SPECIES

Evaluation of proximate and mineral composition of wild *Atriplex* species growing in coastal Mediterranean, Egypt

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ABSTRACT
In this study, the mineral and proximate compositions of *Atriplex* species were analyzed. The Deltaic Mediterranean coastline area is an ideal habitat for the growth of these species organically. *Atriplex lindleyi* had the greatest carbohydrate content, whereas *Atriplex portulacoides* had the highest crude protein and fat content. The total digestible nutrients of the four *Atriplex* species were not significantly different from one another, with the greatest value found in *A. semibaccata*. *Atriplex halimus*, *Atriplex lindleyi*, *A. semibaccata* and *A. portulacoides* were shown to be the most nutritious of the four species investigated. In conclusion, the findings showed that the four *Atriplex* species tested are prospective sources of fodder producing halophytes, with *A. halimus* emerging as the most promising.

Keywords: *Atriplex*, halophytes, digestible nutrients, nutritional value, fodder

1. INTRODUCTION
Today, majorities of the world's population in developing countries are constantly searching for plant-based foods and forage with high nutritional value and pharmacological importance. Moreover, there has been a recent upsurge in the use of wild plants as sources of food, forage and healing properties (Ogundola et al., 2018). The nutritional role of wild plants in the diet is of renewed interest and has been widely reported (Zahran and El-Amier, 2013). Also, the dependence of Bedouin in the desert on wild plants and rural dwellers on wild vegetables for food, feed and medicine, among other uses, has been revealed through numerous reports (El-Amier et al., 2014; El-Zayat et al., 2020). In addition, several essential phytonutrients may be found in wild plants for very little money. Natural minerals (such as zinc, iron, calcium, copper and others) and vitamins (such as vitamins A, B, C, D, E and others) are among the most significant and beneficial phytonutrients (Bongoni et al., 2013).

In the family Chenopodiaceae, the genus *Atriplex* L. is one of the contenders for halophytes that have evolved to living in dry and salty environments across the globe (Manousaki and Kalogerakis, 2011). The genus *Atriplex*, better known by its common name of saltbush, is abundant in the Egyptian flora, where it is represented by 18 species (Boulos, 2002). This genus includes plants that are annuals, herbaceous perennials or shrubs. Its leaves are alternating and have a mealy crust. The subtropical, temperate and subarctic climates are home to many different species that belong to this genus, which has a broad range of diversity. In Egypt, it is found throughout the Nile area, namely the delta and coastal strip along the Mediterranean, as well as the Egyptian desert and Sinai Peninsula (Boulos, 2002). Toxins are not found in any of the species that belong to this genus. In addition, *Atriplex* species are distinguished by their high salt chloride content and some people believe that these plants may be used as edible fodder (El-Shaer and Attia-Ismail, 2015). There is a lack of research that adequately investigates the economic significance of plants and the knowledge of natural resources that can be maintained through time in the environment. The purpose of this research was to investigate the nature of the edaphic factors that influence the nutritive value, energy content and total digestible nutrients of four species of wild *Atriplex* species that are used as fodder in Egypt.

2. MATERIALS AND METHODS

Plant materials collection and preparation

In the current investigation, specimens of *Atriplex* spp. were gathered from a variety of habitats within the research area (Figure 1); these plants are found to flourish in their native environment along the Deltaic Mediterranean coast. *Atriplex halimus*, *Atriplex lindleyi*, *Atriplex protulacoids* and *Atriplex semibaccata* are the species that have been chosen to represent the genus *Atriplex* (Table 1). Plant samples were hand-cleaned, rinsed multiple times with distilled water to remove residual moisture, then dried at 55 to 60 °C (maximum) in a forced air oven for 24 hours during flowering. Pestle and mortar crushed the dry aerial pieces into powder and sieved through 20-mesh. Nutrient analysis utilized dry powder.

