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YIELD, NUTRITIVE VALUE AND FERMENTATION CHARACTERISTICS OF PAKCHONG-1 (*PENNISETUM PURPUREUM* × *PENNISETUM GLAUCUM)* IN SRI LANKA

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Abstract

Two experiments were undertaken for the very first time in Sri Lanka using Pakchong-1 (Pennisetum purpureum × Pennisetum glaucum), a newly introduced hybrid Napier grass; (Experiment 1) Effect of three cutting frequencies namely, 45, 55 and 65 days on growth parameters, herbage yield and quality of Pakchong-1 compared to Hybrid Napier Coimbatoor-4 (CO-4) (Pennisetum glaucum × Pennisetum purpureum) in mid-country wet zone of Sri Lanka; (Experiment 2) Effect of different cutting frequencies on fermentation characteristics of Pakchong-1 compared to CO-4. According to Experiment 1, the height of Pakchong-1 was higher (P<0.05) compared to CO-4 at 6 weeks of age. Among the three cutting frequencies, 65 days has shown a higher (P<0.05) fresh matter and dry matter yields while the highest (P<0.05) crude protein percentage was recorded in the 45 days cutting frequency for Pakchong-1 compared to other treatments. Nitrogen free extract of Pakchong-1 has shown an increasing (P<0.05) trend with maturity. Pakchong-1, harvested at 45 days has shown the highest (P<0.05) in vitro organic matter digestibility compared to other treatments. According to Experiment 2, physical and chemical characteristics of the silage produced from Pakchong-1 at different cutting frequencies are at the satisfactory levels of quality silage. Pakchong-1, harvested at 55 days has shown intermediate quality and good fermentation characteristics. Thus, it can be concluded, Pakchong-1 can be harvested at 55 days cutting frequency for both purposes; feeding livestock and silage preparation.

Keywords: *CO-4 (Pennisetum glaucum × Pennisetum purpureum), Fermentation characteristics, Growth parameters, Napier hybrids, Pakchong-1 (Pennisetum purpureum × Pennisetum glaucum)*

INTRODUCTION

Sri Lanka is basically an agricultural country and the livestock sector, especially the dairy and poultry sectors play a vital role in the agricultural economy of Sri Lanka. In 2015, the total production of cow and buffalo milk in the country was estimated to be 305 and 69 million litres respectively. Presently, the total milk production of the country is adequate only to meet 40% of the requirement (Annonymous, 2015). To be self-sufficient in milk, a further 482 million litres have to be produced annually in Sri Lanka (Annonymus, 2014).

Even though the majority of the dairy breeds are cross-bred animals, the full potential of the dairy cows are not obtained due to the low availability of good quality green forage. Therefore, cultivating and feeding good quality fodder species for dairy animals are vital to maximize the milk production in the country (Premaratne and Premalal, 2006). Pasture and fodders hold an important place in ruminant diets, because they are the cheapest source of feed available in the country (Premaratne et al., 2003). There are many pasture and fodder species such as Guinea grass (*Panicum maximus*), Brachiaria spp (*Brachiaria decumbens*, *Brachiaria* *milliformis, Brachiaria brizantha*), fodder sorghum (*Sorghum bicolor*), maize (*Zea mays*), Napier (*Pennisetum purpureum*) and its hybrids to feed livestock in Sri Lanka. However, the availability of these pasture and fodder species throughout the year is highly variable in different parts of the country as it depends mainly on the bi-model rainfall pattern. Pasture and fodder are scarce during the dry period. Preserved feeds such as hay, silage, leaf meal blocks and total mixed rations play a vital role during this season.

Napier grass varieties are an important forage crop for dairy production in tropical countries (Wanjala et al., 2013) because the Napier grass can be grown with little water and soil nutrients. Hybrid Napier Coimbatoor-4 (CO-4) grass was a newly introduced fodder grass to the Asian region. It was developed by Tamil Nadu Agricultural University (TNAU) by crossing Pearl Millet (*Pennisetum glaucum*) with Napier grass (*Pennisetum purpureum, Schumach*) (Vijayakumar et al., 2009). Hybrid Napier CO-4 grass produces higher green fodder yield than other Napier varieties (Kumar et al., 2015). Management practices and other requirements of CO-4 are similar to that of Hybrid Napier variety CO-3 (*Pennisetum purpureum x Pennisetum americarnum*).

