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ORIGINAL ARTICLE

Mineral Content of Forages in Coconut Triangle, Wet Zone and Dry Zone Dairy Production Regions, During South-West Monsoon in Sri Lanka

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Abstract

The present study was conducted to evaluate the mineral status of forages in three different dairy production zones, Coconut Triangle, Wet Zone, and Dry Zone. Forage samples were collected from *Kotadeniyawa, Udugoda* and *Seeppukulama* representing the three locations, respectively. The samples were analysed using atomic absorption spectrophotometer to determine macro and micro minerals. Levels of Ca, K, Mg and Na in forages were ranged, 0.57-19.9 gram per kilogram dry matter (gkg^{-1} DM), 8.03-11.47 gkg^{-1} DM, 0.65-0.90 gkg^{-1} DM and 0.01-0.60 gkg^{-1} DM respectively. The micro mineral content of tested samples was ranged 21.5-478 mg Fe kg^{-1} DM, 18.7-285 mg Mn kg^{-1} DM, 2.82-103 mg Cu kg^{-1} DM M, 0.03-0.40 mg Co kg^{-1} DM, 0.09-0.25 mg Se kg^{-1} DM, 15.8-298 mg Zn kg^{-1} DM and 0.42-2.64 mg Cr kg^{-1} DM. The results revealed that legumes contain higher levels of Ca, Mg, Fe, Mn and Cu than grasses, while grasses are rich in Zn. The tested mineral contents of forages from three different zones were significantly different ($p<0.05$) except Se. Level of Se in forage varieties showed no significant difference ($p>0.05$) among three zones for most tested varieties except in Koronivia grass (*Brachiaria humidicola*) and Peuro (*Pueraria phaseoloides*).

Keywords: *Coconut triangle, Dry zone, Forages, Macro minerals, Micro minerals, Wet zone*

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1. Introduction

Minerals are inorganic substances required by the animal in small quantities to perform structural, physiological, catalytic, and regulatory functions (NRC 2001; Suttle 2010). These essential minerals comprise of macro and micro elements. The Macro mineral group includes calcium (Ca), phosphorus (P), sodium (Na), chlorine (Cl), potassium (K), magnesium (Mg), and sulphur (S). The Micro mineral group includes cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), zinc (Zn), chromium, (Cr) and fluorine (F) (NRC 2001).

Farm animals obtain most of their mineral requirement from the feeds and forages that they consume. Drinking water is not a major source of minerals for dairy cattle (Suttle 2010). Under the local condition, a considerable amount of cattle feed consists of forages as a component of a cheap source of nutrients (Gedara 2019).

Forages are edible parts of plants, other than separated grain, usually with a considerable amount of cell walls. Forages may be fed to dairy cattle as grazing pasture and fodder or be conserved as hay, silage, or haylage (Dynes et al. 2003). Earlier local dairy farmers used natural forages available in coconut lands, paddy bunds, road sides etc. to feed dairy cattle, which were inferior in quality and quantity. But with the introduction of European dairy cattle breeds to medium/large-scale farms, a trend has arisen to cultivate improved varieties like fodder-maize, fodder-sorghum and Napier varieties (Premarathne and Samarasinghe 2020).

Forages are considered as an important source of minerals for ruminants, because a number of minerals has been associated with the plant cell wall (Whitehead et al. 1985; Spears 1994). Among forages, higher amounts of Ca, Mg, K, Cu, Zn, and Co were reported from the legumes in contrast to grasses, while grasses are rich in manganese (Minson 1990; Underwood 1999). However, the ability of forages to provide an adequate supply of minerals to animals is dependent on the mineral content of the forage as well as the bio availability of the mineral (Spears 1994).

Though forage feeding is economical over concentrate feeding (Perera and Jayasuriya 2008); low productivity of natural forages due to seasonal variation of rainfall, poor nutritional status of soils, weed invasion, less palatability, and low quality are limiting the value of forages (Spears 1994).

Mineral content in forage crops depends on a number of factors including plant species, stage of maturity, dry matter yield, grazing management, climate, season and region etc. (Spears 1994). Mineral concentrations in the same forage species can be different depending on the seasonal rainfall, soil, topography, and biotic factors (Spears 1994; Premaratne et al. 2003; Jacoby et al. 2017).

Studies have been conducted in different regions of the world as well as in Sri Lanka on dry matter yield, nutritive value, and persistence of different forages for dairy cattle (Jayawardana 1985; Premaratne & Premalal 2006; Weerasinghe 2019). Though details are available on ash content in different forage species, very little information is available on the mineral status of forages present in Sri Lanka based on different regions. This study was aimed to evaluate the mineral composition of different improved forage varieties and compare the mineral concentrations of forages in Coconut Triangle, Dry Zone, and Wet Zone dairy production regions. It is important to evaluate the mineral content of different forage crops present in different dairy production regions to enhance the mineral nutrition of ruminants, especially those reared under extensive and semi-intensive management.

2. Materials and Methods

Study Area

Forage samples were collected from three different locations selected based on major dairy production regions in Sri Lanka (Ranaweera and Attapattu 2006). The selected locations were *Kotadeniyawa* Fodder Resource Centre from Coconut Triangle (7.355 ^{0}N, 80.060 ^{0}E), Animal Husbandry Development & Training Centre, *Undugoda* (7.141 ^{0}N, 80.372 ^{0}E) from Wet Zone, and Animal Husbandry Training Centre, *Seeppukulam*a (8.395 ^{0}N,80.581 ^{0}E) from Dry Zone. Selected locations had well managed, improved pasture and fodder collection with variety diversification and they were grown without the application of inorganic fertilizers.

Sample Collection and Chemical Analysis

All the farms were visited on September 2020, during the South-West monsoon period. Forages were selected to represent fodder grasses, fodder legumes, pasture grasses, and pasture legumes as shown in Table. 1.

