Annals of Arid Zone 64(2): 187-197, 2025

Ecophysiological Variability and Species Distribution of Grasses in Kheda and Ahmedabad Districts, Gujarat, India

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Received: February 8, 2025 Accepted: March 24, 2025

Abstract: Study of ecophysiology represents structure and function of grasses in particular ecological area. As grasses are under family poaceae which is one of the major family of plants worldwide, work on ecophysiology has deep insights. Ecological parameters, including the Important Value Index (IVI), density, frequency, and abundance, along with physiological traits such as Relative Water Content (RWC), Specific Leaf Area (SLA), and proline content, were studied across two seasons from Kheda and Ahmedabad districts in the Central Gujarat region. Highest proline content was recorded in *Cynodon dactylon* indicating high resilience of the species with respective average values of 0.33 and 1.23 mg g^{-1} in Ahmedabad and Kheda district respectively and almost, similar kind of results were seen for IVI as it also expressed highest IVI too. Determination of soil parameters in the form of pH, EC, TDS and TSS gave useful correlations with eco-physiological characteristics of the area. pH and Biomass showed positive association in both areas. Additionally, RWC has very strong positive correlations with proline (0.98**), TDS (0.90**), and EC (0.96**) indicated their close interaction in management of adapting mechanism in both these districts. Current work can be of high use in developing research strategies in identification of grasses along with their adaptation traits for plant responses to their environmental challenges.

Key words: Ecology, Physiology, Grasses, IVI, RWC, SLA, Kheda, Ahmedabad.

The grass family Poaceae represents the fourth largest family among flowering plants and the second among monocotyledons with an estimated number of 10,000 species under 700 genera (Dahlgren *et al*. 1985). Grasslands made up of species of Poaceae make up one fifth of the world's vegetational cover. Poaceae comprise the most important group of plants, the grasses and bamboos that have been closely associated with human beings for the past thousands of years. No plant family comes close to Poaceae in its importance to world agriculture. Grasses are found in high number compared to other group of plants on the earth, represent largest family having 10,000 species and around 651 genera. (Clayton & Renvoize, 1986). By any reckoning the grasses are a successful family regarding their

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Citation
Vijayanshi, N.A. and Nakar, R.N. 2025. Ecophysiological variability and species distribution of grasses in Kheda and Ahmedabad districts, Gujarat, India. Annals of Arid Zone 64 (2): 187-197

https://doi.org/10.56093/aaz.v64i2.164614

https://epubs.icar.org.in/index.php/AAZ/article/view/164614

adaptability to changeable environments and their ability to coexist with grazing herbivores and man. Even before the recorded history, the grains of grasses undoubtedly provided a staple food supply for the human race. Grasses inhabit the earth in greater abundance than any comparable group of plants. In earlier days the word "grass" was used for any kind of herbage which were eaten by horses, cattle, and sheep. Today it has been narrowed in meaning to cover specifically the members of the plant family Gramineae (Gould, 1968; Moore, 1960). The grasses (Poaceae or Gramineae) are very natural and distinctive family of flowering plants with remarkable diversity. Of all the flowering plants, they are the most successful in many ways. This success in competition for dominance may be attributed to the fact that they are wind pollinated. They diverge from all other families, particularly in the characters of their embryos, seeds, and fruits (Bews, 1929). Grasslands constitute approximately 25% of the world's terrestrial vegetation cover and are found on every continent across all climatic zones (Heywood *et al*., 2007). They occur in the great diversity of forms and spread over a wide range of habitats. They show high adaptability and competitive nature and thus are cosmopolitan in distribution. Grasses show spread from climatic zones from tropic to highest alpine zones (Simpson, 1990).