Pakchong-1 (*Pennisetum purpureum × Pennisetum glaucum)* is a newly developed hybrid Napier grass and popular among dairy farmers in Thailand. The Thai Department of Livestock Development calls it Napier Pakchong-1 or Super Grass, because it is more nutritious, fast-growing and high-yielding (Kiyothong, 2014). The Pakchong-1 is highly palatable and even the stalks are tender. It has a wide range of adaptability thus, it can be grown in different agro-ecological conditions. If there is an excess harvest, the fodder could be shredded and made into silage or could be fed to vegetable-eating fish like tilapia (*Oreochromis mossambicus)* and Pangasius (*Pangasianodon hypophthalmus*) (Kiyothong, 2014).

However, there is no information available on Pakchong-1 grass under Sri Lankan conditions. Therefore, two experiments were undertaken for the very first time with the objectives of finding out basic information such as best cutting frequency for higher yield and nutritive value when established under Sri Lankan conditions and, the effect of different cutting frequencies on fermentation characteristics of Pakchong-1 compared to CO-4.

MATERIALS AND METHODS

Experiment 1: Effect of cutting frequency on growth parameters, yield and nutritive value of Pakchong-1.

The experimental site for the field experiment was situated between 7°15'947" N, 80°36'2170" E on Mawelawatta Livestock Farm, Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka. The soil type in the area was red-yellow podzolic associated with immature brown loam and average monthly rainfall was 2000 mm (Punniyawardena, 2008). This experiment was undertaken from September to December 2017.

Field establishment

The experiment consisted of four treatments depending on the cutting frequency. Treatment 1 (T1) ; CO-4 cutting at 45 days (control), Treatment 2 (T2) - Pakchong-1 cutting at 45 days, Treatment 3 (T3) - Pakchong-1 cutting at 55 days and Treatment 4 (T4) - Pakchong-1 cutting at 65 days. Napier hybrid CO-4 was considered as the standard and used to compare the data obtained related to Pakchong-1. Thus, CO-4 was established according to the recommendations given by Vijayakumar et al. (2009). Twelve experimental plots were arranged in a Completely Randomized Design (CRD) with 3 replicates per treatment.

The size of each plot was 8 m^2 (2 m x 4 m) and the total area under experimental plots was 96 m^2. The planting holes were prepared to a depth, length and width of 0.3 m. The distance between the two planting holes was 1 m. Thus, each plot had 8 plants and there was 1 m gap between adjacent plots. Stem cuttings of the two fodder species were established in the experimental site in September 2017. The selected Pakchong-1 stem cuttings were having 2 nodes at moderate maturity. Two stem cuttings of Pakchong-1 were established horizontally in each planting hole in the respective plots while rooted CO-4 stem cuttings were planted vertically in the respective plots as per the recommendation.

Soil samples were collected randomly from each plot. Soil and cattle manure samples were analysed for pH by pH electrode method (AOAC, 2005), nitrogen content by Kjeldhal method (AOAC, 2005), phosphate content by Olsen method (Van Ranst et al., 1999) and potassium content by a flame photometer (Van Ranst et al., 1999).

Cattle manure was applied at a rate of 2 kg per hole at the time of establishment. After 20 days of establishment, a mixture of Urea, Triple Super Phosphate and Muriate of Potash were applied at the rate of 20, 12 and 10 g/plant, respectively at a distance of 0.2 m from the base of the plant. The plants were irrigated first at the time of planting. Depending on the rainfall pattern subsequent irrigations were undertaken. Manual weeding was practised whenever required.

