Scientific Paper

Dry matter distribution, leaf area and nutritional quality in two genotypes of *Clitoria ternatea* L.

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Abstract

Objective: To evaluate dry matter distribution, leaf area and nutritional quality in two *Clitoria ternatea* L. genotypes.

Materials and Methods: The plants, 30 days old, were established in the field in a vertical trellis training system. A complete randomized experimental design was applied, with thirty replications per genotype and one plant as experimental unit. Ninety days after the experiment was established, growth and nutritional quality variables were evaluated in the blue and white genotypes of *C. ternatea*.

Results: The genotype affected ($p < 0,05$) the growth and nutritional quality variables, except for the percentages of dry matter, ash, crude fiber, and total digestible nutrients. The blue genotype showed higher dry matter content per plant, leaf/stem ratio, leaf area, crude protein and ethereal extract percentages. The white genotype showed higher percentages of nitrogen-free extract, neutral detergent fiber, acid detergent fiber and acid detergent lignin. Both genotypes had high percentages of dry matter, crude protein and total digestible nutrients, as well as excellent relative forage value. Dry matter intake potential was excellent in the blue genotype, and high in the white genotype.

Conclusions: Growth and yield of the genotypes were different; while dry matter distribution was similar, mainly in the leaves. The blue genotype stood out for its higher vegetative growth (leaves, branches and stem). The white genotype stood out for fruit and flower production. The bromatological composition and nutritional quality of both genotypes were excellent.

Keywords: growth, forage legumes, nutritiva value.

Introduction

Tropical cattle husbandry is based on the grazing of grass monocultures. Grasses and forages constitute the most important fraction of the cattle diet, as well as the most economical feed source in the feeding ration of ruminants in general (Suárez *et al*., 2012; Espinoza-Coronel *et al*., 2020). This is due to the fact that they stimulate rumination and salivation, which allows maintaining the appropriate pH and balanced ruminal flora. However, in the tropics, the production and quality of pastures and forages are characterized by their irregularity, which is due to the species, edaphoclimatic and agroecological conditions, crop management, among other factors that influence the digestibility and nutrient content of forage (Castrejón-Pineda *et al*., 2017; Sosa-Montes *et al*., 2020). In Venezuela, most milk or meat production, and both, is obtained in semi-extensive and extensive systems, from pastures and forages (mainly grasses). Therefore, high-cost balanced supplements are used to cover the nutritional requirements of the animals (Suárez *et al*., 2012).

This situation promotes the search for new feeding strategies, with the inclusion of plant genetic resources of higher nutritional value, adapted to the agroecological conditions of the area. The forage legume *Clitoria ternatea* L. (Asian pigeonwings), because of its wide range of adaptation, production capacity and nutritional value, is among such resources (Castrejón-Pineda *et al*., 2017; Shamnad, 2019). Its benefits contribute to improve the quality of the animal's diet, satisfy the demand for feedstuffs in the dry season and stimulate the application of sustainable animal production techniques, compatible with the environment and natural resources.

Compared with grasses, most legumes have higher crude protein (CP) and dry matter (DM) digestibility, which stimulates higher intake by cattle. This suggests their inclusion in grass-based diets, with the purpose of covering the nutritional

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requirements of grazing animals (Lagunes-Rivera *et al*., 2019; Castro-Rincón *et al*., 2021).

Several studies point out the benefits of *C. ternatea*, in terms of DM yield and nutritional value (Shamnad 2019; Sosa-Montes *et al*., 2020). Yields of 30 t/ha/year have been recorded in Brazil and Mexico, grown with irrigation (Abreu *et al*., 2014; Castrejón-Pineda *et al*., 2017). For such reasons, the objective of this study was to evaluate DM distribution, leaf area and nutritional quality in two *C. ternatea* genotypes (blue and white).

Materials and Methods

Location of the experiment. The experiment was carried out at the university nursery of the School of Agronomy of the University of Zulia (LUZ, for its initials in Spanish), Zulia State, Venezuela. The facility is located at 10º41'12" North latitude and 71º38'05" West longitude, at an altitude of 25 m.a.s.l., in an ecological zone of very dry tropical forest.

Edaphoclimatic conditions. The average annual rainfall was 500 to 600 mm, temperature was 29 ºC, relative humidity 79 % and evapotranspiration (ET) was 2 500 mm. During the experiment, the average daily temperature was 29,3 °C (minimum 24,1 °C; maximum 35,0 °C); while total and daily rainfall were 423 and 4,7 mm, respectively. The soil corresponded to a Typic haplargids, fine loam, of low natural fertility, low moisture retention and pH between 6,26 and 4,95 (Suárez *et al*., 2012).