Different environmental conditions elicit diverse responses in plants at multiple levels. One of the common responses to abiotic stress conditions which is seen in many plant species is free proline accumulation in plant tissue (Špoljarević, *et. al*, 2011). However, ever since the early 80s different research groups found a significant amount of proline in the reproductive organs of different plant species, raising the possibility that the accumulation of this amino acid may also occur in physiological non-stressed conditions for developmental purposes (Mattioli *et al*, 2009). Proline accumulation has been observed in response to various stressors, including salt, drought, high and low temperatures, heavy metals, pathogen infection, anaerobiosis, nutrient deficiency, atmospheric pollution, and UV irradiation (Hare and Cress 1997; Saradhi *et al*. 1995; Siripornadulsil *et al*. 2002). Proline is one of the most common compatible osmolytes in plants experiencing drought stress. For instance, proline levels have been found to increase in pea plants under drought conditions (Sanchez *et al*., 1998; Alexieva *et al*., 2001). Proline accumulation is also triggered by other stressors such as high temperatures and starvation (Sairam *et al*., 2002). The study of proline metabolism in plants has primarily focused on responses to osmotic stress (Verbruggen and Hermans 2008). Proline does not interfere with normal biochemical processes; rather, it aids plants in coping with stress conditions by enhancing their survival (Stewart, 1981). Additionally, proline accumulation in plant tissues serves as a clear indicator of environmental stress, particularly in drought-stressed plants (Routley, 1966). Proline accumulation may also play a role in stress signalling, influencing adaptive responses (Maggio *et al*., 2002). The objective of this study was to deepen our comprehension of the physiological reactions of grass species under drought conditions. Our study highlights the impact of drought stress on proline content, as well as the physiological and ecological responses, across a spectrum of grass species exhibiting varying degrees of drought tolerance. This research delves into multifaceted aspects of grass biology, encompassing their historical evolution and ecological significance within India, with particular emphasis on the region of Gujarat. Furthermore, it sheds light on the pivotal role of proline estimation in elucidating the physiological mechanisms underlying stress adaptation in grasses.

Materials and Methods

***Study Area and Selection of Site*:** Ahmedabad and Kheda districts are located in Gujarat, India, Ahmedabad district, situated in the central part of Gujarat at 23.03°N 72.58°E, covers an area of 464 km². The Sabarmati River divides Ahmedabad into two distinct regions: the eastern bank and the western bank. In Ahmedabad there is large variation in temperature range, from minimum 12° in winter to maximum 45° in recent years with scrubland, grasslands and thorn forest in district. The soils in the district are primarily characterized as medium black to sandy in texture. In contrast, Kheda District, also known as "Charotar," spans from 22°30′ N to 23°18′ N and 72°30′ E to 73°37′ E, covering approximately 3667 km², including a 21.05 km² forest area. Temperature ranges from 10° minimum in cold season to 40° maximum in warm season, having sandy, loamy and saline alkali soils at some places. Vegetation is mixed with moist deciduous and scrub forest in Kheda district. Geography includes nine major rivers, with the Mahi River (Mahisagar) being the most prominent. The district's terrain is primarily flat, with some hilly areas in Kapadvanj Taluka. Major types of soils include kyari, sandy, black, and loamy types which support diverse agricultural activities. In both Ahmedabad and Kheda district, 95% rain fall occurs in monsoon season where average is around 780 to 790 mm yr^{-1}. Current research was conducted in both Ahmedabad and Kheda districts during the summer and winter season of 2023. Ecological investigations employed the established simple quadrate method, involving the strategic placement of 1×1 m quadrates within the study area. The primary objective was to systematically document and enumerates the grass species in each quadrate. Subsequently, grass specimens were meticulously collected from the field for further analysis.

***Ecophysiological Studies*:** A comprehensive suite of ecological parameters was computed based on the collected data, including abundance, density, relative abundance, relative density, and percentage frequency. Density was calculated using formula, Total number of individuals of a species divided by total area studied. Total number of individuals of a species upon total number of quadrats in which the species occurred, gave abundance values. On the other hand, number of quadrats where the species occurred / total number of quadrats studied x 100, gave value of percent frequency. Relative density was calculated with formula, density of species/ total density of all species x 100. Similarly, relative abundance was obtained using formula, abundance of species/ total abundance of species x 100. Diversity indices such as Simpson's Diversity Index ($D = \sum Pi^2$), Shannon Diversity Index ($H' = -\sum Pi \ln(Pi)$), and Pielou's Evenness Index ($J' = H'/H'max$) were computed to provide insights into ecological diversity and evenness. Berger and Parkers index for assessing biodiversity (Berger and Parker, 1970) and Margalef and Menhinick for species richness was also calculated (Margalef, 1969)

