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Research Article

Mineral and Nitrogen Content in the Leaves and Pods of *Piliostigma reticulatum* (DC.) Hochst (*Caesalpinaceae*) in Burkina Faso

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Abstract

The woody species *P. reticulatum* used for food and fodder purposes can be used as a food supplement for humans and animals in Burkina Faso. The objective of this study is to determine the mineral and nitrogen content in the leaves and pods of *P.reticulatum* from four soils. Samples of leaves and pods were collected in 4 soil types (FLIPP, FLIMP, FLTC, and BEHV/F) along a North-South toposequence in Yilou (Burkina Faso). Minerals such as potassium (K), magnesium (Mg), phosphorus (P), calcium (Ca), sodium (Na) and potassium (K), and nitrogen content were evaluated. The results indicate that there is a significant difference ($p < 0.05$) in the calcium content of leaves and pods in FLIMP soils with values of 5053 ± 516 mg/kg and 6400 ± 255 mg/kg respectively. The content in K, Mg, and Na shows no significant difference ($p > 0.05$) in the leaves and pods of the soils studied. The higher nitrogen rate (2.74 ± 0.22%) was found in pods from FLIMP soil. The Ca/P ratios are between 3 and 5 in the leaves and pods which is in line with the standard oscillating between 1 and 7 corresponding to the ideal ratio for animals. The lowest Ca/Mg ratio (1.6) is from the FLIPP soil pod. The Na/K ratio in leaves and pods is less than the ideal ratio of 1:3 intakes for humans. The leaves and pods of *P. reticulatum* are thought to be a good source of minerals for food, medicine, fodder, and fertilization.

Keywords: *Piliostigma reticulatum (DC.) Hochst., soils, leaf, pod, nitrogen, mineral.*

Introduction

Piliostigma reticulatum (DC.) Hochst., of the Caesalpinaceae family is a multipurpose plant found in most cases in the savannas. The species is used in traditional medicine for the treatment of several diseases such as colds, sinusitis (Ouédraogo, *et al.*, 2020), diarrhea and dysentery, ulcers, wounds, rheumatism (Vodouhê, *et al.*, 2022), high blood pressure (Dembélé, *et al.*, 2020), etc. On the edible level, the leaves and the pods are used to acidify the dough of tô (local main made from cereal flour) (Sanou, 2005 ;Dao, 2012), and the leaves are used as a local drink. The ashes of the leaves or of the whole plant are used in the manufacture of soap and as potash for the preparation of the sauce. The pods and leaves are exploited as fodder for livestock (Dao, 2012), and sometimes serve as a dietary supplement for poultry.

P. reticulatum in Burkina Faso, more precisely in the locality of Yilou located in the Center North in the department of Guibaré (province of Bam) is therefore exploited for edible and fodder purposes. The objective of this study is therefore to evaluate the mineral and nitrogen

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content of the leaves and pods of *P. reticulatum* according to the types of soil in order to enhance the edible, therapeutic, fertilizing, and fodder potential of the species.

However, a deficiency in minerals can cause several disorders in humans and animals. As a result, calcium deficiency (tetanic attacks, cramps), phosphorus (tingling and muscle cramps), potassium (cramps), sodium (coordination disorder), and magnesium (fatigue, digestive disorders, cramps, and etc.) are problems encountered in humans and animals.

In addition, in the tropics, protein, mineral, and energy deficiencies are the best known in cattle (Mopoundza, *et al*., 2016). Mineral supplementation accompanied by a protein deficit would influence the reproductive performance of livestock (Mcdowell, 1996).

This study will therefore characterize mineral and nitrogen content in the leaves and pods of *P. reticulatum* from 4 types of soil. This characterization will help to value the use of the mineral and nitrogen content for use in food, medicine, animal husbandry, and agriculture.