At each location for each fodder grass, a composite sample was prepared by collecting samples from 9 points in the field, by walking in a 'W' shape throughout the field. Fodder grasses at the pre-flowering stage were selected for sample collection. The cutting height of fodder grass was 30 cm above the ground. In pasture grasses and legumes, the whole plant without root system was sampled randomly by using 50×50 cm quadrat. For fodder legumes from randomly selected fodder trees, leaves of all mature branches were collected. Three sub samples each 500g were prepared for each forage out of the composite sample using a stainless-steel knife and packed into zip-lock bags and sealed.

Collected samples were chopped and dried in a hot air oven at 72°C until obtaining a constant weight. Dried samples were ground, and stored in airtight polythene packets at room temperature. The samples were digested by using a microwave digester (MARS 6 240/50). For digestion, 0.5 g of dried sample was mixed with 10 mL concentrated nitric acid (70%). The Digested mixture was diluted with deionized water and filtered through Sartorius filter paper. Repeated washings of digestion tube and filter paper were done until the final volume of the filtrate was up to 50 mL. Simultaneous digestion of the reagent blank was undertaken. Digested samples were analysed for Ca, K, Mg, Na, Fe, Mn, Cu, Co, Se, Zn, Cr minerals by using an atomic absorption spectrophotometer (AAS; Thermo Scientific UK). Mineral content (X) was determined as follows:

$$X\ (\mathrm{mgkg^{-1}DM}) = \frac{\text{AAS Reading (ppm)}}{1000} \times \frac{50\ \mathrm{mL}}{\text{Digested sample weight (g)}} \times 1000$$

Each mineral was analysed in three replicates for individual forage variety. The Concentration of macro minerals were expressed as grams per kilogram of dry matter (gkg^{-1} DM) and trace mineral concentrations were expressed as milligrams per kilogram of dry matter (mgkg^{-1} DM).

Table 1: Forage samples collected from the study areas

Forage species	*Kotadeniyawa*	*Undugoda*	*Seeppukulama*
Fodder grasses			
CO-3 (*Pennisetum americarnum* × *Pennisetum purpureum*)	A	A	A
CO-4 (*Pennisetum americarnum* × *Pennisetum purpureum*)	A	A	-
Pakchong hybrid Napier (*Pennisetum purpureum* cv. pakchong1)	A	A	A
Gauthamala (*Tripsacum laxum*)	A	-	-
Guinea "A" (*Panicum maximum*)	A	A	-
Guinea "B" (*Panicum maximum*)	-	A	A
Pasture grasses			
Signal grass (*Brachiaria brizantha*)	A	A	A
Water grass (*Brachiaria mutica*)	A	A	A
Cori grass (*Brachiaria milliformis*)	A	-	-
Ruzi grass (*Brachiaria ruziziensis*)	A	A	A
Koronivia grass (*Brachiaria humidicola*)	A	A	A
Paspalum (*Paspalum dilatatum*)	A	-	A
Buffel grass (*Cenchrus ciliaris*)	A	-	A
Seteria (*Setaria sphacelata*)	A	-	-
Fodder legumes			
Caliandra (*Calliandra calothyrsus*)	A	-	-
Ipil-ipil (*Leucaena leucocephala*)	A	A	A
Gliricidia (*Gliricidia sepium*)	A	A	A
Pasture legumes			
Centro (*Centrosema pubescens*)	A	-	A
Desmodium (*Desmodium intortum*)	A	-	-
Peuro (*Pueraria phaseoloides*)	A	A	-
Stylo (*Stylosanthes guianensis*)	A	-	-

A - Available

Statistical Analysis

Brown-Forsythe test was used to compare the total mean concentration of each mineral based on dairy production region. Then data obtained for each plant variety was subjected to Tukey HSD Post Hoc Test to compare each mineral concentration based on dairy production regions. Statistical significance was determined at $p<0.05$. All the data were analysed using SPSS 16.0 statistical software and Excel. Values are presented as mean ± standard deviation.

3. Results and Discussion

Macro Minerals

The current study indicates mean Ca content of grasses is 2.36 ±1.90 gkg^{-1} DM and 10.90 ±3.55 gkg^{-1} DM for legumes. The results are in agreement with the findings of Minson (1990), where the Ca content of all legumes were higher than grasses (Table 8). Mahusoon et al. (2002) reported that the forage Ca concentration in North Western province, Sri Lanka ranged between 3.3 – 15.6 gkg^{-1} DM. In previous findings, Pavithra et al. (2019) reported a Ca content of 1.05±0.21 gkg^{-1} DM for CO-3, while CO-4 contained 2.00±0.42 gkg^{-1} DM. The values obtained for Ca in the present study (Table 2) are in agreement with Pavithra et al. (2019). CO-3 (Table 2) and Ruzi grass (Table 3) grown at Undugoda farm contained a higher ($p<0.05$) Ca content compared to *Kotadeniyawa* and *Seeppukulama* farms. Centro, Gliricidia, Ipil-ipil (Table 4) and Koronivia grass (Table 3) at *Seeppukulama* farm had higher ($p<0.05$) Ca contents compared to *Kotadeniyawa* and *Undugoda*. The highest ($p<0.05$) Ca content for Water grass (Table 3) was reported from *Kotadeniyawa*.

According to the literature, the level of individual mineral present in forage can vary depending on soil, climate, plant factors and management practices (Spears 1994). Adams (1975) has identified that within a small region, major variations of forage mineral concentrations exist and for some minerals, standard deviation was as larger as the mean value.

Forages are an excellent source of K (Spears 1994) and levels of K in forages are highly variable (Suttle 2010). Mahusoon et al. (2002) reported K concentrations of different forage types in North Western province, ranged from 9.7 – 16.9 gkg^{-1} DM. In this study mean K content of grasses was 10.1 ±0.76 gkg^{-1} DM while it was 9.69 ±0.67

gkg^{-1} DM in legumes (Table 8). Potassium contents in Pakchong hybrid Napier (Table 2), Water grass, Ruzi grass (Table 3) and Gliricidia (Table 4) at *Kotadeniyawa* were higher ($p<0.05$) than *Seeppukulama* farm.