Data collection and sample analysis

Four plants from each plot were randomly selected to measure the growth parameters at the age of 2, 4 and 6 weeks. Growth parameters such as the height of the plant from the base where it touches the soil to the vertically held leaf tip, basal circumference, number of leaves and number of tillers were measured during fortnightly intervals up to the 6^{th} week of growth.

Three cutting frequencies, namely 45, 55 and 65 days (treatment 2, 3 and 4) were tested for Pakchong-1 whereas; the recommended cutting frequency of 45 days under local conditions was practised for CO-4 (treatment 1) plots. Plants were harvested at ground level at each cutting frequency.

Fresh matter yield and leaf to stem ratio (leaf: stem ratio) were measured at each cutting frequency for both species. In addition, at each cutting frequency, sub samples of harvested plants were taken and oven dried at 60^0C for 72 hrs to determine the dry matter content of herbage. Dried samples were ground to pass 1 mm sieve and stored in plastic bottles. The samples were analysed for dry matter (DM), ash, crude protein (CP), crude fiber (CF) and ether extract (EE) according to AOAC (2005). *In vitro* organic matter digestibility (*IVOMD*) was determined according to Tilley & Terry (1963) as modified by Van Soest et al. (1991).

Experiment 2: Effect of cutting frequency on fermentation characteristics of Pakchong-1.

Effect of frequency of harvesting on fermentation characteristics of Pakchong-1 and CO-4 were studied in this experiment. The four treatments used in this experiment were similar to that of Experiment 1; Treatment 1 (T1) ; CO-4 cutting at 45 days (control), Treatment 2 (T2) - Pakchong-1 cutting at 45 days, Treatment 3 (T3) - Pakchong-1 cutting at 55 days and Treatment 4 (T4) - Pakchong-1 cutting at 65 days.

Pakchong-1 grass was obtained from a farmer’s field at Hingurakgoda (8.0422° N, 80.9466° E) and harvested at ground level at each cutting frequency. As per the recommendation, 45 day cutting frequency was practised for CO-4 by harvesting at 10 cm above ground level from the same location. Harvested samples were cut into smaller pieces (3-4 cm in length) using a grass chopper (Mapa, MC 02, Sri Lanka).

Preparation of Bag Silage

The silo was a polythene bag having dimensions of 0.6 m × 1 m and a gauge of 150 double-lined. The bottom line of the bag was sealed using a sealer (TEW, TISH-200, Japan). Upper side of the bag was kept opened for filling.

Preparation of Silage

The experimental design was Complete Randomized Design (CRD) with three replicates. Chopped fresh fodder (CO-4 or Pakchong-1) containing 65-70% of moisture content was divided into three groups (replicates), each containing 10 kg and was carefully packed into a silo bag uniformly. Forty grams of sugar was added to each bag separately to support the fermentation process and mixed well before sealing. Then inside air was removed by using a vacuum pump (Omron, 1/8HP TO 1 HP, Japan). Finally, the bags were sealed and all three replicates of each treatment (4 treatments X 3 Reps = 12 Silos) were stored together in a gunny bag at 22°C for four weeks.

Data collection and sample analysis

Chopped fodder (CO-4 and Pakchong-1) samples were taken and dried at 60°C in a drying oven (Yamato, DX 600, Japan) until it reaches to a constant weight and the dry matter percentage of fodder samples was determined.

The nutrient contents of pre-ensiled materials at each cutting frequency were analysed using the proximate analysis procedure (AOAC, 2005). In addition, *In vitro* dry matter digestibility (*IVDMD*) and *In vitro* organic matter digestibility (*IVOMD*) of silage samples were determined according to Tilley an Terry method, (1963).

Visual Estimation of Silage

After four weeks, silos were opened and the top layer of each silo was removed. Sub samples from middle layers of each silo were taken and transferred to trays for visual estimation; texture, colour, aroma, uniformity and mould formation were observed and recorded.

