PLANT SCIENCE TODAY
Vol 12(sp3): 01–08
https://doi.org/10.14719/pst.8544

eISSN 2348-1900

RESEARCH ARTICLE

Clonal evaluation of *Enterolobium cyclocarpum* (Jacq.) as a superior fodder source for ruminants

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Received: 27 March 2025; Accepted: 25 June 2025; Available online: Version 1.0: 13 August 2025

Cite this article: Sivaprakash M, Ashwin NM, Balasubramanian A, Radhakrishnan S, Sekar I, Vijayan R, Kumar P, Sivakumar B, Navaneethakrishnan S. Clonal evaluation of *Enterolobium cyclocarpum* (Jacq.) as a superior fodder source for ruminants. Plant Science Today. 2025;12(sp3):01–08. https://doi.org/10.14719/pst.8544

Abstract

Enterolobium cyclocarpum, a nitrogen-fixing tree belonging to the family Leguminosae, is known for its satisfactory nutritional traits, including crude fat, crude protein, crude fibre and ash content. The tree's ability to resprout after coppicing and its light-demanding nature at all growth stages are notable. This study investigates the nutritional and anti-nutritional values of leaves of *E. cyclocarpum* clones (EC 1-6) with EC 1-4 (Bhavanisagar source), EC 5 (TNAU source) and EC-6 (Mettupalayam source). This research aims to evaluate the potential of *Enterolobium cyclocarpum* as a supplementary livestock feed during the lean season and involves pollarding six clones at different heights (2, 3, 4 and 5 feet) with four replications per treatment. Nutritional analysis of leaf samples from the six clones was conducted using standard methods: crude protein by Micro-Kjeldahl method, crude fibre by the Weende method, crude fat by the Soxhlet method and ether extract by solvent extraction. The anti-nutritional analysis includes the evaluation of total phenols, tannins, saponins and steroids. The study also examines inter-clonal variations across all parameters. Additionally, ICP-MS analysis was conducted to assess elemental composition. This research investigates the fodder quality and palatability of *E. cyclocarpum* clones, aiming to explore their potential as an alternative fodder source. By addressing the gap between fodder demand and supply, the study seeks to provide a sustainable solution for livestock feed during lean seasons. The findings indicate that *E. cyclocarpum* clones (EC2, 4) are excellent fodder supplements for livestock.

Keywords: anti-nutritional factors; crude protein content; elemental composition; nutritional composition; proximate analysis

Introduction

In India, the total area under cultivated fodder crops is approximately 8.4 m ha on an individual crop basis. The country supports about 15 % of the world's total livestock population on just 2.29 % of the global land area. The green fodder supply is estimated to be 734.2 million tonnes and demand is 827.19 million tonnes. Similarly, the demand for dry fodder is 426.11 million tonnes, while the current supply is around 326.4 million tonnes. At present, the country faces a net deficit of 35.6 % green fodder, 10.95 % dry fodder residues and 44 % concentrate feeds. India's total livestock population is 500.22 million, comprising 397.31 million cattle, 151.17 million buffaloes, 1.087 million mithun and 2.983 million yaks. Additionally, the sheep population stands at 650.7 million and the goat population at 135.17 million (1). In contrast to pasture grasses and herbaceous legumes, the systematic examination of fodder trees and shrubs is a relatively recent development, despite the historical utilization of browse species by pastoral societies for feeding their livestock. There is a widely acceptance that woody species offer various benefits for animal production, including high feeding quality in terms of protein and mineral content, adaptability to a wide range of management practices, longevity and the ability to provide fodder when other species are inactive to cope with adverse climatic conditions (2). *E. cyclocarpum* (Jacq.) Griseb. is a spectacular looking tree with huge spreading and spherical crown. It is a deciduous tree with high nutritive value and moderate palatable pods. This tree was first described in 1809 and 1887 in New Spain; it became known with the name of *Mimosa cyclocarpa*. Then, the British Jacq and Griseb classified it as *E. cyclocarpum* (Jacq.) Griseb. (3). *E. cyclocarpum* is a tropical tree that has played a fundamental part in the development of rural man living from southern Mexico to the middle part of the South American subcontinent (4). It is a fast growing and good coppicing species which yields a lush green foliage at denser ratio at low pollard yield. The current study is carried out with the following scope and objectives as to study the nutritional properties of *E. cyclocarpum* clones for fodder yield and to study the fodder quality and palatability in *E. cyclocarpum* clones. Understanding its suitability as an alternative fodder source is essential to help bridge the gap between the demand and supply.

