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Elemental contents of *Gliricidia-Megathyrsus* mixtures

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ABSTRACT

The role of minerals in animal production, especially ruminants cannot be overemphasized because the imbalance of minerals associated with forages and feeds could lead to such animals not performing to the desired levels or exhibiting defects. This study evaluated the mineral elements and ratios of some of the macro-elements of *Gliricidia sepium* and *Megathyrsus maximus* and their proportional mixtures. The experiment was a completely randomized design with five (5) proportions as treatments; 100% *G. sepium* (100G); 75% *G. sepium* + 25% *M. maximus* (75G:25M); 50% *G. sepium* + 50% *M. maximus* (50 G:50M); 25% *G. sepium* + 75% *M. maximus* (25G:75M) and 100% *M. maximus* (100M). The mineral contents of the mixtures of *Gliricidia* and *Megathyrsus* were determined and the ratios (Ca:P, K:P, N:P, K:Mg, K:(Ca+Mg) were estimated. The effect of proportion was significant ($P < 0.05$) on all the mineral elements and their ratios. The 100% *G. sepium* had the highest concentration of Ca, Mg, Na and N as well as the highest ratios of Ca:P and N:P. *Megathyrsus maximus* was noted to have the highest amount of K as well as K:Mg and K:(Ca+Mg) ratios. The highest concentration of *P* was recorded for 75% *G. sepium* + 25% *M. maximus.* The estimated ranking of the tetany prevention potential of the mixtures were 100M > 25 G:75M > 50 G:50M > 75G:25M > 100G. The forages and the mixtures had sufficient amounts of both macro and micro-elements that could meet requirements of different classes of ruminants.

Keywords: Grasses, Legumes, Mineral, Mixtures, Tolerable limit

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Introduction

Minerals are essential components of livestock diets because they regulate metabolic processes and provide cellular structure. Inadequate nutrition can cause a variety of symptoms, including loss in weight, reproductive disorders, heart disease, anemia, joint problems, and fragile bones (Gupta *et al.,* 2008). Even though there are no overt symptoms, these effects may nonetheless have a negative influence on the health and performance of animals, the root of which might be challenging to identify (Fisher, 2008). The negative impact on the animals might lead to low profitability and eventually death if the situations are not promptly addressed. Forage quality may be affected by specific minerals (Spear, 1994), nitrogen is noted to influence the quality of forages (Dele *et al.,* 2021), also ruminal bacteria need a number of minerals for appropriate growth and metabolism (Durand & Kawashima, 1980). Low levels of these elements in fodder could make it more difficult for microbes to breakdown fiber and the makeup of protein.

Studies have shown that low phosphorus concentrations in forage can impair fiber digestion (Durand & Komisarczuk, 1988). Lopez-Guisa & Satter (1992) proposed that divalent cations could act as a bridge between the negatively charged surfaces of bacterial and plant cell walls, enhancing fiber digestion. Therefore, a major way to address these imbalances in mineral concentration is to avail the animals a balance source of minerals. Sole feeding of either grasses or legumes to animals, even if the quality is high may reduce productivity and make them vulnerable as some of them might have excess concentration of a mineral element, while deficient in others. Even when the nutritional values of all the minerals are satisfied, imbalance can occur, may be due to synergetic-antagonistic relationships of the elements in plants and animals. Invariably, sole feeding of forages might result in poor production and metabolic problems (Marschner, 1995).

In general, legumes are richer in macro-minerals than grasses (Suttle, 2010; Ojo *et al.,* 2016) while members of the grass family are typically known to be deficient in calcium, phosphorus, sodium, cobalt, copper and zinc as well as magnesium, potassium, iron and occasionally, manganese (McDowell, 1996). The mixture of grasses and legumes has been found to consistently have higher concentration of some minerals than sole grasses (Hopkins *et al.,* 1994; Spear, 1994; Ojo *et al.,* 2016). *Gliricidia sepium* (Jacq.) Kunth ex Walp. is one of the major Pantropical forage trees which is rich in protein with high nutritive value (Babayemi & Bamikole, 2006; Heuze & Tran, 2015) and commonly found around homes and used as live-fencing and as well as fodder sources for ruminants along the region of West Africa. *Megathyrsus maximus* (Jacq.) B. K. Simon & S. W. L. Jacobs, usually called Guinea grass, of tropical Africa origin and is spread throughout the tropics (Heuze & Tran, 2020). It is suitable for grazing, conserved fodders as well as cut-and-carry (Dele, 2012). It is a fast-growing, green grass with significant nutritional content that is appealing to animals. However, to meet nutritional needs or enhance animal performance, it is typically advised to add legumes to it. It is necessary to identify ways to increase the mineral contents of the forages that are made available to animals since the quality of feed consumed has a significant impact on ruminant production The aim of this study was to investigate concentrations of mineral elements in *Gliricidia-Megathyrsus* mixtures and effects of their proportion and the ratios on the variations in the contents.

Materials and Methods

Experimental sites

The study was carried out at the Pasture Unit of the Directorate of University Farms and the laboratory of the Department of Pasture and Range Management, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta (FUNAAB) Nigeria. The region lies within South-west Nigeria agro-ecological zone (Latitude 7^{o} 13'49.46''N, Longitude 3^{o} 26'11.98^{o}E). The vegetation is savannah with an average annual rainfall of 1037 mm (Google Earth, 2021). Relative annual humidity is high at 82% average and; temperature ranges between 20.66^{0}C in rainy season and 35.48^{o}C in the dry season (Department of Agro Meteorology, FUNAAB 2021).

