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Performance of the Napier Hybrid Cultivars CO-5 (*Pennisetum glaucum* × *P. Purpureum schumach*) and Sampoorna (*Pennisetum pedicillatum* × *P. americanum*) Harvested at Five Intervals

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Abstract: Low pasture biomass production and fodder scarcity are among the major challenges affecting productivity of dairy cattle farms in Sri Lanka. As a potential solution to this, two Napier hybrid cultivars, CO-5 and Sampoorna, were recently introduced, and a field experiment was conducted to evaluate their growth, dry matter production, and nutritional composition from May to September 2020 to identify the optimum stage of harvest during the Yala season of the year. Plant measurements and samples were collected at five harvest intervals (4, 6, 8, 10, and 12 weeks after planting, respectively), with the plant samples subjected to biomass and nutritional assessments. The number of tillers and leaf length significantly differed ($p = 0.01$) between the two cultivars at 4 weeks harvesting interval (HI), whilst the number of leaves differed at 12-week HI, respectively. Dry matter yield increased ($p = 0.16$) almost linearly, whilst crude protein declined exponentially with CO-5 greater than Sampoorna ($p = 0.057$; 9.3% vs. 8.7%), with increasing harvesting intervals, respectively. In vitro organic matter digestibility and in vitro metabolizable energy contents were similar across weeks 4, 6, and 8 but then decreased. This study demonstrates that higher dry matter yields (12.54 t/ha) can be obtained through harvesting both cultivars at 12 week HIs, but from a nutritional perspective, harvesting at 6 week HIs during Yala season of the year would be optimum for farmers.

Keywords: dry matter yield; CO-5; harvesting interval; in vitro gas fermentation; nutritional composition; pasture quality; Sampoorna

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1. Introduction

Animal milk production has to be increased (per animal) in Sri Lanka to achieve self-sufficiency in milk production [1]. However, there are several constraints to overcome, particularly a shortage in good quality natural pasture, fodder, and crop residues to feed the animals [2]. Pasture and fodder availability is affected by rainfall patterns in Sri Lanka, which mainly depends on the Yala (May to September) and Maha (December to February) monsoon rains. Native grasses decline in nutritional quality (crude protein content (CP) and digestibility) during the dry season whilst forage growth increases with the wet season [3].

Cultivation of perennial high-yielding pasture and fodder cultivars was considered as one of the immediate solutions to feed the increasing dairy herd in Sri Lanka [4]. This resulted in the introduction of the Napier hybrid (*Pennisetum* sp.) fodder cultivars to Sri Lanka a decade ago. They were previously widely grown across Africa and Southeast Asian countries including India [5] due to their adaptability to a wide range of soil conditions, along with their high photosynthetic and water use efficiency [6]. In addition, they exhibit profuse tillering, are easy to establish, have few pest diseases, and are considered as superior in terms of dry matter (DM) production (19.9%) and nutritional quality (e.g., mean CP; 13.2%, mean metabolizable energy (ME); 8.25 MJ/Kg DM [7–10]. These attributes have been observed across different agroclimatic zones in Sri Lanka where the Napier hybrid cultivars are prevalent as the main fodder in cut and fed dairy management systems [10]. Despite this, milk production from these pastures is still not considered as sufficient to fulfil domestic requirements.

Consequently, improved high yielding multi-cut perennial fodder crops like the Napier hybrid grass Sampoorna/DHN-6 (Bajra Line-(IPM14188) × Napier line (FD 184) and the Cumbu Napier hybrid CO (BN)-5: (*Pennisetum glaucum* × *P. purpureum Schumach*) were introduced into Sri Lanka during early 2020. They have previously been widely distributed [11,12] where their rate of establishment has been found to be higher compared to other Napier hybrid cultivars, which is an important and desirable feature as far as a perennial forage crop is concerned [13]. Hence, if improved CO-5 and Sampoorna cultivars can be maintained throughout the year in Sri Lanka in areas with similar climatic conditions, this could potentially be advantageous for livestock industries.