Experimental design. Two treatments were evaluated, corresponding to two *C. ternatea* genotypes (blue and white). A complete randomized experimental design was established, with thirty repetitions per genotype, and one plant as experimental unit.

Experimental procedure. The plant material was obtained from *C. ternatea* seeds (blue and white genotypes), stored at 10 ºC in the plant propagation laboratory of the School of Agronomy, LUZ. The plants, 30 days old, were established in the field, in a vertical trellis conduction system, according to Suárez *et al.* (2012). Six rows, 5 m long, 1 m apart, were used, each with a wire line (18 gauge) at a distance of 0,40 m from the ground. Ten holes were made in each row, 0,50 m apart, to which 1 kg of sand and bovine manure (1:1 ratio) were added, previously washed with water, according to Jiménez *et al.* (2017), without the application of fungicide. Then, the two *C. ternatea* genotypes were planted, for a total of 30 plants each.

Irrigation and weed control were performed manually, every three days. Sanitary inspections were carried out every two weeks. Fertilization with cattle manure available in the region (1 kg/plant) was done once a month. A cover of dry plant material was also placed between the rows of plants to reduce the incidence of weeds and to protect and maintain soil moisture (Suárez *et al*., 2012). The experiment was conducted under full sun exposure.

Study variables. Ninety days after the experiment was established, twelve plants per genotype were randomly selected, without considering those at the end of each row (Suárez *et al*., 2012) for the following analyses:

- *DM distribution*. The DM content per plant (whole aerial part) and its components were determined: leaves (leaflets and petioles), branches and stem, flower buds, flowers and fruits. In addition, the leaf/stem ratio was estimated. The DM per plant was obtained after drying the aerial part in an oven at 65 °C for 48 h. The DM per plant was obtained after drying the aerial part in a stove at 65 °C for 48 h. Afterwards, the weight of the organs was weighed separately. Then, the above-mentioned organs and structures were weighed separately. The leaf/stem ratio was calculated by the ratio of the DM of the leaves to that of the branches and stem.
- *Leaf area per plant*. An optical planimeter (Delta T-Devices Mkm^2), six plants per genotype and a sample of twenty leaves per plant were used to measure leaf area. Only the leaflets of the leaves were used for the reading. Leaf area per plant was calculated by multiplying the specific area of the leaf sample by the MS of leaves per plant. Leaf sample specific area is the ratio of leaf area to leaf sample DM.
- *Nutritional quality*. After drying the aerial part of each plant at 65 °C for 48 h, the material (meal) was ground and stored in plastic bags of 1,0 kg capacity, hermetically sealed and identified until their analysis. DM, ash (Cz), crude protein (CP), ethereal extract (EE), crude fiber (CF), nitrogen-free extract (NFE), total digestible nutrients (TDN) (AOAC 1995); neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) (Van Soest *et al*., 1991) were determined. DM intake potential and relative forage value were calculated according to Linn and Martin (1989).

Statistical analysis. Variance analysis was performed using the GLM procedure of the Statistical Analysis System program. When significant differences were detected, Tukey's test was used to compare means (SAS, 2012).

Results and Discussion

The *C. ternatea* genotype significantly affected ($p < 0,05$) the DM content per plant and that of the components: leaves, leaflets, petioles, branches and stem, flower buds, flowers and fruits. Likewise, it influenced leaf/stem ratio and leaf area (Table 1). For these variables, the blue genotype recorded the highest values, except for DM of flower buds and fruits. The DM values per plant and leaf area in this study far exceeded those reported in other research.

Deminicis *et al.* (2018) reported 2,5 g/plant at 120 days. Luna-Murillo *et al.* (2019) reported 18,8 g/plant at 60 days of cultivation. Meanwhile, Mahfouz *et al.* (2020) referred 5,9 g/plant and 980 cm^2 60 days after transplanting. Morales-Guzmán *et al.* (2020) recorded 0,07 g/plant and 245 cm^2, 30 days after establishment.

DM yields, according to the density of 20 000 plants/ha used in the experiment (1 m spacing between rows and 0,5 m between plants), were equivalent to 1,230 and 0,882 t/ha in the blue and white genotypes, respectively. This result contrasts with a study conducted by Villanueva-Avalos *et al.* (2004), who reported 1,6-2,5 t/ha yield under irrigated conditions. Meanwhile, Mahfouz *et al.* (2020) recorded 1,3 t/ha 60 days after transplanting. The yield of the blue genotype exceeded that indicated by Jiménez-Guillén *et al.* (2013), who reported 0,860 t/ha DM in a grass-legume association (three rows of signal grass, two rows of *C. ternatea*), the latter sown in a run-jet in furrows spaced 0,7 m apart. In this study, the yields of the white genotype corresponded to those of the last authors. However, they did not exceed one ton of DM per hectare.

