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A Comparison of Growth Characteristics, Dry Matter Yield, and Forage Quality Between Mixed Cropping and Pure Stand Systems (Monoculture Systems)

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ABSTRACT

Smallholders beef cattle are facing many problems, such as the unsustainable supply, limited quantity, and poor quality of forage, which all are crucial to increase the population and productivity of their beef cattle. Therefore, the objective of this study was to evaluate the effects of monoculture and mixed cropping system between dwarf napiergrass with siratro and centro on growth characteristics, fresh and dry matter (DM) yield, and forage quality. The study was carried out for 4 months. There were 3 experiment treatments, namely P0 = dwarf napiergrass (*Pennisetum purpureum* cv Mott) planted on monoculture system; P1 = dwarf napiergrass planted in mixed cropping system with siratro (*Macroptilium atropurpureum* cv Siratro); and P2 = dwarf napiergrass planted in mixed cropping system with centro (*Centrocema pubescent*). All treatments were replicated 3 times. All plants on each treatment were planted on 3×3 m plots, with 1 m of distance between the plots. Data were collected four times after transplanting, i.e. August 20th, September 17th; October 28th; and December 16th of 2017, respectively. The results of study indicated that neither plant height nor tiller number in all treatments and measurement periods were significantly affected (p>0.05), except in month-3 (plant height) and month-4 (tiller number). Although treatments did not alter fresh and DM yield (p>0.05), the DM yield from mixed cropping system tended to be higher. Hence, it can be concluded that growth characteristic, productivity, and forage quality in mixed cropping system were better than in monoculture system.

Keywords: Centro, Dwarf napiergrass, Monoculture, Polyculture, Siratro

Introduction

Generally, beef cattle production in Indonesia are conducted by smallholder farmers who hold 2-3 heads of beef cattle (Direktorat Jenderal Peternakan, 2015). The number of people working in livestock production sector in South Sulawesi accounts for 3.4% of total national number (Statistik Peternakan dan Kesehatan Hewan, 2018). Although the number is considered low, the existence of people working in livestock industry are crucial to support the achievement of sovereignty in providing animal protein.

Syahdar *et al*. (2016) previously reported the difficulty in increasing the scale of Bali cattle production due to limited land resources, inadequate forage supply, and limited time. Farmers opt to let their beef cattle to roam paddy field area where natural grasses grow. The fact that farmers have limited knowledge regarding forage management, which combined with poor access to technology, cause them to have no alternative option in providing forage for their cattle. These problems lead to poor animal productivity, which eventually compromises their income.

Forage management can be seen as one of means to increase animal productivity. One of strategies in forage management is providing high quality forage as energy and crude fiber source for livestock. Forage divided into 2 main categories, i.e. grass and legume, which all are essential to supply nutrient for livestock. Livestock productivity is heavily relied on both quality and quantity of feed, which will be utilized for production and reproduction purposes. The nutrient requirement is not only supplied from grass that has high biomass production, but also from legume. Compared to legume (0.3–0.6 ton), grass has higher biomass production (1–2 ton). However, legume contains higher protein (15–25%) than grass (5–15%) (Stur and Horne, 2001).

Dwarf napiergrass (*Pennisetum purpureum* cv. Mott) is a tropical and perennial grass, yet also can flourish in the southern part of Kyushu (Ishii *et al*., 2005a; Utamy *et al*., 2011), either in cut-and-carry system (Utamy *et al*., 2011) or grazing system (Mukhtar *et al*., 2014; Ishii *et al*., 2005b). Dwarf napiergrass has characteristics of densed leaf structure, high in biomass production and quality (Tudsri and Ishii, 2007), as well as requiring chemical and organic fertilizers (Utamy *et al*., 2018).

Legume is a group of plants that able to bind free atmospheric Nitrogen, N, with the help of Rhizobium bacteria activity. Rhizobium establish a symbiotic interaction inside the root of legume, forming nodules. Rhizobium bacteria residing inside the nodules facilitate the process of N fixation into protein which is required and vital for the growth of livestock.