Sourcing of Forage materials and experimental design

Megathyrsus maximus was harvested from a pasture plot that was established in October 2015 on a land area measuring 589 m^2 (31 m x 19 m). At the onset of the rainy season in March 2019, the plot was uniformly cut back to 20 cm height above ground level in order to stimulate re-growth. The plot was top-dressed with 30 kg/ha of NPK 15:15:15 fertilizer while the grass was allowed 6 weeks' period of re-growth before harvesting. The *Gliricidia* leaves were harvested from an already established intensive feed garden at the Directorate of University Farms, FUNAAB. The harvested forage materials were air-dried to constant weight and the two forages were combined into five (5) proportions (treatments) on dry matter basis with five (5) replicates: Sole Gliricidia (100G), 75% Gliricidia + 25% Megathyrsus (75G:25M), 50% Gliricidia + 50% Megathyrsus (50G:50M), 25% Gliricidia + 75% Megathyrsus (25G:75M) and sole Megathyrsus (100M).

Laboratory analysis

Samples of the harvested forages and their mixtures were oven-dried at 65 °C until constant weight, and ground in a Wiley mill to pass through 1.0 mm sieve screen. The nitrogen content, the macro-minerals (Ca, P, K, Mg and Na) and micro-minerals (Cu, Zn, Mn and Fe) were determined according to (AOAC, 1995). Nitrogen (N) was determined by simple digestion, distillation and titration according to (AOAC, 1995). The concentration of Potassium (K) was estimated with a flame photometer after wet digestion in nitric acid and per chloric acid. Concentrations of other minerals were determined with atomic absorption spectrophotometry (Fritz and Schenk, 1979). The relationships between the minerals; Ca:P ratio, K:(Ca + Mg) ratio, K:Mg ratio, N:P ratio, N:K ratio and K:P ratio values were estimated from their contents. Milli-equivalents per 100 g were used to calculate K:(Ca + Mg) and g/kg values to calculate others.

Statistical analysis

The data obtained were subjected to one way analysis of variance (ANOVA), while the treatment means were separated with Tukey HSD test. The box plots were built in SAS statistical software version 9.4.

Results and Discussion

Figure 1 shows the calcium concentration as influenced by proportion of *Gliricidia sepium* and *Megathyrsus maximus* mixtures. The Ca content increased significantly ($p < 0.05$) from 6.89 g/kg DM in the sole *Megathyrsus maximus* to 9.11 g/kg DM in sole *Gliricidia sepium*. It was observed that as the proportion of *G. sepium* increased in the mixtures, the Ca content increased correspondingly. The phosphorus content of the mixture with the highest proportion of *Gliricidia* (75G:25M) was not significantly ($p > 0.05$) different from that of sole *Gliricidia* while the mixture with the least proportion of *Gliricidia* (25G:75M) recorded the least content for *P* (Figure 2). The potassium content increased from 10.07 g/kg DM to 11.75 g/kg DM with the sole *Megathyrsus* having the highest value (Figure 3). Magnesium content of the sole *Gliricidia* was the highest (5.39 g/kg DM) and as the proportion of *Gliricidia* decreased the Mg content declined, with the sole *Megathyrsus* content been the lowest (Figure 4). The sodium content followed similar trend with that of Mg while the nitrogen content increased from 13.60 g/kg DM in sole *Megathyrsus* to 35.48 g/kg DM in sole *Gliricidia* (Figure 5). In Figure 6, the nitrogen concentration ranking was in the order of 100G > 75G:25M > 50G:50M > 25G:75M > 100M.

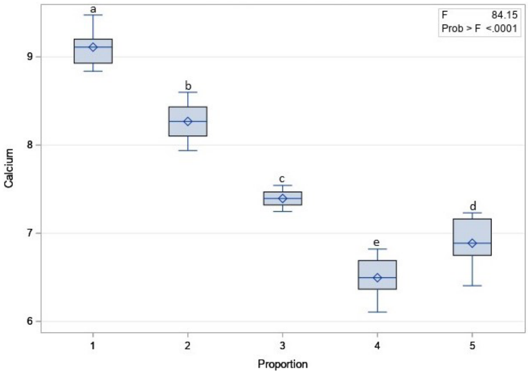

Fig. 1: Box and whisker plots of calcium concentration (g/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures ($p < 0.05$). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

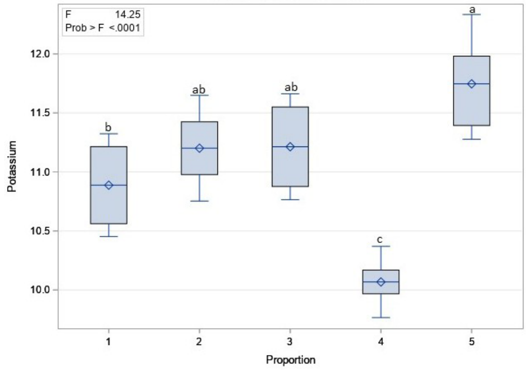

Fig. 3: Box and whisker plots of potassium concentrations (g/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures ($p < 0.05$). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

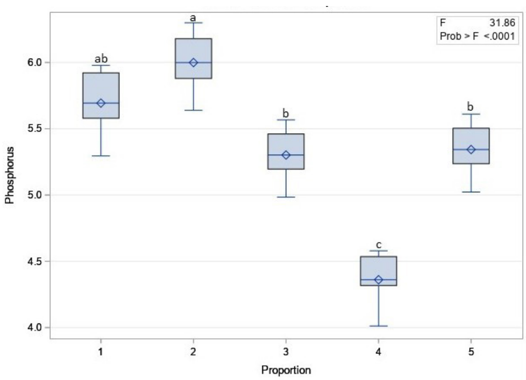

Fig. 2: Box and whisker plots of phosphorus concentration (g/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures ($p < 0.05$). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

