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Comparative Nutritional and Organic Matter of Leaves and Pods from Herbaceous Papilionaceae Ecotype

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Abstract

Crotalaria mucronata and *Crotalaria retusa* are leguminous plants with potential in their leaves, pods, and seeds. However, this potential remains largely underutilized. This study aimed to assess the nutritional content, organic matter, and antinutritional factors in the leaves and pods (including seeds) of *C. mucronata* and *C. retusa* from various ecotypes in Burkina Faso. The organic matter content was determined from the organic carbon content. Na was determined with a flame photometer. N, Cu, P, Mg, Mn, and Zn with the atomic absorption spectrophotometer. Alkaloids were determined by gravimetry. Tannins were determined using the AOAC method. Significant variations in nutrient and element content were observed across ecotypes, especially for nitrogen (for leaves, $p = 0.021$ and pods, $p = 0.0001$), phosphorus (for leaves $p = 0.0001$ and pods $p = 0.0001$), sodium (for leaves, $p = 0.001$ and pods, $p = 0.002$), manganese (for leaves, $p = 0.006$ and pods, $p = 0.001$) and magnesium (for leaves, $p = 0.049$). High organic matter content was found in both leaves (91 ± 1 mg/kg) and pods (96.67 ± 7.05 mg/kg). Nitrogen content was highest in leaves from Gonsé (27 ± 3 g/kg) and pods from Arbollé (29.83 ± 1.00 g/kg). Phosphorus levels ranged from 1.72 to 2.79 g/kg in leaves and 1.82 to 3.34 g/kg in pods. Sodium content was relatively low compared to some other legumes. Magnesium levels were highest in pods (up to 1701 ± 12.6 mg/kg) and lower in leaves. The pods and leaves can be used as organic matter or as potential forage.

Keywords

Burkina Faso; Ecotypes; Nutrient content; Organic matter; Antinutritional factors

1. Introduction

In Sudano-Sahelian areas, herbaceous legume species are generally known for their nutritional value and high organic matter content. These potentialities make them valuable in various fields of application such as agriculture [1], animal husbandry [2], and environmental conservation [3]. In Burkina Faso, among these legumes, two species of the genus Crotalaria (*Crotalaria mucronata* Desv. *Crotalaria retusa* L.) are widely distributed in various regions. These leguminous herbaceous plants are found seasonally in savannah ecosystems and exhibit vigorous growth. According to Ouédraogo *et al*. [4], these species these herbaceous plants grow spontaneously annually in fields and fallows thanks to their seed bank buried in the soil. They are therefore characterized by vigorous rapid growth and thus favoring high production of pods and biomass necessary in livestock feed. It should also be noted that in addition to their ability to fix atmospheric nitrogen in the soil, the high biomass produced by these plants can also be used as organic matter to restore the fertility of degraded soils [4]. Indeed, it appears from several studies that the seeds and leaves of *Crotalaria* contain significant amounts of protein, fibers [5], and minerals including iron, magnesium, calcium, phosphorus, and potassium [6], which are essential for animal nutrition and soil fertility [4]. Studies have shown that certain Crotalaria species can improve soil physico-chemical properties [4], enhance microbial activity, and host bacterial symbionts capable of metabolizing common soil and groundwater contaminants [7-9]. These characteristics confer *Crotalaria* species an ability for soil amendments, erosion control measures, and potential applications in bioremediation [10].

While *Crotalaria species* are often preferred by small ruminants as a feed source [11, 12]. Interestingly, in the North region of Burkina Faso, goats have been observed consuming the pods and leaves of *C. mucronata* after the rainy season, particularly in November and December, highlighting its potential as a natural fodder source.

Despite the potential benefits associated with *C. mucronata* and *C. retusa*, it is evident that these resources remain underexploited. This could be explained by the lack of scientific data, particularly on nutritional values and their fertilizing potential for soils as organic matter.

These data are of capital importance which can make it possible to remove two major constraints of agro-pastoralism in Burkina Faso: (i) the first is linked to the food deficit (quality and quantity) of livestock influencing animal productivity; (ii) and the second is linked to the depletion of crop soils in essential minerals, thus reducing agricultural yields. Hence the need to find palliative measures to ensure the regular supply of good quality fodder for livestock but also innovative technologies to restore the fertility of degraded soils for crop production. It is with this in mind that this study was carried out in order to provide valuable information for the development of sustainable and environmentally friendly practices in agriculture and livestock farming. Obtaining this information on herbaceous legume species will allow the valorization of the resource for better exploitation. The study consists of analyzing the nutritional content, organic matter composition, and the presence or absence of antinutritional factors in the leaves and pods (including seeds) of *C. retusa* and *C. mucronata*.

