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Production and In Vitro Digestibility of Leucaena leucocephala Under Different Seasons and Planting Model Systems in Kupang Regency, Indonesia

Edi Djoko Sulistijo[1,2*] Ifar Subagyo[3] Siti Chuzaemi[3] Herni Sudarwati[3]
1.Doctoral Student of Faculty of Animal Science, University of Brawijaya, Malang 65145, Indonesia
2.Lecturer of Faculty of Animal Husbandry, Universitas Nusa Cendana, Kupang 85228, Indonesia
3.Lecturer of Faculty of Animal Science, University of Brawijaya, Malang 65145, Indonesia

Abstract
Farmers in Kupang had 3 different *Leucaena leucocephala* plantations with each was planted under different local planting methods as their forage resource. In this research, we evaluate the production, nutritional content and *in vitro* digestibility of the *L. leucocephala* in all of the plantations during the early and late dry season as well as during rainy season. The first plantation was planted under Amarasi model (Amarasi plantation), where the *L. leucocephala* were planted in array; the second plantation was planted under Mamar Kering model (Mamar Kering plantation), where the *L. leucocephala* were planted by the natural fauna of the plantation; and the third plantation was planted under Selobua model (Selobua plantation), where the *L. leucocephala* were planted intercropping with crops. The harvest was done every four months from March 2016 to April 2017 by also following local harvesting practices (all of the branches and leaves were cut at 2-3 m above ground). The observed variables include dry matter (DM), organic matter (OM), crude protein (CP), neutral-detergent fiber (NDF), and acid detergent fiber (ADF) content, as well as the in vitro DM and OM digestibility of *L. leucocephala*. All of the obtained data were analyzed with nested ANOVA and followed with LSD test. The results showed that different planting model and season gave differences ($P<0.01$) to the DM, NDF, ADF, in vitro DM and OM digestibility. The study concluded that the Amarasi plantation had the highest production, while overall nutritional content and *in vitro* digestibility of *L. leucocephala* was better during rainy season, and the highest was found in Selobua plantation.
Keywords: Amarasi, Mamar Kering, Selobua, forages, *Leucaena leucocephala*
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1. Introduction

The forage availability for livestock feed has become a common issue whether in an intensive or extensive farming system. The currently available solutions are whether by providing forage plantation, conducting integrated livestock to crop farming system or utilizing different forages in mixed farming systems (Makar, 2002; Simbaya, 2002; Smith, 2002; Delsalle *et al*., 2012). In some places, specific and local practices were done to overcome the threat of feed shortages, yet there was little, if none, comprehensive research available to measure its production. In Kupang Regency, the local practices include Amarasi, Mamar Kering, and Selobua planting system were used for *Leucaena leucocephala* plantation.

In the Amarasi planting system, the *L. leucocephala* were planted in an array with tight spaces between each plant, while in Mamar Kering, the *L. leucocephala* seeds were planted by the local fauna of the plantation, thus resulted in scattered *L. leucocephala* plants and growth along with other perennials. The third planting system is called Selobua, where the *L. leucocephala* was planted intercropping with crops for human consumption (Nulik *et al*., 2000; Roshetko & Mulawarman, 2002; Njurumana, 2008; Kapa, 2007; Sulistijo & Rosnah, 2013).

Previous research on the utilization of forage plantation to support livestock farming in the Kupang Regency has been widely available. However, a quantitative approach to measure the forage production planted with different local practices has yet to be done. In this research, we evaluate the production, nutritional content and *in vitro* digestibility of *L. leucochepala* produced with Amarasi, Mamar Kering and Selobua planting models during early and late dry season as well as during rainy season. The obtained results are expected to contribute to the forage science, especially land utilization as feed source.

