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Water and Energy Use Efficiencies of Sorghum Intercropped with *Acacia nilotica*

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Abstract The performance of sorghum grown as intercrop with 10 m widely spaced *Acacia nilotica* c.v. *Cupressiformis* tree rows was evaluated in an Indian arid region at Pali during 1988 to 1990. The grain yields of sorghum were 134, 683 and 147 kg ha^{-1} and consumptive use values were 302, 300 and 452 mm during 1988 to 1990. The water use efficiencies of the crop (w.r.t grain yield) were 0.44, 2.27 and 0.33 kg mm^{-1} ha^{-1}, whereas the energy use efficiencies (w.rt. biomass) of the crop were 0.42, 0.17 and 0.16 per cent during these respective years. *A. nilotica* trees during the three years of their growth did not interfere with intercrop for moisture and light.

Key words Water and energy use rfficiencies, Sorghum-Aacacia nilotica, Arid agro-forestry systems

Agro-forestry is practiced by the farmers of the Indian arid zone with trees like *Prosopis cineraria*, *Acacia nilotica* (*Khajoor babool*) etc., in combination with different annual crops. Net to pearl millet, sorghum (*sorghum bicolor* (L.) Moench) is an important cereal crop and is grown in an area of 3,98,000 ha, often in combination with different tree species in the arid western Rajasthan. Sorghum yields however are low in the the region and there is a need for better understanding of the water and energy use by the crop in combination with tree species for improving the crop yields. In the preset study, therefore, the growth of sorghum in combination with *A. nilotica* trees was studied.

Materials and Methods

The experiment was conducted at the Regional Research Station of the Central Arid zone Research Institute at Pali (25° 50, N , 73° 15' E, 217 m above MSL). Pali receives an average annual rainfall of 425 mm against the annual potential evapotranspiration of 1650 mm.

The soils of the experimental site were sandy clay loam (Calci orthids) with clay 20 to 25 %, sand 70-80 % and organic carbon 0.3%. The soils have low fertility status with 0.06% total N, 305 kg P ha^{-1} and available K 390 kg ha^{-1} (Bhaskar 1982). The field capacity is 17.2% and wilting point 7.8% for these soils. The soil depth is moderately deep (40-60 cm), below which hard *kanker* (muram) prevails.

A. nilotica c.v. *Cupressiformis* trees were planted with a spacing of 10 x 3 m during 1987. Sorghum (C.V SPV-96) was grown as an intercrop between the tree rows with 45 cm x 10 cm spacing leaving one metre gap from the tree rows either side during 1988 to 1990. At the end of the third year, the trees were having an average height of 3.0 m and girth 13 cm at 10 cm hieght from the ground level.

The leaf area, root length and growth rates of sorghum at periodical intervals were determined from the random sampling of 3 plants each time. Leaf area was measured using a leaf area meter (Li-cor, USA). The net radiation, albedo, soil heatflux, profiles of radiation, humidity nd temperatures were recorded at different growth stages at 2 hourly interval during the day time. Tube solarimeter was used for measurement of radiation interception by the canopy. Water use efficiency (WUE) was worked out based on the consumptive use and biomass production during different phases of plant growth, while energy use efficiency (EUE) was estimated for these periods assuming that 166.8 MJ m^{-2} are required for the production of one gram of dry matter (Lemon 1969). Infra-red thermometer (AG-42) and steady state porometer (Li-cor, USA) were used to measure canopy air temperature differenes, and leaf temperatures, PAR, leaf transpiration and diffusive resistance respectively. The canopy temperatures were mean of 4 samples taken in N,E,S and W directions. The soil moisture was monitored using gravimetric as well as neutron moisture meter (Troxler USA).

