

Micro-meteorological variations and Rain water-use efficiency of a Silvi-pastoral system

A.S. RAO

Central Arid Zone Research Institute, Jodhpur-342 003

Email : asrao@cazri.res.in

ABSTRACT

The solar radiation disposition, soil moisture depletion pattern and rain water-use efficiency of a silvi-pastoral system at Jodhpur were studied during 2000 to 2003. Factorial combination of a pasture viz., *Cenchrus ciliaris* and a fodder shrub viz., *Colophospermum mopane* and with two trees viz., *Hardwickia binata* and *Prosopis cineraria* at two levels of nitrogen (N_0 and N_{20}) were tried. The intercepted insolation varied from 54 to 80% depending upon the leaf area index (0.65-1.40). The albedo varied from 20.3 to 24.4%. Soil moisture depletion was more in all fertilized than unfertilized plots of legume, grass and tree combination treatments. The rain water-use efficiency (WUE) was higher in fertilized plots of *C. ciliaris* (3.37-14.05 kg DM ha⁻¹ mm⁻¹) compared to unfertilized plots (2.65-9.71 kg DM ha⁻¹ mm⁻¹) and it was highest in combination of grass and legume compared to sole components.

Key words: Solar radiation disposition, soil moisture depletion patterns, rain water-use efficiency, silvi-pastoral system.

Silvi-pastoral systems play a prominent role in arid Rajasthan as animal husbandry is key to their economy. Drought conditions prevail frequently in the region influencing the arable crops more than silvi-pastoral systems. Rainfall in the region is not only low, but erratic in nature. In western Rajasthan, fodder is in short supply to the need even in normal rainfall years. During severe drought years, productivity was declined by 82% in rainfall zone of <200 mm, 74% in 200-300 mm and 42% in 300-500 mm rainfall zone (Shankaranarayan *et al.*, 1985). Promising grasses like *C. ciliaris*, if managed well by application of N fertilizer @20 kg N ha⁻¹, the dry forage can be doubled (Rao *et al.*, 1996). *C. cilairis* is grown in the region with trees and shrubs and performs well in the region. The consumptive use of *C. ciliaris* during normal and drought years was 290 and 164 mm, respectively and water-use efficiency was 20.6 kg DMha⁻¹mm⁻¹ and 10.2 kg DMha⁻¹mm⁻¹ (Rao *et al.*, 1993, 1996; Singh and Rao, 1994 and Singh *et al.*, 1996). The present study is made to identify a highly productive silvi-pastoral system in combination with a grass/legume/shrub/tree through studies on soil moisture and rain water-use efficiency of different systems in the arid region of Jodhpur.

MATERIALS AND METHODS

The study on silvi-pastoral system was conducted

at Central Arid Zone Research Institute, Jodhpur (26° 18"N; 73° 01'E and 224 m above MSL) under rainfed conditions during 2000-2003. There were 6 treatments viz., *C. ciliaris* (CV 358), *Lablab purpureous*, *C. ciliaris* + *C. mopane*, *C. ciliaris* + *C. mopane* + *H. binata* + *P. cineraria* and natural grass comprised of *Cenchrus biflorus*, *Aristida fumuculate*, *Indigofera cordifolia* and *Tribulus terrestris*. The fodder legume *Lablab purpureus* was sown alone and also in association with grass during *kharif*. There were two levels of nitrogen (0 and 20 kg ha⁻¹). The grass was established during the rainy season at a spacing of 75 cm apart. Planting of the shrub (*C. mopane*) and trees (*H. binata* and *P. cineraria*) were transplanted at a spacing of 10 X 5 m, there were 18 plants in a plot 30 X 30 m. Treatments were replicated four times in a factorial randomized block design. Forage yield was estimated from the established plots through forage estimation quadrats of 10 m² and two quadrats were taken from each plot. At the end of rainy season in the month of September, grass was cut at 10 cm height from the ground, air dried and weighed.. During 2002, there was a very severe drought in the region and hence the data records of 2001 and 2003 were only analyzed.

