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Research Article

Growth and yield performance of fodder grasses and their impact on soil physico-chemical properties in Jammu subtropics, India

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Abstract

The growth and yield performance of seven fodder grasses were evaluated under tree shade and in open-field conditions during 2021-2023 in the sub-tropical region of Jammu, India. The experiment included 7 treatments representing different grass species: T_1- *Setaria anceps* (var. S-25), T_2- *Sorghum bicolor*, T_3- *Setaria anceps* (var. PSS-1), T_4- *Pennisetum purpureum*, T_5- *Paspalum notatum*, T_6- *Brachiaria decumbens* and T_7- Natural grass, grown both under the shade of *Terminalia chebula* trees and in open (control) conditions. Tree shade recorded a positive effect on growth parameters exhibiting higher plant height, leaf length, and leaf area whereas, physiological attributes (chlorophyll content, crop growth rate, relative growth rate) and yield parameters (fresh and dry yield) of grasses were higher in open conditions. Only a marginal improvement in soil physico-chemical properties compared to the initial fertility status was recorded. The findings suggested that in order to enhance forage production and ensure year-round fodder availability the grass species might preferably be grown in open conditions. *Setaria anceps* var. PSS-1 exhibited the maximum fresh and dry forage yield and might be a suitable choice for open-field cultivation in this region.

Keywords: Fodder yield, Grasses, Open, Shade, Sub-tropical, *Terminalia chebula*

Introduction

The livestock sector is a crucial component of India's agrarian economy, contributing significantly to socio-economic development, nutritional security, and employment generation. It plays a multifaceted role, particularly in rural areas, by providing essential products such as milk, meat, eggs, wool and fiber, while serving as a primary source of livelihood for millions. The sector directly employs approximately 20.5 million people and sustains millions of marginal and landless farmers, highlighting its role in poverty alleviation and rural development (Pathak, 2024). India's total livestock population has reached 535.78 million, reflecting a 4.6 % increase from the previous census in 2012. India holds a dominant position globally, accounting for 57.3% of the world's buffalo population and 14.7 % of its cattle population (Mehta *et al.* 2024). However, despite this substantial livestock base, productivity levels remain sub-optimal due to several systemic challenges. One of the primary constraints is the inadequacy of quality feed and fodder, which accounts for nearly 50% of total production losses in addition to inefficiencies in breeding programs, disease prevalence and limited access to veterinary healthcare (Singh *et al*., 2020). India currently faces a substantial fodder deficit, with a shortfall of 35.6 % in green fodder and 10.9 % in dry forages, a gap projected to widen to 45 % and 11 %, respectively, in the coming years. This growing scarcity poses a significant challenge to the sustainability of livestock farming, necessitating urgent interventions to enhance fodder and feed resource management (Thevathasan and Gordon, 2004).

In Jammu and Kashmir, total fodder production is estimated at 91.5 lakh tonnes, comprising 61.4 lakh tonnes of green fodder and 25.1 lakh tonnes of dry fodder (Mehta *et al.*, 2024). However, the region faces a critical deficit of 67% in green fodder and 27.31% in dry fodder, severely impacting livestock productivity. As of 2023, the union territory's livestock population includes 14.58 lakh cattle, 16.26 lakh sheep, 0.214 lakh buffaloes and 3.17 lakh goats, all of which require adequate nutrition to maintain health and productivity (Mehta *et al.*, 2024).

Given these constraints, a strategic approach to enhance fodder production and ensuring its year-round availability was imperative. This requires not only increasing overall fodder yield but also optimizing its distribution across seasons to mitigate shortages. In this context, the objective of the present study was to evaluate the growth performance of grass species under two different environmental conditions: tree shade and open sunlight, in order to find the most suitable species to be grown in Jammu sub-tropics for higher forage production.