Materials and Methods

Experimental materials

The present research was conducted in the E-Block of the Forest College and Research Institute (FC & RI), Mettupalayam (Latitude 11.19° N, Longitude 77.56° E). Six clones of *E. cyclocarpum* (EC 1 to EC 6) were studied. Among them, EC 1-4 was sourced from Bhavanisagar, Erode; EC 5 from Tamil Nadu Agricultural University (TNAU), Coimbatore and EC 6 from FC & RI, Mettupalayam.

Methods

Sample preparation

The collected leaf samples were cleaned and dried in an oven at 60 °C for 12 hrs. The dried leaf sample was powdered using a mixer grinder and stored in an airtight container for further analysis.

Proximate analysis

Proximate analysis was done to determine the basic nutritional composition which includes moisture content, ash content, crude protein, crude fat and crude fibre. This analysis aims to evaluate the potential use of *E. cyclocarpum* leaves as a feed or food resource for various applications. In the present study, the nutritional and anti-nutritional properties were analysed using standard methods (5).

Nutritional properties

Nutritional properties in plants are defined by the composition and levels of essential nutrients and beneficial compounds that contribute to the dietary requirements and health benefits for consumers (5).

Crude protein

The total nitrogen content was determined using the Micro-Kjeldahl method and the crude protein content was calculated by multiplying the nitrogen percentage by a factor of 6.25.

Crude fat

The crude fat content was estimated using 5 g of dried and ground sample extracted with petroleum ether or diethyl ether in a Soxhlet extraction apparatus. The extracted crude fat was collected in a pre-weighed beaker, which was cooled in a desiccator prior to weighing. The crude fat content was calculated using the following formula:

Crude fat (%)=

$$\frac{\text{Weight of flask with fat (g)} - \text{Weight of empty flask (g)}}{\text{Weight of original sample (g)}} \times 100$$

Ash content

1 g of plant leaf powder was placed in a crucible and initially incinerated over a low flame until a black residue was formed. The sample was then transferred to a muffle furnace and ashed at 550 °C for 3 hrs until white ash was obtained.

$$\text{Ash (\%)} = \frac{\text{Weight of sample after ash (g)}}{\text{Weight of sample (g)}} \times 100$$

Total organic matter content

The organic matter content was estimated using the below formula and expressed in percentage.

Organic matter content (%) =100 - total ash content (%)

Fibre content

Crude fibre and Acid Detergent Fibre (ADF) were determined using the procedure described in a previous study (5) and the Fibertec method respectively (5).

Anti-nutritional properties

Anti-nutritional factors are natural or synthetic compounds found in plant-derived foods that can adversely affect health by inhibiting nutrient intake, digestion, absorption and utilization (5).

Saponin

0.1 g of powdered leaf samples from each clone were added to separate beakers containing 20 mL of distilled water and heated in a water bath for over 5 min. The mixtures were then filtered and 2 mL of each filtrate was diluted with 10 mL of distilled water and shaken vigorously for over a minute. Persistent frothing upon warming indicated the presence of saponins.

Tannin

A quantity of 0.25 g of powdered sample was transferred into a 50 mL conical flask and 10 mL of distilled water was added. The mixture was gently boiled for 30 min and then centrifuged at 5000 rpm for 20 min. The resulting supernatant was collected and diluted to a final volume of 10 mL with distilled water. An aliquot of 0.2-0.5 mL of the extract was taken and diluted with distilled water. To this, 1 mL of sodium carbonate (Na_2CO_3) solution and 0.5 mL of Folin-Denis reagent was added. The mixture was incubated for 30 min at room temperature and the absorbance was measured at 700 nm using a spectrophotometer. If the absorbance exceeded 0.7, the sample was further diluted to fall within the linear range of the standard curve. A reagent blank was prepared using distilled water in place of the extract. A standard curve was prepared using 0-0.5 g of tannic acid.

Elemental analysis

The leaves were dried and analysed for their elemental composition using ICP-MS (6).

Statistical analysis

Data analysis was performed using R-based software PB Perfect for basic statistical analysis, DMRT comparison and for generating box plots and histograms (7).

Results

A detailed study on nutritional, anti-nutritional and elemental composition was conducted under sterile laboratory conditions in accordance with standard protocols. The proximate composition of six *E. cyclocarpum* clones (EC 1 to EC 6) was evaluated (Table 1). The results are discussed below with tables and figures (Fig 1, 2).

