Plant & Fungal Research (2022) 5(1): 12-18
https://doi.org/10.30546/2664-5297.2022.1.12.

June 2022

Proximal, mineral and bioactive attributes of two wild forage legumes of the maritime habitats of southwestern India

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Abstract: This paper aims at documenting the proximal, mineral and bioactive components of two wild coastal forage legumes belonging to the genus *Canavalia*. *Canavalia cathartica* and *C. rosea* (Syn.: *C. maritima*) are frequent on the coastal sand dunes, while another variety of *C. cathartica* is common in the mangroves of southwestern India. These legumes possess an adequate quantity of proximal components (protein, total lipids, ash, total carbohydrates and calorie). Among a total of 17 elements evaluated in leaf flour, all of them are present in one or the other variety of *Canavalia*. Sodium content was the highest in all the varietes of *Canavalia* followed by magnesium, calcium and potassium. Heavy metals like aluminum, cadmium, chromium and nickel were either not present or below detectable levels or in minute quantities. According to NRC-NAS, low Na/P ratio and high Ca/P ratio are desirable to designate a food or feed as suitable for consumption. Accordingly, the Na/P ratio of *Canavalia* varieties is not desirable as it exceeds 1, while the Ca/P ratio is feasible as it is exceeded 1. Among the 12 components by qualitative analysis of leaf samples using chloroform and methanol extracts, seven components were found in both extracts of all three landraces of *Canavalia* (phenols, cardiac glycosides. saponins, terpenoids, flavonoids, alkaloids and quinone glycosides), while they were devoid of coumarins, steroids and phycocyanins. As the agrobotanical features of coastal *Canavalia* spp. are desirable, the leaves serves as good pasture during the summer season in the coastal region due to the scarcity of fresh fodder grasses.

Key Words: *Canavalia, chemical composition, coastal sand dunes, fodder, leaves, mangroves, wild legumes*

INTRODUCTION

Exploration of nutritional and bioactive components of plant origin received prime attention owing to their usefulness in traditional foods and modern medicine. Naturally occurring bioactive compounds are more versatile than synthetic ones owing to their compatibility with the human and livestock systems. Ethnically used plant species, as well as wild plant species, received more concern in the exploration of natural compounds to support human and livestock health. For instance, the livestock industry in Nigeria contributed to the national wealth by popularizing the wild plant species to meet the protein requirement and maintenance of livestock health [Upton, 1985]. In the tropics, forage refers mainly to the grasses and the usefulness of legumes is being neglected [Shelton et al., 2005].

The importance of many underutilized plant species other than grasses recently get their foothold in agriculture by efforts of local expertise of domestication, which is important in rural economy and development [Mabhaudhi et al., 2017]. The underutilized minor legumes and their varieties have several novelties owing to their adaptability, edibility, other usefulness and propagation by ethnic knowledge [Pooppla et al., 2019]. Livestock production and environmental protection go hand in hand and precise means are needed to balance the production of livestock without impinging the environment [Schultze-Kraft et al., 2018]. The current environmental situation especially climate change and global warming are the main concern to developing forage crops that withstand the adverse environmental conditions.

The Indian subcontinent represents more than 17% of the world's livestock population [Singh et al., 2019]. In the coastal sand dunes of the Indian subcontinent, nearly 151 species belong to 41 families of various useful plant species [Arun et al., 1999; Rao, Sherieff, 2002; Bhagya, Sridhar, 2009]. Among these plant species, the family Fabaceae dominates by representing 24 species. Many underutilized legumes with the desired nutrients are easily cultivable to support human and livestock nutrition and health [Sridhar, Seena, 2006]. In the coastal sand dunes of the southwest region of India encompass several wild legumes that serve as a prospective source of nutrition (food and fodder) and pharmaceuticals [Sridhar, Bhagya, 2007, 2009].

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Received 14.04.2022; Received in revised form 27.04.2022; Accepted 20.05.2022

The scope of several tropical legumes in sustainable livestock production in agroclimatic zones in India has been discussed by Singh et al. [2019]. According to Beyra-Matos et al., [2004], the genus *Canavalia* consists of 52 species and they have wide distribution in the Neotropics. However, there seems to be no adequate information about the uses of *Canavalia* spp. similar to other legumes in India as pasture or forage although they possess versatile agrobotanical features [Faruqui et al., 2002]. Cultivation of *Canavalia* spp. has several advantages such as highyielding green manure, soil binding/prevention of soil erosion and soil nitrogen enrichment [Smartt, 1990].