Material and Methods

The samples were collected in Yilou in the North Center of Burkina Faso in the department of Guibaré (Bam Province) (Bazongo, *et al*., 2022). Samples of leaves (3 lots of 200g) and pods (3 lots of 3 pods) were collected along a North–South toposequence in 4 soil types (Fig1.). The soils are namely FLIPP (Ferruginous tropical soils leached indurated shallow), FLTC (Ferruginous tropical soils with spots and concretions), FLIMP (Ferruginous tropical soils leached moderately deep), BEHV/F (Brunified soils/ vertic hydromorphic eutrophic brown soils with ferruginized facies) characterized in previous studies (Table 1) (Bazongo, *et al*., 2022).

About 500 mg of leaves and 500 mg of pods from each sample were dried in an oven then finely ground and calcined at 480° C in a ventilated oven. After sintering the silica, the phosphorus (P) was measured by colorimetry, the potassium (K) and the sodium (Na) by flame photometry, the calcium (Ca) and the magnesium (Mg) by complexometry, and the nitrogen by the Kjeldahl method following the protocol described by the *Bureau National des Sols* (BUNASOLS, 1987).

The XLSTAT 2016 software was used for the comparison of the means according to the Newman-Keuls test at the 5% significance level. Na/K, Ca/P, and Ca/Mg ratios of leaves and pods were calculated for comparison with critical thresholds. PCA biplot of soil, mineral, and nitrogen content in the leaf, and pod of P. reticulatum was performed to find a correlation among the variables studied.

Figure 1: Tree of *P. reticulum* with leaves and pods on their native soils
Legend: 1: FLIPP; 2.FLTC; 3: FLIMP; 4: BEHV/F

Table 1: Physicochemical parameters of the soil (Bazongo, *et al*., 2022)

Parameters	FLIPP	FLIMP	FLTC	BEHV/F
Total nitrogen (%)	0.056	0.07	0.047	0.082
Total phosphorus (ppm)	621	726	782	615
Total potassium (ppm)	1118	1198	879	1358
Assimilable phosphorus (ppm)	1,3	2,16	1,36	4,65
Assimilable potassium (ppm)	18,23	14,71	19,82	9,91
Ca^{2+}(meq/100g)	1.42	1.86	1.11	1.65
Mg^{2+}(meq/100g)	0.83	0.79	0.65	0.9
Na^{+}(meq/100g)	0.07	0.09	0.14	0.38
pH (Water)	6.1	7.72	6.68	6.03

Legend: Soils : FLIPP (Ferruginous tropical soils leached indurated shallow), FLTC (Ferruginous tropical soils with spots and concretions), FLIMP (Ferruginous tropical soils leached moderately deep), BEHV/F (Brunified soils/ vertic hydromorphic eutrophic brown soils with ferruginized facies).

Minerals: Ca2+ : Calcium, Mg2+:Magnesium, Na+:Sodium

Results and Discussion

The values of mineral and nitrogen content in the leaves are recorded in Table 2. Total leaf nitrogen content was 1.8 ± 0.2% in FLTC soil, which was significant ($p < 0.05$) when compared to leaf nitrogen content from other soils. There was a nitrogen content of 0.63 ± 0.47% in leaves from FLIMP soils, 0.60 ± 0.42% in leaves from BEHV/F soils, and 0.13 ± 0.02% in leaves from FLIMP soils.

In FLTC soils the leaves contain more nitrogen than in other soils, and leaves from all soil contain nitrogen except leaves from FLIPP soil where the value is very low.

There is no significant difference ($p > 0.05$) among the 4 soils concerning the content of potassium, magnesium, sodium, and phosphorus in the leaves of *P. reticulatum* with respective mean values of 20276.5 ± 2523.35 mg/kg; 1474.375 ±124.86 mg/kg; 75.515 ± 21.16 mg/kg and 1090.00 ± 99.9 mg/kg dry matter.

The content of calcium in the leaves is statically significant (P < 0.05) according to the soils. The highest content was recorded with leaves from FLIMP soils (5053 ± 516 mg/kg) followed by FLTC (4757 ±351 mg/kg), FLIPP (4148 ±103 mg/kg), and BEHV/F soils (2798 ± 188 mg/kg).

