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Forage Production and Nutrient Content of Different Elephant Grass Varieties Cultivated with *Indigofera zollingeriana* in an Intercropping System

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ABSTRACT

A proper planting system and efficient management are needed to cultivate forage effectively. Therefore, this research aimed to evaluate forage production and nutrient content of different elephant grass varieties grown with Indigofera in the intercropping system and were harvested at different intervals of defoliation. The research was conducted in the dry and rainy seasons using a randomized block design with 3 factors (2x2x2) and 4 replications. The first factor was two different elephant grass varieties consisting of cv. Pakchong and Taiwan, the second factor was the planting pattern, including intercropping and monoculture, while the third factor was harvesting age, comprising 50 days and 60 days. The results showed an interaction effect between grass varieties, planting patterns, and harvesting ages. Intercropping the Pakchong varieties with Indigofera and harvesting at 60 days produced the highest forage fresh weight and DM production, ADF as well as NDF contents and yields, CP yield, and the highest carrying capacity ($p<0.05$) according to DM intake. When harvested at 50 days, Indigofera increased the protein content of forage, but this effect did not occur when it was harvested at 60 days. Furthermore, nutrient yields were not affected by interactions of three factors in the rainy season ($p>0.05$), but in the dry season, the highest ash and CP yields were produced by the Pakchong variety intercropped with Indigofera and harvesting at 60 days. The highest ADF and NDF yields were obtained from the Taiwan varieties grown in monoculture and harvested at 60 days. Based on the results, it was concluded that the two varieties of elephant grass could be cultivated with Indigofera in the intercropping system and harvesting time of 60 days will produce the highest nutrient yield and carrying capacity.

Keywords: harvesting age; Indigofera zollingeriana; intercropping, nutrient production; Pennisetum purpureum

INTRODUCTION

The development of the ruminant livestock business in Indonesia relies heavily on the availability of competitively priced feed that is accessible year-round. Therefore, an alternative forage cultivation system with the right planting system and effective management is needed. Growing multiple forage crops in the same area is one of the most common cultivation practices used in a sustainable agriculture production system to secure forage availability and animal nutrition. The intercropping system cultivates two or more species on the same land with different plant characteristics and growth periods. It plays an important role in increasing land productivity and yield stability (Qin *et al.*, 2013) and improving land utility by using water, nutrients, and solar energy efficiently (Matusso *et al.*, 2014; Moradi *et al.*, 2014). Legumes, for instance, can provide nitrogen through symbiosis with root nodules and inorganic phosphorus in the soil due to a decrease in pH (Ghanbari *et al.*, 2010; Mobasser *et al.*, 2014). Intercropping also increases light interception, infiltration, and reduces evaporation, leading to water conservation by providing shade and enhancing soil structure.

The compatibility of plant species is crucial in applying intercropping system. The selected plant species are intended to increase the complementary effect between plants and minimize competition (Luna *et al.*, 2015). Elephant grass (*Pennisetum purpureum*) is a forage fodder crop currently being cultivated intensively in the ruminant livestock business in Indonesia. This choice is because it produces high-quality biomass with high palatability and wide adaptability (Tessema, 2008). As animal feed, elephant grass contains high nutritional values comprising CP 13%-14%, CF 30%-32%, and Ca 0.24%-0.31%. Therefore, it is suitable for ruminants (Mansyur *et al.*, 2016) and can produce up to 250-500 tons/ha/year of fresh herbage or up to 20-40 tons DM

ha^{-1} $harvest^{-1}$ (Ella, 2002). *Indigofera zollingeriana* is a potential legume source of protein and minerals for livestock. It produces biomass, protein, minerals, and has a high digestibility compared to the other legumes (Suharlina *et al.,* 2016a,b), thereby effectively increasing the digestibility of goat rations when used in complete feeds (Tarigan *et al.,* 2017). Indigofera has a range of adaptations to various environmental conditions and is tolerant of dry stress (Herdiawan *et al.,* 2014).

Optimizing the pattern of forage for livestock through proper harvesting age is also crucial. The older the age, the less water content and the higher the proportion of cell walls compared to the cell content (Beever *et al.,* 2000). Research on the harvesting age of elephant grass has been carried out to produce optimal forage production and quality (Rengsirikul *et al.,* 2011). However, the results showed different production and nutritional characteristics in distinct locations. *P. purpureum* has high forage yield and quality at 60 days for direct grazing and 90 days for harvesting in Mexico (Dios-León *et al.,* 2022), 6 weeks in Malaysia (Zailan *et al.*, 2016), 60 days in Indonesia (Liman *et al.*, 2022), and 6-8 weeks in Thailand (Lounglawan *et al.,* 2014). There are no reports on nutrient production from elephant grass of different varieties grown with Indigofera in the intercropping system and harvested at different ages. Therefore, this research was conducted to evaluate the nutrient production of various elephant grass varieties planted with Indigofera in an intercropping system and harvested at different ages.

MATERIALS AND METHODS

Site Description and Soil Properties

The experiment was conducted from December 2020 to December 2021 at Caringin Kulon Village, Caringin District, Sukabumi Regency, West Java Province, Indonesia. The research site was located at an altitude of 650 m above sea level, while the chemical and biological properties showed that the soil was a dusty clay loam textured Latosol type with a pH value between acidic and neutral, as shown in Table 1. The soil organic C was in the moderate category, while the availability of macronutrients such as N-total and K was low, and P_2O_5 was very high. The experiment was conducted for one year in the rainy and dry seasons, as shown in Figure 1, while the climatic conditions at the site are described in Figure 2.

Layout and Design of the Experiment

The experiment was conducted using a factorial randomized block design with 3 factors (2x2x2) and 4 replications. The first factor was varieties of elephant grass, namely Pakchong and Taiwan. The second factor was the planting pattern which comprised intercropping and monoculture, while the third factor was the harvesting age of 50 days and 60 days. The total number of plots used was 32 units and two months old Indigofera seedlings were planted a month before elephant grass. The planting row was set up on the Indigofera alley plots, while the proportion with elephant grass was 30%:70% according to protein-energy balance (Telleng *et al.,* 2016). The planting distance for elephant grass was 80 x 80 cm, with a distance between rows of 100 cm. Moreover, the experimental plot area was 5 m x 5 m with a fixed number of 42 plants. The monoculture plot consisted of 42 elephant grass plants while intercropping was made up of 24 elephant grass and 18 Indigofera individual plants.