The Napier hybrid CO-5 was ranked the highest in green fodder yield, DM yield, CP yield, and CP content compared to older Napier hybrids (CO-3 and CO-4) during a trial (2009 to 2010) in India [13]. Similarly, Sampoorna (DHN- 6) has exhibited a higher nutritional value (CP; 13.2%) of green fodder throughout the year with minimum inputs in terms of fertilizer and irrigation on repeated fodder cultivation [11]. In addition, both cultivars exhibit profuse tillering, and have soft stems with a high sugar content, making the fodder more palatable and productive than other forage crops, which rapidly reduce in quality with the maturity of the forage. The stage of maturity significantly affects the yield, CP and fiber concentration, ME, and digestibility of fodder, which has a significant effect on feed intake and hence the productivity of the animal [14]. The optimum stage of harvest should be determined as while early harvest leads to higher CP and ME values, it also results in a lower DM yield, which is an important factor in consideration for feeding. In contrast, while harvesting too late might result in greater yields, it may also cause higher neutral detergent fiber (NDF) and acid detergent fiber (ADF) content production with lower CP and ME values, along with decreased digestibility, ultimately causing a lower intake of the animal [14]. The optimum harvesting interval for older cultivars has varied depending on the hybrid Napier variety, along with the prevailing climatic and soil conditions. Previously, optimum stages of harvest have been identified for the Napier hybrid cultivars of CO-3 (*Pennisetum Americanum* × *Pennisetum purpeuruem schum*), CO-4 (*Pennisetum glaucum*× *Pennisetum purpeuruemschum*), and Pakchong (*Pennisetum purpeuruem* × *Pennisetum glaucum*) in Sri Lanka, based on agronomic characters, dry matter yield, and nutritive values (e.g., DM, CP, fiber, and ME concentration) [7,9,10,15]. Sarmini [9] reported that it was best to harvest CO-3 of a 10-week maturity in a dry zone (Kilinochchi District) in Sri Lanka, with DM yield, CP, and DM digestibility averaging 6.12 mt/ha, 10.02%, and 67.87%, respectively. However, Jothirathne [7,15] recommended CO-3 and CO-4 to be harvested at 8-weeks of maturity in the southern wet zone in Sri Lanka to achieve a balance between the pasture quality and production (i.e., DM yield). In addition, Pakchong harvested at a 55 day interval (e.g., 8 weeks) recorded the higher DM yield (2.56 t/ha) with 15.5% CP in a study conducted in the mid-country wet zone in Sri Lanka [16]. These findings highlight the need for specific studies to determine the optimum harvesting interval for these varieties and under relevant agroclimatic zones. In addition, the consideration of anti-nutritive factors is also important to safeguard animal's health, as they can affect the growth and performance of ruminants. Both cultivars have minimum nitrate and oxalate concentrations, but these concentrations do increase slightly with increased maturity [11,17].

Similar information has not been collected on the newly introduced CO-5 and Sampoorna cultivars and forms the basis of the current study. Therefore, this study aimed to determine the agronomic characteristics (plant height, number of tillers, number of leaves, leaf length, leaf width, and stem circumference), DM yield, and nutritional composition (DM, ash, CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), In vitro organic matter digestibility (IVOMD), and in vitro metabolizable energy IVME) of CO-5 and Sampoorna during the Yala season in Sri Lanka and at five different harvesting intervals after planting to obtain the optimum stage of harvest in terms of their agronomic characters, DM yield, and nutritive values to maximize the livestock production for farmers.

2. Materials and Methods

2.1. Study Site

The study site was located at the veterinary research farm (VRF), Gannoruwa, Kandy, Sri Lanka (latitude. 7° 16′44.74′′ N and longitude 80° 35′ 40.32′′ E; altitude of 516 m above mean sea level). The mean annual rainfall is 1773 mm, with the majority occurring from October to November, respectively. The mean annual temperature is 23.5 °C, with the maximum (March) and minimum (December) averaging at 29 °C and 19 °C, respectively [18]. The soil type in the study site was a sandy clay loam with pH of 6.2 (VRI).

The study was conducted under rainfed conditions between May and September 2020, which was during the Yala season (southwest monsoon). The monthly total precipitation and the average minimum and maximum temperatures recorded at the VRF during the year are shown in Figure 1. The total rainfall recorded during the trial was 524 mm, which was 104.8 mm below average compared to the long-term average (628.8 mm) for that period [18].

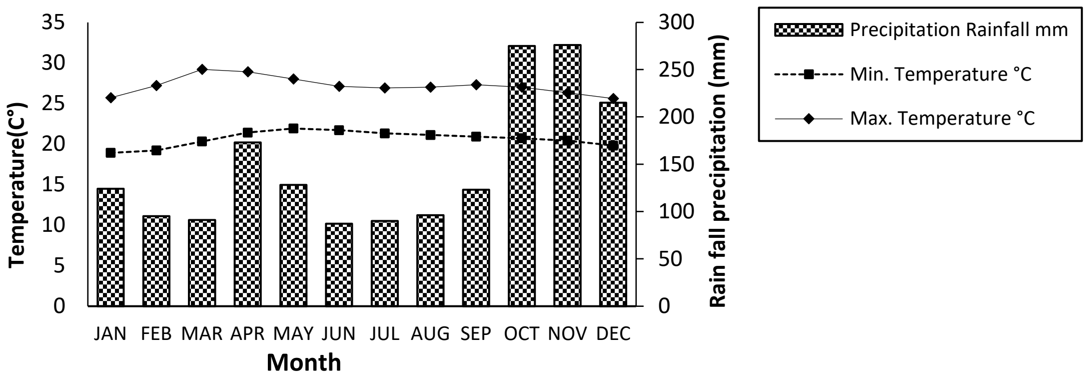

Figure 1. The monthly total precipitation (mm) and average temperature (°C) of the study site during 2020.