Among fodder legumes Ipil-ipil (Table 4) and from the pasture grasses: Koronivia grass, Paspalum, and Buffel grass (Table 3) grown at *Kotadeniyawa* had the highest K contents ($p<0.05$) compared to *Undugoda* farm. In the study, K content of CO-3 (Table 2) at *Undugoda* was higher ($p<0.05$) than that of *Seeppukulama*. Management factors such as soil preparation, irrigation, plant density etc. can be influenced on changes in K content of forages (Robinson 2015).

Magnesium content of CO-3 (Table 2) grown in *Kotadeniyawa* was lower ($p<0.05$) than *Seeppukulama*. Signal grass (Table 3) at *Seeppukulama* contained significantly higher ($p<0.05$) Mg content comparative to *Kotadeniyawa*. Magnesium content of Pakchong hybrid Napier (Table 2), Koronivia grass (Table 3), and Ipil-ipil (Table 4) grown in *Kotadeniyawa* and *Seeppukulama* was significantly higher ($p<0.05$) than same forage varieties grown in *Undugoda*.

In the present study mean Mg levels of grass varieties and legumes were 0.71 ±0.03 gkg^{-1} DM and 0.75 ±0.04 gkg^{-1} DM respectively. Generally, Mg levels in legumes are higher than grasses (Minson 1990) and the current findings are in agreement with Minson (1990).

Mahusoon et al. (2002) has reported a mean value of 3.1±0.7 gkg^{-1} DM of Mg in North Western province, Sri Lanka where the values are higher than the current study findings [0.72 ±0.04 gkg^{-1} DM]. Further the Mg level of most forage varieties grown in *Undugoda* was significantly lower ($p<0.05$) than Mg level at *Seeppukulama*.

In acidic soils Mg is less available to the plants (Miller 2016). Soil pH of *Undugoda* (Red Yellow Podzolic soil – *Galigamuwa* series, pH 5-4.5) (Mapa et al, 1999), is lower than *Seeppukulama*.

This may be the reason for lowest Mg level ($p<0.05$) in Pakchong hybrid Napier (Table 2), Koronivia (Table 3) and, Ipil Ipil (Table 4) grown in *Undugoda* compared to *Seeppukulama* (Reddish Brown Earths – *Madawachchiya* Series, pH 6-7) (Mapa et al, 2010).

Table 2: Macro mineral levels of different types of fodder grasses collected from *Kotadeniyawa, Undugoda* and *Seeppukulama*

Forage	Dairy production zone	Location code	Ca	K	Mg	Na
CO-3	Coconut Triangle	Ko (n =3)	$1.72^{ab} \pm 0.13$	$10.5^{ab} \pm 0.14$	$0.69^{a} \pm 0.01$	$0.13^{a} \pm 0.01$
	Wet Zone	U (n =3)	$2.71^{a} \pm 0.66$	$10.9^{a} \pm 0.38$	$0.71^{ab} \pm 0.01$	$0.05^{bc} \pm 0.01$
	Dry Zone	Sp (n =3)	$1.05^{b} \pm 0.21$	$10.1^{b} \pm 0.29$	$0.71^{b} \pm 0.01$	$0.05^{c} \pm 0.01$
CO-4	Coconut Triangle	Ko (n =3)	2.22 ±0.12	10.9 ±0.53	0.70 ±0.01	$0.08^{a} \pm 0.01$
	Wet Zone	U (n =3)	2.72 ±0.50	10.5 ±0.44	0.71 ±0.01	$0.04^{b} \pm 0.01$
Pakchong hybrid Napier	Coconut Triangle	Ko (n =3)	1.73 ±0.20	$11.1^{a} \pm 0.34$	$0.72^{a} \pm 0.00$	$0.08^{a} \pm 0.01$
	Wet Zone	U (n =3)	1.72 ±0.16	$10.5^{ab} \pm 0.59$	$0.67^{b} \pm 0.02$	$0.03^{b} \pm 0.01$
	Dry Zone	Sp (n =3)	2.01 ±0.27	$9.54^{b} \pm 0.46$	$0.71^{a} \pm 0.01$	$0.11^{c} \pm 0.01$
Gauthamala	Coconut Triangle	Ko (n =3)	1.24 ±0.17	10.6 ±0.04	0.67 ±0.01	0.12 ±0.01
Guinea “A”	Coconut Triangle	Ko (n =3)	$2.85^{a} \pm 0.12$	10.4 ±0.18	$0.70^{a} \pm 0.01$	0.17 ±0.01
	Wet Zone	U (n =3)	$0.81^{b} \pm 0.11$	10.3 ±0.25	$0.66^{b} \pm 0.01$	0.19 ±0.01
Guinea “B”	Wet Zone	U (n =3)	$3.06^{a} \pm 0.28$	$10.3^{a} \pm 0.36$	0.72 ±0.00	$0.23^{a} \pm 0.01$
	Dry Zone	Sp (n =3)	$4.25^{b} \pm 0.52$	$8.89^{b} \pm 0.78$	0.73 ±0.00	$0.52^{b} \pm 0.01$

Ko- Kotadeniyawa, U- Undugoda, Sp- Seeppukulama, All the values are expressed as gkg-1 DM (mean ± standard deviation)

Different letters in the same column for each forage variety indicate statistical difference (P< 0.05)

n - number of field samples

Table 3: Macro mineral levels of different types of pasture grasses collected from *Kotadeniyawa, Undugoda* and *Seeppukulama*