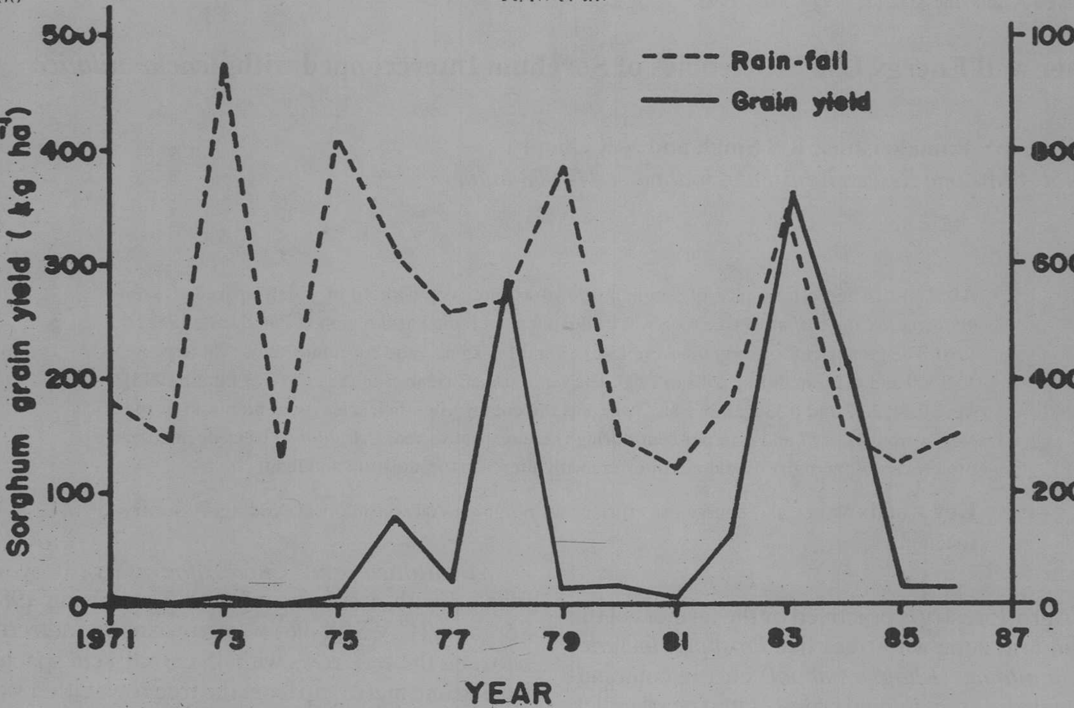

Fig 1 Sorghum Grain yields in relation to rainfall at Pali

Results and Discussion

Sorghum grain yields in relation to rainfall : The rainfall and sorghum production trends in the Pali district during 1971-1986 are shown in fig. 1. In a good rainfall year (1983), the average grain yield of the Pali district was 362 kg ha^{-1} at farmers level. In a year, when rainfall was below 300 mm (1972), the yields were very poor but local farmers continue to cultivate the crop for fooder use.

Under the experimental condiction (1988-1990), the yields were highest 683 kg ha^{-1}) during 1989 with 346 mm of rainfall received during the season. In 1988, the crop had put up maximum biomass with 433 mm rainfall, but continuous rainfall at milk formation/dough stage favoured long smut (*Tolyposporium ehrenbergii*) and reduced the grain production. In 1990, though the initial rainfall was very high, a severe dry spell for 25 days between 6 and 30 days after sowing had significant reduction in the normal growth of the crop. Past rainfall records of the location indicate that such prolonged breaks occur once in every three years reducing the sorghum grain yields.

A comparison between the yields of sorghum with and without trees showed that the area occupied by the base trees resulted in reduction of grain yield of sorghum by 300 kg ha-1 and 67 kg ha-1 (upto 30% reduction) during 1989 and 1990.