Physiological investigations focused on parameters like rresh weight (FW), turgid weight (TW), dry weight (DW), relative water content (RWC), specific leaf area (SLA), and Proline Estimation. RWC and Water Deficit were calculated using established formulas based on FW, DW, and TW, providing insights into the physiological status of leaves (Dheeravathu *et al*. 2018). SLA was calculated by dividing leaf area by leaf dry mass. Proline concentration in leaf samples was determined using a 3% (w/v) aqueous sulfosalicylic acid solution, following Bates *et al*. (1973), with absorbance quantified at 520 nm and expressed as mg g^{-1} of fresh weight (Bates *et al*., 1973).

Soil analysis involved collecting samples from various sites at depths of 0 to 10 cm. These samples were air-dried, sieved through a 2 mm mesh, and subjected to standard chemical analysis. Soil pH was determined using the method outlined by Black (Black, 1973). EC and TDS were measured using portable EC-TDS meter.

***Statistical Analysis and Interpretation of data*:** For statistical analysis, the software PAST4.03.exe was utilized to calculate correlation coefficients and diversity indices, providing a quantitative understanding of ecological relationships and diversity patterns. Microsoft Excel was employed for organizing data, calculating descriptive statistics, and creating graphical and tabular representations. The combined use of these tools ensured accurate analysis, effective data visualization, and a structured presentation of results, facilitating a comprehensive interpretation of the findings.

Results and Discussion

The study conducted in Ahmedabad and Kheda districts revealed significant differences in the diversity and ecological structure of grass species across these regions. Notably, the Importance Value Index (IVI) of *Cynodon dactylon* L. was higher in Kheda district (46.08) compared to Ahmedabad district (29.08) during the summer season. During this study, a total of 26 grass species were identified and analyzed. Kheda district demonstrated greater species richness, with 23 species, whereas Ahmedabad district comprised 14 species. Kheda's greater diversity was evident from its lower dominance index of 0.34, compared to 0.46 in Ahmedabad, and higher values in the Simpson's diversity index, which were 0.66 and 0.53, respectively, and Shannon diversity index, which were

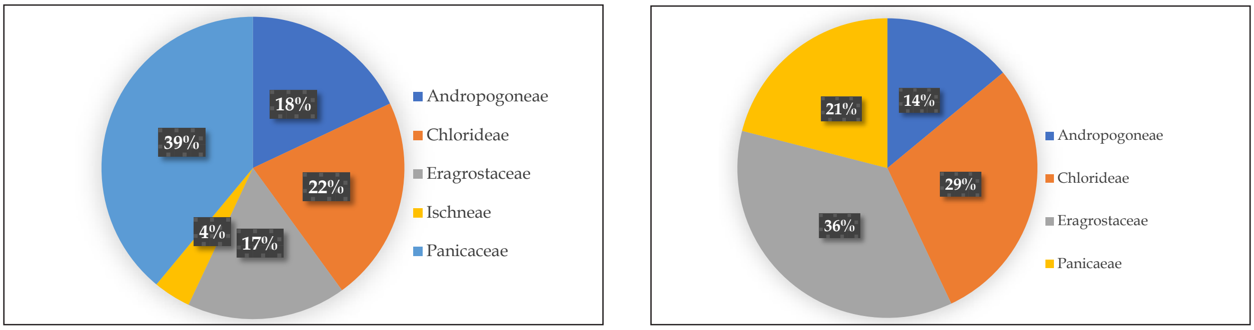

Fig. 1. proportional distribution of grass species across five tribes in (a) Kheda and (b) Ahmedabad district.