Forage	Dairy production Zone	Location code	Ca	K	Mg	Na
Signal grass	Coconut Triangle	Ko (n =3)	0.88^{a} ±0.07	10.4^{ab} ±0.11	0.69^{a} ±0.01	0.07^{a} ±0.00
	Wet Zone	U (n =3)	2.03^{b} ±0.10	9.64^{a} ±0.34	0.72^{bc} ±0.01	0.03^{b} ±0.01
	Dry Zone	Sp (n =3)	2.36^{b} ±0.24	10.7^{b} ± 0.58	0.73^{c} ±0.02	0.19^{c} ±0.01
Water grass	Coconut Triangle	Ko (n =3)	3.48^{a} ±0.95	10.9^{a} ±0.49	0.70 ±0.01	0.58^{a} ±0.01
	Wet Zone	U (n =3)	0.67^{b} ±0.03	10.6^{a} ±0.11	0.67 ±0.01	0.38^{b} ±0.01
	Dry Zone	Sp (n =3)	0.70^{bc} ±0.15	9.62^{b} ±0.33	0.70 ±0.03	0.55^{a} ±0.01
Cori grass	Coconut Triangle	Ko (n =3)	1.76 ±0.07	10.6 ±0.06	0.71 ±0.01	0.30 ±0.01
Ruzi grass	Coconut Triangle	Ko (n =3)	1.78^{a} ±0.13	10.6^{a} ±0.10	0.71 ±0.01	0.15^{a} ±0.01
	Wet Zone	U (n =3)	4.56^{b} ±0.37	10.7^{a} ±0.51	0.73 ±0.01	0.05^{b} ±0.00
	Dry Zone	Sp (n =3)	2.42^{c}±0.12	9.26^{b} ±0.42	0.73 ±0.04	0.07^{c} ±0.01
Koronivia grass	Coconut Triangle	Ko (n =3)	0.66^{a} ±0.08	9.40^{a} ±0.57	0.77^{a} ±0.02	0.35^{a} ±0.01
	Wet Zone	U (n =3)	1.34^{b} ±0.38	8.35^{b} ±0.36	0.68^{b} ±0.01	0.40^{b} ±0.01
	Dry Zone	Sp (n =3)	2.56^{c} ±0.17	9.47^{a} ±0.13	0.74^{a} ±0.03	0.35^{a} ±0.02
Paspalum	Coconut Triangle	Ko (n =3)	3.52^{a} ±0.47	10.3^{a} ±0.22	0.72^{a} ±0.02	0.10^{a} ±0.01
	Dry Zone	Sp (n =3)	11.0^{b} ±0.47	8.63^{b} ±0.14	0.78^{b} ±0.00	0.02^{b} ±0.00
Buffel grass	Coconut Triangle	Ko (n =3)	1.11^{a} ±0.13	10.2^{a} ±0.27	0.66^{a} ±0.01	0.14^{a} ±0.01
	Dry Zone	Sp (n =3)	2.79^{b} ±0.57	9.53^{b} ±0.97	0.72^{b} ±0.01	0.31^{b} ±0.01
Seteria	Coconut Triangle	Ko (n =3)	1.56 ±0.20	10.6 ±0.04	0.66 ±0.00	0.59 ±0.00

Ko- Kotadeniyawa, U- Undugoda, Sp- Seeppukulama, All the values are expressed as gkg-1 DM (mean ± standard deviation)

Different letters in the same column for each forage variety indicate statistical difference ($p< 0.05$), n = number of field samples

Table 4: Macro mineral levels of different types of legumes collected from *Kotadeniyawa, Undugoda* and *Seeppukulama*

Forage	Dairy production Zones	Location code	Ca	K	Mg	Na
Fodder legumes						
Caliandra						
	Coconut Triangle	Ko (n =3)	10.4 ±0.26	8.57 ±0.01	0.72 ±0.01	0.02 ±0.00
Ipil-ipil	Coconut Triangle	Ko (n =3)	12.2[a] ±0.13	9.86[a] ±0.20	0.75[a] ±0.01	0.03 ±0.00
	Wet Zone	U (n =3)	8.55[b] ±0.64	9.16[b] ±0.21	0.71[b] ±0.01	0.04 ±0.01
	Dry Zone	Sp (n =3)	18.9[c] ±1.05	9.44[ab] ±0.32	0.76[a] ±0.01	0.05 ±0.01
Gliricidia	Coconut Triangle	Ko (n =3)	11.1[a] ±0.32	10.1[a] ±0.04	0.73 ±0.01	0.26[a]±0.01
	Wet Zone	U (n =3)	13.9[b] ±0.96	9.98[a] ±0.14	0.75 ±0.02	0.02[b] ±0.01
	Dry Zone	Sp (n =3)	15.7[c] ±0.12	8.51[b] ±0.07	0.77 ±0.01	0.28[a] ±0.02
Pasture legumes						
Centro	Coconut Triangle	Ko (n =3)	4.78[a] ±0.20	10.4 ±0.02	0.72 ±0.02	0.18 ±0.01
	Dry Zone	Sp (n =3)	9.79[b] ±0.64	10.5 ±0.00	0.74 ±0.01	0.17 ±0.01
Desmodium						
	Coconut Triangle	Ko (n =3)	6.92 ±0.29	9.53 ±0.03	0.71 ±0.00	0.07 ±0.00
Peuro	Coconut Triangle	Ko (n =3)	9.98 ±0.48	9.42[a] ±0.56	0.87[a] ±0.02	0.01[a] ±0.00
	Wet Zone	U (n =3)	10.1 ±0.28	10.5[b] ±0.25	0.72[b] ±0.02	0.13[b] ±0.01
Stylo	Coconut Triangle	Ko (n =3)	9.70 ±0.32	10.1 ±0.03	0.73 ±0.01	0.11 ±0.01

Ko- Kotadeniyawa, U- Undugoda, Sp- Seeppukulama, All the values are expressed as gkg-1 DM (mean ± standard deviation)

Different letters in the same column for each forage variety indicate statistical difference ($p < 0.05$)

n = number of field samples

Forages are a poor source of Na (Minson 1990). The Worldwide distribution of Na levels of forages is skewed towards low values. Generally, tropical pasture contains more Na levels than temperate pasture (Minson 1990). CO-3 (Table 2) and Ruzi grass (Table 3) grown in *Kotadeniyawa* had the highest Na content (p<0.05) compared to *Undugoda* and *Seeppukulama.* Between three locations the highest Na content (p<0.05) for Pakchong hybrid Napier (Table 2) and Signal grass (Table 3) was reported from *Seeppukulama.* Koronivia grass (Table 3) grown in *Undugoda* had the highest Na content (p<0.05), while Water grass (Table 3) and Gliricidia (Table 4) had the lowest (p<0.05). Mean Na concentration reported from the present study for grasses and legumes are 0.21 ±0.17 gkg^{-1} DM and 0.11 ±0.09 gkg^{-1} DM respectively which are lower than the values reported by Mahusoon et al. (2002).

