AMOUNT AND DISTRIBUTION OF DIETARY MINERALS IN SELECTED PHILIPPINE FORAGES

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Summary

Eight Philippine forages were studied to obtain the following: 1) nutrient concentrations and digestibility, 2) distribution of the various minerals in fiber fractions through mineral analyses of neutral detergent fiber (NDF) and acid detergent fiber (ADF) residues, and 3) correlation coefficients among the factors affecting forage quality and mineral concentrations. These Philippine forages were paragrass [*Brachiaria mutica* (Forsk.) Stapf], stargrass (*Cynodon plectostachyum* Pilger), napiergrass (*Pennisetum purpureum* Schumach.) calopo (*Calopogonium muconoides* Desv.), centrocema (*Centrocema pubescens* Benth.), gliricidia [*Gliricidia sepium* (Jacq.) Walp.], leucaena [*Leucaena leucocephala* (Lam.) de Wit.] and sesbania [*Sesbania grandiflora* (L.) Poir].

Species differences ($p < 0.01$) were observed on various nutrient fractions including mineral composition and digestibility. The cell wall (NDF) fraction, prepared by boiling in neutral detergent solution, contained the following proportions of the total mineral originally present (%): calcium (Ca), 0.7; phosphorus (P), 14.3; magnesium (Mg), 1.9; potassium (K), 3.7; copper (Cu), 16.4; zinc (Zn), 2.9; molybdenum (Mo), 9.3; cobalt (Co), 16.2; manganese (Mn), 5.6, and iron (Fe), 81.3. The ligno-cellulose (ADF) fraction, prepared by boiling in acid detergent solution, contained the following proportions of the total mineral originally present (%): Ca, 0.2; P, 4.4; Mg, 0.7; K, 2.8; Cu, 32.3; Zn, 1.1; Mo, 8.9; Co, 4.7; Mn, 5.4; and Fe, 36.8. Correlation coefficients among the factors affecting forage quality and mineral concentrations were also observed. Evidently, 75 and 45% of the minerals in grasses and legumes was positively correlated to CP and IVDMD, respectively. Moreover, 55, 80 and 75% of the forage minerals was negatively correlated to NDF, ADF, and ADL fraction, respectively, implying that most of the minerals reside in the non-structural cell components.

(**Key Words** : Tropical Forage, Philippine Forage, Nutrient Content, Mineral Content, Mineral Distribution)

Introduction

Most grazing livestocks from tropical countries including those from the Philippines satisfy their mineral requirements usually from the forages. Since the forages are deficient or in excess of various minerals, therefore, the animals may have subclinical deficiencies or chronic toxicities. Aside from this aforementioned problems, the use of minerals by the animals is constrained by bioavailability. That is, some minerals in the forage are in bound form with other compounds or trapped in the undigested nutrient fractions resulting in slowly release or making these unavailable for use. This also limits the bioavailability of other elements.

The amount of mineral in forage and their bioavailability need to be considered in assessing the mineral requirements of the animals. The mineral content can be determined chemically while bioavailability is much more difficult to estimate. Data are sparse in tropical forages. The bioavailability of mineral can be affected by their location in forage structure. Minerals associated with the plant cell wall may have lower bioavailability or require a longer fermentation time for maximal release like Ca and Zn (Emanuele and Staples, 1990).

This study was conducted with the following objectives: 1) to measure the nutrient concentrations including digestibility of the different Philippine forages, 2) to determine the distribution of the various minerals in fiber fractions, and 3) to estimate correlation coefficients

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among the factors affecting forage quality and mineral concentrations. The forage samples were those used by Serra et al. (1996) to measure the ruminal solubilization of macrominerals.

Materials and Methods

Site of collection

All the forage samples were collected at the vicinity of the Department of Animal Science, College of Agriculture, Central Luzon State University, Philippines (15° 43′ N latitude, 120° 54′ E longitude with an altitude of 76 m). The average temperature [(t max + t min)/2] was 27℃ (highest maxima, April to May; lowest minima, December to January). The average daylength and relative humidity was 11.3 and 78.9%, respectively. Annual rainfall was > 2,000 mm.

