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A study on fuelwood consumption in two villages of Bhaderwah forest division (J&K), India

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Abstract
Maintaining livestock productivity on degraded pasturelands is one of the most pressing challenges facing semi-arid eastern India, where overgrazing and erratic rainfall have left large tracts with less than 30% vegetative cover. This research screened eight tropical forage grass species for drought tolerance, dry matter yield, ground cover, and nutritive value on a degraded pasture at the Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, over two seasons (2021-2023). A Drought Tolerance Index (DTI) compared yields under natural dry-spell conditions with irrigated controls. *Cenchrus ciliaris* recorded the highest DTI (0.83) combined with strong dry matter yield (6.84 t/ha) and broadest ground cover (74%). Panicum maximum produced the highest absolute yield (7.42 t/ha) but had the lowest DTI (0.54). *Dichanthium annulatum* balanced good drought tolerance (DTI 0.78) with the highest palatability ranking. A mixed re-seeding strategy combining *C. ciliaris*, *D. annulatum*, *and Stylosanthes hamata* is recommended for degraded pasturelands.

Keywords: Drought-tolerant grasses, forage, pastureland restoration, livestock feed, *Cenchrus ciliaris*, *Dichanthium annulatum*, rangeland management, dry matter yield, drought tolerance index, semi-arid

Introduction
The challenge is stark: Bihar's livestock population of 36 million depends on roughly 0.4 million hectares of permanent pastures, most producing less than 1.5 t/ha against a requirement of over 4 t/ha [1]. Restoring these pasturelands with drought-tolerant perennial grasses could reduce the forage deficit and stabilise eroded soils [2].
Drought tolerance in grasses involves deep rooting, osmotic adjustment, leaf rolling, dormancy under stress, and rapid regrowth after rain [3]. Species native to the semi-arid tropics, such as *Cenchrus ciliaris* and *Dichanthium annulatum*, have evolved these traits, while high-yielding introductions like Panicum maximum often lack them [4]. The drought tolerance index compares stressed and non-stressed yields, giving a value between 0 and 1 [5].
This research was conducted at Dr. Rajendra Prasad Central Agricultural University, Pusa (25.98 deg N, 85.67 deg E; altitude 52 m), to identify grass species combining drought tolerance with acceptable yield and forage quality for degraded pastureland restoration in Bihar [6, 7, 8].

Material and Methods
Material
Root slips of eight species (*Cenchrus ciliaris*, *Chrysopogon fulvus*, *Dichanthium annulatum*, *Stylosanthes hamata*, *Panicum maximum*, *Brachiaria brizantha*, *Heteropogon contortus*, *Sehima nervosum*) were sourced from the Indian Grassland and Fodder Research Institute, Jhansi. The site was a degraded pasture with sandy loam soil (pH 7.4, OC 0.31%, available N 142 kg/ha). Mean annual rainfall is 1,120 mm, concentrated June-September. A natural dry spell of 32 consecutive rainless days occurred during September-October 2022.

Methods
Species were planted in a RCBD with four replications in July 2021 on 4 m x 3 m plots at 50 cm x 50 cm spacing. Basal dose: 40:30:20 kg $N{:}P_2O_5{:}K_2O$/ha. An irrigated control strip received supplemental water during dry spells; main plots were rain-fed. Three cuts per year

were taken at 8-week intervals. Dry matter yield, ground cover (point-quadrat method), and crude protein (Kjeldahl N x 6.25) were recorded [9]. DTI = stressed yield / irrigated yield, averaged over two seasons [5]. ANOVA with Tukey's HSD at $p<0.05$ in SAS 9.4 [10].

Results

Table 1: Performance of eight forage grass species on degraded pastureland (two-season mean)

Species	DM (t/ha)	DTI	Cover (%)	CP (%)	NDF (%)	Root (cm)	Palatability
C. ciliaris	6.84	0.83	74	8.4	62.3	124	2
C. fulvus	5.21	0.71	58	7.1	67.8	98	5
D. annulatum	5.93	0.78	67	9.2	59.7	87	1
S. hamata	4.18	0.62	51	14.3	48.2	64	3
P. maximum	7.42	0.54	63	10.7	58.4	72	4
B. brizantha	6.31	0.69	61	8.9	63.1	91	6
H. contortus	4.87	0.76	53	6.8	71.4	108	7
S. nervosum	3.96	0.58	38	5.9	73.6	76	8
HSD ($p<0.05$)	0.67	0.08	7	1.1	3.4	12	-

C. ciliaris achieved the best DTI-yield combination. *P. maximum* topped yield but lost nearly half its potential during drought. *D. annulatum* balanced tolerance, yield, and palatability. Ground cover at 18 months ranged from 74% (*C. ciliaris*) to 38% (*S. nervosum*).