Owing to the shrinking land area for agriculture, *Canavalia* Adams. should be considered as a cover crop, green manure and nitrogen enriching crop in agricultural and plantation fields because of its multiphase applications. Due to the long shelf life, more quantities of proteins, fibers and carbohydrates with low fats, *Canavalia* spp. are substantial support to the livestock industry [Emiola et al., 2019]. *Canavalia* spp. are high-yielding green manure forage crops that possess traits like sand binding, erosion prevention and soil enrichment by nitrogen fixation [Smartt, 1990]. Salt-tolerant *Canavalia* spp. is distributed in the pantropical geographic conditions is an immensely valuable source of food and fodder [Mendoza-Gonázlez et al., 2014]. *Canavalia* spp. grown on the coastal sand dunes have a variety of traits like adaptation to withstand xeric habitat, alkaline pH, high temperature, high salinity, wind blow, sand abrasion, sand burial, production of intranodal roots with nodules and recalcitrant seeds [Beyra-Matos et al., 2004; Sridhar, Bhagya, 2007; Gallego-Fernández, Martínez, 2011; Mendoza-Gonázlez et al., 2014]. The nutritional, functional, biochemical and bioactive potential of seeds of *Canavalia* spp. on the west coast of India have been extensively studied [Sridhar, Bhagya, 2021]. As *Canavalia* spp. adapted to the coastal sand dunes, they play significant role in sustainable coastal agriculture. However, studies on the nutritional, biochemical and bioactive properties of leaves of *Canavalia* spp. as livestock feed are limited. Coastal sand dune *Canavalia* spp. are dwindling owing to human interference especially encroachment, sand mining and pollution. Hence, the current study emphasizes the importance of two *Canavalia* species: *Canavalia cathartica* Thoras. (coastal sand dunes and mangroves) and *Canavalia rosea* (SW.) DC. (coastal sand dunes) of southwestern India. Studies carried out on the leaves of *Canavalia* spp. include proximal components, mineral content and biochemical composition.

MATERIAL AND METHODS

Leaf samples and processing. Leaves of *Canavalia cathartica* (Fig. 1a, b) and *C. rosea* (Fig. 1e, f) were collected from the beaches of the southwest coast of Karnataka (Someshwara: 12º54'N, 74º51E) during July 2021. These legumes were identified by the plant taxonomist Professor Kakuje Gopalakrishna Bhat, Poornaprajna College, Udupi, Karnataka, India. The herbarium of specimens of each species was preserved in the Department of Biosciences, Mangalore University, Mangalore, India [*C. cathartica* of sand dunes (CcSDMU-221), *C. cathartica* of mangroves (CcMGMU-222) and *C. maritima* of coastal sand dunes (CmSDMU223)]. Leaves of another variety of *C. cathartica* were collected from the mangroves of the southwest coast of Karnataka (Nethravathi: 12º 50'N, 74º50E) during July 2021 (Fig. 1c, d). Leaf samples of each species were collected from three locations about 100 m apart.

Leaf samples were separated in the laboratory and spread on a paper sheet and sun-dried, left in the shade till the moisture attains <10%. They were powdered using Willey Mill (mesh # 30) and used to assess proximal qualities, mineral composition and phytochemicals.

Proximal analysis. Moisture, crude fiber and ash contents were determined gravimetrically [AOAC, 1999]. Crude protein and total lipids were estimated according to methods by Lowry et al. [1951] and Folch 5 et al. [1957], respectively. Total carbohydrates were calculated according to the formula by Müller and Tobin [1980]:

$$\text{Total carbohydrates (\%)} = 100 - (\text{crude protein} + \text{crude lipid} + \text{crude fibre} + \text{ash})$$

The energy value of leaf samples was determined based on the formula by Ekanayake et al. [1999]:

$$\text{Gross energy (kJ/100 g)} = (\text{Crude protein} + 16.7) \times (\text{Total lipids} + 37.7) \times (\text{Carbohydrates} \times 16.7)$$

Mineral analysis. The mineral composition of leaf samples was evaluated based on Ramamurthy and Kannan [2009]. Leaf samples free from moisture were assessed by the field-emission scanning electron microscope-energy dispersive spectrometer analysis (SEM-EDS) (FESEM Carl Zeiss, Oxford Instruments, USA) at the 15 kV voltage. The SEM images as well

as the corresponding EDS spectrum of samples, depend on the specific properties such as shape, shell and size to calculate the minerals contents.