In DM distribution, the aerial part of the plant of the blue genotype consisted mainly of leaves (52,9 %), then branches and stem (36,4 %) and, to a lesser extent, fruits (5,5 %), flowers (4,7 %) and flower buds (0,6 %). The white genotype showed a similar performance to the blue genotype in the components leaves (48,2 %) and branches and stem (33,9 %). However, in fruits (10,8 %), flowers (6,0 %) and flower buds (1,1 %), the white genotype showed the highest percentages. These results differ from those reported by Jiménez-Guillén *et al.* (2013), who in *C. ternatea* variety Tehuana, associated with *Brachiaria decumbens* Stapf., found higher proportion of stems (50 %), followed by leaves (35-39 %) and fruits (10-12 %). DM per plant of both genotypes was basically represented by leaves, branches and stems: 89,2 % in the blue genotype and 82,1 % in the white one.

When DM, expressed as percentage, was analyzed, it was found that the genotype significantly affected ($p < 0,05$) DM percentage, being higher in the white genotype. This is due to the fact that this genotype for the 90 days of field cultivation showed lower foliage, higher quantity of fruits with seeds (table 1) and lower moisture content (71,7 %) compared with the blue genotype, which showed higher vigor and moisture (74,3 %). The higher number of seed-bearing fruits implies a higher demand for photoassimilates. Of them, from other parts of the plant, both structures constitute destination organs

Table 1. Dry matter content, leaf/stem ratio and leaf area in two genotypes of the forage legume *C. ternatea*.

Variable	Blue genotype	White genotype	SE ±	P - Value
DM, g				
Plant	61,5	44,1	4,320	0,013
Leaf	32,5	21,2	2,061	0,010
Leaflets	29,2	18,8	1,883	0,013
Petiole	3,2	2,4	0,183	0,021
Branches and stem	22,4	15,0	1,694	0,032
Flower buds	0,4	0,5	0,035	0,022
Flowers	2,9	2,7	0,145	0,021
Fruits	3,4	4,8	0,738	0,017
DM, %	25,8	28,3	0,520	0,012
Leaf-stem ratio	1,5	1,42	0,034	0,030
Leaf area, cm^2	7 593,0	6 712,67	264,052	0,018

or irreversible importers, which consume and accumulate photoassimilates - transported via phloem - for metabolism, growth and storage as reserve (Taiz *et al*., 2015).

The DM percentage of the white genotype was similar to that indicated at 120 days (29,6 %) by Deminicis *et al*. (2018), although the value of the blue one was below the report. Similarly, the percentages obtained in the two genotypes (table 1) exceeded those reported in other works. Abreu *et al*. (2014) in seed production, in 90-day-old plants, obtained 19,7 %. Macías-Pettao *et al*. (2021) reported 22,1 % at 90 days after transplanting. These differences can be ascribed to experimental, edaphoclimatic (rainfall) and management (organic fertilization with cattle manure) conditions.

Espinoza-Coronel *et al*. (2020) found that the application of commercial biological fertilizers, which include beneficial microorganisms, organic acids, amino acids, phytohormones and humic acids, endomycorrhizal fungi, and other nutrients (N, P, K and OM), favored fresh forage production in *C. ternatea*.

Regarding rainfall, Scull-Rodríguez *et al*. (2021) found higher DM percentages in *Spathodea campanulata* (*Bignoniaceae*) during the rainy season compared with the dry season.

Even when the two genotypes showed differences in leaf/stem ratio, in favor of the blue genotype, their values were high (table 1), as they contrast with the report by Villanueva-Avalos *et al*. (2004) for 84-day-old plants (0,97). This proved that the growth of the leaves with respect to the stem was higher.

According to Jiménez *et al*. (2017), the leaf/stem ratio is a factor dependent on the distribution of photoassimilates, which could be influenced by environmental stimuli and the vegetative capacity of the plant to modify biomass distribution in the different organs, and thus tolerate adverse conditions. Leaves are the exchange surface between the plant and the environment, as well as the place where photosynthesis occurs. The intensity of these exchanges and photosynthetic activity has a direct relationship with leaf area: the greater the leaf area, the higher the increase in photosynthetic activity, which leads to the production of photoassimilates (Taiz *et al*., 2015; Jiménez *et al*., 2017).

The higher amount of leaves observed in both genotypes, in terms of DM, leaf/stem ratio and leaf area, was associated with the planting frame used, which provided greater spacing between plants, and reduced competition for light, moisture and soil nutrients, which allowed the expression of biomass production capacity per plant. In this regard, Paniagua *et al*. (2020) and Jácome-Gómez and Ramírez-Villalobos (2021) pointed out that, under conditions of lower planting density and full solar exposure, respectively, plants have a higher source of energy and information for photosynthesis and carbohydrate accumulation and, therefore, higher growth rate and biomass production.