2. Methodology

2.1 Time and Location

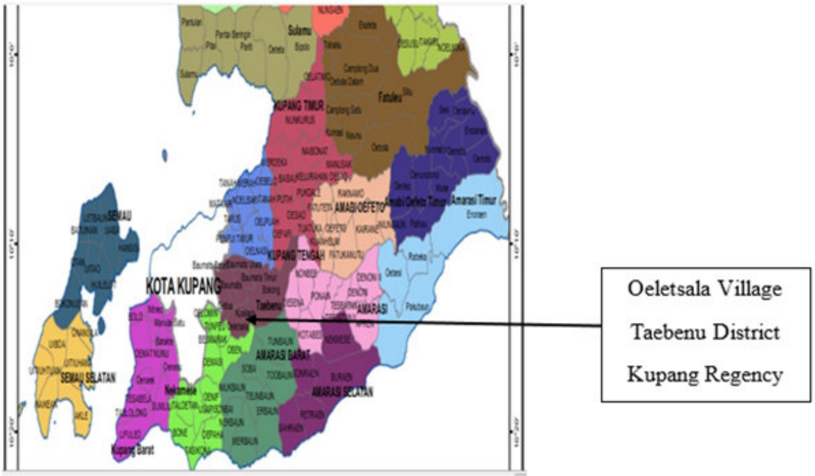

Figure 1. Research location

The research was done in Oeletsala Village, Taebenu District, Kupang Regency, as our previous research (Sulistijo & Rosnah, 2013) showed that the Amarasi, Mamar Kering, and Selobua planting systems for *L. leucocephala* were only found in the area. Each of the planting systems was located in different plantations, henceforth will be written as Amarasi plantation, Mamar Kering plantation, and Selobua plantation. The sample was collected from March 2016 to April 2017. The initial trimming was done in March to April 2016 to homogenize the sample and then followed by harvesting from July to August 2016 for early dry season sample, November to December 2016 for late dry season sample, and March to April 2016 for rainy season sample. The location of Oeletsala Village is presented in Figure 1, while the overview of the land condition and each plantation is presented in Figure 2.

2.2 Materials

The materials used in this research include *Leucaena leucocephala* and chemicals used for the nutritional content analysis (dry matter/DM, organic matter/OM, crude protein/CP, neutral-detergent fiber/NDF, and acid detergent fiber/ADF content) and *in vitro* digestibility.

2.3 Methods

The research was conducted through a field survey method, and the sample was collected by following Noele geological formation, with 4 areas in each plantation were chosen for analysis. Moreover, the sample collection was done by following the local practice, where *L. leucocephala* leaves and branches were cut at 2-3 m above ground. The proximate analysis to measure the DM, OM, and CP was done by following AOAC (1980), the NDF and ADF content were measured by following Goering & Van Soest (1970), and the DM and OM *in vitro* digestibility were done by following Tilley & Terry (1963).

2.4 Data Analysis

The analysis was done with four replications, and the obtained data were analyzed by using analysis of variance with the nested design, followed with LSD test to measure the significances. The combined treatments consisted of plantation (Amarasi, Mamar Kering, and Selobua plantation) and season (early dry season, late dry season, and rainy season). The analysis model used is as follow:

$$Y_{ijk} = \mu + \tau_i + \beta_{j(i)} + \epsilon_{ij(k)}; \quad (1)$$

where:

$Yijk$ = Observation on i plantation, j season and k replication
μ = Mean value
τi = Effect of the i plantation
$\beta j(i)$ = Effect of the j season in i plantation
$\epsilon ij(k)$ = Errors in i, j and k observations
i = 1, 2, 3
j = 1, 2, 3

Figure 2. Overview of the land condition (a); Amarasi plantation (b); Mamar Kering plantation (c); and Seloboa plantation (d)

3. Results and Discussions

3.1 Forages Production

The *L. leucocephala* production under different seasons and plantations is presented in Table 1. The results showed that *L. leucocephala* production was ranged from 453.04 kg DM/Ha /4 months to 1,830.97 kg DM/Ha/4 months or equals to 1,359 tons/Ha/year to 5,493 tons/Ha /year. The results are still in the production standard per unit area as explained by Mannetje & Jones (2000).

Table 1. *L. leucochepala* production based on a different season and planting system (in DM)

Treatments	Forages Production (kg DM/Ha/4 months)
Plantation system	
Amarasi	1,830.97±388.67^{c}
Mamar Kering	453.04±147.20^{a}
Selobua	878.88±256.59^{b}
Different seasons in Amarasi plantation	
Early dry season	1,615.41±345.22^{a}
Late dry season	1,861.12±381.44^{a}
Rainy season	2,016.39±424.52^{a}
Different seasons in Mamar Kering plantation	
Early dry season	494.48±11.08^{a}
Late dry season	549.75±81.42^{a}
Rainy season	314.89±142.39^{a}
Different seasons in Selobua plantation	
Early dry season	923.97±244.23^{a}
Late dry season	812.94±222.83^{a}
Rainy season	899.71±350.74^{a}

Note: The different superscripts in different plantations indicate highly significant differences (p<0.01).

