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Evaluation of Tropical Grasses on Mine Revegetation for Herbage Supply to Bali Cattle in Sorowako, South Sulawesi, Indonesia

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Abstract: The aim of this study was to evaluate forage quality and absorption of heavy metals in grasses of grazing lands in mine revegetation area. Grazing land was dominated by *Brachiaria decumbens* (BD), which occupied about 87% in the pasture' syielding ability of 14.8 Mg DM/ha/year, followed by *Centrocema pubescens* (CP), *Calopogonium mucunoides* (CM) and *Imperata cylindrica* (IC) at 6, 4 and 3%, respectively. Both of *in vitro* dry matter digestibility and organic matter digestibility were the highest in BD and CM, followed by CP and the lowest in IC. Structural carbohydrates of cellulose and hemicelluloses were the highest in BD, contrary to Acid Detergent Lignin (ADL) concentration, which was the highest in IC and the lowest in BD, while CP and CM showed the middle in ADL and cellulose concentrations among the four forage species. Heavy metals of nickel (Ni), chromium (Cr) and lead (Pb) were detected in the order of Ni > Cr > Pb in the grasses examined and harvested on mine-revegetation area in Sorowako, Indonesia.

Keywords: Mine Revegetation, Tropical Grass, Heavy Metal, Digestibility, Structural Carbohydrate

Introduction

It is important to support the national meat self-sufficiency program in Indonesia and one of the essential factors that must be prepared is the availability of forages to livestock. The decreasing trends of farmland and grazing land due to property and urbanization caused more difficulty in forage supply for livestock. Therefore, the reuse of critical land needs to be optimized.

Grasses are the most commonly seeded plants in revegetation programs and produce large amounts of biomass, adapted to initiate regrowth rapidly after mowing or grazing. Grasses have fibrous root systems that hold soil particles in place, thereby controlling erosion (Skousen and Zipper, 2010). Grasses are obtained readily and at reasonable cost and are well-adapted to the infertile, droughty and/or acidic sites often associated with mined areas (Skousen and Zipper, 2010). Mine revegetation area is possible for grazing use.

On the other hand, the utilization of post-mine area as a forage crop land is often associated with low-quality grass and so that this study was aimed to evaluate forage quality of the grasses in the mine revegetation area, in addition with the absorption of heavy metals (Ishii *et al*., 2015). Considerable high content of heavy metal has been reported as a result of several industrial or waste disposal activities in some regions of the world, which could enter to the food chain through different mechanisms and could accumulate in higher organisms such as human beings (WHO, 2007).

Materials and Methods

Forage Sampling, Botanical Species Identification and Chemical Component

This study was conducted in mine revegetation area in Sorowako, Luwu district, South Sulawesi (Indonesia), which had an area of about 2,844 ha. Ten ha in the pasture land was selected as sampling area. The herbages were randomly collected using a 1 m^2 quadrant at 60 replications. Forage herbage was clipped by hand sickle to 2 cm above the ground level. For each clipping, grass species was identified into their respective botanical composition by visual estimation and then performed weighing each grass species. The proportion of each species was squared rank first, second and third respectively multiplied by a factor of 70.2, 21.08 and 8.73. Measurement of biomass production and botanical composition were made by the biomass composition method based on dry weight (Mannetje and Haydock, 1963). The characters of forage quality studied were *In Vitro* Dry Matter Digestibility (IVDMD) and Organic Matter Digestibility (IVOMD), estimated by the pepsin-cellulase assay (Goto and Minson, 1977) method and Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), by the method of Goering and Van Soest (1970). Cellulose and hemicelluloses concentrations were calculated as the differences between NDF and ADF and between ADF and ADL, respectively.

Heavy Metals Quantification

Sample was prepared by the method of digestion using concentrated nitric acid (Solidum *et al*., 2013). The entire metal of nickel (Ni), chromium (Cr) and lead (Pb) concentrations were analyzed using atomic absorption spectrophotometer (Shimadzu AA-7000, Kyoto, Japan).