Legume has ability to fixate N from atmosphere. Sufficient nodulations and light are significant factors affecting the N fixation and transfer process (Raymod *et al*., 2004). Legume contributes directly to livestock productivity as it supplies N-rich feed. In addition, legume also can improve the productivity of grass by increasing its N absorption if planted in the same area with legume.

Siratro (*Macroptilium atropurpureum* cv. Siratro) is a tropical legume which can grow well in the land with acidity ranging from 6.5–8.0; and also can be planted from seedling or vegetatively. Siratro is a perennial and creeping legume. Feeding siratro to livestock can be conducted by cut-and-carry system or grazing system (grazing is better). Besides as a forage, siratro also can be utilized as a green manure. Siratro can adapt and flourish under shade. Centro (*Centrocema pubescens*) is a tropical legume and grows well in the area with >2000 mm year^{-1} of precipitation. Like siratro, centro can be planted from seedling or vegetatively and is a perennial and creeping legume. Feeding system of centro can be conducted by cut-and-carry or grazing system.

Several studies about mixed cropping system have been conducted in various countries, such as in Kenya (Njoka-Njiru *et al*., 2006); in Indonesia (Dhalika, 2006); and in Ireland (Humphreys *et al*., 2012). In Thailand, napiergrass is mixed cropping with *Leucaena leucocephala* produced higher quality of grass (Tudsri *et al*., 2002). In Japan, Tobisa *et al*. (2005) reported that mixed cropping system between legume and grass produced higher quality forages. Furthermore, the advantage of mixed cropping system has been also proven in pasture land in Missipi, US, with a positive result of 0.99–1.21 kg of average daily gain of beef cattle (Mouriño *et al*, 2003). Paciullo *et al*. (2014) recommended that pastureland should implement mixed cropping system to produce organic dairy milk.

Despite the advantages that mixed cropping system may bring, the system has not been widely implemented in the beef cattle production in South Sulawesi, particularly in Barru regency. Barru is well-known with its development of Bali cattle farms, with population reaching 71,857 Bali cattle (Badan Pusat Statistik, 2018). The high population of Bali cattle in Barru requires high forage supply. Unfortunately, the forage availability in Barru is limited, especially during dry season.

Considering the above explanation, it is necessary to investigate the advantage of mixed cropping system to increase forage availability for Bali cattle, which eventually can improve the productivity of the livestock directly. Hence, the objective of this study was to evaluate the effects of monoculture and mixed-cropping system of dwarf napiergrass with siratro and centro on growth characteristics, fresh and DM yield, and quality of the forages.

Materials and Methods

Research location and soil type

This study was carried out in Bonto-Bonto, Lompo Tengah, Lappariaja, Barru Regency, South Sulawesi. The type of soil in the research location is alluvial-litosol. Several characteristics of soils were measured such as pH (H_2O) 6.5–6.7; electric conductivity (EC) 0.3–0.5 ds/M; carbon content (C) 2.08–2.39% (Walkley and Black method); N content 0.18–0.21% (Kjeldahl method); and C/N ratio 9.67–13.33 (Laboratory of Soil Chemistry and Fertility, Faculty of Agriculture, Universitas Hasanuddin, 2017).

Barru regions is located in tropical region, following the offshore climate pattern of west coast of South Sulawesi. According to climate type in Agroclimatology Zone – during rainy season (precipitation more than 200 mm/month) and during dry season (less than 100 mm/month) – Barru regency generally has C-type climate with 5– 6 months of continuous rainy season (in the period October to March) and less than 2 months of continuous dry season (in the period of April to September). Average temperature in Barru regency is 20–35˚C. The average of annual total rain is 94 days, with 2,646 mm of precipitation. The highest precipitation occurs in December and January, with 423 mm and 453 mm of average precipitation, respectively. The average precipitation during plantation period in this study (July 2017) was 172 mm. Meanwhile, the precipitation increased from the first (272 mm) to the second defoliation (1,042 mm) (Balai Besar Wilayah Sungai Pompengan Jeneberang, Kota Makassar, 2018).

