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Mineral Composition of Some Important Indigenous Savanna Forage Shrub Species in Ghana

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ABSTRACT

This study compared the forage quality of *Cajanus cajan, Stylosanthes mucronata, Tephrosia purpurea,* and *Securinega virosa* in the savanna ecological zone of Ghana. The shrubs were cultivated using Randomized Complete Block Design (RCBD) and their growth were monitored. Leaf samples were hand-harvested at 7, 10, and 13 weeks after establishment, air-dried, pulverised, and used for laboratory analysis. Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg) were determined. N, P, K, Ca and Mg contents among the shrubs ranged from 0.74 - 0.79%, 1.32 - 1.99%, 7.63 - 10.09%, 2.22 - 3.06 and 1.08 - 1.38%, respectively. *Stylosanthes mucronata* was significantly lowest in both P (1.318%) and K (7.63%), whilst *Securinega virosa* was significantly highest in K (10.09%). Among the three maturity levels, N, P, K, Ca and Mg contents ranged from 0.31 – 1.05%, 1.51 - 1.93%, 7.46 - 10.43%, 2.63 - 2.67% and 1.28 - 1.30%, respectively. Except for P, which was significantly lowest at 10 weeks after establishment (WAE), N and K were significantly highest at 7 WAE and lowest at 10 and 13 WAE, respectively. It was observed that the shrub species and maturity levels influence the nutrient content of forage shrubs.

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Introduction

Traditional smallholder animal production in Africa is faced with a wide range of challenges, and chief among them is inadequate quality feed supply (Tonamo et al., 2015; Lukuyu et al., 2011). Ruminants in the smallholder sector rely on natural pastures and crop residues for the better part of the year. The available natural pastures and crop residues for animals are generally fibrous and ligneous after harvest and have low or lack some essential nutrients such as protein, carbohydrates, minerals and vitamins, which are necessary for higher rumen microbial fermentation enhanced performance (Akapali, 2018).

Rapid urban population growth and demand for animal protein is provided a boost to urban and peri-urban farming. Urban livestock keeping, although often only a part-time enterprise, benefits the poor and provides a way of diversifying livelihood activities accessible to vulnerable groups. Livestock also provides locally produced food products for people living near the livestock keepers (Wilson, 2018).

Conventional feed resources present and accessible during the dry season are costly for animals due to competition with mankind for livelihood (Lamidi and Ologbose, 2014). This has necessitated the investigation of low-cost alternative feed sources capable of meeting the nutritional requirements of animals. According to Akinmutimi (2007), such alternative feed materials must be less costly, readily available and accessible, and in less demand by humans to enhance the productive and reproductive ability of the smallholder ruminant animals.

A potential alternative may be the utilisation of fodder trees and shrubs. In the recent past, the use of fodder trees and shrubs as a critical source of quality feed for ruminant animals had not been highly encouraged, predominantly on account of deficient knowledge in their potential use and in addition connected with the improvement of the more imaginative framework of feeding (Avornyo et al., 2018). Haftay and Kebede (2014) documented the significance of trees, shrubs, and herbs for their nutritional ability for grazing and browsing animals, particularly in ranges of low-quality feed material. Fodder trees and shrubs relatively contain a significant concentration of crude protein, minerals, and neutral detergent fibre compared with grasses but their mean amount of acid detergent fibre and dry matter are lower (Haftay and Kebede, 2014).

The findings of many researchers revealed that tree and shrub species potentially produce adequate and nutritious forage even in the dry season (Kökten et al., 2012; Kamalak, 2006; Narvaez et al., 2010). Belete et al. (2012) reported that the chemical constitution of browse species changes based on the species. Dicko and Sikena (1992) demonstrated the crude protein level in different browse species to range from 6% to 23%. Solomon (2001) opined that the variation in the nutrient composition of browse species could be linked to such variables as parameters, harvesting regime, season, and location, and others could be hereditary. Beyene (2009) observed that the same species could have different lignin, cellulose and hemicelluloses contents due to morphological differences. The survival and healthy development of animals depend on nutrients such as protein, fat, carbohydrates, and vitamins, and a healthy supply of minerals. Minerals, which are very important for all live organisms, have an essential role in boosting rumen activities and increasing the efficiency of feed usage in ruminants (Suleyman, 2019). It has been observed that, though the part played by trees and shrubs in the tropics is worth recommending, the nutritional value of these forage materials has been heavily placed on introduced species such as *Leucaena leucocephala* and *Gliricidia sepium*.

However, little information is available on the native shrub species of the savanna ecological zone, especially studies on the mineral composition of shrubs as forage. Therefore, the objectives of the study were to determine the mineral content of some native forage shrub species and compare the mineral value of the shrubs at different maturity stages.

Materials and Methods

The study was carried out at the experimental field of the Faculty of Renewable Natural Resources, University for Development Studies, Nyankpala Campus in the Tolon District of the Northern Region of Ghana. This study area is located within the savanna ecosystem at latitude 09° 25' N and longitude 00° 55' W and an altitude of 183 m above sea level. Nyankpala Campus of the University for Development Studies is 16 km away from Tamale, the capital of the Northern Region.