Statistical Analysis

Data on composition of grasses species and biomass production were processed using Microsoft Office Excel 2007. The IVDMD, NDF, ADF, ADL, cellulose, hemicelluloses and heavy metals concentrations were subjected to General Liner Model (GLM) procedure of IBM SPSS Statistic 21, statistical package based on the following statistical model:

$$Y_i = \mu + \alpha_i + e_{ij}$$

Where:

Y_i = The general response of a factor under investigation (IVDMD, IVOMD, NDF, ADF, ADL, cellulose, hemicelluloses and heavy metals concentration)
μ = The general mean peculiar to each observation
α = The *i*th effect on the observed parameter
e_{ij} = The random error term

Results and Discussion

Composition of Grass Species and Biomass Production in the Tropical Pasture

Grazing land was dominated by *Brachiaria decumbens* (BD), which occupied about 87% from 14.8 Mg DM/ha/year of the pasture yielding ability, followed by *Centrocema pubescens* (CP), *Calopogonium mucunoides* (CM) *and Imperata cylindrica* (IC) at 6, 4 and 3%, respectively (Fig. 1). The high production of BD was due to being used as a cover crop, while the other type of grass grows inadvertently. BD, a cover crop, is used to protect the soils from the surface running-off (San *et al*., 1998), has high biomass production (San *et al*., 1998), is produced widely throughout the world (Rao *et al*., 1998) and is well adapted to various soil types, primarily to infertile acid soils (Rao *et al*., 1998; Wenzl *et al*., 2000). CP is a perennial and trailing-climbing herbaceous legume, adapted to sub-humid and humid tropics more than 2000 mm of rainfall and better adapted to acid soils (CSIRO, 2006). CM is a vigorous, creeping, twining or trailing, short-lived perennial herbaceous legume, adapted to the hot, wet tropics with annual rainfall exceeding 1,500 mm and prefers clay soils with pH 4.5-5.0 (CSIRO, 2006). IC is a perennial weedy grass which is short, erect and arises from rhizomes, adapts to 500-5000 mm of rainfall and can tolerate a wide range of soil pH conditions.

In Vitro DM and Organic Matter Digestibility of Forages

In vitro DM and organic matter digestibility of four pasture species were shown in Table 1.

Analysis of variance showed the significant difference ($p<0.05$) in IVDMD and IVOMD of forage species, which were the highest in BD and CM, followed by CP and the lowest in IC (Table 1) and was reflected by the difference in ADL and hemicelluloses concentrations among forage species (Table 2). Therefore, as a source of forages fed to beef cattle, improved species of BD, CM and CP would be superior to native IC in both structural carbohydrate concentration and digestibility.

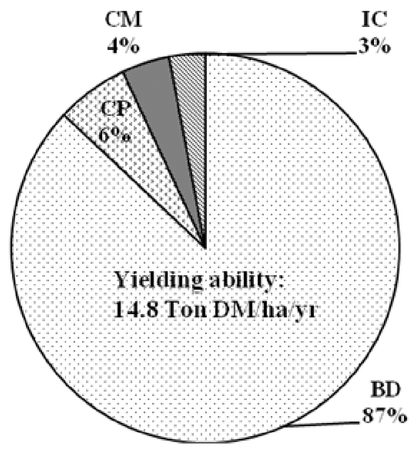

Fig. 1. Species composition of tropical pasture in the region of the present research. †Species: *Brachiaria decumbens* (BD), *Centrocema pubescens* (CP), *Calopogonium mucunoides* (CM) and *Imperata cylindrica* (IC)

Table 1. *In vitro* dry matter and organic matter digestibility of four pasture species

No	Grass Species	% DM	
		Dry matter digestibility	Organic matter digestibility
1	BD	60.00±1.41[a]	59.50±0.71[a]
2	CP	53.00±1.41[b]	51.00±1.41[b]
3	CM	58.50±0.71[a]	56.50±2.12[a]
4	IC	29.00±1.41[c]	25.50±0.71[c]

Species: *Brachiaria decumbens* (BD), *Centrocema pubescens* (CP), *Calopogonium mucunoides* (CM) and *Imperata cylindrica* (IC); Different superscripts in the same column indicate significant difference (p<0.05)

Table 2. Concentration (%) of the structural carbohydrate components of four forages species grown on the post-mining land

Forage species †	Chemical component (%)				
	NDF	ADF	ADL	Cellulose	Hemicelluloses
BD	85.49±0.56[a]	48.66±0.51	9.71±0.13[a]	37.98±0.50[a]	36.83±0.06[a]
CP	70.18±0.40[b]	52.30±3.03	14.76±0.67[b]	34.34±0.86[b]	20.09±0.31[b]
CM	86.29±1.11[a]	50.16±0.69	15.62±0.32[bc]	32.46±0.33[c]	36.13±0.42[a]
IC	67.38±0.28[c]	48.14±0.38	16.23±0.03[c]	31.53±0.45[c]	19.24±0.66[b]

†Species: *Brachiaria decumbens* (BD), *Centrocema pubescens* (CP), *Calopogonium mucunoides* (CM) and *Imperata cylindrica* (IC); Different superscripts in the same column indicate significant difference (p<0.05)