Experiment treatments and design

Pols of dwarf napiergrass and stem cutting of legume were obtained from *Kebun Percontohan* of Gowa Regency, South Sulawesi. This study was carried out in randomized block design, based on the capacity of 3×3 m plots with 1 m of distance between plots. Each plot comprised 7 columns and 4 rows. The number of dwarf napiergrass planted on each treatment was 28 pols. Meanwhile, the number of stems cutting of legume planted between the dwarf napiergrass was 21 stems on each treatment. For clear illustration, please see layout of transplantation (Figure 1). There were 3 treatments on this study, with all treatments were replicated 3 times. Hence, there were 9 plots in total. Experiment treatments were: P0= Monoculture system – dwarf napiergrass, P1= Mixed cropping system – dwarf napiergrass and siratro, P2= Mixed cropping system – dwarf napiergrass and centro.

Plots on P0 groups were given fertilizer with a dose of 30 g N m^{-2} year $^{-1}$, but neither P1 nor P2 groups. Grass and legume were each plant two and one plants per m^2. Each designated plot was planted with grass and legumes accordingly to the experiment treatments. Both grass and legumes were obtained from nursery, with the age of 7 days old. Plots were plowed and given with basal fertilizer before transplantation. The basal fertilizer was commercially organic fertilizer with 12% of organic matter content, 15–24 of C/N ratio, 4–8 of pH, 10–20% of water content, and >10^3 of functional microbes (Pupuk Organik Granule, Berdikari Organik). Dwarf napiergrass were planted on inter-× intra-row space of 1×0.50 m. Transplantation was conducted on July 23rd, 2017. Data measurement and recording were conducted on day-28, -56, -97, and -146, respectively, after the transplantation day. The first defoliation was conducted on day-97 after transplantation, while the second was carried out on day-49 after the first defoliation.

Data collection and analysis

Plant growth characteristics of dwarf napiergrass, such as plant height and tiller number were recorded from 10 plants on random pick on each plot. To evaluate the fresh and DM yield, 2 plants were collected randomly by cutting-height at 10 cm above the ground (Ishii *et al*., 2005b). The data were then converted from g m^{-2} into ton ha^{-1} unit according to this following formula (Tarawali *et al*., 1995),

Total DM yield (ton ha^{-1}) = (Tot FW × (DWss/FWss) × 10^{-2}),

Tot FW = total fresh production (g m^{-2})

DWss = dry weight of sub-sample (g)

FWss = fresh weight of sub-sample (g).

For crude protein, analysis was conducted according to AOAC 2005 Chapter 4B.00, methods 2001.11, while crude fiber analysis refered to SNI 01-2891-1991 point 11 (UPTD Pengujian Mutu Produk Peternakan, Dinas Peternakan dan Kesehatan Hewan Provinsi Sulawesi Selatan, 2017).

Statistical analysis

All data were statistically analyzed on ANOVA analysis using SPSS software for Windows ver. 16.0, Chicago, IL. Statistically