Micro Minerals

Level of Fe in pasture vary widely depending on plant species and soil type. Two studies conducted in New Zealand by Metson and Saunders (1978) and Campbell et al. (1974) reported that Fe content in Rye grass (*Lolium perenne*) and clover (*Trifolium spp.*) pasture ranged from 100-300 mgkg^{-1} DM and 70-111 mgkg^{-1} DM to 2300-3800 mgkg^{-1} DM respectively. Water logging conditions have induced to record high value of Fe in soils (Suttle 2010) and the grasses grown on poor sandy soils reported a Fe content lower than 30 mgkg^{-1} DM (Underwood 1999). In the present study mean Fe levels of grasses and legumes were 131 ±66.5 mgkg-^{1} DM and 178 ±63.9 mgkg^{-1} DM respectively which were higher than the values reported by Khan et al. (2006). Between three locations, the highest Fe values (p<0.05) for Ruzi grass (Table 6), Ipil-ipil, and Gliricidia (Table 7) were reported from *Seeppukulama.* CO-3, CO-4, Pakchong hybrid Napier (Table 5) grown in *Kotadeniyawa* had higher Fe content (p<0.05) comparative to *Undugoda*, while Fe content in Signal grass and Koronivia grass (Table 6) grown in *Kotadeniyawa* was the lowest (p<0.05).

Minson (1990) reported that forage Mn content vary with a mean value of 86 mgkg-^{1} DM, and concentration was generally above 20 mgkg^{-1} DM. The results obtained from current study are in agreement with the above findings, where the mean Mn content of forages was 64.33 ±46.4 mgkg^{-1} DM. In the present study Mn content of grasses and legumes are 61.8 ±39.2 mgkg^{-1} DM and 71.1 ±60.2 mgkg^{-1} DM respectively. According to Suttle (2010) differences in Mn content exist due to soil contamination or contamination while sample processing with steel blades. Thus, in the present study Mn level of CO-3, Pakchong hybrid Napier (Table 5), Signal grass, Water grass, Paspalum (Table 6) from *Seeppukulama* was significantly lower (p<0.05) compared to *Kotadeniyawa*. These values can be justified by distribution of Mn ion in groundwater of Sri Lanka (Dissanayake and Weerasooriya 1985). In *Seeppukulama*, groundwater Mn content was lower than 0.04 ppm while *Kotadeniyawa* has 0.04-0.1 ppm Mn content (Dissanayake and Weerasooriya 1985). The present investigation reported the highest (p<0.05) Mn content for Ruzi grass (Table 6) and Gliricidia (Table 7) from *Seeppukulama*, compared to the other two locations.

The concentration of Cu in forage varies with plant species, soil condition, but except with soil pH (McFarlane et al. 1990). Underwood (1999) reported Cu concentration of forages ranged from 4.5-21.1 mgkg^{-1} DM while Khan et al. (2006) reported mean Cu concentration in pasture grasses as 12.53 ±0.55 mgkg^{-1} DM in summer. Mean Cu content of forages (11.3 ±14.0 mgkg^{-1} DM) in the present study is similar to the previous findings (Khan et al. 2006). Previous studies showed that the Cu concentration of Napier grass (*Pennisetum purpureum*) and Seteria (*Steria sphacelata*) as 4.1 mgkg^{-1} DM and 3.9 mgkg^{-1} DM respectively (Jumba et al. 1995; Suttle 2010). In contrast, the Cu concentrations obtained for the above grasses in the present study were lower (Table 5 and Table 6). Among three locations, CO-3 (Table 5), Signal grass and Koronivia grass (Table 6) grown in *Seeppukulama* and Water grass (Table 6) and Ipil-ipil (Table 7) grown in *Kotadeniyawa* had the highest Cu concentrations (p<0.05). Copper content of Pakchong hybrid Napier (Table 2) grown in *Kotedeniyawa* was higher (p<0.05) compared to *Undugoda*. Generally, tropical legumes are higher in Cu than tropical grasses (Minson 1990). Similarly, in the current study, legumes (8.89 ±2.87 mgkg^{-1} DM) contained higher Cu level than grasses (7.73 ±2.68 mgkg^{-1} DM) (Table 8).

The current study reveals, mean Co concentration of grasses was 0.23 ±0.06 mgkg^{-1} DM while legumes contained 0.20

±0.06 mgkg^{-1} DM. The studies conducted in South Western Punjab and Scotland reported 0.178 ±0.015 mgkg^{-1} DM and 0.02 to 0.22 mgkg^{-1} DM Co concentrations in pasture grasses, respectively (Khan et al. 2006; Suttle 2010), which are in agreement with current findings (Table 8). Pakchong hybrid Napier (Table 5), Signal grass, Ruzi grass, Koronivia grass, Buffel grass (Table 6) and, Ipil-ipil (Table 7) grown in *Seeppukulama* had higher Co content (p<0.05) than the same forages grown in *Kotadeniyawa* and *Undugoda*. CO-3, CO-4 (Table 5) and Koronivia grass grown in *Kotadeniyawa* had higher Co content (p<0.05) comparative to *Undugoda*. In the present study the highest mean Co content (p<0.05) in forages were reported from *Seeppukulama.*

These values are in accordance with the findings reported by Dissanayake and Weerasooriya (1985) related to the distribution of Co ion in ground water in this area. Cobalt ion concentration in ground water of *Seeppukulama* was 0.09-0.12 ppm (Dissanayake and Weerasooriya 1985).

