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Concentration of Micro Minerals in Fiber Fraction of Forages

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Abstract**—**This study was carried out to evaluate concentration of micro minerals (Zn, Fe, Mn, Cu and Se) of forages and their distribution in fiber fraction (neutral detergent fiber/NDF and acid detergent fiber/ADF) in South Sumatra during dry and rainy seasons. Seven species of commonly forages namely *Axonopus compressus*, *Panicum maximum*, *Pennisetum purpuphoides*, *Leucaena leucocephala*, *Centrocema pubescens*, *Calopogonium mucunoides* and *Acacia mangium* were collected at native pasture during rainy and dry seasons. The results showed that micro minerals concentration of forages and their distribution in fiber fraction varied among species and season. In general, concentration of micro minerals was slightly higher in rainy season compared to dry season either in grass or legumes forages. In grass, concentration of Fe and Mn were above the critical level, while 33.3 %, 100 % and 16.7 % of evaluated grass were deficient in Zn, Cu and Se. Data on legume forages show that 75 % of legumes were deficient in Zn and Mn, 62.5 % deficient in Cu and 50 % deficient in Se. There was no species of legume deficient in Fe. Distribution of micro minerals in NDF and ADF were also significantly affected by species and season and depends on the kinds of element measured. Generally, micro minerals were associated in fiber fractions much higher during dry season compared to rainy season. Iron (Fe) and selenium (Se) in forages were the highest elements associated in NDF and ADF, while the lowest was found in Copper (Cu).

Keywords**—**Seasons, forages, micro mineral distribution, fiber fraction.

I. INTRODUCTION

MOST of grazing livestock in tropical countries including Indonesia fulfill their mineral requirements usually only from the forages consumed. Since the forages are frequently deficient or excess in various minerals, the animals may have sub clinical deficiencies or chronic toxicities. Aside from the above mentioned problem, the use of minerals by animals is constrained by their bioavailability. Some minerals in the forages are associated with other compounds or trapped in the undigested nutrient fractions resulting in slowly release or making these unavailable for use. Therefore, in assessing minerals requirement of the animals, both the amount of mineral in forages and their bioavailability need to be considered. The mineral content can be determined chemically while bioavailability is much more difficult to be estimated. The bioavailability of the minerals can be affected by their location in forage structure. Emanuele and Staples, [2] reported that minerals associated with the plant cell wall have lower bioavailability or require a longer fermentation time for maximal release.

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There was no information available concerning mineral distribution and their bioavailability of forages in South Sumatra in relation to different seasons. The aim of this study was to evaluate micro minerals concentration of the forages and their distribution in NDF and ADF during rainy and dry seasons. Part of the current study has been briefly described by Evitayani et al.[4].

II. MATERIALS AND METHODS

Study area and collection of forages samples

The study was conducted in Palembang, South Sumatra province – Indonesia. Seven species of commonly forages namely *Axonopus compressus*, *Panicum maximum*, *Pennisetum purpuphoides*, *Leucaena leucocephala*, *Centrocema pubescens*, *Calopogonium mucunoides* and *Acacia mangium* were collected at native pasture during rainy and dry seasons. Details of the experimental sites and collecting procedures are the same as described in previous study[3].

Determination of micro mineral distribution

Micro minerals (Zn, Fe, Mn and Cu) concentrations in the forages samples and fiber fractions were analyzed using inductively coupled plasma emission spectrometer (SPS7700, Seiko Instruments Inc., Chiba, Japan) after digesting with nitric acid. Selenium (Se) was analyzed through the fluorometric detection of the 2, 3 Diamino-naphthalene (DAN) according to the procedure of Watkinson[26]. The spectrofluoro photometer used was RF- 1500 (Shimandzu Co).

Statistical analysis

Data on micro mineral concentration of forages and their distribution in fiber fraction (NDF and ADF) were analyzed using General Linear Model procedure using StatView® (SAS [19]). Details of the statistical analysis procedure are the same as described in previous study[3].