Materials and Methods

Experimental site and design: The site selected for the study was the Experimental Farm of the Division of Silviculture and Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu. Geographically, the site is located between 32°73′ N latitude and 74°87′ E longitude. The area falls under the sub-tropical zone of the Jammu division and is situated at an altitude of 325 m above mean sea level (amsl). The climate of the area is characterized by hot-dry summers, hot and humid rainy months, and cold winters. The average rainfall of experimental location is about 1000-1200 mm, of which 75 to 80 percent is received during July to September and the rest 20 to 25 percent during winter months from December to February. The maximum temperature rises to 45 °C during May-June and the minimum falls to about 1 °C in the month of December-January (Kumar, 2019). The soil (0-15 cm) of experimental site was analysed before initiation of the trial and was found to be alkaline in nature (7.77-7.85) with normal electrical conductivity (0.26-0.30 dSm^{-1}) and bulk density (1.46 -1.50 g cm^{-3}). The NPK content of the soil was also recorded under low category (184.12-201.56, 9.80-10.15 and 96.32-101.32 kg ha^{-1}, respectively). The experiment included 7 treatments (grass species): T_1- *Setaria anceps* (var. S-25), T_2- *Sorghum bicolor,* T_3- *Setaria anceps* (var. PSS-1), T_4- *Pennisetum purpureum*, T_5- *Paspalum notatum*, T_6 - *Bracharia decumbens* and T_7 - Natural grass grown under the shade *Terminalia chebula* trees as well as in open conditions. The plantation was 11 years old and maintained at a spacing of 5 m × 4 m. A total of 21 plots with dimensions of 4 m × 2.8 m were prepared both under the trees as well as in open conditions. All grass species except *Sorghum bicolor* (T_2) were planted using slips at a spacing of 40 cm × 40 cm making a total of 70 plants per plot, whereas seeds of sorghum were directly sown in the assigned plots. No manure or fertilizer of any kind was used during the experimental trial. The experimental trial was laid out using a randomized block design with 3 replications.

Sampling and methods of analyses: The observations on growth parameters of grasses were recorded before every harvest. A total of three harvests each of green fodder were taken both in the first year as well as second year. The data presented in this paper was the mean of two year data. For data collection, five plants were randomly selected from each treatment plot and were tagged. The selected plants were used for recording all the observations related to growth and the average values of these five plants were taken for statistical analysis. The plant height of the tagged plants was measured in centimetres from the ground level to the top of the tip and the number of tillers per plant was recorded by counting tillers of all the five tagged plants from each plot and the average tiller per plant was worked out (Dash *et al.,* 2022). The length of the leaf was recorded by measuring the length from the junction of main stem to the tip of leaf. For estimation of leaf area, the leaves collected from tagged plants were designated into small, medium and large categories and the number of leaves in each of these categories was counted. Then, 3 leaves from each of these categories were selected and their area was determined with the help of length and breadth method (Musa *et al.,* 2016).

Crop growth rate is the dry matter accumulation of crop communities per unit land area per unit time. The crop growth rate of the grass species was calculated using the following equation (Radford, 1967).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Relative growth rate is the cumulative increase in dry matter per unit time. It was calculated using the following formula (Williams, 1946).

$$RGR = \frac{\log W_2 - \log W_1}{t_2 - t_1}$$

W_1 = Dry weight at time t_1; W_2 = Dry weight at time t_2 and t_2 - t_1 = Time interval in days

For data related to yield, the entire plot was cut approximately 5 cm above the soil surface using sickle at maturity and the fresh weight of whole plot was recorded immediately. After harvesting the whole plot, five sub-samples of fresh material (500 g each) of each treatment were placed in perforated paper bags, brought to the laboratory and oven-dried at 60° C till constant weight was achieved and the dry matter yield was determined from green fodder data (Pandey *et al.,* 2011).

In order to analyse the physico-chemical properties of the soil, composite soil samples were collected randomly from 0-15 cm soil depth by using core sampler (Peterson and Calvin, 1965). The analysis was conducted twice: initially before the commencement of experimental trial and subsequently after the final crop harvest using standard methods. The experimental data collected were subjected to analysis of variance (ANOVA) in a 2-factor factorial design (factor 1: grass species (T) and factor 2: planting conditions (C) i.e. open and shade) by using OPSTAT. Wherever the effects exhibited significance at a 5 percent level of probability, the critical difference (CD) was calculated.

Results and Discussion

Growth parameters: Effect of planting conditions (C), and grass species (T) on growth parameters *viz*. plant height, leaf length, leaf area, number of leaves and number of tillers were recorded (Table 1). Among the two planting conditions, grass species grown under shade recorded significantly higher plant height (100.16 cm), leaf length (46.65 cm) and leaf area (55.43 cm^2). Conversely, the number of tillers (45.25) and leaves (385.09) were recorded higher under open conditions. Among the grass species, T_2 (*Sorghum bicolor*) grown under shaded conditions recorded maximum plant height (140.07 cm), leaf length (73.48 cm) and leaf area (102.87 cm^2), whereas T_3 (*Setaria anceps,* var. S-25) under open conditions exhibited the highest average number of tillers (67.24) and leaves (629.28) per plant. The adaptation of plants to shade involves morphological and physiological adjustments, with variations observed across species and genotypes (Jose *et al.,* 2019).