1.74 and 1.23, respectively. Both regions had similar evenness indices indicating a more even distribution of individuals among species. Additionally, Kheda outperformed Ahmedabad in several diversity indices, highlighting its greater species richness and diversity. The Brillouin index was higher in Kheda (1.72) compared to Ahmedabad (1.22). Similarly, the Menhinick index recorded values of 0.46 for Kheda and 0.24 for Ahmedabad, while the Margalef index was 2.81 in Kheda and 1.60 in Ahmedabad. These results collectively emphasize the superior species diversity present in Kheda district. The equitability index was also higher in Kheda, at 0.55 compared to 0.46 in Ahmedabad, along with Fisher's

Fig. 2. Photographs of selected grass species in Ahmedabad and Kheda districts, Gujarat for eco-physiological studies (1= Chloris barbata Sw., 2= Chloris virgata Sw, 3=Cynodon dactylon (L.) Pers., 4= Dactyloctenium aegyptium (L.) Willd., 5= Desmostachya bipinnata (L.) Stapf, 6= Dichanthium annulatum (Forssk.) Stapf, 7= Digitaria ciliaris (Retz.) Koeler, 8= Eleusine indica (L.) Gaertn., 9= Eragrostis amabilis (L.) Wight & Arn., 10= Eriochloa fatmensis (Hochst. & Steud.) Clayton and 11= Paspalum distichum L. respectively.

alpha, at 3.506 compared to 1.87, and it had a lower Berger-Parker index, at 0.56 compared to 0.66, indicating less dominance by a single species. The Chao-1 estimate aligned with these findings, suggesting higher total species richness in Kheda with 23 species compared to 14 in Ahmedabad. Overall, these results highlight Kheda's more diverse and balanced grassland ecosystem compared to Ahmedabad.

Tribe distribution and diversity: As shown in figure 1 a, Paniceae tribe is the most abundant, having 39% of the total distribution, followed by tribe Chlorideae 22%, making it the second most common tribe. Andropogoneae represented 18% of the distribution, while Eragrosteae comprised 17%. Ischneae tribe was least common, making up only 4% of the total distribution. This data indicated that Paniceae was the dominant tribe in Kheda District, with Chlorideae and Andropogoneae also having significant representation. Eragrosteae had a notable presence, whereas Ischneae was relatively minor in comparison in the current study.

Figure 1b, shows the percentage distribution of various tribes in Ahmedabad District. The Eragrosteae tribe was the most prevalent, making up 36% of the total distribution. Chlorideae was followed, accounting for 29%, and was the second most common tribe. Paniceae represented 21% of the distribution, while Andropogoneae contributed 14%. This data highlighted that Eragrosteae was the dominant tribe in Ahmedabad District, with Chlorideae also had a substantial presence. Paniceae and Andropogoneae were less prevalent but still significant components of the tribe distribution. Figure 2 expresses morphology of selected grass species in Ahmedabad and Kheda districts.

***Relationship among various traits*:** The correlation matrix for various physiological and environmental parameters in the Kheda district revealed significant interrelationships (Table 1). Proline content shows strong positive correlations with both Specific Leaf Area (SLA) (0.87**) and Relative Water Content (RWC) (0.86**), suggesting that larger leaf areas and higher water content are associated with increased proline levels, enhancing stress tolerance. Soil pH moderately influences biomass as indicated by its correlations with fresh weight (FW) (0.786*), dry weight (DW) (0.81*), and turgid weight (TW) (0.51*). Total dissolved solids (TDS) are strongly correlated with electrical conductivity (EC) (0.92**), reflecting higher salinity levels. Notably, EC has a negative correlation with Proline (-0.61**), indicating that increased soil salinity may reduce proline accumulation. The various weight measurements (FW, DW, and TW) are highly interdependent, showing consistent biomass growth relationships, with FW and DW having a correlation of 0.97**. SLA also has a moderate positive correlation with RWC (0.75**), reinforcing the role of larger leaf areas in supporting water balance and stress adaptation. These findings underline the complex interactions between physiological traits and environmental factors, providing insights into how grass species in Kheda adapt to their habitats.

