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Research Article

Comparative nutritive value of an invasive exotic plant species, *Prosopis glandulosa* Torr. var. *glandulosa*, and five indigenous plant species commonly browsed by small stock in the BORAVAST area, south-western Botswana

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Abstract: Nutritive value of an invasive exotic plant species, *Prosopis glandulosa* Torr. var. *glandulosa*, and five indigenous plant species commonly browsed by livestock in Bokspits, Rapplespan, Vaalhoek and Struizendam (BORAVAST), southwest Botswana, was determined and compared. These five indigenous plant species were *Vachellia hebeclada* (DC.) Kyal. & Boatwr. subsp. *hebeclada*, *Vachellia erioloba* (E. Mey.) P.J.H. Hurter, *Senegalia mellifera* (Vahl) Seigler & Ebinger subsp. *detinens* (Burch.) Kyal. & Boatwr., *Boscia albitrunca* (Burch.) Gilg & Gilg-Ben. var. *albitrunca* and *Rhigozum trichotomum* Burch. The levels of Crude Protein (CP), Phosphorus (P), Calcium (C), Magnesium (Mg), Sodium (Na) and Potassium (K) were determined for the plant's foliage and pods (where available). All plant species had a CP value higher than the recommended daily intake. There are however multiple mineral deficiencies in the plant species analysed. Nutritive value of *Prosopis glandulosa* is comparable to those other species despite the perception that livestock that browse on it are more productive than those that browse on the other plant species.

Introduction

Prosopis glandulosa is an invasive leguminous tree/shrub that has valuable characteristics that make it good for alleviating critical fuel wood shortages, forage shortages and limiting the increasing desertification of arid and semi-desert regions. These characteristics include rapid growth, good wood fuel production, pod production, nitrogen fixation, and high drought and salt tolerance (Leakey and Last, 1980). The plant is native to the Americas, Asia and some parts of Africa; however, it is invasive in Southern-Africa, East Africa, Pakistan, India, Brazil and Australia (Paseicznik *et al*. 2001). The plant has a deep tap root system that spreads widely to consume whatever moisture is available in the soil. The branches are covered in spines above the auxiliary buds which can cause damage to flesh (Bainbridge *et al*. 1990). *P. glandulosa* is an important livestock feed, especially in times of drought. However, Stubbendieck *et al*. (1993) state that if livestock overfeed on it, impaction, rumen stasis, and death may occur.

Prosopis invasion in Botswana is recent. It was introduced in southern Kgalagadi in the 1970s to serve two purposes, the first being to stabilise sand dunes that were encroaching into rangelands and the second being to provide fodder for livestock. This plant has however become invasive along the Molopo-Nossob river basins and settlements. It has a tendency to form thickets and clogs boreholes with its extensive root system. Ever since it was introduced in the area, many native plant species have gradually declined in abundance and thus

Table 1: Recommended nutrients' quantities for small stock production.

Macro-mineral	**Concentration**	**Notes**
Calcium	0.17-2.17%	Functions in bone, muscle and nerve contractions; Deficiency causes rickets, bowed limbs, lameness; Vitamin D necessary for calcium absorption; Most grains are deficient in calcium (Carafoli, 1991).
Crude protein	7%	Protein is required for most normal functions of the body, including maintenance, growth, and reproduction, lactation, and hair production. Protein deficiencies in the diet deplete stores in the blood, liver, and muscles and predispose animals to a variety of serious and even fatal ailments. Food intake and dietary digestibility are reduced if dietary crude protein is <6%, further compounding an energy-protein deficiency (McDonald *et al*. 2002).
Magnesium	0.18-0.4%	Functions as a component of bones and function of nervous and muscle system. Major deficiency symptom is grass tetany on lush cool season pastures, excitability, staggering, confusions and loss of appetite. Feed is said to be palatable with high level of magnesium (Ebel and Günther, 1980).
Sodium	0.09-0.21%	Sodium maintains osmotic pressure, regulates acid–base equilibrium and controls water metabolism in the body. The first sign of sodium deprivation is pica or a craving for salt, manifested by avid licking of wood, soil, urine or sweat. This can occur within 2–3 weeks of deprivation. Water consumption can become excessive (polydipsia) and urine output greatly increased. After several weeks, appetite and milk yield begin to decline and the animal loses weight and develops a haggard appearance because of a rough coat, while milk fat content decreases. In a high-producing cow, the breakdown can be sudden, and death ensues (Suttle, 2010).
Phosphorus	0.3%	Functions in soft tissues, bone growth, and regulation of body pH; Deficiency reduces growth, pica, and depraved appetite; Expensive feed ingredient; May be close to adequate if poultry manure has been applied; The formation and maintenance of bone are quantitatively the most important functions of phosphorus (Suttle, 2010).
Potassium	0.8-2.0%	Potassium inevitably contributes to the regulation of acid-base balance and participates in respiration (Suttle, 2010). Potassium has an important role in metabolism. However, forages generally are quite rich in potassium, so a deficiency in grazing goats is extremely rare. Marginal potassium intake is seen only in heavily lactating goats fed diets composed predominately of cereal grains. Excessive potassium intake (particularly in late gestation) may be associated with hypocalcaemia in dairy goats (Moleele, 1998). Deficiency causes reduced growth, pica-depraved appetite, stiffness.

