Exploring seasonal variations in the mineral profile of rotationally grazed tropical pastures on commercial beef and dairy farms in Jamaica

Nugent J. Bernard[1], Martin P. Hughes[1], Cicero H.O. Lallo[1] and Paul G.A. Jennings[2]

[1]*Department of Food Production, The University of the West Indies, St. Augustine, Trinidad and Tobago*
[2]*MARJEN Consulting Group – Spanish Town, Jamaica*

**Corresponding author email: martin.hughes@sta.uwi.edu*

This study explored seasonal variation in the mineral profile of rotationally grazed pastures supporting beef and dairy cattle on commercial farms in Jamaica. While beef and dairy cattle are primarily reared on pasture in Jamaica with minimal supplementary feeding, the mineral profile of Jamaican pastures is largely unknown. Grass samples were collected by "hand plucking" from three (3) dairy and two (2) beef representative farms during the dry (January - March), intermediate (May - July) and wet seasons (September - November) following a stratified random sampling scheme. Laboratory analyses were conducted to determine concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), Zinc (Zn), iron (Fe) and manganese (Mn). Nitrogen concentration was significantly impacted by season ($p < 0.05$) and was highest in the wet season (18.4 – 27.6 g/kg DM) and lowest in the dry season (10 - 25.2 g/kg DM), as expected, since soil moisture directly influences the availability and uptake of N by grasses. Generally, P concentration ranged from 2.63 - 4.26 g/kg DM and was significantly affected by season on all farms, with the exception of one dairy farm (P=0.034). The high level of P found in the present study could be as a result of P accumulation in the soil because of the immobile nature of P making it resistant to leaching. The range obtained indicated that P levels were adequate to satisfy the nutritional requirements of both beef and dairy cattle. The potassium concentration ranged from 4.16 - 12.3 g/kg DM and was influenced by season only in areas when the dry season was severe combined with locations where soil water retention capacity was low. Calcium ranged from 2.05 - 4.19 g/kg DM and was generally highest in the dry season and lowest in the wet season, suggesting the accumulation of Ca under drier conditions in response to drought and heat tolerance mechanisms in grasses. Only on the dairy farms did season significantly affect Mg concentration. Season had no influence on the concentrations of Na, Zn, Fe and Mn. Calcium/phosphorus ratio was significantly affected by season on all farms ($p < 0.05$) and was higher in the dry season. It was concluded that the macro-mineral profile of Jamaican pastures supporting beef and dairy cattle is generally superior in the wet season while micro-minerals seem to be less sensitive to seasonal variations. The concentrations of Ca, Na and Cu in these pastures were below the dietary requirement for lactating dairy cattle and would therefore require supplementation.

Keywords: Mineral profile, tropical pastures, dairy and beef cattle, season, Ca/P ratio, Jamaica

Minerals are very important for growth and development of ruminant livestock (NRC 2001). While some minerals are required in larger quantities, such as the macro-minerals Ca, P, Mg and K and are primarily responsible for structural components of bone and other tissues, others are needed in smaller quantities. Micro-minerals such as Fe, Zn, and Mn, are instrumental components of enzyme cofactors and the endocrine system (NRC 2001). Mineral nutrition is critical in beef and dairy cattle. For example, Ca is a primary mineral constituent of milk, while a deficiency in Mn can cause impaired growth, depressed production and abnormalities of the developing calf (NRC 2001). Animals are unable to synthesize minerals, unlike other nutrients. Therefore, adequate amounts must be provided in the feed or from their environment in order to achieve production targets (Mirzaei 2012). Beef and dairy production systems in Jamaica and the wider Caribbean region are predominantly pasture-based, with little or no supplementary feeding, with the exception of a few dairy operations where mineral blocks and concentrate feeds are provided to supplement nutrients that may be deficient in the pasture.

Productivity on Jamaican cattle farms is well below required levels. With annual average lactation yield of 2,260 L milk/cow, Jennings (2006) estimated that the national dairy herd is performing below 65% of the potential of the Jamaica Hope cattle. Decline in beef output since 1990 was attributed mainly to a 54% reduction in national herd size (Duffus and Jennings 2005), poor conception rate and slow growth rate of calves and fattening animals, which can be linked to inadequate nutrition.

Over the past 50 years, nutritional evaluation of pastures in Jamaica and the extended Caribbean region has focused primarily on protein and energy (Youssef and Brathwaite 1987; Hughes et al. 2011). As a result, the contribution of pastures to mineral intake by grazing cattle and the mineral status of pastures grazed by ruminant animals is currently unknown. In fact, the latest published reports on mineral profiles of pasture grasses in the Caribbean were done by Poland and Schnabel (1980) in Jamaica, Youssef and Brathwaite (1987) and Youssef (2000) in Trinidad and Tobago. The report by Youssef and Brathwaite (1987), concluded that the majority of the 106 grasses studied had adequate levels of P, Mg, Ca, Na and Mn to satisfy the requirements of beef, dairy cattle and sheep. Most of these grasses were, however, deficient in N, P, Zn and Cu while detrimentally high levels of Fe were present in a large proportion of the grasses. Youssef (2000) also observed significant variations in the mineral profile of 28 grasses based on date of harvest. As a result, he recommended frequent analysis of the mineral status of grasses available for grazing in order to adequately supplement the deficient minerals to prevent health and productivity problems.

Since pastures are the primary source of nutrients for beef and dairy cattle in Jamaica, it is essential to know the mineral status of these pastures year-round. It is particularly important to determine if and when mineral supplementation is required or if the reduction in productivity may be as a result of unknown toxic levels of any mineral. This study was conducted to determine the mineral profile of rotationally grazed pastures on two beef and three dairy representative farms in Jamaica during the dry, intermediate and wet seasons.