The statistical analysis showed that different planting model systems affect (p<0.01) *L. leucocephala* production, while different seasons did not affect (p>0.05) the production. The production measurement showed that the produced *L. leucocephala* in Amarasi plantation was higher compared to Mamar Kering and Selobua. The result is expected as the *L. leucocephala* in Mamar Kering and Selobua plantations had unequal densities. The result is supported by the research by Elfeed & Elmagboul (2016) which showed the dense *L. leucocephala* population planted in the dry climatic regions would provide higher total production.

The similar *L. leucocephala* production on different seasons indicates that the harvesting of *L. leucocephala* in every four months did not disrupt its growth. Moreover, during dry seasons (early and late), the rainfalls still occurred. The conditions would provide plenty moisture and water in the soil on the dry climate. The rainfall intensity during this study is presented in Figure 3.

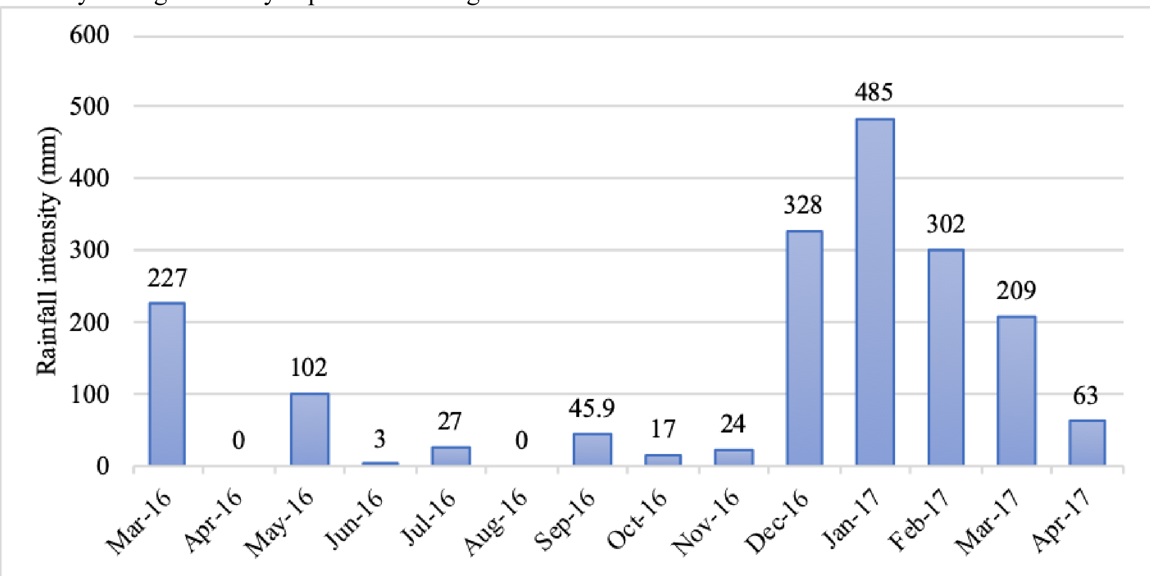

Figure 3. Rainfall intensity during research

3.2 Nutritional Content

The statistical analysis showed that the different seasons and plantations affect (p<0.01) the nutritional content of *L. leucocephala* (Table 2). The results showed that different planting systems affect (p<0.01) the OM, NDF, and ADF content. Moreover, the different seasons on every plantation affect (p<0.01) the DM, OM, NDF and ADF contents of *L. Leucocephala*.

The results showed that the highest DM, NDF and ADF content of *L. leucochepala* were found in the Amarasi plantation. In contrast, the highest OM and CP contents were found in the Selobua plantation. Furthermore, analysis of the different seasons in each plantation showed that the highest DM of *L. leucocephala* was obtained during late dry season, while the highest NDF and ADF content was found during the rainy season. In addition, the OM of *L. leucocephala* in Mamar Kering plantation was not different during all seasons, while the OM in Amarasi and Selobua plantation found to be the highest during rainy season. The CP content of *L. leucocephala* in Amarasi and Mamar Kering plantation in all seasons was not different, while lower CP content of *L. leucocephala* was found during late dry season.

