Influence of *Prosopis cineraria* L. on microclimate conditions under agroforestry system in arid region of India

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ABSTRACT : Microclimate plays significant role in agroforestry systems. Present study was undertaken to understand the microclimate modification through light, canopy temperature and moisture under tree canopy of *Prosopis cineraria* (khejri) for understorey cactus pear in the arid ecosystems of western Rajasthan. Suberization treatment of cladode recorded maximum number of sprouting kids (1.66/cladode) and significantly higher number/cladode was recorded at 20% moisture loss. Tree distance influenced the sprouting behaviour of cladode, irrespective of moisture loss. The cladode with 30% moisture loss (T-3) recorded maximum sprouting of cladode (55%) occurred at 2-3 m distance from tree bole. The average kids /pad of cactus pear was higher at the distance of 1-2 m from tree bole in all treated cladode, except T-3. The light interception by tree canopy followed the decreasing trend as one moved away from tree bole. There was significant difference of about 5-8 °C of soil temperature within canopy and outside canopy. Based on present findings, it can be concluded that khejri trees may provide suitable ecological conditions to crops growing in its vicinity and enhance growth and productivity in arid areas.

Key words: Cactus pear, canopy temperature, light interception and soil moisture.

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1. INTRODUCTION

Prosopis cineraria L. (khejri) is the state tree of Rajasthan. It is widely scattered across the state and a component of traditional agroforestry system being practiced in Rajasthan since time immemorial. This leguminous tree has great economic significance and almost every part of it is utilized. It is extremely drought resistant and important plant species for agri-silvicultural and silvopastoral systems (Srivastava and Hetherington, 1991). Fuel wood is of high calorific value and utilized for making charcoal. Thorny twigs and branches are used for field fencing. Green and dry pods are used as a vegetable. The flowers and bark have medicinal value and are used as medicine (Srivastava and Hetherington, 1991). Therefore, in view of this the tree often termed as 'life line of desert'. Khejri can thrive well on a variety of soils, from sandy to rocky, in regions with 150-750 mm annual precipitation. Aggarwal *et al*. (1976) recorded maximum density, number of ground flora, phytomass production and also higher soil moisture content in surface soil under canopy of *P. cineraria*. It's roots can penetrate deep and can draw moisture and survive under extreme drought situations (Sen and Mehta, 1993).

Modification in microclimate is one of the important features of agroforestry where potential for positive interspecific interaction exists. Microclimate variations and ecophysiological changes were the object of the studies in agrisilvicultural systems in the past (Wallace, 1994; Irvine, 1998). Tree modifies the microclimate and influenced diversity and productivity of canopy zone vegetation by moderation of photosynthetic active radiation (PAR) and soil water content in Indian desert (Singh *et al.,* 2008). The tree canopy of *P. cineraria*, *P. juliflora*, *Azadirachta indica* and *Acacia nilotica* reduced the solar radiation by 83 to 88%. There was a decrease in soil water content (SWC, %) by 23% in the canopy zone of *P. cineraria* when compared with control. The lower SWC in canopy zone of *P. cineraria* could be attributed to the highest community biomass (Singh *et al.,* 2008). The fractions of the incoming PAR which are absorbed by canopies of component crops in intercropping systems mainly depend on leaf area index and canopy structure (Spitters and Aerts, 1983; Lantinga *et al*., 1999; Bastiaans *et al*., 2000). The tree canopy first intercepts the incoming radiation and transmitted radiation is available for the understorey crops. Light fractions are distributed differently within the plant canopy as the upper leaves usually receives sunlight in both diffuse and direct radiation while, the lower leaves receives more diffuse light (Spitters and Aerts, 1983). The trees have been reported to moderate microclimate (temperature and soil moisture) more under extreme climatic conditions than the mild ones (Sharma *et al*., 2002). The growth of multipurpose tree species can improve physical attributes of soil over time such as infiltration rate, water holding capacity and moisture availability through indirect effects of litter fall, understory growth and root distribution which depends upon the species and site conditions.