Table 2: Proportion of mineral and nitrogen content in the leaves of *P. reticulatum in Yilou*

Sols/Site	N (%)	K(mg /kg)	Mg(mg/kg)	Na(mg /kg)	Ca(mg /kg)	P(mg/kg)
FLIPP	0.13 ± 0.02[b]	22989 ± 3326[a]	1610.9 ± 115.8[a]	62.5 ± 0.00[a]	4148 ± 103[b]	1203 ± 106.3[a]
FLTC	1.3 ± 0.49[a]	19495 ± 637[a]	1473 ±179[a]	78.13 ± 5.63[a]	4757 ± 351 [ab]	1050.21 ± 16.54[a]
FLIMP	0.63 ± 0.47[ab]	19311 ± 2759[a]	1510.6 ± 122.9[a]	83.3 ± 36.1[a]	5053 ± 516[a]	1012 ± 106.3[a]
BEHV/F	0.60 ± 0.42[ab]	19311 ± 2528[a]	1303 ± 44.2[a]	78.13 ± 15.63[a]	2798 ± 118[b]	1094.8 ± 130.3 [a]

Legend: Soils: FLIPP (Ferruginous tropical soils leached indurated shallow), FLTC (Ferruginous tropical soils with spots and concretions), FLIMP (Ferruginous tropical soils leached moderately deep), and BEHV/F (Brunified soils/ vertic hydromorphic eutrophic brown soils with ferruginized facies).

Nitrogen matter and mineral: N: Nitrogen, K: Potassium, Mg: magnesium, Na: sodium, Ca: calcium, and P: Phosphorus.

Table 3 is a summary of mineral and nitrogen content recorded in *P. reticulatum* pods at Yilou. The nitrogen content of *P. reticulatum* pods from FLIMP soil (2.74 ± 0.2%) was significantly different (P < 0.05) from the nitrogen content from FLIPP, FLTC, and BEHV/F soils. Levels of 1.99 ± 0.2%, 1.8 ± 0.2%, and 1.75 ± 0.3% total nitrogenous matter are found in pods of FLIPP, FLTC, and BEHV/F soils respectively.

Potassium, magnesium, and phosphorus in the pods do not show a significant difference (P > 0.05) according to their soil of origin. The mean values are 28092.5 ± 6428.37 mg/kg, 2230.55 ± 414.4 mg/kg, and 1237.05 ± 289.6 mg/kg dry matter respectively.

There was a significant difference (P < 0.05) between the calcium content of the pods grown in the 4 soil types. This value was high in pods from FLIMP (6400 ± 255 mg/kg) soils, then FLTC (5414 ± 526 mg/kg), FLIPP (4148 ± 103 mg/kg), and BEHV/F (3942 ± 144 mg/kg) soils.

The leaves and pods showed a high potassium content, which can be explained by the richness of the soil in potassium (Bazongo, *et al*., 2022). FLIMP soils contribute to the nitrogen, calcium, and phosphorus content in the pods. Potassium, magnesium, and sodium contents in the pods are nearly identical in pods from all soils. This indicates that for the search for nitrogen and minerals (calcium and phosphorus) in pods, FLIMP soils are recommended over the other soils studied.

The potassium content in the pods is greater than that obtained in the leaves. This would justify the exploitation of the pods in the form of ash for the preparation of potash in certain localities of Burkina Faso (Dao, 2012).

In addition, the potassium content in leaves is much higher than the one of Yelemou, *et al*. (2020) on the composting effect of woody leaf biomass where the highest potassium content from *P. reticulatum* compost and Burkina phosphate was about 447 mg/kg. The leaves of *P. reticulatum* constitute a good source of potassium for the formulation of fertilizer, which is why they would contribute to the manufacture of compost for agriculture. In fact, regarding the mineral importance in the leaves of *P. reticulum*, minerals other than potassium from leaves or pods can also contribute to soil fertilization.