Table 2. Nutritional composition of the *L. leucochepala* on each treatment

Treatment	DM (%)	OM (%)	CP (%)	NDF (%)	ADF (%)
Plantation					
Amarasi	30.01^{b}	90.54^{a}	18.83^{a}	46.11^{b}	36.54^{b}
Mamar Kering	26.98^{a}	91.11^{ab}	18.78^{a}	46.49^{b}	36.72^{b}
Selobua	29.54^{b}	91.63^{b}	20.00^{b}	44.59^{a}	34.52^{a}
Different seasons in Amarasi plantation					
Early dry season	30.57^{b}	89.38^{a}	18.36^{a}	46.16^{b}	35.21^{b}
Late dry season	36.94^{c}	90.62^{a}	18.41^{a}	39.08^{a}	31.07^{a}
Rainy season	22.54^{a}	91.62^{b}	19.71^{a}	53.09^{c}	43.35^{c}
Different seasons in Mamar Kering plantation					
Early dry season	28.07^{b}	91.23^{a}	18.80^{a}	45.59^{b}	34.77^{a}
Late dry season	30.56^{b}	90.56^{a}	18.32^{a}	40.65^{a}	32.72^{a}
Rainy season	22.31^{a}	91.54^{a}	19.20^{a}	53.23^{c}	42.68^{b}
Different seasons in Selobua plantation					
Early dry season	30.54^{b}	91.37^{a}	20.20^{b}	44.06^{b}	32.83^{a}
Late dry season	36.65^{c}	90.15^{a}	18.43^{a}	39.29^{a}	32.36^{a}
Rainy season	21.42^{a}	93.37^{b}	21.38^{b}	50.43^{c}	38.35^{b}

Note: The different superscripts in different plantations indicate highly significant differences ($p<0.01$); while the different superscripts in combined different seasons and plantations showed significant differences ($p<0.05$). OM, CP, NDF, and ADF were based on the %DM.

The DM content of *L. leucochepala* in Mamar Kering plantation was lower (26.98%) compared to Selobua plantation (29.54%) and Amarasi plantation (30.01%). Mamar Kering plantation is dominated by perennial plants, thus resulted in the condition where *L. leucocephala* grown under shades. This condition could disrupt photosynthesis and reduce the transpiration, which in turn would affect the DM content in plant biomass. The lower DM content on plants grown under shade has been shown on research by Handriawan *et al.* (2016) and Chairudin *et al.* (2015).

As seen in Table 2, the OM content of *L. leucocephala* in Selobua plantation (91.63%) was similar to Mamar Kering plantation (91.11%) but higher than Amarasi plantation (90.54%). This can be caused by the higher soil nitrogen in Selobua plantation (0.28%), which is higher than that of the Amarasi (0.07%) and Mamar Kering (0.07%) plantation. Plants that grow in high soil nitrogen will grow better and accumulate photosynthetic OM as the results. The similar condition has been shown by Koten *et al.* (2012) for sorghum (*Sorghum bicolor (L.) Moench*) and Keraf *et al.* (2015) on Kume grass (*Sorghum plumosum var. Timorense*).

The OM content between harvesting periods the Mamar Kering plantation did not differ caused by the high presence of *L. leucocephala* stands under the shade. Mamar Kering plantation was dominated by perennial trees, so the microclimate and soil moisture tend to be similar throughout the year. The conditions resulted in photosynthesis inhibition and similar growth of *L. leucocephala* as reflected in the OM content of *L. leucocephala* in all seasons. From Table 2, it can be seen that the CP content of *L. leucocephala* was ranged from 18.32 to 21.38%. The CP content is lower than other research on *L. leucocephala* which ranged from 22.16% to 31.8% (Aregheore, 2002; Edward *et al.,* 2012; Soltan *et al.,* 2012; Rimbawanto *et al.,* 2015). The different CP content is allegedly due to the different biomass on leaves and branches fraction. Research by Sulistijo (1994) on gliricidia found that the CP content in leaves is higher compared to the edible stem. This is also in line with Askar (1997) which showed that varied CP content of forage would be affected by the proportion between leaves and petioles aside from the forage varieties, soil fertility, age, and climate. The CP content of *L.leucochepala* in Selobua plantation (20.00%) was higher than Mamar Kering (18.78%) and Amarasi (18.83%) plantation.