2.2. Planting Material, Experimental Design, and Plant Establishment

Two Napier hybrids cultivars were used for the experiment i.e., the Cumbu Napier hybrid CO (BN) 5 (*Pennisetum glaucum* × *P. purpureum schumach*) released from Tamil Nadu University, Coimbatore, and the Sampoorna/DHN-6 (Bajra Line-(IPM14188) × Napier line (FD184), which was developed and released by the Indian Grassland and Forage Institute (IGFRI), Dharward [19]. Mature healthy stem cuttings of the Napier hybrids CO-5 and Sampoorna were obtained from the VRF.

A 2 × 5 factorial experiment was undertaken using a randomized complete block design (RCBD), with each treatment replicated three times. Factor A consisted of two Napier hybrid cultivars (CO-5 and Sampoorna) while factor B comprised five harvesting intervals (4, 6, 8, 10, and 12 weeks after planting) which were based around the intervals which were used in previous trials on older Napier hybrid species [7–10]. Ten plots (5 m × 2 m) were prepared in each block, making a total of 30 plots. In each block, the plots were spaced 1 m apart, and 1 m wide rows separated each parallel located block. Within these plots, ten pits (0.3 m long × 0.3 m wide × 0.3 m deep) were established in accordance with the 'Tambukiza' method (Figure 2) [10]. Fertilizer was then applied to each pit using a blend of urea (20%), triple super phosphate (30%), and muriate of potash (50%) at an equivalent rate of 100 kg/ha [10]. Planting was undertaken by inserting two stem cuttings

(30–45 cm long) 20–25 cm apart into the pit, and then backfilling with the soil that had been previously removed. Two nodes were inserted into the soil leaving a single internode at about 45° angle slanted to the ground. Weeding was performed manually at the time of each harvest.

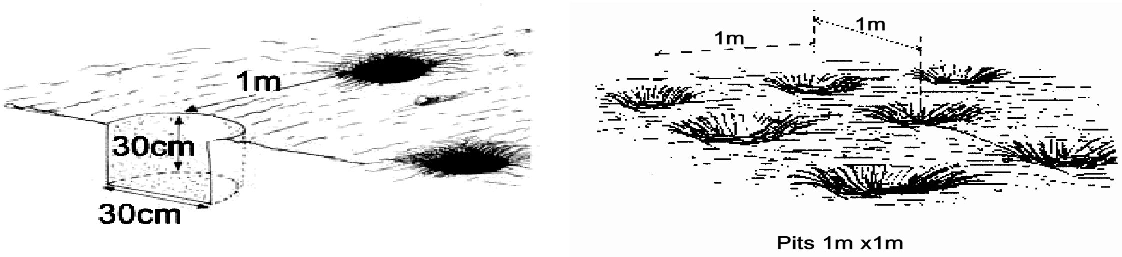

Figure 2. Establishment of the stem cuttings using the single-pit 'Tambukiza' method [10].

2.3. Plant Measurement and Biomass Sampling Procedures

Measurements of the plant's height (to the tip of the top leaf), number of tillers, stem circumference, number of leaves, leaf length, and leaf width were undertaken on 3 plants/plot, just before each of the five designated harvest times. The stem circumference was measured at the first internodes 5 cm above the ground level using a Vernier caliper (Mitutoyo Corporation, 965 Corporate Blvd, Aurora, IL, USA, 60502). The total number of leaves was estimated by multiplying the tiller number per plant and the leaf number per tiller. The fourth leaf from the tiller's tip was used to measure the leaf length and the leaf width, respectively [20] At each HI, plants within a 1 m^2 section in each plot (Sampoorna and CO-5) were cut (5 cm above ground level) for the determination of the fresh and dry weights.