P. cineraria is most valuable agroforestry tree species of arid region. The tree intercropped with different crops *i.e. Vigna mungo* (L.) (mungbean), *Cyamopsis tetragonoloba* (L.) Taub. (clusterbean), *Vigna aconitifolia* (Jacq.) Marechal (mothbean) and *Pennisetum glaucum* (L.) (pearl millet) showed that pulses are more suitable for intercropping than the pearl millet. The intercropping did not cause any adverse effect on the growth of trees due to highly synergistic relationship between *P. cineraria* and understorey crops (Gupta *et al.,* 1998). Soil water content near the tree and in control plot was similar which indicated that *P. cineraria* has been meeting its water requirement from the layers deeper than 75 cm, and thus not competing with the companion agricultural crop (Gupta *et al.,* 1998). Cactus pear (*Opuntia ficus-indica* (L.) Mill.), commonly known as prickly pear or tuna, is a new crop in India. In present bio- and edapho-climatic constraints, enhanced human and livestock pressure and wide spread land degradation, *O. ficus-indica* is viewed as a source to meet multiple requirements of food, fruit, forage and host of other ecological benefits. *O. ficus-indica* is a multipurpose plant which is drought tolerant, having built in survival mechanism (CAM plant), easy to establish, produces large biomass thus having potential for improving the livelihood by rangeland and pastureland management, beside soil and water conservation. The present study was undertaken to understand the microclimate modification through light, canopy temperature and moisture under tree canopy of khejri for understorey crops *viz*. *O. ficus-indica* in arid ecosystems of western Rajasthan.

2. MATERIALS AND METHODS

The study site was located at an altitude of 241.71 m from above mean sea level, latitude of 26.258 °N and longitude of 72.993 °E. The soil of the region is sandy, poor in water-holding capacity and fertility, having 8.3-8.5 pH, 0.10-0.15 dSm^{-1} EC and 0.08-0.09% organic carbon. The annual average rainfall is 365 mm, which is erratic and distributed between July and September. The mean monthly maximum temperature ranges from 43.4 °C (May) to 25.1 °C (December) during winter, and the minimum monthly mean temperature ranges from 29.6 to 9.1 °C in summer and winter seasons, respectively. The weather data on weekly basis during the course of investigation are presented in Figure 1.

The study site was having trees of *P. cineraria* of 30-35 years old planted at 10 m × 5 m spacing. The average girth and height of khejri was 72.63 cm and 5.83 m, respectively with canopy spread of 5.5 – 4.85 m (east-west and north-south). Between the inter-row space, 120 cladodes/pads of cactus pear having similar dimension with moisture loss of 10% (T-1), 20% (T-2), 30% (T-3), 40% (T-4), 50% (T-5) and 60% (T-6) of

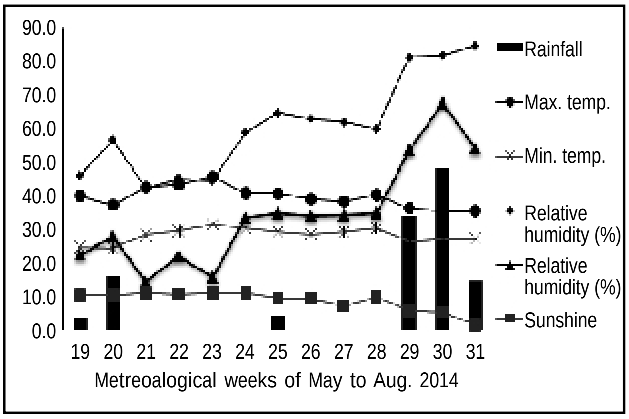

Fig. 1. Trend of weather parameters on weekly basis at CAZRI, Jodhpur.