2. Methods

2.1 Samples collection

The plant material consists of leaves and pods (including pod and seed) of *Crotalaria* in the site of Gonsé I, Arbollé, Diabo and Boulbi (*C. Mucronata*), Gonsé II, Djindjerma and Dinderesso (*C. retusa*) harvested in the period from November to December 2022. The province of Passoré brings together the ecotypes of Arbollé, the province of Kadiogo (Gonsé I, Gonsé II and Boulbi), the province of Houet (Dinderesso) the province of Tuy (Djindjerma) and the province of Gourma (Diabo) (Fig.1). The sites are characterized by lihisols (Arbollé), ferruginous soil (Arbollé and Boulbi), vertisol and hydromorphic soil (Diabo), sesquioxide soils (Dinderesso and Djindjerma) and shallow and infertile soils (Gonsé I and Gonsé II) [4]. About 500g samples of leaf and pods were collected in each provenance. The samples were grind to ensure uniformity and then conserved prior analysis in a zip lock in laboratory condition (about 30°C).

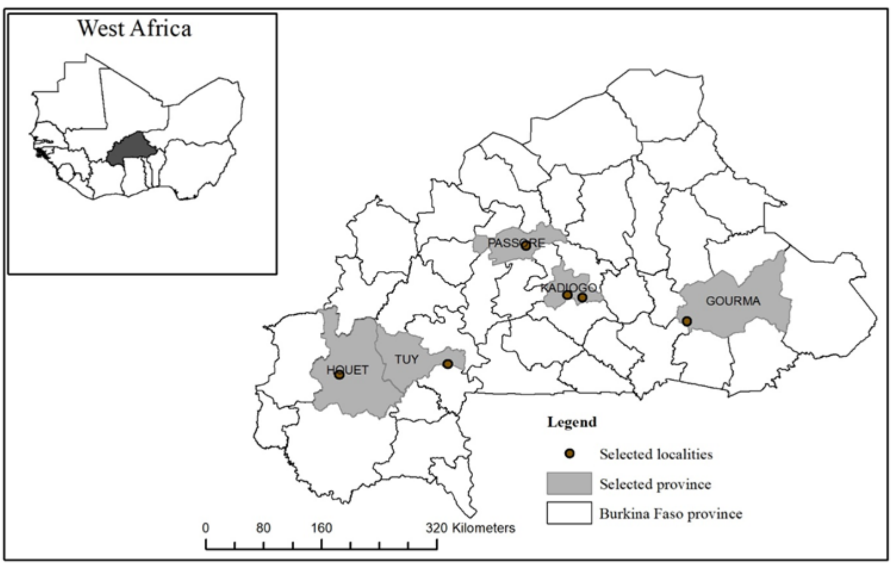

Figure 1. Samples collection sites.

2.2 Mineral analysis

The plant samples underwent mineralization using the Kjeldahl method [13]. This involves treating the samples with a mixture of sulfuric acid (H2SO4), selenium (Se), salicylic acid (C7H6O3), and hydrogen peroxide (H2O2), with selenium acting as a catalyst. The organic matter content was determined from the organic carbon content, using the multiplier coefficient of 1.724 [14]. Sodium (Na) content is determined using a flame photometer, while total copper (Cu), total magnesium (Mg), total manganese (Mn), and total zinc (Zn) are determined using an Atomic Absorption Spectrophotometer (PerkinElmer 900T atomic absorption spectrometer). For the magnesium reading, the samples are diluted with 2000 ppm lanthanum nitrate before analysis. The process involves weighing 0.5 g of the dried and sieved plant sample (with a 0.5 mm sieve) into 75 mL digestion tubes. Then, 5 mL of the sulfuric acid – selenium – salicylic acid mixture solution is added to the tubes and mixed well by shaking. The tubes are then placed on the destruction block and heated at 100 °C for 1 h, 250 °C for 1 h, and 340 °C for 4 h, with 1 mL of hydrogen peroxide added to the tubes at each heating stage. After the digestion, the tubes are allowed to cool slightly under a hood, after which distilled water is added to fill 2/3 of the tubes. The tubes are allowed to cool again and then topped up to the volume.