Among other factors that could have favored the development of the two *C. ternatea* genotypes were irrigation, rainfall (423 mm, distributed during the 90 days of cultivation), and organic fertilization with cattle manure. Taiz *et al*. (2015) and Jácome-Gómez and Ramírez-Villalobos (2021) indicated that environmental and crop management conditions exert their effect through changes in organ differentiation and elongation, as well as in the uptake and distribution of resources among the different plant organs.

The application of cattle manure also contributed to the response of the studied genotypes, due to its physicochemical properties and its possible contribution to plant nutrition. In research conducted on *C. ternatea* (Suárez *et al*., 2012) and other species, it was reported that manure increases leaf area and aerial biomass, among other variables (Jiménez *et al*., 2017; Pírela-Almarza *et al*., 2018). In turn, it can improve soil structure by favoring aeration and moisture retention; in addition, it represents a simple, practical and environmentalist fertilization alternative in agronomic management (Jiménez *et al*., 2017).

Regarding the analyses of meal nutritional quality (table 2), no significant differences were found between genotypes for the DM percentage variable. The value obtained in both genotypes was high, and is in agreement with that reported by Suárez *et al*. (2012) (89,5 and 90,3 %). These results are also in correspondence with the DM content reported by Villanueva-Avalos *et al*. (2004) for the different phenological stages of the plant: vegetative (89,0 % - 42 days), flowering (90,4 % - 56 days), pod or legume formation (90,7 % - 70 days) and seed production (91,1 % - 84 days).

The genotypes did not show significant differences for the percentage of Cz, mineral fraction. The values of both genotypes were high, and differed fr om those recorded in other works. Abreu *et al*. (2014) obtained lower Cz percentage at 70 and 90 days (6,7 % and 6,1 %, respectively),

Table 2. Nutritional quality of blue and white genotypes of the forage legume *C. ternatea*.

Variable	Blue genotype	White genotype	SE ±	P - Value
DM percentage	89,2	91,0	0,283	0,187
Cz percentage	9,7	9,7	0,159	0,341
CP percentage	31,9	29,4	0,256	0,012
EE percentage	5,1	4,2	0,108	0,024
CF percentage	19,2	20,0	0,552	0,219
NFE percentage	33,8	36,5	0,662	0,030
NDF percentage	35,1	40,8	0,134	0,015
ADF percentage	26,3	28,1	0,322	0,023
ADL percentage	5,4	7,1	0,276	0,040
TDN percentage	71,8	71,4	0,137	0,289
DM intake percentage	3,5	3,0	0,053	0,035
Forage relative value	191,8	163,5	2,339	0,027

DM: dry matter, Cz: ash, CP: crude protein, EE: ether extract, CF: crude fiber, NFE: nitrogen free extract, NDF: neutral detergent fiber, ADF: acid detergent fiber: ADL: acid detergent lignin, TDN: total digestible nutrients

while Villanueva-Avalos *et al*. (2004) reported 7,2 % at 84 days and Sosa-Montes *et al*. (2020) 6.8 % at 30 days. In seeds of *C. ternatea*, Espinoza-Coronel *et al*. (2020) recorded 3,4 % Cz. However, the percentage of Cz obtained in this research is in the range reported for forage grasses (7-13 %) (INTAGRI, 2018).

For CP percentage, the *C. ternatea* genotypes showed significant differences ($p < 0.05$). The blue genotype had the highest percentage, a result that coincides with the values (32,1 and 29,6 %) indicated by Suárez *et al*. (2012). Both genotypes showed high CP contents and were above the 22,7 % indicated by Sosa-Montes *et al*. (2020) in 30-day-old plants. These results contrast with the CP percentages reported in other studies. Abreu *et al*. (2014) determined 24,1 % CP at 90 days, and Deminicis *et al*. (2018) 13,6 % at 120 days. Macías-Pettao *et al*. (2021) reported 22,2 % at 90 days and Mahfouz *et al*. (2020) 20,1 % 60 days after transplanting.

The CP percentages of both genotypes at 90 days of cultivation far exceeded the report by Jusoh and Nur (2018) in *C. ternatea* pods (25,5 %). Similarly, the results of both genotypes exceeded those indicated for trees and shrubs (Cabrera-Núñez *et al*., 2019) and other forage legumes (Alatorre-Hernández *et al*., 2018 and Jusoh and Nur, 2018) used in cattle and sheep-goat feeding. The high percentage in both genotypes reflects the high nutritional quality potentially utilizable by the animal in its metabolic processes for weight gain or milk production, and for both. However, the high CP values obtained in the two genotypes can also be associated with the phenological stage of the plants: reproductive, due to the presence of fruits (table 1) with seeds. In the latter, Espinoza-Coronel *et al*. (2020) determined 40,8 % (dry basis).