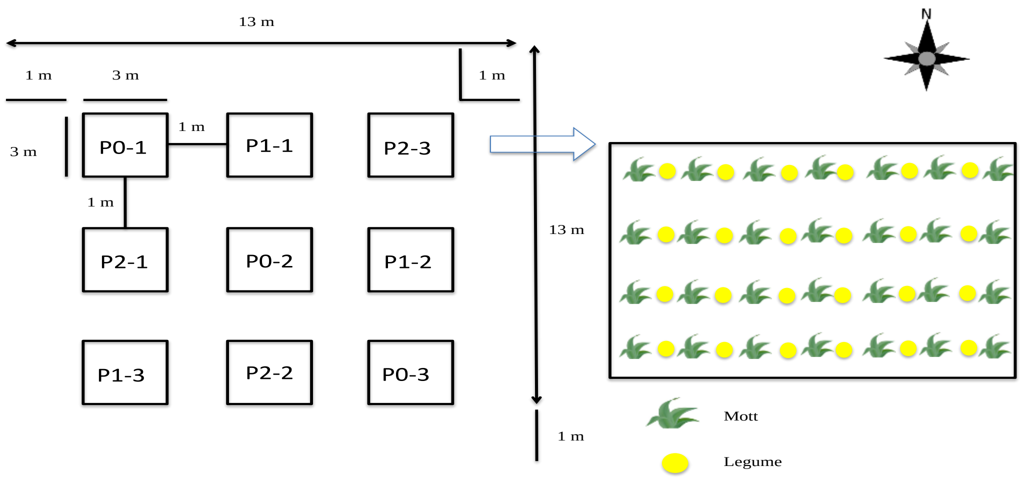

Figure 1. layout of mixed cropping system – dwarf napiergrass and legume. P0 = monoculture system – dwarf napiergrass; P1 = mixed cropping system – dwarf napiergrass and siratro; and P2 = mixed cropping system – dwarf napiergrass and centro.

Table 1. Forage quality of dwarf napiergrass at the first and the second defoliation

Treatments	Forage quality			
	First defoliation		Second defoliation	
	Crude protein (%)	Crude fiber (%)	Crude protein (%)	Crude fiber (%)
P0	12.98	22.11	10.15	27.41
P1	12.04	29.38	10.31	27.74
P2	11.54	24.75	10.68	28.46

Data were average value of dwarf napiergrass.
P0 = monoculture system – dwarf napiergrass; P1 = mixed cropping system – dwarf napiergrass and siratro; and P2 = mixed cropping system – dwarf napiergrass and centro.
Significancy level: $p>0.05$.

different results were subjected to further analysis with 5% of smallest significancy level.

Results and Discussion

Growth characteristics

Treatments on this study did not alter plant height on each measurement period, with exception in month-3, in which P0 groups had highest plant height, but not on P2 (Figure 2). Although the plant height fluctuated on different measurement periods, the growth tended to increase from month-1 to month-3. In month-4 (post second defoliation), the growth starting point was observed lower than month-1. In month-4, the plant height of P1 group was the highest, although no significant difference observed (p>0.05) (Figure 2).

The tiller number increased along with the measurement periods from month-1 to month-4. Although the tiller number were not significantly different (p>0.05) from month-1 to month-3, the tiller number on P1 groups were significantly higher (p<0.05) than P0 and P2 groups (Figure 3).

The unaltered growth characteristics of dwarf napiergrass such as plant height and tiller number can be assumed that the growth was on normal rate. The average of growth characteristics on monoculture system (P0) tended to be higher than mixed cropping system (P1) and (P2). It might be a result of a competition between grass and legume, which affected the growth characteristics of dwarf napiergrass. In addition, the plant population on mixed cropping systems were more densed, limiting the percentage of light plants received. Irfan (1999) reported that high density affected the plant productivity due to the high competition among plants to obtain soil nutrient, sunlight, and space to grow.

In measurement period of month-2 and month-4, the dwarf napiergrass on mixed cropping system were higher. The result might be driven by the ability of centro and siratro in fixating atmospheric N, thus, supplying the N for dwarf napiergrass. Previously, Fujita *et al*. (1992) stated that one of advantages from mixed cropping system is the N supply for other plants. Furthermore, rhizobium bacteria establish a

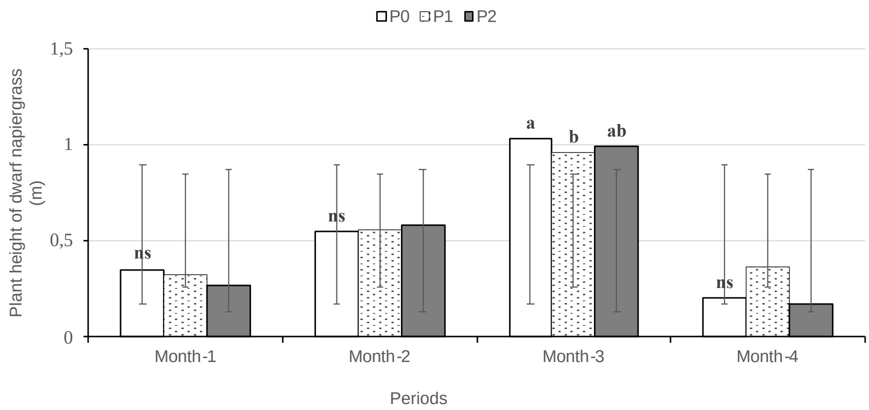

Figure 2.The average value of plant height of dwarf napiergrass on monoculture and mixed cropping system. Different superscripts indicate significant difference (p<0.05). ns = non significant (p>0.05). P0 = monoculture system – dwarf napiergrass; P1 = mixed cropping system – dwarf napiergrass and siratro; and P2 = mixed cropping system – dwarf napiergrass and centro.