The current results reported 0.16 ±0.02 mgkg^{-1} DM Se content in grasses and 0.17 ±0.03 mgkg^{-1} DM Se content in legumes, which were not in line with previously found values (Suttle 2010). Selenium contents did not indicate a significant difference between both grasses and legumes. Suttle (2010) reported Se content of 0.05 ±0.02 mgkg^{-1} DM in fresh grasses in UK and in New Zealand it ranged between 0.005-0.07 mgkg^{-1} DM (Grant and Sheppard 1983). Khan et al. (2006) has reported 0.097±0.003 mg Se kg^{-1} DM in the pasture from South Western Punjab in summer. Current data shows that Se concentration of individual forage variety did not significantly different (p>0.05) among three zones, except in Koronivia grass (*Brachiaria humidicola*) and Peuro (*Pueraria phaseoloides*).

Mean concentration of Se in Koronivia grass (Table 6) and Peuro (Table 7) in *Kotadeniyawa* was significantly higher (p<0.05) than *Undugoda*. Koronivia grass grown in *Kotadeniyawa* was higher (p<0.05) in Se content compared to the *Seeppukulama.*

Table 5: Micro mineral levels of different types of fodder grasses collected from *Kotadeniyawa, Undugoda* and *Seeppukulama*

Forage	Dairy production zone	Location code	Fe	Mn	Cu	Co	Se	Zn	Cr
CO-3	Coconut Triangle	Ko (n =3)	178^{a} ±9.55	207^{a} ±3.90	9.36^{a} ±0.30	0.35^{a}±0.05	0.17±0.01	36.9±1.61	0.49^{a}±0.06
	Wet Zone	U (n =3)	77.3^{bc} ±11.5	50.4^{b} ±5.27	8.81^{a} ±0.40	0.20^{b}±0.01	0.16±0.02	34.7±2.69	0.54^{a}±0.02
	Dry Zone	Sp (n =3)	86.7^{c}±12.3	20.6^{c}±2.60	13.3^{b} ±0.39	0.28^{ab}±0.03	0.13±0.08	51.3±11.4	0.82^{b}±0.07
CO-4	Coconut Triangle	Ko (n =3)	135^{a} ±15.5	68.2 ±2.72	8.79 ±0.92	0.35^{a}±0.02	0.17±0.02	40.0^{a}±0.71	0.78^{a}±0.03
	Wet Zone	U (n =3)	96.8^{b} ±7.19	72.1 ±2.79	8.10 ±0.71	0.21^{b}±0.02	0.17±0.01	26.1^{b}±5.20	0.55^{b}±0.02
Pakchong	Coconut Triangle	Ko (n =3)	125^{a}±9.33	130^{a}±10.5	9.50^{a} ±0.69	0.20^{a}±0.02	0.16±0.03	39.9^{a}±3.78	0.95^{a}±0.02
hybrid	Wet Zone	U (n =3)	83.2^{b} ±8.87	50.6^{b} ±1.69	7.77^{b} ±0.26	0.21^{a}±0.01	0.15±0.02	55.7^{ab}±7.00	0.64^{b}±0.02
Napier	Dry Zone	Sp (n =3)	130^{a}±9.17	37.8^{bc}±3.16	8.95^{ab} ±0.49	0.27^{b}±0.01	0.15±0.02	65.7^{b}±8.72	0.63^{bc}±0.04
Gauthamala	Coconut Triangle	Ko (n =3)	112 ±13.0	44.9 ±2.09	4.19 ±0.98	0.10±0.02	0.16±0.08	38.5±2.56	0.58±0.10
Guinea “A”	Coconut Triangle	Ko (n =3)	100 ±6.68	54.0^{a} ±1.27	5.02 ±0.46	0.11^{a}±0.02	0.17±0.01	40.9^{a}±3.73	0.62^{a}±0.06
	Wet Zone	U (n =3)	115 ±20.2	47.6^{b} ±2.04	5.62 ±0.55	0.21^{b}±0.01	0.14±0.03	24.9^{b}±3.46	0.86^{b}±0.11
	Wet Zone	U (n =3)	176^{a} ±39.4	46.3^{a} ±5.58	10.1^{a} ±0.73	0.21^{a}±0.02	0.15±0.02	30.4±2.04	1.92^{a}±0.66
Guinea “B”	Dry Zone	Sp (n =3)	82.6^{b}±7.66	33.5^{b}±2.53	8.51^{b} ±0.30	0.27^{b}±0.01	0.16±0.02	28.1±3.23	0.64^{b}±0.03

Ko- Kotadeniyawa, U- Undugoda, Sp- Seeppukulama, All the values are expressed as mgkg-1 DM (mean ± standard deviation)

Different letters in the same column for each forage variety indicate statistical difference ($p< 0.05$). n = number of field samples

Table 6: Micro mineral levels of different types of pasture grasses collected from *Kotadeniyawa*, *Undugoda* and *Seeppukulama*