Table 3: Proportion of mineral and nitrogen content in the pods of *P. reticulatum* in Yilou

Sols/Site	N (%)	K (mg/kg)	Mg (mg/kg)	Na (mg/kg)	Ca (mg/kg)	P (mg/kg)
FLIPP	1.99 ± 0.2^{b}	27403 ± 319^{a}	2495 ±745^{a}	69.67 ± 1.53^{a}	4148 ± 103^{b}	1354 ± 379^{a}
FLTC	1.8 ± 0.2 ^{b}	30345 ± 6689^{a}	2042.6 ± 145.2^{a}	87.33 ± 16.77^{a}	5414 ± 526^{ab}	1159.2 ± 150.8^{a}
FLIMP	2.74 ± 0.2 ^{a}	29058 ± 637^{a}	2348 ± 312^{a}	70 ± 3.61^{a}	6400 ± 255^{a}	1432 ± 240^{a}
BEHV/F	1.75 ± 0.3 ^{b}	25564 ± 10956^{a}	2036.6 ± 117.5^{a}	87 ± 11 ^{a}	3942 ± 144 ^{b}	1003 ± 334^{a}

Legend: Soils: FLIPP (Ferruginous tropical soils leached indurated shallow), FLTC (Ferruginous tropical soils with spots and concretions), FLIMP (Ferruginous tropical soils leached moderately deep), and BEHV/F (Brunified soils/ vertic hydromorphic eutrophic brown soils with ferruginized facies).

Nitrogen matter and mineral: N: Nitrogen, K: Potassium, Mg: magnesium, Na: sodium, Ca: Calcium, and P: Phosphorus.

The PCA biplot reveals that components 1 (46.8) and 2 (41.3) account for 88.1% of the variability (Fig.2) and can be used to explain the correlation between soil, leaves and pods for mineral and nitrogen content. Sodium and nitrogen in leaves are correlated with FLTC soil, while FLIPP soil versus FLTC soil is correlated with potassium and phosphorus in leaves.

FLIMP soil is correlated with calcium, potassium, and nitrogen content in the pods, and calcium content in the leaves. Magnesium in the leaves and pods is intermediate between FLIMP soil and FLIPP soil. Phosphorus in the pod is close to FLIMP soil while sodium in the leaf is intermediate with FLTC soil and BEHV/F soil.

FLTC soil plays an important role in *P. reticulatum* leaves nitrogen content. Regarding PCA biplot analysis the content of minerals and nitrogen in the leaves and pods depends on the nature of the soil.

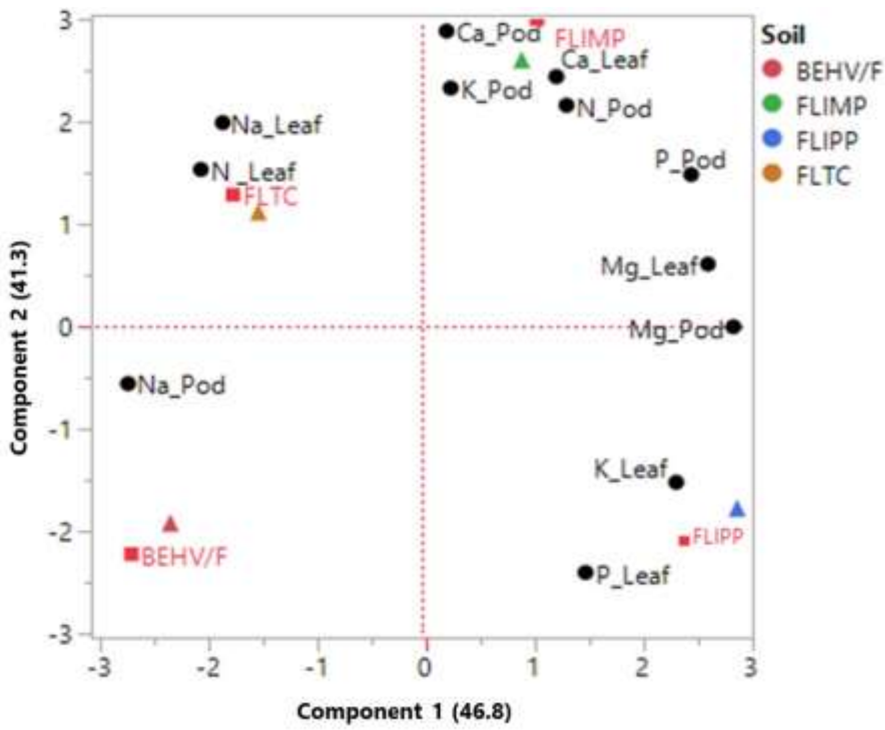

Figure 2: PCA biplot of soil, mineral and nitrogen content in leaves and pods of *P. reticulatum*

Legend: Soil: FLIPP (Ferruginous tropical soils leached indurated shallow), FLTC (Ferruginous tropical soils with spots and concretions), FLIMP (Ferruginous tropical soils leached moderately deep), BEHV/F (Brunified soils/ vertic hydromorphic eutrophic brown soils with ferruginized facies).

