Annals of Arid Zone 32 (4) 245–250 1993

Micro-climatic Impacts on the Relative Growth of *Cenchrus ciliaris* and *Cenchrus setigerus*

A S Rao, K C Singh, Y S Ramakrishna and R S Singh
Central Arid Zone Research Institute, Jodhpur – 342 003 India

Abstract *Cenchrus ciliaris* and *Cenchrus setigerus* created favourable micro-climate within the canopies by maintaining lower temperatures (by 2 to 9°C) and vapour pressure gradients and high humidity (by 3 to 11 %). Energy balance studies showed that the net radiation, soil heat flux and latent heat of vaporization over the grass cover were higher during wet years compared to the values during low rainfall years. Accumulated stress degree days showed that *C. ciliaris* developes an early stress than *C. setigerus*. The transpiration rates of these grasses at vegetative phase were 16 to 18 $\mu g\ cm^{-2}\ s^{-1}$ and diffusive resistances were 0.60 to 0.73 s cm^{-1}. During low rainfall years, *C. ciliaris* produced higher dry matter yield, water and energy use efficiency than *C. setigerus* whereas under high rainfall conditions *C. setigerus* performed better than *C. ciliaris*.

Key words Water and energy use, Micro-climatic impacts, *C. ciliaris*, *C. setigerus*

Forage production plays an important role in the economy of arid regions due to high risk involved with arable farming under the conditions of low and highly variable rainfall in the area. The Indian arid region supports 23 million cattle head inspite of its low levels of forage production, with demand and production being equal only in good rainfall years (Shankaranarayan *et al.* 1985). The average forage production in the arid Rajasthan meets only 44% of the fodder requirement of livestock leaving a gap of 56 % (Shankaranarayan *et al.* 1985). With a view to regenerate and improve the degraded grasslands, Singh and Mishra (1968) studied the energy use efficiency of 13 tropical grasses which varied from 0.23% for semi arid grasslands to 1.66% for dry sub humid grasslands. Sims and Coupland (1979) reported PAR capture efficiency as 0.17% for desert grasslands and found no relationship with the primary production for rainfall beyond 500 mm. The water use efficiency (WUE) of grasslands in western Rajasthan was between 0.33 and 2.24 g m^{-2} mm^{-1} and energy use efficiency (EUE) 0.16 and 1.1% with respect to PAR (Krishnan & Sastri 1979, Krishnan & Rao 1981, Rao & Sastri 1982). These grass species exhibited highest water and energy use efficiency during vegetative growth when the evapotranspiration (ET) of the grasslands meets 0.75% of the potential ET (Rao *et al.* 1984). In this paper, the micro-climatic impacts on the relative growth of *C. ciliaris* and *C. setigerus* in the arid region of Jodhpur are presented.

Materials and Methods

Rainfed pasture, one hectare each of *C. ciliaris* and *C. setigerus* were established in 1989 at Central Arid Zone Research Institute, Jodhpur (26° 18' N, 73° 01' E, 224 m above MSL). The experimental site experiences arid climate with a mean annual rainfall of 366 mm. The soil is sandy loam and soil depth is upto 1 m. The textural composition of the soil is 85% sand, 7% silt and 8% clay. The bulk density is 1.5 g cm^{-3}. This soil can hold 165 mm water at field capacity and 50 mm at 15 atmospheric tension; thus the available soil moisture in the 1 m profile is 114 mm.

The grass yield was recorded through forage estimation quadrants of 10 m^2 at about 15 days interval covering different growth stages of the pastures to evaluate periodical energy and water use efficiency.

The soil temperatures within the grass cover and nearby open area were recorded using soil thermometers at 5,10 and 20 cm. Air and humidity profiles were recorded using an Assman psychrometer and air temperature probes (YSI make, USA). Net radiation using a Funk type radiometer, solar radiation interception with a solar tube and soil heatflux with heatflux plates were recorded. The transpiration and leaf diffusive resistance were recorded using a porometer and canopy temperatures using an infrared thermometer. Soil moisture was recorded weekly at 15 cm interval upto 1 m depth using a neutron moisture meter.