The area experiences an annual rainfall of about 1,034 mm from April to early November with a mean monthly temperature of 22°C. A maximum monthly relative humidity value of 80% can be recorded during the rainy season, while a minimum monthly value of 42% during the dry season is observed. The vegetation is guinea savanna with grasses as the dominant plant species and interspersed with economic but drought-resistant trees such as *Vitellaria paradoxa*, *Adansonia digitata*, and *Tamarindus indica*. The soils are well-drained with low nitrogen content due to the low organic matter cover (Ziblim et al., 2016).

Randomized Complete Block Design (RCBD) was used in this experiment involving four savanna forage shrub species as the treatments with four (4) replications. Experimental plots of size 4 × 4 m were constructed. Healthy and clean seeds of the four selected indigenous shrub species were planted onto the plots at 1 cm depth and spaced 1 m between rows and 1 m within rows, and their growth was monitored. Each plot contained 16 plants. The leaves of four randomly selected plants from each shrub species were harvested for the nutritional analysis.

The green leaves of the various shrub species were harvested and rinsed in distilled water to remove dust. The leaves were chopped, air-dried, and pulverized to pass a 1 mm screened, neatly bagged in well-labeled sample poly-bags to be used for the chemical analysis. All analyses were carried out in triplicate samples.

Shrub specimens (pulverized samples) were transported to the laboratory to analyse the various nutrient components. N, Ca, P, K and Mg were analysed according to standard methods of AOAC (2000), and this was done at the Savanna Agricultural Research Institute (SARI) laboratory in Nyankpala.

All data obtained from the laboratory analysis were subjected to analysis of variance (ANOVA) where mineral levels in the shrubs were compared to the period of harvest using Genstat Release 10.3 DE (2011). Significant treatment means were separated using Fisher's Least Significant Difference at 5% probability.

Results and Discussion

Mean Mineral Composition Of The Shrubs

The mean mineral composition of foliage of the shrub species is presented in Table 1. The study showed no significant difference (P=0.376) among the shrubs in terms of nitrogen content. Though there was no significant difference in the level of N among the shrubs, *C. cajan* had the highest mean N whilst *S. virosa* recorded the least (Table 1). Harvesting time was noticed to have a highly significant (P<0.001) effect on the N content of the shrubs. The N content was higher in shrub species harvested at 10 WAE but lowest at species harvested at 13 WAE (Table 2).

There was a highly significant (P<0.001) variation of P content among the shrubs. The data analysed further indicated that *S. mucronata* was lower in P content than the others (Table 1). Phosphorus content was significantly higher in shrubs harvested at 7 and 13 weeks after establishment (Table 2). On K content, the species had a very high significant (P<0.001) contribution. *Securinega virosa* recorded a higher mean K value whilst *S. mucronata* had the lowest mean K content. Time of harvest also presented a very high significant (P<0.001) effect on the K content of the shrubs. The mean K content was highest in plants harvested at 7 WAE, and potassium values decreased with increasing harvest time.

The mean nitrogen percentage in *C. cajan* was generally lower than those reported by Daryl et al. (2006) on the foliage of woody species in the South African Savanna. The relatively low percentage N values were also inconsistent with those previously reported for *Phalaenopsis violacea* by Du Toit (2003). The generally low N content in the shrubs could be attributed to the low organic matter content of the soil.

Table 1. Means and standard errors for expressions of mineral composition of indigenous shrubs

Species	Mineral content (%)				
	N	P	K	Ca	Mg
C. cajan	0.79[a]	1.87[a]	8.86[a]	2.49[a]	1.21[a]
S. mucronata	0.79[a]	1.32[b]	7.63[b]	3.06[a]	1.49[a]
T. purpurea	0.77[a]	1.93[a]	8.94[a]	2.22[a]	1.08[a]
S. virosa	0.74[a]	1.99[a]	10.09[c]	2.83[a]	1.38[a]
SEM	0.03	0.10	0.21	0.22	0.10
LSD	0.08	0.31	0.62	0.64	0.30

SEM- standard error of means. LSD- least significant difference. Means with the same superscripts within columns are not significantly different at 5% probability.

Table 2. Effects of time of harvest on the mineral composition of indigenous shrubs

Minerals (%)	Weeks After Establishment			SEM	LSD
	7	10	13		
N	0.97[a]	1.05[b]	0.31[c]	0.02	0.07
P	1.93[a]	1.51[b]	1.90[a]	0.09	0.26
K	10.43[a]	8.75[b]	7.46[c]	0.18	0.53
Ca	2.67[a]	2.63[a]	2.64[a]	0.19	0.56
Mg	1.30[a]	1.28[a]	1.28[a]	0.09	0.26

SEM- standard error of means. LSD- least significant difference. Means with the same superscripts within rows are not significantly different at 5% probability

Research indicates that the organic matter content of most savanna soils is low, consequently affecting the N content (Oyinlola and Jinadu, 2012). The general low N concentration in the foliage of the shrub could also be attributed to the likely presence of a high level of condensed tannins (Kumar, 1992).