Cu, Mg, Na, Mn, Zn (ppm) = ((S-W) *K*Vt*D) / P (1)

With W= white reading; S= sample reading; K= constant; Vt= total volume of sample preparation; D= number of dilutions; P= test portion.

2.3 Antinutritional factor determination

The method used for alkaloid determination was a liquid-liquid extraction technique combined with gravimetric analysis [15]. It involves macerating the sample in an acidic solution, followed by alkalization to extract the alkaloids using chloroform. The organic phase was separated and dried, and the alkaloid content was quantified by (%) measuring the weight of the residue after evaporation.

The AOAC [16] method was used to determine tannins, and the results were expressed as a (%) of dry matter.

3. Results and discussion

The study examined the variations in nutrients and elements in leaves and pods of different ecotypes of *C. retusa* and *C. mucronata* (Table 1 and Table 2). The results did not show a significant difference in mineral content among the study ecotypes, including organic matter in leaves (P = 0.069) and pods (P = 0.344), magnesium in pods (P = 0.365), copper in pods (P = 0.06), and zinc in leaves (P = 0.178). Nitrogen (for leaves, P = 0.021 and pods, P = 0.0001), phosphorus (for leaves P = 0.0001 and pods P = 0.0001), sodium (for leaves, P = 0.001 and pods, P = 0.002), manganese (for leaves, P = 0.006 and pods, P = 0.001), and magnesium (for leaves, P = 0.049). Magnesium and copper were significantly different ($P<0.05$) in leaves within the ecotypes. In leaf and pod-included seed the mineral profile follows this order of superiority in terms of content: N > P> Mg > Na > Mn > Zn > Cu. The high values for organic matter in leaves and pods were 91 ± 1 mg/kg and 96.67 ± 7.05 mg/kg, respectively.

The maximum nitrogen content in leaves was from Gonsé I (*C. mucronata*) samples (27 ± 3 g/kg), while the highest content in pods was found in Arbollé (*C.mucronata*) samples at 29.83 ± 1.00 g/kg. Thus, among the studied ecotypes, *C. mucronata* exhibited higher nitrogen content compared to other ecotypes.

Phosphorus content varied between 2.79 ± 0.08 g/kg (Gonsé I, *C. mucronata*) and 1.72 ± 0.03 g/kg (Djindjerma, *C. retusa*) in leaves. In pods, the value varied between 3.34 ± 0.05 g/kg (Arbollé, *C. mucronata*) and 1.82 ± 0.06 g/kg (Boulbi, *C. mucronata*). This showed that phosphorus content in leaves and pods from *C. mucronata* species was the most important in phosphorus.

The sodium content in leaves was highest in the Djindjerma (*C.retusa*) ecotype, reaching 182.33±15.7 mg/kg, while the Gonsé I ecotype had the lowest leaf sodium levels at 92.33±6.66 mg/kg.

In pods, the sodium content ranged from a maximum of 278.67 ± 3.2 mg/kg in the Dinderesso (*C.retusa*) ecotype to a minimum of 245.33 ± 5.51 mg/kg in the Arbollé (*C.mucronata*) ecotype. Despite this variation, the overall sodium levels in the pods and leaves were relatively low, suggesting that the pods or leaves are not likely to be a significant source of sodium.

However, the sodium content in our pod-included seeds was higher than that found in white beans (*Phaseolus vulgaris* L.), which have a value of around 190 mg/kg. In contrast, the sodium levels in our samples were lower than those reported in peas (*Pisum sativum* L.), which can reach up to 300 mg/kg [17]. Our results for nitrogen and phosphorus content differed from the values reported in other legume species, such as *Mucuna* (N:17.5 g/kg; P: 1.1 g/kg), *Pueraria* (N: 8.1g/kg; P: 0.8 g/kg) [18].

The results showed that the nitrogen and phosphorus levels in the studied *Crotalaria* species were high, suggesting their potential use as compost or soil fertilizer. In comparison, phosphorus content in some legumes, such as white beans (*P. vulgaris*) and soybeans, can be as high as 4300 mg/kg [17]. *Crotalaria* species such as legumes known for their nitrogen-fixing abilities, can contribute substantially to soil improvement when used as green manure or mulch [19]. In fact, as legumes, *Crotalaria* plants fix atmospheric nitrogen through symbiotic relationships with rhizobia bacteria in their root nodules [20]. This fixed nitrogen becomes available in the soil as the plant material decomposes.