Materials and methods

Site description

The study sites were five commercially managed cattle farms located in areas representative of cattle producing areas in Jamaica. Of the five farms, three were dairy farms: Serge Island Dairies (17° 56' 52"N, 76° 28' 46"W), Unity Valley Dairy, (18° 15' 0" N, 77° 7' 0" W) and Edward's Dairy (18° 19' 0" N, 77° 59' 0" W) and two were beef farms: Grove Place (18° 7' 0" N, 77° 31' 0" W) and Barkeith Farms, (17° 58' 0" N, 77° 45' 0" W) [Figure 1]. Paddock sizes on the farm ranged between 2 to 3 ha, separated by wire fencing to facilitate rotational grazing. Grazing management, description of soil type and rainfall pattern (30-year mean and current) were previously described by Hughes et al. (2011). The Jamaica Hope was the dominant dairy cattle breed while beef cattle herds had a combination of the Jamaica Red and Jamaica Brahman breeds. Seasonal variations in grazing management on the respective farms were negligible. Signal grass (*Brachiaria decumbens* cv. Basilik) was the dominant grass species at Edwards Dairy and Grove Place, while African Star (*Cynodon nlemfuensis*) was the main grass species at Serge Island Dairies, Unity Valley Dairy and Barkeith Farms. Previous soil surveys indicated that the pH of these soils ranged from 5.3-7.6 while nitrogen, phosphorus and potassium contents ranged from 0.20-0.42%, 9-141 ppm and 0.14-0.39 ppm, respectively. Seasons were determined based on historical rainfall patterns. Dry, intermediate and wet seasons were identified by the periods: January – March, May - July and September - November, respectively (Hughes et al. 2011).

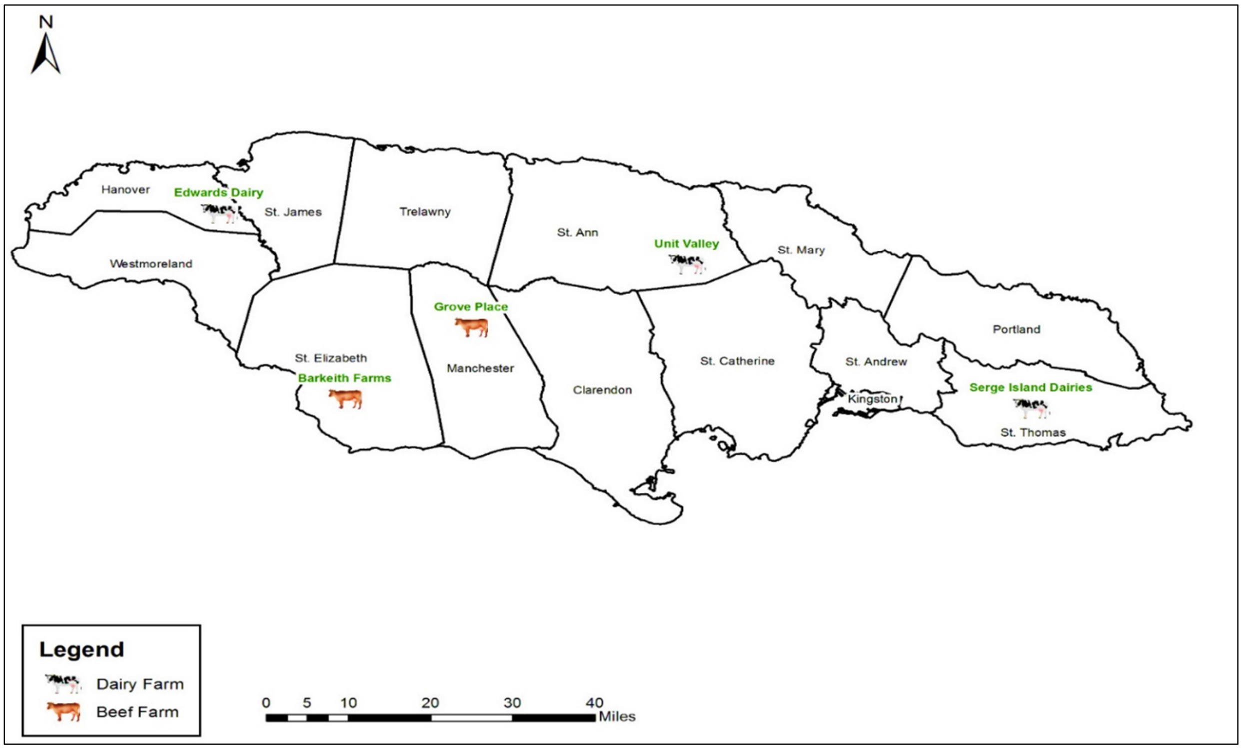

Figure 1: Locations of farms/study sites in Jamaica

Sample collection

Collection of grass samples was guided by a stratified random sampling design. A paddock (approximately 2 - 3ha.) representative of the total pasture area was selected for sampling. This paddock was divided into two strata. Sections of the pasture heavily infested with weeds or areas that were inundated were excluded from the sampling areas. Samples taken from each stratum were pooled and treated separately. The paddock was sampled twice in each season. Samples were collected by “hand-plucking” to simulate grazing (Cook 1964) from at least 20 randomly selected locations within either stratum of the pasture while walking in a zig-zag pattern. The greatest portion of the samples collected comprised leaf material from the upper sward canopy and represented an approximation to the forage considered most likely to be consumed by the grazing cattle at first exposure to a fresh paddock. These “plucks” were pooled to give an average representation of the respective stratum. Sampling was carried out by the same individual on all occasions. Care was taken to ensure that the samples were free of soil material and any other potential contaminants. Bulked samples from each stratum and sampling frequency within season represented the replicates for this experiment (r=4). Twelve independent samples were collected from each farm, yielding a total of 60 samples for the experiment.

