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Research Paper

Comparison of forage production and nutritive value of 10 *Grona* spp. accessions in Danzhou, Hainan, China

Producción y valor nutritivo de 10 accesiones de Grona *spp. en Danzhou, Hainan, China*

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Abstract

The demand for high-quality forages is increasing in tropical regions, and could be filled with legume species of the genus *Grona*, which have good nutritive value. In this study, a comparison of the forage production and nutritive value of 10 accessions of *Grona* spp. was carried out in the field at Danzhou, Hainan from 2016 to 2018. Yield, plant height, survival rate, leaf:stem ratio and concentrations of crude protein, crude fiber, crude fat (ether extract), nitrogen free extract, crude ash, calcium and phosphorus were measured. Results showed that *Grona strigillosa* (syn. *Desmodium strigillosum*) cv. Reyan No. 27 and *G. heterocarpa* subsp. *ovalifolia* (syn. *Desmodium ovalifolium*) cv. Maquenque displayed the best performance, owing to their 261.3% and 235.6% higher dry matter yields, respectively, compared with the Control germplasm, *G. heterocarpa* subsp. *ovalifolia* cv. Reyan No. 16 in 2018. Cultivar Maquenque had a higher survival rate than the Control ($P<0.05$). Regarding nutritive value, cv. Reyan No. 27 exhibited higher crude fat and crude fiber but lower Ca concentrations than the Control ($P<0.05$). Based on PCA ranking, we concluded that cvv. Maquenque and Reyan No. 27 could be used as suitable candidate materials for livestock production in tropical regions of China. Further studies on their tannin concentrations and their acceptability by animals are needed before practical recommendations can be made.

Keywords: Comprehensive evaluation, *Desmodium*, forage legumes, PCA, tropical pastures.

Resumen

La demanda de forrajes de alta calidad está aumentando en las regiones tropicales y podría ser satisfecha con leguminosas del género *Grona* que se caracterizan por un buen valor nutritivo. En un estudio de campo, llevado a cabo en Danzhou, Hainan, entre 2016 y 2018, fueron comparadas la producción de forraje y el valor nutritivo de 10 accesiones de *Grona* spp. Para el efecto se determinaron el rendimiento, la altura de planta, la tasa de supervivencia, la relación hoja:tallo y las concentraciones de proteína cruda, fibra cruda, grasa bruta, extracto libre de nitrógeno, ceniza, calcio y fósforo en tejido. Según los resultados, *Grona strigillosa* (sin. *Desmodium strigillosum*) cv. Reyan No. 27 y *G. heterocarpa* subsp. *ovalifolia* (sin. *Desmodium ovalifolium*) cv. Maquenque mostraron el mejor desempeño, debido a sus rendimientos de materia seca más altos (261.3% y 235.6%, respectivamente), en comparación con el germoplasma testigo (*G. heterocarpa* subsp. *ovalifolia* cv. Reyan No. 16) determinados en 2018. La tasa de supervivencia del cv. Maquenque fue más alta que la del testigo ($P<0.05$). En cuanto al valor nutritivo, el cv. Reyan No. 27 presentó concentraciones de

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grasa bruta y fibra cruda más altas pero una concentración de Ca más baja que las del testigo (P<0.05). Con base en la clasificación por PCA, los cvs. Maquenque y Reyan No. 27 son buenos candidatos para contribuir a la producción animal en la región tropical de China. No obstante, se requieren estudios sobre las concentraciones de taninos en estos materiales y su aceptabilidad por los animales antes de poder hacer recomendaciones prácticas.

Palabras clave: *Desmodium*, evaluación compuesta, leguminosas forrajeras, pastos tropicales, PCA.

Introduction

The demand for high-quality animal products in developing countries is increasing year by year with the improvement of living standards and consumption changes (Lee 2018). However, the development of livestock production is usually limited by insufficient high quality forage supply. For example, in the tropical region of Hainan province of China, the main forages are king grass [*Cenchrus purpureus* × *C. americanus* (syn. *Pennisetum purpureum* × *P. glaucum*)] and *Stylosanthes* spp., which are not adapted to all edaphic conditions and production systems, resulting in livestock production below its potential (Zi et al. 2018). Therefore, it is crucial to invest in developing and utilizing new forage resources with high production and nutritive value in tropical regions (Kambashi et al. 2014).

