up to 50%, then declined. The highest plant fresh biomass was under 50% shade (1086 g) followed by 25% shade (1007.83 g). However, fresh biomass was minimum (875.52 g) under full sun light condition. The dry weight followed the similar trend in the plants subjected to shade treatment (Fig. 1). However, higher dry weight was recorded in the plants exposed to full sun light conditions. The maximum shoot fresh: dry weight ratio (0.57) was recorded in the plant grown subjected to without shade treatment. However, among the shade treatments shoot fresh and dry weight ratio were higher under 50% shade condition (0.33), which was at par with 25% (0.27) and 75% (0.27) shade levels.

Table.1 Effect of shading on Cactus pear survival and growth

Treatment	Day to sprouting (days)	Plant survival (%)				No. of sprouts/cladodes				Plant height (cm)			
		1 MAP	3 MAP	6 MAP	12 MAP	1 MAP	3 MAP	6 MAP	12 MAP	1 MAP	3 MAP	6 MAP	12 MAP
Shade 25%	24.08 ±2.28	95.66 ±8.33	93.33 ±8.33	93.33 ±8.33	91.66 ±4.41	1.42 ±0.33	2.00 ±0.25	3.33 ±0.17	8.08 ±0.74	18.31 ±1.29	22.09 ±1.98	36.81 ±1.52	83.71 ±1.73
Shade 50%	25.08 ±1.99	91.66 ±8.33	91.66±8.33	76.66 ±1.66	75.00 ±2.88	1.17 ±0.46	2.25 ±0.52	3.00 ±0.80	8.33 ±0.67	17.04 ±0.42	20.53 ±1.23	37.13 ±4.55	100.94 ±0.77
Shade 75%	25.83 ±1.88	91.66 ±8.33	83.33±8.33	75.0 ±0.00	71.33 ±4.09	1.67 ±0.60	1.75 ±0.14	1.83 ±0.17	8.00 ±0.58	24.35 ±0.89	28.56 ±2.43	41.00 ±6.44	117.33 ±2.03
Full sunlight	29.28 ±1.30	100.0 ±0.00	91.66±4.41	83.33 ±4.41	81.66 ±6.00	1.33 ±0.36	1.83 ±0.60	3.42 ±0.58	6.92 ±0.58	7.36 ±1.57	10.42 ±1.33	27.67 ±1.73	50.72 ±1.43
C.D (5%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.74	5.99	16.09	6.05
SE(m)	1.90	7.21	5.611	4.689	5.104	0.45	0.42	0.56	0.40	1.13	1.81	4.56	1.72