Nitrogen matter and mineral : N: Nitrogen, K: Potassium, Mg: magnesium, Na: sodium, Ca: Calcium, P: Phosphorus.

The ratio of minerals from leaves and pods is recorded in table 4. The ratio of Ca/P of leaves is in intervals 2.6 (BEHV/F soil) and 5 (FLIMP soil). Meanwhile, this value is including between 3.15 (FLIPP soil), and 4.54 (FLIMP soil) for pods. As for the ratio Ca/Mg the lower value (1.6) is from pods of FLIPP soil and the higher value (3.34) is from leaves of FLIMP soil. The Na/K ratio is very low and is inferior to 1 for leaves and pods from all soils.

The Ca/P ratio for leaves and pods found in our study is favorable for good cattle feeding. Work carried out by Jeon, *et al*., (2021) has shown that the ideal ratio for animals is between 1 and 7. The high value of this ratio would lead to a decrease in the efficiency of the phytase enzyme in forming insoluble Ca-phytate complexes (Tamim, *et al*., 2004; Jeon, *et al*., 2021).

The Na/K ratio of the leaves and the pods is less than 1, which indicates the leaves and the pods can contribute to fighting against cardiovascular diseases (He and Graham, 2008). This would justify the use of *P. reticulatum* leaves in the treatment of hypertension in traditional medicine (Deluccia, *et al*., 2019; Dembélé, *et al*., 2020).

The Ca/Mg ratio of the pods is lower in the pods than in the leaves. The lowest values in the pods were from FLIPP and BEHV/F soils with respective values of 1.6 ± 0.2, and 1.963 ± 0.8. These values are included in the ratio of 2:1 indicated by Deluccia, *et al*., (2019) to avoid an increased risk of inflammatory, metabolic, and cardiovascular disorders. Pods of *P reticulatum* can then be used as a functional food.

Table 4: Ratio of minerals Ca/P, Ca/Mg and Na/K of *P. reticulatum* leaves and pods from four soils

Soils	Leaf			Pod		
	Ca/P	**Ca/Mg**	**Na/K**	**Ca/P**	**Ca/Mg**	**Na/K**
FLIPP	3.5 ± 1[a]	2.56 ± 0.5[a]	0.002 ± 0.000[a]	3.15 ± 0.77[a]	1.6 ± 0.2[a]	0.002 ± 0.000[a]
FLTC	4.5 ± 0.3[a]	3.24 ± 0.22[a]	0.004± 0.000[a]	4.76 ± 1.09[a]	2.6 ± 0.3[a]	0.003[a] ± 0.000
FLIMP	5 ± 1[a]	3.34[a]±0.06[a]	0.004 ±0.001[a]	4.54 ± 0.68[a]	2.751 ± 0.3[a]	0.002 ± 0.000[a]
BEHV/F	2.6 ± 1.5[a]	2.13 ± 0.8[a]	0.004 ± 0.001[a]	4.17 ± 1.65[a]	1.963 ± 0.8[a]	0.003 ± 0.001[a]

Legend: Soils: FLIPP (Ferruginous tropical soils leached indurated shallow), FLTC (Ferruginous tropical soils with spots and concretions), FLIMP (Ferruginous tropical soils leached moderately deep), and BEHV/F (Brunified soils/ vertic hydromorphic eutrophic brown soils with ferruginized facies).
Mineral ratio: Ca/P: phosphocalcic ratio, Ca/Mg: Calcium to magnesium, and Na/K: Sodium to potassium ratio.