livestock is forced to browse on this plant, especially during the dry season as it is a perennial evergreen plant species. There has been a growing perception that small stock feeding on this plant tend to be much more productive than those browsing indigenous plant species.

In the BORAVAST (Bokspits, Rapplespan, Vaalhoek and Struizendam) area small stock farming is prominent, however cattle, horses, donkeys and mules are also bred in the area. Husbandry in a semi-arid region like Botswana is characterized by cycles of under-nutrition and over-nutrition (phased nutrition). Nutritional needs of small stock vary from individual to individual based on maintenance, growth, pregnancy, lactation, activity and environment. Generally, sheep and goats consume 2-4% of their body weight of dry matter feed (Ensminger, 2002). This varies from creature to creature based on the weight of the animal. Small stock requires energy, protein, vitamins, fibre and water. Energy is usually the most limiting nutrient. Minerals such as calcium, crude protein, magnesium, phosphorus, potassium and sodium are required by small stock for adequate animal production. They play a major role in the skeletal, nervous system functions and function of other systems in the body (Ensminger, 2002).

Tree leaves from *Acacia* (now split into *Vachellia* and *Senegalia*, Kyalangalilwa *et al*. 2013) species are an important component of the diets of goats and sheep (Holecheck, 1984; Papachristou and Nastis, 1996). Results from a study by Abdulrazak *et al*. (2000) on *Acacia* species showed that the crude protein of *Acacia* foliage is high enough to use as a supplement to low quality diets, and that these species are rich in most minerals. They tend to remain green longer into the dry season and their chemical composition varies very little with season. However, *Acacia* species have the disadvantage of containing phenolic compounds, which include tannins. These compounds have a negative effect on the feeding value of the browse and affect intake and digestibility of the diet (Abdulrazak *et al*. 2000). The leaves are high in crude protein, energy and minerals (Le Houerou, 1980). However, the use of browse by herbivores is restricted by the detrimental effects of the tannins contained in them (Provenza, 1995). Productivity of sheep and goats feeding on foliage of these trees is therefore, often low. Feeding trials have shown that the feeding value of *Acacia* foliage is low although the crude protein content is high.

Table 1 shows the recommended daily nutrients' quantities for small stock production. It also states the function of the various macronutrients and the results of deficiencies in these minerals.

As mentioned earlier, there is a perception in BORAVAST that small stock that feed on *Prosopis* are much more productive than those that browse on indigenous plant species. Thus, the aim of this study was to determine and compare the nutritive value of *Prosopis glandulosa* and five indigenous plant species commonly browsed on by small stock in the BORAVAST area. Mineral nutrients studied were crude protein (CP), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), which are all important for animal production.

Materials and methods

The study area

The study site was BORAVAST, which is an acronym for Bokspits (20º 53' 16.88" S, 20º 41' 30.63" E), Rapplespan (26º 49' 50.20" S, 20º 48' 52.89" E), Vaalhoek (26º 53' 19.96" S, 20º 42' 01.95" E) and Struizendam (26º 39' 28.23" S, 20º 38' 27.38" E). These are villages located in the Kgalagadi District in the South-Western most tip of Botswana (Fig. 1). The area receives an annual average rainfall of about 200mm, making it one of the driest in Botswana. Kgalagadi South is made up of two main landform types; the riverbed and the upland. The upland land system is characterized by aeolian sand deposit forming undulating to rolling longitudinal dunes.