Chemical Analysis of Silage

The dry matter contents of respective silage samples were determined by oven drying at 60°C for 72 hours whereas, pH was measured using a pH meter. Water-soluble carbohydrate (WSC) (AFIA, 2009), lactic acid (Barnett, 1951) and ammonia nitrogen (Parsons et al., 1984) in the silage samples were also measured.

Statistical Analysis

Experiment 1

Growth parameters (height of the plant, basal circumference, number of leaves and number of tillers per plant), yield data (fresh and dry), leaf : stem ratio and nutrient quality parameters were subjected to analysis of variance (ANOVA) using SAS version 9.3.1 (SAS, 2010) and mean separation was done by Least Significant Difference Test.

Experiment 2

Nutritional and fermentation data were analysed using SAS version 9.1 (SAS, 2004). The means were compared using Duncan's Multiple Range Test (DMRT) procedure in PROC GLM.

RESULTS AND DISCUSSION

Experiment 1: Effect of cutting frequency on growth parameters, yield and nutritive value of Pakchong-1.

Soil nutrient content

Table 1 shows the soil nutrient content and the pH at the experimental site at Mawelawatta Livestock Farm. Considering the lower level of nitrogen content in the site, adjusted level of urea (20 g/plant) was applied to the fodder species mixing with triple supper phosphate (12 g/plant) and muriate of potash (10 g/plant).

Growth parameters of CO-4 vs Pakchong-1

The growth parameters of CO-4 vs Pakchong-1 at 2, 4 and 6 weeks of age are shown in Table 2.

Table 1: **Characteristics of soil and cattle manure**

Nutrient	Soil	Cattle manure
Nitrogen (ppm)	0.012	3.36
Phosphate (ppm)	5.47	499.09
Potassium (ppm)	126.30	204.44
pH	6.99	-

Table 2: Growth parameters of CO-4 *vs* Pakchong-1 at 2, 4 and 6 weeks of age

	Weeks after planting		
	2	4	6
Height of plant (cm)			
CO-4	41.0±5.2^{a}	60.2±7.1^{a}	92.5±13.3^{b}
Pakchong-1	23.6±5.2^{b}	55.4±9.6^{a}	101.5±12.8^{a}
Basal circumference (cm)			
CO-4	2.3±0.3^{a}	3.9±0.7^{a}	6.1±0.7^{a}
Pakchong-1	2.1±0.5^{a}	3.5±0.8^{a}	6.1±0.8^{a}
No. of leaves/plant			
CO-4	12.1±4.0^{a}	86.1±22.4^{a}	194.4±41.6^{a}
Pakchong-1	5.1±1.8^{b}	19.5±33.6^{b}	51.0±22.1^{b}
No. of tillers/plant			
CO-4	2.5±0.7^{a}	16.0±5.6^{a}	25.5±6.7^{a}
Pakchong-1	1.1±0.3^{b}	3.4±2.7^{b}	6.8±3.0^{b}

$^{a, b}$ Means (Mean ± SE) with different superscripts in a column for a particular parameter is different (P<0.05)

According to table 2, the height of CO-4 was higher (P<0.05) at the 2nd week of age, however by the 6th week of age, the height of Pakchong-1 grass was higher (P<0.05) than the CO-4. The slower rate of growth at the beginning in the Pakchong-1 may be due to the use of stem cuttings at the establishment. However, once the stem cuttings were well established in the field, Pakchong-1 recovered the growth rate. Similar results have been obtained by Wangchuk et al., (2015) at first harvest at 40 days after field establishment.

According to Table 2, the number of leaves per plant and number of tillers per plant were higher (P<0.05) in CO-4 at 2, 4 and 6 weeks of age compared to Pakchong-1 grass. According to Muldoon & Pearson (1979), when plants had more number of tillers per plant, it had a positive relationship with dry matter yield . According to Muldoon and Pearson (1979), the short varieties of Napier had denser tillering capacity compared to the tall varieties of Napier showing a difference in photosynthesis ability. When there are a higher number of tillers in the plant, it re-establishes its lost photosynthesis area (Wangchuk et al., 2015). Lafarge & Loiseau (2002) reported that tiller production is an important factor in the survival of tropical grasses. According to Wangchuk et al. (2015), Pakchong-1 tend to produce fewer but bigger tillers comparatively to that of other Napier hybrids.