Table 1 Salient ecological features of studied *Atriplex* species

Scientific name	Duration	Life form	Chorotype	Habitat	Location data
Atriplex halimus L.	Perennial	Nph	ME+SA-SI	Rw, Hw, Dr, La	31°31'39.63"N 31°19'7.70"E
A. lindleyi Moq.	Annual	Th	ME+IR-TR+ER-SR	D, Hw	31°25'43.55"N 31°33'36.79"E
A. portulacoides L.	Perennial	Ch	ME+IR-TR+ER-SR	Sm	31°19'40.49"N 32° 5'45.43"E
A. semibaccata R. Br.	Perennial	H	AUST	Sm, Rw, Hw,	31°30'12.40"N 31°22'4.42"E

Ch: Chamaephytes, H: Hemicryptophytes, Nph: Nanophanerophytes, Th: Therophytes, ME: Mediterranean, IR-TR: Irano-Turanina, ER-SR: Euro-Siberian, SA-SI: Saharo-Sindian, AUST: Australian, Rw: Railways, Hw: High ways, Dr: Drains, La: Lake, D: Desert, Sm: Salt marshes

Soil analysis

Soil samples were collected; air dried, combined, sieved through a 2 mm mesh screen to remove larger particles like gravel and then sealed in plastic bags for further physical and chemical testing (Piper, 1947; Jackson, 1962; Allen et al., 1974).

Proximate Analysis

Moisture, ash, crude lipid, crude fiber and nitrogen content were all calculated using techniques approved by the Organization of Official Analytical Chemists (AOAC). Each sample's crude protein was determined by multiplying its total nitrogen by a factor of 6.25 (AOAC, 1995). In our study, we used a technique quite similar to Handel, (1968) for isolating individual carbohydrate fractions. Both glucose and sucrose were measured using Handel, (1968) technique. The amount of dissolved sugars was calculated using the Southgate, (1991). Powder from the aerial sections was extracted using the procedures of Allen et al., (1974) for the mineral elements Na, K, Ca, Mg, Fe, Mn, Cu and Zn.

Determination of total carbohydrates

Total carbohydrate content (TC) was calculated according to the equation described by AOAC, (1995)

$$\% TC = 100 - (\% MC + \% TA + \% CFa + \% CFi + \% CP)$$

Where MC: Moisture content, TA: Total ash, CFa: Crude fat, Cfi: Crude fiber and CP: Crude protein.

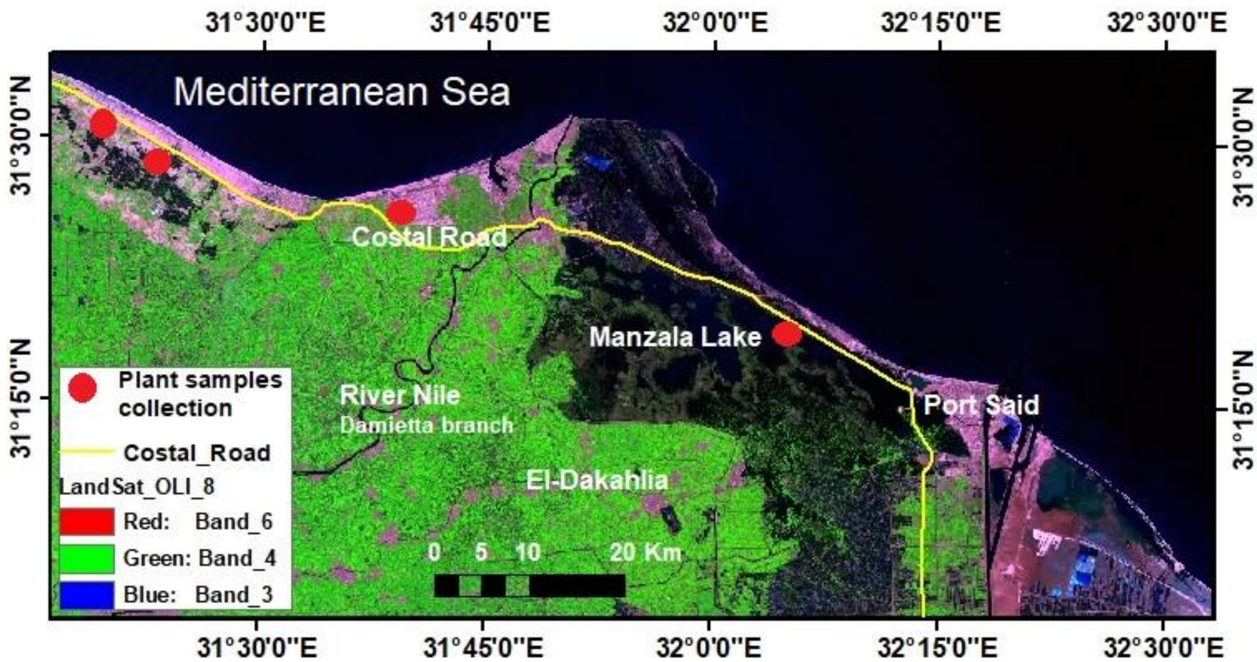

Figure 1 Map of the Nile Delta region showing different sites of plant samples collection