Kgalagadi vegetation type is generally described as arid shrub savanna (Weare and Yalala, 1971). The BORAVAST area is characterised by different landforms of sand dunes, inter-dunes and river valley. The landforms are occupied by differing plant species. The sand dunes are usually colonized by *Stipagrostis amabilis* (Schweick.) De Winter and *S. namaquaensis* (Nees) De Winter on the apex/crest. The lower part of the dune usually consists of *Schmitdia kalaharien*sis Stent and *Stipagrostis obtusa* (Delile) Nees. The inter-dunes mainly consist of *Rhigozum trichotomum* Burch. and other few grass species. *R. trichotomum* is mostly dominant in flat areas especially where calcrete is near the ground surface. Large trees are mostly found in the inter-dunes. These trees include *Vachellia erioloba* (E. Mey.) P.J.H. Hurter, *V. haematoxylon* (Willd.) Seigler & Ebinge and *Senegalia mellifera* (Vahl) Seigler & Ebinger subsp. *detinens* (Burch.) Kyal. & Boatwr. *Boscia albitrunca* (Burch.) Gilg & Gilg-Ben. var. *albitrunca*, *Boscia foetida* Schinz and *Vachellia haematoxylon* are found on relatively flat areas and on inter-dunes. The valleys of the rivers Molopo and Nossop contain mainly tree species *Vachellia erioloba*, *V. hebeclada*, *V. luederitzii* (Engl.) Kyal. & Boatwr., *Rhigozum trichotomum* and a diversity of herbs and grasses too many to mention here. These river valleys and empty spaces in the villages, including along internal roads and those connecting the villages, are invaded by a number of *Prosopis* species. Muzila *et al*. (2011) recorded four species of this genus in the BORAVAST area, being *Prosopis chilensis* (Molina) Stunz emend Burkart, *P. juliflora* Swartz DC, *P. velutina* Wooton and *P. glandulosa* Torrey.

Study design

A direct observation on foraging behaviour of goats in BORAVAST revealed that they browsed on *Prosopis glandulosa*, *Vachellia hebeclada*. subsp. *hebeclada*, *V. erioloba*, *Senegalia mellifera* subsp. *detinens*, *Boscia albitrunca* and *Rhigozum trichotomum*, hence these plants were selected for the study. Foliage samples were collected in brown paper bags from *Prosopis glandulosa*, *Vachellia hebeclada*. subsp. *hebeclada*, *V. erioloba*, *Senegalia mellifera* subsp. *detinens*, *Boscia albitrunca* and *Rhigozum trichotomum* in the BORAVAST area in December 2012. Mature pods were collected from *Prosopis glandulosa*, *Vachellia hebeclada*. subsp. *hebeclada* and *V. erioloba*. This was because small stock browses only on mature pods because young pods tend to contain high levels of tannins and are unpalatable. The samples were oven dried at 105ºC