Table 1. Average of organic matter and minerals in the leaf of *Crotalaria* ecotypes

Ecotypes	OM (%)	N (g/kg)	P (g/kg)	Na (mg/kg)	Mn (mg/kg)	Mg (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Gonsé I (*C. mucronata*)	91±1[a]	27 ±3[a]	2.79±0.08[a]	92.33±6.66[b]	29.67±5.51[ab]	375±25[ab]	3.16±0.76[ab]	16.33±5.69[a]
Gonsé II (*C. retusa*)	90.33±2.06[a]	22±2[ab]	1.88±0.1[b]	173.3±27.5[a]	31.67±4.51[a]	367.7±73.2[ab]	4±1[ab]	14.33±2.52[a]
Dinderesso (*C.retusa*)	89.67±1.76[a]	18±3[ab]	1.87±0.11[b]	161.7±20.2[a]	28.67±5.69[ab]	289±67.2[b]	2.4±0.79[b]	17.33±3.51[a]
Djindjerma (*C.retusa*)	85±3.61[a]	19±4[ab]	1.72±0.03[b]	182.33±15.7[a]	19±3.46[b]	356.3±57.3[ab]	5±1[a]	15.67±3.21[a]
Boulbi (*C.mucronata*)	85±1[a]	17.33±2[b]	1.85±0.18[b]	102.0±18.5[b]	21.33±2.52[ab]	317±51.9[ab]	3.53±0.42[ab]	17±1[a]
Arbollé (*C.mucronata)*	85±7.21[a]	22±5[ab]	2.63±0.08[a]	162.7±28.3[a]	30.33±4.04[ab]	456.3±41.6[a]	3.67±0.57[ab]	22±2[a]
Diabo (*C. mucronata*)	82.67±3.79[a]	17.33±3.21[b]	1.82±0.175[b]	141.3±20.1[ab]	20.33±1.52[ab]	333.3±51.3[ab]	2.93±0.4 [ab]	19.50±2.12[a]
P	0.069	0.021	0.0001	0.001	0.006	0.049	0.01	0.178

Note. This means not sharing any letters is significantly different.

Table 2. Average of organic matter and minerals in pod including seeds of *Crotalaria* ecotypes

Ecotypes	OM (%)	N (g/kg)	P (g/kg)	Na (mg/kg)	Mn (mg/kg)	Mg (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Gonsé I (*C. mucronata*)	95.67±5.15[a]	26±2.28[abc]	2.01± 0.03[c]	271.67±2.89 [ab]	45.48±4.75[b]	1636±31.9[a]	4.57±1.4[a]	34.24±3.67[ab]
Gonsé II (*C. retusa*)	95.33±8.12[a]	26.6±5.12 [ab]	2.86±0.14[b]	277±6.08[ab]	56.33±3.21[a]	1701±12.6[a]	7.62±2.08[a]	40.33±1.53[a]
Dinderesso (*C.retusa*)	96.33±10.06[a]	25.33±8.22[bc]	2.74±0.21[b]	278.67±3.2[a]	52±2[a]	1545±92.5[a]	6.87±1.32[a]	38.85±3.06[a]
Djindjerma (*C.retusa*)	95.00±3.18[a]	28.5±6.18[ab]	2.98±0.07[ab]	253±10.82[bc]	41.33±3.21[bc]	1523±15.2[a]	4.33±0.78[a]	34±1[ab]
Boulbi (*C.mucronata*)	96.67±7.05[a]	23.33±3.71[c]	1.82±0.06[c]	269.67±0.57[ab]	45.74±3.30[b]	1600±10[a]	4.40±0.42[a]	37.58±5.51[ab]
Arbollé (*C.mucronata)*	95.87±3.56[a]	29.83±1.00[a]	3.34±0.05[a]	245.33±5.51[c]	35.67±4.04[c]	1547.3±42.4[a]	2.5±0.5[a]	27.33±4.04[b]
Diabo (*C. mucronata*)	95.20±3.89[a]	29±1.42[ab]	2.14±0.21[c]	260.7±17.9[bc]	42.33±2.52[b]	1590±85.4	3.80±0.08[a]	30.83±5.11[ab]
P	0.344	0.0001	0.0001	0.002	0.001	0.365	0.06	0.015

Note. This means not sharing any letters is significantly different.