Forage	Dairy production zones	Location code	Fe	Mn	Cu	Co	Se	Zn	Cr
Signal grass	Coconut triangle	Ko (n =3)	92.1^{a}±9.85	39.7^{a}±2.32	3.30^{a}±0.12	0.16^{a}±0.02	0.14±0.02	71.8^{a}±5.44	0.65±0.06
	Wet Zone	U (n =3)	179^{bc} ±14.9	126^{b}±3.75	8.27^{b}±0.22	0.23^{b}±0.02	0.17±0.01	50.7^{bc}±5.70	0.64±0.01
	Dry Zone	Sp (n =3)	159^{c}±8.06	25.0^{c}±0.47	13.1^{c}±0.53	0.30^{c}±0.02	0.14±0.01	43.5^{c}±5.69	0.70±0.05
Water grass	Coconut triangle	Ko (n =3)	242±57.1	68.1^{a}±1.10	4.90^{a}±0.12	0.17^{a}±0.01	0.16±0.02	83.3^{a}±10.1	0.52^{a}±0.03
	Wet Zone	U (n =3)	175±20.6	43.7^{b}±0.33	3.71^{b}±0.43	0.25^{b}±0.01	0.14±0.01	60.3^{b}±1.95	1.08^{b}±0.05
	Dry Zone	Sp (n =3)	146±25.8	49.5^{c}±2.21	2.97^{c}±0.16	0.27^{bc}±0.01	0.15±0.02	93.3^{a}±3.42	0.98^{bc}±0.07
Cori grass	Coconut triangle	Ko (n =3)	189±4.92	77.6±3.32	9.45±0.52	0.18±0.02	0.17±0.03	275±22.1	0.62±0.09
Ruzi grass	Coconut triangle	Ko (n =3)	116^{a}±9.16	60.3^{a}±2.29	6.24^{a}±0.37	0.17^{a}±0.02	0.16±0.02	84.6^{a}±7.06	0.54^{a}±0.02
	Wet Zone	U (n =3)	113^{a}±12.5	35.2^{b}±2.28	7.54^{ab}±0.33	0.21^{b}±0.01	0.18±0.01	93.2^{a}±4.00	0.70^{bc}±0.04
	Dry Zone	Sp (n =3)	390^{b}±81.6	79.9^{c}±4.77	8.34^{b}±1.00	0.28^{c}±0.02	0.13±0.03	61.3^{b}±3.34	0.76^{c}±0.03
Koronivia grass	Coconut triangle	Ko (n =3)	23.0^{a}±1.24	42.9^{a}±0.88	2.52^{a}±0.25	0.28^{a}±0.02	0.19^{a}±0.01	27.6^{a}±0.86	0.99^{a}±0.12
	Wet Zone	U (n =3)	66.7^{b}±4.64	95.9^{b}±11.4	6.71^{b}±0.93	0.23^{b}±0.02	0.14^{b}±0.01	67.6^{b}±1.86	0.71^{b}±0.08
	Dry Zone	Sp (n =3)	93.5^{bc}±18.5	31.6^{a}±5.60	9.82^{c}±0.37	0.31^{a}±0.01	0.12^{bc}±0.01	81.3^{c}±5.98	0.65^{bc}±0.03
Paspalum	Coconut triangle	Ko (n =3)	117^{a}±4.81	125^{a}±5.42	7.43±0.44	0.17^{a}±0.01	0.15±0.03	53.6^{a}±10.3	0.44^{a}±0.03
	Dry Zone	Sp (n =3)	107^{b}±2.15	36.7^{b}±2.44	9.94±2.89	0.32^{b}±0.01	0.16±0.02	25.2^{b}±2.57	0.81^{b}±0.81
Buffel grass	Coconut triangle	Ko (n =3)	129±11.8	25.9^{a}±1.16	6.16^{a}±0.23	0.16^{a}±0.01	0.16±0.03	53.4±7.79	0.97^{a}±0.15
	Dry Zone	Sp (n =3)	110±10.9	44.6^{b}±5.16	9.14^{b}±0.10	0.25^{b}±0.01	0.15±0.03	62.4±7.49	0.68^{b}±0.05
Seteria	Coconut triangle	Ko (n =3)	114±13.9	45.3±2.21	5.79±0.68	0.14±0.02	0.16±0.02	53.6±3.95	0.91±0.01

Ko- Kotadeniyawa, U- Undugoda, Sp- Seeppukulama, All the values are expressed as mgkg-1 DM (mean ± standard deviation), Different letters in the same column for each forage variety indicate statistical difference (p< 0.05), n = number of field samples

Table 7: Micro mineral levels of different types of legumes collected from *Kotadeniyawa, Undugoda* and *Seeppukulama*

Forage	Dairy production zone	Location code	Fe	Mn	Cu	Co	Se	Zn	Cr
Fodder legumes									
Caliandra	Coconut triangle	Ko (n =3)	197 ±5.38	65.6 ±2.80	10.1 ±0.49	0.19±0.02	0.18±0.04	40.0±3.26	0.50±0.03
Ipil-ipil	Coconut triangle	Ko (n =3)	162[a] ±7.12	42.6[a] ±1.37	11.0[a] ±0.35	0.17[a]±0.01	0.18±0.02	48.8[a]±2.03	0.56[a]±0.37
	Wet Zone	U (n =3)	118[b] ±8.55	62.7[b] ±4.82	7.13[b] ±0.18	0.22[b]±0.02	0.16±0.03	30.6[b]±0.42	0.57[a]±0.05
	Dry Zone	Sp (n =3)	251[c]±12.0	65.2[bc]±2.76	9.44[c] ±0.42	0.29[c]±0.02	0.15±0.02	20.3[c]±2.06	0.86[b]±0.07
Gliricidia	Coconut triangle	Ko (n =3)	156[a] ±6.36	31.8[a] ±2.37	5.91[a] ±0.77	0.17[a]±0.03	0.17±0.01	47.7[a]±4.04	0.47[a]±0.01
	Wet Zone	U (n =3)	99.5[b] ±9.05	34.9[a] ±1.48	4.71[b] ±0.06	0.24[b]±0.02	0.17±0.03	16.6[b]±0.11	0.69[b]±0.04
	Dry Zone	Sp (n =3)	195[c]±13.6	55.1[b]±2.22	6.43[a] ±0.25	0.26[bc]±0.01	0.14±0.01	16.4[bc]±0.97	0.83[c]±0.03
Pasture legumes									
Centro	Coconut triangle	Ko (n =3)	132[a]±28.1	50.3[a]±0.53	9.56[a]±0.55	0.18[a]±0.02	0.14±0.04	44.5±4.39	0.46[a]±0.03
	Dry Zone	Sp (n =3)	336[b]±18.1	69.8[b]±2.29	14.5[b]±0.75	0.26[b]±0.01	0.16±0.01	42.3±2.16	0.71[b]±0.01
Desmodium	Coconut triangle	Ko (n =3)	166±6.79	272±17.7	10.5 ±0.46	0.18±0.01	0.16±0.01	36.8±1.50	0.52±0.04
Peuro	Coconut triangle	Ko (n =3)	114[a]±12.6	51.9±4.90	5.61[a]±0.39	0.30[a]±0.01	0.24[a]±0.01	33.2[a]±0.79	1.72[a]±0.15
	Wet Zone	U (n =3)	218[b]±26.4	63.2±5.89	10.0[b]±0.57	0.22[b]±0.01	0.14[b]±0.02	38.1[b]±1.48	0.67[b]±0.04
Stylo	Coconut triangle	Ko (n =3)	164±31.5	59.0±6.08	12.2±0.21	0.20±0.01	0.17±2.43	63.4±3.58	0.50±0.06

