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Thecnical note

Productive performance and nutritional value of *Pennisetum purpureum* cv. Cuba CT-115 grass at different regrowth ages

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Abstract:

Grass species forage yield and nutritional value directly affect livestock production performance. They also vary in response to regional climate and soil conditions. Forage yield and nutritional value in *Pennisetum purpureum* cv. Cuba CT-115 were evaluated at five regrowth ages (30, 45, 60, 75 and 90 d) in three seasons (dry, rainy and northwinds). A completely randomized block design with repeated measures was used, with four replicates per treatment. In all three seasons, maximum height was reached at 75 d: 127.1 cm in the dry season, 151.6 cm in the rainy season and 137.0 cm the northwind season. Forage yield was highest (27.0 t DM ha^{-1}) at 90 d in the rainy season, with a growth rate of 300.2 kg DM ha^{-1} d^{-1}, 7.3% crude protein and 37.0% *in situ* digestibility of dry matter. The leaf:stem ratio was highest at 30 d in all seasons, with a 1.65 average value. Crude protein content was highest in the northwind season at 30 and 45 d, with a 15.6 % average value. In all three seasons, digestibility was highest at 30 (mean= 49.3 %), 45 (51.8 %) and 60 d (48.2 %). Based on forage yield, use of *P. purpureum* cv. Cuba CT-115 grass for open grazing is recommended for cutting at 90 days' regrowth and based on its nutritional quality is recommended for grazing at 60 days' regrowth, both during the rainy season.

Key words: *Pennisetum purpureum*, Forage yield, Growth rate, Quality.

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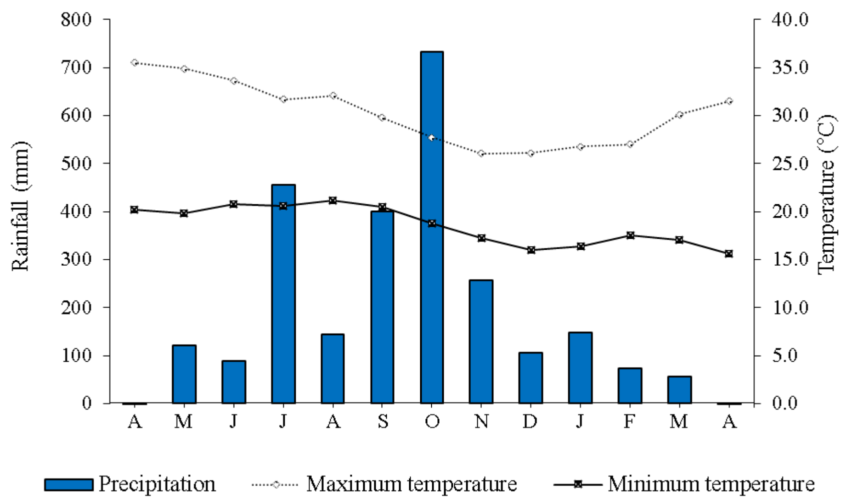
In the humid tropics of Mexico, forages are the main feed source for cattle. Forage availability and its nutritional value varies between seasons. Production is highest during the rainy season and declines during the northwind and dry seasons(1). Meat and milk production in grazing cattle respond directly to forage production, with decreased yields as forage production drops. Consequently, there is an ongoing search for forage species that meet animal nutritional requirements while maintaining constant, year-round production(2). The grass *Pennisetum purpureum* cv. Cuba CT-115 is part of this search. Created from a clone of King grass generated through tissue culture, this cultivar was originally introduced in Cuba in the 1990s. Its short internodes and low height make apt for direct grazing. In addition, beginning at four to six months of age it has high biomass production (15 t MS^{-1} ha) and higher nutritional value than the Cameroon, Dwarf and Taiwan cultivars of King grass(2,3).

Understanding a forage species' growth and production performance, and consequent forage availability, in a specific region is vital to designing management strategies that maximize animal production(4). Seasonal variations in growth rate, leaf biomass, leaf area index and plant height are used as criteria for guiding optimal and sustainable pasture management(5,6). Cutting frequency also influences forage yield(7). Seasonal and annual forage growth and yield are a direct function of weather conditions, soil fertility and management practices(8). To obtain maximum forage yield each forage species requires specific seasonal management(9). It is therefore important to understand a forage species' productive behavior and optimal harvest time since these parameters directly affect forage yield and pasture persistence(10).