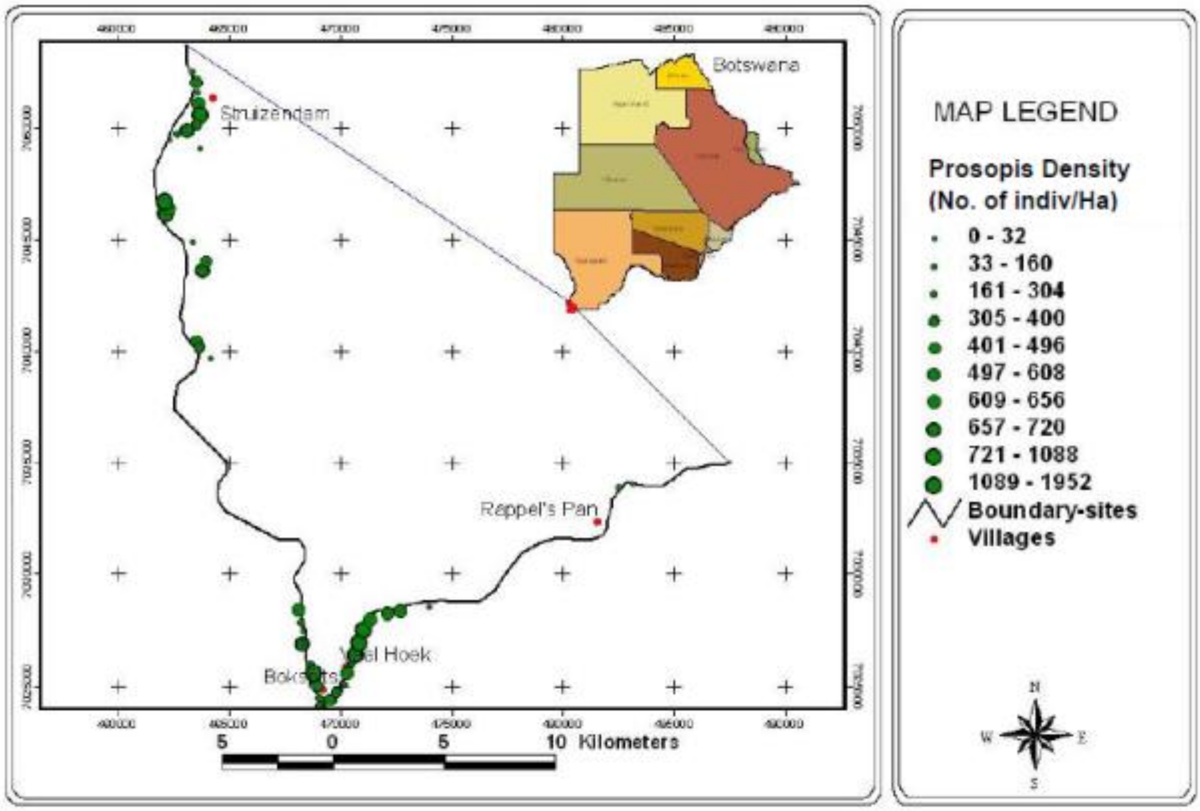

Fig. 1: Study area showing Prosopis invasion.

for 24 hours to determine dry matter content after which they were ground through a 2mm sieve using the Thomas-Willey Laboratory Mill then stored in airtight plastic bags pending analysis. Crude protein was determined using a Nitrogen Determinator. Calcium and Magnesium were determined by Atomic Absorption Spectrophotometer while Sodium and Potassium were determined by using a Flame Photometer.

Statistical analysis

Because there are more than two sample groups (plant species) being analysed the student t-test was adequate for this analysis. This is because in an independent-samples t-test, the means of two groups are compared. There were nine sample groups being analysed and thus at least 72 possible t-tests called pair-wise comparisons. A procedure that compares all nine group means simultaneously was needed to see if there were any differences when they were considered as a group. Thus, the procedure used in this analysis was the one-way Analysis of Variance (ANOVA). The one-way ANOVA procedure involves a test called the overall F-test, named such because its test statistic follows the F distribution. The analysis should show that there is a significant difference between the means of the sample groups and thus a follow-up analysis was conducted to test pair-wise comparisons. This was the Bonferroni Method, which is conceptually the simplest and which can be done without statistical software (Baldi and Moore, 2009).

Results

Chemical composition

Crude Protein

1. There was a statistically significant difference between the plant samples as determined by ANOVA ($F_{(8, 9)} = 288.549$, $p = 0.000$).
2. *Senegalia mellifera* leaves had the highest concentration of crude protein, followed by *Boscia albitrunca* leaves and *Rhigozum trichotomum* leaves (Fig. 2).
3. There was a significant difference between the CP level of *Vachellia erioloba* leaves and pods however the difference between *Prosopis glandulosa* leaves and pods and *Vachellia hebeclada* leaves and pods was very small or of no significance.

Mineral composition

Calcium

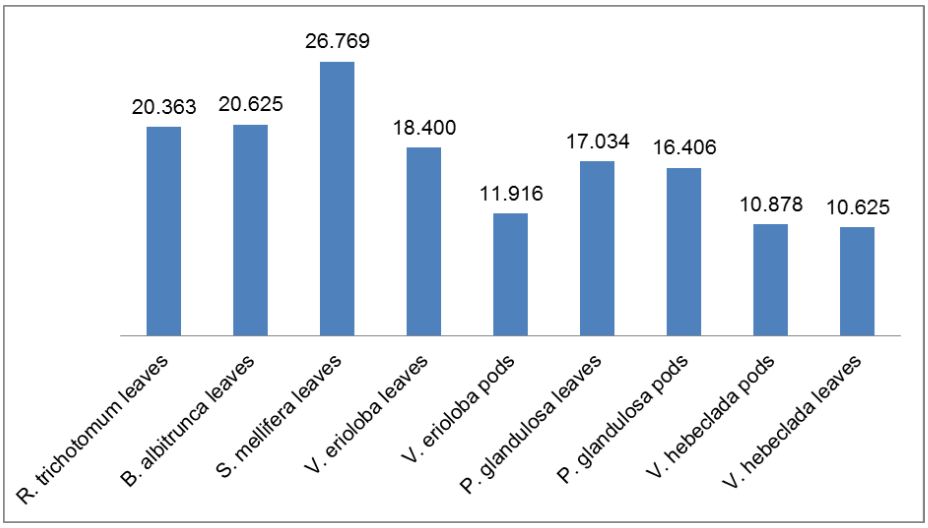

Fig. 2: CP content (%) of different browse species in BORAVAST area.