Tropical forage legumes have the potential to contribute significantly to sustainable intensification of livestock production (Schultze-Kraft et al. 2018). Based on our prior evaluation of nutritional concentrations (Chen et al. 2010; Liu et al. 2014), an important and well known legume genus is *Desmodium*, from which the genus *Grona* was recently separated, based on morphological, palynological and molecular data (Ohashi and Ohashi 2018). *Grona* comprises currently 21 species and subspecies recognized by GRIN, the taxonomic database of the USDA Genetic Resources Information Network (npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch), among them some species well known by the tropical forages plant research community, such as *G. barbata*, *G. heterocarpa* subsp. *ovalifolia*, *G. heterophylla*, *G. strigillosa* and *G. triflora*.

The Chinese Academy of Tropical Agricultural Sciences (CATAS) introduced more than 800 *Desmodium* and *Grona* accessions to China from the International Center for Tropical Agriculture (CIAT). Evaluations of *Grona heterocarpa* subsp. *ovalifolia* (Prain) H. Ohashi & K. Ohashi [syn. *Desmodium ovalifolium* (Prain) Wall. ex Merr.] accession CIAT 350 and *G. strigillosa* (Schindl.) H. Ohashi & K. Ohashi (syn. *Desmodium strigillosum* Schindl.) accession CIAT 13158 resulted in the release of cultivars Reyan No. 16 and Reyan No. 27, respectively, with good performance in Hainan. *G. heterocarpa* subsp. *ovalifolia* is a creeping stoloniferous herb or subshrub, with height ranging from 0.1 to 0.5 (occasionally 1.0) m, which grows well in tropical and subtropical climates, is adapted to infertile acid soils and drought-tolerant (Cook et al. 2020). *G. strigillosa* has been less researched so far. It is a semi-erect subshrub growing up to about 0.5 m, morphologically similar to *G. heterocarpa* subsp. *heterocarpa* (Figure 1). The species has shown promise on acid, low-fertility soils in Colombia and southwestern Nigeria (Thomas and Schultze-Kraft 1990; Larbi et al. 2000).

Figure 1. *Grona strigillosa* at CATAS, Hainan, China.

Previous studies have shown that *Grona* spp. present average tannin concentrations at a relatively moderate level of about 2.09% (Li et al. 2013), but reduction of methanol-extractable condensed tannin concentration in leaves of *G. heterocarpa* subsp. *ovalifolia* (syn. *D. ovalifolium*) by the addition of polyethylene glycol resulted in increased intake and nitrogen retention by sheep (Carulla et al. 2001). Plants of *Grona* spp. can be used as protein supplements with roughage for ruminants, increasing the value of feed and reducing production costs.

Production and nutritive value of tropical forage legumes can vary widely in different areas with different climatic conditions and soil types. *G. heterocarpa* subsp. *ovalifolia* (syn. *D. ovalifolium*) performed well on a low-phosphorus, acid soil in southern Ethiopia, producing dry matter (DM) yields of 2,977 kg/ha and 2,652 kg/ha in 1989 and 1990, respectively (Larbi et al. 1995). Based on forage production and quality, *G. strigillosa* (CIAT 13155), along with *Centrosema arenarium* (CIAT 5236), were considered the most promising species for the development of silvopastoral systems in the west African forest-savanna transition zone and in similar tropical environments (Larbi et al. 2000).

However, little information is available about the relative performance of various *Grona* spp. accessions in tropical China, both in terms of forage production and nutritive value. To meet the demand for high-quality animal products in China and improve livestock production, it is essential to increase the quantity and quality of forage available, which can be achieved through selecting and breeding the accessions with the highest production and nutritive value. Therefore, the objective of this study was to examine the performance of 9 accessions of *G. heterocarpa* subsp. *ovalifolia* (syn. *D. ovalifolium*) and 1 accession of *G. strigillosa* in terms of yield and nutritive value, in the tropical region of China, over 3 years.