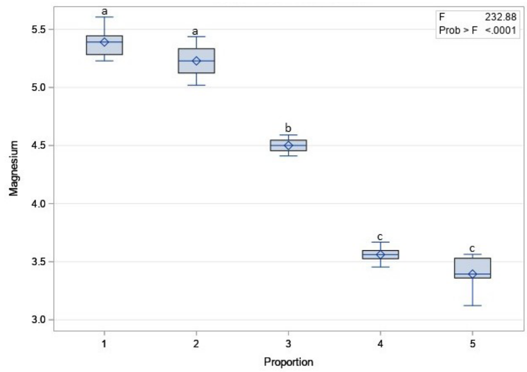

Fig. 4: Box and whisker plots of magnesium concentrations (g/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures ($p < 0.05$). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

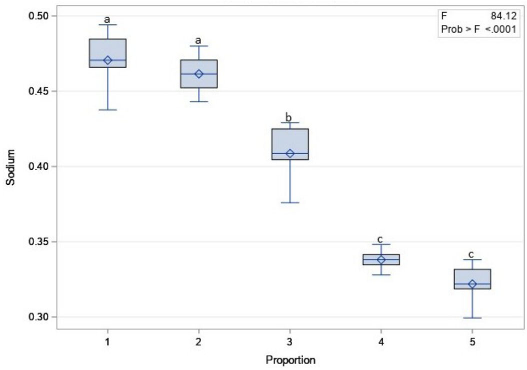

Fig. 5: Box and whisker plots of sodium concentrations (g/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures ($p < 0.05$). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

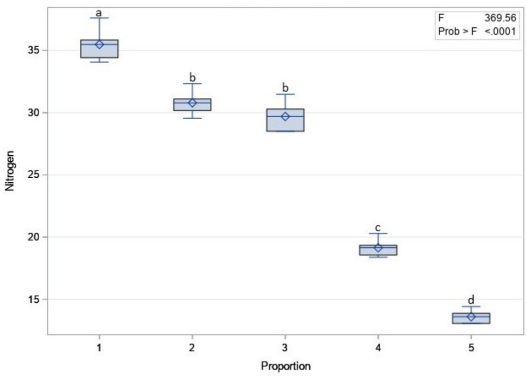

Fig. 6: Box and whisker plots of nitrogen concentrations (g/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures ($p < 0.05$). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

Fig. 7 showed the concentration of manganese as affected by *Gliricidia* and *Megathyrsus* proportions. The manganese content was significantly (p < 0.05) affected by the proportions, the highest (119.78 mg/kg DM) content was observed in sole *Megathyrsus* while the least (76.24 mg/kg DM) recorded for the mixture with the least *Gliricidia* (25G:75M). The iron (Fe) content significantly (p < 0.05) increased with increase in the proportion of *Gliricidia*, with sole *Megathyrsus* having the least value (Figure 8). In Figures 9 and 10, similar trend was also observed for the Cu and Zn contents of the forage mixtures, respectively.

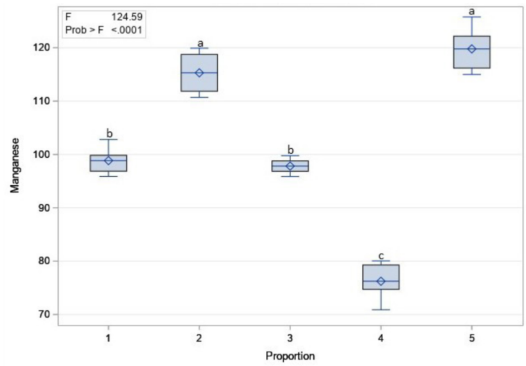

Fig. 7: Box and whisker plots of manganese concentration (mg/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures ($p < 0.05$). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

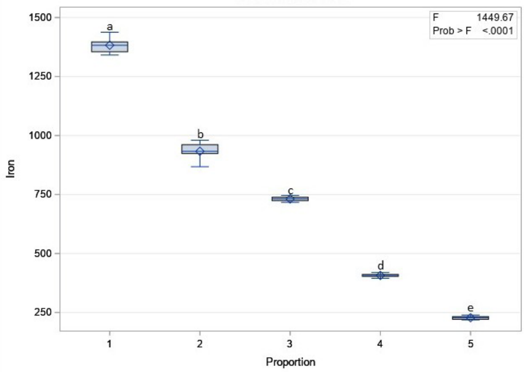

Fig. 8: Box and whisker plots of iron concentration (mg/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures (p < 0.05). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

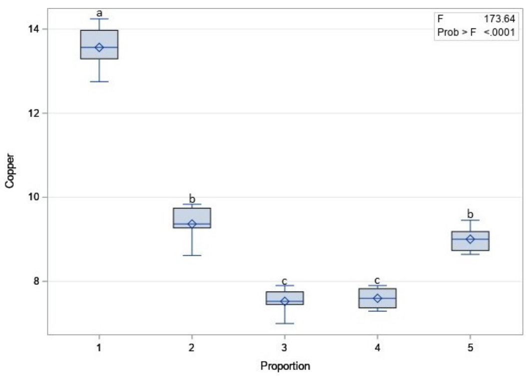

Fig. 9: Box and whisker plots of copper concentration (mg/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures (p < 0.05). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

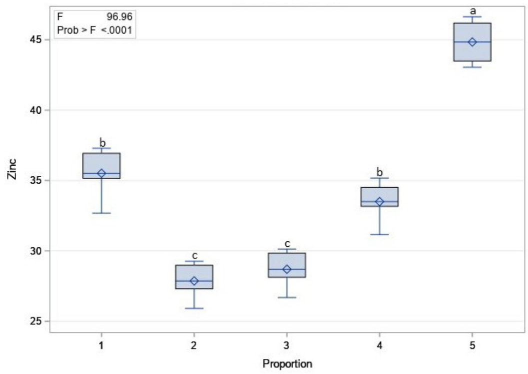

Fig. 10: Box and whisker plots of zinc concentrations (mg/kg DM) of Gliricidia-Megathyrsus mixtures as influenced by mixture proportion. Different lower-case letters depict significant differences among the five proportion of mixtures (p < 0.05). Proportions include: 1: Sole Gliricidia (100G), 2: 75% Gliricidia + 25% Megathyrsus (75G:25M), 3: 50% Gliricidia + 50% Megathyrsus (50G:50M), 4: 25% Gliricidia + 75% Megathyrsus (25G:75M) and 5: sole Megathyrsus (100M)