Fresh and dry (DM) yield and leaf to stem ratio of CO-4 and Pakchong-1 at different cutting frequencies

Table 3 shows the yield and leaf: stem ratio of CO-4 and Pakchong-1 at different cutting frequencies.

Table 3: Fresh and dry matter yields and leaf: stem ratio of CO-4 and pakchong-1 at different cutting frequencies

Treatment	Fresh matter yield (ton/ha/year)	Dry matter yield (ton/ha/year)	Leaf : stem ratio
Treatment 1	100.6±14.8^{c}	12.5±1.6^{c}	0.88±0.03^{b}
Treatment 2	98.8±7.7^{c}	12.2±0.8^{c}	1.42±0.03^{a}
Treatment 3	147.5±18.2^{b}	15.4±1.6^{b}	1.34±0.06^{a}
Treatment 4	185.1±9.2^{a}	22.7±1.5^{a}	0.84±0.14^{b}

$^{a, b, c}$ Means (Mean ± SE) with different superscripts in a column are different (P<0.05)
Treatment 1- CO-4 harvested at 45 days, Treatment 2- Pakchong-1 harvested at 45 days, Treatment 3- Pakchong-1 harvested at 55 days, Treatment 4- Pakchong-1 harvested at 65 days

When considering fresh or dry matter yields, there was no significant difference between CO-4 and Pakchong-1 at 45 days, however fresh or dry matter yields were higher (P<0.05) in Pakchong-1 harvested at 55 and 65 days when compared to CO-4 and Pakchong-1 harvested at 45 days. Similarly, Wangchuk et al. (2015) has also observed a higher DM yield per plant in Pakchong-1 compared to Napier hybrid CO-3. Obok et al. (2012) stated that there was a positive correlation between plant height and fodder yield in Napier grasses when grown in Central Gujarat. In the present experiment, Pakchong-1 had a higher plant height with age (Table 1) and higher fresh and dry yields (Table 2) supporting the above observation.

Leaf to stem ratio is an important parameter that influences the nutritive value and voluntary intake of animals (Minson and McLeod, 1970). Leaf to stem ratio was similar between CO-4 at 45 days and Pakchong-1 at 65 days whereas higher (P<0.05) values were observed in Pakchong-1 at 45 days and 55 days (Table 3). The lower (<0.05) leaf: stem ratio in Pakchong-1 at 65 days compared to 45 and 55 days may be due to the increase in the proportion of stems compared to the leaves with age (Karanja, 1984; Kariuki, 1989; Smart et al., 2004; Tessema et al., 2010). Supporting the above finding, Wangchuk et al. (2015) has also obtained a lower (P<0.05) leaf : stem ratio for Pakchong-1 at 60 days cutting interval (0.82) compared to 40 days cutting interval (4.80). According to Butt et al. (1993), when the cutting frequency is longer, it stimulates the growth of stems and affects negatively on the leaf production.

Nutritive value of CO-4 and Pakchong-1 (Mawelawatte farm)

Table 4 presents the nutritive value of CO-4 and Pakchong-1 grasses at different cutting frequencies. Ash, CP, EE and *IVOMD* percentages were higher (P<0.05) at the 45-day cutting frequency in both CO-4 and Pakchong-1 compared to Pakchong-1 at 55 and 65 days cutting frequencies. Lowest (P<0.05) Ash, CP, EE and *IVOMD* percentages were observed in the 65 days cutting frequency compared to other treatments. In support of the present finding, Wangchuk et al. (2015) also observed that the CP percentage of Pakchong-1 decreased drastically from 28.2 % at 40-day to 8.8 % at 80-day cutting intervals, respectively. According to literature Napier grasses are usually negatively related to CP content with the maturity (Minson and McLeod, 1970). Under good management practices, Pakchong-1 is considered as a crop with a higher CP concentration (16−18%) (Kiyothong, 2014). The CP percentage in the present experiment varied between 17.7% to 13.3% at 45 and 65-day cutting frequency, respectively. However, CP % in Pakchong-1 in the present experiment is within the range recommended for the livestock diets. According to Table 4, longer the cutting frequency higher (P<0.05) the CF and NFE percentages. In general, NFE content of forage is decreased with the maturity due to the increase in structural components such as cellulose and hemicellulose in the cell wall (Minson and McLeod, 1970; Van Soest, 1994; Tessema et al., 2010). However, in the present experiment even though the *IVOMD* decreased with the longer cutting frequency, NFE percentage was increased. A possible explanation may be as Kiyothong (2014) stated that with maturity, Pakchong-1 had tender stems with less structural components.