Table 3. Concentration (mg DM/kg) of heavy metal (Ni, Cr and Pb) in four forage species

Element of metal †	Forage species			
	BD	CP	CM	IC
Ni	4.2±1.12	4.7±0.93	4.5±1.11	4.5±1.27
Cr	0.6±0.23	0.6±0.35	0.6±0.29	0.7±0.32
Pb	0.3±0.15	0.4±0.11	0.3±0.13	0.3±0.17

†: Nickel (Ni), chromium (Cr) and lead (Pb)

The highest digestibility of BD among the four species might be due to several factors as follows: (1) BD is a prostrate-type improved grass, (2) BD grows well on mine-revegetation area compared with other species, (3) BD has younger aged leaves, compared with other species. The high IVDMD of BD in this study was relevant with the review in Low (2015). It is reported that IVDMD of BD was 56-78% up to five weeks of age, while it decreased to a range of 41.6-63.7% as the pasture matured.

Imperata cylindrica has the lowest digestibility compared with the other species, corresponding with Ako *et al.* (1992), showing that the IC digestibility was essentially lower than the forage species in general, due to the higher fiber concentration than the improved forage grasses.

Chemical Component (NDF, ADF, ADL, Cellulose and Hemicelluloses) of Forages

Analysis of variance showed the non-significant difference in ADF concentration among four forage species, while the levels of NDF, ADL, cellulose and hemicelluloses differed among some species (p<0.05) in Table 2. The NDF concentration was the highest in CM and BD, followed by CP and the lowest in IC (p<0.05). However, ADL concentration was lower in BD than the other three species (p<0.05). Cellulose concentration was the highest in BD, followed by CP and the lowest in CM and IP (p<0.05). Hemicelluloses concentration was higher in BD and CM than in CP and IP (p<0.05) (Table 2).

Therefore, structural carbohydrates of cellulose and hemicelluloses were the highest in BD and contrarily, ADL concentration was the highest in IC and lowest in BD. CP and CM showed the middle in ADL and cellulose concentrations among the four forage species (Table 2).

Concentration of Heavy Metals (Ni, Cr and Pb)

Mining area is always associated with heavy metals that may be contaminated in the surrounding environments (Boom, 2002). Heavy metals can be contaminated with the dust spreading on every surface in the area because of blasting rocks during mining (Bruce *et al*., 2003; Onder *et al*., 2007; Gutiérrez-Ginés *et al*., 2010; Ishii *et al*., 2015). Heavy metals can also be increased when the soil and grass samples were taken near the shelter mining waste products (Boom, 2002). Therefore, when these forage resources are used as animal feed, they should cause a huge negative impact on animals, following to the human health damage by the consumption of livestock products.

Four forage species harvested on mine-revegetation area in Sorowako showed that BD possessed 4.2±1.12, 0.6±0.23 and 0.3±0.15 mg DM/kg for Ni, Cr and Pb, respectively (Table 3). Heavy metals found in CP were 4.7±0.93, 0.6±0.35 and 0.4±0.11 mg DM/kg for Ni, Cr and Pb, respectively (Table 3). CM contained 4.5±1.11 mg DM/kg of Ni, 0.6±0.29 mg DM/kg of Cr and 0.3±0.13 mg DM/kg of Pb (Table 3). IC had 4.5±1.27 mg DM/kg of Ni, 0.7±0.32 mg DM/kg of Cr and 0.3±0.17 mg DM/kg of Pb (Table 3).

Conclusion

Grazing lands on mine-revegetation area in Sorowako were dominated by *Brachiaria decumbens* (BD) and only a small portion covered by *Centrocema pubescens* (CP), *Calopogonium mucunoides* (CM) *and Imperata cylindrica* (IP). Both of IVDMD and IVOMD were the highest in BD and CM, followed by CP and the lowest in IC, which was corresponded with the highest structural carbohydrates of cellulose and hemicelluloses and lowest ADL concentration in BD. Heavy metals of Ni, Cr and Pb, found in four forage species harvested on mine-revegetation area in Sorowako, Indonesia, need the careful attention for feeding to livestock.

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Author's Contributions

Syamsuddin Hasan: Designed the experiments and analyzed the data.

Asmuddin Natsir: Performed the experiments and wrote the manuscript.

Ambo Ako: Performed the experiments and analyzed the data.

Andi Purnama: Performed the experiments and analyzed the data.

Yasuyuki Ishii: Wrote the manuscript and analyzed the data.

Ethics

This manuscript has not been published or presented elsewhere in part or in entirely and is not under consideration by another journal. All the authors have approved the manuscript and agree with submission to the esteemed journal. There are no conflicts of interest to be declared.

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