The elongation of plant height under shade could be attributed to reduced light intensity. Diminished light level stimulates the activity of protein (expansins), leading to increased cell division and elongation (Dash *et al.,* 2022). Rezai *et al.* (2018) demonstrated that shading significantly influenced leaf size, noting that plants grown under 50% and 70% shade exhibited larger leaves compared to those grown under full sunlight. The regulation of tiller production in grasses is influenced by genetic and physiological factors, as well as their interaction with environmental conditions (Assuero and Tognetti, 2010). Higher levels of shading could decrease the rate of tillering by delaying the development of tiller buds into tillers (Anthony and Thomas, 2015). The rate of leaf production is dependent on the number of tillers produced, thus resulting in a similar trend as observed in the number of tillers produced. On the similar lines, Jose *et al.* (2019) reported higher number of tillers and leaves in fodder grasses in the open conditions compared to grasses grown under coconut and rubber trees.

Physiological parameters: It is evident from the data presented in Table 2 that planting conditions and grass species exhibited a significant effect on chlorophyll content and crop growth rate (CGR) whereas, the effect was found to be non-significant in case of relative growth rate (RGR). Among the two planting conditions, the grass species grown in open conditions recorded higher CGR

Table 1. Growth character of fodder grasses grown under tree shade and in open conditions

Treatments (T)	Planting conditions (C)									
	Shade	Open	Shade	Open	Shade	Open	Shade	Open	Shade	Open
	Plant height (cm)		Leaf length (cm)		Leaf area (cm^2)		Number of tillers per plant		Number of leaves per plant	
T_1: *Setaria anceps* (var. S-25)	104.41	70.84	53.85	41.49	68.93	53.10	58.32	64.44	516.46	579.84
T_2: *Sorghum bicolor*	140.07	72.73	73.48	49.99	102.87	69.98	10.08	12.20	41.62	58.18
T_3: *Setaria anceps* (var. PSS-1)	110.51	73.98	59.81	45.94	61.60	47.32	62.54	67.24	572.84	629.28
T_4: *Pennisetum purpureum*	125.39	85.73	64.38	48.19	64.38	48.19	52.89	56.90	449.29	498.97
T_5: *Paspalum notatum*	68.68	51.12	32.75	29.90	42.90	39.16	31.85	38.95	261.76	323.70
T_6: *Bracharia decumbens*	95.40	67.59	33.33	31.66	41.99	39.89	47.65	58.48	355.03	440.45
T_7: Natural grass	56.64	25.91	8.93	5.32	5.36	3.20	16.35	18.56	137.61	165.18
Mean	100.16	63.99	46.65	36.07	55.43	42.98	39.95	45.25	333.52	385.09
Factor	CD (P<0.05)	SEM	CD (P<0.05)	SEM	CD (P<0.05)	SEM	CD(P<0.05)	SEM	CD (P<0.05)	SEM
T	2.74	0.94	1.15	0.39	1.38	0.47	1.17	0.40	13.10	4.48
C	1.46	0.50	0.61	0.21	0.74	0.25	0.62	0.21	7.00	2.40

Table 2. Physiological attributes of fodder grasses grown under tree shade and in open conditions

Treatments (T)	Planting conditions (C)					
	Shade	Open	Shade	Open	Shade	Open
	Chlorophyll content (SPAD value)		Crop growth rate (g $m^{-2}day^{-1}$)		Relative growth rate (g $g^{-1}day^{-1}$)	
T_1: *Setaria anceps* (var. S-25)	37.83	32.62	8.06	10.17	0.0096	0.0099
T_2: *Sorghum bicolor*	32.05	26.38	5.76	7.09	0.0109	0.0117
T_3: *Setaria anceps* (var. PSS-1)	37.45	32.22	6.12	7.91	0.0096	0.0098
T_4: *Pennisetum purpureum*	39.56	37.30	4.96	7.16	0.0109	0.0112
T_5: *Paspalum notatum*	36.10	34.90	6.63	9.84	0.0106	0.0109
T_6: *Bracharia decumbens*	32.92	29.91	4.34	6.66	0.0098	0.0105
T_7: Natural grass	23.88	20.58	3.09	6.05	0.0104	0.0115
Mean	34.25	30.56	5.57	7.84	0.0103	0.0108
Factor	CD (P<0.05)	SEM	CD (P<0.05)	SEM	CD (P<0.05)	SEM
T	1.04	0.36	0.70	0.24	NS	0.00
C	0.56	0.19	0.37	0.13	NS	0.00