Table 1. Proximate composition of *E. cyclocarpum* clones (g /100 g DM)

Clones	CP (%)	CF (%)	C. Fib (%)	T. Ash (%)	T.Org (%)	Tannin (%)	Saponin (%)	DM (%)	ADF (%)
EC 1	19.578^{b}	6.060^{a}	16.970^{a}	5.750^{cb}	94.250^{ac}	4.742^{ab}	3.458^{a}	19.472^{ab}	4.835^{a}
EC 2	21.245^{a}	6.383^{a}	16.532^{a}	6.000^{c}	94.000^{a}	5.135^{a}	2.803^{a}	18.865^{b}	4.543^{a}
EC 3	19.433^{b}	5.963^{a}	16.990^{a}	7.750^{ac}	92.250^{cb}	3.618^{ab}	3.370^{a}	19.733^{ab}	5.062^{a}
EC 4	21.232^{a}	6.565^{a}	17.648^{a}	7.250^{ab}	92.750^{bc}	3.340^{b}	2.825^{a}	20.215^{a}	4.630^{a}
EC 5	19.470^{b}	6.398^{a}	17.715^{a}	6.500^{bc}	93.500^{ab}	4.148^{ab}	3.112^{a}	20.253^{ab}	4.815^{a}
EC 6	19.002^{b}	6.532^{a}	17.202^{a}	6.000^{cc}	94.000^{ab}	4.327^{ab}	2.610^{a}	19.373^{ab}	4.612^{a}
Mean	**19.993**	**6.317**	**17.176**	**6.542**	**93.458**	**4.218**	**3.030**	**19.652**	**4.750**
SE (d)	**0.234**	**0.301**	**0.393**	**0.371**	**0.371**	**0.464**	**0.350**	**0.320**	**0.246**
CD (P = 0.05)	**0.497**	**0.641**	**0.837**	**0.790**	**0.790**	**0.988**	**0.745**	**0.682**	**0.525**

*a, b and c: Means followed by the same letters are not significantly different at P = 0.05.

**Where CP - Crude protein, CF- Crude fat, C.Fib - Crude fibre, T. Ash - Total ash, T.Org - Total organic matter, DM - Dry matter, ADF - Acid digestibility fibre.