cineraria tree as alley crop at 1 m × 1 m spacing using ridge and furrow method. Soil moisture content was assessed by gravimetric method at 0-15 cm depth along the gradient, below the tree and outside of tree canopy *i.e.* at distance of 1, 2, 3, 4 and 5 m from tree beside in open condition (control). Similarly, light intensity/radiation (quantum flux) and soil temperature was recorded under the tree canopy and outside the canopy with the help of Luxmeter (model-MQ-301) and Infrared thermometer (OAKTON Infra Pro), respectively at 1, 2, 3, 4 and 5 m from tree bole diagonally during three time a day *i.e.* morning (10-11 AM), afternoon (1-2 PM) and evening (4-5 PM). Then, average intensity of light outside and inside tree canopy was computed and light interception by the tree canopy was calculated in percentage by using following formulae:

$$\text{Intensity (\%)} = \frac{I_0}{I_1} \times 100$$

$$\text{Interception by trees (\%)} = \frac{I_0 - I_1}{I_0} \times 100$$

Where, I_1 = Quantum flux under the tree canopy (I_1) and

I_0 = Quantum flux outside the canopy (I_0)

To study the radial directional effect of tree canopy on cactus pear, their sprouting survival were observed at 1, 2, 3, 4 and 5 m distance from tree bole in radial direction at 7 days interval from planting for three month *i.e.* May-July.

3. RESULTS AND DISCUSSION

The sprouting kids/cladode were influenced significantly by various moisture content of cladode as per treatment (Table 1). The maximum number of sprouting kids (1.66/cladode) and significantly more number/cladode were recorded at 20% moisture loss (T-2) than other treatment, but were at par with 10% (T-1) and 30% (T-3) moisture loss treatment. 40% (T

4), 50% (T-5) and 60% (T-6) moisture loss treatments were at par with each other. These findings are in consonance with Inglese (2010), who reported that 1-2 years old cladodes seasoned at 20-25 °C so as to lose 20% of their fresh weights and planted at the end of rainy season, gave best results. The maximum kids (46) were recorded in 20% moisture loss treatment with cent percent sprouting pads and minimum (15) in 60% moisture loss treatment with 50% sprouting pads.

The tree distances influenced sprouting behaviour of cladode, irrespective of moisture loss in cactus pear (Table 2). The maximum sprouting of cladode (55%) was recorded at 2-3 m distance from tree bole in T-3, and 40, 40, 45, 15 and 25% sprouting in T-1, T-2, T-4, T-5 and T-6, respectively. The sprouting was recorded lowest (5%) at 1-2 m distance from tree bole in T-5 and 10% sprouting in T-1, T-2, T-3 and T-4 treatments.

The average kids produced/pad of cactus pear was higher at 1-2 m distance from tree with 10, 20, 40 and 50% moisture loss but 30% moisture loss treatment recorded more number of kids at distance of 2-3 m from tree bole. Overall, the more number of kids/pad were produced at 1-2 m distance from tree (Figure 2). These results are related to other authors finding that the presence of triacontanol, a plant growth promoting substance in leaves of *Prosopis* species may increase the growth of plants under canopy of trees that are affected by leaf litter fall. Increase in the yields of grass under *P. cineraria* was assumed due to the increased soil fertility around the trees (Shankar *et al*., 1976). Triacontanol was found to be effective in increasing growth and water uptake of rice seedlings (Reis *et al*., 1977) and also to promote germination, growth and stubble sprouting in corn and barley. Aggarwal *et al.* (1976) also reported higher biomass of forage crop under khejri tree canopy which might be due to higher fertility status.

Microclimate modification under tree canopy

Light interception: Data revealed that maximum (48.6%) of full PAR interception was observed by tree

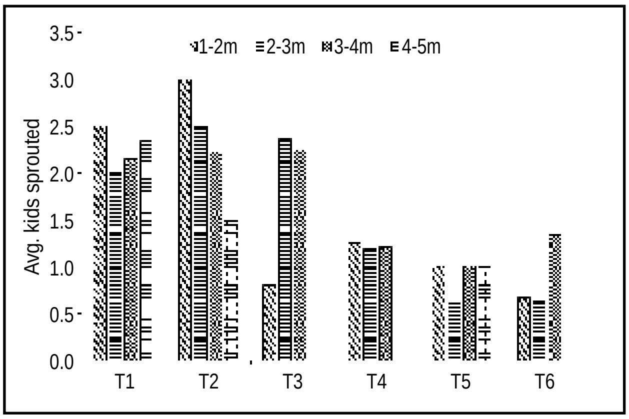

Fig. 2. Average kids produced/pad with different treatment as influenced by bole distance.