2.4. Forage Sample Laboratory Analysis

At respective HI's, a 500 g sub sample from each replicate plot was oven dried at 60 °C (hot air oven, YCO-010-010-2005, England, 2015) until a constant weight was achieved and then weighed. Afterwards, they were ground (Christy Hunt grinder, 1067, Essex, UK, 2005) through a 1 mm sieve in preparation for the analysis of the DM [AOAC (2005) DM# 934.01] [21] content, and three replicates from each sample were used to analyze the forage quality (ash, CP, NDF, ADF, IVOMD, and IVME). Ash was determined by combusting the samples in a muffle furnace (Daihan lab tech/LEF-2035-0, Namyangju, Korea, 2010) at 550 °C for 6 h [AOAC (2005) #942.05] [21]. The modified Kjeldahl method [21] was used for nitrogen determination, which was then multiplied by 6.25 to determine the CP content [AOAC (2005) #984.13]. NDF and ADF contents were determined according to the methods of Van Soest [22]. OMD and ME contents were determined using the in vitro procedure described by Menke [23]. Briefly, the adult rumen-fistulated male sheep (body weight = 30 ± 0.6 kg) were fed with ad libitum hybrid Napier grass and 150 g of concentrate per day to fulfill their maintenance requirement. Rumen liquor was collected from 24 h fast sheep into a CO_2 flushed thermal flask, and was immediately transferred to the laboratory and strained through a four-layered muslin cloth. Oven-dried samples of about 200 ± 5 mg were weighed in triplicate into 100 mL glass syringes (SGE, Canberra, Australia) with pistons. Freshly prepared reducing solution with rumen fluid of 40 mL was added to each tube and these syringes were then incubated in a water bath (Clifton, Jermany, 2015) at 39 °C for 24 h. The tubes were gently shaken every 1 hr. The volume of gas that was produced from each syringe was recorded prior to incubation at 0 h and then 2, 4, 6, 8, 12, and 24 h of incubation, respectively. The OMD and ME were calculated based on the 24 h net gas production, and the gas production was corrected for the blank and the Hay standard (Hohenheim University, Stuttgart, Germany, 2020) according to Makkar [24]. The experiment was conducted for two consecutive days to minimize the occurrence of errors. Ethical clearance was obtained by the veterinary research committee (VRC) at the VRI by the number VRI/VRC/2020-02-02-07(2507) 02. In addition, water soluble carbohydrate

(WSC) and oxalate content were analyzed using the spectrophotometric method using the UV spectrophotometer (HITACHI, UH 5300, Spectrophotometer, Hitachi-shi, Japan, 2016) and precipitation method [25,26], respectively.

2.5. Data Analysis

The data were analyzed using Minitab 16 [27] using a general linear model with two-factor ANOVA to compare the mean differences between these two Napier hybrids and five harvesting intervals. Turkey's LSD test was used to assess the differences between the means. Differences between the means were considered as statistically significant if the obtained *p*-values were less than 0.05.

3. Results

3.1. Forage Growth Characters

The stem height and leaf width were found to be similar ($p > 0.05$) between the cultivars, but there was a significant difference observed between the HI's ($p < 0.05$) (Table 1). For the stem height, it increased with the increasing HI, albeit at a slightly decreasing rate over time. The leaf width only significantly increased between the 4 to 8 week HI, but not thereafter.

Table 1. Growth characters of two hybrid Napier cultivars at five harvesting intervals during the Yala season in 2020.

Parameter	Cultivar	HI (Weeks)					S.E.M	Level of Significance		
		4	6	8	10	12		C	HI	C × HI
Stem height (cm)	CO-5/Sam [1]	127.29 ^{f}	186.55 ^{de}	224.0 ^{bcd}	243.8 ^{abc}	272.80 ^{a}	5.80	0.17	0.00	0.17
Tiller number	CO-5	56.00 ^{a}	51.00 ^{ab}	35.44 ^{bcd}	49.11 ^{ab}	40.22 ^{abcd}	2.50	0.00	0.00	0.00
	Sam	30.33 ^{d}	41.00 ^{abcd}	32.78 ^{cd}	49.00 ^{abc}	40.67 ^{abcd}				
	Mean [2]	43.16 ^{b}	46.00 ^{abcd}	34.11 ^{bcd}	49.05 ^{abc}	40.445 ^{abcd}				
Number of leaves	CO-5	552.60 ^{abc}	574.00 ^{abc}	508.70 ^{abc}	656.80 ^{a}	519.20 ^{abc}	29.68	0.00	0.00	0.00
	Sam	299.20 ^{d}	450.20 ^{bcd}	406.20 ^{cd}	636.20 ^{ab}	582.70 ^{abc}				
	Mean [2]	425.9 ^{b}	512.10 ^{abc}	457.45 ^{abc}	646.50 ^{a}	550.95 ^{abc}				
Basal stem circumference (cm)	CO-5	4.47 ^{d}	5.60 ^{abc}	5.62 ^{abc}	4.94 ^{bcd}	4.12 ^{d}	0.19	0.62	0.00	0.00
	Sam	4.78 ^{cd}	5.89 ^{ab}	6.46 ^{a}	5.68 ^{abc}	4.84 ^{cd}				
	Mean [2]	4.62 ^{cd}	5.74 ^{ab}	6.04 ^{ab}	5.31 ^{abc}	4.48 ^{cd}				
Leaf length (cm)	CO-5	88.33 ^{d}	110.89 ^{ab}	109.67 ^{abc}	113.33 ^{ab}	96.44 ^{cd}	2.11	0.03	0.00	0.00
	Sam	100.94 ^{bcd}	117.44 ^{a}	114.11 ^{a}	117.44 ^{a}	117.00 ^{a}				
	Mean	94.63 ^{cd}	114.16 ^{a}	111.86 ^{a}	115.38 ^{a}	106.72 ^{b}				
Leaf width (cm)	CO-5/Sam [1]	2.47 ^{d}	3.39 ^{c}	4.23 ^{ab}	4.03 ^{ab}	3.94 ^{abc}	0.00	0.16	0.00	0.11

[1] Values are means. Means within a variable with similar superscripts are not significantly different based on a Duncan's multiple range test, ($p = 0.05$); C; cultivar, HI; harvesting interval, SEM; standard error of mean; and Sam, Sampoorna. [2] Average of cultivar means (i.e., HI main effect means).