Experiment 2: Effect of cutting frequency on fermentation characteristics of Pakchong-1

Table 5 presents the nutritional composition of pre-ensiled materials (initial samples) of Pakchong-1 at different cutting frequencies and CO-4, obtained from the farmer's field at Hingurakgoda.

Similar to the Experiment 1, Ash, CP, and EE percentages of Pakchong-1 decreased (P<0.05) while NFE has increased (P<0.05) when frequently harvested (45 days) compared to longer cutting intervals (55, 65 days) (Table 5). The highest (P<0.05) CP percentage was observed at Pakchong-1 at 45-day cutting frequency compared to other treatments. When Pakchong-1 grass matures from 45 days to 65 days, CP percentage was relatively decreased (P<0.05) by 22% (Table 5). Pitaksinsuk et al. (2010) found that CP percentage in Pakchong-1 decreased from 18% to 12.2% when harvested at 45 days compared to 60 days of cutting frequency.

Table 4: Nutritive value (%) of CO-4 and Pakchong-1 at Mawelawatte farm.

Treatment	ASH	CP	CF	EE	NFE	IVOMD
Treatment 1	13.6±0.4^{a}	16.4±0.2^{b}	32.1±1.1^{c}	6.9±0.06^{a}	22.0±4.0^{d}	69.77±0.5^{a}
Treatment 2	13.1±0.1^{a}	17.1±0.1^{a}	32.3±0.8^{c}	7.0±0.10^{a}	24.6±0.8^{c}	70.21±0.9^{a}
Treatment 3	12.4±0.1^{b}	15.2±0.1^{c}	33.3±0.1^{b}	6.2±0.07^{b}	28.4±1.5^{b}	68.33±0.6^{b}
Treatment 4	12.0±0.3^{c}	13.7±0.2^{d}	34.3±0.1^{a}	5.7±0.03^{c}	31.1±0.6^{a}	60.88±1.2^{c}

$^{a, b, c}$ Means (Mean ± SE) with different superscripts in a column are different (P<0.05)
Treatment 1- CO-4 harvested at 45 days, Treatment 2- Pakchong-1 harvested at 45 days, Treatment 3- Pakchong-1 harvested at 55 days, Treatment 4- Pakchong-1 harvested at 65 days
CP= Crude protein, CF= Crude fiber, EE= Ether extract, NFE= Nitrogen free extract, IVOMD- *In vitro* organic matter digestibility

Table 5: Nutritional composition (%) of Pre ensiled materials of Pakchong-1 and CO-4 at Hingurakgoda

Treatment	Ash	CP	CF	EE	NFE
Treatment 1	13.5 ± 0.3^{a}	16.3 ± 0.7^{b}	31.7 ± 0.1^{c}	6.1 ±0.02^{c}	25.2 ± 0.9^{c}
Treatment 2	13.9 ± 0.2^{a}	17.1 ± 0.1^{a}	32.4 ± 0.2^{c}	7.1 ± 0.1^{a}	23.7 ±0.2^{d}
Treatment 3	12.9 ± 0.1^{b}	15.2 ± 0.1^{c}	34.3 ± 0.4^{b}	6.3 ± 0.1^{b}	26.6 ±0.3^{b}