Fertilization was carried out using organic fertilizer (4 tons ha^{-1}), triple super phosphate (100 kg P_2O_5 ha^{-1}), and potassium chloride (100 kg K_2O ha^{-1}) at the time of planting. Meanwhile, N fertilizer (urea) was applied two weeks after planting at 150 kg ha^{-1}. Organic fertilizer was applied once at planting, while the inorganic fertilizer was applied thrice with the same dose during the trial period, namely at planting and after the first and third defoliations. Plants embroidery was conducted two weeks after planting. The first trimming was carried

Table 1. Chemical and physical quality of the experimental site in Caringin Village, Caringin District, Sukabumi (0.2-0.4 m depth)[1]

Measurements	Value
pH H_2O	6.7
pH KCl	5.4
C-organic (%)	2.1
N-total (%)	0.19
C/N ratio	11
P_2O_5 (ppm)	289
Ca (cmol/kg)	18.8
Mg (cmol/kg)	1.9
Na (cmol/kg)	0.3
K (cmol/kg)	0.8
Aldd (cmol/kg)	88.3
CEC (cmol/kg)	24.7
Texture	
Sand (%)	8.8
Dust (%)	55
Clay (%)	36.2

Note: [1]Indonesian Soil Research Institute, 2021. KCl= potassium chloride, C= Carbon, N= Nitrogen, C/N= carbon-nitrogen ratio, Ca= Calcium, Mg= Magnesium, Na= Sodium, K= Potassium, Aldd= Aluminum can be exchanged, CEC= Cation Exchange Capacity.

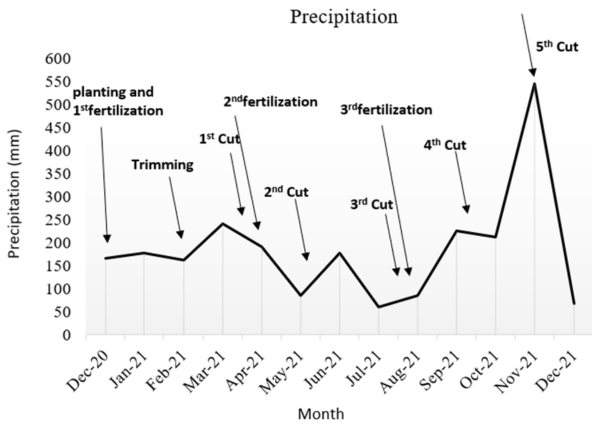

Figure 1. Harvesting and fertilizing schedule during the research

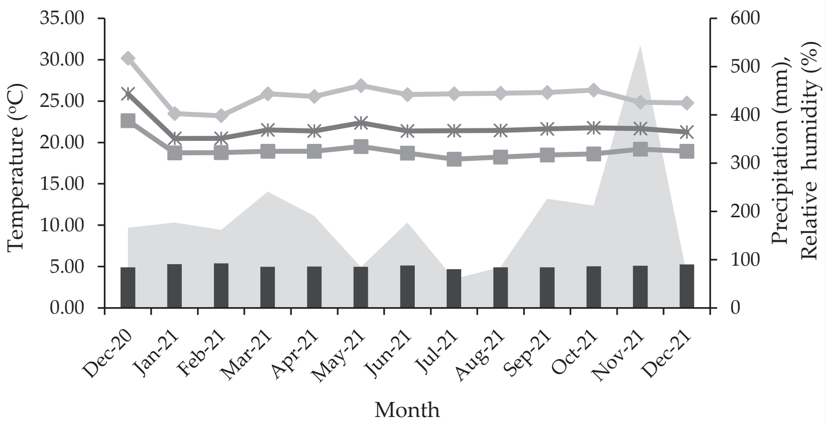

Figure 2. Conditions of rainfall, air temperature, and relative humidity at the experimental site during the research.

out 2 months after planting to ensure the uniformity of plant regrowth, while maintenance and weed control were performed when necessary. The experimental plants were harvested 5 times during the period of experiments and the defoliation interval was conducted according to treatments. Elephant grass was trimmed 20 cm from the ground, while Indigofera was pruned 100 cm from the soil surface and then weighed to determine fresh weight production. Samples from both plants were taken separately and then composited, dried, and weighed to determine DM yield and nutrient quality.

Chemical and Statistical Analysis

About 2000 grams of fresh samples of each plant from every plot were taken and then dried in the sunlight for 2 days. The samples were further dried in an oven at 60 °C for 48 hours and ground to a size of 1 mm for chemical analysis. Dry Matter (DM), ash, and Crude Protein (CP) contents were analyzed based on the AOAC method (2005). Meanwhile, Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) contents were assessed in line with Van Soest *et al.* (1991). DM production of each plot was calculated based on fresh weight and after-drying data. CP, ash, NDF, and ADF yields were determined by multiplying DM production with the nutrient content of the harvested herbage. Carrying capacity was calculated based on DM production of total forage (elephant grass + Indigofera) generated from forage harvested per plot and converted to ha divided by ruminant DM intake, assuming that cattle consume 8 kg DM/day/AU about 2% of body weight. The data were then analyzed statistically using analysis of variance (ANOVA) with SAS Student software. The Honest Significant Difference (HSD) test was carried out when there was a significant difference between treatments.

RESULTS

Dry Matter Yield

DM yield was significantly influenced (p<0.05) by the interaction of elephant grass varieties, planting patterns, and harvesting age, as shown in Table 2. Differences in DM yield occurred dynamically at each defoliation time. DM yield increased at the first and second defoliations, decreased in the third defoliation during the dry season, and increased again in the fourth and fifth defoliations during the rainy season. The highest value was produced by the Taiwan varieties planted in monoculture (4th and 5th defoliations) and harvested at 60 days, as well as Pakchong variety intercropped with Indigofera at 3rd defoliation.