Ko- Kotadeniyawa, U- Undugoda, Sp- Seeppukulama, All the values are expressed as mgkg-1 DM (mean ± standard deviation)

Different letters in the same column for each forage variety indicate statistical difference (p< 0.05), n = number of field samples

Table 8: Mean mineral value for grass and legumes reported from each dairy production zone

	Grass			**Legumes**		
	Ko (n=39)	U (n=27)	Sp (n=27)	Ko (n=21)	U (n=9)	Sp (n=9)
Macro mineral (gkg-1 DM)						
Ca	1.89±0.91	2.18±1.23	3.24±3.09	9.30±2.58	10.8±2.75	14.8±4.60
K	10.5±0.42	10.2±0.78	9.53±0.62	9.71±0.60	9.87±0.67	9.48±1.00
Mg	0.70±0.03	0.70±0.03	0.73±0.02	0.75±0.06	0.73±0.02	0.75±0.02
Na	0.22±0.18	0.15±0.15	0.24±0.20	0.10±0.09	0.06±0.06	0.17±0.12
Micro mineral (mgkg-1 DM)						
Fe	129±52.5	120±45.2	145±95.7	156±26.5	145±63.7	260±70.9
Mn	76.1±50.3	63.1±30.1	39.9±17.4	82 .0±84.8	53.6±16.17	63.4±7.49
Cu	6.36±2.39	7.41±1.88	9.34±3.02	9.28±2.55	7.29±2.67	10.1±4.05
Co	0.20±0.08	0.22±0.02	0.28±0.02	0.20±0.05	0.23±0.01	0.27±0.02
Se	0.16±0.01	0.16±0.02	0.14±0.01	0.18±0.03	0.16±0.02	0.15±0.01
Zn	69.2±64.5	49.2±22.8	56.9±22.6	44.9±9.93	28.5±10.9	26.3±14.0
Cr	0.70±0.20	0.85±0.44	0.74±0.11	0.68±0.46	0.64±0.06	0.80±0.08

Ko- Kotadeniyawa, U- Undugoda, Sp- Seeppukulama,

All the values are expressed as mean ± standard deviation, n = number of field samples

According to Minson (1990), Zn content of most of the pasture species in worldwide, ranged between 7-100 mgkg^{-1} DM and it is in accordance with the current study values. A significantly higher Zn content (p<0.05) was observed in CO-4, Guinea "A" (Table 5), Signal grass, Paspalum (Table 6), Ipil-ipil, and Gliricidia (Table 7) grown in *Kotadeniyawa*, than same forages in *Seeppukulama* and *Undugoda*. The highest

Zn content (p<0.05) for Koronivia grass (Table 6) was recorded from *Seeppukulama*, while Zn content in Ruzi grass (Table 6) grown in *Seeppukulama* was the lowest (p<0.05). The mean Zn content in grasses and legumes were 59.8 ±44.7 mgkg^{-1} DM and 36.8 ±13.3 mgkg^{-1} DM, respectively. Pasture in New Zealand recorded 16-45 mg Zn kg^{-1} DM (Grace et al. 2010) while in South Western Punjab pastures contained 49.32 ±1.64 mg Zn kg^{-1} DM in winter and 25.01 mg Zn kg^{-1} DM in summer (Khan et al., 2006).

Level of Cr is abundant in soil than in crops. Generally, legumes are relatively rich in Cr than grasses (Suttle 2010). In contrast the mean Cr content in grasses was reported as 0.75 ±0.29 mgkg^{-1} DM and in legumes, it was 0.70 ±0.33 mgkg^{-1} DM in the present study. Grace et al. (2010) reported a Cr content of 0.2-4.2 mg Cr kg^{-1} DM for legumes and 0.1-0.35 mg Cr kg^{-1} DM for grasses found in Eastern European countries. In the present study, Cr content in CO-3 (Table 5), Gliricidia and Ipil-ipil (Table 7) grown in *Seeppukulama* was significantly higher (p<0.05) than *Kotadeniyawa* and *Undugoda*. While, Cr content of CO-4, Pakchong hybrid Napier (Table 5), Koronivia grass (Table 6) grown in *Kotadeniyawa* was higher (p<0.05) than other two locations. Chromium content of Water grass and Ruzi grass (Table 6) at *Undugoda* and *Seeppukukama* did not differ (p<0.05). But Cr content of these two types of grasses grown at *Undugoda* was significantly higher (p<0.05) than *Kotadeniyawa*.

Mineral contents of forages vary according to the season (Spears 1994). However, this study has been conducted during South-West monsoon period of the year only. Therefore, it is suggested to conduct the study in both seasons to obtain a comprehensive conclusion.

4. Conclusions

It can be concluded that legumes contain higher levels of Ca, Mg, Fe, Mn, and Cu than grasses, while grasses are rich in Zn. The results revealed that the minerals tested were significantly different in the three locations (*Udugoda, Seeppukulama and Kotadeniyawa*) except for Se. The tested forage species contained sufficient levels of K, Fe, Mn, and Se for dairy cattle according to the NRC recommendations but considerably low in Na. By considering the macro and micro mineral contents in the tested forages, it can be concluded, that a mixture of forages containing both grasses and legumes is better for feeding dairy cattle in Coconut Triangle, wet and dry zones. Further investigations at different seasons are suggested for better recommendations.

Conflicts of Interest: The authors have no conflicts of interest regarding this publication.

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