Treatment 4	12.1± 0.3[c]	13.3 ± 0.1[d]	29.7 ±0.6[a]	5.7 ± 0.1[d]	29.7 ±0.6[a]

[a, b, c, d] Means (Mean ± SE) with different superscripts in a column are different (P<0.05)
Treatment 1- CO-4 harvested at 45 days, Treatment 2- Pakchong-1 harvested at 45 days, Treatment 3- Pakchong-1 harvested at 55 days, Treatment 4- Pakchong-1 harvested at 65 days
CP= Crude protein, CF= Crude fiber, EE= Ether extract, NFE= Nitrogen free extract

The crude protein content of different cutting frequencies of Pakchong-1 observed in the present experiment are similar to those reported by Pitaksinsuk et al. (2010). Hybrid Napier CO-4 at 45-day cutting frequency had lower (P<0.05) percentages of CP, ash, EE and CF compared to Pakchong-1 at 45-day cutting frequency.

Recent reports indicate that water-soluble carbohydrates (WSCs) and dry matter (DM) contents of crops are principally important factors for the development of the lactic acid bacteria during ensilage (Jones et al., 1992; Yahaya et al., 2002). Therefore, Nitrogen free extract (NFE) and moisture contents of the initial samples are very important for good quality silage production. Nitrogen free extract represents the soluble carbohydrate such as sugars and starch of the feed/forage. Also, NFE is the major end product of starch and sugars' fermentation by the lactic acid bacteria during silage making. Therefore, Higher NFE content in forage results in higher levels of lactic acid production and consequently decrease the pH of the end products (Wilson and Wilkins, 1973). When Pakchong-1 grass matures from 45 days to 65 days, NFE percentage has been relatively increased (P<0.05) by 20% (Table 5). The highest (P<0.05) NFE percentage was observed in Pakchong-1 harvested at 65 days compared to other treatments.

Tessema et al. (2010) also found that higher cutting frequency reduces the growth and development whereas, longer intervals between harvest lead to accumulation of fibre and reduction in quality. Napier grass contains a higher proportion of structural cell wall carbohydrates that rapidly increases with the maturity causing a decline in crude protein concentration and digestibility (Van Soest, 1994). Total ash content is another important criterion in determining the quality of forage and it represents the total mineral content of the forage (Stokes and Prostko, 1998).

Comparison of physical characteristics of Pakchong-1 and CO-4 silage

According to Podkowka & Podkowka, (2011) colour and smell can be used to recognize well-fermented silage. The colour of the well-fermented silage should be light green or dull yellow, whereas that of the poorly fermented silage will be olive, blue-green or dark brown (Podkowka and Podkowka, 2011). In this experiment, the physical characters of all silages were satisfactory and had a brownish-green colour and a pleasantly fruity odour. Though the texture of all silage except Pakchong-1 harvested at 45 days was firm and soft, Pakchong-1 harvested at 45 days had a moist texture. The silages prepared from all cutting frequencies had no moulds, while the moulds were present only on the top layer of silage prepared from Pakchog-1 harvested at 65 days. Gordon et al. (1963) reported that, if the forage is too moist then the mould infections can be seen.

Comparison of fermentation characteristics of Pakchong-1 and CO-4 silage

According to the results, the lowest (P<0.05) lactic acid content was observed with CO-4 silage harvested at 45 days cutting frequency compared to all Pakchong-1 silages (Table 6). The lactic acid content of Pakchong-1 has been increased (P<0.05) with maturity. This high lactic acid content in Pakchong-1 silages is related to the higher NFE or WSC in the pre-ensiled material (Table 5).

Wilson and Wilkins (1973) reported that high concentrations of WSC are necessary for optimum silage fermentation. Therefore, when crops are ensiled, WSC are fermented by lactic acid bacteria under anaerobic condition and that will increase the accumulation of lactic acid resulting in a low pH.