The elemental ratios of the forage mixtures were significantly ($p < 0.05$) influenced by the proportions as shown in Table 1. Sole *Megathyrsus* was observed to have recorded the least Ca:P ratio whereas sole *Gliricidia* recorded the highest Ca:P value (1.6). The K:P ratio was observed to range from 1.87 in the mixture with the least proportion of *Gliricidia* (25G:75M) though not significantly different ($p > 0.05$) from sole *Gliricidia*, to 2.31 in the mixture with the highest proportion of *Gliricidia* (75G:25M), which as well is statistically similar to that of sole *Megathyrsus*. The effect of proportion on the N:P ratio showed that the sole *Gliricidia* had the highest (6.25) value and the *Megathyrsus* had the least (2.55) value. Sole *Megathyrsus* had the highest values of 3.47 and 0.48 for K:Mg and K:(Ca+Mg) ratios, respectively while the lowest values were recorded for the sole *Gliricidia*.

TABLE 1

Effect of proportion on the ratios of macro minerals of *Gliricidia-Megathyrsus* mixtures

Proportions	Ca:P	K:P	N:P	K:Mg	K:(Ca+Mg)
100G	1.60[a]	1.91[c]	6.25[a]	2.02[d]	0.31[c]
75G:25M	1.49[b]	2.31[a]	5.14[b]	2.14[d]	0.34[c]
50G:50M	1.40[c]	2.12[b]	5.61[ab]	2.49[c]	0.39[b]
25G:75M	1.38[c]	1.87[c]	4.40[c]	2.83[b]	0.42[b]
100M	1.29[d]	2.20[ab]	2.55[d]	3.47[a]	0.48[a]
SEM	0.02	0.04	0.27	0.11	0.01

[a, b, c, d]: Means in same column with different superscripts are significantly ($p < 0.05$) different

Sole Gliricidia (100G); 75% Gliricidia + 25% Megathyrsus (75G:25M); 50% Gliricidia + 50% Megathyrsus (50G:50M); 25% Gliricidia + 75% Megathyrsus (25G:75M) and sole Megathyrsus (100M). SEM = Standard Error of Mean

Minerals are important dietary component in keeping livestock healthy and productive. Adequate amounts of essential minerals must be provided in the animal's diet to ensure proper metabolic function (Kennedy, 1991). The nitrogen content of the sole *Gliricidia* investigated was recorded to be superior to that of the *Megathyrsus* and other mixtures, due to genotypical differences. As expected, the N content declined with the increase in the proportion of *Megathyrsus*. The Ca content of the sole *Gliricidia* recorded in this study was higher than the range (1.8–8.2 g/kg DM) recommended as requirement for all classes of ruminants (McDowell, 1992, 1997; Khan *et al.,* 2006; Farhad, 2012) and the Ca content of the sun-dried Gliricidia (2.2 g/kg DM) reported by (Lamidi & Ogunkunle, 2015). The variation might be due to the air-drying method employed in this study. The Ca content of *Megathyrsus* was in the range (1.8–8.2 g/kg DM) reported above. The Ca content of sole *Megathyrsus* in this study fell within the range (1.9–17.5 g/kg DM) reported by (Heuze & Tran, 2020) whereas that of sole *Gliricidia* fell within (6.2–17.1 g/kg DM) reported by (Heuze & Tran, 2015). The Ca contents fell below the maximum tolerable limit (20.0 g/kg DM) reported by (NRC, 2005) above which there will be intake suppression.

The higher Ca content of the sole *Gliricidia* as against *Megathyrsus* in this study is in line with the report of (Barker & Pilbeam, 2007; Juknevicius & Sabiene, 2007; Lowe *et al.*, 2016) that legumes are generally inherently higher in Ca than grasses. The forages and their mixtures in this study can adequately supply Ca needed for bone and teeth formation for cattle (NRC, 2000) especially the calves. The proportion of *Gliricidia* in the mixtures affect the Ca content and explain why Ca content was lowered with reduction in the *Gliricidia* proportions (8.27, 7.39, and 6.50 g/kg DM for 75G:25M, 50G:50M and 25G:75M, respectively). The lower Ca content of sole *Megathyrsus* was improved in mixture with *Gliricidia*, hence the higher Ca content that will be available to animals as suggested by (Juknevicius & Sabiene, 2007; Ojo *et al.*, 2016). Going by the Ca content of the two forages and their mixtures, they are all considered to be high Ca-containing forages (McDowell & Valle, 2000) because they contained Ca above 3.0 g/kg DM higher than that required for all classes of ruminants. The phosphorus (P) requirement for grazing ruminants has been reported to be met by forages (McDowell, 1976; Underwood, 1981) but the P content of the forages and their proportions in this study have been noted to be higher than 2.5 g/kg DM which is the critical level of P for ruminants (McDowell, 1992, 1997).