Sample preparation and analysis of chemical composition

The samples collected were immediately transported to the Animal Nutrition Laboratory at the Bodles Agricultural Research Station (17° 56' 0" N, 77° 7' 0" W) where they were temporarily stored in a freezer at -4°C. In preparation for chemical analysis, the samples were dried at 60°C in a force-draft oven to constant weight. The dried samples were ground in a stainless steel hammer mill (Thomas Wiley Laboratory mill, model 4; Thomas Scientific USA) to pass through a 1.0

mm sieve and stored in labelled, air-tight plastic bags.

Mineral analyses were undertaken at the Department of Food Production Laboratory at The University of the West Indies, Trinidad and Tobago. Dried plant samples were ashed in a muffle furnace set at 600°C prior to mineral analysis. Mineral concentrations of calcium, magnesium, copper, zinc, iron and manganese were done with the atomic absorption spectrometry (AAS) analytical technique (Model: PerkinElmer 1998-2000 AA analyst 700 Atomic Absorption Spectrometer – (PerkinElmer Instruments LLC: Ueberlingen). Analysis of phosphorus was carried out by the Ascorbic Acid Method using the UV- Spectrometer (model: UV- Mini-1240 SHIMADZU - Agilent Technologies, Waldbronn). Potassium and sodium contents were determine by using the atomic absorption spectrometry (AAS) analytical technique (Model: PerkinElmer Analyst 200 Atomic Absorption Spectrometer - PerkinElmer Instruments LLC: Ueberlingen). Nitrogen was determined at the analytical laboratory of the Bureau of Standard, Jamaica, by the Kjeldahl method (AOAC 2005; 976.05) using an automated steam distillation/titration unit (FOSS – Kjeltec 2300 Analyzer) with 1% boric acid as the receiving solution and 0.1 M hydrochloric acid as the titrant. The end point was determined photometrically.

Statistical analysis and calculations

Statistical analysis was done separately for each farm using the Minitab 17 software. The level of significance was set at $p < 0.05$. Macro- (N, P, K, Ca, Mg, Na), micro (Fe, Zn, Mn, Cu) mineral compositions and Ca:P ratio were analysed by one way analysis of variance (ANOVA). Season (dry, intermediate and wet) was the fixed effect. Treatment means were separated using Tukey's multiple comparison. The Ca:P ratio was calculated by dividing calcium concentrations by the respective phosphorus values.

Results and discussion

Effect of season on macro-minerals concentration

The effect of season on concentration of macro-minerals is presented in Table 1. Nitrogen was significantly affected by season on all farms ($p < 0.05$) except for Unity Valley Dairy and Grove Place. For the farms that recorded significant differences, N concentrations were highest in the wet season and lowest in the dry season. In the wet and intermediate seasons, N concentration was only significantly different at Edwards Dairy. High N concentration in tropical grasses is very common during the rainy season (Kering et al. 2011; Onyeonagu et al. 2013) because soil moisture directly influences the availability and uptake of N by grasses. Nitrogen in pastures on beef farms ranged between 10- 21.3 g/kg DM while levels on dairy farms were in the region of 19.8-27.6 g/kg DM. Overall, N concentrations were highest at Serge Island Dairies (22.4-27.6 g/ kg DM) and Unity Valley Dairy (25.2-27.2 g/kg DM) and lowest at Barkeith Farms (10.2-21.3 g/kg DM). These N values were similar to those reported by Onyeonagu et al. (2013) for four grasses in Nigeria. Feedstuff N is often represented as crude protein (N × 6.25). The minimum dietary requirement for crude protein is 80g/kg DM (Minson 1980). It is therefore evident that the level of N (CP) in pastures supporting beef and dairy cattle in Jamaica far exceeds this threshold. In fact, the level of N reported is adequate to support the Jamaica Hope dairy cow in peak lactation providing the required level of DM intake can be achieved (NRC 2001).

Table 1: Effect of season on macro-nutrients (N, P, K, Ca, Mg and Na) concentration (mean ± SE) of rotationally grazed pasture