Moreover, the soil in Selobua plantation was more fertile compared to other plantations as reflected by higher soil nitrogen. The more fertile soil conditions would lead to better growth of shoots, branches, and leaves. The application of nitrogen fertilizer would also increase the leaf's area and higher photosynthetic velocity, thus resulted in an increase of CP content (McDonald *et al.,* 2010). In Table 2, it can also be seen that the different CP content on different seasons was only found in Selobua plantation. The CP content in Selobua plantation during rainy season was 21.38%, while during early dry and late dry seasons were 20.20% and 18.43%, respectively. Both Amarasi, Mamar Kering and Selobua plantations were located in the dry and barren area, thus water availability becomes the major factor in determining plant's growth. The water availability in soil would support the utilization of soil nitrogen by plants. The similar water availability in all plantations is then lead to the higher nitrogen soil Selobua plantation as the determining factor which affects different CP content, even though further confirmations in regard to this matter would be recommended.

The NDF and ADF content of *L. leucocephala* in this research were ranged from 39.08 to 53.23% and 31.07 to 42.68%, respectively. The obtained NDF and ADF content were higher compared to other research (Aegheore, 2002; Edward *et al.,* 2012; Soltan *et al.,* 2012) which showed that the NDF of *L. leucocephala* were ranged from 33.6 to 49.1% and the ADF were 22.8 to 42.11%. Moreover, the trend of NDF and ADF content of *L. leucocephala* on each plantation in this research was in contrast to the respective CP content. The results indicate that the higher available nitrogen soil would result in higher *L. leucocephala* along with its CP and lower fiber content. In regards to the result, research by Egan *et al.,* (1985) showed that NDF is a less soluble compound, consisted of cellulose, hemicellulose, and lignin, which build the cell walls along with ADF. The higher CP, which builds the cell nucleus would the growth of cell wall growth, and thus resulted in lower NDF and ADF of the plant (Crowder & Chheda, 1982).

3.3 In Vitro Digestibility

The *in vitro* digestibility of DM (IVDM) and OM (IVOM) in this research are presented in Table 3. The statistical analysis showed that the different planting models resulted in different ($p<0.01$) *in vitro* digestibility of *L. leucocephala*, with the different seasons, resulted in different ($P<0.05$) *in vitro* digestibility as well. In Table 3, it can be seen that the highest IVDM and IVOM of *L. leucocephala* were found on Selobua plantation. The results were regarding the higher CP content and lower NDF and ADF content of *L. leucocephala* in Selobua plantation. Kim & Jang (1988) showed that higher CP content would have resulted in higher digestibility, while higher fiber content would have resulted in lower digestibility.

Table 3. Digestibility of lamtoro forages based on garden type and harvest period

Treatment	IVDM (%)	IVOM (%)
Plantation		
Amarasi	53.90^{a}	52.19^{a}
Mamar Kering	53.90^{a}	52.25^{a}
Selobua	55.21^{b}	53.77^{b}
Different seasons in Amarasi plantation		
Early dry season	53.05^{a}	51.90^{a}
Late dry season	53.89^{ab}	51.90^{a}
Rainy season	54.77^{b}	52.78^{a}
Different seasons in Amarasi plantation		
Early dry season	53.92^{a}	52.59^{a}
Late dry season	53.81^{a}	52.49^{a}
Rainy season	53.97^{a}	51.68^{a}
Different seasons in Amarasi plantation		
Early dry season	55.93^{b}	54.25^{b}
Late dry season	54.38^{a}	52.87^{a}
Rainy season	55.38^{ab}	54.20^{b}

Note: The different superscripts in different plantations indicate highly significant differences ($p<0.01$); while the different superscripts in combined different season and plantation showed significant differences ($p<0.05$).

In Table 3, it can also be seen that different seasons and planting systems did not give significant effects. However, there is a tendency that the rainy and early dry seasons have resulted in better *in vitro* digestibility of *L. leucocephala*. The condition is caused by higher CP content and lowers NDF content of *L. leucocephala* due to the higher water availability in those seasons. According to McDonald *et al.,* (2010) the NDF digestibility would be determined by lignification.

4. Conclusion

- Forage production of *L. leucocephala* in the Amarasi plantation is higher than Selobua and Mamar Kering plantation. However, the *L. leucocephala* production in three planting systems did not affect by different seasons.
- The overall nutritional content and in vitro digestibility of L. leucocephala was better during rainy season, and the highest was found in Selobua plantation.

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