III. RESULTS AND DISCUSSION

Micro mineral concentration of forages

There was significant difference ($P<0.05$) in micro mineral concentration of grass and legume forages within species and seasons (Table 1). In rainy season, Zn concentration of grass varied from 33.7 (*P. maximum*) to 44.4 mg/kg (*A. compressus*); Fe from 148 (*P. purpuphoides*) to 498.1 mg/kg (*A. compressus*); Mn from 136.8 (*P. maximum*) to 572 mg/kg (*P. purpuphoides*); Cu from 5.6 (*P. maximum*) to 10.1 mg/kg DM (*P. purpuphoides*) and Se concentration from 0.10 (*P. purpuphoides*) to 0.20 mg/kg (*P. maximum*), respectively. The concentration of these elements slightly decreased in dry season, in which Zn concentration varied from 29.9 (*P. maximum*) to 34.2 mg/kg (*A. compressus*); Fe from 131.5 (*P. purpuphoides*) to 511.4 mg/kg (*A. compressus*); Mn from 69.0 (*P. purpuphoides*) to 208.7 mg/kg (*A. compressus*); Cu from 8.5 (*P. purpuphoides*) to 9.7 mg/kg DM (*A. compressus*) and Se concentration from 0.09 (*A. compressus*) to 0.12 mg/kg (*P. purpuphoides*), respectively. Similar with grass, data on legume showed that concentration of micro mineral in rainy season was relatively higher than in dry season. The highest concentrations of Zn, Cu and Se were found in *C. pubescens* during rainy season (40.2, 16.6 and 0.405 mg/kg), while the highest concentrations of Fe and Mn were found in *C. mucunoides* (589.6 mg Fe/kg in dry season and 49.2 mg Mn/kg in rainy season). The lowest concentrations of Zn and Cu were observed in *A. mangium* during dry season (25.0 and 3.8 mg/kg), Fe and Mn in *L. leucocephala* (138.8 and 22.2 mg/kg) and the lowest Se concentration was noted in *C. mucunoides* (0.071 mg/kg) during dry season. The results also show that 75 % of the observed legumes were deficient in Zn and Mn, and 62.5 % deficient in Cu and 50 % deficient in Se. Concentrations of the micro elements both in grass and legumes in the present study were within the ranges for the tropical forages as reported by several researchers [5,7,18,20]. The mean of Zn concentration of grass (34.7 mg/kg DM) and legume forages (31.1mg/kg DM) were almost similar with study of Minson[15] which obtained value of 36 mg Zn/kg DM in pasture. The mean Fe and Cu concentrations were significantly higher ($P<0.01$) in legumes (287.1; 10.4 mg/kg DM) than in grass (278.9; 9.0 mg/kg DM). This finding was in agreement with the study of Minson[14] and Miller[15] who reported that concentration of some micro minerals are normally higher in legume than in grass. In across, Mn concentration had significantly higher ($P<0.001$) in grass (241.2 mg/kg DM) compared to legumes (33.7 mg/kg DM). These findings were in agreement with previous study reported by Fleming[6], Underwood[25] and Minson[15] that micro minerals concentrations in legumes were lower than in grass. The mean of Cu concentration was slightly higher than the requirement for sheep (7.0 mg/kg DM)[17]. Decreasing Cu concentration of grass and legume forages may occur with advancing maturity, climatic and seasonal changes[22]. The mean Se concentration was slightly higher in legume than grass (0.48 vs 0.28 mg/kg DM). Between the seasons, Se concentration of grass and legume forages slightly higher in rainy season than in dry season and are higher than required in the feed for ruminants (0.2 mg/kg DM) as recommended by NRC[16].