1. There was a statistically significant difference between the plant samples as determined by ANOVA ($F_{(8, 45)}$ = 2.152, p = 0.050).
2. Leaves of legumes i.e., *Vachellia*, *Senegalia* and *Prosopis* species, contained more Calcium than leaves of *Rhigozum trichotomum* and *Boscia albitrunca* (Fig. 3).
3. Leaves of the legumes contained more Calcium than their pods.
4. *Senegalia mellifera* subsp. *detinens* leaves had the highest Calcium levels, followed by those of *Vachellia erioloba*, then *Vachellia hebeclada* and finally *Prosopis glandulosa*.
5. Pods sampled from *Vachellia erioloba*, *V. hebeclada* and *Prosopis glandulosa*, contained Calcium in the range 0.06 % to 0.08%.

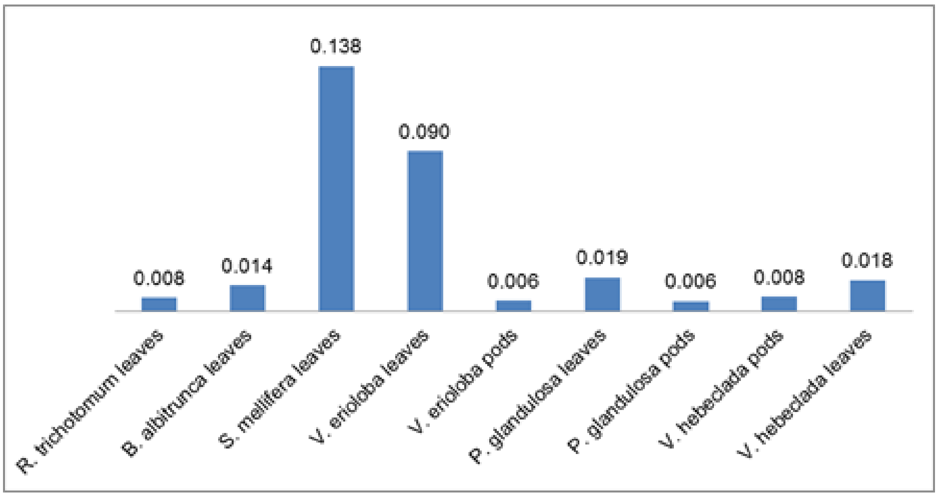

Fig. 3: Ca content (%) of different browse species in BORAVAST area.

Sodium

1. There was a statistically significant difference between the plant samples as determined by ANOVA ($F_{(8, 45)}$ = 6.456, p = 0.000).
2. Leaves had more sodium content than pods in *Vachellia hebeclada* but *Prosopis glandulosa* and *Vachellia erioloba* recorded lower sodium concentration in their leaves than the pods (Fig. 4).
3. *Vachellia hebeclada* and *Rhigozum trichotomum* had more overall sodium content than *Prosopis glandulosa*.

4. *A. hebeclada* leaves had the highest Na content followed by *R. trichotomum* leaves and *P. glandulosa* pods.

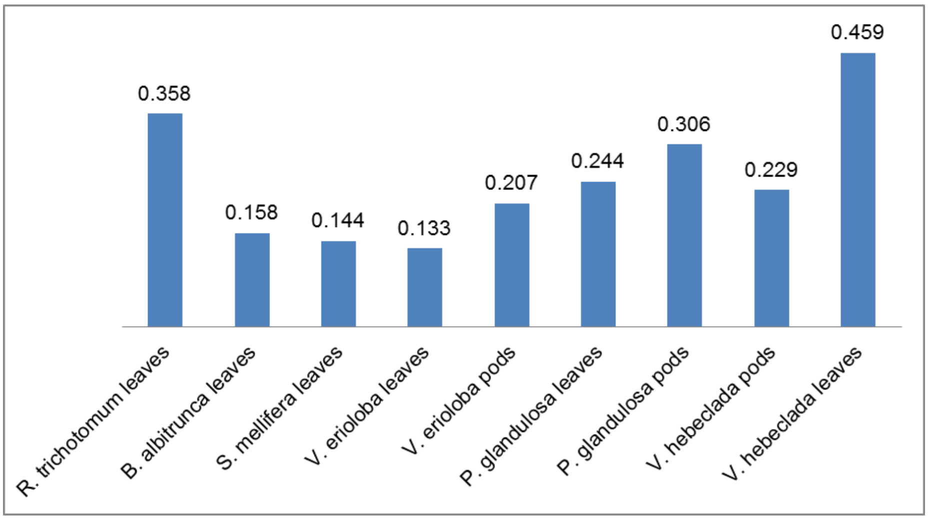

Fig. 4: Na content (%) of different browse species in BORAVAST area.