The consumptive use of grasses at different stages were calculated by the soil water balance method of Thornthwaite and Mather (1955) wherein the soil moisture depletion in 1m soil depth was also taken into account under these pasture grasses. The water use efficiency was calculated as the quantity of dry matter production per unit of water consumed by the grass. The energy use efficiencies of the grasses were calculated as a ratio of actual energy utilized by the grass for dry matter production to the total energy received. The accumulated dry matter was converted into energy units at the rate of 3990 cal cm^{-2} for producing 1 g of dry matter (Lemon 1969).

Results and Discussion

Micro-climatic conditions

The annual rainfall values during the study period of 1989 to 1992 were 230, 844, 204 and 436 mm, respectively. The air temperatures during the growing period varied from 18 to 42°C. Soil temperatures were upto 45°C and they were lower in the grass cover than in the open field by 2 to 9°C. Similarly air temperatures were also buffered by the grass canopy reducing the diurnal variation by1 to 2°C. the humidity and vapour pressure profiles within the grass species indicated that the humidity in the grass cover was 3 to 11 % higher than in the open area creating favourable micro-climate with low vapour pressure gradients; thereby reducing the transpiration requirements.

Day time energy balance over the grass cover

The energy balance parameters under *C. ciliaris* and *C. setigerus* at vegetative stage (Table 1) showed that the latent heat of vaporization (LE) was higher in 1990 and 1992 compared to 1989. This is because 1990 and 1992 were wet years compared to 1989. In these years, the percentage of net radiation to insolation was lower and soil heatflux was higher. The net radiation values were higher under bare soil conditions especially in the dry year because of lower percentage retention of insolation.

Albedo varied from 22 to 23 % under the grass cover, whereas it was 20 to 23 % in the open area. Because of vigorous growth of *C. ciliaris*, 55 to 61% of the radiation was intercepted by its canopy, whereas lesser percentage of radiation (44%) was intercepted by the canopies of *C. setigerus*.

Canopy-air temperatures (T_c-T_a) and stress degree days

During 1989, the canopy temperatures varied between 28.3 to 34.1°C at flowering stage (Ist week of September) and 31.9 to 42.0°C at seed formation stage (2nd week of October). The canopy air temperature differences (T_c-T_a) were -1.3 to -8.1°C upto pre flowering stage and -4.4 to +5.1°C from seed formation to maturity stages. The positive values of T_c-T_a showing water stress conditions were observed from Ist week of October under these grasses.

Table 1 *Energy balance (MJ m^{-2}) under Cenchrus species at vegetative stage*

	C. ciliaris			*C. setigerus*			Open area		
	1989	1990	1992	1989	1990	1992	1989	1990	1992
Total radiation	24.2	17.1	19.0	24.2	17.1	19.0	24.2	17.1	19.0
Net radiation	14.8	7.9	8.5	14.8	7.7	8.9	15.3	7.6	8.5
Soil heatflux	1.8	2.5	2.3	1.9	1.4	2.3	2.7	2.1	2.5
Latent heat of vaporization	7.6	6.7	8.2	7.5	8.0	7.8	6.2	7.4	8.0
Albedo (%)	19	22	21	20	23	20	22	20	23
Canopy interception (%)	60	61	55	44	44	42	–	–	–