No data has yet been published on the productive behavior of *P. purpureum* cv. Cuba CT-115 under the climatic and soil conditions of the state of Tabasco, Mexico. The present study objective was to evaluate the forage yield and nutritional value of *P. purpureum* cv. Cuba CT-115 at different regrowth ages during the dry, rainy and northwind seasons in Cambisol soil in the Chontalpa region of Tabasco.

The experiment was carried out under seasonal conditions from April 2011 to April 2012, at the Experimental Field of the Colegio de Postgraduados, in the state of Tabasco, Mexico, (17°59'15.6" N, 93°35'06.9" W; 12 m asl). Regional climate is Am, warm humid, with summer rains, 2,251 mm average annual rainfall and 26 °C average annual temperature(11). Rainfall during the experimental period was 2,576 mm, with 6. 9% falling in the dry season, 70.3 % in the rainy season and 22.8 % in the northwind season. The highest rainfall (723 mm) during the experimental period was recorded in October. Average temperature during the experimental period was 24.4 °C, with seasonal averages of 25.6 °C in the dry season, 25.7 °C in the rainy season and 21.8 °C in the northwind season. Maximum temperature during the experimental period was 35.3 °C in April and the minimum was 16.0 °C in December (Figure 1). Soil in the experimental field is Cambisol, with a clay loam texture, pH 5.5, 1.9 % organic matter (OM), 0.14 % nitrogen (N) and 21.4 mg kg^{-1} phosphorous (P).

Figure 1: Average monthly temperature and rainfall during experimental period at Experimental Field at Cárdenas, Tabasco



The *P. purpureum* cv. Cuba CT-115 pasture used in the present study was planted in 2009, in furrows spaced at 0.80 m and 1 m between plants. Since then, it has been grazed with cattle. A uniform manual cut was done on April 1, 2011, at an approximate height of 10 cm above ground surface. After this initial cut the field was fertilized with 100 kg nitrogen (urea) in three 33.3 kg applications: one in April, July and October. Weed control was done manually at the beginning of the experimental period.

Experimental design was a completely random block design involving five regrowth ages (30, 45, 60, 75 and 90 d) and three seasons (dry, March-May; rainy, June-October; and northwind, November-February). Four replicates were done of each treatment (e.g., regrowth age), using season as a repeated measurement(12). Samples were collected after reaching each successive regrowth age. Each of the twenty experimental plots consisted of four rows (4 m long, 0.80 m apart). The plots measured 4 x 3.2 m, with a total area of 12.8 m^2, and an effective area of 4.8 m^2 consisting of the central furrows.

Measurements were taken of plant height and these used to calculate forage yield, and growth rate (GR). The leaf:stem ratio was quantified using plant samples. Analyses were done of dry matter (DM), crude protein (CP), *in vitro* digestibility of dry matter (IDDM), neutral detergent fiber (NDF) and acid detergent fiber (ADF). Plant height, from soil surface to the top of the flag leaf[13], was measured immediately prior to cutting. Forage yield was estimated by harvesting plants inside the 4.8 m^2 effective area from ground level. A representative 3 kg subsample was taken from the harvested forage, washed and dried at 65 °C for 72 h in a forced air oven. Calculation of dry matter yield (DM) was done using the formula: DM = FM x % DM/100, where FM= fresh matter[13]. The leaf:stem ratio was calculated using a 2 kg subsample of the harvested forage. Its leaf and stem components were separated, weighed and dried at the temperature and time indicated above. Growth rate (GR) was calculated with the formula: GR= HF/t, where GR= growth rate (kg DM $ha^{-1}d^{-1}$), HF= harvested forage (kg DM ha^{-1}) and t= days elapsed between forage harvests[14]. Both DM and CP content were measured following the applicable AOAC techniques[15]. Established protocols were used to quantify IDDM at 24 h[16], and NDF and ADF[17]. All analyses were run at the Animal Science Laboratory of the Colegio de Posgraduados, Tabasco.