The *C. ternatea* genotype had significant influence ($p < 0,05$) on the EE percentage. The highest content was reached by the blue genotype, and is similar to the 4,9 % reported by Macías-Pettao *et al*. (2021) 90 days after transplanting. The percentages of both genotypes were considered high compared with the works conducted by Sosa-Montes *et al*. (2020), who obtained 3,1 % at 30 days of age. They were also high with regards to the 3,5 % reported by Villanueva-Avalos *et al*. (2004). However, they were different (9,2 and 6,4 % at 28 and 35 days of regrowth, respectively) from those reported by Castrejón-Pineda *et al*. (2017). The values obtained here for the two genotypes are in the range of the EE percentage (3-8 %) indicated for forage grasses (INTAGRI, 2018).

Regarding the CF percentage, the genotypes did not show significant differences. The values for both were low compared with other studies. Villanueva-Avalos *et al*. (2004) reported 38,3 % at 84 days. Sosa-Montes *et al*. (2020) determined higher percentages than 40 % in 30-day-old plants. Mahfouz *et al*. (2020) and Macias *et al*. (2021) obtained 19,2 and 29,6 % at 60 and 90 days after transplanting, respectively.

Regarding the NFE percentage, the two genotypes showed differences (p < 0,05), with the highest value in the white one. The percentages of both were above those recorded by Sosa-Montes *et al.* (2020) in 30-day-old plants (26,9 %) and by Villanueva-Avalos *et al*. (2004) (32,3 %). In addition, they are similar to the value reported by Macías-Pettao *et al*. (2021) 90 days after transplanting (35,2 %).

Genotype significantly affected (p < 0,05) the NDF percentage. The highest value was reached by the white genotype, which was close to that indicated by Abreu *et al*. (2014) at 90 days (42,3 %). However, the results do not correspond with other studies that have obtained higher percentages of NDF: 46,5 % at 30 days (Sosa-Montes *et al*., 2020); 54,2 % at 84 days (Villanueva-Avalos *et al*., 2004) and 66,8 % at 120 days (Deminicis *et al*., 2018).

According to the quality standards for forages, described by Linn and Martin (1989), the NDF percentage in the blue genotype was located in the category of less than 40 % (excellent quality) and that of the white genotype, between 40 and 46 % (high quality).

NDF is constituted by cellulose, hemicellulose and lignin, and represents the total insoluble fiber of the forage, for which the species with low NDF content (<41 %), such as the two evaluated genotypes, have higher potential for intake by the animal and, therefore, are generally of higher quality and economic value.

Regarding the ADF percentage, the least digestible fraction of the forage, the genotype showed significant differences (p < 0,05). The highest value was recorded by the white genotype. The percentages of both genotypes were low and different from those reported by Villanueva-Avalos *et al*. (2004) at 84 days (46,9 %).

Higher ADF percentages have been reported in other studies. Sosa-Montes *et al*. (2020) reported 38,7 % at 30 days. Meanwhile, Castrejón-Pineda *et al*. (2017) reported 31,1 and 34,5 % at 28 and 35 days of regrowth. Deminicis *et al*. (2018) reported 53,8 % at 120 days. However, the ADF percentage obtained in the two genotypes is in the parameter indicated by Linn and Martin (1989) for the category lower than 31 % (excellent quality), when the plants were 90 days old in the field.

The genotypes showed differences (p < 0,05) in the ADL percentage. The highest value was found in the white genotype, close to that reported by Abreu *et al.* (2014) with 7,6 %, at 90 days. However, it differed notably from that reported by Villanueva-Avalos *et al.* (2004) at 84 days (16,1 %) and by Sosa-Montes *et al*. (2020) at 30 (8,8 %). The ADL percentage of the blue genotype was slightly higher than 5 %; while that of the white genotype was between 5 and 10 %. This classifies them as having high and moderate nutritional value, respectively, according to Vargas (2002). Even when the two genotypes were 90 days old in the field, their fiber and lignin contents were within acceptable limits. In adult plants, these parameters tend to be higher, so the digestibility and potential intake of forages are reduced. For every one-percentage unit increase in lignin, digestible DM decreases by three or four percentage units (Linn and Martin 1989).

No significant differences were found for the TDN percentage due to genotype effect. The values of the two genotypes were found in the category higher than 65 % (excellent quality) described by Linn and Martin (1989). In this regard, other research on *C. ternatea* has shown 68,9 and 69,9 % *in vitro* and *in situ* DM digestibility, in 30-day-old plants (Sosa-Montes *et al*., 2020) and 61,1 % *in vitro* digestibility, at 35 days of regrowth (Castrejón-Pineda *et al*., 2017).