According to Underwood and Suttle[23,24], increasing soil water can have a negative influence on soil trace mineral especially Se. In contrast, the tendency for the lower mineral content of grass and legume forages in dry season is probably a reflection of the influence of rainfall. Several studies [5,7,10,18] have reported that seasonal fluctuations in micro mineral composition persisted in grazing pasture. Results of the present study also showed that Fe (rainy and dry seasons) of forages were not deficient. However, Zn was deficient in *A. mangium*; Mn was deficient in *C. pubescens, L. leucocephala* and *A. mangium*; Cu was deficient in *A. compressus, P. purpuphoides, P. maximum, C. mucunoides* and *A. mangium* and Se was deficient in *A. compressus*, respectively. While in dry season, Zn was deficient in seven species except for *A. compressus*; Mn was deficient in *C. pubescens, L. leucocephala* and *A. mangium*; Cu was deficient in seven forage species except for *C. pubescens* and Se was deficient in *C. mucunoides*, respectively. However, deficiency of Zn in grass and legume were 33.3% and 100%; deficiency of Cu was 100% in grass and 62.5% in legume; deficiency of Mn was 75% in legume and 16.7% in grass, and deficiency of Se was 50% in legume. McDowell[11,12] reported that of Zn, Cu, Mn and Se were the most severe mineral limitation to grazing livestock in tropical countries especially in Indonesia; while individual evaluation of samples based on Fe requirements of 50 mg/kg DM indicated that none of grass and legume forages were deficient in Fe[12]. The zero incidence of iron (Fe) deficiency in grass and legume forages in both rainy and dry seasons was also obtained by Prabowo et al.[18].

Mineral proportion of forages in Neutral Detergent Fiber (NDF)

The micro mineral proportion of grass and legume forages in NDF is shown in Table 2. Both seasons and species significantly ($P<0.05$) affected Zn, Fe, Mn, Cu and Se. In rainy season, the highest proportion of Zn in NDF of grass was 26.1 % (*A. compressus)* and the highest was 51.3 % (*P. maximum*), Fe varied from 29.8 (*P. purpuphoides*) to 60.1 % (*A. compressus*); Mn from 1.3 (*A. compressus*) to 2.8 % (*P. purpuphoides*); Cu from 7.0 (*P. purpuphoides*) to 20.5 % (*A. compressus*) and Se ranged from 12.9 (*A. compressus*) to 25.2 % (*P. maximum*), respectively. In dry season, proportion of Zn in NDF was relatively higher than in rainy season. Proportion of Zn associated in NDF ranged from 37.1 (*P. purpuphoides*) to 54.2 % (*P. maximum*), Fe from 33.2 (*P. purpuphoides*) to 79.1 % (*A. compressus*), Mn from 1.9 (*A. compressus*) to 3.3 % (*P. maximum*), Cu from 6.2 (*P. purpuphoides*) 26.3 % (*A.compressus*) and Se varied from 10.8 (*A. compressus*) to 20.1 % (*P. purpuphoides*), respectively. Data on legume forages showed that the lowest proportion of Zn, Fe, Mn, Cu and Se in NDF during rainy season were 5.7 % in *C. pubescens*, 32.0 % in *C. mucunoides*, 3.2 % in *C. pubescens*, 10.3 % in *C. pubescens* and 9.2 % in *C. mucunoides* while the highest proportion were 42.0 % (*C. mucunoides*), 81.8 (*L. leucocephala*), 30.9 % (*L. leucocephala*), 66.0 % (*A. mangium*) and 78.1 % (*L. leucocephala*), respectively.