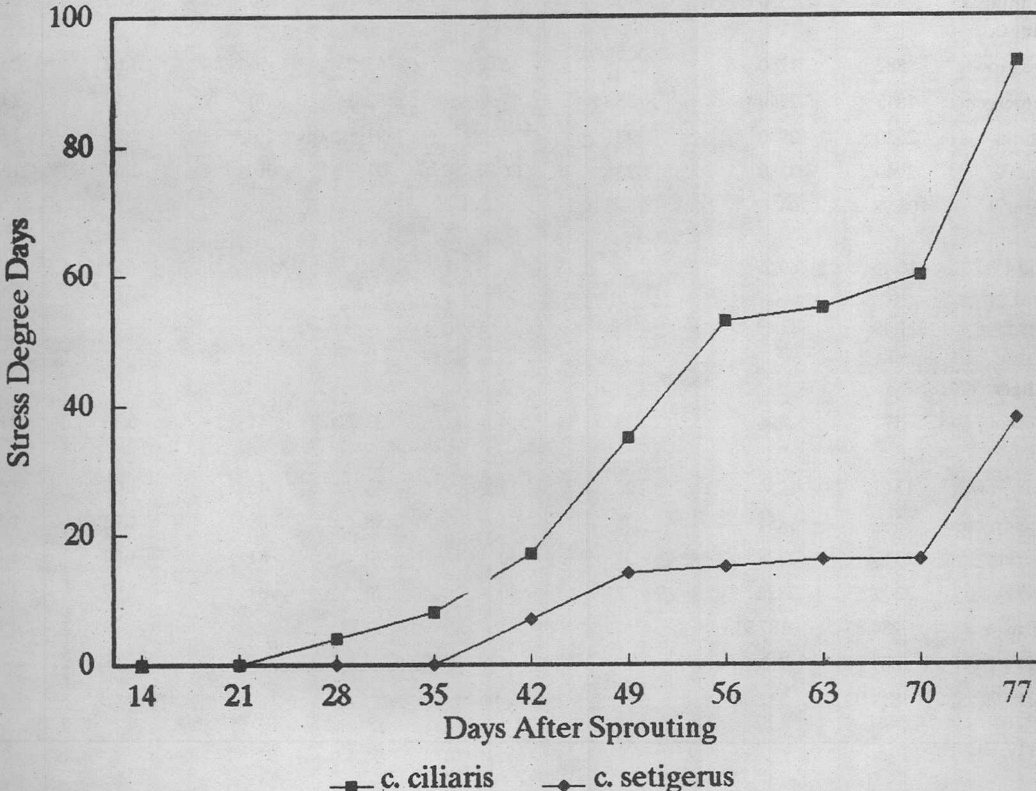

Fig 1 Stress degree days (SDD) under *Cenchrus* species at Jodhpur 1990

Table 2 *Phenological characteristics of Cenchrus species*

Stage	Dry forage kg ha^{-1}		Tillers plant^{-1}		Plant height (cm)		LAI	
	1990	1991	1990	1991	1990	1991	1990	1991
C. ciliaris								
Sprounting & tillering	486	550	17	15	47	50	0.83	0.94
Active growth	882	1260	23	16	63	56	1.62	2.00
Ear emergence	1815	2240	25	17	82	90	1.62	2.00
Flowering	2520	2980	23	26	91	101	1.67	1.92
Harvest	2940	3380	23	26	91	101	1.67	1.92
SEm +	108.98	204.22						
CD 1%	416.76	780.93						
CD 5%	311.49	583.68						
C. setigerus								
Sprounting & tillering	574	596	23	14	37	41	0.83	0.86
Active growth	1315	1254	28	17	47	46	1.62	1.54
Ear emergence	2330	1854	25	23	58	68	1.92	1.52
Flowering	2836	2478	32	30	70	81	1.97	1.74
Harvest	3200	2822	32	30	70	81	1.97	1.74
SEm +	284.83	187.91						
CD 1%	1089.21	718.56						
CD 5%	814.09	537.06						

In 1990, the canopy temperatures ranged from 28.4°C to 37.8°C during the non stress period. The canopy temperatures in general remained lower by 3°C under the *C. setigerus* than under *C. ciliaris*. The grasses experienced stress from the last week of August and the accumulated stress degree days (SDD) at the time of harvest were 93 under *C. ciliaris* compared to only 36 under *C. setigerus* (Fig.1) as a result of higher use of moisture for biomass development by *C. ciliaris* during early stages of growth leading to higher stress than in *C. setigerus*.

Transpiration rates and diffusive resistance of grasses

The transpiration rate and diffusive resistance at noon time during peak vegetative stage of grasses were 16 μg cm^{-2} s^{-1} and 0.73 s cm^{-1} for *C. ciliaris* and 18 μg cm^{-2} s^{-1} and 0.60 s cm^{-1} for *C. setigerus*. The above values remained persistent when leaf temperatures were between 33.1 to 35.2°C and PAR was 1770 and 2270 μE m^{-2} s^{-1} and soil moisture was between 25 and 50% of the AWC.