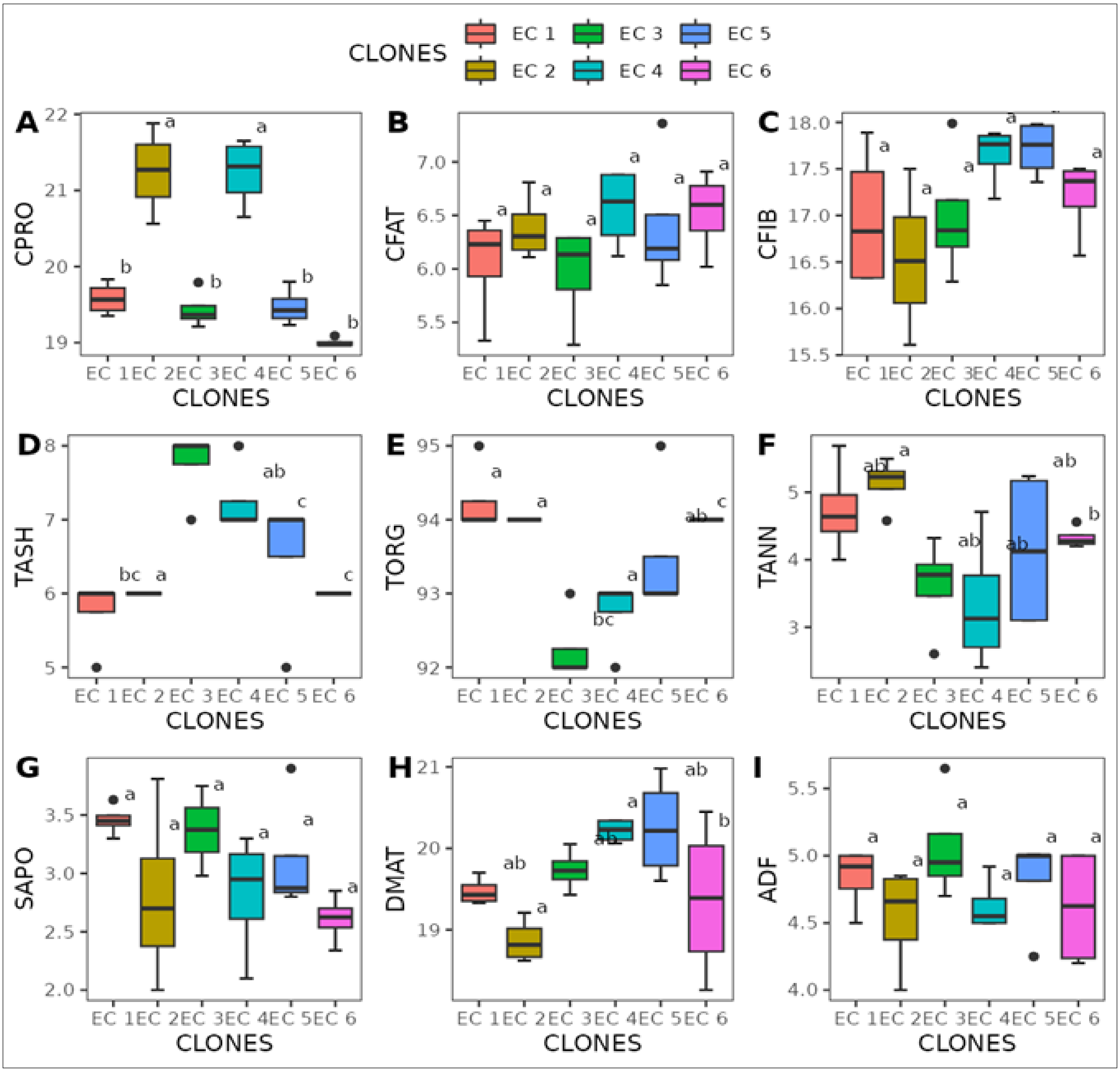

Fig. 1. Box plot representation of proximate composition of *E. cyclocarpum* clones (g /100 g DM).