		Macro-nutrients (g/kg DM)					
Site	Season[1]	N	P	K	Ca	Mg	Na
Serge Island	Dry	22.4±2.2^{b}	2.94±0.4^{a}	9.63±0.3^{b}	2.93±0.3^{a}	2.92±0.6^{a}	0.54±.04^{a}
	Interm.	26.9±1.2^{a}	3.63±0.4^{a}	10.1±0.7^{b}	2.86±0.3^{a}	4.02±0.2^{b}	0.53±.03^{a}
	Wet	27.6±2.7^{a}	3.44±0.3^{a}	12.0±0.4^{a}	2.53±0.2^{a}	4.03±0.3^{b}	0.44±.04^{a}
Unit Valley Dairy	Dry	25.2±1.5^{a}	3.62±0.3^{a}	11.3±0.5^{a}	3.12±0.4^{a}	4.26±0.6^{a}	0.45±.05^{a}
	Interm.	26.8±1.9 ^{a}	3.91±0.3^{a}	10.5±1.8^{a}	3.08±0.5^{a}	3.73±0.3^{a}	0.58±.08^{a}
	Wet	27.2±2.6	4.26±0.4^{a}	12.3±1.6^{a}	2.96±0.3^{a}	4.13±0.3^{a}	0.49±.09^{a}
Edwards Dairy	Dry	20.2±0.8^{b}	2.63±0.2^{ab}	10.6±0.8^{a}	2.87±0.8^{a}	3.34±0.4^{a}	0.52±.02^{a}
	Interm.	19.8±1.1 ^{b}	3.81±1.0^{a}	10.4±1.6^{a}	2.65±2.8^{a}	2.93±0.3^{ab}	0.44±.04^{a}
	Wet	23.8±2.6 ^{a}	2.63±0.3^{b}	11.2±1.1^{a}	2.05±3.3^{b}	2.09±0.6^{b}	0.54±.05^{a}
Grove Place	Dry	15.8±2.4^{a}	2.95±0.5^{a}	9.71±1.0^{a}	3.51±0.7^{a}	2.36±0.6^{b}	0.43±.08^{a}
	Interm.	18.7±0.9 ^{a}	3.43±0.3^{a}	8.94±1.4^{a}	3.28±0.3^{a}	3.42±0.2^{a}	0.45±.05^{a}
	Wet	19.3±1.8 ^{a}	2.82±0.2^{a}	9.72±0.2^{a}	2.31±0.9^{b}	2.62±0.2^{b}	0.46±.06^{a}
Barkeith Farms	Dry	10.0±2.2^{b}	3.33±0.3^{a}	4.17±1.7^{b}	4.19±0.7^{a}	3.45±0.5^{a}	0.41±.01^{a}
	Interm.	21.3±7.1^{a}	3.72±0.2^{a}	7.01±1.1^{a}	3.04±0.3^{b}	3.43±0.3^{a}	0.45±.05^{a}0.
	Wet	18.4±2.8 ^{ab}	3.35±0.5^{a}	9.33±3.0^{a}	3.09±0.1^{b}	3.53±0.3^{a}	42±.08^{a}

[a,b,] Items within column for the respective site with different superscripts differ significantly ($p < 0.05$)

[1]Season: Dry = dry season; Interm. = intermediate season; Wet = wet season

The concentrations of P were unaffected by season except for grasses at Edward's Dairy (P=0.034), where P content was highest during the intermediate season. This was in contrast to results obtained by Onyeonagu et al. (2013), who reported P concentrations of four tropical grasses in Nigeria to be significantly affected by season and species.

For example, for *Megathyrsus maximus* (formerly *Panicum maximum*) and *Andropogon gayanus*, P concentrations were highest in the dry season while P concentrations for *Cynodon nlemfuensis* and *Pennisetum purpureum* were highest in the rainy season. Mokolopi (2019) noted that P content of natural pastures in South Africa increased significantly with moderate rainfall. Pasture P concentrations were fairly consistent across farms, ranging between 2.63 and 4.26 g/kg DM, which were higher than those previously reported by Youssef and Brathwaite (1987) under similar Caribbean conditions. The high P levels found in the present study could be a result of P accumulation in the soil because of the immobile nature of P making it resistant to leaching. It must be noted that the reported P concentrations of Jamaican pastures are adequate to satisfy the P requirements of all classes of ruminants including the Jamaica Hope dairy cattle in peak lactation (NRC 2001).

Serge Island Dairies (p = 0.000) and Barkeith farms (p=0.020) were the only farms where pasture K concentrations were influenced by season. This may be because these areas experienced harsher dry seasons and are dominated by soils with very poor water retention capacities which caused these soils to dry out very quickly. On these farms, pasture K concentrations were highest in the wet season (9.33-12.0 g/kg DM) and lowest in the dry season which can be attributed to increased availability and uptake of K because of the presence of soil moisture during the wet season. Onyeonagu et al. (2013) also observed significantly higher K in *Megathyrsus maximus*, *Andropogon gayanus, Cynodon nlemfuensis* and *Pennisetum purpureum* during the wet season. The reported range (4.17g/kg-12.3 g/kg DM) of pasture K concentrations on Jamaican cattle farms falls within the range observed by Onyeonagu et al. (2013), but was higher than those reported by Youssef and Brathwaite (1987) and lower than values reported elsewhere (Poland and Schnabel 1980; Kawas et al. 1993; Khan et al. 2007a).

However, it must be noted that Jamaican pastures contain just about enough K to meet the requirements of the respective animals that they support (NRC 2001; NRC 2016) without negatively impacting Mg absorption from the rumen (Dua and Care 1995).

Season influenced the Ca concentrations of Jamaican pastures on all farms except Serge Island Dairies (p=0.097) and Unity Valley (p=0.814). For the dry and intermediate seasons, Ca concentrations differed significantly at Barkeith farms while for the wet and intermediate season, Ca differed significantly at Edwards Dairy and Grove Place. Generally, Ca concentration was highest in the dry season and lowest in the wet season. This was similar to that reported by Mokolopi (2019) who found that the concentration of Ca in natural pastures in South Africa significantly increased during periods of little or no rainfall. This is so because calcium is involved in regulating the response mechanism of plants to environmental stress such as heat and dry conditions (Jiang and Huang 2001). Therefore, Ca accumulation in dry environments will improve drought and heat tolerance of the plant. The Ca concentration of Jamaican pastures ranged between 2.05 to 4.19 g/kg DM which is well below those previously reported by Poland and Schnabel (1980) for Jamaica and Youssef and Brathwaite (1987) for Trinidad. Pastures supporting dairy cattle generally had lower Ca than those grazed by beef herds. The Ca requirements for the typical Jamaica Hope dairy cow with daily milk yield of 20 – 25kg at peak lactation is approximately 5.7g/kg DM (NRC 2001). The requirements for all classes of beef cattle range between 1.3 - 4.2 g/kg DM (NRC 2016). It is therefore evident that Ca concentrations of grazed pastures on the beef farms will adequately satisfy beef cattle requirements while supplemental Ca must be provided for the dairy animals.