This implied that, there might not be the need for P supplementation for animals reared on forage species used in this study as the forages and their mixtures could provide sufficient P needed for optimal productivity of all classes of ruminants. The P content declined with decrease in the proportion of *Gliricidia* in the mixtures. The P contents recorded in this study were higher than the range (1.8–4.8 g/kg DM) categorized as needed to meet the requirement of ruminants (McDowell & Valle, 2000), except for the P content of the mixture with the least proportion of *Gliricidia* (25G:75M) whose P value fell within the range. The relatively higher P content of *Gliricidia* as against that of *Megathyrsus* is in agreement with the reports of (Minson, 1990; Tanko, 2014) that legumes generally contained higher P content than grasses. The P content of *Megathyrsus* in this study was higher than the range of 1.69–3.37 g/kg DM reported by (Dele, 2012) for some organically fertilized grasses, the difference with the *Megathyrsus* in this study might have been caused by the fertilizer type applied, which is a compound inorganic fertilizer (NPK 15:15:15). The P content range (4.36–6.00 g/kg DM) reported in this study is lower than the maximum tolerable limit reported by Crawford (2007). The high P content of the forage proportions in this study confirmed that they are high quality forages that are good source of phosphorus which can reduce the cost of Phosphorus supplementation and can be a solution to P deficiency in ruminants especially during the dry season.

The importance of Potassium in animal diets has been linked to the maintenance of nerve and muscle excitability, as well as water and acid-base balance (Suttle, 2010). The K content of the forages and their mixtures are higher than the range (6–10 g/kg DM) recommended for dairy cattle (NRC, 2001). The higher K concentration recorded for *Megathyrsus* in this study is in concomitant with (Juknevicius & Sabiene, 2007; Kelling *et al.*, 2014) that grasses accumulate K than legumes. The forages and their mixtures, if fed to ruminants cannot result in K toxicity (NRC, 2000). In addition, the fact that K content above 30 g/kg DM is toxic and could not result to K deficiency for all the classes of ruminants. In cattle, K toxicity is extremely rare, probably because of the body's ability to excrete potassium and regulate absorption, dairy cattle have a high level of tolerance to high levels of K in feed (NRC, 2005). The low Mg concentration of sole *Megathyrsus* as recorded in this study is in line with the report of Juknevicius & Sabiene (2007) that grasses generally accumulate less Mg when compared with legumes. The Mg of *Megathyrsus* is similar to 3.40 g/kg DM reported by (Heuze & Tran, 2020). The Mg content of sole *Gliricidia* fell within the range of 2.6–7.2 g/kg DM reported by (Heuze & Tran, 2015). The forages and their mixtures had Mg content higher than the range (1–2 g/kg DM) recommended by (McDowell, 1992; 1997) for different classes of ruminants. The submission of (NRC, 2000) that Mg content greater than 4 g/kg DM is considered toxic, which inferred that sole *Gliricidia* and its inclusion in a mixture above 25% with Megathyrsus could result in Mg toxicity.

The N content of the forages and their mixtures is higher than the critical limit of 8 g/kg below which ruminant forage intake and rumen microbial activity would be negatively affected (Van Soest, 1994), and these values are higher than the minimum range of 10.4–12.8 g/kg DM prescribed for optimum performance of tropical ruminant animals (Minson, 1981). As a result, forages and their mixtures used in this study are sufficient for meeting the nitrogen (protein) requirements of growing calves in order to generate a high level of ammonia in the rumen from degradable nitrogen (protein) and ensure an efficient digestion process (Ørskov, 1995). For modest livestock productivity, the nitrogen content of the forage for ruminants in the tropics ranges from 17.6 to 22.4 g/kg of the dry matter, this alludes to the fact that the mixtures containing *Gliricidia* in this study have higher N content to meet the requirement of the different classes of ruminants.

Manganese is one of the minerals required for normal reproduction, and a lack of it has been linked to delayed or irregular oestrus as well as a low conception rate in ruminants (ARC, 1980). The higher Mn content of *Megathyrsus* as against that of *Gliricidia* is aligned with the report of (MacPherson, 2000) that grasses have considerably higher Mn content than legumes. The Mn contents of the forages and their mixtures are far below the toxic level (> 1000 mg/kg DM) reported by (NRC, 2000). The antagonistic relationship between Fe and Mn in this study is obvious as they tend to be inversely related to *Gliricidia* having higher Fe (1382.40 mg/kg DM) content and lower Mn (98.85 mg/kg DM) content and *Megathyrsus* having higher Fe (227.89 mg/kg DM) content and lower Mn (119.78 mg/kg DM) content. Iron is necessary for all living organisms especially in animals to transport oxygen and energy production through electron transfer in the mitochondrial respiratory chain and it is also referred to as a double-edged sword as it is important for living but also potentially toxic through the generation of oxidative stress (Lasocki *et al.,* 2014). The Fe content of the sole *Gliricidia* was above 1000 mg/kg DM, a concentration with potential toxicity to animals (NRC, 2000) and could limit intake of other mineral elements.

Invariably, feeding sole *Gliricidia* could lead to iron toxicity but as the proportion of *Megathyrsus* increased in the mixtures, the Fe content reduced, which is a major advantage. According to (Juknevicius & Sabiene, 2007), sole feeding of forages could cumulate into high demerit as against mixing them. The high content of Fe in the sole *Gliricidia* might be that the *Gliricidia* leaves used for this study were harvested from *Gliricidia* planted around cattle dung site, as manures are generally reported to contain high Fe content (Chaudhary *et al.,* 2011). The lower concentration of Fe in *Megathyrsus* as against that of *Gliricidia* is in line with the report of (Juknevicius & Sabiene, 2007) that legumes accumulate Fe than grasses. Both *Gliricidia* and *Megathyrsus* as well as their mixtures in this study contained enough Fe above the 30 – 50 mg/kg DM recommended to meet Fe requirement of ruminants for optimal performance (MacPherson, 2000).