Similar trend with grass, the proportion of Zn, Fe, Mn, Cu and Se in legume tended to increase during dry season, ranged from 7.0 (*C. pubescens*) to 45.0 (*C. mucunoides*) for Zn, 25.0 (*C. mucunoides*) to 75.3 % (*L. leucocephala*) for Fe, 6.7 (*C. pubescens*) to 36.1 % (*L. leucocephala*) for Mn, 9.0 (*C. pubescens*) to 67.2 % (*A. mangium*) and from 11.0 % (*C. mucunoides*) to 35.2 % (*A. mangium*), respectively. The great variation of micro mineral proportion in NDF could be reflecting the mineral affinity to the cell wall that affected their bioavailability and cause deficiency symptoms to the grazing animals. The proportion of Zn and Fe in NDF of this study almost similar with the data obtained by Kincaid and Cronrath [9] and Ibrahim et al.[8] who reported 31 %, 77 % and 45 % of total Zn and Fe were located in NDF fraction of lucerne hay. The mean Zn and Fe proportion in NDF of grass was 41.0 and 27.1 %, while in legume the proportion of Zn and Fe was 51.6 and 58.8 %, respectively. In contrast, Serra et al.[21] reported that the mean proportion of Zn and Fe in NDF of forages were 2.9 % and 81.3 %, respectively. Between micro mineral elements, Mn was lowest proportion in NDF reflecting the low affinity to the cell wall [21]. The relative higher of micro mineral proportion in NDF during dry season could be due to fluctuation of rainfall and differences of these elements in affinity to the cell wall, that could affect the solubility and hence deficiency symptom to the grazing animals[8,9,21].

Mineral proportion of grass and legume in ADF

The micro mineral proportion of forages in ADF was significantly ($P<0.05$) different in both seasons and species (Table 3). The proportion of micro mineral in ADF of grass during rainy season ranged from 1.0 % (*P. maximum*) to 4.0 % (*P. purpuphoides*) for Zn, 28.0 % (*A. compressus*) to 41.4 % (*P. maximum*) for Fe, 1.1 % (*P. maximum*) to 17.0 % (*A. compressus*) for Mn, 1.0 % (*P. purpuphoides*) to 3.1 % (*A. compressus*) for Cu and 15.3 % (*A. compressus*) to 55.9 % (*P.maximum*) for Se, respectively. While, in dry season the micro mineral proportion associated with ADF was higher than in rainy season, varied from 1.5 % (*P. maximum*) to 5.5 % (*A. compressus*) for Zn, 29.7 % (*P. purpuphoides*) to 56.3 % (*P. maximum*) for Fe, 2.6 % (*P. maximum*) to 19.8 % (*A. compressus*) for Mn, 1.7 % (*P. purpuphoides*) to 3.1 % (*P. maximum*) for Cu and 25.9 % (*P. purpuphoides*) 57.4 % (*P. maximum*) for Se, respectively. In legumes, the proportion of micro mineral in ADF during rainy season varied from 1.7 % (*C. pubescens*) to 4.2 % (*C. mucunoides*) for Zn, 16.9 % (*C. mucunoides*) to 55.9 % (*L. leucocephala*) for Fe, 4.1 % (*C. pubescens*) to 29.3 % (*C. mucunoides*) for Mn, 1.4 % (*C. pubescens*) to 3.0 % (*C. mucunoides*) for Cu and 8.4 % (*C. mucunoides*) to 34.8 % (*L. leucocepahala*) for Se, respectively. While in dry season, the lowest proportion of Zn, Fe, Mn, Cu and Se elements were 1.2 % (*C. pubescens*), 35.9 % (*L. leucocephala*), 5.2 % (*L. leucocephala*), 1.2 % (*A. mangium*) and 10.7 % (*C. mucunoides*) and the highest of Zn, Fe, Mn, Cu and Se elements were found in *L. leucocephala* (7.4 %), *C. pubescens* (48.2 %), *C. mucunoides* (30.8 %), *L. leucocephala* (5.1 %) and *L. leucocephala* (59.9 %), respectively.

The wide variation of micro mineral proportion in ADF residue in the present study shows that the rate of affinity of these elements with lingo cellulosic materials differed each other[1,8,9,12,2]. The average of Zn proportion in ADF of grass (3.4 %) and legume (3.9 %) in the present study was similar with the result of Ibrahim et al.[9] who indicated that 3 % of Zn remained in ADF fraction of *Gliricidia*. The highest proportion elements in ADF were found in Fe and Se (37.1 and 38.6 % for grass) and 35.3 and 34.4 % for legume. Similar result was reported Ibrahim et al.[8] and Serra et al.[21]. In general, grass contained higher proportion of micro mineral in NDF than legume reflecting a higher trapped of the elements into ligno-cellulose.