Forage samples

The different samples collected were categorized into three groups, i.e. 1) grasses: paragrass [*Brachiaria mutica* (Forsk.) Stapf], stargrass (*Cynodon plectostachyum* Pilger) and napiergrass (*Pennisetum purpureum* Schumach.); 2) creeping legumes: calopogonium or calopo (*Calopo- gonium mucunoides* Desv.) and centrocema (*Centrocema pubescens* Benth.); and 3) tree legumes: gliricidia or kakawate [*Gliricidia sepium* (Jacq.) Walp], leucaena or ipil-ipil [*Leucaena leucocephala* (Lam.) de Wit.] and sesbania or katuray [*Sesbania grandiflora* (L.) Poir].

Sampling of forages was done during the wet season. The grass samples were collected by cutting the young vegetative portion of the plant. The vines of creeping legumes were included in the samples whereas the leaves including the petioles of the tree legumes were sampled. All the samples were dried and ground to pass in a 2-mm screen Wiley mill. They were stored in plastic containers for later experiment and analyses.

Experimental procedure

The different forage species were analyzed for their ash, CP, fiber contents, various fiber fractions, mineral concentration and IVDMD.

The association of the different mineral elements to the cell wall matrix including its ligno-cellulose compound was determined. Neutral detergent solution (NDS) and acid detergent solution (ADS) were used to treat the forage samples. The NDS and ADS were prepared according to the methods of Goering and Van Soest (1970).

Treatment with NDS and ADS was done by boiling 1 g of the forage sample with 100 ml of solution for 1 h in a 600 ml beaker. The solution was filtered through a pre-weighed nylon filter and washed five times with hot deionized water. The filters with the residues were transferred to porcelain crucibles, dried at 60℃ for 2 d and weighed to estimate the loss of dry matter during extraction.

Laboratory analyses

All the forage samples collected were analyzed for their dry matter (DM), ash and crude protein (CP) contents by standard procedures (AOAC, 1984). NDF and ADF were assessed by nonsequential procedure of Goering and Van Soest (1970). Lignin was determined on acid detergent lignin (ADL) following ADF analysis. Hemicellulose was calculated as the difference between NDF and ADF. Cellulose was estimated as the difference between ADF and ADL. Neutral detergent soluble or cell content (CC) was determined (100%-NDF%). *In vitro* dry matter disappearance (IVDMD) was performed following the technique of Tilley and Terry (1963) as modified by Goering and Van Soest (1970).

Ground forage samples and those detergent residues collected were prepared for mineral analysis using a wet ashing procedure. All prepared solutions were analyzed for their mineral contents (i.e., Ca, P, Mg, K, Cu, Zn, Mo, Co, Mn, and Fe) using an Inductively Coupled Plasma Emission Spectrometer (ICPS-2000, Shimadzu Co., Kyoto, Japan).

Statistical analyses

The data on nutrient content including mineral concentrations and digestibility of the forages were statistically analyzed by completely randomized design and means were compared with Duncan's multiple range test (Steel and Torrie, 1980). Correlation coefficients among the factors affecting forage quality (CP, NDF, ADF, ADL, and IVDMD) and mineral concentrations were computed.

Results and Discussion

Chemical composition and IVDMD

Table 1 shows the chemical composition including the IVDMD of the forage species. The ash content of the forages varied from 7.5 to 11.5% DM. Calopo and gliricidia had the lowest and highest ($p < 0.01$) ash content, respectively. As expected, the legumes contained more CP than those grasses. The CP content of the forages varied from 10.6 to 31.0% DM. Napiergrass and sesbania gave the lowest and highest ($p < 0.01$) CP content, respectively. The observed values for ash and CP

TABLE 1. ASH, CRUDE PROTEIN, FIBER FRACTIONS AND *IN VITRO* DRY MATTER DIGESTIBILITY OF SELECTED PHILIPPINE FORAGES

Forage	DM (%)	Ash	CP	NDF	ADF	ADL	IVDMD
		....	....	% DM	....	....	
Grasses							
Para	90.1	9.1^{bcd}	11.5^{f}	65.8^{b}	39.7^{b}	2.1^{ef}	68.7^{a}
Star	92.4	9.6^{bc}	16.3^{e}	70.1^{a}	36.3^{c}	1.3^{f}	66.0^{a}
Napier	89.0	10.4^{ab}	10.6^{f}	66.8^{b}	40.2^{ab}	1.8^{f}	67.4^{a}
Creeping legumes							
Calopo	88.3	7.5^{e}	20.9^{d}	56.8^{c}	39.4^{b}	5.9^{b}	56.6^{b}
Centrocema	88.3	7.9^{dc}	24.4^{c}	51.5^{d}	41.2^{a}	7.6^{a}	47.9^{c}
Tree legumes							
Gliricidia	92.4	11.5^{a}	26.4^{bc}	31.2^{e}	20.6^{d}	4.8^{bc}	65.4^{a}
Leucaena	90.7	9.3^{bcd}	26.9^{b}	31.4^{e}	19.6^{d}	3.1^{de}	58.4^{b}
Sesbania	89.0	8.3^{cde}	31.0^{a}	20.3^{f}	16.5^{e}	3.6^{cd}	65.3^{a}
Mean		9.2	21.0	49.2	31.6	3.8	62.0
SEM		0.3	0.5	0.3	0.5	0.2	1.0