DM yield of Indigofera was also significantly influenced (p<0.05) by the interaction of elephant grass varieties and harvesting ages (Table 3) at the third and fifth defoliations. Production of Indigofera varied when grown with the Taiwan variety (225.85-809.57 kg DM/ha/harvest) and the Pakchong variety (320.99-1280.69 kg DM/ha/harvest). The highest yield was produced by Indigofera planted with both grass varieties and harvested at 60 days.

There was a significant difference (p<0.05) in the annual total DM yield of both forage varieties with different planting patterns and harvesting ages as shown in Table 4. The highest total DM yield was produced from Pakchong grown in monoculture and harvested at 60 days (44.56 tons ha^{-1} year^{-1}). This was due to the difference in the number of individual plants per plot, making the production of Pakchong higher than those grown in intercropping system. However, there was no significant difference (p>0.05) in DM yield of Taiwan grown in monoculture or intercropping systems.

Nutrient Composition

As shown in Table 5, DM, ash, CP, ADF, and NDF contents were significantly affected (p<0.05) by the interaction between elephant grass varieties, planting patterns, and harvesting ages in the rainy season. The results showed that the highest DM content (15.55%-20.07%) was obtained from the two varieties of elephant grass in the intercropping system with Indigofera harvesting at 60 days. The highest ash content of 16.53%-20.89% was obtained from both varieties of elephant grass in monoculture planting harvested at

Table 2. Total dry matter yield (ton/ha/harvest) of two elephant grass varieties with Indigofera in different planting patterns and harvest ages

Harvest ages	Varieties			
	Taiwan		Pakchong	
	Intercropping	Monoculture	Intercropping	Monoculture
First defoliation (April)				
50 DAP	5.28 ± 2.33	7.56 ± 1.81	6.85 ± 2.39	5.63 ± 1.91
60 DAP	6.51 ± 2.16	7.79 ± 1.42	8.12 ± 1.69	6.99 ± 2.87
Second defoliation (May-June)				
50 DAP	6.27 ± 1.00[b]	6.93 ± 0.35[b]	5.60 ± 0.54[b]	5.59 ± 0.31[b]
60 DAP	6.30 ± 0.73[b]	8.84 ± 0.87[a]	9.10 ± 0.53[a]	10.24 ± 1.31[a]
Third defoliation (July-August)				
50 DAP	2.66 ± 0.42[c]	4.73 ± 0.87[abc]	2.93 ± 0.55[c]	4.07 ± 0.19[bc]
60 DAP	4.76 ± 0.54[abc]	5.41 ± 1.25[ab]	6.42 ± 1.34[a]	5.67 ± 1.48[ab]
Fourth defoliation (September-October)				
50 DAP	3.38 ± 0.66[d]	4.03 ± 0.68[cd]	4.12 ± 1.03[cd]	3.53 ± 0.28[d]
60 DAP	6.55 ± 1.92[bc]	9.24 ± 1.46[a]	7.87 ± 1.01[ab]	7.78 ± 0.81[ab]
Fifth defoliation (October-December)				
50 DAP	6.10 ± 1.26[b]	7.98 ± 1.88[ab]	6.18 ± 0.67[ab]	5.97 ± 0.52[b]
60 DAP	8.35 ± 2.59[ab]	9.97 ± 2.84[a]	7.14 ± 0.42[ab]	9.46 ± 2.18[ab]

Note: Means in the same defoliation with different superscripts in lowercase differ significantly ($p<0.05$). DAP= days after planting.

Table 3. Dry matter yield of *Indigofera zollingeriana* (kg/ha/harvest) intercropping with two elephant grass varieties and different harvest ages

Varieties	Harvest age	Defoliation				
		First	Second	Third	Fourth	Fifth
Taiwan	50 DAP	575.53±160.72	568.69±164.31	225.85±111.07[b]	438.96±148.83	267.60±127.09[b]
	60 DAP	809.57±350.61	432.39±106.95	490.69±138.10[a]	399.22± 60.49	565.24±224.70[a]
Pakchong	50 DAP	1058.68±113.29	560.65± 86.09	377.30±151.22[ab]	529.82±146.43	320.99±157.76[b]
	60 DAP	1280.69±430.08	626.44± 88.67	613.36±174.32[a]	613.62± 42.45	543.87±108.15[a]

Note: Means in the same column with different superscripts differ significantly ($p<0.05$). DAP= days after planting.

Table 4. Annual total dry matter yield (ton/ha/year) of two elephant grass varieties with Indigofera in different planting patterns and different harvest ages

Planting composition	DM yield in 50 Day	DM yield in 60 Day
Taiwan sole cropping	42.38±6.24[ab]	41.69±4.85[ab]
Taiwan in mixed cropping with *Indigofera zollingeriana*	33.49±6.19[ab]	30.84±6.35[b]
Pakchong sole cropping	34.71±1.21[ab]	44.56±9.79[a]
Pakchong in mixed cropping with *Indigofera zollingeriana*	31.84±4.33[b]	38.64±4.04[ab]
Total mixed cropping (Taiwan + *Indigofera zollingeriana)*	36.28±6.61[ab]	33.54±6.21[ab]
Total mixed cropping (Pakchong + *Indigofera zollingeriana)*	35.17±4.25[ab]	42.32±3.78[ab]

Note: Means in the same column with different superscripts differ significantly ($p<0.05$). DM= dry matter.

50 days. Furthermore, Taiwan and Pakchong varieties intercropped with Indigofera and harvested at 50 days, had the highest total CP ranging from 14.99%-17.95%, while elephant grass planted in monoculture and harvested at 60 days produced the highest CF fraction. ADF of Taiwan varieties ranged from 43.64%-45.42% and NDF in the Pakchong varieties was between 72.78% and 73.68%. Forage qualities of both varieties, which were intercropped and harvested at 50 days, indicated higher content of CP and lower fiber fraction content than those harvested at 60 days.