Potassium

1. There was a statistically significant difference between the plant samples as determined by ANOVA ($F_{(8, 45)}$ = 12.256, p = 0.000).
2. *Vachellia hebeclada* leaves had the highest potassium content followed by *R. trichotomum* leaves and *P. glandulosa* pods (Fig. 5).
3. *Vachellia erioloba* and *Prosopis glandulosa* had more potassium in their pods than in their leaves however; *Vachellia hebeclada* had more potassium in its leaves than its pods.

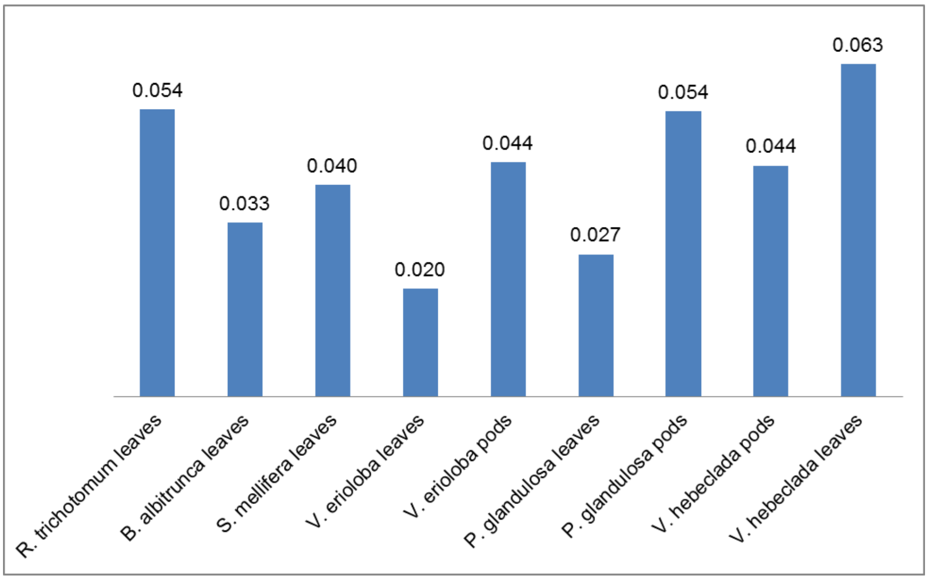

Fig. 5: K content (%) of different browse species in BORAVAST area.

Magnesium

1. There was a statistically significant difference between the plant samples as determined by ANOVA ($F_{(8, 45)}$ = 769.795, p = 0.000).
2. *Boscia albitrunca* leaves recorded very high average magnesium, roughly 14 times higher

than all the other plant species (Fig. 6)

3. *B. albitrunca* leaves had the highest Mg content followed by *Vachellia hebeclada* leaves and *Prosopis glandulosa* leaves.
4. In plant species whereby leaves and pods were analysed, more magnesium was found in the leaves than in the pods.

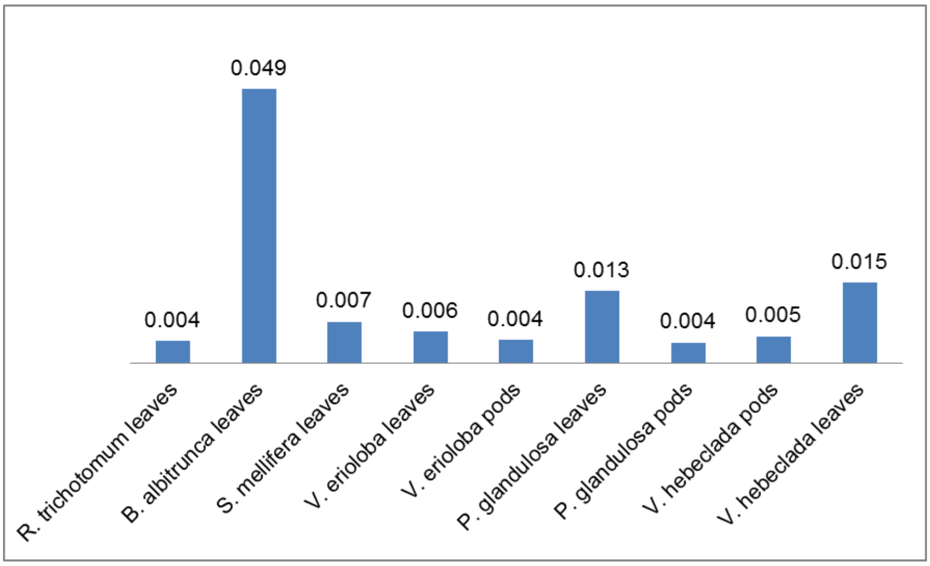

Fig. 6: Mg content (%) of different browse species in BORAVAST area.