The correlation matrix for various parameters measured in Ahmedabad revealed several significant relationships (Table 2). Proline

Table 1. Results from linear correlations between pairs of quantitative parameters of different grass Species in Summer Season in Kheda district

	Proline	pH	TDS	EC	FW	DW	TW	SLA
Proline								
pH	NS							
TDS	-0.55**	NS						
EC	-0.61**	0.37*	0.92**					
FW	NS	NS	NS	NS				
DW	NS	NS	NS	NS	0.97**			
TW	NS	NS	NS	NS	0.96**	0.95**		
SLA	0.87**	NS	-0.49**	-0.55**	NS	NS	NS	
RWC	0.86**	NS	NS	NS	NS	NS	NS	0.75**

All values are r values, and ** indicates significance at 0.01 whereas * shows significance at 0.05 (p value <0.05)

Table 2. Results from linear correlations between pairs of quantitative parameters of different grass Species in Summer Season in Ahmedabad district

	Proline	pH	TDS	EC	FW	DW	TW	SLA
Proline								
pH	NS							
TDS	0.87**	NS						
EC	0.93**	NS	0.98**					
FW	NS	NS	NS	NS				
DW	-0.48*	NS	NS	-0.40*	0.94**			
TW	NS	NS	NS	NS	0.94**	0.93**		
SLA	NS	NS	NS	NS	NS	NS	NS	
RWC	0.98**	NS	0.90**	0.96**	NS	-0.47*	NS	NS

All values are r values, and ** indicates significance at 0.01 whereas * shows significance at 0.05 (*p* value <0.05)

showed strong positive correlations with TDS (0.87**), EC (0.93**), and RWC (0.98**), and a moderate positive correlation with SLA (0.40), but a notable negative correlation with DW (-0.48*). pH exhibits weak negative correlations with Proline (-0.30), TDS (-0.33), and RWC (-0.31), and a weak positive correlation with SLA (0.05). TDS strongly correlates positively with EC (0.98**), RWC (0.90**), and Proline (0.87**), and shows moderate positive correlations with TW (0.59) and SLA (0.44). EC shares strong positive correlations with TDS (0.98**), RWC (0.96**), and Proline (0.93**), while FW is moderately positively correlated with DW (0.94**), TW (0.94**), and SLA (0.53). DW is strongly positively correlated with FW (0.94**) and TW (0.93**), but negatively with Proline (-0.48*), TDS (-0.37), and EC (-0.40). TW shows strong positive correlations with FW (0.94**) and DW (0.93**), while SLA moderately correlates with RWC (0.46) and weakly with other parameters. RWC has very strong positive correlations with Proline (0.98**), TDS (0.90**), and EC (0.96**), and moderate positive correlation with SLA (0.46*). These relationships indicate that Proline, TDS, EC, and RWC are closely linked, and that weight measures (FW, DW, TW) are similarly related, with pH exhibiting weaker correlations overall.

Figure 3 show the distribution of grass species across five tribes (Andropogoneae, Chlorideae, Eragrosteae, Ischneae, and Paniceae) in Ahmedabad and Kheda districts. In Ahmedabad, the Andropogoneae tribe comprises 4 species, whereas Kheda has 2 species. The Chlorideae tribe shows a relatively balanced distribution with Ahmedabad housing 5 species and Kheda 4 species. For the Eragrosteae tribe, Kheda slightly exceeds Ahmedabad with 5 species compared to 4 species. The Ischneae tribe is represented by 1 species in Ahmedabad and is absent in Kheda. Notably, the Paniceae tribe demonstrates a significant disparity,