Results were evaluated with an analysis of variance (ANOVA) to identify statistical differences between the studied factors: treatments, seasons and the treatments x season interaction. A Tukey test (α=0.05) was applied for a multiple comparison of means for treatments, seasons and the treatments x season interaction. Significant differences were analyzed following the general guide A factor (treatments) effects in each B factor (season) level[18]. All analyses were run with the Proc Mixed procedure and Slice instruction in the SAS ver. 9.4 software[19].

The ANOVA identified differences ($P<0.05$) in the treatments x seasons interaction in all the evaluated variables. Plant height increased as regrowth age increased, the highest value (165.1 cm) being recorded at 90 d in the rainy season; this is 10.8 % higher than in the northwind season and 15.4 % higher than in the dry season. Forage yield also increased as regrowth age increased, the highest yield (27.0 t DM ha^{-1}) also being observed at 90 d in the rainy season. In all three seasons, leaf:stem ratio values decreased as regrowth age increased, the highest value (1.79) being recorded at 30 d in the rainy season. Growth rate (GR) was highest (300.2 kg DM $ha^{-1}d^{-1}$) at 90 d in the rainy season. Average GR in the rainy season was 237.3 kg DM $ha^{-1}d^{-1}$, which is 105 % higher than in the northwind season and 148 % higher than in the dry season (Table 1).

Table 1: Plant height, forage yield, leaf:stem ratio and growth rate in *Pennisetum purpureum* cv. Cuba CT-115 at different regrowth ages in three seasons

Seasons	Regrowth age (days)				
	30	**45**	**60**	**75**	**90**
Plant height (cm)					
Dry	59.4^{c}	91.5^{b}	96.0^{b}	127.1^{a}	147.2^{a}
Rainy	64.4^{c}	103.8^{b}	123.3^{b}	151.6^{a}	165.1^{a}
Northwind	45.0^{c}	64.7^{c}	98.5^{b}	137.0^{a}	138.9^{a}
Forage yield (t DM ha^{-1})					
Dry	4.0^{b}	4.2^{b}	3.9^{b}	5.0^{b}	10.7^{a}
Rainy	5.9^{c}	6.6^{c}	16.3^{b}	20.3^{b}	27.0^{a}
Northwind	3.1^{c}	2.9^{b}	7.8^{ab}	11.8^{a}	11.3^{a}
Leaf:stem ratio					
Dry	1.73^{a}	1.69^{a}	0.79^{b}	0.82^{b}	0.76^{b}
Rainy	1.79^{a}	1.15^{b}	0.88^{bc}	0.72^{c}	0.56^{c}
Northwind	1.43^{a}	1.26^{ab}	0.85^{bc}	0.94^{bc}	0.75^{c}
Growth rate (kg DM ha^{-1} d^{-1})					
Dry	134.8^{a}	92.9^{a}	65.4^{a}	66.8^{a}	119.3^{a}
Rainy	196.4^{bc}	147.7^{c}	272.0^{ab}	270.9^{ab}	300.2^{a}
Northwind	103.4^{ab}	65.3^{b}	129.2^{ab}	156.9^{a}	125.5^{ab}

^{abc} Different letter superscripts in the same row indicate statistical difference (Tukey, $P<0.05$).

In all three seasons, DM increased as regrowth age increased. The highest average values were recorded at 90 d: 23.7 % in the dry season, 19.4 % in the rainy season and 15.4 % in the northwind season. At all five regrowth ages, DM values were higher in the dry season, with a 19.7 % average. This average is 16.2 % higher than in the rainy season and 35 % higher than in the northwind season. Crude protein (CP) values decreased as regrowth age increased. The highest values were all recorded at 30 d: 15.7 % in the northwinds season, 12.5 % in the dry season and 10.4 % in the rainy season. At all five regrowth ages, average CP values were highest (13.1 %) in the northwind season. This value is 50.6 % higher than in the rainy season and 57.8 % higher than in the dry season. In all three seasons, IDDM remained unchanged up to 60 d regrowth and decreased after 75 d regrowth. The lowest NDF values were observed at 45 d in the dry and rainy seasons. No differences were found at any of the regrowth ages in the northwind season. In contrast, ADF content increased as regrowth age increased, the highest value (47.1 %) being observed at 90 d in the rainy season, which had 43.2 % average ADF.