Tiller number, leaf number, average basal stem circumference, and leaf length all exhibited significant cultivar × HI interactions ($p < 0.01$). The Napier hybrid CO-5 had more tillers (56 versus 30.33, respectively) and leaves (552.6 versus 299.2, respectively) than Sampoorna at the 4-week HI, but not during other harvesting intervals (Table 1). In contrast, Sampoorna had a significantly greater ($p < 0.01$) leaf length than CO-5 at the 12-week HI (117 cm versus 96.44 cm), but they were similar for all the shorter HI's.

3.2. Forage Production

DM content, DM yield, and leaf stem Ratio (LSR) were not found to be significantly different between the cultivars ($p > 0.05$) but they were significantly different between the HI's ($p < 0.01$), and for DM content there was a significant C × HI interaction observed ($p < 0.05$) (Table 2). Despite some variability across the HI's, overall, there was a greater increase in the DM content between the 4th to 12th week HI observed for CO-5 than

Sampoorna. For DM yield, it tended to increase almost linearly with the increasing HI across both cultivars (Table 2). Across both cultivars, the maximum LSR tended to occur between the 6 and 8 week HI's, when it averaged 2.09 and 2.05, respectively.

Table 2. Forage yield performance of two Napier hybrid cultivars at five harvesting intervals during the Yala season in 2020.

Parameter	Cultivar	HI (Weeks)					S.E.M	Level of Significance		
		4	6	8	10	12		C	HI	C × HI
DM (%)	CO-5	14.64 [e]	16.33 [cde]	14.42 [e]	17.36 [bcd]	22.19 [a]	0.54	0.54	0.00	0.01
	Sam	16.00 [e]	16.21 [cde]	14.96 [de]	18.86 [bc]	19.97 [ab]				
	Mean [2]	15.32 [e]	16.27 [cde]	14.69 [de]	18.11 [bc]	21.08 [a]				
DM yield (t/ha)	CO-5/Sam [1]	1.87 [d]	4.19 [cd]	6.04 [c]	8.41 [ab]	12.54 [a]	89.12	0.16	0.00	0.61
LSR	CO-5/Sam [1]	1.16 [d]	2.09 [a]	2.05 [ab]	1.67 [bc]	1.51 [abc]	0.13	0.06	0.00	0.63

[1] Values are means. Means within a variable with similar superscripts are not significantly different based on a Duncan's multiple range test, (p = 0.05); DM; dry matter, LSR; leaf stem ratio, C; cultivar, HI; harvesting interval, SEM; standard error of mean; and Sam, Sampoorna. [2] Average of cultivar means (i.e., HI main effect means).

3.3. Nutrient Composition

CP, ash, ADF, NDF, IVOMD, IVME, and WSC content were all determined to be similar ($p > 0.05$) for both CO-5 and Sampoorna, but they were all significantly affected by the HI (Table 3).

Table 3. Nutritional values of two hybrid Napier cultivars at five harvesting intervals during the Yala season in 2020.

Parameter	Cultivar	HI (Weeks)					S.E.M	Level of Significance		
		4	6	8	10	12		C	HI	C × HI
CP (%)	**CO-5/Sam [1]**	**17.90 a**	**11.90 b**	**6.80 c**	**4.60 d**	**3.90 d**	**0.41**	**0.05**	**0.00**	**0.18**
Ash (%)	CO-5	13.10 [b]	10.39 [c]	8.44 [de]	7.33 [ef]	6.54 [ef]				
	Sam	15.19 [a]	10.12 [cd]	6.81 [ef]	5.49 [f]	6.55 [ef]				
	Mean [2]	14.1 a	10.2 b	7.6 [c]	6.5 [cd]	6.4 [d]	0.34	0.22	0.00	0.00
ADF (%)	CO-5/Sam 1	37.50 c	38.70 c	42.80 b	48.90 a	49.90 a	0.83	0.11	0.00	0.27
NDF (%)	CO-5	64.78 [d]	67.70 [cd]	73.51 [ab]	75.65 [ab]	77.61 [a]				
	Sam	62.72 [d]	73.86 [ab]	73.28 [ab]	75.85 [ab]	73.67 [ab]				
	Mean [2]	63.70 [c]	70.80 [b]	73.40 [ab]	75.60 [a]	75.70 [a]	1.34	0.97	0.00	0.00
IVOMD (%)	CO-5/Sam 1	54.00 b	58.60 a	59.80 a	50.40 c	46.20 d	1.16	0.19	0.00	0.23
IVME (MJ/kg DM)	CO-5/Sam [1]	7.83 b	8.63 a	8.92 a	7.51 bc	6.91 c	0.17	0.38	0.00	0.08
WSC (%)	CO-5	14.47 [cd]	17.97 [bc]	16.64 [c]	21.53 [ab]	22.10 [ab]				
	Sam	11.85 [d]	15.95 [cd]	22.41 [ab]	23.08 [a]	23.62 [a]				
	Mean [2]	13.16 [c]	16.96 [bc]	19.52 [a]	22.30 [ab]	22.86 [ab]	0.90	0.15	0.00	0.00
Oxalate (%)	CO-5	0.58 [a]	0.58 [a]	0.49 [ab]	0.44 [abc]	0.29 [bc]	0.04	0.00	0.00	0.05
	Sam	0.58 [a]	0.44 [abc]	0.26 [c]	0.34 [bc]	0.31 [bc]				
	Mean [2]	0.58 [a]	0.51 [ab]	0.37 [c]	0.39 [bc]	0.30 [c]				

