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Morphological responses, biomass production and nutrient of *Pennisetum purpureum* cv. Pakchong under different planting patterns and harvesting ages

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Abstract. *Ernawati A, Abdullah L, Permana IG, Karti PDMH. 2023. Morphological responses, biomass production and nutrient of* Pennisetum purpureum *cv. Pakchong under different planting patterns and harvesting ages. Biodiversitas 24: 3439-3447.* Napier grass is one of the most popular grasses in tropical and subtropical regions and is a promising forage crop due to its high biomass production, nutritional quality and wide-range adaptability**.** An optimal management practice is required to maintain production and quality of Napier grass. This experiment examined the morphological responses, forage biomass production, and nutrient biomass of the Napier grass var Thailand (Pakchong) grown under different planting patterns and harvesting ages. The experiment used a completely randomized factorial design 2 x 2, with the first factor was planting pattern (monoculture and intercropping with *Indigofera zollingeriana*) and the second factor was the harvesting age (50 and 60 days). Each treatment combination was trialed at 5x5 m plot with four replicates. The results showed that planting pattern and harvesting age had significant effect ($p<0.05$) on tiller numbers, leaves and stem biomass, stem-to-leaves ratio, fresh and dry weight production, and nutrient biomass, except for ash biomass. The highest tiller number was obtained in the intercropping pattern and harvesting age of 50 days. The highest leaves and stem biomass were produced in both planting pattern and harvesting age of 60 days. The fresh and dry weight production and nutrient biomass of Pakchong in intercropping pattern and harvesting of 60 days were higher than those of monoculture cropping. Nonetheless, effect on stem-to-leaves ratio had inconsistent result. The results of this study imply that the best production and nutrient biomass of Napier grass cv. Pakchong were obtained from the grass intercropped with Indigofera and harvesting age of 60 days.

Keywords: Biomass nutrition, harvesting age, *Indigofera zollingeriana,* intercropping, Pakchong

INTRODUCTION

In developing countries like Indonesia, livestock production is constrained by a lack of continuity in the supply of good quality forage. Napier grass or elephant grass (*Pennisetum purpureum*) is one of the most popular grasses in livestock rearing (cattle, buffalo, sheep, and goats) in tropical and subtropical regions in the world (Kandel et al. 2015). Napier grass is widely used by breeders because it has high adaptability to wide range of ecological conditions, good growth, high biomass production and has a deep root system to survive drought conditions, and is very suitable for supplying forages using cut and carry technique (FAO 2016). However, Napier grass's productivity and nutritional quality are largely determined by the cultivar, which is influenced by environmental conditions and management practices (Oliveira et al. 2015).

Recently, Napier grass Pakchong 1 hybrid cultivar (*Pennisetum purpureum* cv. Pakchong) has been introduced from Thailand into Indonesia. Under good management, Pakchong is known as a forage with fast growth, produces high biomass, contains high crude protein (16-18%) when harvested at the age of 45 days, has a wide adaptation range, and can be ratooned up to 8 years (Kiyothong 2014). The dry production of the Pakchong cultivar can reach 438-500 tonnes/ha/year with 5 to 6 harvesting intervals per year (Waranit and Chaugool 2014). This biomass is higher than corn biomass with productivity of 46.53 tonnes/ha/year (Paramuji et al. 2020) and sorghum of 64.14 tonnes/harvest (Liman et al. 2018).

Only now, optimal Napier grass management practices are still being determined. Proper harvest management is essential for high production and quality (Sriagtula et al. 2021; Tulu et al. 2022). Several research results have discussed harvesting management in optimizing the biomass and quality of Napier grass (Wangchuk et al. 2015; Ahmed et al. 2021; Liman et al. 2022; Sathees and Santhiralingam 2022; Onjai-uea et al. 2023). Short intervals of cutting between harvests can reduce growth and development, but long cutting intervals can lead to a high accumulation of fiber and decrease forage quality (Sathees and Santhiralingam 2022; Onjai-uea et al. 2023). In addition, an appropriate planting pattern is also needed to produce optimal quality and biomass, one of which is by applying intercropping system with legumes.

Intercropping of grasses and legumes is a form of efficient resource utilization that can increase land productivity compared to monoculture planting (Matusso et al. 2014; Mobasser et al. 2014; Moradi et al. 2014). Leguminous plants exhibit resource efficiency by producing nitrogen through a symbiotic association with root nodules and supplying inorganic phosphorus by lowering the soil pH (Mobasser et al. 2014). The intercropping system contributes to improved resource utilization through enhanced light interception, increased soil infiltration, reduced water evaporation, water conservation in the soil, and enhanced soil structure (Zhuang et al. 2013). Intraspecies interactions among microorganisms in the rhizosphere influence nutrient availability and uptake by plants, further enhancing their ability to utilize resources effectively (Zhuang et al. 2013). Such rationales suggest an opportunity for increasing animal feed production by planting Napier grass intercropped with local legumes, such as *Indigofera zollingeriana*.