Determination of energy content and total digestible nutrient

The calculation of energy content (EC) and total digestible nutrient (TDN) were evaluated using the formula given by Indrayan et al., (2005).

$$EC\ (Cal/100g) = 4\times \text{crude lipid} + 9\times \text{ether extract} + 4\times \text{carbohydrate}$$

$$TDN\ (\%) = 0.623\ (100+1.25\ \text{ether extract}) - P\ 0.72$$

3. RESULTS AND DISCUSSION

Soil properties

Table 2 shows that the mineral component of the soil where *Atriplex* species thrive is often wet, alkaline (pH = 7.87 - 9), electrically conducting (0.47-1.14 $mS.cm^{-1}$), sandy to sand-silty in texture and has a relatively small quantity of clay (2.06-9.45%) (Singh and Schulze, 2015). Cation exchange capacity, the soil's ability to store positively charged molecules or ions, of mineral nutrients, is also enhanced by soil organic matter (Meetei et al., 2020). The content of organic carbon ranged from 0.27% to 0.60% in the soil of *A. lindleyi* and *A. halimus*, respectively. Calcium carbonate contents are relatively high, the greatest (19.47%) and lowest (1.49 %) values were found in the soil of *A. lindleyi* and *A. semibaccata*, respectively. Calcium carbonate reduced Sorghum bicolor dry matter and grain yield, according to Patil and Patil, (1981). But yields tended to increase with the addition of organic matter.

Table 2 Physical and chemical properties of soil samples collected from the habitats of the studied *Atriplex* species, Deltaic Mediterranean coastal desert, Egypt

Soil variable	*Atriplex* species			
	A. halimus	*A. lindleyi*	*A. portulacoides*	*A. semibaccata*
Ph	9.00±0.10	7.87±0.06	8.62±0.18	8.42±0.18
EC $mS.cm^{-1}$	1.14±0.04	0.47±0.05	0.95±0.09	0.50±0.08
$CaCO_3$ %	3.44±0.36	19.47±2.64	3.58±0.66	1.49±0.14
OC %	0.60±0.04	0.27±0.03	0.54±0.03	0.35±0.03
Na^+ mg/100g dry wt	100.40±3.06	236.28±33.05	581.80±91.78	399.03±46.51
K^+ mg/100g dry wt	13.04±0.41	82.56±17.11	224.93±44.93	170.66±22.95
Ca^{++} mg/100g dry wt	25.29±0.59	580.16±142.41	1369.21±332.76	1273.53±177.37
Mg^{++} mg/100g dry wt	12.23±0.31	166.15±39.45	424.60±92.23	348.90±48.56
Sand %	84.60±0.76	90.01±0.97	94.10±0.58	91.48±0.64

Silt %	5.95±0.42	7.35±0.96	2.95±0.21	2.85±0.21
Clay %	9.45±0.38	2.06±0.11	2.95±0.57	5.68±0.65
Soil texture	Loamy sand	Sand	Sand	Sand

EC: Electrical conductivity; OC: Organic carbon

Macronutrients are essential for plant growth and a good overall state of the plant (Tripathi et al., 2014). The highest values of macro-element (Na^+: 581.80, K^+: 224.93, Ca^{++}: 1369.21 and Mg^{++}: 424.60 mg/100g dry wt.) was recorded in *A. portulacoides* and lowest values (Na^+: 100.40, K^+: 13.04, Ca^{++}: 25.29 and Mg^{++}: 12.23 mg/100g dry wt.) was recorded in *A. halimus*. This result is in harmony with other studies related to the vegetation structure of this area (El-Amier, 2016; Al-Hadithy et al., 2018).