Soils of the experimental area were sandy loamy camborthids and contains 85-87% sand, 5-6% silt and

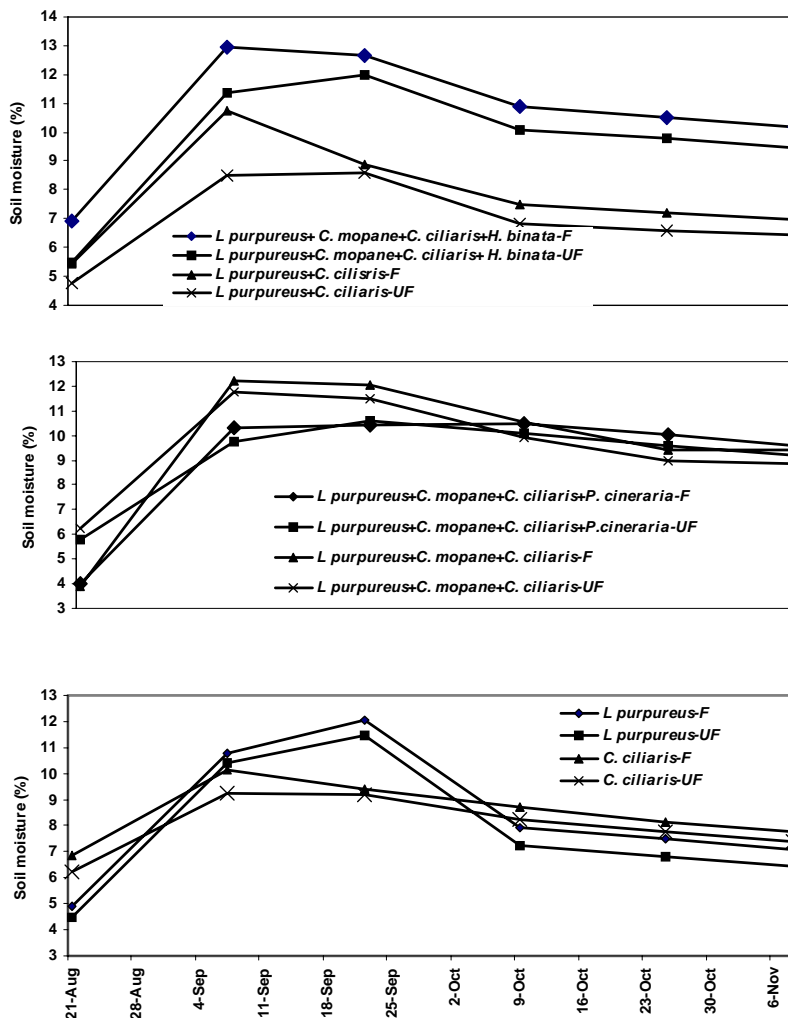


Fig. 1 : Soil moisture (%) depletion in different silvi-pastoral systems after monsoon rains receded at Jodhpur during 2001

6-7% clay. The water holding capacity of the soil was 10% and wilting point 4%. The LAI was measured using a digital canopy analyzer and radiation interception using a tube solarimeter, net radiation using a net radiometer and albedo using an albedo meter. The soil moisture content was measured at weekly intervals (by TDR soil moisture) at soil depths of 0-15, 15-30, 30-45, 45-60 and 60-75 cm during 2000-03. Consumptive use was calculated from effective rainfall and soil moisture depletion. The rain water-use efficiency (WUE) was calculated in kg dry matter produced per unit area and per mm of water received. The Jodhpur location receives a mean annual rainfall

of 365 mm.

RESULTS AND DISCUSSION

Micro-meteorological variations

The profiles on relative humidity and air temperatures at 5, 25 and 50 cm heights in the silvi-pastoral systems showed a decreasing pattern in relative humidity by 1 to 5% from surface to top of the canopies, whereas, the air temperatures were on the rising trend up to 2°C depending upon the canopy cover under different systems.

Table 1: Solar radiation disposition in a silvi-pastoral system at Jodhpur (2001)

Treatment	Fertilizer status	Leaf area index	Radiation interception (%)	Net radiation	Soil heatflux MJ m ⁻²	Albedo (%)
<i>L. purpureus</i> + <i>C.mopane</i> +	F	1.05	75	14.8	2.19	24.4
<i>C. ciliaris</i> + <i>H.binata</i>	UF	1.02	73	15.1	2.73	21.7
<i>C. ciliaris</i> + <i>L. purpureus</i>	F	1.33	79	14.8	2.52	21.1
	UF	1.20	72	15.8	2.91	20.4
<i>L. purpureus</i> + <i>C. mopane</i> +	F	1.14	68	14.6	3.06	21.7
<i>C. ciliaris</i> + <i>P. cineraria</i>	UF	1.00	66	14.1	2.39	21.4
<i>C. ciliaris</i> + <i>L. purpureus</i> +	F	1.40	67	14.7	2.49	22.6
<i>C. mopane</i>	UF	1.35	80	15.0	2.55	20.3
Sole <i>L. purpureus</i>	F	1.35	76	15.3	2.69	20.6
	UF	0.65	54	15.2	2.59	22.2
Sole <i>C. ciliaris</i>	F	1.17	70	15.3	2.60	20.3
	UF	1.14	65	15.7	2.67	20.8