The Na/K and Ca/P ratios of leaf samples were calculated.

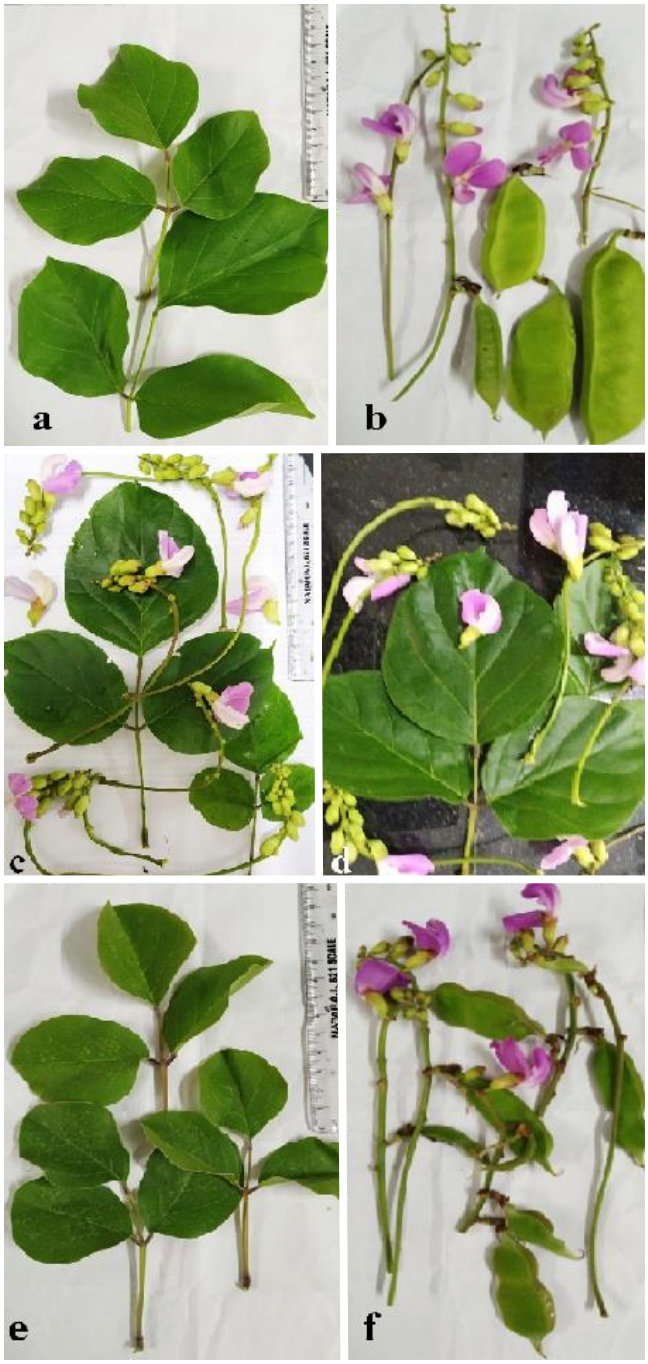

Figure 1. Leaves (a), inflorescence and pods (b) of *Canavalia cathartica* of coastal sand dunes (a, b); leaves and inflorescence (c and d) of *Canavalia cathartica* of mangroves (c, d); leaves (e), inflorescence and pods (f) of *C. rosea* of coastal sand dunes (e, f) (Scale in cm).

Biochemical analysis. Leaf samples (5 g) were extracted using chloroform (30 ml) and methanol (40 ml) separately on a rotary shaker (150 rpm, 12 hr) at laboratory temperature (242ºC) followed by agitation in a refrigerator (8-10 ºC) for overnight. On centrifuging the extracts, the supernatants used for qualitative analysis of bioactive components by color reaction (phenols, cardiac glycosides, terpenoids, coumarins, flavonoids, alkaloids, steroids, quinone, quinone glycosides, carotenoids and phycocyanins), whereas formation of froth and emulsion to ascertain the presence of saponins [Trease, Evans, 1989, 2002; Safowora, 1993; Herborne, 1998; Parekh, Chanda, 2007; Soares et al., 2013].