DM and ash contents were not significantly affected ($p>0.05$) by the interaction between the three factors. In contrast, CP, NDF, and ADF contents were significantly different ($p<0.05$) during the dry season. The highest total CP was found in the Pakchong variety, which was intercropped and harvested at 50 days (11.97%-14.15%), while the lowest was found in the Taiwan variety, grown in monoculture and harvested at 60 days. The highest NDF and ADF contents were obtained from the Taiwan variety grown in monoculture and harvested at 60 days. Meanwhile, the lowest content of NDF and

Table 5. Nutrient composition (%) of two elephant grass varieties with Indigofera in different planting patterns and different harvest ages

Season	Nutrient composition (%)	Harvest age	Varieties			
			Taiwan		Pakchong	
			Intercropping	Monoculture	Intercropping	Monoculture
Rainy season	Dry matter	50	14.91 ± 0.30^{ab}	12.60 ± 0.82^{b}	15.69 ± 0.88^{ab}	13.66 ± 2.69^{b}
		60	17.81 ± 2.26^{a}	14.81 ± 0.40^{ab}	17.58 ± 1.39^{a}	14.82 ± 1.91^{ab}
	Ash	50	13.13 ± 1.52^{c}	18.26 ± 1.84^{a}	15.41 ± 0.47^{abc}	18.71 ± 2.18^{a}
		60	12.62 ± 0.93^{c}	16.59 ± 1.12^{ab}	12.02 ± 0.63^{c}	14.41 ± 1.65^{bc}
	Crude protein	50	14.93 ± 0.69^{a}	11.10 ± 1.44^{c}	16.47 ± 1.48^{a}	12.03 ± 0.70^{bc}
		60	14.06 ± 0.62^{ab}	11.62 ± 0.58^{bc}	14.26 ± 2.05^{ab}	10.35 ± 0.40^{c}
	NDF	50	61.34 ± 1.72^{bc}	67.24 ± 0.74^{b}	57.54 ± 3.10^{c}	69.16 ± 0.68^{ab}
		60	66.12 ± 2.50^{bc}	68.93 ± 0.50^{ab}	65.62 ± 5.34^{bc}	73.23 ± 0.45^{a}
	ADF	50	39.93 ± 2.55^{b}	41.45 ± 1.20^{ab}	42.33 ± 1.57^{ab}	42.55 ± 0.42^{ab}
		60	42.94 ± 0.90^{ab}	44.53 ± 0.89^{a}	42.77 ± 2.27^{ab}	40.71 ± 1.46^{b}
Dry season	Dry matter	50	16.18 ± 1.68	14.90 ± 0.97	16.77 ± 0.38	16.07 ± 1.77
		60	15.56 ± 0.56	16.99 ± 0.22	16.42 ± 1.99	15.55 ± 0.42
	Ash	50	13.62 ± 1.82	15.51 ± 1.70	13.59 ± 0.53	15.52 ± 1.53
		60	12.80 ± 0.78	14.07 ± 0.98	12.90 ± 1.68	12.61 ± 0.56
	Crude protein	50	12.22 ± 1.11^{ab}	11.41 ± 0.45^{bc}	13.06 ± 1.09^{a}	11.36 ± 0.50^{bc}
		60	12.90 ± 1.04^{ab}	10.42 ± 0.27^{c}	12.34 ± 0.49^{ab}	9.84 ± 0.90^{c}
	NDF	50	53.05 ± 1.56^{b}	55.11 ± 1.17^{b}	48.59 ± 1.90^{d}	48.53 ± 1.30^{d}
		60	50.02 ± 0.59^{cd}	61.31 ± 1.03^{a}	52.52 ± 0.91^{bc}	53.60 ± 1.29^{b}
	ADF	50	75.67 ± 3.12^{cd}	78.76 ± 1.47^{abc}	71.52 ± 1.65^{d}	78.06 ± 2.05^{bc}
		60	74.82 ± 1.84^{cd}	82.80 ± 1.00^{a}	75.44 ± 2.52^{cd}	80.19 ± 1.02^{ab}

Note: Means with in the same nutrient composition of each season with different superscripts differ significantly ($p<0.05$). NDF= neutral detergent fiber, ADF= acid detergent fiber, DAP= days after planting.

Table 6. Nutrition composition (%) of *Indigofera zollingeriana* intercropping with two elephant grass varieties and different harvest ages

Season	Varieties	Harvest age	Nutrition composition (%)				
			DM	Ash	CP	ADF	NDF
Rainy season	Taiwan	50	21.95±0.84	10.41±0.70	35.46±2.96^{a}	25.76±2.38	34.47±1.36^{b}
		60	22.14±3.76	10.07±0.32	31.91±2.88^{ab}	28.47±1.85	32.27±1.83^{b}
	Pakchong	50	24.37±0.68	10.33±0.39	33.76±1.69^{ab}	28.81±0.46	31.61±1.16^{b}
		60	24.93±3.33	10.20±0.98	29.98±0.66^{b}	28.17±1.83	38.18±1.24^{a}
Dry season	Taiwan	50	20.56±0.64	10.90±0.60	29.52±0.58^{b}	32.23±1.61^{ab}	36.91±0.17^{b}
		60	20.88±2.16	10.55±0.24	29.52±0.38^{b}	32.71±0.89^{a}	40.32±1.54^{a}
	Pakchong	50	22.91±0.75	10.60±0.26	31.58±0.83^{a}	29.68±1.19^{b}	35.13±0.63^{b}
		60	22.88±1.01	10.17±0.40	30.17±1.27^{ab}	30.95±1.58^{ab}	35.56±1.04^{b}

Note: Means in the same column with different superscripts differ significantly ($p<0.05$). NDF= neutral detergent fiber, ADF= acid detergent fiber, DAP= days after planting.

ADF was produced in the Pakchong variety, which was intercropped and cut at 50 days.

The nutrition composition of Indigofera showed inconsistent results when grown with Pakchong and Taiwan varieties, as shown in Table 6. In the rainy season, the highest CP of Indigofera was produced when grown with the Taiwan variety and harvested at 50 days (35.46%), but in the dry season, the highest value was obtained when grown with the Pakchong variety and harvested at 50 days (31.58%). Meanwhile, the highest ADF and NDF contents in Indigofera were obtained when grown with Pakchong variety and harvested at 60 days in the rainy season and when grown with the Taiwan variety and harvested at 60 days in the dry season.