IV. Conclusion

From the above results, it could be concluded that nutritive value of forages in South Sumatra assessed by distribution of micro mineral either in intact forages or in fiber fractions (NDF and ADF) greatly varied between species and seasons. In rainy season, the concentration of Fe and Se was above the requirement of the ruminants, while in dry season some of the forages were deficient for these elements. A high content of cell wall constituent (NDF and ADF) has been associated by attachment more minerals into the cell wall. However, most of the mineral elements were found in the cell contents and should be available to the ruminants.

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TABLE I MICRO MINERAL CONCENTRATION OF GRASS AND LEGUME (mg/kg DM)

Forage species	Season	Zn	Fe	Mn	Cu	Se
Critical level*		33	50	40	11	0.2
Toxic level		750	500	1000	25	2.0
Grass species						
A. compressus	Rainy	44.40	498.10	282.60	9.20	0.13
	Dry	34.20	511.40	208.70	9.70	0.09
	Se	*	**	***	Ns	*
P. purpuphoides	Rainy	33.70	148.40	572.50	10.10	0.10
	Dry	32.30	116.40	69.00	8.50	0.12
	Se	Ns	***	***	*	Ns
P. maximum	Rainy	33.70	265.70	136.80	5.60	0.20
	Dry	29.90	131.50	123.00	9.50	0.10
Legumes species	Se	Ns	***	**	*	*
C. pubescens	Rainy	40.20	297.40	37.30	16.60	0.41
	Dry	27.90	282.60	29.00	15.00	0.30
	Se	**	**	**	Ns	*
C. mucunoides	Rainy	35.80	525.00	49.20	9.30	0.08
	Dry	30.00	589.60	38.40	8.80	0.07
	Se	Ns	***	**	*	Ns
L. leucocephala	Rainy	32.90	157.20	27.10	11.60	0.13
	Dry	26.20	138.80	22.20	8.60	0.12
	Se	**	**	*	*	Ns
A. mangium	Rainy	30.60	159.40	38.90	9.80	0.20
	Dry	25.00	147.00	27.50	3.80	0.11
	Se	*	**	**	**	*
Mean of grasses	Overall	34.7±1.9	278.9±0.7	241.2±1.0	9.0±0.3	0.28±0.0
Deficiency (%)	Overall	33.33	0.00	0.00	100.00	16.67
Sig. of effect	Species	Ns	***	***	*	Ns
	Season	Ns	**	***	**	*
	Spe. X Sea.	Ns	**	***	Ns	Ns
Mean of legumes	Overall	31.1±1.1	287.1±0.6	33.7±2.6	10.4±1.3	0.48±0.1
Deficiency (%)	Overall	75.00	0.00	75.00	62.50	50.00
Sig. of effect	Species	***	***	***	***	***
	Season	Ns	*	*	Ns	Ns
	Spe. X Sea.	**	Ns	*	Ns	Ns
Grass X Legume		Ns	**	***	*	Ns

Se: Season effect in rainy and dry seasons
*** : P<0.001; ** : P<0.01; * : P<0.05 and Ns : non significant

TABLE II MICRO MINERAL PROPORTION IN NDF OF GRASS AND LEGUME (%)