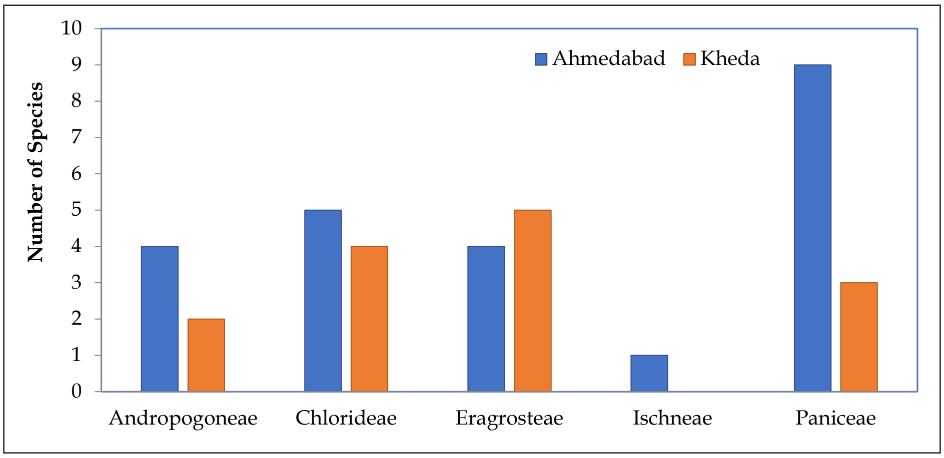

Fig. 3. Grass species distribution species across five tribes – Andropogoneae, Chlorideae, Eragrosteae, Ischneae, and Paniceae – in Ahmedabad and Kheda districts.

with Ahmedabad containing 9 species while Kheda has 4 species. These findings indicate higher species richness in the Paniceae and Ischneae tribes within Ahmedabad, whereas Kheda exhibits greater species richness in the Eragrosteae tribe. The distribution patterns observed suggests distinct ecological variations and biodiversity between the two districts.

The comparative analysis of grass diversity between Ahmedabad and Kheda districts and the peri-urban sites studied by Gupta and Narayan highlights distinct ecological patterns. Our study revealed species counts ranging from 14 to 23, while Gupta and Narayan reported higher counts (18 to 34). The Margalef and Menhinick indices in our study (1.588 to 2.815 and 0.2333 to 0.4623) were lower compared to their study (3.69 to 7.17 and 1.80 to 3.40). Similarly, the Shannon Index was higher in Gupta and Narayan's sites (2.25 to 2.95) than ours (1.157 to 2.283), indicating greater diversity (Gupta and Narayan, 2006).

Evenness indices (Pielou's and Brillouin's) also pointed to more equitable species distribution in Gupta and Narayan's sites. Dominance, measured by the Berger-Parker Index, was higher in our study, especially in Ahmedabad during summer (0.692), indicating lower diversity compared to Gupta and Narayan's sites (0.19 to 0.36).

These findings underscore the higher biodiversity in peri-urban areas compared to urban sites, likely due to varied habitats and less anthropogenic pressure. This study highlighted the need for targeted conservation strategies to enhance habitat diversity. The Shannon-Weiner diversity index in our study areas ranged from 1.742 to 2.283, whereas the Terai grasslands in Uttar Pradesh reported a higher index of 4.0 (Shukla, 2009). Similarly, the Himalayan grasslands show a Shannon-Weiner diversity index ranging from 1.75 to 2.63, illustrating the variability in species diversity across different ecological zones (Reshi *et al*., 2009). In our study, *Cynodon dactylon* L. exhibited the highest Importance Value Index (IVI) values during the summer, with 46.08 in Kheda and 29.08 in Ahmedabad. This contrasts with the findings in Rajasthan's grasslands, where *Lasiurus scindicus* dominated with an IVI of 63.6 in the *Lasiurus-Panicum* grassland, indicating a more pronounced dominance in a highly arid environment (Krishna *et al*, 2014). In terms of species richness, Kheda showed higher species diversity with 23 species compared to Ahmedabad's 14 species.