Phosphorus

1. There was a statistically significant difference between the plant samples as determined by ANOVA ($F_{(8,\ 45)} = 2.282$, $p = 0.038$).
2. *Rhigozum trichotomum* had the highest P value, followed by *P. glandulosa* pods and *V. hebeclada* leaves and pods (Fig. 7).
3. *Vachellia hebeclada* had more P in its leaves than its pods whereas *V. erioloba* and *Prosopis glandulosa* had more P in their pods than their leaves.

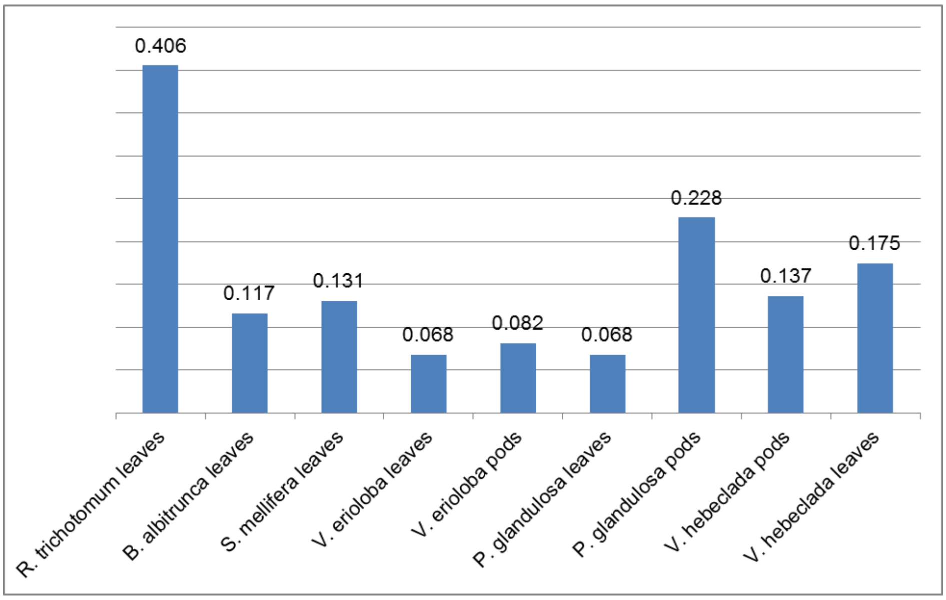

Fig. 7: P content (%) of different browse species in BORAVAST area.

Discussion

Overall the results show that there was a significant difference in the nutritional value of *Vachellia erioloba, Vachellia hebeclada, Senegalia mellifera, Boscia albitrunca, Rhigozum trichotomum* and *Prosopis glandulosa*. Thus, the perception that *Prosopis glandulosa* is more nutritious than native plant species commonly browsed on by small stock in the BORAVAST area of Botswana has been proven to be incorrect by this study. There was also some nutrient partitioning within the plant. This was evident when evaluating the samples collected from mature pods in comparison with those of foliage. For instance *Vachellia erioloba* leaves had a Ca level 15 times higher than that of the pods. *Prosopis glandulosa* and *Vachellia hebeclada* leaves had a Ca level 3 times higher than that of their pods. The Ca levels ranged from 0.06 to 0.138%. These fall far below the recommended daily intake for small stock production which is 0.17 to 2.17%. All the plant species examined were deficient in Ca. This could be attributed to low soil fertility in the area as it is characteristic of sandy soils (Norton, 2013). Due to the Ca deficiency, the small stock in BORAVAST should have hampered productivity, but that is not the case. This suggests that the animals are getting their Ca from other sources other than the plant species analysed in this study.

Vachellia hebeclada leaves had the highest concentration of Na as compared to other samples examined, followed by *Rhigozum trichotomum* leaves and *Prosopis glandulosa* pods. In cases where both leaves and pods were analysed, the leaves had a higher mineral concentration than the pods. This is a further confirmation of mineral partitioning in the plant species.