[a,b,c,d,e,f] Means within column having different superscripts differ ($p < 0.01$).

contents of forages were generally within the range typical for the tropical grass and legumes species (NRC, 1981; Serra et al., 1994).

Cell walls (NDF) comprise 20-80% of forage dry weight (Wilson, 1994). Findings of the present study were within the range varying from 20.3 to 70.1% DM. The other fiber fractions, ADF, varied from 16.5 to 41.2% DM whereas the ADL fraction varied from 1.3 to 7.6% DM. Sesbania gave the lowest ($p < 0.01$) NDF and ADF fractions. Stargrass had the highest and lowest ($p < 0.01$) NDF and ADL fraction, respectively. Centrocema had the highest ($p < 0.01$) ADF fraction. The general trend in NDF, however, was grass > creeping legume > tree legume. In ADF the trend was grass and creeping legume > tree legume whereas in ADL the trend was creeping legume > tree legume > grass. Thus, creeping legumes had higher amount of various fiber fractions than the tree legumes but in terms of percentage of the total cell wall content (NDF), the various fiber fractions were almost the same. On the other hand, grass species were higher in hemicellulose but lower in ADL and almost the same for cellulose when compared to the two groups of legumes.

The IVDMD varied from 47.9 to 68.7% DM. The grass species (paragrass, napiergrass and stargrass) and tree legumes (gliricidia, and sesbania) had higher ($p < 0.01$) IVDMD than other forage species. Although the different legume species had higher percent soluble cell contents (this could be estimated from 100%-NDF%) than those grass species. Their IVDMD were the same or lower than the latter. As reported by Topps (1992), tropical legumes had phenolic compounds 10 to 20% DM. Most of these compounds show a broad-spectrum antimicrobial activity which reduces fermentation rates in the rumen (Topps, 1992).

Mineral concentrations of forages

Table 2 shows the macro- and micromineral concentrations of some Philippine forages. The concentrations of the various elements in grasses and tree legumes were within the ranges typical for these forages (Fujihara et al., 1992a,b; Serra et al., 1994). It had also some similarities with the findings of Little et al. (1989) on Indonesian ruminant forages. The findings of the present study showed that differences ($p < 0.01$) existed in terms of various mineral contents across species.

As expected the trend on Ca and Mg contents of forages was legumes > grasses but the trend on P content was the reverse, grasses > legumes. Between the two legume groups, the tree species were higher in Ca and Mg concentrations than those creeping species. The K content of the various forages was higher in grasses except in gliricidia.

The trend on the Cu content of the forages was creeping legumes > grasses > tree legumes. The Zn content of leucaena was exceptionally high followed by the grasses. The Mo content of tree legumes was markedly higher than the other forages whereas, the Co content of all forages was fairly the same. The tree legumes, sesbania and leucaena had the highest Mn and Fe concentration, respectively.