Note: F=Fertilized UF= Unfertilized

The LAI, radiation interception, net radiation, soil heat flux and albedo under various silvi-pastoral systems at Jodhpur measured at peak vegetative stage during 2001 are presented in Table 1. The highest LAI of 1.40 was observed in *C. ciliaris*+ *L. purpureus* + *C. mopane* and the lowest of 0.65 was in sole *L. purpureus*. In general, LAI was high in all the fertilized plots compared to unfertilized plots. The variations in LAI were strongly reflected in solar radiation interception (Table 1). The solar radiation interception varied from 54 to 80 per cent depending upon the canopy cover in different systems. The daytime net radiation varied from 14.1 to 15.8 MJ m⁻², soil heatflux from 2.19 to 3.06 MJ m⁻² and albedo from 20.3 to 24.4 per cent.

Soil moisture depletion pattern

The soil moisture depletion pattern in different silvi-pastoral systems after monsoon rains receded are shown in Fig.1. Maximum soil moisture depletion was recorded under sole *L. purpureus* or sole *C. ciliaris* and in combination of the earlier two systems compared to other pasture plots in combination with tree/shrub system. Further, it was clear that the soil moisture requirement of the legume was higher at the establishment stage as compared to the grass. The soil moisture content was also higher in deeper soil layers compared to surface layer. Also, in general soil moisture depletion was more in fertilized than in unfertilized plots because of better growth of grass due to

application of nitrogen.

Consumptive use and rain water-use efficiency

The total productivity, consumptive use and water-use efficiencies of different silvi-pastoral systems under fertilized and unfertilized conditions are shown in Table 2. Among the fertilized plots, the consumptive use was the highest (238 mm) in sole *C. ciliaris*/*L. purpureus* and the lowest (222 mm) in *C. ciliaris* + *L. purpureus*. The highest forage productivity of 3119 kg DM ha⁻¹ was in *C. ciliaris* + *L. purpureus* with a water use efficiency of 14.05 kg DM ha⁻¹ mm⁻¹ followed by 3094 kg DM ha⁻¹ in *C. ciliaris*+ *L. purpureus* + *C. mopane* with a water-use efficiency of 13.28 kg DM ha⁻¹ mm⁻¹. Though, the sole *L. purpureus* consumed more water, its water-use efficiency was lowest (3.37 kg DM ha⁻¹ mm⁻¹). Fertilizer enhanced the forage productivity of silvi-pastoral system by 67.2% in the *C. ciliaris* + *L. purpureus* followed by 46.8% in *C. ciliaris* and to 28.0% in sole *L. purpureus* and also in *L. purpureus* + *C. mopane* + *C. ciliaris* + *P. cineraria*. The consumptive use was also high in fertilized plots compared unfertilized plots. The study also shows that the legume performed well in combination with grass/trees rather than if it is grown as a sole legume.

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Table 2: Average Consumptive use and water-use efficiency of different silvi-pastoral systems during 2001 and 2003 at Jodhpur

Treatment	Fertilized			Unfertilized		
	Total productivity (kg DM ha ⁻¹)	Consumptive use (mm)	Water-use efficiency (kg DM ha ⁻¹ mm ⁻¹)	Total productivity (kg DM ha ⁻¹)	Consumptive use (mm)	Water-use efficiency (kg DM ha ⁻¹ mm ⁻¹)
<i>L. purpureus</i> + <i>C. mopane</i> + <i>C. ciliaris</i> + <i>H. binata</i>	2681	228	11.76	1963	212	9.26
<i>C. ciliaris</i> + <i>L. purpureus</i>	3119	222	14.05	1865	211	8.84
<i>L. purpureus</i> + <i>C. mopane</i> + <i>C. ciliaris</i> + <i>P. cineraria</i>	2631	231	11.39	2056	224	9.18
<i>C. ciliaris</i> + <i>L. purpureus</i> + <i>C. mopane</i>	3094	233	13.28	2242	231	9.71
Pure <i>L. purpureus</i>	802	238	3.37	627	237	2.65
Pure <i>C. ciliaris</i>	2606	238	10.94	1775	235	7.55
Natural pasture	1966	230	8.54	1400	232	6.03

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