Indigofera zollingeriana is a potential leguminous plant utilized as a source of protein and minerals for livestock (Suharlina et al. 2016; Ernawati et al. 2022), effectively increasing the digestibility of goat rations when used in complete feed (Tarigan et al. 2017). Indigofera contains high crude protein and minerals, low tannins (Abdullah 2010), and high dry matter digestibility (72-81%) (Abdullah 2010). Indigofera has a wide range of adaptations to various environmental conditions and is tolerant to dry stress (Herdiawan and Krisnan 2014). Information on management practices and planting systems that affect the morphological characteristics, production, and nutritional biomass of Napier grass cv Pakchong when intercropped with *I. zollingeriana* has yet to be reported. Therefore, the main objective of this study was to evaluate growth characteristics, biomass production and nutrient of Napier grass (cv. Pakchong) in an intercropping system with Indigofera under different harvesting ages. We expected the results of this study might inform the feasibility of developing alternative cropping system using Napier grass (cv. Pakchong) for the production of livestock forage.

MATERIALS AND METHODS

Study period and area

The study was conducted from December 2020 to December 2021 (one year) in Caringin Kulon Village, Caringin Sub-district, Sukabumi District, Indonesia (6˚57’-7˚25’ N dan 106˚49’-107˚ E), located at an altitude of 500-800 m above sea level (Figure 1). The research was conducted on latosol soil with a dusty clay texture with a neutral pH of 6.7. C-organic soil is in the medium category. The availability of macronutrients such as N-total is low, P_2O_5 is very high, and the availability of K is low (Table 1). The soil with those characteristics indicates that the soil conditions at the research site are categorized as less fertile soil. The highest rainfall occurred in the fifth harvest (275 mm/month). The average temperature was 21.56ºC, sunlight intensity was 32.74%, and relative humidity was 87.96%. In contrast, the lowest rainfall occurred in the third harvest, with rainfall intensity (72.50 mm/month), an average temperature of 21.44ºC, the sunlight intensity of 61.03%, and relative humidity (82.31%) (Figure 2).

Experimental procedures

Cultivation

The cuttings of Napier grass cv. Pakchong were obtained from the Agrostology Field Laboratory of the Faculty of Animal Science, IPB, while the *Indigofera zollingeriana* seedlings were obtained from the Jonggol Animal Research and Education Unit (UP3J). Indigofera seedlings were planted on research land that had been prepared and divided into 16 plots after being sown for 2 months. Planting distance of Napier grass was 80 x 80 cm^2 with a distance between rows of 100 cm. The area of the experimental plots was 5 x 5 m^2, and the distance between the plots was 1.5 m. In monoculture planting, the plot consisted of 42 Napier grass plants. On the other hand, the intercropping system consisted of 24 Napier grass plants and 18 Indigofera plants for each plot. The study was conducted using a factorial randomized block design with two factors (2x2) and four replications. The first factor is the planting pattern (intercropping and monoculture), and the second is the harvesting age (50 days and 60 days).

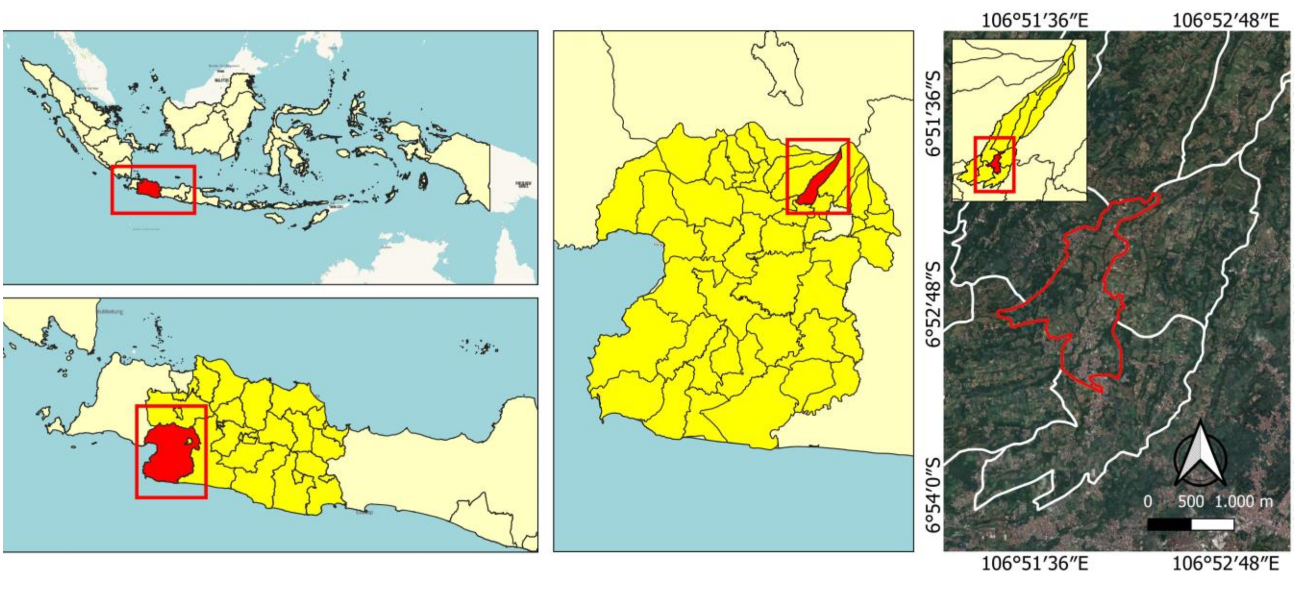

Figure 1. Location of the experimental site in Caringin Village, Caringin Sub-district, Sukabumi District, West Java, Indonesia