[1] Values are means. Means within a variable with similar superscripts are not significantly different based on a Duncan's multiple range test, (p = 0.05). [2] Average of cultivar means (i.e., HI main effect means) DM; dry matter, CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber, IVOMD; in vitro organic matter digestibility, IVME; in vitro metabolizable energy, WSC; water soluble carbohydrate, C; cultivar, HI; harvesting interval, SEM; standard error of mean; Sam, Sampoorna.

Furthermore, a significant C × HI interaction ($p < 0.05$) occurred for ash, NDF, and WSC content. For both cultivars, CP content decreased exponentially from an average maximum of 17.9% at the 4-week HI to a minimum of 3.9% at the 12-week HI, respectively. Ash % was significantly greater for Sampoorna (15.2%) than CO-5 (13.1%) at 4 weeks, but it then declined more rapidly in Sampoorna, such that the two cultivars were not significantly different ($p > 0.05$) from the 8-week HI onwards. For both cultivars, NDF % was lowest at the 4-week HI. It remained relatively low for CO-5 (67.7%) at the 6-week HI but was significantly higher for Sampoorna (73.9%). For all longer HI's, the NDF % was similar ($p > 0.05$), ranging between 73.3 and 77.6%, respectively. Similarly, the ADF content for both cultivars was lowest (from 37.5 to 38.7%, respectively) at the two shortest HI's and greatest at the three longest HI's (from 42.8 to 49.9%, respectively). Both the IVOMD % and IVOME content were not determined to be significantly different between the cultivars ($p > 0.05$) and was highest at the 6- and 8-week HI's. Initially, the WSC content increased for both cultivars with increasing HI, but Sampoorna and CO-5 reached their maximum WSC contents at the 8 and 10-week HIs, respectively. The Napier hybrid CO-5 had a higher ($p = 0.00$) oxalate content than Sampoorna at the 8-week HI, but both cultivars were determined to be similar ($p > 0.05$) at other HI's.

4. Discussion

This study has provided information on the growth, yield, and nutritional quality of CO-5 and Sampoorna at different harvesting intervals. The variations and similarities between the different parameters among CO-5 and Sampoorna suggest room for the selection of harvest intervals to improve the yields and nutritional values under Sri Lanka's prevailing environmental conditions.