RESULTS AND DISCUSSION

Proximal features. The moisture content of three-leaf flours was below 4.6%, which was higher in mangrove *C. cathartica* as well as *C. rosea* of sand dunes than the sand dune *C. cathartica* (Tab. 1). The content of crude protein also showed a significant difference as seen in moisture content. The total lipids, ash, total carbohydrates and energy were in high quantity in *C. cathartica* spp. than *C. rosea.* The crude fiber in mangrove *C. cathartica* was lower compared to the sand dune *C. cathartica* and *C. rosea.*

The crude protein value of leaves of coastal *Canavalia* spp. is substantially lower than *C. brasiliensis* and *C. ensiformis* of Nigeria, so also the ash content [Emiola et al., 2019]. However, the crude fiber content of coastal *Canavalia* spp. is comparable with *C. brasiliensis* and *C. ensiformis.* A similar study carried out by Tijani et al. [2019] on C. maritima of Nigeria showed higher protein and ash contents, while the content of total lipids is alike and the rest of crude fiber and carbohydrates were higher in the present study. Such differences in proximal qualities could be attributed due to different *Canavalia* spp. growing in varied geographic locations.

Mineral composition. Among the 17 elements evaluated in leaf flour, all were present in one or the other variety of *Canavalia* (Tab. 2). Sodium content was the highest in all the varieties of *Canavalia* followed by magnesium, calcium and potassium. Heavy metals like nickel, aluminum, cadmium and chromium were either not present or below detectable levels (BDL) or in minute quantities. The low Na/P ratio and high Ca/P ratio are desirable to designate a food or feed suitable for consumption (NRC-NAS, 1989). Accordingly, the Na/P ratio of *Canavalia* varieties is not desirable as it exceeds 1, while the Ca/P ratio is feasible as it is exceeded 1.

Comparing minerals in leaves of the coastal

Table 1. Proximal composition of leaves of *Canavalia* spp. on a dry mass basis (n=3, mean±SD).

	Canavalia cathartica (Sand dune)	*Canavalia cathartica* (Mangrove)	*Canavalia rosae* (Sand dune)
Moisture (%)	3.2±0.12	4.4±0.01	4.5±0.01
Crude protein (%)	1.8±0.03	3.3±0.03	3.6±0.02
Total lipids (%)	3.5±0.03	4.8±0.02	3.0±0.02
Crude fibre (%)	18.6±0.02	15.3±0.02	29.1±0.25
Ash (%)	4.3±0.1	4.8±0.2	3.9±0.12
Total carbohydrates (%)	68.8±2.1	67.5±3.3	56.0±1.2
Calorific value (kJ/100 g)	1311±16.5	1361±22.2	1107±12.6

Table 2. Mineral composition (%) leaf samples Canavalia spp. on a dry mass basis (n=3, mean; BDL, below detectable limit; NP, not present).

	C. cathartica (Sand dune)	*C. cathartica* (Mangrove)	*C. rosae* (Sand dune)
N	0.385	0.512	0.220
P	0.260	0.418	0.232
Ca	1.280	1.760	1.305
Na	2.120	2.450	1.820
K	0.820	0.940	0.655
Mg	1.625	1.845	1.560
Mn	0.038	0.055	0.046
Zn	0.280	0.415	0.242
Fe	0.022	0.038	0.030
Cu	0.012	0.048	0.025
S	0.135	0.280	0.112
Cl	0.008	0.012	BDL
Si	0.025	0.018	0.020
Ni	0.005	0.002	NP
Al	0.0012	NP	0.0018
Cd	BDL	NP	BDL
Cr	BDL	0.0028	0.0015
Na/P ratio	8.2	5.9	7.8
Ca/P ratio	4.9	4.2	5.6

Canavalia varieties with *C. braziliensis* Lindl. and *C. ensiformis* (L.) DC. of Nigeria, calcium and magnesium contents were higher in coastal *Canavalia*, while potassium content is comparable [Emiola et al., 2019]. Other minerals like phosphorus, iron and zinc were lower in coastal *Canavalia* varieties than Nigerian *Canavalia* spp. Other minerals (nitrogen, phosphorus, calcium, sodium, potassium, magnesium, manganese, zinc, iron and copper) in leaves of coastal *Canavalia* varieties were higher than *C. rosea* of Nigeria [Tijani et al., 2019].