Phenological characteristics

The biomass rates of *C. ciliaris* and *C. setigerus* for good rainfall year 1990 and low rainfall year 1991 are given in Table 2. Though *C. setigerus* showed better growth upto tillering stage than *C. ciliaris*, the dry matter rates were highest for *C. ciliaris* at harvest stage. *C. setigerus* produced more

Table 3 *Dry matter yield, consumptive use, water and energy use efficiencies of Cenchrus species*

	1989	1990	1991	1992	Mean
Annual rainfall (mm)	230	844	204	436	428
C. ciliaris					
Dry matter (kg ha^{-1})	4610	2940	3380	4970	3975
Consumptive use (mm)	204	363	164	290	255
Water use efficiency (kg mm^{-1} ha^{-1})	22.6	8.1	20.6	17.1	15.6
Energy use efficiency (%)	0.37	0.27	0.34	0.43	0.35
C. Setigerus					
Dry matter (kg ha^{-1})	4056	3200	2822	5550	3907
Consumptive use (mm)	210	339	174	294	254
Water use efficiency (kg mm^{-1} ha^{-1})	19.3	9.4	16.2	18.9	15.4
Enrgy use efficiency (%)	0.32	0.29	0.28	0.48	0.34

tillers than *C. ciliaris*. *C ciliaris* is taller than *C. setigerus* and also the average area of a single leaf of *C. ciliaris* was 30 cm^2 compared to that of *C. setigerus* (7 cm^2) resulting higher LAI and forage yield by *C. ciliaris* than *C. setigerus* even under low rainfall conditions.

Water and energy use efficiencies

C. ciliaris produced 2940 to 4970 kg ha^{-1} of dry forage yield, whereas *C. setigerus* yielded 2822 to 5550 kg ha^{-1} (Table 3). The total consumptive use of these grasses varied between 164 and 363 mm. In low rainfall years like 1989 and 1991, there was small variation in the total consumptive use of these two species, but *C. ciliaris* consumed most of the available water at earlier stages and produced higher yield and water use efficiency than *C. setigerus*. In 1990 and 1992, the rainfall was above normal resulting in favourable conditions to *C. setigerus* to produce higher yield (by 260 to 580 kg ha^{-1}) and water use efficiency than *C. ciliaris*.The energy use efficiency of *C. ciliaris* was higher than *C. setigrus* during low rainfall years, whereas with increase in rainfall, the energy use efficiency of *C. setigerus* was higher than that of *C. ciliaris*.

Acknowledgments

The authors are thankful to Dr J Venkateswarlu, Director and Dr. BL Jain, Head, Division of Resource Management, CAZRI, Jodhpur for their encouragement and providing facilities. The authors appreciate and thank all the technical staff of Range Management and Climatology Sections for recording the data.

References

Krishnan A & Sastri ASRAS 1979 Energy balance and photosynthetic and water use efficiency of *Cenchrus ciliaris* grass cover. *Archiv Fur Meteorologie Geophysik Und Bioklimotologie*, Series B **27** 95-104

Krishnan A & Rao GGSN 1981 Water use efficiency of *Lasiarus sindicus* grass cover in the arid zone of India. *Indian Journal of Ecology*, **8** 8-16

Lemon ER 1969 Important microclimatic factors in soil water plant relationships. *Modifying the Soil and Water Environments for Approaching the Agricultural Potential of the Great Plains.* Great Plains Agricultural Council, **34** 95-102

Rao GGSN & Sastri ASRAS 1982 Water and energy use efficiency of native grasslands in the arid region of India. *Archiv Fur Meteorologie Geophysik Und Bioklimotologie* Series B **31** 127-132

Rao GGSN, Ramana Rao BV & Bhati GN 1984 Influence of water availability on water and energy use efficiencies of some arid grass species. *Tropical Ecology* **25** 117-124

Shankarnarayan KA, Rao GGSN & Ramana Rao BV 1985 Grassland productivity and its associative climatic characterisctics in western Rajasthan. *Tropical Ecology* **26** 157-163

Sims PL & Coupland RT 1979 producers. In : *World Grassland Ecosystem.* (Ed. RT Coupland) Cambridge University press, London pp 49-72

Singh JS & Mishra R 1968 Efficiency of energy capture by grassland vegetation of varanasi. *Current Science* **38** 636-637

Thornthwaite CW & Mather JR 1955 *Water Balance*. Publications in Climatology Drexel Institute of Technology, Centerton, New Jersey **8** 1-104

(Received July 1993 Accepted October 1993)