4.1. Forage Growth Characters

The stem height of the two cultivars increased with maturity from 1.28 m to 2.72 m between 4 to 12-week HI's, respectively, which is consistent with earlier studies on the older Napier hybrids. For example, Jothirathne [7] and Sarmini [9] reported an increase in height from 1.0 m to 2.0 m for CO-3 and CO-4 between 4- to 10-weeks of maturity, respectively, in southern wet and dry zones in Sri Lanka. Like CO-3 and CO-4, CO-5 and Sampoorna exhibited a similarly slow growth at the 4- and 8-week HI's due to their slow establishment using stem cuttings, but once established they grew rapidly (Table 1) under the prevailing environmental conditions (e.g., climate and soil) at the experimental site [7,9,16]. The ability of both CO-5 and Sampoorna to produce more than 30 tillers within four weeks from being transplanted is also similar to what has been observed in other Napier hybrid cultivars, and promotes persistence and high yields [10,28,29]. Previous studies of CO-3 and CO-4 recorded 33–34 tillers at 4–8 weeks maturity [7]. In contrast, Pakchong had the lowest number of tillers compared to the other Napier hybrids in the wet zone of Sri Lanka, recording an average of 1.1, 3.4, and 6.8 tillers at 2, 4, and 6 week maturity stages, respectively, which was attributed to its slow adaptation under the prevailing conditions [16]. The tiller numbers for Sampoorna at the 6, 8, and 10-week HI's were higher than those reported by Anthony [19] and may be attributed to its physiological factors and their interaction with the environment [30,31]. The number of leaves for both cultivars within the study period was not affected by the HI due to a persistent moisture period during the Yala season, which was also illustrated by Anthony [17] in a previous study. The number of leaves of CO-3 and CO-4 were similar at three harvesting intervals (mean 250) in the southern wet zone, as both varieties had similar number of tillers throughout the study, respectively [7]. Both CO-5 and Sampoorna had their highest basal stem circumference at the 8-week HI, which then gradually declined with maturity in agreement with the previous records of Napier hybrid cultivars (*Pennisetum sp*) [32]. Samarawickrama [16] reported that Pakchong exhibited an increasing basal stem circumference from 2 (2.1 cm) to 6 weeks of maturity (6.8 cm). The average leaf width and leaf length of both cultivars within the five harvesting intervals ranged between 2.5–4.2 cm and 95–115 cm, respectively, and was comparable with studies at 6, 8, and 10-week HI's in India [17,31]. Studies conducted in Sri Lanka found that the CO-3 and CO-4 leaf length and leaf width ranged between 75 cm–100 cm and 3–4 cm, respectively [7,9,16]. In the current study, the leaf width and leaf length were not affected by the HI due to the environmental stability and the genetic variations except at the 4-week HI, which can be attributed to a slow early growth of the two cultivars [17]. Overall, the similarities between CO-5 and Sampoorna growth parameters, such as the stem height, basal tiller circumference, and leaf width, suggests that both of the cultivars could be selected for their use in livestock production systems in Sri Lanka.

4.2. Forage Biomass Production

The DM content for both cultivars increased with maturity due to the accumulation of fibrous tissues and their cell wall structure [33,34]. Sampoorna recorded a 19.97% DM content at the 12-week HI in the current study, which was comparable with a similar experiment undertaken in Karnatake, India [29,35]. However, previous studies on hybrid Napiers in Sri Lanka recorded 12%-16% DM contents of CO-3 and CO-4 at the 4th, 6th, and 8th week of harvest in the Southern wet zone, compared with 17% in the mid-country wet zone at 6-weeks of maturity [10]. Similarly, the DM yield of both cultivars increased with increasing HI, from 1.87 to 12.58 between 4-to-12-week HI's, respectively, and was consistent with the records for several other Napier hybrid cultivars [30,35]. However, in the current study, the average DM yield of both cultivars at the 12-week HI (12.58 t/ha) was superior to 5.32 t/ha reported at a similar stage in India [28,36]. In general, with most Napier hybrid cultivars prevailing in the country (CO-3, CO-4, and Pakchong) having similar numbers of tillers and leaves at respective HI's, it is not surprising that there are minimal differences in the DM yield between the Napier hybrid cultivars in Sri Lanka [7–10]. However, the current values of the DM yield of CO-5 and Sampoorna were higher than in previously introduced cultivars (CO-3, CO-4, Pakchong) at 4, 6, 8, and 10-week HI's in Sri Lanka [7,9,10,16], which were established at similar distances of 1 m × 1 m [10]. Therefore, these yield variations may be attributed to the genetic variations of these Napier hybrids and the rainfall patterns of different agroclimatic zones.

The LSR is an important parameter that influences the nutritive value and voluntary feed intake of animals [37]. There was no difference in the LSR between the cultivars, with the highest ratio observed between the 6 to 8 week HI's, averaging 2.09 and 2.05, respectively which were comparable with previous records in India at similar HI's, following which they then declined with maturity [29,35]. Samarawikrama [16] recorded a decrease in the LSR of Pakchong from 1.42 to 0.88 between the 6-to-10-week maturity stages. The differences in the LSR with increasing HI have been associated with a greater leaf production in the early growth stage HI's and greater stem growth at long HI's, respectively [37,38]. However, variations in the LSR may also be attributed to the prevailing environmental conditions, soil fertility, and water stress of the plants [39].

4.3. Nutritional Quality Parameters

The nutritional quality of forage is as important as the yield in the selection of the optimal grasses for livestock production. The average ash content of both Napier hybrids decreased progressively from the 4 to 12-week HIs (between 14.1%–6.4%) (Table 3) with advancements in maturity due to the natural dilution processes and translocation of minerals to the roots [30,40]. For Sampoorna, the average ash content at the 6-week HI was 10.2%, which is higher than at a comparable stage in an Indian study (6.06%), which could be attributed to differences in the mineral content of the soil and the forage [17]. Similar to ash content, the average CP content of both cultivars declined with the increasing HI due to the increased accumulation of structural carbohydrates in the cell wall [30,41]. The average CP content of both cultivars at the 6-week HI was 17.9%—comparable with similar HI's in India [28]. Considering the previous hybrid Napier studies [7] in Sri Lanka, CO-4 and CO-3 exhibited no statistical significance between their CP and ash content at their 6- and 8-week frequencies (CO-3; CP: 14.29%, 13.47%, and ash: 8.32%, 6.81%, and CO-4: CP; 14.50%, 13.53%, and ash: 7.64%, 7.13%), respectively. Similarly, Premarathne [10] revealed a 15–16% CP content at 6-weeks of maturity in the mid-country wet zone, while Sirmila [9] recorded a 10.92% CP content of CO-3 at 10-weeks of maturity in the northern region of Sri Lanka. The differences between the HI of different cultivars may be attributed to variances in the soil conditions and the environmental factors between these locations [17]. The CP content for both cultivars was only above the critical level (>7% CP) at the two shortest HI's (i.e., 4 and 6 weeks), which is vital for both sustaining the rumen microflora and consequently for voluntary feed intake in ruminants [34].