The genotypes showed significant differences (p < 0,05) in DM intake potential and relative forage value in these variables. The blue genotype recorded the highest value. According to standards suggested by Linn and Martin (1989), DM intake potential was of excellent quality in the blue genotype (higher than 3), and high in the white genotype (3-2,6). The relative forage value in both genotypes was of excellent nutritional quality (higher than 151).

When considering globally the results obtained in the nutritional quality of both genotypes, the blue genotype obtained the highest values of CP, EE, DM intake potential and relative forage value. The white genotype achieved the highest percentages of NFE, NDF, ADF and ADL. Despite these differences, the two genotypes showed high DM, CF and TDN percentages, as well as acceptable values of NDF, ADF, DM intake potential and relative forage value. These parameters demonstrated the nutritional quality and energy value of *C. ternatea*, excellent as a feed supplement for cattle.

These good results can be ascribed to the type of plant used (herbaceous legume), the phenological stage, the ecological management with manure and the presence of rainfall during the experiment, which could have contributed to the plants expressing their maximum development potential, even on a poor soil with low biological activity and presence of argillic, which corresponds to the report by Suárez *et al*. (2012). In grasses associated with the legume *Lotus uliginosus* Schkur, Castro-Rincón *et al*. (2021) confirmed the favorable effect of high rainfall on CP content, which has also been corroborated in the species *S. campanulata* in a study by Scull-Rodríguez *et al*. (2021).

Conclusions

The growth of blue and white genotypes, in terms of DM per plant, leaf/stem ratio and leaf area, was different. However, the DM distribution and leaf/stem ratio in both genotypes showed similar performance, consisting mainly of leaves. The blue genotype stood out for its higher vegetative growth, and the white genotype for fruit and flower production.

In both genotypes, nutritional quality was excellent. This proved the potential, in the short term, of this forage legume in agricultural production systems in Venezuela, due to its excellent bromatological composition.

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Conflict of interest

The authors declare that there is no conflict of interest among them.

Authors' contribution

- Maribel Ramírez-Villalobos. Research design and development, data processing, analysis and interpretation, manuscript revision, editing and writing.
- Aly Urdaneta Urdaneta-Fernández. Research development, data processing and manuscript writing.
- Hallely-Suarez. Research development, data processing and manuscript writing.
- Wilmer Mercado. Research development, data processing and manuscript writing.
- Jesús Manuel Iglesias-Gómez. Technical revision and manuscript writing.

Bibliographic references

Abreu, M. L. C.; Vieira, R. A. M.; Rocha, N. S.; Araujo, R. P.; Glória, L. S.; Fernandes, A. M. *et al. Clitoria ternatea* L. as a potential high quality forage legume. *Asian Australas. J. Anim. Sci.* 27 (2):169-178, 2014. DOI: http://dx.doi.org/10.5713/ajas.2013.13343.

Alatorre-Hernández, A.; Guerrero-Rodríguez, J. de D.; Olvera-Hernández, J. I.; Aceves-Ruíz, E.; Vaquera-Huerta, H. & Vargas-López, S. Productividad, características fisicoquímicas y digestibilidad *in vitro* de leguminosas forrajeras en trópico seco de México. *Rev. mex. de cienc. pecuarias*. 9 (2):296-315, 2018. DOI: https://doi.org/10.22319/rmcp.v9i2.4361.

AOAC. *Official methods of analysis*. Washington: Association of Official Analytical Chemists, 1995.

Cabrera-Núñez, Amalia; Lammoglia-Villagomez, M.; Alarcón-Pulido, Sara; Martínez-Sánchez, C.; Rojas-Ronquillo, Rebeca & Velázquez-Jiménez, S. Árboles y arbustos forrajeros utilizados para la alimentación de ganado bovino en el norte de Veracruz, México. *Abanico vet*. 9:1-12, 2019. DOI: https://doi.org/10.21929/abavet2019.913.

Castrejón-Pineda, F. A.; Corona-Gochi, L.; Rosiles-Martínez, R.; Martínez-Pérez, Paulina; Lorenzana-Moreno, Angélica Valeria; Arzate-Vázquez, L. G. *et al. Características nutrimentales de gramíneas, leguminosas y algunas arbóreas forrajeras del trópico mexicano: fracciones de proteína (A, B1, B2, B3 y C), carbohidratos y digestibilidad in vitro*. México: Universidad Nacional Autónoma de México. https://papimes.fmvz.unam.mx/proyectos/manuales_nutricion/Manual_ Fracciones.pdf, 2017.