Nutrient Yield

In the rainy season, total DM yield was significantly affected ($p<0.05$) by the interaction between varieties and harvesting age, with the highest DM yield culminating from the Taiwan variety harvested at 60 days, as shown in Table 7. However, DM, ash, CP, NDF, and ADF yields were not significantly affected ($p>0.05$) by the interaction among the three factors. The CP yield was significantly affected ($p<0.05$) by planting patterns and interactions between elephant grass varieties and cropping patterns (Table 7). The highest was produced from the Pakchong variety in an intercropping with Indigofera. Based on the results, Indigofera increased the CP yield of the Pakchong variety but not that of Taiwan. Meanwhile, harvesting age affected NDF yield significantly ($p<0.05$), with the highest value stemming from plants harvested at 60 days.

In the dry season, DM, ash, CP, NDF, and ADF yields were significantly affected ($p<0.05$) by interactions among elephant grass varieties, planting patterns, and harvesting ages. The highest total DM yield was obtained from Taiwan grass, grown in monoculture and harvested at 60 days. The highest CP was obtained from the Pakchong variety, planted in monoculture or intercropping and harvested at 60 days. Meanwhile, the highest ADF and NDF yields were produced from the two varieties grown and harvested using a similar method. There was also a decrease in the yield of all nutrients in the dry season compared to harvesting carried out in the rainy season.

Potential Carrying Capacity

The livestock potential carrying capacity was not significantly affected ($p>0.05$) by elephant grass varieties, planting patterns, harvesting age, and their interactions in the first defoliation. However, there were significant differences ($p<0.05$) in the 2nd to 5th defoliations. Based on the data shown in Table 8, in the second defoliation, the total forage yield (elephant grass + Indigofera) can meet DM needs of livestock ranging from 7.61-15.78 AU/ ha, while that of the third, fourth, and fifth defoliations ranged from 3.58-10.6 AU/ha, 4.37-14.62 AU/ha, and 6.61-20.53 AU/ha respectively. The highest potential carrying capacity was obtained from the Pakchong variety intercropped with Indigofera and harvested at 60 days in the 2nd and 3rd defoliations, as well as from the Taiwan variety in the monoculture system and harvested at 60 days in the 4th and 5th defoliations. These results show that the potential carrying capacity of livestock fluctuated at different defoliations. The carrying capacity tended to be high in the rainy season and decreased during the dry season in the 3rd defoliation.

DISCUSSION

Intercropping grass and legumes is a way to increase forage production while potentially reducing nitrogen fertilization. Aside from containing high nutrient and protein, legumes can also fix air nitrogen through symbiosis with rhizobium bacteria, improving soil nutrient composition and creating a stable agroecosystem (Rajaii & DahMardeh, 2014). However, in this experiment, forage production in the intercropping

Table 7. Nutrient yield (ton/ha/harvest) of two elephant grass varieties with Indigofera in different planting patterns and different harvest ages

Season	Nutrient yield (ton/ha/harvest)	Harvest age	Varieties					
			Taiwan		Average T*U	Pakchong		Average P*U
			Intercropping	Monoculture		Intercropping	Monoculture	
Rainy season	Total dry matter yield	50	0.79 ± 0.35	0.85 ± 0.24	0.82 ± 0.28^{b}	1.07 ± 0.35	0.79 ± 0.37	0.93 ± 0.36^{ab}
		60	1.15 ± 0.37	1.41 ± 0.21	1.28 ± 0.28^{a}	1.15 ± 0.23	1.01 ± 0.39	1.08 ± 0.36^{ab}
	Total ash yield	50	0.70 ± 0.34	1.24 ± 0.38		1.06 ± 0.38	1.04 ± 0.33	
		60	0.83 ± 0.31	1.30 ± 0.31		0.98 ± 0.24	1.03 ± 0.49	
	Total crude protein yield	50	0.79 ± 0.34	0.76 ± 0.27		1.11 ± 0.36	0.69 ± 0.27	
		60	0.91 ± 0.27	0.91 ± 0.21		1.13 ± 0.14	0.72 ± 0.28	
		Average T*I	0.85 ± 0.29^{ab}	0.84 ± 0.24^{ab}		1.12 ± 0.25^{a}	0.70 ± 0.25^{b}	
	Total NDF yield	50	3.26 ± 1.53	4.53 ± 1.10		3.99 ± 1.56	3.89 ± 1.31	
		60	4.33 ± 1.53	5.37 ± 1.00		5.39 ± 1.45	5.12 ± 2.14	
	Total ADF yield	50	2.13 ± 1.05	2.81 ± 0.75		2.92 ± 1.09	2.39 ± 0.81	
		60	2.81 ± 0.96	3.46 ± 0.58		3.50 ± 0.86	2.82 ± 1.08	
Dry season	Total dry matter yield	50	0.36 ± 0.05^{c}	0.63 ± 0.13^{abc}		0.36 ± 0.05^{c}	0.65 ± 0.05^{abc}	
		60	0.59 ± 0.03^{bc}	0.92 ± 0.22^{a}		0.84 ± 0.12^{ab}	0.88 ± 0.24^{ab}	
	Total ash yield	50	0.30 ± 0.08^{b}	0.66 ± 0.16^{a}		0.29 ± 0.02^{b}	0.63 ± 0.07^{ab}	
		60	0.48 ± 0.05^{ab}	0.76 ± 0.19^{a}		0.68 ± 0.22^{a}	0.72 ± 0.19^{a}	
	Total crude protein yield	50	0.27 ± 0.05^{c}	0.44 ± 0.08^{abc}		0.29 ± 0.06^{c}	0.40 ± 0.02^{bc}	
		60	0.49 ± 0.07^{abc}	0.62 ± 0.14^{ab}		0.64 ± 0.15^{a}	0.64 ± 0.15^{a}	
	Total NDF yield	50	1.17 ± 0.15^{c}	2.59 ± 0.47^{ab}		1.05 ± 0.11^{c}	1.98 ± 0.06^{abc}	
		60	1.89 ± 0.13^{bc}	2.98 ± 0.69^{a}		2.72 ± 0.53^{ab}	3.03 ± 0.74^{a}	
	Total ADF yield	50	1.66 ± 0.19^{cd}	3.34 ± 0.66^{ab}		1.55 ± 0.15^{d}	3.18 ± 0.10^{abc}	
		60	2.82 ± 0.14^{bcd}	4.48 ± 1.05^{a}		3.90 ± 0.68^{ab}	4.55 ± 1.20^{a}	

Note: Means in the same nutrient yield of each season with different superscripts differ significantly ($p<0.05$). NDF= neutral detergent fiber, ADF= acid detergent fiber, DAP= days after planting, T= Taiwan, P= Pakchong, U= Harvesting ages, I= planting patterns, V=Varieties, T*I= Interaction between varieties and planting patterns, T*U= Interaction between Taiwan and harvesting age, P*U= Interaction between Pakchong and harvesting age.