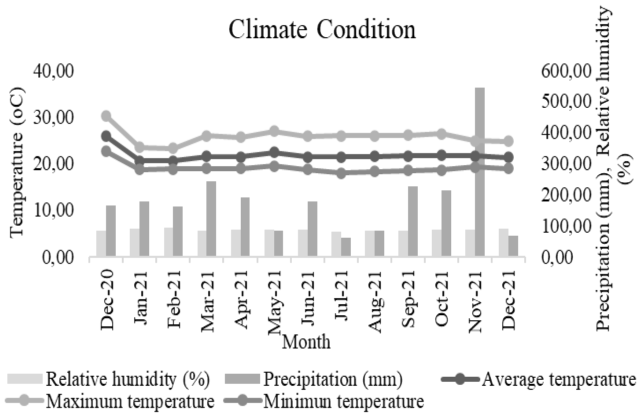

Figure 2. Climate conditions in term of rainfall and air temperature at the experimental site

Fertilization and maintenance

Fertilization was carried out using organic fertilizers, P and K fertilizers at the planting time at a dose of 4 tons/ha and 100 kg/ha. Meanwhile, N fertilizer was applied two weeks after planting at 150 kg/ha (around the plant). The dose was used three times during the trial period. Replacement planting was done two weeks after planting. The first pruning was carried out two months after planting in the experimental plot. This pruning aimed to ensure uniform plant regrowth and remove residue from the location of the plant seed collection, then measure and harvest according to treatment.

Parameters observed

The variables measured in this study were plant height, stem diameter, leaf width, leaf number, leaf length, tiller numbers, stem-to-leaf ratio, fresh and dry weight production, dry matter, ash, crude protein, NDF, and ADF biomass. Morphological characteristics were observed 1 day before harvesting with the number of samples used as many as ten clumps in each plot. All plant samples were taken from the inner plants of the plot to avoid border effects. To facilitate observation, plant samples were marked with a red string. Plant height, leaf width, and leaf length were measured with ruler in the tallest tiller on each plant. The tallest tiller was also used to measure stem diameter with calipers.

Fresh forage from each plot was harvested at 50 and 60 days according to treatment. Napier grass was trimmed 20 cm from the ground, but Indigofera was pruned 100 cm from the soil surface and then weighed to determine fresh weight production. Samples of plants from each plot were taken as much as 2000 g of fresh, then the stems and leaves were separated and dried in the sun for 2 x 24 hours. The samples were then dried in an oven at 60°C for 48 hours and ground to a size of 1 mm for further chemical analysis. The content of dry matter (DM), ash, and crude protein (CP) was analyzed based on the AOAC method (2005). The content of acid detergent fiber (ADF) and neutral detergent fiber (NDF) was analyzed based on the method of Van Soest et al. (1991). Furthermore, the nutrition content data in the third harvest was used to calculate biomass nutrition.

Data analysis

The data were analyzed statistically using analysis of variance (ANOVA) with SAS Student software. If there was a significant difference between treatments ($p<0.05$) it was continued with post-hoc Tukey's honestly significant difference (HSD) test.

RESULTS AND DISCUSSION

Morphological characteristics

The measurement of stem diameter, leaf number, leaf length and leaf width of Pakchong grass are shown in Table 2. The results showed no significant difference ($p>0.05$) in stem diameter, leaf number, leaf length, and lead width of Pakchong between planting intercropped with Indigofera and monoculture planting, between harvesting at 50 and 60 days and the interaction between factors. This is because intercropping and harvesting up to 60 days did not show competition in obtaining sunlight, nutrients, and water to form morphological characteristics between grasses and competition between pakchong and Indigofera. In addition, Pakchong grass is still in the vegetative development stage until the age of 60 days, so the plant's vegetative parts are still growing dominantly (Anis et al. 2016). Besides that, the effect of intercropping on plant vegetative growth is closely related to plant adaptability and the selection of suitable plant species (Dantata 2014). Pakchong grass and Indigofera have different growth characteristics. Pakchong grows vertically, while Indigofera grows horizontally. Both plants are very suitable for intercropping because of their different morphological characteristics. The stem diameter, leaf number per plant, leaf length, and leaf width of Pakchong ranged from 1.67-1.92 cm, 10.19-11.56 leaf per plant, 83.13-104.04 cm, and 2.88-3.79 cm, respectively. This result was higher than Wangchuk et al. (2015) that revealed the stem diameter of Pakchong grass in Thailand was 1.31 cm and produced 7 leaf numbers per plant. This difference because the climatic conditions differ greatly between the 2 countries.

Leaves are plants' main organs because they function as photosynthetic organs that can produce photosynthates used for plant growth and development. The ability of plants to carry out photosynthesis is determined by the number of leaves. The number of leaves has a positive correlation with chlorophyll content. Leaf width is a parameter that shows the potential of plants to carry out photosynthesis and is also a productivity potential of plants in the field. Leaf width is related to the ability of plants to absorb sunlight to carry out photosynthetic activities. The wider the leaf, the higher the solar radiation received so that more photosynthates are produced. However, a wider leaf also has the potential to reduce yields because the leaves at the bottom continue to carry out greater respiration than is produced in the photosynthesis process, so the distribution of photosynthates to other organs is reduced. The lower leaves do not photosynthesize efficiently because they do not get enough light.