Season significantly affected Mg concentrations at Grove Place (p = 0.017), Serge Island Dairies (p = 0.044) and Edwards Dairy (p = 0.013). The higher Mg concentrations in the dry season (2.36-4.26 g/kg DM) compared to the wet season (2.09-4.12 g/kg DM) could be as a result of direct competition by other cations in the soil such as Ca^{++} and $NH4^{++}$ reducing Mg^{+} uptake by the plant (Ziblim et al. 2012) or a dilution effect because of rapid grass growth in the wet season. However, this was in contrast to Mokolopi (2019), who observed a positive response in Mg content of natural pastures to rainfall. The range of Mg in Jamaican pastures suggests that the Mg contents are well above dietary needs of dairy (NRC 2001) and beef animals (NRC 2016). Similarly, the Mg contents of tropical grasses reported by others in the Caribbean were adequate to satisfy dietary requirements (Poland and Schnabel 1980; Youssef and Brathwaite 1987). Grove Place generally had the lowest Mg concentrations possibly because other cations such as calcium and aluminium may have dominated these bauxitic soils.

Season had no influence on pasture Na concentration ($p > 0.05$). The concentrations of Na were generally similar on all farms. The Na concentrations of pastures on Jamaican dairy and beef farms ranged between 0.44-0.58g /kg and 0.41-0.46g /kg DM, respectively. Dietary Na requirements for dairy and beef cattle are of the order of 1.9 – 2.2g/kg DM (NRC 2001) and 0.6 – 1.0 g/kg DM (NRC 2016), respectively. It is therefore clear that pastures supporting cattle on commercial farms in Jamaica would not satisfy their Na requirements. In fact, Na concentrations on Jamaican cattle farms were found to be below the 0.6 g/kg DM critical level, hence the need for supplementary Na. Sodium has been widely cited as one of the most deficient mineral in tropical grasses (Poland and Schnabel, 1980; Youssef and Brathwaite 1987; Khan et al. 2007a; Mirzaei 2012). Youssef and Brathwaite (1987) reported that 41% of the grasses examined had Na levels below 1 g/kg DM.

According to the NRC (2001), detrimental effects from low dietary Na have been somewhat avoided because the evolution of cattle coincided with their long-term exposure to feeds with insufficient Na so that these animals developed the ability to efficiently absorb Na from the digestive tract and conserve it via the kidney. There is evidence to suggest that Na concentrations of pasture are dependent on the growth environment, with temperate forages having higher Na than those in the tropics (Morris 1980), as well as species, e.g. *Digitaria* spp and *Brachiaria* spp are categorized as high and low Na species, respectively (Poland and Schnabel 1980).

Effect of season on calcium: phosphorus ratio

The observed effect of season on Ca:P ratio is presented in Figure 2. The ratio of Ca:P was significantly affected by season on all farms ($p < 0.05$). The C:P ratio was consistently highest during the dry season (1.3:1 – 0.9:1) because Ca content was relatively highest during this period. Pastures supporting beef cattle generally had higher Ca:P ratios than those grazed by dairy herds. Overall, Ca:P ratios were highest at Barkeith Farms (1.3:1 – 0.8:1) and lowest at Edwards Dairy (1.1: 1 – 0.6: 1). The predominant bauxitic soil type supporting pasture growth on the beef farms could have accounted for the higher Ca content of the pasture herbage, resulting in these farms recording the highest Ca:P ratios. The Ca:P ratio is arguably the most important feature of calcium nutrition in the lactating dairy cow (Underwood and Suttle 1999) because an imbalance will trigger absorption from bones, thus adversely affecting health and production. In the present study, the Ca:P ratio on dairy farms fell well below the recommended 2:1 ratio for lactating and 1.6:1 ratio for dry dairy cows (Underwood and Suttle 1999), especially outside of the dry season. The low Ca:P ratios reported were primarily the result of the relatively high P concentrations of these pastures.

In most cases, concentrations of P exceeded that of Ca which can reduce absorption of the latter from the digestive tract, causing the animal to metabolize Ca from skeleton tissues (NRC 2001) if supplemental Ca is not provided in the diet.