Copper deficiency has been identified as one of the most common problems in cattle production worldwide, with clinical and sub-clinical symptoms. In Cu deficient animals, puberty and fertility are delayed, the immune system is suppressed, hair colour may be altered as well as rough, lameness with bone fractures, anaemia, and sudden death due to ruptured blood vessels or myocardial atrophy may occur (Hill & Shannon, 2019). The Cu content recorded in this study ranged from 7.5 – 13.5 mg/kg DM, which according to (McDowell, 1997) is sufficient to meet the Cu requirement of all classes of ruminants. The Cu content of the sole *Gliricidia* was above the recommendation of (McDowell, 1997) but fell within the range of 4 – 22 mg/kg DM) reported for *Gliricidia* by (Heuze & Tran, 2015). The Cu content of *Megathyrsus* was higher than the mean of Cu recorded by (Heuze & Tran, 2020) for 123 samples of *Megathyrsus*. This could be as a result of the fertilizer (NPK) applied to *Megathyrsus*, which was in line with the report of (Pasley *et al*., 2019) that nitrogen fertilizer promotes the uptake of Cu in plants. The variation in the Cu content of *Gliricidia* and *Megathyrsus* with *Gliricidia* having a higher

Cu was in line with the report of (Juknevicius & Sabiene, 2007). The Cu content of mixtures with *Gliricidia* ≤ 50% was slightly higher than the range (6 – 7 mg/kg DM) categorized as Cu marginally deficient for dairy cattle, which could cause blood neutrophil depression (Torre *et al.,* 1996).

Zinc (Zn) as a micro-element is an essential component of a number of critical enzymes and their activities in animal nutrition (White, 1993). The Zn content of the forages and the mixture (25G:75M) were within the range (30–50 mg/kg DM) as recommended by several authors (Judson & McFarlane, 1998; Paterson & Engle, 2005; Khan *et al.,* 2009) and above 30 mg/kg DM (McDowell, 1985) for ruminants but the mixtures with 50% and above *Gliricidia* fell below the critical levels recommended. The implication is that these mixtures will require Zn supplementation when fed to animals. According to (MacPherson, 2000), the forages and their mixtures in this study are categorized as being marginal in threshold (20 – 40 mg/kg DM) Zn concentration for cattle except for *Megathyrsus* which was above the marginal threshold. The Zn content is as well far less than the toxic (> 500 mg/kg DM) as prescribed by (NRC, 2001). The toxic effects of excessive Zn intake in the diet, is decreased feed intake and induced Cu deficiency. Ruminants, on the other hand, have a high tolerance for this element, so poisoning will be extremely rare (Fisher, 2008).

Dietary ratios of minerals in animal feed have been reported to play more important roles than individual elements (Reiné *et al.,* 2020; Dele *et al.*, 2021). Mineral balance is critical for animal health. Mineral element deficiency in the diet cannot be compensated for by the others. These elements must be in a specific proportion. Ca and P, for example, are closely related to animal health and metabolism, as well as critical to maintain a proper Ca and P balance in relation to vitamin D (Tekeli & Ates, 2005). The Ca:P ratios of the forages and their mixtures in this study fell within the range (1-7:1) recommended for maintaining optimal performance of ruminants (NRC, 2000). The highest Ca:P ratio was recorded for *Gliricidia*, which agrees with (Reine *et al.*, 2020) that legumes generally have better Ca:P ratios than grasses. The highest N:P ratio recorded for *Gliricidia* in this study attest to it that legumes are inherently higher in nitrogen and phosphorus when compared to their grass counterparts. The N:P ratios recorded in this study were lower than those reported by (Dele *et al.*, 2021) for fertilized *Arachis hypogaea*.

The K:(Ca+Mg) ratio maximum tolerable limit has been reported to be 2.2 and this inferred that the K:(Ca+Mg) ratio recorded in this study showed that, the sole *Gliricidia* with the lowest K:(Ca+Mg) ratio is the most preferred because of the highest Ca and Mg content which helped in balancing against K, because lower content of Ca and Mg could lead to grass tetany (Dele *et al.*, 2021). The K:(Ca+Mg) ratios of the forages and their mixtures showed that cattle if fed with any of the forages under investigation cannot be affected by grass tetany. The ratio K:(Ca+Mg) shows the forage's ability to cause hypomagnesemic tetany, parturient hypocalcemia, or both in ruminants, whereas K:Mg is more applicable to hypomagnesemic tetany. The K:Mg ratio in this current study fell within 2–6:1 recommended optimal ratios (Jakubus & Graczyk, 2022). The K:Mg ratios under investigation was similar to the trend of the K:(Ca+Mg) with the *Gliricidia* having the least value, with the highest corresponding Mg content. The hypomagnesemic tetany in the ruminant grazing on tropical forage, have not been reported (Minson, 1990), which validates the Mg content of the forages and their mixtures to be high enough to meet the dietary requirement of ruminants.

Conclusion and Recommendation

The study showed that forage mixtures are recommended for ruminant animals for adequate mineral nutrition and optimum productivity. For a balance of mineral supply for body functioning, a mixture of *Gliricidia* and *Megathyrsus* at 50:50 and 75:25 is recommended as potential source of minerals.

REFERENCES

AOAC (1995) Official methods of analysis, 16th ed. (Association of Official Analytical Chemist, Airlington, VA).

ARC (1980) Agricultural Research Council. The nutrient requirements of ruminant livestock. Technical review by an agricultural research council working party, Commonwealth Agricultural Bureau, Farnham Royal, UK.

Babayemi, J. & Bamikole, M. (2006) Supplementary value of *Tephrosia bracteolata, Tephrosia candida, Leucaena leucocephala* and *Gliricidia sepium* hay for West African dwarf goats kept on range. *Journal of Central European Agriculture,* **7**(*2*), 323–328.

Barker, A. & Pilbeam, D. (2007) Handbook of plant nutrition. CRC press, Boca Raton, USA, pp. 104–294.

Chaudhary, S.K., Rai, U.N., Mishra, K., Huang, H.G., Yang, X.E., Inouhe, M. & Gupta, D.K. (2011) Growth and metal accumulation potential of *Vigna radiata* L. grown under fly-ash amendments. *Ecological Engineering,* **37**, 1583–1588. doi:10.1016/j.ecoleng.2011.04.004.