Materials and Methods

Site characteristics

The experimental site was located east of Nada, Danzhou, PR China in the province of Hainan (19°30′ N, 109°30′ E; 149 masl). It has a tropical monsoon climate characterized by hot and rainy summers (May–October), and cold, dry winters and springs (November–April). Mean annual rainfall (2010–2018) is 2,153 mm. Mean monthly maximum and minimum temperatures range from 22 to 35 °C and from 14 to 25 °C, respectively. The soil type is a latosol formed on granite, with characteristics of the top 40 cm as follows: pH 4.5–5.5; alkaline hydrolyzable nitrogen 85–100 mg/kg; organic matter 10–12 g/kg; available P 8.5–12.5 mg/kg detected by the hydrochloric acid-ammonium fluoride method (LY/T1233-1999/5); and available K 50–65 mg/kg.

Experimental materials

Ten *Grona* spp. accessions, including cvv. Reyan No. 16, Reyan No. 27 and Maquenque, were used in this experiment, all of which were obtained from CIAT (Table 1).

Experimental design and management

A single factor randomized block design was used with 3 replications, for a total plot number of 30 (10 accessions × 3 replications). Plot size was 26 m^2 (6.5 × 4 m), and plant spacing was 0.5 × 0.5 m. Guard rows were set up around the experimental site. Seedlings were propagated in a greenhouse by planting seeds on 4 January 2016 and were transplanted into the plots on 25 April 2016. No fertilizer was applied during the experiment, and weeds were removed manually every 2 weeks.

Measurements

The first harvest was carried out 3 months after transplanting in July 2016, leaving a stubble height of 20 cm, and forage yields from the whole plots were recorded subsequently every 4 months until 2018. Fresh material was weighed immediately in the field and random samples of about 1,000 g were collected from each plot and oven-dried at 70 °C until constant weight for determining DM yields.

Before each harvest, 10 plants were selected at random from each plot and height was measured, using a rule to measure from the ground to the highest leaves of the plant. After the final harvest in 2018, all surviving plants were counted, and survival rate was calculated as the ratio of the number of plants remaining and the number transplanted into the plots in April 2016 expressed as a percentage.

Leaf:stem ratio was determined during the first harvest each year, i.e. 25 July 2016, 27 February 2017 and 25 February 2018, respectively. Five to 10 plants (total fresh weight about 1,000 g) were collected at random from each plot and separated into leaf and stem before oven-drying at 70 °C for calculation of leaf:stem ratio.

Samples for determining nutrient composition were collected before the first harvest in 2017 and crude protein (CP), crude fat (ether extract, EE), crude fiber (CF), nitrogen free extract (NFE), crude ash (ash), calcium (Ca) and phosphorus (P) concentrations were determined following the protocols of Owens et al. (2010).

Data analysis

All data were subjected to analysis of variance (SAS 8.1; SAS Institute Inc., Cary, NC). Treatment means were separated using the least significant difference test at P=0.05.

Comprehensive evaluation of production and nutritive value using PCA

Comprehensive evaluation of the 10 accessions was performed on the data collected using Principal Component Analysis (PCA), and ranking values for each accession were calculated with the formula:

Ranking value $=\sum_{i=1}^{n} x_i PC_i$,

where: x is the contribution of PC_i; and n is the number of PCs considered for the ranking (in this case the first 4) (Liu et al. 2015).

Table 1. Details of 10 *Grona* spp. accessions used in this study.