TABLE 2. MACRO- AND MICROMINERAL CONCENTRATIONS OF SELECTED PHILIPPINE FORAGES

Forage	Ca	P	Mg	K	Cu	Zn	Mo	Co	Mn	Fe
	············ g/kg DM ············				·················· mg/kg DM ··················					
Critical level[1]	3	2.5	2	0.6 to 0.8	10	30	>6	0.1	30 to 40	30
Grasses										
Para	2.8^{g}	2.0^{c}	1.9^{de}	9.6^{ab}	9.0^{ab}	82.8^{b}	14.7^{c}	1.4	54^{d}	222^{cd}
Star	3.9^{f}	2.8^{a}	1.7^{e}	8.9^{bc}	8.8^{ab}	77.2^{b}	14.9^{c}	1.3	69^{c}	326^{bcd}
Napier	3.5^{fg}	2.0^{c}	1.7^{e}	8.0^{cd}	7.1^{bc}	50.4^{cd}	14.4^{c}	2.0	33^{f}	404^{bc}
Creeping legumes										
Calopo	7.7^{e}	1.9^{cd}	2.2^{c}	7.0^{ef}	10.0^{ab}	60.8^{c}	16.2^{c}	1.0	54^{d}	309^{bcd}
Centrocema	8.9^{d}	1.7^{d}	2.0^{cd}	5.6^{g}	11.2^{a}	40.4^{d}	15.1^{c}	1.5	77^{b}	393^{bc}
Tree legumes										
Gliricidia	13.7^{b}	1.8^{cd}	14.6^{a}	10.3^{a}	6.6^{bc}	55.1^{c}	33.0^{a}	2.5	43^{e}	192^{d}
Leucaena	15.1^{a}	1.4^{e}	3.0^{b}	6.4^{fg}	7.1^{bc}	101.3^{a}	20.6^{b}	1.7	36^{f}	772^{a}
Sesbania	10.4^{c}	2.5^{b}	2.2^{c}	7.3^{de}	5.0^{c}	30.0^{e}	15.3^{c}	1.6	99^{a}	432^{b}
Mean	8.2	2.0	2.4	7.9	8.1	62.2	18.0	1.6	58	381
SEM	0.2	0.1	0.04	0.2	0.7	2.1	0.5	0.3	1.2	35

^{a,b,c,d,e,f,g} Means within column having different superscripts differ ($p < 0.01$).

[1] Concentrations below which is deficient or above which, in the case of Mo, is excessive based on ruminant needs (McDowell, 1985).

The various concentrations of mineral elements of the forages were compared to the critical levels based on ruminant needs (McDowell, 1985). The elements P and Cu of tree legumes were below the critical levels. Supplementation of these two elements would be the proper solution because most of the forages had low concentrations of these two elements. The Ca element should be taken cared of also, especially if the ruminants would graze a pure stand of grass pasture because of their low Ca content. Even in legumes with high Ca content its bioavailability is in question because it is in bound form as calcium oxalate (Ward and Harbers, 1982). Earlier McManus et al. (1979) and Ward and Harbers (1979) found out that the cell wall was mineralized with crystalline forms of Ca, thereby limiting its bioavailability to the animals. The findings of the present study confirmed to the low levels of plasma Ca, P and Cu of grazing Philippine goats (Fujihara et al., 1992a,b).

The Mg concentration of grasses was below the critical level. This could be alleviated by grazing or browsing of mixed forage species by ruminants because other forage species had high Mg concentrations. As reviewed by Minson (1990), only 14% of the tropical grasses contained less than 2 g Mg/kg DM. Hence, Mg deficiency is not a critical element in the tropics.

The Mo element should be watched because of its high concentration in all forages. It was reported elsewhere (Serra et al., 1995) that Philippine native forages also contained this element above 6 mg/kgDM. In fact, it was published by McDowell (1985) that Mo toxicity and Cu deficiency were reported in the Philippines. Elevated Mo intake depress Cu availability and may produce a physiological Cu deficiency in ruminants (Fleming, 1973; Ward, 1978; Mills, 1987; Keen and Graham, 1989). As outlined by Grace (1991), the signs of Mo chronic toxicity at 5-20 mg/kg dietary DM are poor growth rates, impaired reproduction in cattle aside from decreased Cu absorption as mentioned earlier. Probably, this is one reason for the low Cu plasma in Philippine grazing goats (Fujihara et al., 1992b), aggravated by low forage Cu concentrations. Low Cu:Mo ratio, 2:1 or less will produce physiological Cu deficiency (Ward, 1978) and the ratio obtained in the present study was less than the desired ratio.

Mineral concentrations of NDF residues

Table 3 shows the percent of total mineral located in NDF fraction. Differences of species in each element were not computed due to some empty cells (presence of undetected element).