Castro-Rincón, E.; Carulla-Fornaguera, J. E. & Cárdenas-Rocha, E. A. Calidad nutricional de cinco gramíneas asociadas a *Lotus uliginosus* Schkuhr en el trópico alto de Colombia. *Pastos y Forrajes*. 44:eE07. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942021000100007&lng= es&tlng=es, 2021.

Deminicis, B. B.; Vieira, H. D.; Deminicis, Renata G. da S.; Lima, E. da S.; Valente, T. N. P.; Amorim, Mariá M. *et al.* Produção de matéria seca, composição química e radicular de leguminosas forrageiras tropicais semeadas por fezes bovinas. *Sci. Agrar. Parana*. 17 (3):282-287. https://e-revista.unioeste.br/index.php/scientiaagraria/article/view/19610/13434, 2018.

Espinoza-Coronel, A. L.; Franco-Ochoa, D. A.; Fajardo-Espinoza, P. G.; Real-Goya, G. E. & Pincay-Ganchozo, R. A. Crecimiento y rendimiento de *Clitoria ternatea* con la aplicación de fertilizantes biológicos. *Nexo Agropecu*. 8 (2):43-51. https://revistas.unc.edu.ar/index.php/ nexoagro/article/view/30257, 2020.

INTAGRI. *Valor nutritivo de los forrajes y su relación con la nutrición proteica de rumiantes*. México: INTAGRI. Serie Ganadería, No. 05 https://www.intagri.com/articulos/ganaderia/valor-nutritivo-de-los-forrajes-y-su-relacion-con-la-nutricion-proteica, 2018.

Jácome-Gómez, L. R. & Ramírez-Villalobos, Maribel del C. Incidencia del sombreado, biorreguladores y bioestimulante en el desarrollo y rendimiento del pasto Mombaza (*Panicum maximum* Jacq.). *Rev. Fac. Agron (LUZ).* 38 (2):382-403. https://www.produccioncientificaluz.org/index.php/agronomia/ article/view/35505, 2021.

Jiménez, I. J.; Ramírez, Maribel; Petit, Belkis; Colmenares, Ciolys & Parra, I. Efecto de hongos micorrízicos arbusculares y estiércol de bovino en el crecimiento inicial y pigmentación en *Capsicum frutescens* L. *Bioagro*. 29 (2):137-144. http://ve.scielo.org/scielo.php? script=sci_arttext&pid=S1316-33612017000200008&lng=es&tlng=es, 2017.

Jiménez-Guillén, R.; Quero-Carrillo, A. R.; Pérez-Pérez, J.; Martínez-Hernández, P. A.; Hernández-Garay, A.; Tovar-Salinas, J. L. *et al.* Composición de la biomasa en una asociación de pasto señal con clitoria pastoreada a diferentes asignaciones de forraje. *Rev. mex. de cienc. pecuarias*. 4 (2):185-199. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-11242013000200005&lng=es, 2013.

Jusoh, S. & Nur_Hafifah, C. S. Nutritive value, palatability and selectivity of 10 different legume herbages by rabbits. *Mal. J. Anim. Sci*. 21 (2):69-75. http://mjas.my/mjas-v2/ rf/pages/journal/v21i2/7-NutritiveShokri.pdf, 2018.

Lagunes-Rivera, S. A.; Guerrero-Rodríguez, J. de D.; Hernández-Vélez, J. O.; Ramírez-González, J. de J. M.; García-Bonilla, Dulce V. & Alatorre-Hernández, A. Rendimiento de materia seca y valor nutritivo de cuatro leguminosas herbáceas en la zona tropical de Hueytamalco, Puebla, México. *Rev. mex. de cienc. pecuarias*. 10 (4):1042-1053, 2019. DOI: https://doi.org/10.22319/rmcp.v10i4.4660.

Linn, J. & Martin, N. *Forage quality tests and interpretation*. Extension Service Publication AG-F0-2637. St. Paul, USA: University of Minnesota Agriculture. https://conservancy.umn.edu/bitstream/handle/11299/207442/MN2500_AGFO_2637_revised1989.pdf?sequence=1&isAllowed=y, 1989.

Luna-Murillo, R.; Espinoza-Coronel, Ana; Morales-Torres, Marioxy; Espinosa-Cunuhay, K.; Franco-Ochoa, D. & Zambrano-Montes, S. A. Rizosfera de las asociaciones de gramíneas y leguminosas de interés ganadero. *Revista Multidisciplinaria*. 1 (1). https://dateh.es/index.php/main/article/view/35, 2019.