An increase in plant height at greater regrowth ages is normal behavior in upright growth grasses[20]. The highest height was recorded in the rainy season and can be attributed to the higher rainfall (1,812 mm) and temperature (25.7 °C) values recorded in that season. In *P.*

purpureum, both higher rainfall and temperature favor photosynthesis, and consequently growth. As expected, the lower precipitation (586 mm) and temperature (21.8 °C) of the dry season, in addition to its shorter days, high winds and greater cloud cover, negatively affected plant photosynthesis capacity, slowing growth. Lower heights have been reported previously for *P. purpureum* cv. Cuba CT-115. For example, during the dry season heights of 31 cm at 75 d regrowth and 53 cm at 90 d have been reported(21). In a study evaluating *P. purpureum* clones, height was 68 cm at 60 d regrowth during the rainy season and 64 cm at 90 d in the dry season(22). In an evaluation of 12 *P. purpureum* species, heights during the rainy season were 56.4 cm at 60 d regrowth and 66.3 cm at 90 d. In the present study, regardless of season, average plant height at 60 d regrowth was 105.9 cm. Since maximum height for direct grazing of this grass cultivar is 100 cm(23), 60 d regrowth is apparently the optimal time of use for this grass under the present study conditions.

Forage yield was highest (27.0 t DM ha^{-1}) in the rainy season at 90 days' regrowth; this yield was 139 % higher than in the northwind season and 151 % higher than in the dry season. There is a positive correlation between plant age and yield, and rainfall and yield, as observed elsewhere(24). The forage yields observed in the present study are notably higher than previously reported for the studied cultivar. For example, one study found a 3.8 t DM ha^{-1} yield during the rainy seasons and a 1.2 t DM ha^{-1} yield during the dry season(22). In eight *P. purpureum* clones, yields of 2.5 t DM ha^{-1} were observed in the rainy season and 0.47 t DM ha^{-1} in the dry season(25). Such broad discrepancies in results may result from variations in climate conditions, crop management practices and soil fertility. Forage yield distribution in the present study was 5.6 t DM ha^{-1} in the dry season, 7.4 t DM ha^{-1} in the northwinds season and 15.2 t DM ha^{-1} in the rainy season. The lower yield observed during the dry season can be attributed to the substantially lower rainfall (178 mm) during this season, which negatively affects the biochemical process of plant photosynthesis(24). In the northwind season, the lower yield is more probably due to its lower temperatures rather than the relatively lower precipitation.

In all three seasons the leaf:stem ratio was highest at 30 d regrowth, which can be attributed to the higher number of leaves present at early ages in this grass species. This parameter decreased from 1.65 at 30 d to 0.69 at 90 d, analogous to the decrease from 1.33 at 33 d to 0.77 at 90 d reported elsewhere for *P. purpureum*(26).

The high GR observed in the present study during the rainy season can be attributed to the higher rainfall and temperatures (1,812 mm and 25.7 °C, respectively) occurring during this season. These favor plant metabolic activity, increasing the amount of photosynthates and, consequently, DM production. In contrast, the lack of rainfall in the dry season clearly limits plant growth. In all three seasons GR increased at 60, 75 and 90 d regrowth, indicating an increase in DM yield with age. The same response has been reported previously in *P. purpureum* cv. Cuba CT-115(27,28), as well as in *P. purpureum* cv. King(29).

The above growth response also accounts for the greater fiber accumulation with age observed in the present results, which is normal in tropical grasses[26]. It occurs because the proportion of cell wall in a plant, directly associated with DM content, increases with age as the leaf:stem ratio tips in favor of stems, more vascular bundles appear, cell content decreases and water is lost[28,29]. In the present results, DM content was highest (23.7 %) in the dry season, perhaps due to water stress caused by greater leaf maturation and senescence, and consequent DM accumulation. Compared to stems, leaves have a higher senescence rate because their surface is more sensitive, causing them to lose more water[29].

The lower CP content with greater regrowth age observed in the present results can be attributed to the lower leaf:stem ratio with plant age. The higher leaf:stem ratio at younger ages results in higher CP content since protein occurs in greater quantities in leaves. In addition, synthesis of structural components such as cellulose, hemicellulose and lignin increases as plants mature, lowering forage quality in grasses. The highest CP content in the present results were lower than reported elsewhere for this cultivar during the rainy season (14.5 % at 28 d, 12.0 % at 56 d and 11.0 % 84 d regrowth)[28]. However, CP contents at all the regrowth times and in all three seasons in the present study were above the 7 % minimum CP level required for proper rumen functioning[30].