The effect of planting pattern and harvesting age on plant height and tiller numbers of Pakchong grass are presented in Table 3. The plant height of Pakchong grass was not significantly affected ($p>0.05$) by the interaction between planting pattern and harvesting age but was significantly affected by each factor ($p<0.05$). Dynamic plant height occurred at each time of harvest. There was a decrease in plant height from the first to third harvest and increased again at the fourth and fifth harvest. The highest plant height resulted from Pakchong intercropped with Indigofera at first until the fifth harvest, except in the third harvest. This result indicates that Pakchong in the intercropping system can use nutrients efficiently to grow optimally. This can occur because in intercropping system, nutrients are more readily available for Pakchong. In addition, Pakchong harvested at 60 days also produced taller plants in the second until fourth harvest. This result indicates that Pakchong still grows vegetatively until 60 days, thus producing a higher plant height than plants harvested at 50 days because the vegetative growth has yet to occur optimally. In this study, the plant height of Pakchong reached 235.56 cm, which is lower than in the study by Wangchuck et al. (2015) which can reach 244 cm.

The tiller numbers of Pakchong grass were significantly affected ($p<0.05$) by the interaction between planting pattern and harvesting age in the third harvest (Table 3). This harvest period showed the lowest rainfall resulting in stress, and Pakchong planted in intercropping with Indigofera was better at producing tillers than planting in monoculture ($p<0.05$). In addition, the tiller number was higher when Pakchong was harvested at 50 days than at 60 days ($p<0.05$). The significant decline in tiller number with increasing harvesting age conforms with the reports of other studies that tillering is enhanced under frequent cutting (Riaz et al. 2023). Increased tillering is an adaptive feature to tolerate frequent harvest by re-establishing lost photosynthetic area and maintaining the basal area. Increasing tiller numbers eliminates apical dominance by harvest and activating basal shoots.

In contrast, the low tiller numbers at older harvesting ages has been associated with high levels of tiller mortality under reduced harvesting frequency and hormonal regulation (Shang et al. 2021). The highest number of tillers reached 66.50 which was produced on plants grown intercropped with Indigofera and harvested at 50 days. High tiller numbers indicate stable productivity and are linked to better persistence after periods of unfavorable environmental conditions (Riaz et al. 2023). The greater the number of tillers, the higher the growing point for leaf development. It will be related to the availability of energy reserves (carbohydrates) to support the regrowth of forage plants (Anis et al. 2016).

Biomass production

The interaction between planting pattern and harvesting age also had a significant effect ($p<0.05$) on the leaves and stem biomass (Table 4). The highest leaf yield reached 75.15 kg/plot produced by Pakchong in the monoculture system and harvested at 60 days (fifth harvest). In addition, each factor also had a significant effect on leaf biomass. The higher leaves biomass produced from Pakchong in monoculture cropping than intercropping at all harvest periods is because the number of plants per plot in monoculture cropping was higher than that in intercropping. Besides that, leaves biomass was also higher when harvested at 60 days than at 50 days. This indicates that the leaves of Pakchong still grow until 60 days, resulting in higher leaves biomass. Leaf fraction determines the pasture quality and animal performance related to the amount of leaf in the diet (Puteri et al. 2015; Anis et al. 2019).

Table 1. Soil chemical and physical properties in the experimental site in Caringin Village, Caringin Sub-district, Sukabumi (0.2-0.4 m depth)

Soil property	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: C/N: carbon-nitrogen ratio, Ca: Calcium, Mg: Magnesium, Na: Sodium, K: Potassium, Aldd: Alumunium can be exchanged, CEC: Cation Exchange Capacity

Table 2. Some morphological traits of Pakchong grass under different planting patterns and harvesting ages

Treatments	Parameters			
	Stem diameter (cm)	Leaf number per plant	Leaf length (cm)	Leaf width (cm)
Planting patterns				
P	1.71±0.20	10.28±1.62	93.58±18.56	3.53±0.93
PI	1.81±0.15	11.09±1.07	98.23±6.00	3.24±0.34
p-value	0.316	0.261	0.575	0.471
Harvesting age				
50	1.72±0.20	10.41±1.34	89.04±14.82	3.29±1.04
60	1.80±0.14	10.97±1.35	102.77±9.74	3.47±0.24
p-value	0.418	0.428	0.120	0.647
Interaction of planting patterns and harvesting age				
P50	1.75±0.15	10.19±1.43	83.13±24.91	3.70±1.58
PI50	1.69±0.25	10.63±1.25	94.96±4.73	2.88±0.49
P60	1.67±0.14	10.38±1.80	104.04±12.20	3.35±0.28
PI60	1.92±0.15	11.56±0.90	101.50±7.27	3.59±0.19
p-value	0.117	0.593	0.392	0.198
SE	0.045	0.339	4.00	0.191