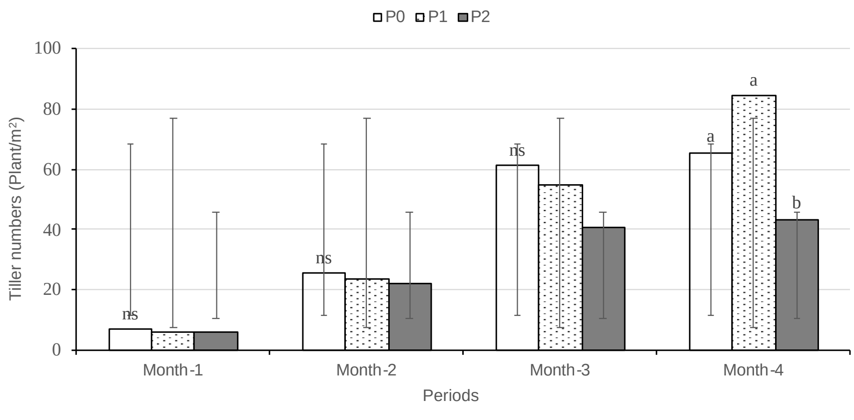

Figure 3.The average number of tillers of dwarf napiergrass on monoculture and mixed cropping system. Different superscripts indicate significant difference (p<0.05). ns = non significant (p>0.05). P0 = monoculture system – dwarf napiergrass; P1 = mixed cropping system – dwarf napiergrass and siratro; and P2 = mixed cropping system – dwarf napiergrass and centro.

symbiotic interaction in colony inside the root of legume. The rhizobium bacteria fixate and convert N into ammonia that can serves as N-source. This type of rhizobium is well known as plant-growth-promoting Rhizobacteria (PGPR), which was firstly studied by Kloepper and Beauchamp (1992). PGPR play roles in supplying soil nutrients, synthesizing and converting phytohormones to increase the growth of plant (Kloepper, 1991). The bacteria also stimulates the synthesis of auxin hormone, thus, the soil becomes fertile (Ahmed and Hasnain, 2014).

Measurement in month-4 or post second defoliation, the growth characteristics of dwarf napiergrass were varied compared to in month-1, with the same starting growing. P1 groups tended to be higher than P0 and P2, although no significant difference indicated ($p>0.05$).

The tiller number of dwarf napiergrass increased along with the measurement periods. Generally, delay of defoliation is followed by the increased tiller number. The mixed cropping system between dwarf napiergrass and legume did not significantly alter the tiller number from month-1 to month-3, yet did in month-4. The tiller number of P1 in month-4 was significantly greater than P0 and P2 ($p<0.05$). In contrast to plant height, the tiller number on mixed-croppings system between dwarf napiergrass and siratro tended to be greater.

Production of fresh and dry matter, and forage quality

Experiment treatments on this study did not affect fresh weight and DM yield, either of dwarf napiergrass, legume, or annual total yield. For dwarf napiergrass, the fresh and DM yield increased from the first to the second defoliation. Meanwhile for legume, the fresh and DM yield were relatively unchanged (Figure 4).

On this study, the highest average of fresh weight of dwarf napiergrass was obtained in P1 group (38.46 ton ha^{-1} year^{-1}), followed by P2 (30.54 ton ha^{-1} year^{-1}) and P0 (20.75 ton ha^{-1} year^{1}), respectively. The yield obtained on this study was still higher than previous studies by Utamy *et al*. (2018) and Ishii *et al*. (2013) on monoculture system. Furthermore, Njoka-Njiru *et al*. (2006) in Kenya, Seresinhe dan Pathirana (2000) in Sri Lanka; and Tudsri and Kaewkunya (2002) in Thailand reported that dry matter production of grass was higher on mixed cropping system. Banik *et al*. (2006) stated that legume can help the formation of soil structure, increase internal soil drainage, infiltration, aeration, microbe activity, and root development.