The lower IDDM values with greater regrowth age observed in the present study were due to the higher leaf:stem ratio at 30, 40 and 60 days' regrowth than at 75 and 90 days' regrowth (Table 2). Older forage plants have higher DM percentages and more NDF and ADF content because, as they mature, the proportion of stems increases and that of leaves decreases (i.e., the leaf:stem ratio drops), increasing the amount of structural carbohydrates and lignin, which directly influence forage digestibility and use efficiency[31]. The average IDDM in the present results (46.2 %) is considered low, although it is only slightly lower than the 50.1 % reported for this cultivar at 56 days' regrowth and 24 h incubation[32]. The average rainy season NDF (75.5 %) and ADF (43.2 %) values in the present results are similar to the 72.2 % NDF and 44.1 % ADF reported for another *Pennisetum* species[33]. In the present study, both NDF and ADF contents were highest in the rainy season at 60, 75 and 90 days' regrowth. This is probably due to the higher rainfall and temperature values in this season, which would generate more growth, more stem production and, consequently, more DM, cellulose, hemicellulose and lignin accumulation[17]. The present results coincide with the literature, which indicates that tropical grasses grow and mature quickly, causing changes in their chemical composition and decreased forage nutritional quality.

Table 2: Nutritional value of *Pennisetum purpureum* cv Cuba CT-115, at different age of regrowth in three seasons

Seasons	**Regrowth age (days)**				
	30	**45**	**60**	**75**	**90**
			Dry matter (%)		
Dry	17.4^{b}	18.4^{b}	19.3^{b}	19.6^{b}	23.7^{a}
Rainy	14.4^{b}	14.7^{b}	16.2^{ab}	17.9^{ab}	19.4^{a}
Northwind	10.6^{b}	11.2^{ab}	12.2^{ab}	14.4^{ab}	15.4^{a}
			Crude protein (%)		
Dry	12.5^{a}	7.8^{b}	7.1^{b}	7.0^{b}	7.4^{b}
Rainy	10.4^{a}	10.9^{a}	7.9^{b}	7.0^{b}	7.3^{b}
Northwind	15.7^{a}	15.5^{a}	13.0^{b}	11.2^{bc}	10.3^{c}
			In situ degradation of dry matter (%)		
Dry	48.1^{ab}	54.3^{a}	49.4^{ab}	46.7^{b}	42.9^{b}
Rainy	51.3^{a}	49.8^{a}	45.1^{ab}	40.2^{b}	37.0^{c}
Northwind	48.6^{a}	51.3^{a}	50.1^{a}	39.0^{b}	39.3^{b}
			Neutral detergent fiber (%)		
Dry	60.7^{c}	62.9^{bc}	67.4^{ab}	70.5^{a}	64.4^{bc}
Rainy	70.1^{b}	70.0^{b}	77.0^{a}	79.7^{a}	80.6^{a}
Northwind	65.4^{a}	68.0^{a}	67.1^{a}	70.8^{a}	68.2^{a}
			Acid detergent fiber (%)		
Dry	31.6^{c}	33.6^{bc}	39.3^{ab}	34.3^{bc}	43.6^{a}
Rainy	38.8^{b}	40.3^{b}	44.9^{ab}	45.0^{ab}	47.1^{a}
Northwind	33.8^{b}	34.9^{ab}	35.9^{ab}	36.9^{ab}	40.8^{a}

^{abc} Different letter superscripts in the same row indicate statistical difference (Tukey, $P<0.05$).

Forage yield of the grass *Pennisetum purpureum* cv. Cuba CT-115 studied here increased with regrowth age, providing a yield distribution of 53.9 % in the rainy season, 26.2 % in the northwind season and 19.9 % in the dry season. Total annual production under the experimental conditions was 28.2 t DM ha^{-1}. Forage nutritional value in terms of CP, IDDM, and NDF and ADF content decreased with regrowth age. From a forage yield and quality perspective, *Pennisetum purpureum* cv. Cuba CT-115 grass is best at 60 days' regrowth for direct grazing and 90 days' for cutting.

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