P. reticulatum leaves and pods have an important magnesium content. Magnesium is a mineral involved in bone structure and teeth and is sometimes used to relieve fatigue (Azouagh, 2020). This may be due to the use of *P. reticulatum* leaves in traditional medicine for the treatment of certain diseases such as rheumatism, and toothache, or as a sedative (Vodouhê, *et al*., 2022). Magnesium also plays an important role in glucose metabolism by facilitating the formation of glycogen and is involved in the synthesis of lipids (Mariko, 2018). In fact, the leaves and pods could be used to supplement magnesium deficiency in humans and animals. The important value of magnesium in the pods would participate in the skeletal growth of animals. The work carried out by Lemus (2018) mentioned that magnesium in animals is involved in skeletal growth, milk production, and muscle control. The pods of *P. reticulatum* are rich in magnesium and can contribute to calcium supply in the manufacture of feed for livestock.

Furthermore, the pods of *P. reticulatum* would contribute as a fodder plant in its potassium supply to balance potassium deficiencies in livestock feed. Indeed, animals need potassium for milk production, muscle contraction, and maintenance of the enzyme system (Lemus, 2018).

Sodium was also found in the pods and leaves of *P. reticulatum*. Whereas the body's sodium intake per day is a recommended rate of 1500 mg/day for children and adolescents 1 to 18 years of age (Gowrishankar, *et al*., 2020), therefore the plant (leaves and pods) can be used as a drink.

Calcium has been reported in *P. reticulatum* leaves and especially in pods with high levels. While, calcium is a mineral involved in bone ossification (Mensah, *et al*., 2008; Atchibri, *et al*., 2012). Thus, *P. reticulatum* used in the pharmacopoeia for the treatment of bone-related diseases could be justified by the high content of calcium found in the leaves and pods. Calcium is also important for animal skeletal growth, milk production, nerve impulse, and maintenance of the enzyme system (Lemus, 2018). The high calcium content in the pods of *P. reticulatum* may serve *as* good fodder for animals.

The phosphorus content is also interesting in the leaves and pods of *P. reticulatum*. This richness of the leaves and pods in phosphorus can be a help in traditional and modern medicine to solve the problems of phosphorus deficiency. Indeed, phosphorus is found in large quantities in the bones and linked to calcium contributing to giving good rigidity to bones and teeth. (Mariko, 2018).

The proportion of nitrogen and phosphorus recommended for good nutrition varies according to the animals (Coleman and Moore, 2003; Gourley, *et al.,* 2012). It is around 10% for ruminants (cattle and sheep) intended for meat production, 20-30% for animals intended for dairy production, and 30% to 45% for pig and poultry production (Gourley, *et al*., 2017; Qi, *et al*., 2017). It will thus be possible to use the pods of *P. reticulatum* with regard to the nitrogen and phosphorus rate obtained as an ingredient in the manufacture of animal and poultry feed. Moreover, some authors have indicated that a protein deficiency would lead to a limit on ingestion, and use of fodder (Coleman and Moore, 2003; Ladoh-Yemeda, *et al*., 2016), which leads to saying that the pods and leaves of *P reticulatum* may contribute to solving this effect.

Calcium, potassium, magnesium, and phosphorus are major elements in a forage (Meschy, 2010). Thus, their high rate in the pods and leaves of *P. reticulatum* would indicate the quality of good fodder for this species.

Conclusion

The contents of mineral in the leaves and pods of *P. reticulatum* are high and vary according to the types of soil. The concentration of minerals is in most cases high in the pods compared to the leaves. Calcium concentration is high in leaves and pods from FLIMP soils. The ratio of nitrogen is high in the pods compared to the leaves and the highest rate in the pods is that of FLIMP soils and the highest rate in the leaves is that of FLTC soils. The leaves and pods of *P. reticulatum* with a richness in mineral content can be valued on the medicinal, agricultural, and food levels for humans and animals. The species could intervene as a complement to the composition of animal feed. They could be used to solve mineral deficiency problems in humans and animals. *P. reticulatum* leaves can also be used as compost for fertilizing soils with potassium deficiency. The pods and leaves of *P. reticulatum* can be a good source of food for humans, but another study on the toxicity of the plant is important before its rational use for the well-being of the population.

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