Accession No.	Species	Origin
CIAT 13083	*Grona heterocarpa* subsp. *ovalifolia*	Ubon Ratchathani, Thailand
CIAT 13305	*Grona heterocarpa* subsp. *ovalifolia*	Terengganu, Malaysia
CIAT 13108	*Grona heterocarpa* subsp. *ovalifolia*	Negeri Sembilan, Malaysia
CIAT 13114	*Grona heterocarpa* subsp. *ovalifolia*	Terengganu, Malaysia
CIAT 13120	*Grona heterocarpa* subsp. *ovalifolia*	Yala, Thailand
CIAT 13087	*Grona heterocarpa* subsp. *ovalifolia*	Prachuap Khiri Khan, Thailand
CIAT 3788	*Grona heterocarpa* subsp. *ovalifolia*	Narathiwat, Thailand
cv. Reyan No. 27 (CIAT 13158)	*Grona strigillosa*	Surin, Thailand
cv. Maquenque (CIAT 13651)	*Grona heterocarpa* subsp. *ovalifolia*	Trat, Thailand
Control cv. Reyan No. 16 (CIAT 350)	*Grona heterocarpa* subsp. *ovalifolia*	Southeast Asia (commercial cover crop cultivar)

Results

Dry matter yield

Only CIAT 3788 and CIAT 13120 had significantly higher DM yields (mean 12,180 kg/ha) than Control *G. heterocarpa* subsp. *ovalifolia* cv. Reyan No. 16 (9,730 kg/ha) in 2016 but neither exceeded the DM yield of *G. strigillosa* cv. Reyan No. 27 (11,688 kg/ha; Table 2). In 2017, only *G. strigillosa* cv. Reyan No. 27 had significantly higher DM yield than the Control cv. Reyan No. 16 (13,438 vs. 9,890 kg/ha). In 2018, both *G. strigillosa* cv. Reyan No. 27 and cv. Maquenque had significantly higher DM yields than Control cv. Reyan No. 16 (9,933 and 8,956 vs. 3,801 kg/ha, respectively), representing increases of 161 and 136%, respectively (Table 2). Over 3 years, *G. strigillosa* cv. Reyan No. 27, CIAT 3788, CIAT 13120 and cv. Maquenque had higher DM yields than Control cv. Reyan 16, while CIAT 13083 and CIAT 13108 had the lowest biomass production.

Plant height

Height of the 10 accessions ranged between 17.0 and 63.1 cm, with *G. strigillosa* Reyan No. 27 being tallest, while CIAT 13083 and CIAT 13108 were the shortest ($P<0.05$) (Table 3).

Survival rate

Survival rates varied markedly from 13 to 93% with cv. Maquenque having a significantly higher survival rate than the Control cv. Reyan No. 16, while CIAT 13083 had a significantly lower survival rate than all other accessions ($P<0.05$).

Leaf:stem ratio

While leaf:stem ratio varied from 0.71:1 (*G. strigillosa* cv. Reyan No. 27) to 0.98:1 (CIAT 13108 and 13120), there were no significant differences among accessions for this parameter ($P>0.05$) (Table 3).

Nutrient composition

Significant differences were observed in CF, EE, ash, NFE, Ca and P concentrations among the 10 accessions (Table 4). However, the most important component, i.e. crude protein %, did not differ between accessions, with an average of 12.7%. Only *G. strigillosa* cv. Reyan No. 27 had a significantly higher EE (2.81%) than the Control. CIAT 13305, CIAT 13108, CIAT 13087 and *G. strigillosa* cv. Reyan No. 27 had significantly higher CF (mean 35.8%) than the Control (34.6%). Ca concentration varied from 0.74 to 1.57% with no accession containing a higher level than Control ($P>0.05$). Similarly, P concentration varied from 0.19 to 0.29% in the various accessions with no accession containing a higher level than the Control ($P>0.05$).

Comprehensive evaluation

The first 4 components of the PCA (PC1, PC2, PC3 and PC4) explained 87.6% of the variance between the 10 *Grona* spp. accessions (Table 5). HT, EE and P were driving PC1, with loadings >0.4; NFE and DM were driving PC2, with loadings >0.3; ash and CP were driving PC3, with loadings >0.3; and for PC4, ash and Ca were the key parameters, with loadings >0.4.