Table 1. Sprouting pattern of cladode as influenced by moisture content

Moisture loss of cladode	Sprouting kids/pads	Maximum kids produced	Sprouted cladode	% sprouted	% Non-sprouted
T-1 (10%)	1.60	43	20	100	0
T-2 (20%)	1.66	46	20	100	0
T-3 (30%)	1.51	39	17	85	15
T-4 (40%)	1.22	24	13	65	35
T-5 (50%)	1.09	17	10	50	50
T-6 (60%)	1.05	15	10	50	50
$LSD_{0.05}$	0.17				

Table 2. Sprouted cladode as influenced by different distances from tree bole

Treatments	Sprouted Cladode at different distances from tree bole			
	1-2 m	2-3 m	3-4 m	4-5 m
T1	2 (10)*	8 (40)	7 (35)	3 (15)
T2	2 (10)	8 (40)	8 (40)	2 (10)
T3	2 (10)	11 (55)	4 (20)	0
T4	2 (10)	9 (45)	2 (10)	0
T5	1 (5)	3 (15)	5 (25)	1 (5)
T6	3 (15)	5 (25)	2 (10)	0

* Figures in parenthesis indicates the % sprouted cladode

canopy at 1 m distance from tree bole in all the treatment which followed the decreasing trend as one moves away from tree bole (Figure 3). However, the least PAR interception (38.1%) was recorded at 4 m distance from tree bole. Newaj *et al.* (2003) reported increased light interception with the increase in distance from tree bole. The reduction in light availability for the underneath crop increases with decrease in tree spacings. Solar irradiance was reduced by 45-65% under *Acacia tortilis* and *Adansonia digitata* (Belsky *et al.*, 1989). *Vitellaria* trees of 7 m height and 4.7 m crown diameter also decreased PAR directly under and outside crowns by 40 and 20%, respectively. Under larger trees (average crown diameters of 8.4 to 11.2 m for *Vitellaria* and 9.5 to 17.1 m for *Parkia* trees), PAR was reduced by 75 % (Jonsson, 1995).

It was evident that percent soil moisture was more at distance of 1 m from tree bole in treatments T-1, T-3 and T-4 but T-2, T-5 and T-6 plots recorded high moisture at a distance of 2 m from tree (Figure 4). The reason was shade of canopy spread of the tree. Overall, soil moisture decreased with the increasing distance radially from tree as observed from tree distances. Aggarwal *et al*. (1976) and Gupta and Saxena (1978) studied the effects of trees on soil physical characteristics after 15 years growth and observed higher moisture content in soils under the canopy of *P. cineraria* than under *P. juliflora*. This was attributed to relatively higher organic matter content, litter fall and a deeper root distribution, confirmed by a higher depletion of moisture from deeper layers under *P. cineraria*, contrasted with the surface spread of lateral roots of *P. juliflora* which depleted moisture from shallow soil layers. Hazra (1989) also reported increase in field capacity from 14.1 to 16.2% and a decrease in bulk density from 1.58 to 1.37 g/cm^3 in soil under the canopy of *Albizia lebbeck* as compared to the open field.

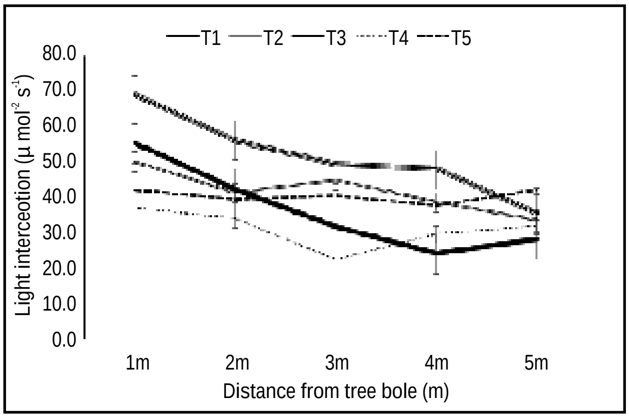

Fig. 3. Light Interception (%) by canopy of tree at radial distance.