Note: Means in the same column with different superscripts in lowercase differ significantly ($p<0.05$). P (Pakchong in monoculture planting), PI (Pakchong grown intercropped with Indigofera), P50 (Pakchong monoculture planting harvested at 50 days), PI50 (Pakchong grown intercropped with Indigofera and harvested at 50 days), P60 (Pakchong monoculture planting harvested at 60 days), PI60 (Pakchong grown intercropped with Indigofera and harvested at 60 days)

Planting pattern, harvesting age, and their interaction also had a significant effect on the stem biomass of Pakchong ($p<0.05$). The interaction between factors produced inconsistent stem biomass in the third harvest. Still, the highest stem biomass was found in Pakchong grown in monoculture cropping and harvested at 60 days (128.41 kg fresh/plot). The lower rainfall likely caused the lowest biomass in the third harvest. Stem biomass was higher in monoculture cropping in all harvest ages than in intercropping. In addition, the highest stem biomass was found in Pakchong harvested at 60 days. This occurs because cutting as the plant ages causes the cell wall carbohydrate structure to increase rapidly, resulting in higher plant dry matter and higher stem biomass. When the harvesting age is too old, the plant's vegetative growth stops and begins to enter the generative phase. In this phase, the lignification process begins, so the dry matter and crude fiber content are low, which causes the low production of stem biomass at a young age than in older age.

The stem-to-leaves ratio (SLR) was affected by the interaction between planting pattern and harvesting age ($p<0.05$) in the third harvest (Table 5). Nonetheless, the SLR showed an inconsistent effect in this study. The lower stem-to-leaves ratio which indicates good quality of forage was resulted from Pakchong grown intercropped with Indigofera and harvested at 50 days. The increase in SLR with the increase in harvesting age agrees with the reports of Puteri et al. (2015) that SLR increase with increased harvest frequency. Increased SLR with increased harvesting age is a function of the longer periods of physiological growth with reduced harvest frequency stimulating stem growth at the expense of leaf production. The higher SLR in this result conforms the study by Wangchuck et al. (2015) that Pakchong has a high stem DM yield, resulting in a higher SLR. The dry matter production is contributed by the formation of leaves and stems, which are influenced by cell division and elongation. Both physiological processes involve high metabolic activity, including the accumulation of dry matter through photosynthetic activity by utilizing atmospheric CO_2 (Puteri et al. 2015).

Table 3. Plant height and tiller number of Pakchong grass under different planting patterns and harvesting ages

Treatment	Harvest				
	First	Second	Third	Fourth	Fifth
Plant height (cm)					
Planting patterns					
P	209.38±19.06^b	206.11±12.78^b	194.15±22.96	189.46±36.60^b	208.54±8.41^b
PI	231.80±22.53^a	220.55±7.92^a	184.68±35.46	216.00±25.91^a	237.78±16.58^a
p-value	0.030	0.001	0.385	0.042	0.005
Harvesting age					
50	217.44±26.97	207.42±14.69^b	179.76±26.37^b	180.95±31.70^b	223.23±22.40
60	223.74±20.21	219.24±7.06^a	208.07±18.57^a	224.51±18.01^a	223.09±18.24
p-value	0.486	0.002	0.006	0.004	0.987
Interaction of planting patterns and harvesting age					
P50	202.66±15.78	197.12±11.30	184.46±15.92	159.46±20.62	206.46±8.05
PI50	232.22±29.42	217.72±9.63	157.06±29.47	202.44±26.24	230.00±18.85
P60	216.09±21.87	215.10±6.16	203.83±26.94	219.46±17.34	210.63±9.40
PI60	231.39±17.85	223.39±5.69	212.31±5.57	229.56±19.70	235.56±16.53
p-value	0.432	0.058	0.117	0.177	0.600
SE	4.34	1.42	5.18	5.61	3.96
Tiller numbers/clump					
Planting patterns					
P	42.22±3.94	38.98±7.17^b	37.89±5.67^b	37.06±5.61^b	39.33±5.18^b
PI	45.72±6.85	49.22±9.91^a	55.38±14.09^a	43.41±4.07^a	48.72±6.74^a
p-value	0.277	0.001	0.000	0.014	0.005
Harvesting age					
50	42.88±2.38	51.10±7.29^a	54.10±15.38^a	37.79±5.78^b	46.99±7.23^a
60	45.06±7.81	37.09±6.66^b	39.17±6.43^b	42.67±4.89^a	41.07±7.10^b
p-value	0.488	0.000	0.001	0.044	0.048
Interaction of planting patterns and harvesting age					
P50	41.56±2.15	45.08±4.35^b	41.71±4.61^b	35.33±7.80^b	43.54±3.83^{ab}
PI50	44.19±1.99	57.13±2.90^a	66.50±10.99^a	40.25±1.06^{ab}	50.44±8.69^a
P60	42.88±5.51	32.88±1.29^c	34.08±3.86^b	38.79±2.15^{ab}	35.13±0.80^b
PI60	47.25±9.96	41.31±7.36^{bc}	44.25±3.58^b	46.56±3.31^a	47.01±4.76^a
p-value	0.779	0.426	0.040	0.511	0.360
SE	1.51	1.08	1.52	1.04	1.29