Table 8. Carrying capacity (AU/ha) of two elephant grass varieties with Indigofera in different planting patterns and different harvest ages

Harvest ages	Varieties			
	Taiwan		Pakchong	
	Intercropping	Monoculture	Intercropping	Monoculture
First defoliation				
50 DAP	8.46 ± 3.74	10.64 ± 1.94	10.97 ± 3.84	9.02 ± 3.06
60 DAP	8.89 ± 2.95	12.11 ± 2.90	11.10 ± 2.32	9.54 ± 3.92
Second defoliation				
50 DAP	8.61 ± 1.00^{e}	11.10 ± 0.56^{bcd}	8.98 ± 0.86^{de}	8.96 ± 0.49^{de}
60 DAP	10.05 ± 1.60^{cde}	12.08 ± 1.19^{abc}	12.44 ± 0.72^{ab}	13.99 ± 1.79^{a}
Third defoliation				
50 DAP	4.26 ± 0.68^{c}	7.57 ± 1.40^{ab}	4.69 ± 0.88^{bc}	6.53 ± 0.30^{abc}
60 DAP	6.50 ± 0.74^{abc}	7.40 ± 1.71^{ab}	8.77 ± 1.83^{a}	7.75 ± 2.02^{a}
Fourth defoliation				
50 DAP	5.42 ± 1.05^{c}	6.45 ± 1.10^{c}	6.60 ± 1.65^{c}	5.66 ± 0.46^{c}
60 DAP	8.95 ± 2.62^{bc}	12.62 ± 2.00^{a}	10.74 ± 1.38^{ab}	10.63 ± 1.11^{ab}
Fifth defoliation				
50 DAP	8.33 ± 1.72^{b}	9.70 ± 2.20^{b}	9.90 ± 1.07^{b}	9.56 ± 0.83^{b}
60 DAP	12.79 ± 3.01^{ab}	15.98 ± 4.55^{a}	9.75 ± 0.58^{b}	12.93 ± 2.98^{ab}

Note: Means in the same defoliation with different superscripts in lowercase differ significantly ($p<0.05$). DAP= days after planting.

system at 2.66-9.10 tons ha^{-1} was lower than that of the monoculture system, namely 3.53-10.24 tons ha^{-1}. This difference is due to inter- and intraspecies competition between plants (Koten *et al.,* 2013). The low forage production per unit ton ha^{-1} is presumably due to the sub-optimal spacing arrangement, causing competition for growth space. Elephant grass grows invasively and widely form multi tiller, which suppresses the growth of Indigofera. This effect was indicated by the lower DM production compared to that of monoculture (2291 kg/ha/harvest) (Abdullah & Suharlina, 2010). The height and width of the canopy between intercropped plants also reduce the infiltration of sunlight and the overall yield (Supriyatman, 2011). According to Shandu and Nathan (2021), intercropping cultivation requires proper spacing because it determines plant growth and yield per unit of the planted area. In addition, the cutting interval affects production, nutrient quality, and regrowth ability (Kumalasari *et al.,* 2017). The non-optimal growth and low productivity indicate that Indigofera did not contribute significantly to the increasing production but enhanced forage nutrition in the intercropping system with elephant grass.

Forage production occurred dynamically throughout the five defoliations, which could be associated with seasonal changes in rainfall, temperature, relative humidity, and light intensity. These factors influenced nutrient availability in the soil and photosynthetic rate as well as affected the growth and production of forage. Previous research reported a positive correlation between rainfall and yield (Crespo & Alvarez, 2014). Soil moisture content plays an important role in nutrient availability in soil solution. Lower water content in the soil leads to less nutrient ion absorption, thereby hampering the mass flow of water (Dios-León *et al.,* 2022). Forage production is also influenced by nutrient availability in the soil, which is closely related to the activity of microorganisms in the rhizosphere (Zhuang *et al.,* 2013). In this part, microbial-plant interactions play an important role in various aspects related to vital processes in the ecosystem, such as carbon absorption and nutrient cycle (Zhuang *et al.,* 2013). The composition of these microbes greatly varies among plant species with the amount and type of exudate released (Matusso *et al.,* 2014). Each plant species creates different rhizosphere environments and the further the phylogenetic relationship, the more different the microbial composition in the formed rhizosphere (Ofek *et al.,* 2014; Bouffaud *et al.,* 2014). This implies that intercropping cultivation can improve the soil microenvironment around the plant roots due to the diversity of species growing on the same land compared to monoculture cultivation (Matusso *et al.,* 2014). Positive plant-microbial interactions can increase nutrient availability and uptake, thereby affecting plant growth and health, enhancing crop productivity (Matusso *et al.,* 2014). Different light intensities at each harvest also caused dynamic changes in forage production at each defoliation. In the dry season, the high light intensity with low rainfall hampered nutrient breakdown. Meanwhile, the availability of nutrients that can be utilized by plants reduced forage production during harvesting in the dry season. The availability of nutrients that can be absorbed by the plant will then affect the metabolism and nutrient content. According to previous research, light intensity affects plant metabolism, influencing forage production (Wang *et al.,* 2017).