Manganese content was highest in leaves from the Gonsé II (*C. retusa*) ecotype at 31.67 ± 4.51 mg/kg, while the Djindjerma (*C.retusa*) ecotype had the lowest leaf manganese levels at 19 ± 3.46 mg/kg. In pods, manganese ranged from 56.33 ± 3.21 mg/kg in Gonsé II to 35.67 ± 4.04 mg/kg. The relatively high manganese content in both pods and leaves suggests that these plant parts could serve as good sources of manganese for various applications.

Magnesium content was highest in pods of the Gonsé II ecotype, reaching 1701 ± 12.6 mg/kg. In leaves, magnesium levels were lower, ranging from 456.3 ± 41.6 to 289±67.2 mg/kg. Compared to some other legumes, such as *Canavalia ensiformis*, *Vigna unguiculata, Phaseolus vulgaris*, *Mucna pruriens*, and *V. Umbellata* with a value higher than 1800 mg/kg [21], which can have magnesium levels exceeding 1800 mg/kg, the magnesium content in our samples was relatively lower.

The highest copper content was found in pods, reaching 7.62±2.08 mg/kg, while the lowest leaf copper level was observed in the Dinderesso ecotype at 2.4±0.79 mg/kg. Compared to some other legumes, such as *V. unguiculata, P. aseolus vulgaris*, *M. pruriens*, and *V. Umbellata* which can have copper levels up to 43 mg/kg [21], the copper content in both the leaves and pods of *C. retusa* and *C. mucronata* was relatively low. This suggests that these *Crotalaria* species may not be a significant source of copper.

Zinc in the pod was in the interval of 40.33±1.53 mg/kg and 27.33±4.04 mg/kg, corresponding to the ecotype of Gonsé II and Arbollé, respectively. Leaf zinc levels were lower, varying between 22±2 mg/kg and 14.33±2.52 mg/kg. Compared to other legumes such as *V. unguiculata, P. aseolus vulgaris*, *M. pruriens*, and *V. Umbellata* [21], the zinc content in both the leaves and pods of *C. retusa* and *C. mucronata* was relatively low. The zinc content observed in our study was similar to the levels reported in blue lupine, white lupine, yellow lupine, lentil, and grass pea [22]. The manganese levels observed in our study were lower than those reported in some other legumes [21]. However, the content of manganese and zinc in leaves, copper, and phosphorus in both leaves and pods was close to the recommended values for a mixture of leguminous and cereal forages [23].

The nutritional value of *C. mucronata* and *C. retusa* can be used to enhance the nutritional balance of livestock. A study showed that the nutritional value composition of *C. retusa* was characterized by important levels of protein, various minerals, and micronutrients [6]. These beneficial nutrients found in Crotalaria species make them a valuable feed supplement that can improve the overall health and productivity of livestock. Furthermore, the pods and leaves of Crotalaria species, with their high organic matter content, can be effectively utilized as residues to enhance soil fertility. Numerous studies have demonstrated that incorporating crop residues into agricultural practices can significantly improve soil biological properties and overall soil health [24, 25]. By using *Crotalaria* species as both a livestock feed and a soil amendment, farmers can create a sustainable and regenerative agricultural system that benefits both animal and plant production. The study showed that the *Crotalaria* plant was rich in magnesium and contained significant levels of copper and zinc, which can be beneficial for livestock nutrition and contribute to a balanced diet.

The study highlights significant variations in nutrient and element content among different ecotypes, particularly in nitrogen, phosphorus, sodium, manganese, and magnesium. The maximum values for these nutrients were observed in specific ecotypes.

The results found in this study highlight the importance of considering ecotype variations in plant nutrition and their implications on plant growth and productivity. These results highlight the fact that the nutritional value of plants can vary considerably depending on their ecotype or geographical origin. Variations in nutrient content can be influenced by factors such as origin, ecological conditions, and agricultural practices.