MAP: Months after planting

Table.2 Effect of shading on Cactus pear growth and TSS content

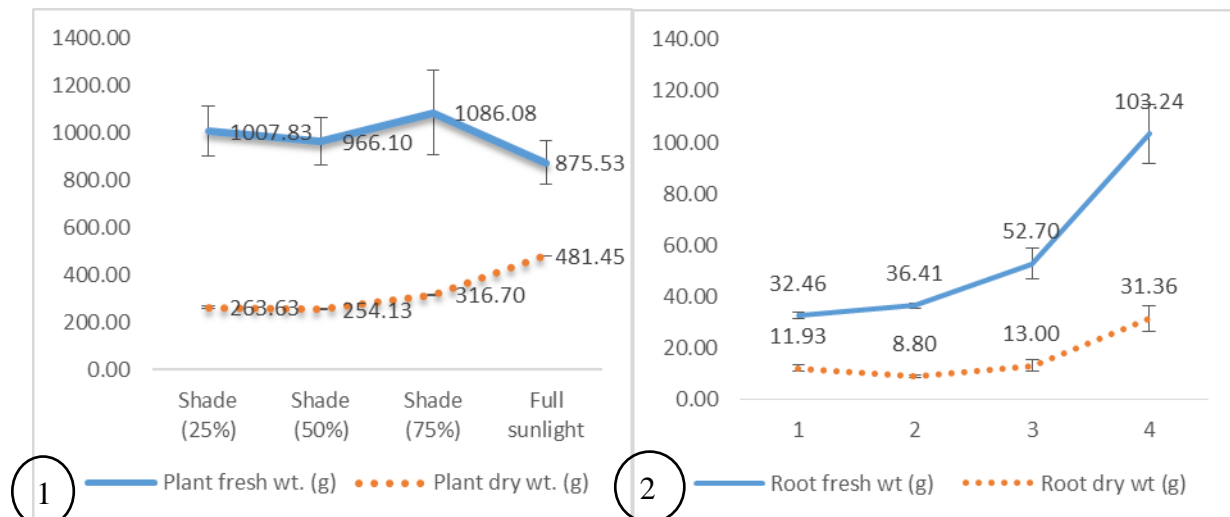
Treatment	Cladodes width (cm)				Cladodes thickness (mm)				Cladodes length (CM)				Cladode TSS
	1 MAP	3 MAP	6 MAP	12 MAP	1 MAP	3 MAP	6 MAP	12 MAP	1 MAP	3 MAP	6 MAP	12 MAP	
Shade 25%	2.45 ±0.30	2.88 ±1.10	3.03 ±0.25	7.42 ±0.37	3.18 ±0.35	3.15 ±0.51	4.99 ±1.71	15.28 ±1.44	8.60 ±0.17	12.43 ±0.50	17.33 ±0.60	21.57 ±0.47	2.90 ±0.34
Shade 50%	2.00 ±0.09	2.38 ±0.72	3.68 ±1.00	7.25 ±0.19	2.07 ±0.51	4.24 ±0.32	5.12 ±0.89	14.09 ±0.23	7.73 ±0.39	12.07 ±0.81	16.20 ±0.58	22.40 ±1.50	2.43 ±0.22
Shade 75%	1.96 ±0.61	2.75 ±0.08	2.73 ±0.16	6.67 ±0.51	3.78 ±1.15	3.31 ±0.20	5.49 ±1.00	13.57 ±0.33	8.57 ±0.20	12.57 ±1.17	20.20 ±0.44	27.33 ±0.64	2.30 ±0.36
Full sunlight	2.46 ±0.51	3.07 ±0.50	5.53 ±0.87	8.58 ±0.17	5.08 ±1.28	4.40 ±1.15	9.55 ±1.44	19.50 ±1.80	7.73 ±0.39	11.40 ±0.59	17.40 ±0.59	20.83 ±1.28	3.03 ±0.38
C.D. (5%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.75	N/A	N/A	1.50	4.29	N/A
SE(m)	0.43	0.57	0.71	0.39	0.91	0.66	1.12	1.06	0.31	0.81	0.43	1.22	0.38

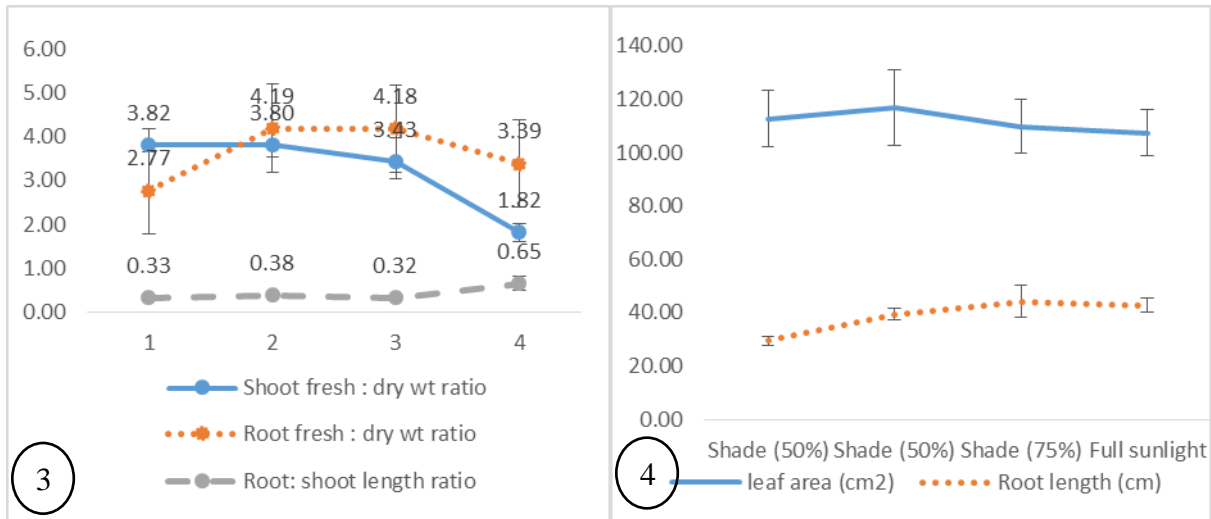
MAP: Months after planting

Image.1-4 Root growth of cactus affected by different shade levels (A 25% shade (T₁); B 50% shade (T₂); C 75% shade (T₃) and D full sun control (0% shade) (T₄)