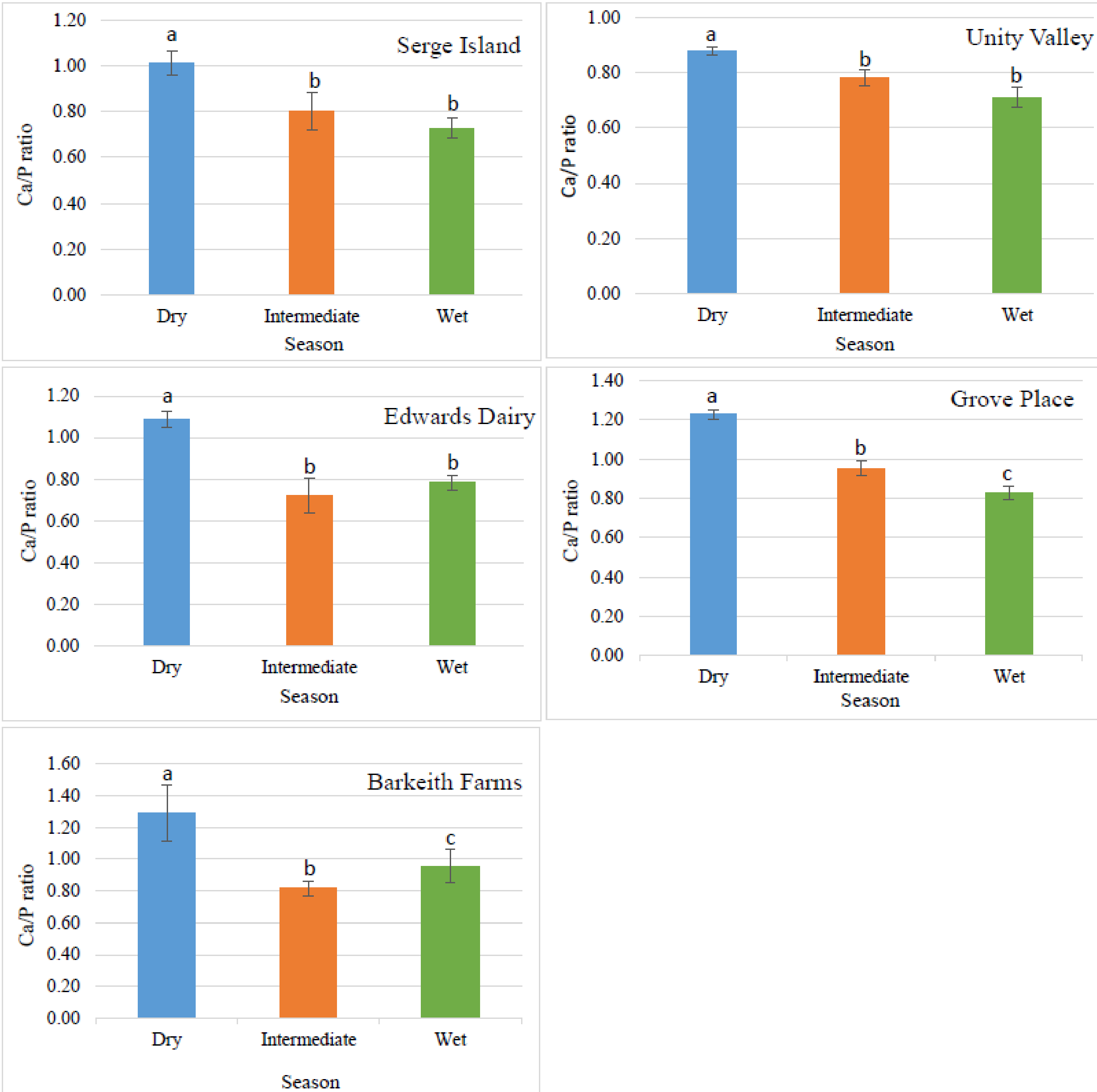

Figure 2: Influence of season on Ca/P ratio of rotationally grazed pastures in Jamaica

Table 2: Effect of season on micro-nutrients (Cu, Zn, Fe and Mn) concentration (mean ± SE) of rotationally grazed pasture

		Micro-nutrients (mg/kg DM)			
Site	Season[1]	Cu	Zn	Fe	Mn
Serge Island	Dry	3.22±0.9[a]	69.4±4[a]	475±90[a]	141±14[a]
	Interm	4.35±0.5[a]	62.1±9[a]	351±11[b]	123±49[a]
	Wet	4.60±0.5[a]	68.3±6[a]	484±70[a]	124±12[a]
Unity Valley Dairy	Dry	3.42±0.2[a]	56.9±9[a]	485±17[a]	145±36[a]
	Interm	1.74±0.14[b]	49.4±4[a]	492±17[a]	122±12[a]
	Wet	2.16±0.2[c]	54.3±3[a]	462±14[a]	125±24[a]
Edwards Dairy	Dry	2.61±.01[a]	35.2±5[a]	501±7[a]	142±9[a]
	Interm	2.62±.22[a]	24.5±6[a]	443±13[b]	110±25[a]
	Wet	2.61±.11[a]	33.3±3[a]	337±10[c]	146±24[a]
Grove Place	Dry	1.91±.11[a]	69.9±9[a]	285±4[a]	127±2[a]
	Interm	3.20±.10[b]	59.4±4[a]	294±5[a]	83±3[b]
	Wet	1.92±.12[a]	54.5±7[a]	371±4[b]	121±4[a]
Barkeity Farms	Dry	1.96±0.6[b]	32.2±2[a]	345±11[a]	139±52[a]
	Interm	2.76±0.6[ab]	27.4±4[a]	357±6[a]	84±9[a]
	Wet	3.94±0.4[a]	29.8±4[a]	420±12[b]	83±6[a]

[a,b] Items within column for the respective site with different superscripts differ significantly ($p < 0.05$)
[1]Season: Dry = dry season; Interm. = intermediate season; Wet = wet season