Forage harvested at 60 days and planted in the intercropping system produced high yield, DM, and CF but had low CP compared to those harvested at 50 days. According to Dios-León *et al.* (2022) and Zailan *et al.* (2016), the harvest age is an important factor that affects CP content because the leaf: stem ratio decreases with plant age. As the plant age increase, its water content reduces and the proportion of cell walls increases, culminating in higher DM and CF contents (Luna *et al.*, 2015), but CP content decreases due to the differences in plant physiological phases (Zailan *et al.*, 2016). CP yield is closely related to DM yield and CP content of plants. Higher CP content in the intercropping system of grass with Indigofera indicates the high availability of nutrients, especially fixable N, which can increase DM yield (Kordi *et al.*, 2020) and reduce CF due to the assimilation of sufficient N to compose protein (Luna *et al.*, 2015). Furthermore, NDF and ADF contents in forage plants tend to increase as they age. This increase is because the proportion of stems increases while the amounts of leaves decrease, leading to a higher concentration of structural carbohydrates and lignin. These changes directly affect the digestibility of forage and its use efficiency (Luna *et al.*, 2015). The findings align with the existing literature, suggesting that rapid growth and maturation of tropical grass can cause changes in their chemical composition, leading to a decline in the nutritional quality of their forages. However, the total annual DM yield of forage was not significantly different when harvested at 50 and 60 days. This is because elephant grass can compensate for the difference in forage yield in each defoliation period with more harvesting frequencies to produce biomass that is not significantly different as a whole. Previous research revealed that the low CP in elephant grass could be compensated by an increase in forage yield produced (Peiretti *et al.*, 2015). In addition, the protein content can be increased by planting it alongside Indigofera. This is attributed to the high nitrogen availability in the soil by the nitrogen-fixing Indigofera. The protein content is also enhanced by the complementary mixing of both components.

The carrying capacity is the amount of forage (elephant grass + Indigofera) that can be provided for livestock and is expressed in AU/ha. Based on the results, intercropping elephant grass with Indigofera and harvesting it at 60 days of age can increase DM yield. Carrying capacity is positively correlated with DM yield of elephant grass with Indigofera and fluctuates based on seasons. However, Indigofera in this research did not significantly increase the carrying capacity. This is due to its low production, which reduced the total forage (Indigofera with elephant grass) production. The greater the level of forage production per unit land area, the higher its ability to accommodate livestock (Mourino *et al.*, 2003). Fariani (2008) also revealed that forage components, both grass and legumes, occupy 60%-70% of the cost of raising ruminants, hence, their availability and quality must be considered.

CONCLUSION

Based on the results, planting elephant grass varieties of Pakchong and Taiwan in a monocropping system and harvesting at the age of 60 days culminated in high DM and nutrient yield, as well as carrying capacity compared to an intercropping system with Indigofera and harvesting at the age of 50 days. However, the highest total annual DM yield was produced from Pakchong plants grown in monoculture and harvested at 60 days.

CONFLICT OF INTEREST

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REFERENCES

AOAC. 2005. Official Methods of Analysis of AOAC International. 18th ed. Assoc. Off. Anal. Chem., Arlington.

Abdullah, L. & Suharlina. 2010. Herbage yield and quality of two vegetative parts of indigofera at different times of first regrowth defoliation. Med. Pet. 33:44-49. https://doi.org/10.5398/medpet.2010.33.3.169

Beever, D. E., N. Offer, & M. Gill. 2000. The Feeding Value of Grass and grass Products. In: Grass: Its Production and Utilization Ed. A. Hopkins. Oxford, UK: Blackwell Science Ltd for British Grasslands Society. p. 140–195.

Bouffaud, M. L., M. A. Poirier, D. Mulle, & Y. MoënneLoccoz. 2014. Root microbiome relates to plant host evolution in maize and other Poaceae. Environ. Microbiol. 16:2804-2814. https://doi.org/10.1111/1462-2920.12442

Crespo, G. & J. Alvarez. 2014. Comparison of biomass production of *Pennisetum purpureum* clones N fertilized. Cub. J. Agric. Sci. 46:427-433.

Ella, A. 2002. Productivity and Nutritional Value of Several Types of Grass and Feed Legumes Planted on Wet Climate in Dryland Using Inorganic Fertilizer. South Sulawesi Agricultural Technology Assessment Institute. Makassar.

Fariani, A. 2008. Development of ruminant based on posture availability and labours in Musi Rawas Regency-South Sumatera. J. Indones. Trop. Anim. Agric. 3:145–157.

Ghanbari, G., M. Dahmardeh, B. A. Siahsar, & M. Ramroudi. 2010. Effect of maize (*Zea mays L.*) - cowpea (*Vigna unguiculata L.*) intercropping on light distribution, soil temperature and soil moisture in the arid environment. J. Food. Agric. Environ. 8:102-108.

Dios-León, G. E. D., J. A. Ramos-Juárez, F. Izquierdo-Reyes, B. M. Joaquín-Torres, & F. Meléndez-Nava. 2022. Productive performance and nutritional value of *Pennisetum purpureum* cv. Cuba CT-115 grass at different regrowth ages. Rev. Mex. Cienc. Pecu. 13:1055-1066. https://doi.org/10.22319/rmcp.v13i4.5217

Herdiawan, I., L. Abdullah, & D. Sopandi. 2014. Forage nutritional status of *Indigofera zollingeriana* at various levels of drought stress treatment and pruning interval. Indones. J. Anim. Vet. Sci. 19:91-103. https://doi.org/10.14334/jitv.v19i2.1037

Kumalasari, N. R., G. P. Wicaksono, & L. Abdullah. 2017. Plant growth patterns, forage yield, and quality of *Indigofera* *zollingeriana* influenced by row spacing. Med. Pet. 40:14-19. https://doi.org/10.5398/medpet.2017.40.1.14

Kordi, S., Z. S. Saeid, S. K. Jalil, W. Weria, & A. S. Dennis. 2020. Intercropping system and N_2 fixing bacteria can increase land use efficiency and improve the essential oil quantity and quality of Sweet Basil (*Ocimum basilicum* L.). Front. Plant Sci. 11:1-14. https://doi.org/10.3389/fpls.2020.610026

Koten, B., R. D. Soetrisno, N. Ngadiyono, & B. Soewignyo. 2013. The appearance of intercropped forage production of Arbila (*Phaseolus lunatus*) with inoculum rhizobium and sorghum (*Sorghum bicolor*) on Arbila planting spacing and number of sorghum rows. Anim. Sci. 11:26-33.