Biochemical components. Among 12 components by qualitative analysis of leaf samples using chloroform and methanol extracts, seven components were found in both extracts of all three varieties of *Canavalia* (phenols, cardiac glycosides. saponins, terpenoids, flavonoids, alkaloids and quinone glycosides), while they were devoid of coumarins, steroids and phycocyanins (Tab. 3). Quinone was confined to both the extracts of *C. rosea* and methanol extract of mangrove *C. cathartica*. Carotenoides were confined to sand dune *C. cathartica* (both extracts) and in chloroform extract of mangrove *C. cathartica.*

Leaves of *C. cathartica* collected from Thiruvannamalai (Tamil Nadu) showed many bioactive compounds based on qualitative assay (phenols, tannins, flavonoids, glycosides, steroids, terpenoids and reducing sugars) [Saraswathi et al., 2018]. In addition, several bioactive compounds have been reported based on GC-MS analysis. Leaves of *C. rosea* collected from Nigeria

Table 3. Qualitative phytochemical assessment of chloroform and methanol extracts of leaves of *Canavalia* spp. (+, presence; -, absence).

	C. cathartica (Sand dune)		*C. cathartica* (Mangrove)		*C. rosae* (Sand dune)	
	Chloroform	Methanol	Chloroform	Methanol	Chloroform	Methanol
Phenols	+	+	+	+	+	+
Cardiac glycosides	+	+	+	+	+	+
Saponins	+	+	+	+	+	+
Terpenoids	+	+	+	+	+	+
Coumarins	-	-	-	-	-	-
Flavonoids	+	+	+	+	+	+
Alkaloids	+	+	+	+	+	+
Steroids	-	-	-	-	-	-
Quinone	-	-	-	+	+	+
Quinone glycosides	+	+	+	+	+	+
Carotenoids	+	+	+	-	-	-
Phycocyanins	-	-	-	-	-	-

also possess several bioactive components (alkaloids, cardiac glycosides, flavonoids, saponins, steroids and terpenoids) [Tijani et al., 2019]. These compounds along with antioxidant potential in the leaves of *Canavalia* serve as suitable pastures for the livestock in the coastal region. Similarly, the leaves of *C. brasiliensis* and *C. ensiformis* have been considered as potential feed supplements owing to their high content of protein and minerals with low levels of antinutritional components [Emiola et al., 2019; Tijani et al., 2019].

CONCLUSION

This study projected the importance of the legume pasture of coastal *Canavalia* spp. They possess good nutrient, mineral and bioactive components and serve as potential livestock feed. The traditional knowledge of local people is also the same and leaves of *Canavalia* spp. serve as summer feed as they grow in the coastal region (sand dunes and mangroves) vigorously without any human effort. This pasture is useful to livestock exclusively or in the combination nine of grasses. As *Canavalia* spp. in coastal sand dunes have already acclimatized to the extreme conditions (high temperature, salinity and alkaline pH), they will be efficient and environmentfriendly forage legumes under the threat of climate change and global warming. The authors recommended leaves of *Canavalia* spp. as good protein supplements especially during the dry seasons where there is a scarcity of fresh grass. Further studies on the fiber content, roughage value and antioxidant potential of coastal *Canavalia* spp. tolerant to harsh climatic conditions will be useful to grow them in the agricultural fields as green manure, mulch and livestock feed in the future.

ACKNOWLEDGMENT

The authors are grateful to the Mangalore University for supporting this study and the Department of Biosciences for offering the laboratory facilities. We appreciate constructive discussion by Dr. Mahadevakumar, Karnataka State Open University, Mysore, India.