Nutritional value

The chemical composition of the shoot systems of all *Atriplex* species is shown (Table 3). There was little variance across the *Atripex* species studied in terms of their moisture content. In *A. lindleyi* it was 7.59%, whereas in *A. portulacoides* it was 17.56%. In comparison, the average moisture content of *A. semibaccata* was 14.76% and that of *A. halimus* was 9.71%. *A. lindleyi* had a dry matter percentage of 92.41%, *A. halimus* was 90.29% and *A. semibaccata* was 85.24%. *A. portulacoides* (82.44%) had the lowest value.

According to Table 3, there were large differences in the amounts of crude protein, fat, fiber, ash and carbohydrates found in the four *Atriplex* species that were analyzed. Crude fiber, protein, fat and total nitrogen were all greatest in *A. portulacoides* and *A. halimus*, respectively, among the species tested. The four species have very identical ash percentages, ranging from 9.28% in *A. lindleyi* to 11.27% in *A. halimus*. Nevertheless, when looking at crude fiber, total nitrogen and fat, none of the four species fit that description. While comparing the crude fiber content of different species, *A. portulacoides* (17.67%) had much more than *A. halimus* (8.73%). *A. lindleyi* had the lowest estimated amount of total nitrogen (1.56%), whereas *A. portulacoides* had the highest (2.58%). In contrast, the protein and fat content varied from 9.75% and 2.48% in *A. lindleyi* to 16.15% and 4.52%in *A. portulacoides*, respectively.

A. lindleyi had the lowest glucose and sucrose concentrations, at 0.94 and 6.27 mg/g dry weight, respectively, while *A. halimus* had the highest, at 1.84 and 17.66 mg/g dry weight. *A. halimus* had the largest total soluble sugar content (37.76 mg/g dry weight), while *A. lindleyi* had the lowest (24.45 mg/g dry weight). In contrast, polysaccharide content varied greatly across species, with the greatest value found in *A. halimus* (181.58 mg/g dry weight) and the lowest in *A. lindleyi* (92.43 mg/g dry weight). Plants in coastal areas have to produce more bioactive compounds as a means of adaptation to the higher levels of stress caused by salt than in inland areas (Vafadar-Shoshtari et al., 2017).

Table 3 Proximate composition of *Atriplex* species aerial parts

Nutrients	*Atriplex* species			
	A. halimus	*A. lindleyi*	*A. portulacoides*	*A. semibaccata*
Moisture content %	9.71±0.81	7.59±0.63	17.56±1.46	14.76±1.23
Dry matter %	90.29±7.52	92.41±7.70	82.44±6.87	85.24±7.10
Total ash %	11.27±0.94	9.28±0.69	10.04±0.84	9.63±0.80
Crude fiber %	8.73±0.73	11.83±0.99	17.67±1.47	15.43±1.29
Crude lipid %	4.29±0.36	2.48±0.21	4.52±0.38	3.6±0.30
Crude protein %	13.31±1.11	9.75±0.81	16.15±1.35	10.56±0.88
Total nitrogen %	2.13±0.18	1.56±0.13	2.58±0.22	1.69±0.14
Carbohydrate fraction (mg g^{-1} dry weight)				
Glucose	1.84±0.15	0.94±0.08	1.62±0.14	1.38±0.12
Sucrose	17.66±1.47	6.27±0.52	14.35±1.20	9.46±0.79
Total soluble sugar	37.76±2.01	24.45±1.87	34.04±1.80	27.36±2.15

Determination of carbohydrates, energy content and total digestible nutrients

A. lindleyi had the greatest total carbohydrate content (676.60 mg/g dry plant) whereas *A. semibaccata* had the lowest (607.78 mg/g dry plant) (Figure 2). Forage's nutritional value is determined by the proportion of necessary elements to those that provide energy (Dewhurst et al., 2009). When assessing forage's suitability as animal feed, its digestibility of organic matter is crucial (Schubiger et al., 2001). The current investigation shows that the shoot system of *Atriplex* species has high digestibility and energy content, as shown (Figure 1). The greatest percentage of total digestible nutrients was found in *A. semibaccata* (57.50%), followed by *A. lindleyi*

(57.21%) and *A. halimus* (56.06%), with the lowest value being found in *A. portulacoides* (54.19%). There were no noticeable variations between the nutritional value (kcal/100 g dry weight) of the four species and they could be ordered descending according to their nutritional value: *A. halimus* (341.45) > *A. lindleyi* (331.96) > *A. semibaccata* (311.76) > *A. portulacoides* (317.76). Abdel-Razik et al., (1988) found that the average yearly TDN value of edible forage was 75% DM. To put this in perspective, Tremetsberger (2010) found that the TDN in red clover (*Trifolium pratense*) ranged from 73.1% to 66.4%.