Water and energy use efficiencies of sorghum crop : The consumptive use values of sorghum were 302, 200 and 452 mm during 1988, 1989 and 1990 establishing a water use efficiency of 0.44, 2.27 and 0.33 kg mm^{-1} ha^{-1} (Table 1). The low WUE during 1988 was due to attack of long smut at grain formation

Table 1 *Water and energy use efficiencies of sorghum*

Year	Seasonal rainfall mm	Grain yield kg ha^{-1}	Total biomass kg ha^{-1}	Consumptive use mm	Water use efficiency kg. mm^{-1} ha^{-1}	Energy use efficiency %
1988	433	134	4744	302	0.44	0.42
1989	346	683	2064	300	2.27	0.17
1990	765	147	1716	452	0.33	0.16

Table 1 *Energy balance (MJm^{-2}) over sorghum*

	Incoming radiation	Net radiation	Latent heat of vaporization	Sensible heatflux	Soil headflux	Albedo %
Sorghum	21.3	16.9	−9.4	−6.1	−1.5	20
Bare soil	21.3	15.3	−7.8	−3.9	−3.6	22

stage, whereas during 1990 it was due to drought conditions. The energy use efficiencies (EUE) w.r.t. biomass production during the respective years were 0.42, 0.17 and 0.16 per cent.

Energy balance over surghum crop : The net radiation (recorded on 18.8. 1990) over the crop was 16.9 MJ m^{-2} and was 0.8 times that of the insolation (Table 2). The latent heat of vaporization was estimated based on the average consumptive use during the period. Under the bare soil conditions, the albedo was higher, but the net radiation was lower than under the cropped condictions. The sorghum had a maximum leaf area of 2670 cm^2 $plant^{-1}$ at vegetative stage (average LAI = 4.3) during 1988 intercepting 35% of the insolation. The LAI's of sorghum at vegetative stage in 1989 and 1990 were 2.76 and 2.61.

Leaf Temperature and transpiration rate from sorghum : The leaf temperature at vegetative phase when the soil moisture was at optimum, varied from 35.9 C to 36.9° C between 10.00 h to 15.00 h (Table 3). The diffusive resistance for the corresponding period varied from 0.04 to 0.09 s cm^{-1}, whereas the transpiration was 92.6 to 136.4 $\mu g\ cm^{-2}\ s^{-1}$. During 1990, the transpiration rates were high at vegetative phase and not showed any moisture stress.

Table 3 *Lef temperatures, diffusive resistance and transpiration rates of sorghum*

	Mean value of 8 samples		
	10.00 h	13.00 h	15.00 h
Leaf temperature, (° C)	35.9	36.9	36.4
Relative humidity, (%)	53	50	52
PAR (μ E $m^{-2} s^{-1}$)	1048	1740	1016
Diffusive resistance (sm^{-1})	0.09	0.04	0.05
Transpiration ($\mu g\ cm^{-2} s^{-1}$)	92.6	129.4	136.4

Stress variation in different intercrops : The relative stress (indicated by the difference between canopy and air temperatures) in these crops (Table 4) decreased in the order of sorghum (- 0.8), guar (-4.3), moong (-4.8) and *A. nilotica* (-5.9). Similar trends were continued in all the samples taken for each crop during all the three years. The observations on rooting pattern of *A. nilotica* tree showed that the lateral root extension was upto 1.3 m and tap root penetrating 2.0 m vertically down the profile. However, the maximum root density was between 0.2 to 0.4 m depths and 0.5 m round the trunk indicating its least competition for moisture extraction with the intercrops. The measured radiation interception by the *A. nilotica* trees varied from 60% within the 0.1 m radius from the base to 0% at 2 m distance from the stem. Thus, it is only in 1 m out of the 8 m inter spaced between the trees where the intercrop is grown under partially shaded (0-15 %) conditions.

Table 4 *Canopy temperatures in an agroforestry system*

	10:00 h		13:00 h		15:00 h	
	Tc	Tc–Ta	Tc	Tc–Ta	Tc	Tc–Ta
Tree component						
A.nilotica	31.9	−5.9	35.0	−6.0	32.2	−6.1
Intercrop						
Sorghum (SPV-96)	34.6	−0.8	37.3	−0.4	33.6	−4.9
Guar (2470/12)	32.1	−4.3	33.1	−4.9	31.0	−7.1
Moong (S-8)	32.3	−4.8	33.2	−5.6	31.5	−6.2

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