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Short Communication

Forage Yield of *Cenchrus ciliaris* Pasture and its Prediction in the Arid Region of Rajasthan

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The Indian arid zone of western Rajasthan is characterized by low and erratic rainfall. Arable farming is possible once in three years. Hence, the main economy of this region is dependent on forage production to support its 23 million head of livestock. Only 44% fodder requirement of the livestock in the region is met during normal rainfall years leaving a deficit of 56% (Shankarnarayan *et al.*, 1985). *Cenchrus ciliaris* is one of the important grasses among the seven major pasture types available in the Indian arid zone. *Cenchrus ciliaris* is a perennial, nutritive, highly palatable grass and performing better under arid conditions. In this paper, forage yield and its estimation using the RANGETEK model, water and energy-use efficiencies of *Cenchrus ciliaris* are studied.

The experiment was conducted at the Central Arid Zone Research Institute, Jodhpur (26°18'N, 73°01'E, height above MSL 224 m). *C. ciliaris* was planted at a spacing of 75 x 25 cm in 1988. The soil of the experimental site was loamy sand in texture having an effective depth of 100 cm. The field capacity was 10.2% water, wilting coefficient 2.8% water and bulk density 1.55 g cm^{-3}. The soil was poor in organic matter (0.25%), medium in available phosphorus (18 kg ha^{-1}) and available potassium (200 kg ha^{-1}). The average annual rainfall at Jodhpur is 360 mm with a coefficient of variation of 70% and usually occurs within a 75 day period. Fertilizer was applied at the rate of 20 kg N ha^{-1} per season. The grass yield was recorded in the pasture through forage estimation quadrat of 10 m^2 at about 20-25 day interval. There were 10 quadrats taken for estimation of forage yield. The correlation coefficients between weather parameters and grass yields were also calculated. Water use of the grass was calculated from the soil moisture depletion through 90 cm depth. Soil moisture contents were determined by neutron moisture meter. The water-use efficiency (WUE) was calculated from dry matter produced per unit of water consumed. The heat-use efficiency (HUE) of the grass was calculated from dry forage yield per unit degree (in °C) of heat consumed by the grass (Lemon, 1969). The accumulated degrees of heat (in °C) during the growing season was used for calculation of heat-use efficiency.

Table 1. Correlation coefficients between weather parameters and dry forage yield of C. ciliaris

Weather parameter	Value of correlation coefficient
Rainfall	0.778*
Rainy days	0.873
Maximum temperature	-0.928
Minimum temperature	-0.382
Relative humidity	0.928**
Pan evaporation	-0.869**
Wind speed	-0.864**
Duration of sunshine	-0.579

* Significant at 5% level
** Significant at 1% level

Table 2. Dry forage yield, water and heat-use efficiencies of C. ciliaris

	1990	1991	1992	1993	1994	Mean
Dry forage yield (kg ha^{-1})	2938	3380	2958	2345	2626	2849
Water use (mm)	363	164	290	157	365	268
Water-use efficiency (kg ha^{-1} mm^{-1})	8.1	20.6	10.2	14.9	7.2	12.2
Heat-use efficiency (kg ha^{-1} $°C^{-1}$)	0.27	0.34	0.43	0.20	0.19	0.29

The soil water balance and forage yield index (ratio of transpiration, T to potential transpiration, T_p) was calculated using RANGETEK model (Ross Wight and Neff, 1983). The model is used for real time simulation of daily soil water content, soil evaporation and plant transpiration to forecast forage production in terms of a ratio of actual to potential transpiration (yield index). Annual forage yield was calculated by the relationship, Yield = Potential yield x T/T_p (Ross Wight *et al.*, 1984). The model was driven by the daily maximum and minimum temperatures, precipitation and solar radiation. Soil characteristics like field capacity, wilting point, infiltration rate, slope, textural properties and plant variables were used in the model.

Rainfall at Jodhpur is confined to the months of July and August. Rains receded early in 1992, whereas, there was 7 week break in monsoon of 1993. Seasonal rainfall at Jodhpur varied from 182 mm in 1991 to 775 mm in 1990. Rainfall in July accounted for more than 75% of the total rainfall of 1990. Rainfall was well distributed during 1991 and therefore grass yield was maximum (3380 kg ha^{-1}). In 1993, low and uneven distribution of rainfall led to low yield (2345 kg ha^{-1}). Though 1992 was a normal rainfall year, but there was drought in July. The mean yield of *C. ciliaris* during 1990 to 1994 was 2849 kg ha^{-1}. Yield of *C. ciliaris* reached maximum with rainfall between 180 and 250 mm during growing season.

Rainfall, rainy days and relative humidity showed a positive correlation with forage yield, whereas air temperatures, pan evaporation, wind speed and duration of sunshine showed a negative correlation (Table 1).

The total water use of *C. ciliaris* varied between 157 and 365 mm with a mean value of 268 mm (Table 2). In low rainfall years of 1991 and 1993, the water use was low (157 to 164 mm) with a little variation in total water use of the grass, whereas in high

Table 3. Soil water balance, yield index and estimated dry forage yield of C. ciliaris at Jodhpur using the RANGETEK model

	1990	1991	1992	1993	1994	Mean
Seasonal rainfall (mm)	775	182	383	188	533	412
Potential soil evaporation (mm)	86	83	93	95	96	91
Actual soil evaporation (mm)	38	27	33	35	80	43
Potential transpiration (mm)	232	203	249	248	280	242
Actual transpiration (mm)	144	113	158	101	162	136
Yield index	0.81	0.77	0.80	0.62	0.76	0.75
Actual dry forage yield (kg ha^{-1})	2938	3380	2958	2345	2626	2849
Predicted dry forage yield (kg ha^{-1})	3220	3061	3181	2465	3021	2990
Deviations (%)	+9	-10	+5	+5	+15	+5

rainfall years of 1990 and 1994, its water use was high (363-365 mm). The WUE of *C. ciliaris* was high in 1991 (20.6 kg ha^{-1} mm^{-1}) and low in 1994 (7.19 kg ha^{-1} mm^{-1}). The HUE of the grass varied from 0.19 to 0.43 kg ha^{-1} $°C^{-1}$ (Table 2). Rao *et al.* (1993) also reported similar results.

Soil water balance parameters computed using RANGETEK model (Table 3) revealed that potential transpiration varied from 203 to 280 mm with a mean of 242 mm, whereas actual transpiration from 101 to 162 mm with a mean value 136 mm. The potential soil evaporation varied from 83 to 96 mm with mean value 91 mm, whereas the actual values were between 27 and 80 mm with a mean of 43 mm. The yield index which is a ratio of actual to potential transpiration was the lowest (0.62) in 1993 and the highest (0.81) in 1990 showing the levels of forage yield from the potential yield of the experimental plots. While computing yield index, the transpiration values were used upto peak vegetative growth. The predicted yields using the RANGETEK model were 3220, 3061, 3181, 2465 and 3021 kg ha^{-1} during 1990 to 1994 (Table 3). The deviations between the predicted forage from the recorded yield were between -10 and +15%.

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