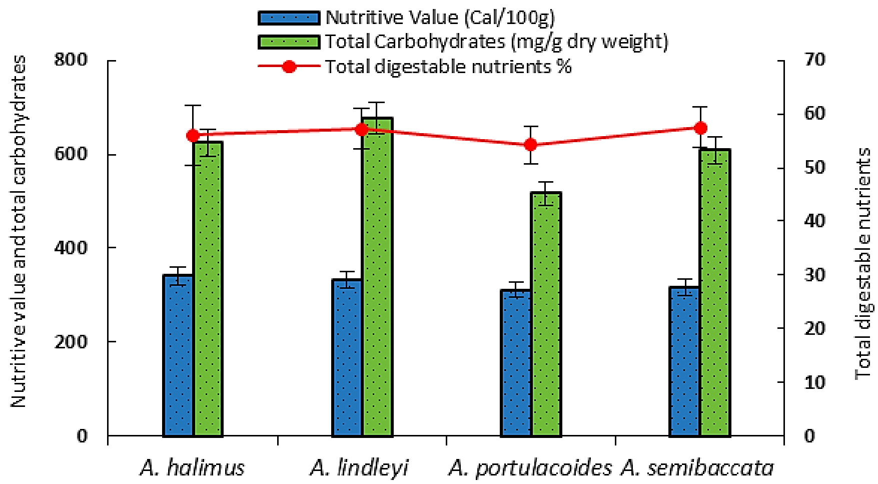

Figure 2 Total carbohydrates, nutritive value and total digestible nutrients of four selected *Atriplex* species

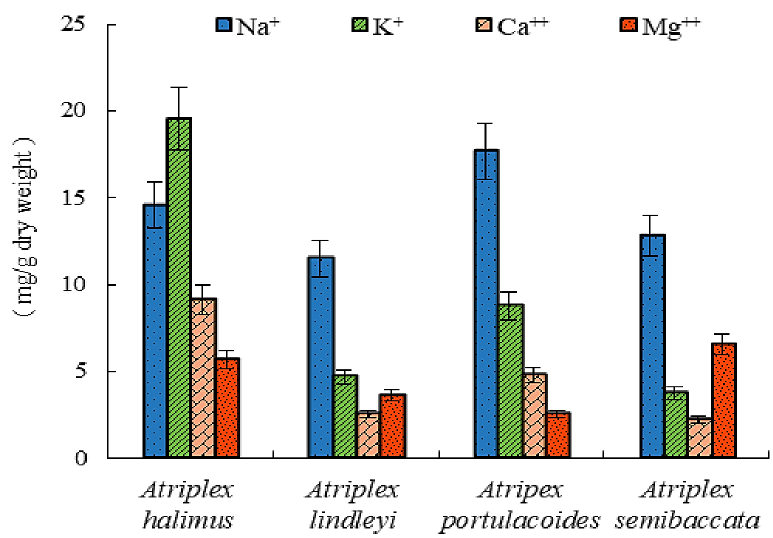

Figure 3 The macro-elements concentrations in the studied *Atriplex* species

Macro and micro elements

Figure 3 depicts that aerial shoot of *Atriplex* species were found to have high quantities of sodium and potassium. The Na^{+} concentrations of both *A. portulacoides* and *A. halimus* (17.68 and 14.56 mg/g) were higher followed by those of *A. semibaccata* (12.8 mg/g) and *A. lindleyi* that has the lowest concentration (11.51 mg/g) among the tested species. *A. halimus* had a higher K^{+} and Ca^{++} concentrations of 19.56 and 9.16 mg/g followed by *A. portulacoides* (8.78 and 4.80 mg/g) while *A. lindleyi* and *A. semibaccata* showed the lowest concentrations of 4.69, 2.56 and 3.75, 2.25 mg/g, respectively. While, Mg^{++} concentrations of both *A. semibaccata* and *A. halimus* (6.54 and 5.66 mg/g) were higher followed by those of *A. lindleyi* (3.62 mg/g) and *A. portulacoides* that has the lowest (2.57 mg/g) concentration among the tested species (Figure 3).