The resulting ranking order for the 10 accessions was: cv. Maquenque > cv. Reyan No. 27 > CIAT 3788 > cv. Reyan No. 16 > CIAT 13305 > CIAT 13087 > CIAT 13108 > CIAT 13114 > CIAT 13120 > CIAT 13083 (Table 6).

Table 2. Dry matter yields of 10 *Grona* spp. accessions from 2016 to 2018.

Accession No.	Dry matter yield (kg/ha)			
	2016	2017	2018	Total
CIAT 13083	4,215e[1]	3,467d	568e	8,250
CIAT 13305	9,406cd	9,832bc	2,703cde	21,942
CIAT 13108	5,354e	3,243d	1,192 de	9,789
CIAT 13114	10,281abc	8,762bc	3,976 bc	23,020
CIAT 13120	12,102a	10,328b	4,279bc	26,708
CIAT 13087	11,877ab	7,117c	3,442cd	22,436
CIAT 3788	12,257a	10,442b	6,013b	28,713
cv. Reyan No. 27	11,688ab	13,438a	9,933a	35,060
cv. Maquenque	7,460d	10,189bc	8,956a	26,605
Control cv. Reyan No. 16	9,730bc	9,890bc	3,801bc	23,421
Mean	9,437	8,671	4,486	

[1]Within columns, means with different letters are significantly different at P<0.05.

Table 3. Height and leaf:stem ratio of 10 *Grona* spp. accessions and survival rate in 2018.

Accession No.	Height (cm)	Survival rate (%)	Leaf:stem ratio
CIAT 13083	17.0c[1]	13.1d	0.84:1a
CIAT 13305	26.2bc	57.4bc	0.86:1a
CIAT 13108	18.1bc	53.7bc	0.98:1a
CIAT 13114	24.9bc	41.7bc	0.93:1a
CIAT 13120	27.8bc	31.4c	0.98:1a
CIAT 13087	27.2bc	54.5bc	0.75:1a
CIAT 3788	34.9bc	78.2ab	0.94:1a
cv. Reyan 27	63.1a	65.1bc	0.71:1a
cv. Maquenque	35.4b	93.3a	0.85:1a
Control cv. Reyan 16	25.8bc	64.4bc	0.86:1a
Mean	30.0	55.3	0.87:1

[1]Within columns, means with different letters are significantly different at P<0.05.

Table 4. Nutritive value of 4-month-old forage from 10 *Grona* spp. accessions in 2017.

Accession No.	Crude protein (%)	Ether extract (crude fat) (%)	Crude fiber (%)	Crude ash (%)	Nitrogen free extract (%)	Ca (%)	P (%)
CIAT 13083	12.8a[1]	1.68bc	33.1c	5.49ab	37.5bc	0.78c	0.20e
CIAT 13305	12.8a	1.92abc	35.8a	4.68d	35.7efg	0.84c	0.25bc
CIAT 13108	13.0a	1.77bc	35.5a	5.38abc	35.1fg	1.15ab	0.19e
CIAT 13114	12.1a	1.15c	33.3c	5.04cd	38.5ab	1.57a	0.20e
CIAT 13120	13.0a	2.42ab	33.6c	5.69a	36.2def	0.97ab	0.29a
CIAT 13087	12.6a	1.84bc	35.9a	5.4abc	34.5gh	0.91ab	0.22d
CIAT 3788	12.6a	1.79bc	31.6d	5.19bc	39.2a	0.74c	0.27ab
cv. Reyan No. 27	12.9a	2.81a	36.1a	5.08bcd	33.8h	0.78c	0.27ab
cv. Maquenque	12.6a	2.47ab	31.2d	5.74a	38.4ab	1.1ab	0.24cd
cv. Reyan No. 16	12.8a	1.65bc	34.6b	5.08bcd	36.7cd	1.08ab	0.27ab
Mean	12.7	1.95	34.1	5.28	36.6	0.99	0.24

[1]Within columns, means with different letters are significantly different at P<0.05.