Note: Means in the same column and harvest with different superscripts in lowercase differ significantly ($p<0.05$). P (Pakchong in monoculture planting), PI (Pakchong grown intercropped with Indigofera), P50 (Pakchong monoculture planting harvested at 50 days), PI50 (Pakchong grown intercropped with Indigofera and harvested at 50 days), P60 (Pakchong monoculture planting harvested at 60 days), PI60 (Pakchong grown intercropped with Indigofera and harvested at 60 days)

Table 4. Leaf and stem biomass production (kg fresh/plot) of Pakchong grass under different planting patterns and harvesting age

Treatment	Defoliation				
	First	Second	Third	Fourth	Fifth
Leaf biomass					
Planting patterns					
P	56.79[a]	60.12[a]	46.52[a]	55.39[a]	62.37[a]
PI	40.37[b]	49.07[b]	37.94[b]	40.72[b]	46.18[b]
p-value	0.007	0.016	0.015	0.003	0.000
Harvesting age					
50	43.35	49.25[b]	34.74[b]	40.18[b]	44.61[b]
60	53.82	59.94[a]	49.72[a]	55.93[a]	63.95[a]
p-value	0.054	0.018	0.001	0.002	0.000
Interaction of planting patterns and harvesting age					
P50	51.84	52.62	40.36	49.60	49.60[b]
PI50	34.86	45.89	29.11	30.76	39.62[c]
P60	61.75	67.62	52.67	61.18	75.15[a]
PI60	45.89	52.25	46.77	50.67	52.74[b]
p-value	0.908	0.276	0.376	0.280	0.017
SE	2.37	1.86	1.44	1.81	1.06
Stem biomass					
Planting patterns					
P	121.90[a]	115.59[a]	67.25[a]	88.75[a]	107.97[a]
PI	88.00[b]	91.27[b]	53.04[b]	69.05[b]	85.04[b]
p-value	0.007	0.001	0.011	0.022	0.019
Harvesting age					
50	95.62	85.97[b]	46.84[b]	57.11[b]	89.89
60	114.29	120.89[a]	73.45[a]	100.69[a]	103.12
p-value	0.084	0.000	0.000	0.000	0.134
Interaction of planting patterns and harvesting age					
P50	111.10	96.84	62.66[a]	69.41	87.52[b]
PI50	80.14	75.11	31.02[b]	44.80	92.25[b]
P60	132.71	134.35	71.83[a]	108.09	128.41[a]
PI60	95.88	107.43	75.07[a]	93.30	77.83[b]
p-value	0.768	0.599	0.004	0.510	0.007
SE	4.81	2.38	2.24	3.58	4.02

Note: Means in the same column and defoliation with different superscripts in lowercase differ significantly ($p<0.05$). P (Pakchong in sole planting), PI (Pakchong grown intercropping with Indigofera), P50 (Pakchong sole planting harvested at 50 days), PI50 (Pakchong grown intercropping with Indigofera and harvested at 50 days), P60 (Pakchong sole planting harvested at 60 days), PI60 (Pakchong grown intercropping with Indigofera and harvested at 60 days).

The planting pattern and harvesting age also had a significant effect ($p<0.05$) on the fresh and dry weight production of Pakchong grass (Table 6) from the third until the fifth harvest. The highest fresh production reached 6.65 kg/clump produced by Pakchong grown in intercropping with Indigofera and harvested at 60 days. In line with the fresh production, the highest dry weight production reached 0.82 kg/clump was also produced in Pakchong grass intercropped with Indigofera and harvested at 60 days. The proportion of dry matter contained in forages changes with the age of the plant. The older plant, the less water content, and the proportion of cell walls is higher than the cell content. If the cell wall content of the plant is more significant, the plant will contain more dry matter. The dry matter production of Napier grass generally correlates with

Table 5. Stem to leaves ratio of Pakchong grass under different planting patterns and harvesting age

Treatment	Defoliation				
	First	Second	Third	Fourth	Fifth
Stem to leaves ratio					
Planting patterns					
P	2.209	1.93	1.46	1.61	1.75
PI	2.205	1.86	1.34	1.66	1.93
p-value	0.988	0.590	0.207	0.824	0.459
Harvesting age					
50	2.26	1.75[b]	1.32	1.45	2.08
60	2.16	2.04[a]	1.49	1.82	1.60
p-value	0.699	0.042	0.079	0.078	0.072
Interaction of planting patterns and harvesting age					
P50	2.22	1.85	1.56[a]	1.45	1.78
PI50	2.29	1.64	1.07[b]	1.45	2.39
P60	2.19	2.00	1.36[ab]	1.78	1.72
PI60	2.12	2.08	1.61[a]	1.87	1.48
p-value	0.785	0.278	0.002	0.827	0.102
SE	0.129	0.0621	0.0430	0.0939	0.117

Note: Means in the same column and defoliation with different superscripts in lowercase differ significantly ($p<0.05$). P (Pakchong in sole planting), PI (Pakchong grown intercropping with Indigofera), P50 (Pakchong sole planting harvested at 50 days), PI50 (Pakchong grown intercropping with Indigofera and harvested at 50 days), P60 (Pakchong sole planting harvested at 60 days), PI60 (Pakchong grown intercropping with Indigofera and harvested at 60 days).

plant height. The potential for dry matter production increases with increasing plant height because it allows the conversion of the elements contained to nutrients (Costa et al. 2016). According to Wangchuk et al. (2015), Pakchong grass has higher biomass production than other grasses such as CO-3 and Giant grass.