According to Van [41], the maturity of forage causes a progressive increase in the cell wall's contents, as occurred with the average NDF and ADF contents in the current study, which increased from 63.70% to 75.70%, and 37.5% to 49.90% between the 4 and 12-week HI's, respectively. However, these NDF and ADF values (74–78% and 42–47%, respectively) were within the range of CO-3 harvested in the mid-country wet zone in Sri Lanka [10]. This is also consistent with Basyble [42], who observed a similar trend when the hybrid Napier grass (*Pennisetum purpeureum*) was harvested at the 8 and 12-week HI's. However, the fiber composition of these forages depends on many factors, such as the genotypic characters, environmental conditions, and harvesting stages of the plant [43]. Digestibility of the plant tissues depends on the proportion of the cell contents and cell wall constituents (Table 3). This was illustrated in our study, with the highest average IVOMD content for both cultivars at the 6 (58.60%) and 8 week (59.80%) HI's, which then progressively declined. Regarding previous studies conducted in Sri Lanka, Pakchong displayed 70.21%, 68.33%, and 60.88% IVOMD contents at 6th, 8th, and 10th week intervals, while CO-4 was found to have a 69.7% IVOMD content, all of which were higher than in the current study [15,16]. This could be attributed to the decline in the CP content and the increase in the detergent fibers. In addition to the nutritional composition, stress factors, such as fertilizer, water, and climate may cause variances in their digestibility [34,41].

Moir [44] indicated that the quantity of ME is the first limiting factor for milk production. The average IVME values of CO-5 and Sampoorna ranged between 7.83 MJ/kg DM and 8.92 MJ/kg DM during the 4 to 12-week HI's and were found to be higher than the average energy production of the Napier hybrids (7.1 MJ/kg DM) reported by Turano [43]. In addition, the values we obtained were comparable with the study conducted on CO-3 and CO-4 in the southern wet zone in Sri Lanka [15]. For example, CO-3 had 6.72 and 7.45 MJ/KgDM and IVME content at 4 and 6 weeks, respectively, whilst CO-4 had 7.90 and 8.87 MJ/kg DM at similar intervals. The IVME values of the present study during the five harvesting intervals followed the similar pattern of the IVOMD contents, meaning hence that ME is a derivative of IVOMD, and the main factors affecting the ME value of forages also influences its digestibility [33].

Water soluble CHO content of the forages determine the quality of the ensiled forages [45]. The highest WSC concentration was found in the 12th week of harvest for both cultivars. Compared to the WSC content of Pakchong and the CO-4 hybrid Napiers in Sri Lanka, CO-5 and Sampoorna recorded the higher WSC concentrations at each harvesting interval, respectively [8]. Therefore, it is evident that in this study, irrespective of the harvesting interval, CO-5 and Sampoorna cultivars are both suitable to be used for silage production due to their higher WSC contents.

Oxalate, an anti-nutritive factor, of the present study averaged between 0.30% to 0.58% for both cultivars during the 4 to 12-week HI's, respectively, and was below the permissible limit of 4% [46], which were comparable with the earlier records in India [47]. The oxalate concentration of both cultivars was reduced with the increasing HI and height of the plants in agreement with Sridhar and Rahman [48,49]. However, oxalate content varies with the seasonality and genotype of the Napier hybrids [50].

5. Conclusions

Both CO-5 and Sampoorna performed well at the experimental site, but they varied in terms of several growth characteristics and their nutritional composition. CO-5 was superior to Sampoorna in terms of their tiller number and number of leaves, whereas Sampoorna was superior in terms of their leaf length to CO-5. The highest DM yield and DM content of CO-5 and Sampoorna can be obtained by harvesting both cultivars at 12-week HI, though highest of the CO-3 and CO-4 can be obtained at the 8th week at the wet zone, and in the 10th week at the dry zone in Sri Lanka, respectively. However, in terms of their nutritional composition, a 6-week HI appears to be the optimum harvesting interval for both cultivars. Further research with animal performance trials considering the different agroclimatic zones and detailed economic analysis are recommended to obtain more concrete results.

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