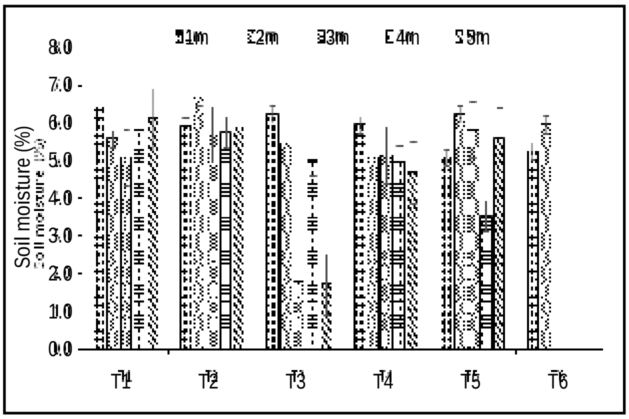

Fig. 4. Soil moisture at radial distances (1 to 5 m) under tree canopy.

The least soil temperature (41.7 °C) was recorded at 1 m distance under tree canopy during summer month (July, 2014) which was 7.97 °C lower than soil temperature outside the canopy (49.67 °C). As one move away from tree, the soil temperature increases and recorded 42.6 °C at 2 m, 43.6 °C at 3 m and 44.7 °C at 4 m distance. It was evident that canopy cover of *P. cineraria* has ameliorating effect on soil temperature which is beneficial for intercrop under agroforestry system. Temperature reduction has been held responsible for enhanced yields under *Faidherbia* crowns. There is some evidence that extreme heat negatively affects crop establishment and subsequent growth (Peacock *et al.*, 1990; McIntyre *et al.*, 1993). Using vertical artificial screens, Van den Beldt and Williams (1992) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) showed that the effect of shade on soil temperatures contributed to better growth of millet during seedling establishment. They argue that root damage due to high temperature rather than water deficits caused differences in millet performance and that crops would not be able to take advantage of the greater soil fertility around *F. albida* trees without the moderated temperature associated with them. Maximum radiation around mid day in May under almost leafless *F. albida* was about half that in the open and shade affected soil temperature substantially (Van den Beldt and Williams, 1992).

Figure 5 depicted that soil moisture content were highest in T-1 and T-2 in comparison to other treatment plots, while T-3 showed the lowest moisture content. Light interception by tree canopy was highest in T-6 so it got lowest PAR and lowest light interception was recorded under T-4. However, maximum temperature was recorded in T-1 and lowest temperature of soil was observed under T-6 which was due to less light availability in the treatment. The trees have been reported to moderate microclimate more under extreme climatic condition, particularly the temperature and soil moisture conditions than under mild ones (Sharma *et al*., 2002).

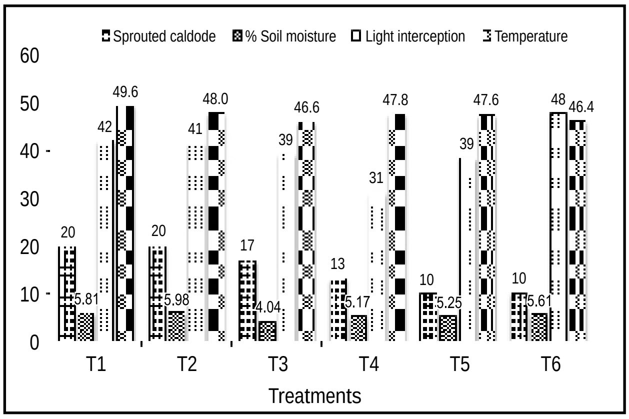

Fig. 5. Ecological parameters across the radial distance under tree canopy.

4. CONCLUSION

It can be concluded that *P. cineraria* (khejri) provides suitable ecological conditions to the crops in its vicinity and enhance the growth and productivity of crops in arid areas. Hence, to practice sustainable agriculture in arid zones, this multipurpose tree species should be conserved and promoted in agroforestry systems.

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