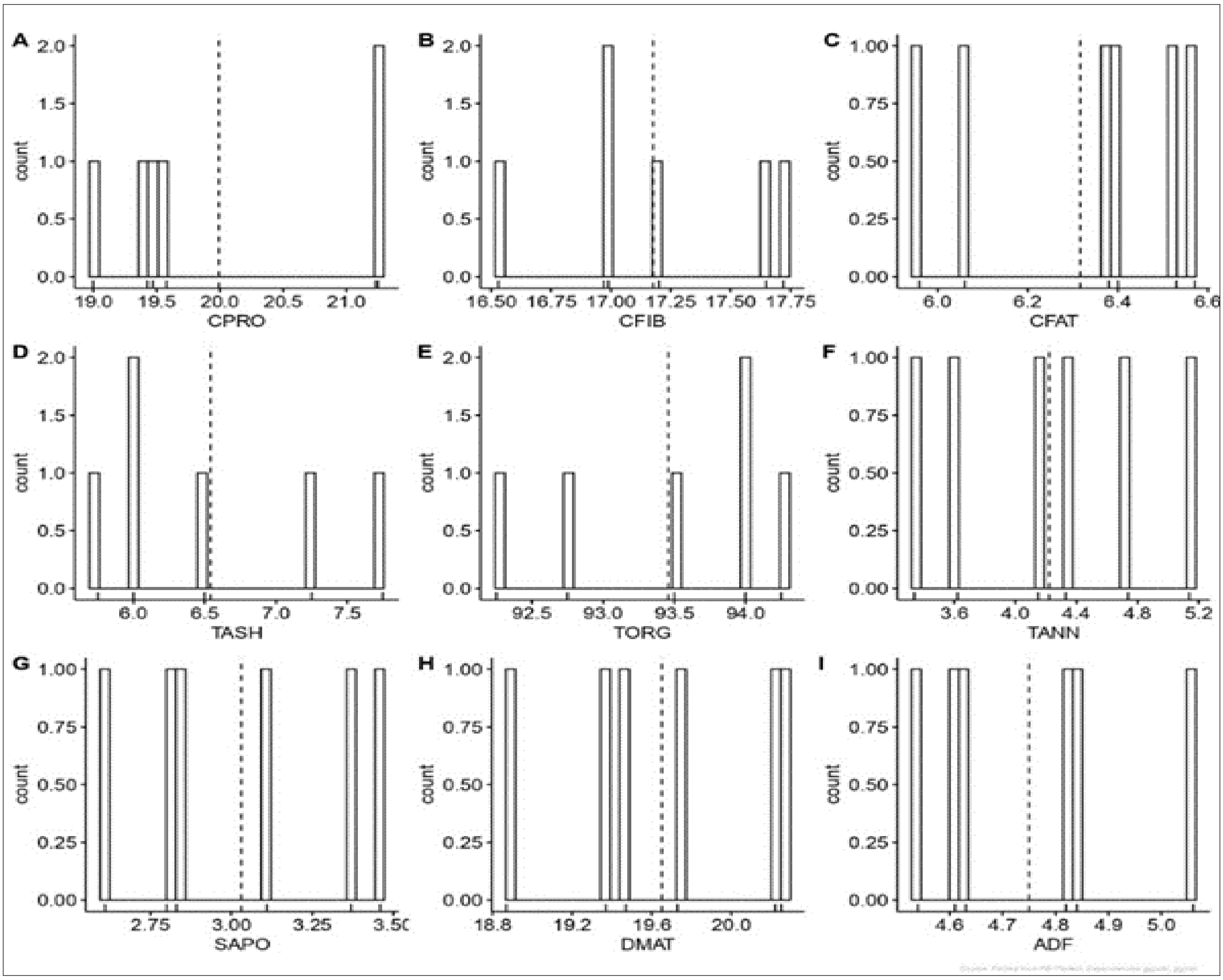

Fig. 2. Histogram of proximate composition of *E. cyclocarpum* clones (g /100 g DM).

Crude protein (CP)

CP is a critical indicator of the nutritional value of plant material, especially for animal feed. The CP content of *E. cyclocarpum* clones ranged from 19.00 % to 21.24 %. Clones EC 2 and EC 4 recorded the highest CP content, with values of 21.24 % and 21.23 % respectively. In contrast, clones EC 1, EC 3, EC 5 and EC 6 exhibited lower CP levels, ranging from 19.00 % to 19.57 %. EC 2 (21.245 %) and EC 4 (21.232 %) have significantly higher CP content compared to EC 1 (19.578 %), EC 3 (19.433 %), EC 5 (19.470 %) and EC 6 (19.002 %).

Crude fibre

Crude fibre is essential for the digestive health of ruminants, aiding in proper digestion and nutrient absorption. The crude fibre content of *E. cyclocarpum* clones ranged from 16.53 % to 17.72 %, with the highest value observed in EC 5 (17.72 %) and the lowest in EC 2 (16.53 %). EC 2 (16.53 %) had significantly lower crude fibre content compared to EC 4 (17.648 %), EC 5 (17.715 %) and EC 6 (17.202 %). A higher crude fibre content is beneficial for maintaining proper digestive functions.

Dry matter (DM)

DM is a crucial parameter for determining the actual nutrient content of feed, as it indicates the total solid content, which is essential for determining both nutritional value and intake levels. In *E. cyclocarpum* clones, it ranges from 18.865 % to 20.253 %. Clone EC 5 exhibited the highest dry matter content (20.253 %) while EC 2 had the lowest (18.865 %). EC 4 (20.215 %) and EC 5 (20.253 %) showed significantly higher DM content compared to EC 2 (18.865 %).

Crude fat (CF)

CF is an essential parameter for providing energy and essential fatty acids that contribute to the energy value of the fodder, impacting the overall caloric intake of the consuming animals. In *E. cyclocarpum* clones, CF ranged from 5.96 % to 6.56 %. Specifically, clone EC 4 exhibited the highest CF content at 6.565 %, while clone EC 3 had the lowest at 5.96 %. The remaining clones, EC 1, EC 2, EC 5 and EC 6, showed intermediate values of 6.06 %, 6.38 %, 6.39 % and 6.53 % respectively. Clones EC 4 (6.565 %), EC 2 (6.383 %), EC 5 (6.398 %) and EC 6 (6.532 %) had higher crude fat content compared to EC 1 (6.060 %) and EC 3 (5.963 %).

Acid detergent fibre (ADF)

ADF is a measure of indigestible fibre, which affects the digestibility of the feed. It is important as it indicates the indigestible portion of the feed, impacting the overall fibre digestibility and nutritional quality. The values range from 4.543 % to 5.062 %. Clone EC 3 had the highest ADF content (5.062 %), while clone EC 2 had the lowest (4.543 %). EC 3 (5.062 %) had significantly higher ADF content compared to EC 2 (4.543 %).

Ash Content

Total ash is vital as it reflects the inorganic mineral content necessary for various metabolic processes. Ash content in *E. cyclocarpum* clones varies between 5.75 % and 7.75 % with highest in EC 3 and lowest in EC 1. EC 3 (7.750 %) had significantly higher total ash content compared to EC 1 (5.750 %) and EC 6 (6.000 %). Previous studies on *Ficus asperifolia* and *F. sycomorus* reported ash content values of 11.25 % and 10.24 % respectively.