Fig.1-4 Effect of shading on cactus fresh and dry biomass production. (1: Plant fresh and dry weight; 2: Root fresh and dry weight; 3: shoot and root fresh: dry weight ratio & root: shoot length ratio; 4: leaf area and root length)





Among the treatment, the highest root weight was observed in control (103.24 g) followed by under 75% shade (52.70 g) and 50% shade (36.41 g) (Fig 2). While, minimum fresh root weight was in 25% shade. The similar trend was noted for dry root weight, except for 50% shade in which minimum dry root weight recorded. The root fresh: dry weight ratio was maximum in 25% shade (37), closely followed by without shade control (0.30) treatment.

The aim of study was to determine the shade tolerance limit of cactus pear for cultivation under agroforestry or horti-based cultivation or inter cropping with other agronomic crops. Plant survival of cactus pear was significantly ($p < 0.05$) influenced by different levels of plant shading. Plants grown under less shade levels increased the establishment of plantlets than without shade control. While, as shade level increased more than 50% plant mortality was observed mainly due to microbial rotting of cladodes. This may be due to high humidity inside the shade net and cactus plant are susceptible to microbial infection under high moisture conditions (Gaurav *et al.*, 2015). Reduced radiation level increased plant height due to longitudinal

growth of cladode. Plants grown under higher shade level are found to be tallest followed by lower shade level. Cladode length was more in the plant received shading than those in the open field. The number of cladodes was found to be highest in plants grown in 50% shade. It seems that shade had positive effect on growth traits of cactus pear. Higher plant height and no. of leaves of cordyline plant was recorded under shade condition compared to open condition (Gaurav *et al.*, 2015). Similar observations were reported in tomato where, taller plants were recorded when grown under partial shade condition (Bibi *et al.*, 2012). While, plants grown under open condition (control) had the lowest plant height (Hlatshwayo and Wahome, 2010). Growth of cactus cladode was influenced under the low radiation level than open sun, mainly because, cactus leaves (cladodes) grew more longitudinally than those in the open field. However, the leaf thickness and width were reduced in plants grown in shade. This trend was supported by previous study where, lowest leaf thickness and width were noted under high shading of plants [9, 12]. Full sun exposure resulted highest TSS content, although the difference was non-significant. Leaf area was lowest under open condition and it increased with

increasing shade level upto 50% shade afterword it declined. It showed that partial shade increased leaf area in cactus plants. Increase in leaf area under shading conditions was observed in plants grown in environments with low light intensity [9, 13]. However, extreme shading had negative effects on expansion and growth of cactus leaves. Reduction in photosynthesis and subsequent growth due to not receiving the sufficient amount of light may be a possible reason for this (Srikrishnah *et al.*, 2015). However, higher leaf area under shade conditions might be possibly due to greater relative growth rate in shaded plants (Marenco and Reis., 1998).

The root length found to be increasing with increase in shade levels. The root volume, no. of roots (data no presented) and shoot: root length ratio, was found to be better in plants grown in full sun condition followed by under 50% shade and minimum in 75% shade level, this may be due favorable growing condition under shade (Gaurav *et al.*, 2015). The light availability strongly affected daily dry matter production of cactus plant. Fresh weight of whole plant was found to be increased with increase in shade level up to 50%, then declined. However, root weight was more under full sun (control) followed by shade treatment. Plant biomass and productivity are interrelated, which influence the growth and development of a crop (Gaurav *et al.*, 2015; Srikrishnah *et al.*, 2015 and Guo, 2007).

Shade has significant influence on cactus pear growth and biomass production. Compare to open sun conditions, shading (upto 50%) is beneficial for plant establishment, leaf area and biomass production. However, higher shading (75%) has negative effect on plant survival due to microbial rotting, and lower dry biomass reduction.

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