The comparative analysis of Relative Water Content (RWC) between our study on various grass species in Ahmedabad and Kheda districts and findings from previous studies on drought stress highlights significant insights into drought tolerance mechanisms. Our data indicate varying RWC values among species across the two districts, with notable differences such as *Eleusine indica* exhibiting high RWC in Ahmedabad (0.82) but low in Kheda (0.08), and *Dactyloctenium aegyptium* showing a decrease from 0.03 in Ahmedabad to -0.29 in Kheda. Previous research has established that drought stress significantly reduces biomass production and growth in many plant species (Maliwal and Sutaria 1992, Ashraf *et al*. 1998, Karsten and MacAdam 2001, Tavakol and Pakniyat 2007, Siddiqui 2013). The observed reduction in RWC under drought conditions aligns with our findings, where species like *Cynodon dactylon* and *Dactyloctenium aegyptium* show negative RWC values in Kheda, indicating stress. Studies also suggest that species maintaining higher RWC under drought conditions, such as *H. mucronatum*, exhibit better drought tolerance due to efficient intracellular water regulation (Schonfeld *et al*. 1988, Merah 2001, Siddiqui *et al*. 2014). This is supported by our data, where *Ophiuros exaltatus* shows high RWC in both districts (0.89 in Ahmedabad and 0.46 in Kheda), suggesting strong drought tolerance.

The differences in RWC among species between Ahmedabad and Kheda reflect physiological variations and adaptability to environmental conditions. High RWC in some species, such as *Eleusine indica* in Ahmedabad, suggests better water retention capabilities in less drought-prone environments. In contrast, species with negative RWC in Kheda highlight the stress impact under more severe drought conditions. Overall, our study corroborates existing literature that RWC is a reliable indicator of drought tolerance and adaptation, emphasizing the importance of understanding species-specific responses to manage and conserve grasslands effectively under varying climatic conditions.

Table.3. Showing the Comparative Proline levels in Common Grass Species across winter and Summer Seasons in Ahmedabad and Kheda districts

	Proline value in winter		Proline value in summer	
Plant name	Ahmedabad	Kheda	Ahmedabad	Kheda
Chloris barbata Sw.	0.13±0.05	0.94±0.45	2.78±0.34	0.24±0.18
Chloris virgata Sw.	0.05±0.05	0.76±0.37	0.66±0.26	0.04±0.02
Cynodon dactylon (L.) Pers.	0.32±0.06	0.74±0.52	1.23±0.43	1.08±0.68
Dactyloctenium aegyptium (L.) Willd.	0.07±0.05	0.85±0.55	0.62±0.40	0.35±0.30
Desmostachya bipinnata (L.) Stapf	0.17±0.01	0.74±0.45	0.91±0.49	0.43±0.41
Dichanthium annulatum (Forssk.) Stapf	0.03±0.01	0.72±0.21	1.08±0.40	0.03±0.00
Digitaria ciliaris (Retz.) Koeler	0.12±0.14	0.66±0.34	0.51±0.01	0.09±0.08
Eleusine indica (L.) Gaertn.	0.26±0.13	1.34±0.17	0.51±0.46	0.26±0.35
Eragrostis amabilis (L.) Wight & Arn.	0.07±0.01	0.58±0.56	0.98±0.21	0.07±0.10
Eriochloa fatmensis (Hochst. & Steud.) Clayton	0.21±0.20	0.86±0.42	0.98±0.65	0.06±0.07
Paspalum distichum L.	0.10±0.04	0.54±0.75	0.09±0.06	0.18±0.05

Our study revealed distinct variations in proline content across different plant species between the winter and summer seasons in Ahmedabad and Kheda (Table 3). In Ahmedabad, *Chloris barbata* Sw. showed a proline value of 0.13±0.05 in winter and significantly higher levels in summer (2.78±0.34). Conversely, in Kheda, the same species had a proline value of 0.94±0.45 in winter, which drastically dropped to 0.24±0.18 in summer. Notably, *Cynodon dactylon* (L.) Pers. exhibited moderate proline levels in both districts and seasons, with values ranging from 0.32±0.06 in winter to 1.23±0.43 in summer in Ahmedabad, and from 0.74±0.52 in winter to 1.08±0.68 in summer in Kheda.