Treatment of NDS extracted nearly all of the Ca element in the forages. The values obtained in the present study were lower than the findings of Whitehead et al. (1985) on temperate forages following different method of cell wall extraction. However, following the same cell wall extraction by NDS, the data of Kincaid and Cronrath

TABLE 3. PERCENT OF TOTAL MINERAL LOCATED IN NDF RESIDUE

Forage	Ca	P	Mg	K	Cu	Zn	Mo	Co	Mn	Fe
					%					
Grasses										
Para	ND[1]	5.8	0.9	2.3	8.1	0.9	3.9	0.7	2.2	54.3
Star	0.6	9.8	2.4	2.5	8.8	1.5	8.3	15.2	4.2	85.5
Napier	1.7	5.5	3.1	2.1	14.7	5.4	11.5	25.6	9.3	65.1
Creeping legumes										
Calopo	1.1	10.3	4.3	3.7	10.0	4.1	11.1	10.4	8.1	112.5
Centrocema	ND	11.5	1.0	2.6	7.9	2.6	5.6	3.7	2.5	33.4
Tree legumes										
Gliricidia	1.4	27.9	0.8	3.6	24.9	3.3	6.7	21.9	3.4	94.0
Leucaena	ND	30.1	1.0	5.8	17.6	1.1	6.6	6.5	11.0	96.2
Sesbania	0.8	13.5	1.8	7.3	39.0	4.6	20.8	45.5	4.0	109.4
Mean	0.7	14.3	1.9	3.7	16.4	2.9	9.3	16.2	5.6	81.3
SEM	–	2.9	0.3	0.4	2.6	0.4	1.3	3.6	0.8	7.0

[1] ND = not detected.

(1983) as percent of total Ca remained in NDF fraction of lucerne or alfalfa hay (*Medicago sativa*) was 24%. Using two types of NDS with or without EDTA, a chelating agent, the former type extracted nearly all Ca in tropical feeds but not on later type (Ibrahim et al., 1990).

The percentage of total P remained in the NDF fraction was higher as compared to other macrominerals. It was recognized that P element had affinity to the cell wall especially of those legumes and much more of the tree legumes. The findings of Kincaid and Cronrath (1983) and Ibrahim et al. (1990) on lucerne and gliricidia was 31 and 2.5%, respectively. The low P concentration in legumes as discussed earlier and its association to the cell wall fraction could be aggravated by their low bioavailability to the ruminants.

The element Mg and K had also some little affinity to the cell wall fractions as shown by their presence in NDF fraction. Similar findings were observed by other workers (Kincaid and Cronrath, 1983; Ibrahim et al., 1990) to any type or kind of forages.

The solubility of Cu in NDS ranged from 61 to 92% for the various forages of the present study. The findings of Ibrahim et al. (1990) showed 68 and 84% Cu solubility in guineagrass (*Panicum maximum*) and gliricidia, respectively. For temperate forage (lucerne hay), Cu solubility in NDS was 71% (Kincaid and Cronrath, 1983). This reflects the affinity of Cu to the cell wall that probably affects their bioavailability. Their low concentration in the tropical forages as discussed earlier and their attachment to or trapped in the cell wall matrix could deliver a deficiency symptoms to the grazing animals.

The NDS had nearly extracted all Zn element in the forages. The same trend was observed by Ibrahim et al. (1990) except in jack tree (*Artocarpus heterophyllus*) with 33% of total Zn located in NDF fraction. Also, 31% of total Zn was located in the NDF fraction of lucerne hay (Kincaid and Cronrath, 1983).

Fairly proportions of Mo were found in NDF fraction of various forages. They were more available for the ruminants because of their excess concentration in the forages as presented earlier and their high solubility. Their release seemed not affected by the cell wall fraction.

The percent Co found in the NDF fraction was variable. It was exceptionally high in sesbania. Almost one half was associated to the cell wall. On the contrary, paragrass had almost released all the Co element. No definite pattern of Co solubility in NDS was observed.

The Mn element was also very low in its concentration in the NDF fraction. It is mostly released by NDS treatment. It shows, they have low affinity to the cell wall.

The data for solubility of Fe in NDS were quite low. Kincaid and Cronrath (1983) reported a 77 and 45% of total Fe in the NDF fraction of lucerne and hay silage, respectively. The findings of the present study showed that all species had more than 33% of total Fe remained in the NDF fraction. Although there were two species, i.e. calopo and sesbania had a value above 100%, it could be assumed that Fe has strong affinity to the cell wall.

This study shows that the mineral concentrations in the forages had two fractions, the soluble and insoluble. The former was easily removed by neutral detergent extraction and the latter remained in the cell wall complex. Previous studies with different methods support the findings of the present study that cell wall contained minerals. These were X-ray diffraction and electron optical techniques by McManus et al. (1977, 1979) and Ward and Harbers (1979); mechanical extraction by Whitehead et al. (1985), neutral detergent extraction by Kincaid and Cronrath (1983), and neutral detergent extraction with and without EDTA by Ibrahim et al. (1990).