Crawford, G. (2007) Avoiding mineral toxicity in cattle. University of Minnesota Extension Beef Center https://fyi.extension.wisc.edu/wbic/files/2010/12/Factsheet_MineralToxicity.pdf.

Dele, P.A., Akinyemi, B.T., Okukenu, O.A., Anotaenwere, C.C., Enwete, F.E., Kasim, O.B., Amole, T.A., Sowande, O.S., Olanite, J.A., Arigbede, O.M. & Jolaosho, A.O. (2021) Forage elemental concentrations and ratios of two groundnut (*Arachis hypogaea L*) varieties: effect of fertilizer type. *Nigerian Journal of Animal Science,* **23**(3), 140–150.

Dele, P.A. (2012) Evaluation of dry matter yield and nutritive quality of forage, hay and silage produced from three grasses fertilized with animal manures. Ph.D. Thesis, Federal University of Agriculture, Abeokuta, pp. 263.

Durand, M. & Kawashima, R. (1980) Influence of minerals in rumen microbial digestion. Pp 375–408. In Y. Ruckebusch and P. Thivend (ed.) Digestive physiology and metabolism in ruminants. MTP Press Limited, Lancaster, England.

Durand, M. & Komisarczuk, S. (1988) Influence of major minerals on rumen microbiota. *The Journal of Nutrition,* **118**, 249–260. DOI: 10.1093/jn/118.2.249.

Farhad, M. (2012) Minerals profile of forages for grazing ruminants in Pakistan. *Open Journal of Animal Science,* **2**, 133–141. DOI**:** 10.4236/ojas.2012.23019.

Fisher, G.E.J. (2008) Micronutrients and animal nutrition and the link between the application of micronutrients to crops and animal health. *Turkish Journal of Agriculture and Forestry,* **32**, 221–233.

Fritz, J.S. & Schenk, G.H. (1979) Quantitative analytical chemistry. 4th ed., Allyn and Bacon, Inc., Boston, Massachusetts.

Gupta, U.C., Wu, K. & Liang, S. (2008) Micronutrients in soils, crops, and livestock. *Earth Science Frontiers,* **15**, 110–125. doi.org/10.1016/S1872-5791(09)60003-8.

Heuzé, V. & Tran, G. (2015) *Gliricidia* (*Gliricidia sepium*). Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/552. Last updated on May 11, 2015, 14:34.

Heuzé, V. & Tran, G. (2020) Guinea grass (*Megathyrsus maximus*). Feedipedia, a programme by

INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/416. Last updated on September 15, 2020, 15:40.

Hill, G.M. & Shannon, M.C. (2019) Copper and zinc nutritional issues for agricultural animal production. *Biological Trace Element Research*, **188**(1), 148–159. doi:10.1007/s12011-018-1578-5.

Hopkins, A., Adamson, A.H. & Bowling, P.J. (1994) Response of permanent and reseeded grassland to fertilizer nitrogen. 2. Effects on concentrations of Ca, Mg, Na, K, S, P, Mn, Zn, Cu, Co and Mo in herbage at a range of sites. *Grass and Forage Science*, **49**, 9–20. doi.org/10.1111/j.1365-2494.1994.tb01971.x.

Judson, G.J. & McFarlane, J.D. (1998) Mineral disorders in grazing livestock and the usefulness of soil and plant analysis in the assessment of these disorders. *Australian Journal of Experimental Agriculture*, **38**, 707–72. doi.org/10.1071/EA97145.

Jakubus, M. & Graczyk, M. (2022) Quantitative changes in various nutrient ratios in fodder plants as an effect of compost and fly ash application. *International Journal of Environmental Research* and *Public Health,* **19**, 8136. https:// doi.org/10.3390/ijerph19138136.

Juknevičius, S. & Sabienė, N. (2007) The content of mineral elements in some grasses and legumes. *Ekologija*, **53**(1), 44–52.

Kelling, K., Peters, J., Rankin, M., Undersander, D. & Clover, R. (2014) Potassium in forages. *Focus on Forage*, **4**, 1–2.

Kennedy, D.W. (1991) Ruminal distribution and utilization of zinc and magnesium as influenced by dietary source and energy level. LSU Historical Dissertations and Theses. 5127. https://digitalcommons.lsu.edu/gradschool_disstheses/5127.

Khan, Z.I., Ashraf, M., Ahmad, K., Ahmad, N., Danish, M. & Valeem, E.E. (2009) Evaluation of mineral composition of forages for grazing ruminants in Pakistan. *Pakistan Journal of Botany*, **41**, 2465–2476.

Khan, Z.I., Ashraf, M., Hussain, A. & Mcdowell, L.R. (2006) Seasonal variation of trace elements in a semiarid veld pasture. *Communications in Soil Science and Plant Analysis*, **37**, 1471–1483. doi.org/10.1080/00103620600585914.

Lamidi, A.A. & Ogunkunle, T. (2015) Chemical composition, mineral profile, and phytochemical properties of common feed resources used for small ruminant animal production in South-West, Nigeria. *International Journal of Science and Nature*, **6**, 92–96.

Lasocki, S., Gaillard, T. & Rineau, E. (2014) Iron is essential for living! *Critical Care*, **18**(6), 678. doi:10.1186/s13054-014-0678-7.

Lopez-Guisa, J.M. & Satter, L.D. (1992) Effect of copper and cobalt addition on digestion and growth in heifers fed diets containing alfalfa silage or com crop residues. *Journal of Dairy Science,* **75**, 247–256. DOI: 10.3168/jds.S0022-0302(92)77759-5.

Lowe, K.F., Hume, D.E. & Fulkerson, W.J. (2016) Forages and pastures: Perennial forage and pasture crops – species and varieties. *Encyclopedia of Dairy Sciences*, pp. 576–585.