Macías-Pettao, R. K.; Tapia-Ramírez, C. S.; Pincay-Ganchozo, R. A. & Álvarez-Perdomo, G. R. Respuesta agronómica y composición química de *Clitoria ternatea* en el subtrópico. *Nexo Agropecu.* 9 (2):13-18. https://revistas.unc.edu.ar/index.php/nexoagro/article/view/35048, 2021.

Mahfouz, H.; Megawer, E. A.; Maher, A. & Shaaban, A. Integrated effect of planting dates and irrigation regimes on morpho-physiological response, forage yield and quality, and water use efficiency of clitoria (*Clitoria ternatea* L.) in arid region. *Arch. Agron. Soil Sci.* 66 (2):152-167, 2020. DOI: https://doi.org/10.1080/03650340.2019.1605165.

Morales-Guzmán, G.; Alarcón, A.; Ferrera-Cerrato, R.; Rivera-Cruz, María del C.; Torres-Bustillos, L. G. & Mendoza-López, Ma. Remedios. Efecto de bacterias emulsificantes en la atenuación de la fitotoxicidad de suelos contaminados con petróleo intemperizado. *Rev. biol. trop.* 68 (2):692-703, DOI: http://dx.doi.org/10.15517/rbt.v68i2.39327.

Paniagua, L.; Arias, L. Alpízar, A.; Castillo, M.; Camacho, M.; Padilla, J. & Campos, M. Efecto de la densidad de siembra y edad de rebrote en la producción y composición bromatológica de *Tithonia diversifolia* (Hemsl.) A. Gray. *Pastos y Forrajes.* 43 (4):275-283. http://scielo.sld.cu/scielo.php? script=sci_arttext&pid=S0864-03942020000400275&lng=es&tlng=es, 2020.

Pírela-Almarza, Á. Y.; Aguirre-Serpa, O. E.; Ramírez-Villalobos, Maribel del C.; Petit, Belkis; Bracho, Belkys & Parra, I. Efecto de hongos micorrízicos arbusculares y del estiércol de ovino en el desarrollo inicial de la lechosa (*Carica papaya* L.) var. Maradol roja. *Bioagro*. 30 (1):79-86. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1316-33612018000100008&lng=es&tlng=es, 2018.

SAS. *SAS/STAT User's guide, Release 9.1.3*. Cary, USA: SAS Institute Inc, 2012.

Scull-Rodríguez, Idania; Elías-Iglesias, A.; Pérez-Fuentes, D.; Savón-Valdés, Lourdes L.; Herrera-Villafranca, Magaly & Pompa-Castillo, Natacha. Efecto de la época del año en los componentes nutricionales de *Spathodea campanulata* Beauv. *Pastos y Forrajes*. 44:eE09. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942021000100009&lng=es&tlng=es, 2021.

Shamnad, J. Mineral and nutritional potential of *Clitoria ternatea* L. variants as forage. *J. Trop. Agric*. 57 (2):163-166. http://jtropag.kau.in/index.php/ojs2/article/view/867, 2019.

Sosa-Montes, E.; Alejos-de la Fuente, J. I.; Pro-Martínez, A.; González-Cerón, F.; Enríquez-Quiroz, J. F. & Torres-Cardona, María G. Composición química y digestibilidad de cuatro leguminosas tropicales mexicanas. *Rev. Mex. Cienc. Agríc*. 11 (spe24):211-220, 2020. DOI: https://doi.org/10.29312/remexca.v0i24.2371.

Suárez, Hallely; Mercado, W.; Ramírez, Maribel; Bracho, Belkys; Rivero, J. & García, D. E. Caracterización morfoagronómica y evaluación del contenido proteínico en dos genotipos de *Clitoria ternatea* L. cultivados en un sistema de espalderas. *Pastos y Forrajes*. 35 (4):365-379. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942012000400002&lng=es&tlng=es, 2012

Taiz, L.; Zeiger, E.; Møller, I. M. & Murphy, A. *Plant physiology and development*. Sunderland, USA: Sinauer Associates, 2015.

Van Soest, P. J.; Robertson, J. B. & Lewis, B. A. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci*. 74 (10):3583-3597, 1991. DOI: https://doi.org/10.3168/jds.S0022-0302(91)78551-2.

Vargas, B. *Pastos y forrajes*. Serie Tecnología Agropecuaria, No. 6. Bogotá: Editorial Guadalupe Ltda. ICFES, 2002.

Villanueva-Avalos, J. F.; Bonilla-Cárdenas, J. A.; Rubio-Ceja, J. V. & Bustamante-Guerrero, J. de J. Agrotecnia y utilización de *Clitoria ternatea* en sistemas de producción de carne y leche. *Téc. Pec. Méx*. 42 (1):79-96. http://www.redalyc.org/articulo.oa?id=61342107, 2004.