The significantly higher N content in plants harvested at 10 WAE could result from the succulent nature of the initial shoots formed on the shrubs (Mountousis et al., 2008; Kamalak, 2006). Kacar et al. (2006) reported tight relationships between N concentration and the physiological activities of plants. Nitrogen concentration is high in tissues and organs in which physiological activity is most significant, as in leaves.

However, the low N content of shrubs harvested at 13 WAE could be attributed to the relative increase in structural material (cell wall constituent and lignin) and storage compounds such as starch. This observation agrees with Marie and Jan (2003), who indicated that some nutrients get lost through remobilization as leaves senescence or through leaching.

The mean P concentration in all the shrubs was higher than the maximum value of P (0.38%) reported for most tree leaves by Mandal (1997). It was, however, more significant than the requirements of dairy cattle (0.31-0.40% of diet DM) as well as sheep (0.16-0.38%) recommended by NRC (2001). The minimum P-value of 1.318% for *S. mucronata* observed in the study was higher than the minimum animal requirement of 0.20% of DM, as reported in Rahim et al. (2013). In these cases, P supplementation will not be prudent. The high P content in the shrubs could have resulted from the ability of the shrubs to extract available P from the soil. Phosphorus is highly susceptible to leaching by heavy rains and runoffs, but the water supply to the experiment was manual, and therefore leaching might have been avoided (King et al., 2015). The significantly low Phosphorus-value recorded by *S. mucronata* could be due to its ability to conduct available P through its physiological activities. It was noted that different plant species responded differently to the absorption of nutrients from the soil (Wang and Moore, 2014).

However, P contents in all the shrub species were within the normal requirement range of 1.20 - 4.80% in shrub foliage recommended by NRC, according to Kindu et al. (2009). The significantly low P content in the shrubs harvested at 10 WAE could have resulted from moisture stress. Adequate soil moisture content is an essential driver of the availability of P. Moisture supply to the plants during the experiment was temporarily affected by inadequate water in the area, which could have affected the availability and uptake of P from the soil (Khosla and Alley, 1999).

Mean K content for the shrub species exceeded the normal requirement range of 5.0 - 10.0% (Kindu et al., 2009). The food requirement of K for milk-producing cows is 0.80 % of DM (NRC, 2001), but the maximum tolerable level of K is 3% (NRC, 1985). The mean minimum K value obtained from this study was 4.63% more than the maximum tolerable level, and the shrubs could be an alternative source of K for ruminant diets. The significant variation in mean K content among the shrubs is attributable to their different physiology, which could have influenced the uptake of K (Wang and Moore, 2014).

The study observed that mean K content declined significantly ($P<0.05$) this corroborates with Kabaija and Smith (1988) and Ziblim et al. (2015) who conducted a similar study and found that K content declines significantly due to the age of the shrubs. This decline may be due to the dilution of this element in a great quantity of dry matter produced and accumulated with advancing age. Potassium plays an essential role in the photosynthesis process, where it is involved in stomatal regulation and enzyme activation (Lebaudy et al., 2008). A decrease in photosynthesis is closely connected with a reduced potassium content in the forage leaves (Jin et al., 2011).

The Ca content was relatively similar for all the shrubs, which may be attributed to their characteristic structure. The mean Ca content of the shrubs was more significant than the feed requirements for milk-producing cows (0.43 - 0.60% of DM) endorsed by NRC (2001). According to NRC (1985), ruminants can tolerate Ca contents up to 2% of DM, indicating that the shrub species investigated have more than enough Ca to provide animals that feed on them. Also, the mean Ca content obtained for all the shrub species during the harvesting periods was within the normal requirement range of 1.90 - 8.20% in shrub foliage, according to Kindu et al. (2009). The shrub leaves contained a relatively higher Ca level in the period that the research was carried out (dry season), which agrees with the results obtained by Abdul-Razak et al. (2000) and Aganga et al. (2000). Therefore, the four (4) shrub species may provide a good source of Ca supplement in the dry season. Plant maturity did not significantly influence the Ca content of the shrubs.

Similarly, the mean Mg contents of the shrubs were very close. The indifference in the Mg content could be attributed to their genetic factors since Mg is mainly located within the protoplasm (Spears, 1994). Magnesium contents for all the shrubs were within the normal requirement range of 1.0 - 2.50% for ruminants. The Mg values recorded from the study were more than the requirement of Mg (0.12 - 0.18% of diet DM) for sheep (NRC, 1985). Generally, the high concentration of the minerals in the shrubs is attributable to their availability in the soil (Lukhele and Van Ryssen, 2003).

Conclusion

The findings of this investigation indicated that the maturity stage has a major effect on the mineral content of plant leaves. Though *Cajanus cajan, Stylosanthes mucronata, Tephrosia purpurea, and Securinega virosa* have the potential to reduce mineral deficits, their optimum harvesting phases must be determined before they may be suggested in special dietary programs. In scenarios where a food-based approach is being pursued to correct iron and zinc deficiencies, these leafy vegetables must be collected when still young (between 7 and 10 WAE).

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