Mineral concentrations of ADF residues

The proportion (%) of the total content of each element in the ADF fraction is presented in table 4. Due to some empty cells (presence of undetected element), differences of species in each element were not analyzed.

Treating the various forages with ADS provide information on the proportion of mineral elements associated to ligno-cellulose compound (ADF). The mineral elements attached or trapped in this compound are either not available or is considered a slowly release for absorption. Their release are possibly due to enzymatic activity.

TABLE 4. PERCENT OF TOTAL MINERAL LOCATED IN ADF RESIDUE

Forage	Ca	P	Mg	K	Cu	Zn	Mo	Co	Mn	Fe
					%					
Grasses										
Para	ND[1]	0.7	ND	1.6	14.3	0.8	6.9	10.0	5.2	46.7
Star	ND	0.7	0.6	2.3	15.2	1.0	9.0	16.0	5.3	40.1
Napier	ND	0.7	0.4	2.1	19.5	1.7	8.7	11.3	5.7	37.7
Creeping legumes										
Calopo	ND	3.3	0.4	2.3	12.9	3.3	13.4	ND	5.3	48.7
Centrocema	ND	1.8	0.02	2.7	4.1	0.2	5.6	ND	4.9	12.3
Tree legumes										
Gliricidia	1.2	5.8	1.3	2.6	82.0	1.4	3.4	ND	7.7	39.0
Leucaena	ND	9.7	0.4	4.6	51.1	0.1	11.4	ND	6.6	22.4
Sesbania	0.2	12.3	2.4	4.2	49.2	0.3	12.8	ND	2.5	47.9
Mean	0.2	4.4	0.7	2.8	32.3	1.1	8.9	4.7	5.4	36.8
SEM	–	1.1	–	0.3	6.5	0.3	0.8	–	0.4	3.3

[1] ND = not detected.

The ADS nearly extracted all macrominerals especially Ca. The pH of ADS was 1.5 to 2. Ward and Harbers (1982) measured Ca and oxalic acid extracts from lucerne leaflets using HCl acid from 1 N to 0.06 N with pH 0.7 to 3.2. Their results showed that extracted Ca decreased to 81% of the total at pH 1.3 and then gradually to 65% at pH 3.2 whereas oxalic acid extraction at pH 1.3 was 33% and near nil at pH 3.2. They assumed that extracted Ca at or below pH 2.3 was associated predominantly with equivalent extracted oxalic acid. Their observations in relation to the present study, showed that the ADS extracted most Ca element and calcium oxalate.

Other macrominerals (P, Mg and K) had some proportions remaining in the ADF fraction. Probably, they were trapped in the ligno-cellulose compound or mineralized as in the case of P and K (McManus et al., 1977, 1979; Ward and Harbers, 1979). Nevertheles, ADS could extract most of the macrominerals in the cell wall as supported by previous reports (Edwards et al., 1977; Kincaid and Cronrath, 1983; Ibrahim et al., 1990).

Generally, higher proportion of Cu remained in the ADF fraction against those found in the NDF fraction that was observed in the present study. Probably, this elements is associated to ligno-cellulose compound Similar trend was observed by Kincaid and Cronrath (1983), when they found 43 vs. 29% and 62 vs. 46% as proportion of total mineral located in ADF and NDF of lucerne hay and grass silage, respectively. Ibrahim et al. (1990) found a similar proportion of Cu remained in both residues of NDF and ADF using various tropical feeds. On the contrary, ADS removed about 90% of Cu in the cell wall of Coastal bermudagrass (Edwards et al., 1977).

The Zn, Mo and Mn elements had also appeared in small proportion in ADF fraction. The ADS extracted all the Co in the legumes but not in grasses. The highest proportion among minerals that was left in the ADF was Fe that ranged from 12.3 to 48.7%. Previous report of Edwards et al. (1977) showed that Fe was not detected, Mn was 90 to 97% released and Zn was 80 to 100% remaining in the ADF fraction of Coastal bermudagrass. In another report, Kincaid and Cronrath (1983) had also found higher proportion of Zn, Fe in ADF fraction of lucerne hay and grass silage. Their data were 23, 19 and 24, 17% for Zn and Fe of lucerne hay and grass silage, respectively. The report of Ibrahim et al. (1990) indicated that 3, and 36% remained in ADF fraction of gliricidia and jack tree, respectively.