Forages are generally poor in Na due to soil, plant and husbandry factors (Minson, 1990). Na is readily leached from soils with a low cation exchange capacity (Edmeades and O'Connor, 2003). The distribution of pasture Na concentrations worldwide is skewed towards low values, with 50% of samples containing <1.5% Na, and low values are more common in tropical than in temperate pastures: 50% of tropical legume samples contain <0.4% Na (Minson, 1990). The plant species analysed in this study fall within the concentration ranges noted by Minson (1990). The samples had Na values ranging from 0.133 to 0.458%. *A. hebeclada* leaves and pods, *P. glandulosa* leaves and pods and *R. trichotomum* leaves recorded Na levels above the required levels for animal production. No plant species analysed had a Na level below the required level for adequate goat and sheep production.

Vachellia hebeclada leaves had the highest potassium concentration, followed by *Rhigozum trichotomum* leaves and *Prosopis glandulosa* pods. Potassium was also partitioned in plant tissue as in the case of calcium and sodium. Pods of *Vachellia erioloba* and *Prosopis glandulosa* had more potassium than their leaves whereas *Vachellia hebeclada* leaves had more K than the pods. 0.8 to 2% K is required for adequate production in small stock (Suttle, 2010). None of the analysed plant species meet this requirement and thus the livestock must have another source for this mineral. Ward (1966) and Suttle (2010) stated that a deficiency of K causes reduced growth, and pica-depraved appetite.

Boscia albitrunca leaves had a magnesium concentration 3 times higher than the sample with the next highest concentration (*Vachellia hebeclada* leaves). Apart from this the magnesium concentrations of the different plant species were not very varied. Even though *Vachellia erioloba* leaves had a higher magnesium concentration than the pods, the difference was very minimal. *Prosopis glandulosa* leaves also had a higher Mg concentration than the pods and the difference was significant. *Vachellia hebeclada* leaves had more Mg than the pods and the difference was very significant. The required Mg level for adequate small stock is 0.18 to 0.4%. Even though *B. albitrunca* recorded the highest Mg value in comparison to the other plant species analysed, it was deficient in the mineral and thus all the plant species had Mg values far below the required Mg value for small stock production.

Crude protein content is the major factor limiting the production of small stock and animals need as much as seven percent of their feed for adequate growth (McDonald *et al*. 2002). *Vachellia erioloba* had the highest CP content of all the plant species analysed. Together with *Senegalia mellifera*, *Boscia albitrunca* and *Rhigozum trichotomum* had higher CP levels than *Prosopis glandulosa*. *Vachellia hebeclada* had the lowest CP content. There was a significant difference between the plant species CP levels. All the plant species had CP content levels above the recommended CP concentration by McDonald *et al*. (2002). This could be due to the nitrogen fixation characteristic of the plant species as they are all leguminous plants.

A deficiency in Phosphorus results in reduced growth, pica (an eating disorder in which non-nutritional objects are eaten persistently) and a depraved appetite (Suttle, 2010). The recommended P content for small stock is 0.3% (Suttle, 2010). There was a significant difference between the P values of the different plant species analysed. *Rhigozum trichotomum* was the only plant species with a P concentration above the recommended P concentration. The second highest P value was that of *Prosopis glandulosa* pods. *Prosopis glandulosa* leaves had the lowest P values together with *V.*

erioloba leaves. Almost all the plant species were deficient in P. *Prosopis glandulosa* had a P very close to the recommended P value.

Mineral concentrations in plants generally reflect the adequacy with which the soil can supply absorbable minerals to the roots. However, plants react to inadequate supplies of available minerals in the soil by limiting their growth, reducing the concentration of the deficient elements in their tissues or, more commonly, by reducing growth and concentration simultaneously. The extent to which a particular response occurs varies with different minerals and different plant species or varieties and with the soil and climatic conditions.

Nevertheless, the primary reason for mineral deficiencies in grazing animals, such as those of phosphorus, sodium, cobalt, selenium and zinc, is that the soils are inherently low in plant-available minerals (Alloway, 2004).

Conclusions

From the results of this study, it is evident that browse species analysed had multiple deficiencies in minerals considered. Crude protein was the only one that was generally higher than the recommended daily intake for small stock. Small stock can be given such minerals as Phosphorus which can be easily supplemented in feed. *Prosopis glandulosa* was comparable to other browse species in terms of its mineral composition despite the perception in BORAVAST that it is much more nutritious than the other browse species.

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