Comparatively, other studies have shown substantial proline accumulation in various crops under drought conditions. For instance, sorghum and maize demonstrated significant differences in proline content, with sorghum averaging 8.7 micromoles/100 mg of fresh leaf weight, significantly higher than maize's 5.3 micromoles/100 mg (Frantová *et al*., 2024). This high proline content in sorghum has been linked to its better drought tolerance and higher Relative Water Content (RWC), as noted in previous research (Yamada *et al*., 2005; Blum and Ebercon, 1976). Further, studies involving exogenous proline applications in plants, such as cauliflower, have shown enhanced RWC due to increased internal proline content (EL-Bauome *et al*., 2022). This exogenous proline application also increases chlorophyll content and crop yield through the increased activities of crucial enzymes like superoxide dismutase, peroxidase, and catalase (Hanif *et al*., 2021). Additional evidence supports the link between proline accumulation and drought tolerance, with more drought-tolerant varieties showing higher proline levels (Quilambo, 2004). Conversely, drought-resistant rice varieties exhibited lower proline contents (Dien *et al*., 2019). However, barley plants have also demonstrated proline accumulation under stressful conditions (Frimpong *et al*., 2021).

The observed proline variations in our study align with findings that proline accumulation is a common response to drought stress across different species, as it aids in maintaining cellular water balance and protecting cellular functions. For instance, *Eleusine indica* (L.) Gaertn. in our study showed a marked increase in proline content in Kheda (1.34±0.17) during winter, indicating a potential adaptive mechanism to stress conditions. This trend is consistent with other crops like wheat and sunflower, which also exhibit higher proline levels under stress (Ghosh *et al*., 2022; Keyvan, 2010).

These differences underscore the varied adaptive strategies of plant species in different regions and environmental conditions, with proline serving as a key indicator of drought tolerance. The higher proline levels in some species during stressful conditions suggest their potential for better drought resilience, contributing to their survival and productivity in arid environments.

This study provides a comprehensive analysis of the ecophysiological adaptations and diversity of grass species in Ahmedabad and Kheda districts, revealing distinct ecological patterns. Kheda demonstrated higher species richness and diversity, with indices like Shannon-Weiner, Simpson, and Margalef reflecting a more balanced ecosystem compared to Ahmedabad. These findings highlight Kheda's relatively stable grassland ecosystem, likely influenced by lower anthropogenic pressure and more favourable environmental conditions.

Conclusion

Physiological investigations revealed key adaptive mechanisms, such as variations in proline content and Relative Water Content (RWC), which underscore the grasses' resilience to environmental stresses. Proline accumulation, in particular, emerged as a critical factor in drought tolerance, with higher levels associated with greater adaptability under stress. Species like *Cynodon dactylon*, which showed consistently high Importance Value Index (IVI) and adaptive physiological traits, were identified as dominant and resilient, particularly during summer. Tribal distribution analysis highlighted ecological distinctions, with Kheda exhibiting greater representation of the Paniceae and Eragrosteae tribes, while Ahmedabad showed a higher prevalence of Chlorideae and Ischneae tribes. These patterns underscored the influence of regional environmental conditions on species composition and distribution. The correlation analyses further illuminated complex interrelationships between physiological traits and environmental factors, such as the role of Specific Leaf Area (SLA) and Relative Water Content (RWC) in enhancing drought resilience. Variations in soil parameters, including Electrical Conductivity (EC) and Total Dissolved Solids (TDS), were also found to significantly influence physiological responses, emphasizing the importance of soil health in sustaining grassland ecosystems. In general, this study highlighted the ecological significance of grasslands in Ahmedabad and Kheda districts, highlighting the critical need for conservation strategies tailored to local environmental conditions. By enhancing biodiversity and reducing anthropogenic pressures, these ecosystems can be better preserved, ensuring their resilience against future climatic challenges.

Acknowledgment

The Authors are Thankful to Shri Govind Guru University, Godhra, for providing the necessary resources and to the Knowledge Consortium of Gujarat (KCG), Government of Gujarat, for financial support.

Conflict of Interest

Authors declare that there isn't any conflict of interest.

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Printed in June 2025