

Thus, it may be noticed that in case of non-availability of the appropriate strains of *Rhizobium*, the application with cowpea-*Rhizobium* will serve the purpose to get augmented yield benefits in these pasture legumes.

Natural nodulation and herbage yield were maximum with *Sesbania grandiflora* followed by

Albizia lebbek, *Acacia tortilis*, *Dichrostachys cinerea* and *Leucaena leucocephala* failed to nodulate on red soil (Table 3). In view of the generally poor natural nodulation observed, seeds of these species should be inoculated with specific rhizobia for better early establishment and higher biomass productivity.

Table 3.

Nodulation and herbage yield (average of 30 plants) of tree species in different soils

	Soil types								
	Red			Medium black			Mixed red and black		
	Nodules (No./plant)	Forage yield (g/plant)		Nodules (No./plant)	Forage yield (g/plant)		Nodules (No./plant)	Forage yield (g/plant)	
	Green	Dry		Green	Dry		Green	Dry	
<i>Sesbania sesban</i>	1	4.3	1.2	5	1.5	0.4	2	2.0	0.5
<i>S. grandiflora</i>	16	1.1	0.3	25	4.2	1.0	48	7.6	0.8
<i>Albizia lebbek</i>	3	0.6	0.3	6	0.8	0.4	18	1.6	0.8
<i>Dichrostachys cinerea</i>	Nil	1.3	0.6	4	0.4	0.2	Nil	1.1	0.5
<i>Acacia tortilis</i>	Nil	0.6	0.2	Nil	0.5	0.2	Nil	0.4	0.1
<i>Leucaena leucocephala</i>	Nil	8.0	2.1	Nil	1.8	0.4	2	5.0	1.4

The native rhizobial population for *Leucaena leucocephala* was extremely low (10^3 cells/g dry soil). *L. leucocephala* required specific *Rhizobium* for biomass production as cowpea-*Rhizobium* failed to produce the desired grains. Efficacy of single and multi-strains *Rhizobium* inoculant was studied in *L. leucocephala* var. K 28. Inoculant containing multi strains of proven efficacy gave better performance than that of single strain application (Table 4). Similar findings indicating the superiority of mixed strains inoculant in *L. leucocephala* have also been reported by Shinde and Relwani (1981).

Results of these investigations clearly indicate the significant role of different N^2 -fixers in establishment and biomass production of grasses, legumes as well as shrub-cum-tree legumes.

References

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Table 4
Effect of single and multi-strain inoculum on-nodulation and herbage yield of *Leucaena leucocephala* (var. K 28)

Treatments	Nodules (No./plant)	Forage yield (g/plant)	
		Green	Dry
Control (no inoculation)	3	2.9	0.7
Jhansi S-8	10	3.5	0.9
TAL-582	13	3.1	0.9
LL-28-2	6	3.3	0.8
JS-8 + 28-2	16	3.6	1.0
582 + 28-2	10	3.7	1.0
JS-8 + 582	20	3.9	1.0
JS-8 + 28-2 + 582	19	4.0	1.0

Water Use Efficiency and Biomass Production of Two Perennial Grasses From the Chihuahuan Desert (Mexico)

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Perennial grasses occupying low-lying areas which receive a surplus of water by runoff form the basis of forage resources for cattle rearing activities in

the Mapimi Bolson (Chihuahuan Desert, 26°40'N, 103°40'W, altitude 1100 m, annual rainfall 264 mm, mean annual temperature 22.8°C). The two most important species are *Hilaria mutica* (Buckl.) Benth. and *Sporobolus airoides* (Torr.) Torr. The species rarely coexist and they live in separate communities where each is the only tussock grass present, accounting for more than 95 per cent of a total ground cover of the herbaceous strata which varies between 20 per cent and 40 per cent. These communities cover roughly 20 per cent of a 172,000 ha mapped area. In general *S. airoides* grasslands occupy a topographically lower position than *H. mutica* grasslands. The former stand in low-lying areas where water accumulates after heavy rains and is transported towards salt lakes, whereas *H. mutica* grasslands occupy the next position in a gradient of decreasing intensity and periodicity of flooding. This distribution may be influenced by differences in the ability of the species to exploit the different water supply patterns, as well as by differences in soil salinity.

In this paper the questions of how water use efficiency (WUE) and leaf water potential (LWP) vary at different levels of water deficit in the soil are discussed in relation to the observed distribution of both grasses. These results are part of an integral study of the grassland ecology of this area with the aim of developing models for predicting forage production for management purposes.