Total organic matter (T.org)

Total organic matter indicates the organic constituents of the plant material, excluding ash. Organic matter is crucial for providing energy and supporting various physiological functions in livestock. Clone EC 1 exhibited the highest T.org content at 94.250 %, statistically like EC 2 (94.000 %) and EC 6 (94.000 %), but significantly higher than EC 3 (92.250 %) and EC 4 (92.750 %).

Tannin content

Tannins are secondary metabolites that play a role in plant defence mechanisms and can influence palatability, nutrient absorption and protein digestibility in animals. Tannin content varied significantly among the clones. Clone EC 2 showed the highest tannin level at 5.135 %, which was significantly greater than that of EC 4, the lowest at 3.340 %. Clones EC 1 (4.742 %), EC 3 (3.618 %), EC 5 (4.148 %) and EC 6 (4.327 %) exhibited intermediate levels of tannin.

Saponin content

Saponins are secondary metabolites with both beneficial and anti-nutritional properties. They are known for their medicinal properties and can affect metabolism and immunity of livestock. Saponin content did not show significant differences among the clones, with values ranging from 2.61 % in EC 6 to 3.45 % in EC 1. The saponin content for the remaining clones fell between these values, specifically, EC 2 (2.80 %), EC 3 (3.37 %), EC 4 (2.82 %) and EC 5 (3.11 %). Clone EC 1 (3.458 %) had significantly higher saponin content compared to EC 4 (2.825 %), EC 6 (2.610 %) and EC 2 (2.803 %).

Elemental analysis

E. cyclocarpum leaves were checked for their macro-elemental composition (Table 2). The sodium (Na) content in leaves ranged from 5.76 ppm to 9.19 ppm with EC 4 clone showing higher sodium content of 9.91 ppm whereas lower is observed in EC 6. Magnesium (Mg) composition in leaves ranged from 7096.26 ppm to 7595.48 ppm with EC 4 responding towards higher level and the lowest by EC 1. Phosphorus (P) in leaves varied between 517.39 ppm to 809.36 ppm with EC 4 having higher level and EC 5 showing lesser composition. The potassium (K) content in leaves scaled between 11052.39 ppm to 15385.72 ppm, with EC 4 the highest and EC 6 the lowest. Calcium (Ca) content in the leaves ranged from 6024.47 ppm to 6500.4 ppm, with EC 4 exhibiting the highest concentration and EC 6 the lowest. Iron (Fe) content ranged from 21.37 ppm to 59.26 ppm, with the highest value observed in EC 4 and the lowest in EC 6.

Discussion

High CP content is beneficial as it contributes to the dietary protein requirement of livestock. In comparison, the CP content of other fodder tree species (Table 3) varies considerably-for example, *Adansonia digitata* (13.54 %), *Mangifera indica* (6.35 %) and *Albizia lebbeck* (19.50 %). *E. cyclocarpum* exhibited higher CP content compared to many species, such as *Mangifera indica* and *Terminalia catappa*, but is comparable to *Albizzia lebbeck* and higher than *Ficus thonningii* (13.54 %) and *Kigelia africana* (9.01 %). The higher CP content in *E. cyclocarpum* clone 2 and 4 suggests it could be a valuable protein source in animal feed, outperforming many species like *M. indica* and *T. catappa* (10, 11). Crude fibre content varies widely among different species. Previous studies have reported values such as 41.13 % in *Spondias mombin*, 33.15 % in *Ceiba pentandra* 41.75 % in *Terminalia superba*, 19.41 % in *Adansonia digitata*, 30.48 % in *Ficus thonningii* (11, 12). Compared to *Enterolobium* clones higher crude fibre contents were also observed in *Acacia modesta* (22.00 %), *A. nilotica* (22.80 %), *Grewia populifolia* (17.83 %), *Melia azedarach* (24.25 %) and *Morus alba* (18.96 %). In contrast, *Albizia lebbeck* exhibited a lower crude fibre value of 13.91% (Table 3). *E. cyclocarpum* generally has a lower crude fibre content compared to other compared fodder species, indicating it might be more digestible.

Higher DM content indicates less water content and higher nutrient concentration per unit weight. Previous studies have reported significant variation in DM content among different species, ranging from 14.12 % in *Ficus sycomorus* to 60.90 % in *Indigofera gerardiana* (10-12) (Table 3). Most species reported by. (Table 3) have higher DM content compared to *E. cyclocarpum*. The relatively lower DM content of *E. cyclocarpum* suggests higher moisture levels, which may affect its storage stability and preservation potential.