For example, 1.49 and 0.55 mg/g of iron and copper were found in *A. halimus*, followed by 1.18 and 0.46 mg/g in *A. portulacoides*, and finally 0.35, 0.03 and 0.03, 0.02 mg/g in *A. lindleyi* and *A. semibaccata*, respectively. The greatest concentration of manganese was found in *A. portulacoides* (0.09 mg/g), followed by *A. halimus* (0.05 mg/g), while the lowest quantities were found in *A. lindleyi* (0.04 mg/g) and *A. semibaccata* (0.01 mg/g). Nevertheless, the zinc content was lowest in *A. halimus* and *A. semibaccata* (0.03 and 0.01 mg/g, respectively) and greatest in *A. portulacoides* (0.06 mg/g), followed by *A. lindleyi* (0.04 mg/g) (Figure 4).

Animals need macro- and micronutrients for structural, physiological, catalytic and regulatory activities. Mineral elements replicate and differentiate cells in living beings (Keshri et al., 2019). Low-quality diet reduced mineral absorption or assimilation or increased mineral demand during intense development, pregnancy and lactation may cause mineral shortages (Radwinska and Zarczynska, 2014). According to the ARC, (1980) and NRC, (2001) systems, gestating or lactating beef cows need 38 mg/kg of potassium, 15.4 mg/kg of calcium, 3 mg/kg of magnesium, 6.8 mg/kg of sodium, 45 µg/kg of zinc, 2 µg/kg of manganese and 7.1 µg/kg of copper. Mineral balance is crucial for animal health since mineral deficiency or excess may harm productivity and health. Forage mineral content is mostly governed by site characteristics (geology and soils), plant community and harvest timing (Rezaei et al., 2006).

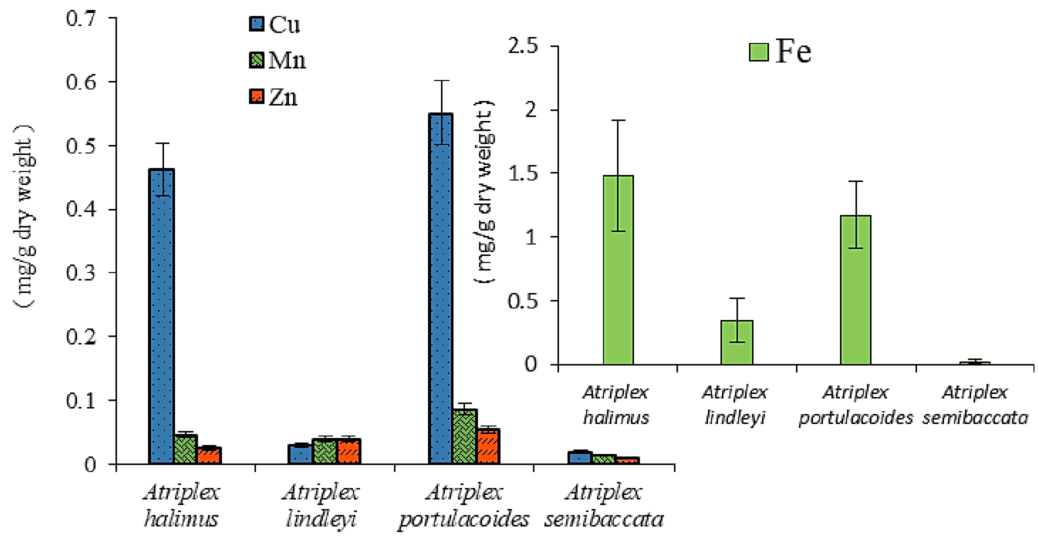

Figure 4 The micro-elements concentrations in the studied *Atriplex* species

4. CONCLUSION

In the present study, *Atriplex* species have a good forage value and can be used for the biomass production on saline soils. The total digestible nutrients and the nutritional values of the four studied wild *Atriplex* species were in appropriately higher levels that allow them to be used as promising source of valuable fodder producing halophytes. These species could be ordered descendingly on the basis of their usage as fodder: *A. halimus*, *A. lindleyi*, *A. semibaccata* and *A. portulacoides*. It is highly recommended to apply further studies for formulation of fodders using these species.

Informed consent: Not applicable.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study for sample collection & experimentation.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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