Correlation coefficients

The correlation coefficients among the factors affecting forage quality and mineral concentrations in the forages are presented in table 5. The CP was positively correlated to P ($p < 0.01$) and Mn ($p < 0.05$) in grasses but negatively correlated to Cu ($p < 0.01$) in legumes. The NDF fraction was positively correlated to Ca ($p < 0.05$) and P ($p < 0.01$) in grasses but negatively correlated to Ca ($p < 0.05$) and positively correlated to Cu ($p < 0.01$) in legumes. The ADF fraction was negatively correlated to P ($p < 0.01$) and Mn ($p < 0.05$) in grasses; negatively and positively correlated to Ca ($p < 0.05$) and Cu ($p < 0.01$), respectively in legumes. The ADL fraction was negatively correlated to Ca and P ($p < 0.05$) in grasses; negatively and positively correlated to Ca ($p < 0.05$) and Cu ($p < 0.01$), respectively in legumes. The IVDMD was positively correlated to K ($p < 0.05$) but negatively correlated to Cu ($p < 0.01$) in legumes.

Evidently, 75 and 45% of the elements (both grasses and legumes) were positively correlated to CP and IVDMD, respectively. Moreover, 55, 80 and 75% of the elements were negatively correlated to NDF, ADF, and ADL respectively. The findings on the various fiber fractions and its correlations to the macro- and microminerals were similar to the observation of Kellogg et al. (1994). They concluded the various minerals in their study were more closely associated with non-structural components due to their negative correlation to fibrous components (hemicellulose, cellulose and lignin) of the forage (bermudagrass).

Improving forage quality by increasing CP and digestibility or decreasing fiber fractions could deliver a varying effects on the concentration of various minerals. As presented by Fleming (1973), the influence of nitrogen fertilizer to increase growth and CP content of the forage resulted in either increase or decrease in various mineral concentrations. No definite pattern could be derived. The fiber content of forages was also manipulated by harvesting at different growth stages. Consequently, the concentrations of minerals were also affected. The findings of this study support previous works that, factors affecting forage quality (CP, fiber fractions and digestibility) exert an influence on the concentration of minerals in the forage.

TABLE 5. CORRELATION COEFFICIENTS AMONG THE FACTORS AFFECTING FORAGE QUALITY AND MINERAL CONCENTRATIONS OF SELECTED PHILIPPINE FORAGES

Concept	CP	NDF	ADF	ADL	IVDMD
Grasses					
Ca	0.63	0.85*	−0.65	−0.84*	−0.70
P	0.95**	0.94**	−0.98**	−0.85*	−0.74
Mg	−0.02	−0.40	0.03	0.34	0.30
K	0.20	−0.18	−0.20	0.27	0.35
Cu	0.51	0.16	−0.53	−0.12	−0.06
Zn	0.46	0.12	−0.46	0.05	0.18
Mo	0.32	0.05	−0.33	−0.39	−0.34
Co	−0.38	−0.35	0.35	−0.03	−0.11
Mn	0.88*	0.66	−0.88*	−0.50	−0.35
Fe	−0.06	0.26	−0.02	−0.36	−0.43
Legumes					
Ca	0.47	−0.65*	−0.75*	−0.67*	0.46
P	0.45	−0.38	−0.26	−0.17	0.50
Mg	0.14	−0.38	−0.50	−0.30	0.57
K	0.18	−0.40	−0.48	−0.27	0.75*
Cu	−0.81**	0.90**	0.93**	0.83**	−0.84**
Zn	−0.22	0.03	−0.17	−0.41	−0.04
Mo	0.09	−0.32	−0.43	−0.23	0.53
Co	0.44	−0.56	−0.57	−0.26	0.52
Mn	0.43	−0.18	0.04	0.16	−0.04
Fe	0.27	−0.26	−0.30	−0.50	−0.17

*($p < 0.05$); **($p < 0.01$).

Conclusion

The different Philippine forages that were studied had some mineral elements below or above than the desired concentrations as judged by published values (i.e., P, Cu and Mo). A proportion of mineral elements could be found in cell wall or NDF fraction (i.e., P, Cu, Co and Fe) and ligno-cellulose compound or ADF fraction (i.e., Cu and Fe). These elements attached or possibly trapped in the cell wall and its fraction could be released at slow rate or possibly not released at all. However, most of the mineral elements were found in the cell contents and therefore should be available to the ruminants.

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