By recognizing and accounting for these ecotype-related differences in plant nutrition, researchers and farmers can better optimize plant growth and productivity. Understanding the unique nutritional profiles of different plant ecotypes allows for more targeted and efficient use of plant resources, whether for livestock feed, soil amendment, or direct human consumption. Taking into account variations in ecotypes is a crucial step in developing sustainable and resilient agricultural systems capable of maximizing the benefits of plant resources.

The study also examined antinutritional factors in the leaves and pods of the plants. The alkaloid content in the leaves and pods was not significantly different with $P = 0.88$ and $P = 0.549$, respectively, with a value interval of 0.26±0.05% to 0.19±0.03% in the leaves (Table 3). In the pods, the alkaloid value ranged from 0.07±0.003% to 0.12±0.01%. The average tannin content was not significant in leave ($P = 0.120$) and was significantly different in pod ($P = 0.044$). The high value of tannin in the pod was from Arbollé (0.080±0.001%) for the leaf the high value was from Dinderesso and Diabo (0.04±0.002%). The content of the antinutritional factor showed that the plants of *C. mucronata* and *C. retusa* can be used as forage.

Table 3. Antinutritional factors (alkaloid and tannin) in leaf and pod including seed of *C. mucronata and C. retusa*

	Alkaloid (%)		Tannin (%)	
Ecotypes	Leaf (%)	Pod	Leaf (%)	Pod (%)
Gonsé I (*C. mucronata*)	0.19±0.03[a]	0.10±0.02[a]	0.02±0.006[a]	0.076±0.006[ab]
Gonsé II (*C. retusa*)	0.26±0.05[a]	0.12±001[a]	0.02±0.005[a]	0.06±0.02[bc]
Dinderesso (*C.retusa*)	0.20±0.01[a]	0.08±0.002[a]	0.04±0.002[a]	0.07±0.01[abc]
Djindjerma (*C.retusa*)	0.24±0.08[a]	0.07±0.003[a]	0.03±0.003[a]	0.083±0.006[a]
Boulbi (*C.mucronata*)	0.20±0.01[a]	0.13±0.05[a]	0.02±0.006[a]	0.056±0.006[bc]
Arbollé (*C.mucronata)*	0.19±0.09[a]	0.05±0.001[a]	0.03±0.004[a]	0.080±0.001[a]
Diabo (*C. mucronata*)	0.20±0.03[a]	0.13±0.005[a]	0.04±0.002 [a]	0.076±0.006[ab]
P	0.88	0.549	0.120	0.044

Note. This means not sharing any letters is significantly different.

These relatively low levels of alkaloid are encouraging for the potential use of *Crotalaria* as forage. Tannins can have both positive and negative effects on animal nutrition. While they can reduce protein digestibility and feed intake, they may also have beneficial anthelmintic properties [26]. These findings are generally consistent with other research on *Crotalaria* species. For instance, a study on C. *retusa* found low concentrations of antinutritional factors in both leaves and seeds, including phytate (0.01% in leaves, 0.06% in seeds) and oxalate (0.07% in leaves, 0.09% in seeds [6]. This further supports the potential of *Crotalaria* species as a forage crop. The relatively low levels of anti-nutritional factors suggest that *C. mucronata* and *C. retusa* could indeed be used as forage. The consumption of leaves and pods of *Crotalaria* species, especially *mucronata*, by goats could be explained by the high nutritional values in the organs analyzed and also by their low level of alkaloids and tannins. However, it's crucial to consider that different animal species may have varying tolerances to these compounds. For example, ruminants are generally more tolerant of antinutritional factors than monogastric animals [27, 26]. Digestibility tests would be valuable to reinforce these results. Such tests would provide more concrete evidence of how well animals can utilize the nutrients in *Crotalaria* and how the antinutritional factors affect overall feed efficiency [28]. But we can remember that other species of *Crotalaria* such as *C. ochroleuca* showed significant digestibility around the 10th week of growth of the plant.

4. Conclusion

The research emphasizes the nutritional significance and ecotype variances in *C. mucronata* and *C. retusa*. The leaves and pods of these plants contain abundant organic matter and minerals while exhibiting low levels of anti-nutritional factors such as alkaloids and tannins. As a result, they can serve as feed resources and contribute to soil fertility, especially, those of the species *C. mucronata*. The study underscores the significance of accounting for ecotype variations in plant nutrition and their impact on plant development and productivity. Further research on digestibility and toxicity will provide important insights for the efficient utilization of this species as a forage or food legume.

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