In comparison, the dry weight of the plant is influenced by the growth rate and preparation time of the dry matter itself. This is thought to be caused by the accumulation of dry matter biomass which is highly dependent on the age of the plant. A more extended harvesting period will lead to more accumulation of dry matter biomass compared to a shorter lifespan (Berliana et al. 2021).

In addition, the fresh weight and dry weight production fluctuated across harvest periods, maybe because it was influenced by rainfall conditions that fluctuated throughout the year. There was a decrease in forage production in the first to third harvests and increased again in the fourth and fifth harvests. This can occur due to seasonal changes that occur during plant maintenance. The third harvest was in the dry season with the lowest rainfall and the highest light intensity, resulted in a decrease in forage production due to differences in the availability of nutrients that can be utilized by plants due to differences in the breakdown of nutrients in different seasons. Harvesting at the fifth harvest showed that Pakchong grown intercropped with Indigofera and harvested at 50 days was not significantly different from that harvested at 60 days. It showed that intercropping with Indigofera can increase Pakchong biomass.

Table 6. Fresh weight and dry weight production (kg/clump) of Pakchong grass under different planting patterns and harvesting ages

Treatment	Harvest				
	First	Second	Third	Fourth	Fifth
Fresh weight production					
Planting patterns					
P	4.25±0.85[b]	4.18±0.72[b]	2.71± 0.51[b]	2.93±1.26[b]	4.06±0.90[b]
PI	5.35±1.22[a]	5.85±0.99[a]	3.79±1.39[a]	4.45±1.76[a]	5.47±0.72[a]
p-value	0.020	0.000	0.000	0.002	0.001
Harvesting age					
50	4.33±1.12[b]	4.30±0.94[b]	2.48±0.22[b]	2.37±0.70[b]	4.38±1.38[b]
60	5.27±0.62[a]	5.73±1.02[a]	4.02±1.21[a]	5.01±1.24[a]	5.14±0.48[a]
p-value	0.039	0.000	0.000	0.000	0.034
Interaction of planting patterns and harvesting age					
P50	3.88±0.80	3.56±0.32	2.45±0.23[b]	2.83± 0.10[c]	3.26±0.35[b]
PI50	4.79±1.44	5.04±0.71	2.51±0.23[b]	3.15±0.60[bc]	5.49±1.00[a]
P60	4.63±0.83	4.81±0.28	2.96±0.61[b]	4.03±0.71[b]	4.85±0.31[a]
PI60	5.91±0.41	6.65±0.26	5.08±0.27[a]	6.00±0.69[a]	5.44±0.46[a]
p-value	0.647	0.469	0.000	0.012	0.025
SE	0.193	0.120	0.088	0.131	0.153
Dry weight production					
Planting patterns					
P	0.47±0.10[b]	0.47±0.16[b]	0.30±0.08[b]	0.39±0.14[b]	0.47±0.14[b]
PI	0.64±0.19[a]	0.64±0.20[a]	0.43±0.18[a]	0.54±0.22[a]	0.60±0.07[a]
p-value	0.010	0.000	0.001	0.000	0.004
Harvesting age					
50	0.50±0.14	0.40±0.08[b]	0.27±0.02[b]	0.34±0.08[b]	0.47±0.13[b]
60	0.60±0.14	0.71±0.13[a]	0.46±0.14[a]	0.59±0.14[a]	0.61±0.10[a]
p-value	0.079	0.000	0.000	0.000	0.002
Interaction of planting patterns and harvesting age					
P50	0.44±0.05	0.33±0.02	0.24±0.01[b]	0.31±0.02[c]	0.36±0.03[b]
PI50	0.57±0.18	0.47±0.06	0.30±0.03[b]	0.37±0.09[bc]	0.58±0.08[a]
P60	0.50±0.08	0.61±0.08	0.36±0.09[b]	0.46±0.05[b]	0.59±0.13[a]
PI60	0.71±0.03	0.82±0.06	0.56±0.11[a]	0.72±0.11[a]	0.63±0.05[a]
p-value	0.473	0.203	0.027	0.002	0.028
SE	0.0256	0.0135	0.0137	0.0109	0.0172

Note: Means in the same column and harvest with different superscripts in lowercase differ significantly ($p<0.05$). P (Pakchong in monoculture planting), PI (Pakchong grown intercropped with Indigofera), P50 (Pakchong monoculture planting harvested at 50 days), PI50 (Pakchong grown intercropped with Indigofera and harvested at 50 days), P60 (Pakchong monoculture planting harvested at 60 days), PI60 (Pakchong grown intercropped with Indigofera and harvested at 60 days)

Table 7. Nutrient biomass (kg/clump) of Pakchong grass under different planting patterns and harvesting ages