Effect of season on the concentration of micro-minerals

The effect of season on the concentrations of Cu, Zn, Fe and Mn is presented in Table 2. The concentrations of Cu were significantly affected by season on most farms ($p < 0.05$). Pasture Cu concentrations were marginally higher in the wet and intermediate seasons compared to the dry season. Maturity (Mirzaei 2012), soil type, and interaction with other soil minerals (Khan et al. 2007a) seem to have a bigger impact on Cu uptake than season. For example, Cu uptake is restricted when calcium is in the carbonate form (Khan et al. 2007b), and molybdenum and sulphur are present in high quantities (Mirzaei 2012). Of the 4 grasses studied by Khan et al. (2007a), only *Paspalum notatum* showed significant increase in the concentrations of Cu from winter to summer. All other grasses remained unaffected by season. The Cu concentrations of Jamaican pastures ranged between 1.74-4.60 mg/kg DM. Pastures supporting beef cattle generally had lower Cu than those grazed by dairy animals. The highest concentrations of Cu were observed from Serge Island Dairies (3.2-4.6 mg/kg DM). In the main, these Cu values are lower than those in the reports of Poland and Schnabel (1980) and Youssef and Brathwaite (1987) and fall well below required level of 9.0-11.0 mg/kg DM for lactating Jersey-type cows (NRC 2001; McDowell 2003). Consequently, dairy cattle that are supported on these pastures are at risk of suffering from symptoms of Cu deficiency such as anaemia, reduction in growth, poor reproduction triggered by delayed or depressed oestrus, fragile and easily fractured bones and depigmentation (NRC 2001; Mirzaei 2013), if supplemental Cu is not provided.

Zinc concentrations were independent of season ($p > 0.05$). Serge Island Dairies recorded the highest Zn contents across all seasons. The Zn concentrations ranged between 24.5-69.4 mg/kg DM on dairy and 27.4-69.9 mg/kg DM on beef farms. The concentrations of Zn in tropical grasses vary widely based on reports in the literature (Khan et al. 2007b; Mirzaei 2012) but are not easily influenced by season (Khan et al. 2007a). The Zn requirements for a small-breed lactating dairy cow in peak lactation is 45 mg/kg DM (NRC 2001). Only pastures found at Edwards Dairy failed to meet this requirement. If 30 mg/kg DM is accepted as the Zn requirements for beef cattle (McDowell et al. 1983), then beef cattle grazing these pastures will have adequate supply of Zn. The Zn concentrations of the pastures under study fell within the upper range of the report of Youssef and Brathwaite (1987) and were in-sync with values reported by Poland and Schnabel (1980).

The Fe concentration was significantly influenced by season on all farms except for Unity Valley Dairy ($p=0.757$). However, there was no clear pattern as to Fe response to season, particularly on the dairy farms, which could be attributed to the diversity in soil types and characteristics among these farms. On the other hand, the beef farms located on identical soil types recorded highest Fe concentrations during the wet season. It must be noted that the Fe concentrations obtained in the present study are significantly higher than those previously reported by Poland and Schnabel (1980). The Fe concentrations of pastures supporting dairy and beef cattle in Jamaica ranged between 337-501 mg/kg DM and 285-420 mg/kg DM, respectively, which is below the maximum tolerable limit of 1000 mg/kg DM (NRC 2001). The precise dietary Fe requirement is not clear, but it is believed to be below 100 mg/kg DM for most ruminants. Young calves and pregnant cows have the highest Fe requirements (NRC 2001).

Iron toxicity is of great concern especially in tropical grasses, where Fe concentrations tend to be very high (Youssef and Brathwaite 1987; Khan et al. 2007a; Mirzaei 2012). The concentration of Mn was not significantly affected by season ($p > 0.05$). It was previously pointed that there are large variations in the Mn concentrations in grasses, primarily influenced by species, soil type, pH and fertilizer applied (NRC 2001; Khan et al. 2004). However, Khan et al. (2007a) and Velasquez-Pereira et al. (1997) showed that season can affect Mn concentrations as well. The Mn concentrations on beef cattle farms (83-139 mg/kg DM) were lower than those on dairy farms (110-146 mg/kg DM). Generally, these values were within range of those previously reported in the Caribbean (Poland and Schnabel 1980; Youssef and Brathwaite 1987; Youssef 2000) and elsewhere (Khan et al. 2007a; Mirzaei 2012) and would adequately satisfy the requirements of ruminants without the risk of toxicity (NRC 2001).

Conclusion

It was concluded that the macro-mineral profile of Jamaican pastures supporting beef and dairy cattle is generally superior in the wet season, while micro-minerals seem to be less sensitive to seasonal variations, particularly on dairy farms. The mineral profile of these pastures indicated that they can adequately satisfy the requirements for beef and milk production if the required DM intake requirements are achieved. Calcium, Na and Cu levels, particularly on the dairy farms, were the only exception, necessitating supplementation. The generally favourable mineral profiles can be attributed to the favourable soil types that support grass growth and the predominantly leaf portions that were sampled. Toxic levels were not recorded for any mineral. It is also worth noting that the mineral status of the pastures under study corresponded well to the last known report on the mineral profile of pasture grasses in Jamaica, almost 40 years ago (Poland and Schnabel 1980).

Acknowledgement

We are sincerely grateful to The University of the West Indies, for providing financial support to undertake this research. Special thanks are also extended to the Jamaica Dairy Development Board, Bodles Research Station and the owners of the respective farms.

Conflict of interest declaration

The authors declare there are no actual or potential conflict of interest associated with this work.

References

AOAC (Association of Analytical Chemist). 2005. Official Methods of Analysis. 18th ed. Arlington, VA: AOAC

Cook, C.W. 1964. "Symposium on Nutrition of Forages and Pastures: Collecting Forage Samples Representative of Ingested Material of Grazing Animals for Nutritional Studies." *Journal of Animal Science*. **23**:265-270.

Dua, K. and A.D. Care. 1995. "Impaired Absorption of Magnesium in the Aetiology of Grass Tetany." *British veterinary Journal*. **151**:413-426.

Duffus, G.B. and P.G.A. Jennings. 2005. "The Current Status of the Jamaican Cattle Sector, Final Report. Kingston - Jamaica: Jamaica Investment Limited and Jamaica Dairy Development Board.