Liman, A. K. Wijaya, Erwanto, Muhtarudin, C. Septianingsih, T. Asidiq, T. Nur, & K. Adhianto. 2022. Productivity and quality of Pakchong-1 hybrid grass (*Pennisetum purpureum* x *Pennisetum Americanum*) at different harvesting ages and fertilizer levels. Pak. J. Biol. Sci. 25:426-432. https://doi.org/10.3923/pjbs.2022.426.432

Lounglawan, P., W. Lounglawan, & W. Suksombat. 2014. Effect of cutting interval and cutting height on yield and chemical composition of King Napier grass (*Pennisetum purpureum* x *Pennisetum Americanum*). APCBEE Procedia 27-31. https://doi.org/10.1016/j.apcbee.2014.01.075

Luna, M. R., M. E. Chacon, R. J. Ramirez, P. G. Alvarez, P. P. Alvarez, P. K. Plua, & M. A. Alava. 2015. Yield and quality of two species of *Pennisetum* in Ecuador. Rev. Electron. Vet. 16:1-10.

Mansyur, T. Dhalika, R. Z. Islami, I. Hernawan, & U. H. Tanuwiria. 2016. Estimation of *In Vitro* Digestibility of Forage Sorghum Based on Crude Protein Content and Fiber Fraction. Proceedings of the Ongoing National Seminar 8. Sumedang. [July 16, 2022].

Matusso, J. M. M., J. N. Mugwe, & M. Mucheru-Muna. 2014. Potential role of cereal-legume intercropping systems in integrated soil fertility management in Sub-Saharan Africa smallholder farming systems. Res. J. Agric. Environ. Manag. 3:162-174.

Mobasser, H. R., M. R. Vazirimehr, & K. Rigi. 2014. Effect of intercropping on resources use weed management and forage quality. Intern. J. Plant. Anim. Environ. Sci. 4:706-713.

Moradi, H., M. Noori, A. Sobhkhizi, M. Fahramand, & K. Rigi. 2014. Effect of intercropping in agronomy. J. Nov. Appl. Sci. 3:315-320.

Mourino, F., K. A. Albrecht, D. M. Schaefer, & P. Berzaghi. 2003. Integrated systems. Agron. J. 95:652-659. https://doi.org/10.2134/agronj2003.6520

Ofek, M., M. Voronov-Goldman, Y. Hadar, & D. Minz. 2014. Host signature effect on plant root-associated microbiomes revealed through analyses of resident vs active communities. Environ. Microbiol. 16:2157–2167. https://doi.org/10.1111/1462-2920.12228

Peiretti, P. G., F. Gai, & S. Tassone. 2015. Nutritional value and fatty acid profile of Niger (*Guizotia abyssinica*) plant during its growth cycle. Livest. Res. Rur. Develop. 27:18-25.

Qin, A. Z., G. B. Huang, Q. Chai, A. Z. Yu, & P. Huang. 2013. Grain yield and soil respiratory response to intercropping systems on arid land. Field Crops Res. 144:1-10. https://doi.org/10.1016/j.fcr.2012.12.005

Rajaii, M. & M. DahMardeh. 2014. The evaluation of corn and peanut intercropping on the efficiency of using the environmental resource and soil fertility. J. Agric. Sci. 6:99-108. https://doi.org/10.5539/jas.v6n4p99

Rengsirikul, K., Y. Ishii, K. Kangvansaichol, P. Pripanapong, P. Sripichitt, V. Punsuvon, P. Viathanosat, G. Nakamanee, & S. Tudsri. 2011. Effects of inter-cutting interval on biomass yield, growth components and chemical composition of Elephant grass (*Pennisetum purpureum Schum.*) cultivars as bioenergy crops in Thailand. Grassl. Sci. 57:135–141. https://doi.org/10.1111/j.1744-697X.2011.00220.x

Shandu, R. K. & S. B. Nathan. 2021. Effect of planting density on the yield and growth of intercropped tomatoes and peppers in Florida. HortScience. 15667:1-5.

Suharlina, D. A. Astuti, Nahrowi, A. Jayanegara, & L. Abdullah. 2016a. Nutritional evaluation of dairy goat rations containing *Indigofera zollinggeriana* using the in vitro rumen fermentation technique (RUSITEC). J. Dairy Sci. 11:100-105. https://doi.org/10.3923/ijds.2016.100.105

Suharlina, D. A. Astuti, Nahrowi, A. Jayanegara, L. Abdullah. 2016b. *In vitro* evaluation of concentrate feed containing *Indigofera zollingeriana* in goat. J. Indones. Trop. Anim. Agric. 41:196-203. https://doi.org/10.14710/jitaa.41.4.196-203

Supriyatman, B. 2011. Introduction of Corn and Peanut Intercropping Technology. Agricultural Research and Development Agency. Center for Food Crops Research and Development, Bogor.

Tarigan, A., S. P. Ginting, I. I. Arief, D. A. Astuti, & L. Abdullah. 2017. Physical quality and digestibility *in vitro* determination of green pellet concentrate based on *Indigofera zollingeriana*. J. Anim. Vet. Sci. 22:114-123. https://doi.org/10.14334/jitv.v22i3.1651

Telleng, M., K. G. Wiryawan, P. D. M. H. Karti, I. G. Permana, & L. Abdullah. 2016. Forage production and nutrient composition of different sorghum varieties cultivated with indigofera in intercropping system. Med. Pet. 39:203-209. https://doi.org/10.5398/medpet.2016.39.3.203

Tessema, Z. 2008. Effect of plant density on morphological characteristics, yield and chemical composition of Elephant grass (*Pennisetum purpureum (L.) Schum*). East. Afric. J. Sci. 2:55–61. https://doi.org/10.4314/eajsci.v2i1.40365

Van Soest, P. J., J. B. Robertson, & B. A. Lewis. 1991. Methods of dietary fibre, neutral detergent, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Wang, S. 2017. Responses of net primary productivity to phenological dynamics in the Tibetan Plateau, China. Agric. For. Meteorol. 232:235-246. https://doi.org/10.1016/j.agrformet.2016.08.020

Zailan, M. Z., H. Yaakub, & S. Jusoh. 2016. Yield and nutritive value of four Napier (*Pennisetum purpureum*) cultivars at different harvesting ages. Agric. Biol. J. North. Americ. 7:213-219.

Zhuang, X., J. Gao, M. Ma, S. Fu, & G. Zhuang. 2013. Review bioactive molecules in soil ecosystems: Masters of the underground. Int. J. Mol. Sci. 14:8841-8868. https://doi.org/10.3390/ijms14058841