Table 3. Yield parameters of fodder grasses grown under tree shade and in open conditions

Treatments (T)	Planting conditions (C)			
	Shade	Open	Shade	Open
	Forage fresh weight (t ha^{-1})		Forage dry weight (t ha^{-1})	
T_1: *Setaria anceps* (var. S-25)	70.98	83.04	15.81	18.41
T_2: *Sorghum bicolor*	38.42	42.70	10.11	11.80
T_3: *Setaria anceps* (var. PSS-1)	79.20	87.93	16.84	20.33
T_4: *Pennisetum purpureum*	66.16	74.98	10.92	12.21
T_5: *Paspalum notatum*	52.25	62.30	12.50	15.83
T_6: *Bracharia decumbens*	42.24	49.72	8.87	10.04
T_7: Natural grass	16.91	23.79	7.86	11.55
Mean	52.31	60.64	11.85	14.31
Factor	CD (P<0.05)	SEM	CD (P<0.05)	SEM
T	2.57	0.88	0.56	0.19
C	1.38	0.47	0.30	0.10

(7.84 $m^{-2}day^{-1}$) and chlorophyll content (34.25). The higher CGR under open conditions probably be due to presence of more sunlight which might have exhibited higher photosynthetic efficiency and in turn accumulated higher biomass. According to Kishore *et al.* (2021) utilization of light energy in an intercropping system depends on the interception of photosynthetically active radiation (PAR) by the leaves of intercrop and its assimilation to produce biomass. Renu *et al.* (2017) also recorded higher crop growth rate and relative growth rate values in new pearl millet hybrids grown as sole compared to intercropping systems. Likewise Mishra *et al*. (2020) reported 40% reduction in relative growth rate (RGR) of *Phalaris minor* in 55% shading compared to open conditions.

Yield parameters: The data presented in Table 3 clearly indicated that both planting conditions and grass species had a significant impact on forage fresh and dry yield. Among the two planting conditions, forage yield was higher in open-field conditions, with fresh yield recorded at 60.64 t ha^{-1} and dry yield at 14.31 t ha^{-1}. This variation could be attributed to absence of competition for nutrients from trees and increased light availability in open fields resulting in production of more tillers and hence more leaves. Furthermore, the greater exposed photosynthetic area in open conditions enhanced solar radiation interception, thereby facilitating higher photosynthetic activity. Notably, among the grass species, T_3 (*Setaria anceps*, var. PSS-1) grown under open conditions exhibited the highest fresh (87.93 t ha^{-1}) and dry (20.33 t ha^{-1}) forage yields. Deepthi *et al*. (2024) stated that fodder yield was directly influenced by tiller production, with increased tillering under open conditions contributing to higher

Table 4. Effect of fodder grasses on physico-chemical properties of soil

Treatments (T)	Planting conditions (C)											
	Shade	Open	Shade	Open	Shade	Open	Shade	Open	Shade	Open	Shade	Open
	Soil pH		**Bulk density ($g\ cm^{-3}$)**		**Electrical conductivity ($dS\ m^{-1}$)**		**Available nitrogen ($kg\ ha^{-1}$)**		**Available phosphorus ($kg\ ha^{-1}$)**		**Available potassium ($kg\ ha^{-1}$)**	
T_1: *Setaria anceps* (var. S-25)	7.71	7.78	1.42	1.47	0.32	0.27	205.85	194.32	11.32	10.22	106.53	98.42
T_2: *Sorghum bicolor*	7.75	7.84	1.44	1.46	0.31	0.27	214.39	196.12	11.25	10.01	107.72	98.33
T_3: *Setaria anceps* (var. PSS-1)	7.69	7.81	1.43	1.47	0.30	0.28	216.52	195.65	10.88	9.75	106.28	99.20
T_4: *Pennisetum purpureum*	7.68	7.83	1.42	1.48	0.30	0.28	211.34	193.49	11.29	10.05	105.44	98.13
T_5: *Paspalum notatum*	7.70	7.82	1.42	1.48	0.30	0.27	217.96	195.50	10.94	10.37	107.28	97.92
T_6: *Bracharia decumbens*	7.73	7.84	1.44	1.47	0.31	0.27	209.54	192.24	10.99	10.36	106.87	98.26
T_7: Natural grass	7.72	7.80	1.43	1.45	0.31	0.28	216.95	195.32	10.94	10.51	107.30	98.92
Mean	7.71	7.82	1.43	1.47	0.32	0.27	213.22	194.66	11.09	10.18	106.77	98.45
Factor	CD(P<0.05)	SEM	CD(P<0.05)	SEM	CD (P<0.05)	SEM	CD (P<0.05)	SEM	CD (P<0.05)	SEM	CD (P<0.05)	SEM
T	NS	0.02	NS	0.00	NS	0.00	3.54	0.36	NS	0.24	NS	0.00
C	0.02	0.01	0.01	0.01	0.01	0.00	1.89	0.19	0.32	0.13	0.90	0.00
Initial value	7.77	7.85	1.46	1.50	0.30	0.26	201.56	184.12	10.15	9.80	101.32	96.32