Forage species	Season	Zn	Fe	Mn	Cu	Se
Grass species						
A. compressus	Rainy	26.10	60.10	1.30	20.50	10.80
	Dry	37.80	79.10	1.90	26.30	12.90
	Se	***	**	Ns	*	*
P. purpuphoides	Rainy	39.20	29.80	2.80	7.00	14.00
	Dry	37.10	33.20	3.60	6.20	20.10
	Se	*	**	*	Ns	*
P. maximum	Rainy	51.30	43.10	3.30	18.40	25.20
	Dry	54.20	64.50	1.80	22.80	21.20
Legumes species	Se	*	***	*	*	*
C. pubescens	Rainy	5.70	60.10	3.20	10.30	15.30
	Dry	7.00	75.20	6.70	9.10	13.40
	Se	*	**	*	Ns	*
C. mucunoides	Rainy	42.00	32.00	9.40	11.50	9.20
	Dry	45.20	25.20	11.20	12.80	11.00
	Se	Ns	**	**	Ns	*
L. leucocephala	Rainy	20.30	75.30	30.90	16.80	78.10
	Dry	18.50	81.20	36.10	19.20	84.80
	Se	Ns	**	Ns	**	**
A. mangium	Rainy	36.10	61.30	11.90	66.00	33.60
	Dry	42.00	60.10	10.19	67.20	35.20
	Se	**	Ns	Ns	Ns	Ns
Mean of grasses	Overall	41.0±3.9	51.8±0.7	2.5±0.5	16.9±3.4	17.4±2.1
Sig. of effect	Species	***	***	**	***	***
	Season	***	**	ns	*	**
	Spe. X Sea.	**	**	*	ns	ns
Mean of legumes	Overall	27.1±0.6	58.8±0.7	14.6±2.6	26.6±0.8	35.1±1.0
Sig. of effect	Species	***	***	***	***	***
	Season	Ns	*	*	Ns	Ns
	Spe. X Sea.	**	Ns	*	Ns	Ns
Grass X Legumes		**	*	***	***	***

Se : Season effect in rainy and dry seasons
*** : P<0.001; ** : P<0.01; * : P<0.05 and Ns : non significant

TABLE III MICRO MINERAL PROPORTION IN ADF OF GRASS AND LEGUME (%)

Forage species	Season	Zn	Fe	Mn	Cu	Se
Grass species						
A. compressus	Rainy	3.09	28.00	16.98	3.09	15.30
	Dry	5.54	34.50	19.75	2.04	26.87
	Se	*	**	*	*	***
P. purpuphoides	Rainy	3.95	32.76	6.79	0.97	30.56
	Dry	5.07	29.70	10.45	1.67	25.87
	Se	*	Ns	*	Ns	*
P. maximum	Rainy	1.03	41.40	1.05	2.25	55.87
	Dry	1.49	56.34	2.57	3.07	57.42
Legumes species	Se	*	**	Ns	Ns	*
C. pubescens	Rainy	1.65	37.37	4.08	1.41	30.45
	Dry	1.24	48.20	7.34	2.05	29.86
	Se	*	**	**	Ns	Ns
C. mucunoides	Rainy	4.12	16.90	29.34	3.02	8.40
	Dry	6.55	40.60	30.77	4.11	10.67
	Se	*	***	*	Ns	**
L. leucocephala	Rainy	2.28	55.90	8.40	2.75	34.80
	Dry	7.35	35.90	5.17	5.05	59.87
	Se	*	***	*	*	***
A. mangium	Rainy	2.81	31.34	9.16	2.05	25.98
	Dry	5.23	42.30	13.32	1.15	30.65
	Se	*	**	*	Ns	*
Mean of grasses	Overall	3.4±0.7	37.1±4.2	9.6±1.9	2.2±0.2	35.3±0.8
Sig. of effect	Species	***	*	***	*	***
	Season	**	Ns	Ns	Ns	**
	Spe. X Sea.	**	Ns	Ns	Ns	**
Mean of legumes	Overall	3.9±1.6	38.6±3.8	13.4±3.7	2.7±0.5	34.4±0.5
Sig. of effect	Species	**	**	***	**	***
	Season	***	Ns	*	Ns	***
	Spe. X Sea.	**	**	Ns	Ns	***
Grass X legume		Ns	Ns	**	Ns	*

Se:Season effect in rainy and dry seasons
*** : $P<0.001$; ** : $P<0.01$; * : $P<0.05$ and Ns : non significant