CF contributes to the overall energy density of feed. Significant differences in CF content were observed among the *E. cyclocarpum* clones. A fat content ranging from 5 % to 7 % in fodder crops is generally considered favourable, as moderate fat levels provide essential energy for livestock without contributing to excessive weight gain or associated health issues. The CF content of *E. cyclocarpum* leaves is higher compared to previously studied species such as *F. roxburghii* (2.34 %), *B. hainla* (3.22 %) (13, 14) as well as Mauritian variety of *Mangifera indica* (3.92 %).

Table 2. Elemental analysis in *E. cyclocarpum* leaves

Elements (ppm)	EC 1	EC 2	EC 3	EC 4	EC 5	EC 6	Mean	SE (d)	CD
Na	6.35	8.31	7.84	9.19	7.37	5.76	7.47	1.153935	2.423264
Mg	7096.26	7349.06	7293.71	7595.48	7396.32	7288.43	7336.543	148.6964	312.2625
P	716.77	784.92	692.7	809.36	517.39	542.7	677.3067	111.4341	234.0116
K	11422.76	14413.5	13302.39	15385.72	12425.84	11052.39	13000.43	1548.742	3252.358
Ca	6222.62	6517.06	6150.4	6500.4	6024.47	6300.4	6285.892	178.1225	374.0572
Fe	41.92	51.76	29.79	59.26	31.97	21.37	39.345	13.07771	27.4632

Table 3. Proximate composition comparison of various tree species

References	Tree species	DM (%)	CP (%)	CF (%)	ADF (%)	Ash (%)
Present study	***E. cyclocarpum* 1**	**18.87**	**21.25**	**16.53**	**4.54**	**6.00**
	***E. cyclocarpum* 2**	**20.22**	**21.23**	**17.65**	**4.63**	**7.25**
	***E. cyclocarpum* 3**	**19.47**	**19.58**	**16.97**	**4.84**	**5.75**
	***E. cyclocarpum* 4**	**20.25**	**19.47**	**17.72**	**4.82**	**6.50**
	***E. cyclocarpum* 5**	**19.73**	**19.43**	**16.99**	**5.06**	**7.75**
	***E. cyclocarpum* 6**	**19.37**	**19.00**	**17.20**	**4.61**	**6.00**
(9)	*Adansonia digitata*	41.44	13.54	19.41	42.46	6.24
	Bombax glabra	28.81	16.41	26.41	39.79	9.60
	Ceiba pentandra	31.64	16.19	33.15	41.65	10.15
	Ficus thonningii	21.63	13.54	30.48	52.62	12.12
	Kigelia Africana	32.19	9.01	35.49	48.36	12.46
	Mangifera indica	43.79	6.35	38.31	39.96	7.05
	Milicia excelsa	38.11	8.00	32.05	29.95	11.51
	Newbouldia laevis	43.07	9.89	29.25	28.39	8.46
	Spondias mombin	32.22	15.45	41.13	37.7	8.63
	Tabebuia rosea	35.27	13.32	31.28	39.96	5.27
	Terminalia superba	26.58	15.45	41.75	38.92	9.83
	Terminalia catappa	25.80	7.22	26.18	44.81	9.50
	Treculia Africana	38.33	9.19	37.04	47.65	10.98
(8)	*Ficus asperifolia*	19.01	20.27	–	–	11.25
	Ficus sycomorus	14.12	17.24	28.68	–	10.24
(10)	*Acacia modesta*	53.43	16.26	22.00	–	8.08
	Acacia nilotica	44.78	11.81	22.80	–	7.86
	Albizzia lebbeck	37.24	19.50	13.91	–	10.41
	Elaeagnus angustifolia	58.12	11.12	26.45	–	11.23
	Ficus religiosa	50.50	11.70	27.21	–	12.90
	Grewia optiva	38.17	19.37	26.16	–	13.91
	Grewia populifolia	45.20	15.07	17.83	–	10.05
	Gymnosporia royleana	40.86	15.67	26.64	–	7.88
	Indigofera gerardiana	60.90	12.20	30.50	–	9.00
	Melia azedarach	21.70	14.09	24.25	–	5.30
	Morus alba	54.69	15.43	18.96	–	12.17
	Prosopis cineraria	46.15	15.23	18.49	–	8.16
	Ziziphus mauritiana	40.38	14.21	18.19	–	11.88
	Ziziphus mummularia	23.28	11.48	26.60	–	7.93

Lower ADF is generally better as it indicates higher digestibility of the feed. ADF values are higher in other studied species, ranging from 28.39 % to 52.62 % (Table 3), with examples including *A. digitata* (42.46 %), *F. thonningii* (52.62 %) and *T. catappa* (44.81 %) (9). *E. cyclocarpum* has substantially lower ADF content, suggesting a higher digestibility compared to these species. Lower CF and ADF contents in *E. cyclocarpum* imply better digestibility, making it a suitable species for animal feed, especially when compared to high-fibre species like *Ceiba pentandra* and *Terminalia superba*.