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Hindistanın cənub-qərbindəki dənizkənarı məskənlərdə iki yabanı yem paxlasının proksimal, mineral və bioaktiv xüsusiyyətləri

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Bu məqalə *Canavalia* cinsinə aid iki yabanı sahilyanı yem paxlasının proksimal, mineral və bioaktiv komponentlərinin öyrənilməsinə həsr edilib. *Canavalia cathartica* və *C. rosea* (Syn.: *C. maritima*) sahil qum təpələrində, *C. cathartica*-nın digər variasiyası isə Hindistanın cənub-qərbindəki manqrov ağaclıqlarda geniş yayılmışdır. Bu paxlalılar kifayət miqdarda proksimal komponentlərə (zülal, ümumi lipidlər, kül, ümumi karbohidratlar və kalori) malikdirlər. Yarpaq ununda qiymətləndirilən 17 elementdən hər biri *Canavalia* növlərinin bu və ya digər variasiyasında mövcuddur. *Canavalia* cinsi növlərinin variasiyalarında ən yüksək natriumun, sonra maqnezium, kalsium və kaliumun miqdarı olmuşdur. Alüminium, kadmium, xrom və nikel kimi ağır metallar ya aşkar edilməyib, ya da aşkar edilə bilən səviyyədən aşağı və ya az miqdarda olub. NRC-NAS-a görə, aşağı Na/P nisbəti və yüksək Ca/P nisbəti qida və ya yem kimi istifadə üçün uyğundur. Müvafiq olaraq, *Canavalia* variasiyalarının Na/P nisbəti 1-i keçdiyi üçün qənaətbəxş deyil, Ca/P nisbəti isə 1-i keçdiyi üçün qənaətbəxşdir. Xloroform və metanol ekstraktlarından istifadə etməklə yarpaq nümunələrinin keyfiyyət təhlili nəticəsində *Canavalia* cinsinin iki növünün ekstraktında 12 komponentdən yeddisi (fenollar, ürək qlikozidləri, saponinlər, terpenoidlər, flavonoidlər, alkaloidlər və quinon qlikozidlər) aşkar edilmişdir, kumarinlər, steroidlər və fikosiyaninlər tapılmamışdır. Sahilyanı *Canavalia* növlərinin aqrobotanik xüsusiyyətləri arzuolunandır, yarpaqları təzə yem otlarının azlığı səbəbindən sahil bölgəsində yay mövsümündə yaxşı otlaq bitkisi kimi xidmət edir.

Açar sözlər: *Canavalia, kimyəvi tərkibi, sahil qum təpələri, yem, yarpaqlar, manqrov ağaclıqları, yabanı paxlalılar*

Проксимальные, минеральные и биоактивные свойства двух диких кормовых бобовых из прибрежных местообитаний юго-западной Индии

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Статья посвящена изучению проксимальных, минеральных и биоактивных компонентов двух диких прибрежных кормовых бобовых, принадлежащих к роду *Canavalia*. *Canavalia cathartica* и *C. rosea* (Syn.: *C. maritima*) часто встречаются на прибрежных песчаных дюнах, в то время как другой вид *C. cathartica* распространен в мангровых зарослях на юго-западе Индии. Эти бобовые обладают достаточным количеством проксимальных компонентов (белка, общих липидов, золы, общих углеводов и калорий). Среди 17 элементов, оцененных в листовой муке, все они присутствуют в том или ином сорте *Canavalia*. Содержание натрия было самым высоким во всех вариациях видов рода *Canavalia*, за которым следовали магний, кальций и калий. Тяжелые металлы, такие как алюминий, кадмий, хром и никель, либо отсутствовали, либо были ниже определяемого уровня, либо в ничтожных количествах. Согласно NRC-NAS, низкое соотношение Na/P и высокое соотношение Ca/P желательны, чтобы пища или корм считались пригодными для употребления. Соответственно, соотношение Na/P сортов *Canavalia* считается неудовлетворительным, так как превышает 1, а в соотношение Ca/P допустимо, так как превышает 1. Среди 12 компонентов при качественном анализе образцов листьев с использованием хлороформного и метанольного экстрактов семь компонентов были обнаружены в обоих экстрактах двух видов рода *Canavalia* (фенолы, сердечные гликозиды, сапонины, терпеноиды, флавоноиды, алкалоиды и хинон-гликозиды), при этом они были лишены кумаринов, стероидов и фикоцианинов. Поскольку агроботанические особенности прибрежной *Canavalia* spp. являются удовлетворительными, она может служить хорошим пастбищным растением в летний сезон в прибрежном районе из-за нехватки свежих кормовых трав.

Ключевые слова: *Canavalia, химический состав, прибрежные песчаные дюны, корм, листва, мангровые заросли, дикорастущие бобовые*