Table 6: Fermentation characteristics (%) of Pakchong-1 and CO-4

Treatment	DM	pH	WSC	LA	NH3-N	IVOMD	IVDMD
Treatment 1	19.1 ± 0.1[c]	4.4 ± 0.04[a]	2.5 ± 0.1[a]	1.1 ± 0.1[a]	0.03 ± 0.001[c]	62.3 ± 0.1[b]	54.8 ± 0.4[c]
Treatment 2	17.5 ± 0.1[d]	4.4 ± 0.03[a]	0.7 ± 0.1[b]	1.4 ± 0.1[c]	0.04 ± 0.004[b]	64.4 ± 0.2[a]	59.3 ± 0.5[a]
Treatment 3	20.8 ± 0.2[b]	4.3 ± 0.02[b]	0.8 ± 0.1[b]	9.1 ± 0.1[b]	0.04 ± 0.003[bc]	59.0 ± 0.2[c]	56.9 ± 0.4[b]
Treatment 4	25.6 ± 0.8[a]	4.1 ± 0.02[c]	0.7 ± 0.02[b]	9.3 ±0.02[a]	0.05 ± 0.004[a]	57.0 ± 0.1[d]	54.0 ± 0.1[c]

[a, b, c, d] Means (Mean ± SE) with different superscripts in a column are different ($P<0.05$)
Treatment 1- CO-4 harvested at 45 days, Treatment 2- Pakchong-1 harvested at 45 days, Treatment 3- Pakchong-1 harvested at 55 days, Treatment 4- Pakchong-1 harvested at 65 days
DM= Dry Matter, WSC= Water Soluble Carbohydrate, LA= Lactic Acid, NH_3-N= Ammonia Nitrogen, IVOMD **%=** *In vitro* organic matter digestibility percentage and IVDMD % = *In vitro* dry matter digestibility percentage

Ensiling of Pakchong-1 at 45-day cutting frequency has shown a higher (P<0.05) pH compared to 55 days and 65 days cutting frequencies whereas CO-4 at 45 days had the highest (P<0.05) pH value. In general, low pH in silage indicates better fermentation of forage and thereby longer keeping quality of silage. Losses occur as protein in the grass is broken down into ammonium nitrogen (NH_3-N) by enzymes and bacteria during poor fermentation. According to Kung (2010), level of ammonia nitrogen content of good quality grass silage should be less than 8-12%. In this experiment ammonia nitrogen content of all silages was less than 1%, indicating all silages were well preserved. The DM content of all Pakchong-1 silages was higher (P<0.05) compared to CO-4 silage except pakchong-1 at 45 days cutting frequency. The highest (P<0.05) DM content (25.6%) of silage was recorded in Pakchong-1 at 65 days cutting frequency compared to other treatments. According to literature, when the forage has less dry matter content, there will be a considerable loss of juice and the silage will be poor quality unless a preservative is added (Gordon et al., 1963).

According to Table 6 Pakchong-1 silage at 45 days cutting frequency had a higher (P<0.05) *IVOMD* and IVDMD compared to CO-4 at 45 days cutting frequency. *In vitro* organic matter digestibility and *IVDMD* of Pakchong-1 silages were gradually decreased with maturity. Gunha et al. (2015) also found that *IVDMD* of Pakchong-1 at 45 days cutting frequency was 58.6% but it has been decreased to 53.9% when harvested at 60 days of cutting frequency.

CONCLUSION

Napier hybrid Pakchong-1 has shown that fresh and dry matter yields increased without compromising much of its quality, such as CP and NFE with maturity. Pakchong-1 exhibited a taller growth habit than CO-4 with a higher leaf: stem ratio. As the stalks of Pakchong-1 are tender its potential as a high-quality fodder is more certain under local conditions. The physical and chemical characteristics of the silage produced from Pakchong-1 at different cutting frequencies are at the satisfactory levels of quality silage. Pakchong-1, harvested at 55 days has shown intermediate quality and good fermentation characteristics. Thus, it can be concluded that the most effective stage of harvest of Pakchong-1 considering both aspects; feeding livestock and making silage will be 55 days cutting frequency.

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