The ash content reported by previous researchers is significantly higher in some species, whereas in the present crops it is lower and comparable to *Enterolobium*, as observed in *A. digitata* (6.24 %), *M. indica* (7.05 %) and *Tabebuia rosea* (5.27 %) (9, 14). (15) reported that the ADF content in some fodder trees ranges between 5.30 % and 13.91 % (Table 3). For instance, *M. azedarach* had a lower ash content of 5.30 % compared to *Enterolobium*. *E. cyclocarpum* exhibited a moderate ash content compared to these species. The moderate ash content indicates a balanced mineral composition, comparable to several other species but not excessively high, which is beneficial for animal nutrition. EC 5 had an intermediate T.org content of 93.500 %, which was not significantly different from the highest or the lowest values, highlighting variability in organic matter content among the clones. This indicates that EC 2 may have the highest potential for tannin-related benefits or drawbacks depending on its use, while EC 4 might be preferable in scenarios where lower tannin content is advantageous. Studies on *M. indica* and *T. rosea* reported a negative result for the presence of tannins, whereas *A. digitata* and *Tetrapleura africana* showed a positive result for the presence of tannin (9, 13, 14). The lack of significant variation in saponin content among the clones studied suggests that saponins are relatively stable across genotypes, contributing uniformly to the overall nutritional profile. Previous studies reported that *M. indica* and *T. rosea* contain 1.50 % of saponin, while *A. digitata* and *T. africana* contain 3.00 % (9). Earlier studies have also examined the elemental composition of major nutrients in important tree fodders (15, 16).

Statistical significance

The statistical analysis shows that, for most parameters, clones with the same letters are not significantly different at P = 0.05, as indicated by Duncan's Multiple Range Test (DMRT). This highlights the significant variability among the clones for certain parameters, contributing the understanding of their nutritional value and suitability for various uses, particularly in the fodder and animal feed industries.

Conclusion

The proximate composition analysis of *E. cyclocarpum* clones reveals significant variability in both nutritional and anti-nutritional parameters, which are crucial for determining their suitability for fodder and other uses. Clones EC 2 and EC 4 exhibited the highest CP contents at 21.245 % and 21.232 % respectively, making them superior in terms of protein availability, which is vital for livestock growth and productivity. EC 4 also stands out with the highest CF (6.565 %), enhancing its energy value. Conversely, EC 3 showed the highest crude fibre (17.715 %) and total ash (7.750 %), indicating a higher mineral content, essential for metabolic functions. Despite EC 2's high tannin content (5.135 %), which could affect palatability and protein digestibility, it has a favourable balance of other nutrients. EC 1 is notable for its highest saponin content (3.458 %), which can have medicinal benefits but might affect metabolism if used excessively. DM content, critical for determining total solid content, is highest in EC 5 (20.253 %), indicating its suitability for dry fodder production. EC 3's highest ADF (5.062 %) suggests a higher indigestible portion, impacting overall fibre digestibility. Based on the comprehensive analysis, EC 2 emerges as the best clone due to its superior CP content and balanced nutritional profile, making it highly suitable for high-protein fodder production. EC 4 also stands out as a strong candidate, owing to its high levels of both protein and fat, providing a good balance of energy and nutrition.

Hence, pellatization of the leaf samples in trace amounts, mixed with existing fodder, can be considered for inclusion in concentrate blocks for ruminant feeding. Additionally, based on observations of ruminant feeding behaviour, it is suggested that an adaptation or incubation period may be necessary to allow animals to become accustomed to the direct consumption of this crop.

Acknowledgements

The authors gratefully acknowledge the Forest College and Research Institute for providing the research field and Tamil Nadu Agricultural University for financial assistance.

Authors' contributions

MAN designed the research methodology, conducted the entire research work, collected the data, recorded biometric observations and drafted the manuscript. MS and AB helped establish the trial, guided the research and contributed to brainstorming. SR, IS and RV assisted in the study design and supported the statistical analysis. PK, BS and SN provided interpretations and critically appraised the study.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical issues: None

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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