Hughes, M.P., P.G.A. Jennings, V. Mlambo and C.H.O. Lallo. 2011. "Exploring Seasonal Variations in Sward Characteristics and Nutritive Value of Tropical Pastures Grazed by Beef and Dairy Cattle on Commercial Farms in Jamaica." *Journal of Animal Science Advances* **1:**47-60.

Jennings, P.G. 2006. "A Prospective on the Market Potential of the Jamaica Hope." Presentation to Annual Conference. *The Jamaica Society for Agricultural Science, Bodles*, 20 Sept.

Jiang, Y. and B. Huang. 2001. "Effects of Calcium on Antioxidant Activities and Water Relations Associated with Heat Tolerance in Two Coo-Season Grasses." *Journal of Experimental Botany* **52:**341- 349.

Kawas, J.J., G.T. Armmienta, J.R. Kawas, R. Ramirez, E. Olivares and O. Torres. 1993. "Seasonal Changes of Mineral Concentrations of Tropical Grasses in Mexcio. *ID No 1538* 101." http://www.internationalgrasslands.org/files/igc/publica t ions/1997/2-17-

Kering, K.M., J.A. Guretzky, E. Funderburg and J. Mosali. 2011. "Effect of Nitrogen Fertilizer Rate and Harvesting Season on Forage Yield, Quality and Macronutrient Concentrations in Midland Bermuda grass." *Agronomy and Horticulture* – Faculty Publications. 555. http://digitalcommons.unl.edu/agronomyfacpub/555

Khan, Z.I., M. Ashraf, and A. Hussain. 2007a. "Evaluation of Macro Mineral Contents of Forages: Influence of Pasture and Seasonal Variation." *Asian-Australasian Journal of Animal Sciences* **20**:908-913.

Khan, Z.I., M. Ashraf, K. Ahmad, I. Mustafa and M. Danish. 2007b. "Evaluation of Micro Minerals Composition of Different Grasses in Relation to Livestock Requirements." *Pakistan Journal of Botany* **39:**719-728.

Khan, Z.I., A. Hussain, M. Ashraf, E.E. Valeem and M.S. Akhtar. 2004. "Seasonal Variation in Soil and Forage Mineral Concentrations in a Semiarid Region of Pakinstan." *Pakistan Journal of Botany* **36:**635-640.

McDowell, L.R. 2003. *Minerals in Animal and Human Nutrition*. 2nd ed. Gainesville, Florida: Department of Animal Science, University of Florida

McDowell, L.R., J.H. Conrad, G.L. Ellis and L.K. Loosli. 1983. "Minerals for Grazing Ruminants in Tropical Regions." *Extension Bulletin Anim. Sci.* Dept. Univ. of Florida.

Mirzaei, F. 2012. "Mineral Profile of Forages for Grazing Ruminants in Pakistan." *Open Journal of Animal Sciences* **2**:133-41.

Minson, D.J. 1980. "Nutritional Differences between Tropical and Temperate Pastures." In *Grazing Animals*, edited by F.H.W. Morley, 167-182. Slough, UK.: CAB. Furnham Royal.

Mokolopi, G.B. 2019. "Phosphorus, Calcium and Magnesium Contents of Pasture and their Effect on Body Condition Score and Body Mass of Communal Cattle Depending on Natural Pasture of Mogosane Village, of the North-West Province, South Africa." *Tropical Animal Health and Production,* **51**:2067-2071.

Morris, J.G. 1980. "Assessment of Sodium Requirements of Grazing Beef Cattle: A Review." *Journal of Animal Science* **50:**145-152.

NRC. 2001. *Nutrient Requirements of Dairy Cattle*. 7th Rev. Ed. *National Research Council.* Nat. Acad. Sci., Washington, DC

NRC. 2016. *Nutrient Requirements of Beef Cattle*. Eighth Revised Edition*, The National Academies of Sciences Engineering Medicine.*

Onyeonagu, C.C., N.P. Obute and M.S. Eze. 2013. "Seasonal Variation in the Anti-Nutrient and Mineral Components of Some Forage Legumes and Grasses." *African Journal of Biotechnology,* **12**:142-149.

Poland, J.S., and J.A. Schnabal. 1980. "Mineral Composition of *Digitaria decumbens* and *Brachiaria decumbens* in Jamaica." *Tropical Agriculture* **57:**259–264.

Underwood, E.J. and N.F. Suttle 1999. *The Mineral Nutrition of Livestock*. 3rd ed. Wallingford – UK: CABI Publishing.

Velasquez-Pereira, J.B., L.R. McDowell, J.H. Conrad, N.S. Wilkinson, and F.G. Martin. 1997. "Mineral Levels in Soils, Fodder and Cattle in Nicaragua. II. Macrominerals and Oorganic Forage Composition." *Revista de la Faccultad de Agronomia, Universidad del Zulia, Maracaibo-Venezuela* **14:**91-110.

Youssef, G.F., and R.A.I. Brathwaite. 1987. "The Mineral Profile of Some Tropical Grasses in Trinidad." *Tropical Agriculture (Trinidad),* **64**:125-128.

Youssef, G.F. 2000. "Within-Season Variations in the Mineral Content of Tropical Grasses." *Tropical Agriculture (Trinidad),* **77**:213-219.

Ziblim, A.I., K.A., Timothy and A. Phillip. 2012. "Effects of Season on the Mineral (Potassium, Calcium, Phosphorus, Magnesium) Levels of *Pennisetum pedicellatum* in Northern Ghana." *Greener Journal of Agricultural Science* **2:**329-333.