The average DM yield in this study was 23.93–26.84 ton ha^{-1} year^{-1}. In the assumption that one unit of ruminant livestock requires 6.25 kg of DM of day^{-1} (NRC, 1984), therefore the carrying capacity of DM yield for adult beef cattle suitable for 10–12 unit of livestock.

The crude protein and crude fiber content were not significantly affected by treatments ($p>0.05$) on the first and the second defoliation. Crude protein content decreased from the first to the second defoliation on all plants. In contrast, crude fiber increased. On this study, the period between the first and the second defoliation were 97 days for the former and 49 days for the latter. Like other tropical grasses, the crude protein content of dwarf napiergrass decreased as reaching the mature stage. The delay defoliation period cause the thickening of plant's cell wall, thus compromising its digestibility (McDonald *et al*., 2002).

Mansyur *et al*. (2005) added that crude protein content would decrease following the wider interval of defoliation. Aside from the age of the plant itself, the reduction of crude protein content was also influenced by the reduction of ratio of leaves, leaf petals, and stems. The leaves has higher protein content than the leaf petals and stems.

Although on the first defoliation legume has not yet been able to increase the crude protein content, however, the legume increased the crude protein content of dwarf napiergrass on the

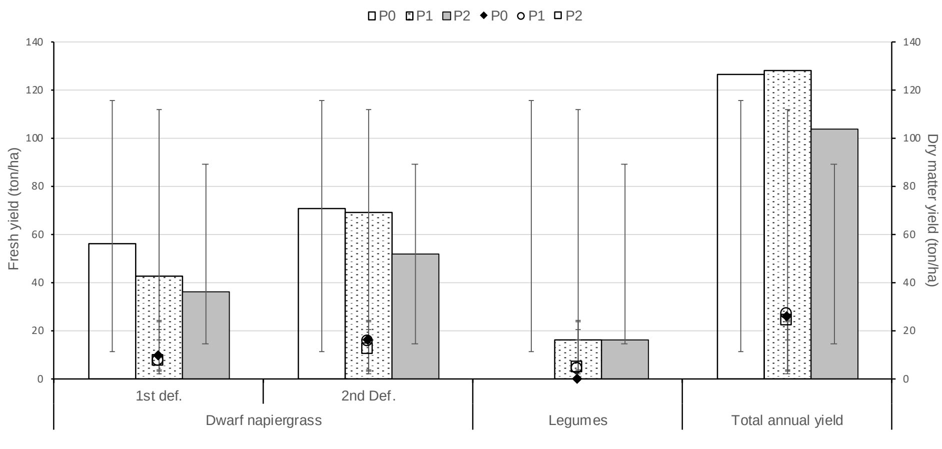

Figure 4. Average value of fresh yield, dry matter yield, and total annual yield of dwarf napiergrass on monoculture and mixed cropping systems. P0 = monoculture system – dwarf napiergrass; P1 = mixed cropping system – dwarf napiergrass and siratro; and P2 = mixed cropping system – dwarf napiergrass and centro.

second defoliation. Tudsri *et al*. (2002) stated that legume augmented the forage quality on mixed cropping system.

The crude protein content on this study ranged 11.54–12.98% (at the first defoliation) and 10.15–10.68% (at the second defoliation), which have met the minimum standard requirement for ruminant livestock, 7%. Crude protein less than 7% will cut ruminal microbes activity which can lead to poor livestock animal performance (Hassen *et al*., 2001; Stur and Horne, 2001).

Conclusions

Mixed cropping system did not alter growth characteristics, fresh production, and DM yield of dwarf napiergrass. Plant height and tiller number of dwarf napiergrass were varied and affected by measurement periods. The crude protein content of dwarf napiergrass on mixed cropping system was higher on than on monoculture system.

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