A factorial design using two species under three water soil regimes and seven replicates was used. Soil water regimes were determined according to the function of soil water potential so as to maintain p^F of around 2, 3 and 4.2 in each treatment. Additional pots for each treatment without plants were used to account for evaporation produced in spite of the mulching.

Plastic pots with 5,900 g of dry soil mulched with a layer of 4 cm of coarse sand to prevent soil evaporation were used. Clay and sand contents of the soil were 14.6 and 65.8 per cent respectively. Soil moisture content determined by the pressure membrane method were 0.116, 0.072

and 0.054 $\text{cm}^3 \cdot \text{cm}^{-3}$ for p^F 2.5, 3 and 4.2.

After 15 days for germination and 30 days for establishment (at field capacity) after planting out, the experiment was run for 120 days in a growth chamber with a 13 hour photoperiod (at 30°C and 75% relative air humidity) and 11 hour dark period (at 25°C and 85% relative air humidity). Photosynthetically active radiation was $300 \mu\text{E}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. The watering was done every 3-4 days after weighing each pot so as to replace exactly the water lost during the period. An extra set of pots was used to measure the biomass accumulated during the establishment period.

During the last week of the experiment pre-dawn and mid-day LWP were measured with a pressure chamber for a random sample of each species and treatment. At the end of the experiment oven dry weights of shoots and roots were determined.

Fig. 1a shows the means of total biomass. An ANOVA showed that there were significant (here and hereafter $p < 0.05$) differences between species and watering regimes. Besides the general trend of decreasing biomass production as water stress increased it is clear from the graph that *S. airoides* produced more biomass than *H. mutica* at p^{F2} .

Fig. 1b shows the WUE values (expressed as grams of dry matter per litre of water transpired). An ANOVA showed that there were significant differences between watering regimes but that there was no difference between species. A Tukey multiple range test showed that the WUE at p^{F2} differed significantly from those at p^{F3} and 4.2.

Finally, Fig 1c shows the values of pre-dawn LWP. An ANOVA showed that there were significant differences between species and watering regimes. Mid-day LWP were always below -50 bars and commonly exceeded the range of the measuring apparatus, so that no analysis can be made with this information.

The main points in the results worthy of discussion here are:

- *S. airoides* produced more biomass than *H. mutica* when soil water was easily available.