Table 5. Principal components eigenvalues, proportion of variance explained and loadings for each variable.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Eigenvalue	3.749	2.423	1.725	0.859	0.597	0.424	0.157	0.067	0
Proportion of variance	0.37	0.24	0.17	0.09	0.06	0.04	0.02	0.01	0
Cumulative proportion	0.37	0.61	0.79	0.88	0.94	0.98	0.99	1	1
Dry matter	0.381	0.342	-0.248	-0.041	0.317	0.063	-0.089	-0.197	0.355
Height	0.428	0.157	-0.169	0.246	0.060	-0.528	0.262	0.576	-0.025
Survival rate	0.224	0.364	-0.114	0.281	-0.762	0.345	-0.153	0.041	0.008
Crude protein %	0.279	-0.370	0.369	-0.134	-0.130	0.388	0.556	0.247	0.149
Ether extract %	0.452	-0.012	0.253	0.294	0.074	-0.110	0.235	-0.681	-0.050
Crude fiber %	0.136	-0.511	-0.396	0.119	0.018	0.128	-0.215	0.028	0.608
Ash %	-0.035	0.053	0.665	0.446	0.188	0.012	-0.445	0.234	0.253
Nitrogen free extract %	-0.247	0.505	0.178	-0.307	-0.040	-0.053	0.305	-0.011	0.587
Calcium %	-0.311	0.173	-0.253	0.549	0.374	0.464	0.366	0.071	-0.085
Phosphorus %	0.403	0.199	0.044	-0.382	0.340	0.449	-0.254	0.205	-0.250

Table 6. Coordinates of the accessions on the first 4 components (PC1, PC2, PC3 and PC4) and resulting ranking values for 10 *Grona* spp. accessions.

Accession No.	PC1	PC2	PC3	PC4	Ranking value	Ranking order
CIAT 13083	10.73	6.35	-3.07	1.73	15.74	10
CIAT 13305	27.92	23.79	-13.14	16.78	55.35	5
CIAT 13108	21.07	18.77	-9.27	14.59	45.17	7
CIAT 13114	21.63	20.58	-9.74	11.36	43.83	8
CIAT 13120	22.79	16.13	-8.77	10.05	40.21	9
CIAT 13087	26.84	21.42	-12.17	17.07	53.17	6
CIAT 3788	35.04	36.92	-14.57	23.33	80.72	3
cv. Reyan No. 27	47.77	32.42	-21.07	28.88	88.00	2
cv. Maquenque	38.83	42.27	-15.86	28.56	93.80	1
cv. Reyan No. 16	28.74	27.51	-13.09	18.43	61.59	4

Discussion

Forage quality is determined mainly by DM yield and nutrient composition (Kambashi et al. 2014). An important reason why different forage materials show great variations in these parameters is genetic diversity. Previous studies show that *Grona* spp. have a rich genetic diversity in terms of morphology and molecular markers. Fan et al. (2010) used 10 morphological parameters to cluster 23 *Grona* spp. and *Desmodium* spp. accessions into 4 groups, while Liu et al. (2014) divided 37 accessions of *Grona* spp. and *Desmodium* spp. into 6 groups using 16 morphological indicators. Similarly, Luo et al. (2016) used 8 EST-SSR to analyze the genetic diversity and phylogenetic relationship of 16 *Grona* spp. and *Desmodium* spp. accessions, dividing them into 5 groups according to cluster analysis, when the similarity coefficient was 0.73. Wang et al. (2017) used the amplified fragment length polymorphism (AFLP) molecular marker technique to analyze the genetic diversity and phylogenetic relationships of 46 *Grona* spp. and *Desmodium* spp. accessions from 5 local species and 2 introduced species, and a NTSYS cluster analysis divided them into 6 categories. The rich phenotypic diversity among different accessions of *Grona* is obviously a reflection of their genetic differences. Our study showed that yields and nutritional composition differed significantly between the 10 accessions tested, which suggests that there are genetic differences between the accessions.