MacPherson, A. (2000) Trace-mineral status of forages CAB *International* 2000. *Forage Evaluation in Ruminant Nutrition* (ed. Givens, D.I., Owen, E., Axford, R.F.E. and Omed, H.M.), pp. 345–371.

Marschner, H. (1995) Mineral nutrition of higher plants. 2nd ed. Academic Press.

McDowell, L.R. (1976) Beef cattle production in developing countries; University of Edinburgh Press: Edinburgh, U.K.

McDowell, L.R. (1985) Nutrition of grazing ruminants in warm climates. Academic Press, Orlando, Fl.

McDowell, L.R. (1992) Minerals in animal and human nutrition. Academic Press, San Diego, pp. 524.

McDowell, L.R. (1996) Feeding minerals to cattle on pasture. *Animal Feed Science and Technology*, **60**(3–4), 247–271. doi.org/10.1016/0377-8401(96)00983-2.

McDowell, L.R. (1997) Minerals for grazing ruminants in tropical regions, 3rd ed. University of Florida, Gainesville, Florida, USA, pp. 81.

McDowell, L.R. & Valle, G. (2000) Major minerals in forages CAB *International* 2000. *Forage Evaluation in Ruminant Nutrition* (ed. Givens, D.I., Owen, E., Axford, R.F.E. and Omed, H.M.), pp. 373–397.

Minson, D.J. (1981) Nutritional differences between tropical and temperate pastures In: Grazing animals. Disciplinary approach. *World Animal Science* Volume **34**, Elsevier, Amsterdam, Netherlands, pp. 143–157.

Minson, D.J. (1990) *Forage in Ruminant Nutrition*. Academic Press, London, pp. 483.

NRC (1984) Nutrient requirements of beef cattle. 6th ed. National Research Council, National Academy Press, Washington DC.

NRC (1995) Nutrient requirement of beef cattle 6th ed. Washington, DC.

NRC (2000) Nutrient requirements of beef cattle. 7th ed. National Academy Press Washington, DC. http://www.nap.edu/books/0309069343/html.

NRC (2001) Nutrient requirement of dairy cattle. 7th ed. Academic Press, Washington. http://www.nap.edu/catalog/9825.html#toc.

NRC (2005) Mineral tolerance of animals, second revised edition. National Research Council of the National Academies. The National Academies Press, Washington D.C.

Ojo, V.O.A., Oyebanjo, E.D., Opayemi, O.T., Mustapha, S.O., Adelusi, O.O., Adeoye, S.A., Anele, U.Y., Ogunsakin, A.O., Jolaosho, A.O. & Onifade, O.S. (2016) Effects of seasonal changes on the nutritive quality of *Moringa oleifera* and *Panicum maximum* silage. *Slovak Journal of Animal Science*, **49**(2), 76–84.

Ørskov, E.R. (1995) Optimizing rumen environment for cellulose digestion. In Rumen Ecology Research Planning (eds. R. J. Wallace and A. Lahlou-Kassi). Proceedings of a Workshop held at ILRI, Addis Ababa, Ethiopia, 13-18 March 1995, pp. 177–182.

Pasley, H.R., Cairns, J.E., Camberato, J.J. & Vyn, T.J. (2019) Nitrogen fertilizer rate increases plant uptake and soil availability of essential nutrients in continuous maize production in Kenya and Zimbabwe. *Nutrient Cycling in Agroecosystems*, **115**, 373–389 https://doi.org/10.1007/s10705-019-10016-1.

Paterson, J.A. & Engle, T.E. (2005) Trace mineral nutrition in beef cattle in: 2005 Nutrition Conference, The University of Tennessee: Tennessee.

Reiné, R., Ascaso, J. & Barrantes, O. (2020) Nutritional quality of plant species in pyrenean hay meadows of high diversity. *Agronomy*, **10**(6), 883. doi.org/10.3390/agronomy10060883.

Spears, J.W. (1994) Minerals in forages. In: forage quality, evaluation, and utilization. G. C. Fahey, ed. American Society of Agronomy Crop Science Society of America Soil Science Society of America Madison, WI., pp. 281–317 http:// doi.wiley.com/10.2134/1994.foragequality.c7.

Suttle, N.F. (2010) Mineral nutrition of livestock. 4th ed. CABI, Cambridge. http://dx.doi.org/10.1079/9781845934729.0000.

Tanko, R.J. (2014) Assessment of forage legumes for rangeland improvement in the northern guinea savanna of Nigeria, PhD Thesis, Ahmadu Bello University, Zaria, Nigeria.

Tekeli, A.S. & Ates, E. (2005) Yield potential and mineral composition of white clover (*Trifolium repens* L.) tall fescue (*Festuca arundinacea* Schreb.) mixtures. *Journal of Central European Agriculture*, **6**, 27–34. doi=10.1.1.1063.9978&rep=rep1&type=pdf.

Torre, P.M., Harmon, R.J., Hemken, R.W., Clark, T.W., Trammell, D.S. & Smith, B.A. (1996) Mild dietary Cu sufficient depresses blood neutrophil function in dairy cattle. *Journal of Nutritional Immunology*, **4**(3), 3–24. https:// doi. org/10.1300/J053v04n03_02.

Underwood, E.J. (1981) The mineral nutrition of livestock; Commonwealth Agricultural Bureaux: London.

Van S.P.J. (1994) Nutritional ecology of the ruminant, 2nd ed. Ithaca, NY USA: Comstock Publishing Associates/Cornell University Press, pp. 476.

White, C.L. (1993) The zinc requirements of grazing ruminants. In: Robson, A.D. (ed.) Zinc in soils and plants. *Developments in Plant and Soil Sciences*, 55. Springer, Dordrecht. https://doi. org/10.1007/978-94-011-0878-2_14.