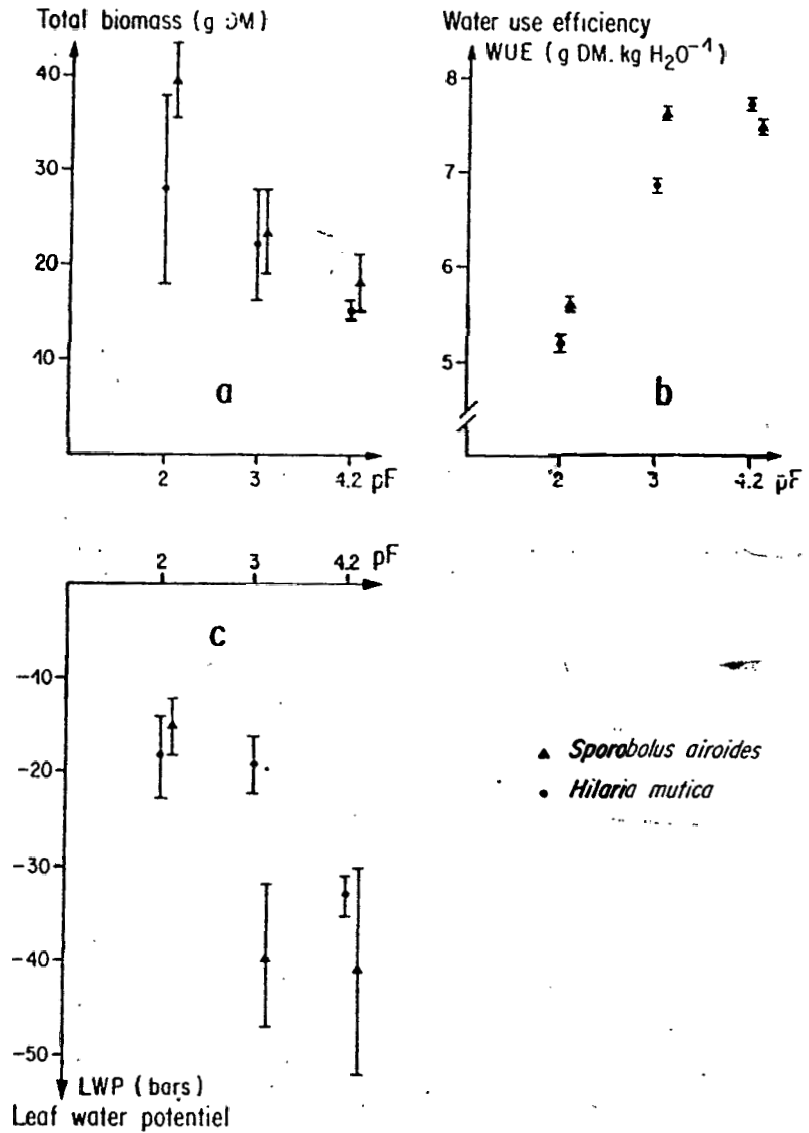


Fig. 1 (a) Total biomass for both species under three soil moisture levels ($\bar{x} \pm \text{st. dev.}$) (g. DM.)
 (b) Water use efficiency ($\bar{x} \pm \text{st. dev.}$) (gDm.KgH₂O⁻¹)
 (c) Pre-dawn leaf water potential LWP ($\bar{x} \pm \text{st. dev.}$) (bars)
 Triangles : *Sporobolus airoides*, Dots : *Hilaria mutica*.

- The WUE increased with water stress in both species. The observed values for *H. mutica* are higher than those reported by Dwyer and DeGarmo (1970), probably due to the high relative air humidity maintained in the growth chamber (Fisher and Turner, 1978).
- LWP decreased with water stress in both species but *H. mutica* developed low LWP only in the most driest regime whereas *S. airoides* did so at the intermediate level of water stress. It is worth mentioning that the readings were taken seven days after the final watering so that the soil water contents were lower than those occurring during the experiment.

All these results indicate that *S. airoides* has some advantages over *H. mutica* in flooded environments. Despite the fact that both perennial grasses need supplementary run off water to develop dense populations in the semiarid environment of the Bolson de Mapimi, *S. airoides* seems to be able to exploit the water available during flood conditions more successfully than *H. mutica* would have some advantages towards the other end of the gradient due to its ability to maintain relatively better LWP as water stress increases (Fig 1c). Other morphological and phenological features may enhance the ability of *H. mutica* to compete more efficiently with *S. airoides* in this situation. For *Hilaria mutica*, internodes elongation and leaf growth are concomitant, depending on environmental factors. A dry period stops the growth whereas a pulse of rain induces a new growth period. The flowering is linked to the number of internodes of the shoot. Each tuft always includes a population of shoots with variable numbers of internodes, allowing after each rain a new period of growth and reproduction.

By contrast *Sporobolus airoides* has only one or two annual growth periods and needs relatively large amounts of water to start growth of leaves and the development of new tillers or of flowering stalks.

References

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Tissue Water Relations of *Cassia tora* from Sun and Shaded Habitat

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Although many studies of the water relations of plants have been made, only a few of them relate to the behaviour of plants under the normal conditions of their habitat. The aim of the present investigation has been to gain information concerning the water balance of plants in their natural environment of sun and shaded habitat. In sun habitat, conditions tend to be somewhat extreme when the rates of evaporation are very high and water supply is limited. The data reported here are of studies made in mid April to June (1982-1984) in *Cassia tora* growing well both in sun and shaded habitats in derelict land. This plant is a summer annual and usually starts to grow in the field as soon as first rain falls i.e. in the middle of March or first week of April.

Previous investigations have stressed the importance of the water factor in respect of plant distribution of wetland and dryland habitat species (Nazrul - Islam 1983) and also in crop plants grown under waterlogged and non-waterlogged conditions (Nazrul-Islam and Yasmin 1982; Nazrul-Islam and Alam 1986; Nazrul-Islam 1987). Bannister (1964a, b, c) also has explained that there is a good correlation between the distribution of species with regard to soil moisture and water relations of the species concerned. Hygen (1953) has attempted an ecological characterisation of plants in terms of their rates of stomatal and cuticular transpiration. Okali (1971) also has shown the water relations of some woody species in relation to their distribution. Similar studies have been made in the present investigation with *Cassia tora* from sun and shaded habitat.