Plant height had a marked impact on DM yields of the 10 *Grona* spp. accessions. The DM yield decrease from 2016 to 2018 may be a reflection of declining survival rates as some plants from all accessions died during the study. CIAT 13083 had the lowest DM yield in 2018 (568 kg/ha) and had the lowest survival rate (13%). In contrast cv. Maquenque had an excellent survival rate of 93% and equal highest DM yield in 2018 (8,956 kg/ha). The differences between accessions in terms of survival rates were possibly a function of the regular 4-monthly harvest times and accessions with higher survival rates may have higher tolerance of regular harvesting (Mukangango et al. 2020).

The fact that *G. strigillosa* cv. Reyan No. 27 was the tallest accession at 63.1 cm reflects the growth form of this species (semi-erect subshrub vs. the prostrate growth habit of *G. heterocarpa* subsp. *ovalifolia*). The somewhat shrubby habit of *G. strigillosa* was also reflected in the lowest leaf:stem ratio, although differences were not significant.

Interestingly CIAT 13108 had a leaf:stem ratio of 0.98:1, but CP% of forage was not different from that of the other accessions. Despite differences in leaf:stem ratio from 0.70:1 to 0.98:1, no significant differences were detected and no differences in CP concentration.

Crude protein, crude fat and crude fiber are usually used as important indicators of the nutritive value of forages (Lauriault and Kirksey 2004). In this study, average CP, EE and CF concentrations were 12.6, 2.47 and 31.2% for cv. Maquenque and 12.9, 2.81 and 36.1% for cv. Reyan No. 27, respectively. When compared with average CP and ADF concentrations (10.5 and 39.7%, respectively) of *Stylosanthes guianensis* reported by Li et al. (2014), the *Grona* spp. accessions tested have a relatively good nutritive value, especially with respect to CP concentration. Our results also showed that *G. strigillosa* cv. Reyan No. 27 had significantly lower Ca concentration than Control *G. heterocarpa* subsp. *ovalifolia* cv. Reyan No. 16.

Conclusions

Based on this comprehensive evaluation of 10 *Grona* spp. accessions, it appears that *G. heterocarpa* subsp. *ovalifolia* cv. Maquenque and *G. strigillosa* cv. Reyan No. 27 were the most promising accessions in this environment, displaying good DM yields, high CP concentration and good survival rates under regular harvesting. They are possible candidate materials for improving livestock production in tropical regions of China, but further evaluation, e.g. feeding experiments, should be conducted to test acceptability to animals and performance of livestock, especially as forage from *Grona* spp. can contain high levels of tannins.

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References

(Note of the editors: All hyperlinks were verified 15 December 2020.)

Carulla JE; Lascano CE; Klopfenstein T. 2001. Reduction of tannins level in a tropical legume (*Desmodium ovalifolium*) with polyethylene glycol (PEG): Effects on intake and N balance, digestion and absorption by sheep. Archivos Latinoamericanos de Producción Animal 9:17–24. hdl.handle.net/10568/44378

Chen YQ; Zhou HL; Liu GD. 2010. Review on *Desmodium* as feed resources. Pratacultural Science 2010(10):173–178. bit.ly/37oBK4q

Cook BG; Pengelly BC; Schultze-Kraft R; Taylor M; Burkart S; Cardoso Arango JA; González Guzmán JJ; Cox K; Jones C; Peters M. (2020). Tropical Forages: An interactive selection tool. 2nd and revised Edn. CIAT, Cali, Colombia and ILRI, Nairobi, Kenya. www.tropicalforages.info

Fan XY; Liu GD; Yu DG. 2010. Exterior morphological variation of *Desmodium* Desv. and research on its morphological type. Journal of Anhui Agricultural Sciences 2010(19):10051–10053. bit.ly/3gV22i3

Kambashi B; Boudry C; Picron P; Bindelle J. 2014. Forage plants as an alternative feed resource for sustainable pig production in the tropics: A review. Animal 8:1298–1311. doi: 10.1017/S1751731114000561