yields. Additionally, a reduction in solar radiation negatively affected photosynthetic efficiency and carbohydrate assimilation (Anthony and Thomas, 2015). Similarly Jose *et al.* (2019) reported that fodder grasses cultivated in the open conditions produced higher fresh biomass compared to those grown under shade.

Impact of fodder grasses on soil physico-chemical properties: The data regarding physico-chemical properties of soil towards the end of the experiment recorded only a marginal improvement compared to the initial values (Table 4). More specifically, it recorded an increase in soil electrical conductivity (EC), nitrogen (N), phosphorus (P) and potassium (K) contents, whereas pH and bulk density (BD) values exhibited a decreasing trend both under the shade as well as in open conditions. It might be attributed to increase in soil organic matter content brought about by incorporation of biomass of the intercrops resulting in better aggregation properties of soil. In addition, the intercultural operations might have contributed in decreasing the compactness of soil and hence increased soil aeration. Organic matter is a very important part of soil and usually used as an important index of the soil fertility level, and contains nutrient elements needed for plant growth (Wang *et al.*, 2023). Among the two planting conditions, lower pH (7.71) and bulk density (1.43 $g\ cm^{-3}$) were recorded under tree shade. It was attributed to higher accumulation of organic matter in the form of leaf litter, twigs and root biomass under tree based agroforestry system and the decomposition of these organic materials produced acids, such as folic acid and humic acid, which contributed to soil acidification *i.e.*, lowering of soil pH (Singh, 2018). Similar results were also reported by Devi *et al.* (2020) and Sharma *et al.* (2022). Sharma (2011) found that soil with higher organic matter content also tended to exhibit lower bulk density due to the lower particle density of organic matter and the formation of soil aggregates.

In the present study, higher nitrogen (213.22 $kg\ ha^{-1}$), phosphorus (11.09 $kg\ ha^{-1}$) and potassium (106.77 $kg\ ha^{-1}$) contents were recorded under the shade of *Terminalia chebula* trees. The accumulation and subsequent decomposition of organic constituents contributed to heighten nitrogen accumulation under tree-based agroforestry systems relative to tree-less plots. Singh *et al.* (2021) observed greater total nitrogen stock in tree + fodder wheat based agroforestry systems relative to sole wheat plots. The enhancement in phosphorus under tree shade could be attributed to the ability of woody perennial components to absorb phosphate ions from deeper soil layers and redistribute them to upper layers through the decomposition of litter. Sharma (2011) identified factors such as denser fine roots, microbial activity, mycorrhizal associations and root-induced phosphorus solubility as major contributors to increased available phosphorus under tree-based agroforestry systems. Potassium regulates transpiration, respiration, enzymatic activity and the synthesis of proteins and carbohydrates (Sharma *et al*., 2022) and also plays a critical role in opening and closing of stomata, water balance, and osmotic potential regulation (Erel *et al*., 2013). The higher potassium content under tree based systems was also recorded earlier (Devi *et al*., 2020; Sharma *et al*., 2022).

Conclusion

Fodder grasses produced higher forage yields (both fresh and dry) when grown under open conditions *i.e.,* tree-less plots in comparison to tree shade. More specifically, *Setaria anceps* var. PSS-1 might be adopted and grown on open fields under sub-tropical conditions of Jammu for higher forage production in order to meet the fodder demands of livestock in the region.

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