Treatment	Nutrient biomass (kg/clump)				
	Dry matter	Ash	Crude protein	ADF	NDF
Planting patterns					
P	4.72±1.35[b]	4.07±0.84[b]	3.30±0.85[b]	20.21±5.84[b]	13.13±4.18[b]
PI	7.07±2.60[a]	5.75±1.90[a]	4.91±1.70[a]	28.95±10.35[a]	19.57±7.25[a]
p-value	0.000	0.006	0.001	0.001	0.001
Harvesting age					
50	4.23±0.62[b]	3.91±0.47[b]	3.10±0.43[b]	17.80±2.38[b]	11.52±1.99[b]
60	7.56±2.24[a]	5.91±1.86[a]	5.12±1.61[a]	31.36±8.61[a]	21.19±6.03[a]
p-value	0.000	0.002	0.000	0.000	0.000
Interaction of planting patterns and harvesting age					
P50	3.71±0.15[c]	3.58±0.14	2.75±0.10[b]	15.88±0.66[c]	9.87±0.44[c]
PI50	4.75±0.40[bc]	4.25±0.43	3.45±0.32[b]	19.72± 1.70[bc]	13.16±1.36[bc]
P60	5.72±1.24[b]	4.56±0.99	3.85±0.93[b]	24.54± 5.39[b]	16.39±3.50[b]
PI60	9.39±1.11[a]	7.25±1.50	6.38±0.97[a]	38.18±4.46[a]	25.98±3.35[a]
p-value	0.011	0.061	0.019	0.020	0.037
SE	0.206	0.235	0.160	0.871	0.645

Note: Means in the same column and rows with different superscripts in lowercase differ significantly ($p<0.05$). NDF: Neutral detergent fiber, ADF: Acid detergent fiber, P (Pakchong in monoculture planting), PI (Pakchong grown intercropped with Indigofera), P50 (Pakchong monoculture planting harvested at 50 days), PI50 (Pakchong grown intercropped with Indigofera and harvested at 50 days), P60 (Pakchong monoculture planting harvested at 60 days), PI60 (Pakchong grown intercropped with Indigofera and harvested at 60 days)

Biomass nutrition

Based on the research results shown in Table 7, nutrient content was significantly influenced by the interaction between planting pattern and harvesting age ($p<0.05$), except for ash biomass. The highest dry matter (9.39 kg/clump), crude protein (6.38 kg/clump), acid detergent fiber (ADF) (38.18 kg/clump), and neutral detergent fiber (NDF) (25.98 kg/clump) content was produced in Pakchong grown in intercropping with Indigofera and harvested at 60 days. The production characteristics and good nutrient quality of Pakchong grass intercropped with Indigofera and harvested at 60 days old were closely related to the complementary relationship between the two plant species planted.

Indigofera, planted in a mixture of Pakchong grass, contributed to providing nutrients, especially N elements, which play a role in cell division and affect plant growth. This is in line with Mangiring et al. (2017) and Ali et al. (2014), which state that nitrogen is an essential element for plant growth, so plant growth will be hampered if nitrogen is unavailable to plants. Intercropping can also improve the soil microenvironment (Ryu et al. 2019). Soil microorganisms play an important role in maintaining soil functions, including mineralization and mobilization of nutrients needed by plant growth. Ali et al. (2013) also found that legume plants in a grass/legume mixture would improve availability of nutrient in the soil, especially nitrogen and phosphorus content. In addition, planting legumes can also improve the physio-chemical properties of the soil so that the growth of other plants in intercropping can also increase (Mus et al. 2016). According to Kaca et al. (2017), intercropping requires proper planting arrangements, both the legume and the type of grass planted.

Intercropping between Pakchong grass with Indigofera in a field showed a successful transfer of N from Indigofera to Pakchong, so it is hoped that it will increase the production and quality of Pakchong. The higher dry weight may be caused by better absorbtion of solar energy used in the photosynthesis process and the ability to use it more efficiently so that the dry weight produced is also higher. The availability and absorption of nitrogen from N fixation of rhizobium in Indigofera nodules assists Pakchong planted with Indigofera. The Nitrogen (N) absorbed by plants in the form of NO_3 will be converted through the reduction process to NH_3 by reductase enzyme and then synthesized into crude protein. Thus the higher the supply of N, the higher the crude protein content formed. If sufficient N is available to plants, the chlorophyll content in the leaves will increase, and the photosynthesis process will also increase so that more assimilation is produced, resulting in better plant growth (Ryu et al. 2019). Good N assimilation will reduce the crude fiber content because with good N assimilation, the supply of N is sufficient for forming proteins, causing the crude fiber content to decrease (Sanchez et al. 2010). Intercropping is a way to increase crop production and quality because it does not require external input, improves soil nutrients, increases soil fertility, saves water, and increases agroecosystem stability (Rajaii and DahMardeh 2014). In intercropping, the nutrient content is better than in monoculture planting. According to Halim et al. (2013), leguminosae affected the productivity of intercropped grass. Intercropping of Pakchong grass with Indigofera also had better average biomass and quality than the sole planting pattern and resulted in the highest biomass nutrition.

In conclusion, based on the study results, the morphological characteristics of Napier grass (cv. Pakchong) has inconsistent result in different planting patterns and harvesting ages. Still, the highest production and nutrient content of Pakchong grass were produced in plants intercropped with Indigofera and harvested at 60 days old.

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