Larbi A; Lazier J; Ochang J; Addle A. 1995. Dry matter production of thirteen tropical legumes in association with Rhodes grass (*Chloris gayana* cv. Callide) on an acid soil in Ethiopia. Tropical Grasslands 29:88–91. bit.ly/3gV63mD

Larbi A; Awojide AA; Adekunle IO; Ladipo DO; Akinlade JA. 2000. Fodder production responses to pruning height and fodder quality of some trees and shrubs in a forest-savanna transition zone in southwestern Nigeria. Agroforestry Systems 48:157–168. doi: 10.1023/A:1006291413670

Lauriault LM; Kirksey RE. 2004. Yield and nutritive value of irrigated winter cereal forage grass-legume intercrops in the southern high plains, USA. Agronomy Journal 96:352–358. doi: 10.2134/agronj2004.3520

Lee MA. 2018. A global comparison of the nutritive values of forage plants grown in contrasting environments. Journal of Plant Research 131:641–654. doi: 10.1007/s10265-018-1024-y

Li M; Chen YQ; Zi XJ; Zhou HL. 2013. Feeding values assessment of species of *Desmodium*. Chinese Journal of Grassland 35(6):53–57.

Li M; Zi XJ; Zhou HL; Hou GY; Cai YM. 2014. Chemical composition and *in vitro* digestibility of *Stylosanthes guianensis* varieties. Grassland Science 60:125–129. doi: 10.1111/grs.12046

Liu MM; Yan LL; Zhang Y; Liao L; Bai CJ; Wang ZY. 2014. Morphological diversity of *Desmodium* Desv. Chinese Journal of Tropical Crops 35:1897–1904.

Liu YM; Zhang XZ; Tran H; Shan L; Kim J; Childs K; Ervin EH; Frazier T; Zhao BY. 2015. Assessment of drought tolerance of 49 switchgrass (*Panicum virgatum*) genotypes using physiological and morphological parameters. Biotechnology for Biofuels 8:152. doi: 10.1186/s13068-015-0342-8

Luo XY; Zhang RH; Jia QL; Wang WQ; Bai CJ; Ding XP. 2016. Analysis and application of transferable EST-SSR markers from *Stylosanthes* to *Desmodium*. Pratacultural Science 2016(11):2237–2247. bit.ly/3raTBUH

Mukangango M; Nduwamungu J; Naramabuye FX; Nyberg G; Dahlin AS. 2020. Biomass production and nutrient content of three agroforestry tree species growing on an acid

Anthropic Ferralsol under recurrent harvesting at different cutting heights. Agroforestry Systems 94:857–867. doi: 10.1007/s10457-019-00455-8

Ohashi H; Ohashi K. 2018. *Grona*, a genus separated from *Desmodium* (Leguminosae tribe Desmodieae). Journal of Japanese Botany 93(2):104–120. bit.ly/38pHPgD

Owens FN; Sapienza DA; Hassen AT. 2010. Effect of nutrient composition of feeds on digestibility of organic matter by cattle: A review. Journal of Animal Science 88:151–169. doi: 10.2527/jas.2009-2559

Schultze-Kraft R; Rao IM; Peters M; Clements RJ; Bai CJ; Liu GD. 2018. Tropical forage legumes for environmental benefits: An overview. Tropical Grasslands-Forrajes Tropicales 6:1–14. doi: 10.17138/TGFT(6)1-14

Thomas D; Schultze-Kraft R. 1990. Evaluation of five shrubby legumes in comparison with *Centrosema acutifolium*, Carimagua, Colombia. Tropical Grasslands 24:87–92. bit.ly/388cLBD

Wang CM; Ren J; Lan PX; Ma XL; Li YC; Bai CJ; Xu L. 2017. Genetic Diversity of *Desmodium* Desv. on AFLP analysis. Chinese Journal of Tropical Crops 38:521–528.

Zi XJ; Li M; Zhang YG; Wang DF; Zhou HL. 2018. Research progress on roughage resources in tropical China. Acta Ecologiae Animalis Domastici 2018(1):80–83. bit.ly/3gQxzBM

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