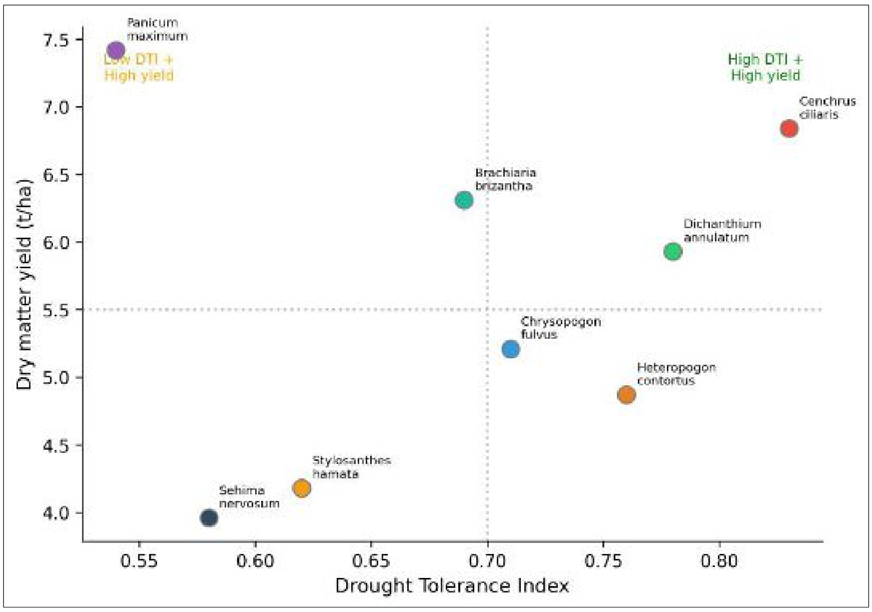

Fig 1: Drought tolerance index versus dry matter yield for eight forage grass species

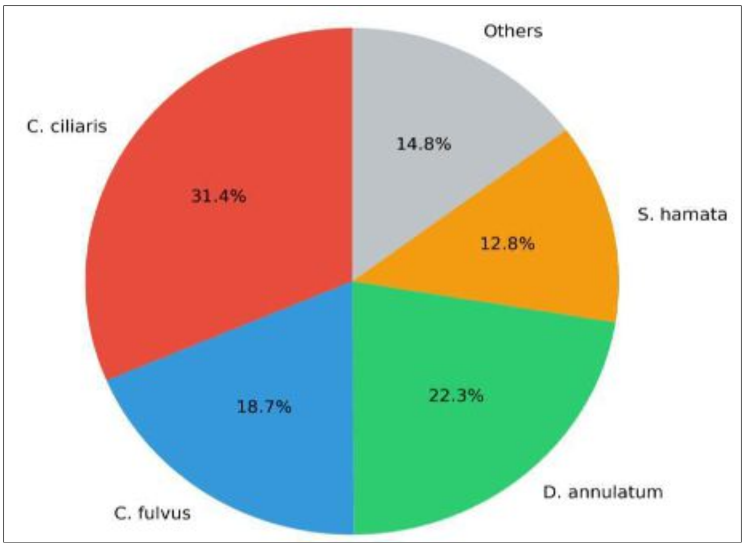

Fig 2: Ground cover contribution of dominant species at 18 months post-establishment

The scatter plot (Figure 1) places *C. ciliaris* in the ideal upper-right quadrant (high DTI, high yield). *P. maximum* falls in the upper-left zone, suitable only where irrigation is available. The pie chart (Figure 2) shows natural dominance of drought-adapted species, with *C. ciliaris* contributing 31.4% of total cover.

Discussion

C. ciliaris's DTI of 0.83 reflects its deep root system (124 cm) accessing subsoil moisture, combined with dormancy capability during prolonged drought [4]. Its CP content (8.4%) meets the minimum maintenance requirement for adult cattle (7%), though supplementation is needed for growing stock [11]. *D. annulatum*'s high palatability makes it a valuable companion species; livestock in Bihar graze mixed swards, and a palatable component encourages intake [12].

S. hamata, although ranking poorly on DTI (0.62), contributes nitrogen fixation and high CP (14.3%), improving overall sward nutritional value [13]. The practical message: a seeding mixture of *C. ciliaris* (dominant), *D. annulatum* (palatability), and *S. hamata* (legume) offers the best combination for restoration. *P. maximum* should only be recommended where supplemental irrigation is available, as its yield advantage disappears under stress [14, 15].

Conclusion

Among eight forage species, *Cenchrus ciliaris* offered the best combination of drought tolerance, dry matter production, and ground cover establishment on degraded pastureland in Bihar. *Dichanthium annulatum* ranked highest for palatability with good drought tolerance. A mixed re-seeding strategy combining these two species with the legume *Stylosanthes hamata* is recommended. Panicum maximum, despite the highest yield, is unsuitable for rain-fed degraded sites. Future work should track species persistence over longer periods, monitor animal performance on restored swards, and assess the soil recovery trajectory.

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