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RESEARCH ARTICLE

EFFECT OF CUTOFF FREQUENCIES ON PRODUCTIVITY AND CRUDE PROTEIN CONTENT IN FOUR CLONES OF PENNISETUM PURPUREUM CULTURED IN LUVISOLIC SOILS

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Abstract

The objective of this study was to evaluate the forage production and the crude protein content of the OM-22, CT-115, CT-169 and Purple King grass clones of *Pennisetum purpureum* by three cutoff frequencies. The experiment was carried out in the Chetumal Experimental Field of INIFAP in Quintana Roo, with humid subtropical climate Aw1, at 10 masl, temperature of 27.6 °C and an average annual precipitation of 1300 mm. The soils of the study area are the so-called luvisols. An experimental design block randomly was used in an arrangement of divided plots where the largest plot was the species under study and the sub-plot the cutoff frequency (60, 90 and 120 days) with 3 repetitions per treatment. The sowing was done in plots of 4 x 9 m, samplings were carried out according to the cutting date. Statistical Analysis System (SAS) was used for ANOVA procedure, statistical analysis and means comparison accord Tukey test. The variables measured were: plant height (PH), plant circumference average (PCA), leaf length (LL), leaf width (LW), shoots number average (SNA), buds number average (BNA) and dry matter production (DMP). Results indicated differences ($P < 0.05$) for cutting frequencies (60, 90 and 120) and clones, in the variables: PH with 176.5, 189 and 2.5 cm respectively, for LL with 91.1, 95.6 and 99.2 cm, BNA for cuts the trend was 8.1, 7.4 and 5.4 buds per ten stems for 120, 90 and 60 days respectively. Among clones the average values were 9.9, 8.7, 7.5 and 6.6, for CT169, King grass purple, OM22 and CT 115, respectively. For PCA the results indicate differences among clones and cutting frequencies. For DMP, results indicated that differences were observed for cuts ($P \leq 0.05$) where the highest DMP was 120 days followed by 90 and 60 with averages of 70, 44 and 31 ton DM/ha respectively. For interaction, the highest average was 78 ton DM/ha for the clone OM22 cut to 120 days.

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Introduction:-

The Low productivity of livestock in tropic is one of the characteristics which is due to combination of many factors as breeds, health aspects, management practices and animal nutrition, this last depend on the forage quality and

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production. Feeding base in grazing cattle principally came from low quality and unproductive native grams, naturalized pastures, crop residues and in some cases commercial food (Zepeda *et al.*, 2018).

Continuous grazing with high loads of animals, annual burning of grasslands, prolonged dry season, sporadic attack of spotted spittlebug of pastures (*Cercopidae*) and low levels of nitrogen and possible immobilization of phosphorous in soil has generated a degradation process which decrease its productivity per year. Forage species production in tropic are characterized for a high seasonality which is caused by precipitation and temperature variation (Herrera, 2009).

One of the problems that limit the livestock development is the lack of good quality forage species adapted to the environmental conditions of livestock zones in entity (Sosa *et al.*, 2015). To solve this problem, the introduction and establishment of forage species (gramineous) with high production potential, quality, persistence and adaptation to edaphic and climatic condition in tropic zone is one of effective ways to increase and to improve the production and productivity of livestock.

Forage genetic resources contribute in an important way the ecological and productive equilibrium of natural and induced ecosystems, however, nowadays is commonly depend of many forage species without consider the genetic potential which can satisfy the livestock requirements, for instants OM-22, CT-115, CT-169, like so *Pennisetum* cv king grass (KNG) which was generated by genetic crosses (Martínez, 2010; Caballero-Gómez *et al.*, 2016). King Grass, introduced to Cuba in 80's, was used as donor plant in a breeding program by The Animal Institute Science and from this program, new clones were obtained of which Cuba CT-115 and Cuba-169 were selected for grazing. The first one showed low-growth and trampling tolerance and the second one showed high and fast growth (Martínez *et al.*, 1996), furthermore, this last was used to obtain the Cuba OM-22 variety by *P. purpureum* x *P. glaucum* crossing.

Previous research with these two grasses carried out in Yucatan Peninsula (Ramos *et al.*, 2013), allowed to identify adapted species to the region. These species showed productive potential and were considered as an alternative to improve the livestock productivity. Nevertheless, in forage species quality and production depend on three important factors: height, harvesting time and cut frequency (Santana *et al.*, 2010). *Pennisetum* genus has species that show fast growing and present high yielding from 23 to 30 t/ha from 4 to 20 weeks (Jukanti *et al.*, 2016; Lawal, 2016; Sandhu *et al.*, 2019), however, chemical composition, digestibility and nutritive value can be affected by regrowth age (Ramos *et al.*, 2013). In a research presented by Hinojosa *et al.* (2014), cutoff frequencies (30,45,60 and 75 days) in Maralfalfa (*Pennisetum* sp.) showed the higher annual dry matter yield (34.8 t/ha/year⁻¹) at 75 days of cut. On the other hand, Madera *et al.* (2013) concluded that the age of the plant at cutting affected the yielding in *P. purpureum* in a research established in Yucatan, Mexico. Similar results were reported by Cerdas and Vallejos (2010) in Cameroon grass in a dry zone in Costa Rica.

This study was realized to improve the production and quality in clones of *Pennisetum purpureum* cultured in Yucatan region with vertisol soils. The analysis and evaluation of three cutoff frequencies in this species permitted to obtain the background future research which could contribute in future plant breeding programs.

Materials and methods:-

Study localization, climate and soil conditions:

The present study was carried out from 2013 to 2015 in Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), campo experimental Chetumal, located in Othon P. Blanco, Quintana Roo at 3.5 km of Xul-Ha community with 21°30' N and 89°29' W coordinates. Climate conditions are 27.6° C and 62.3% of relative humidity on average, annual medium precipitation is 1300 mm and the period with the most precipitation was from June to November. Experimental plots were established in vertisol soils with high montmorillonite content which form cracks in dry season.

Experimental design and plot preparation:

Four clones of *P. purpureum* (OM-22, CT-115, CT-169 and Purple king grass) with 18 months old were established in a random complete blocks design with arranged in divided plots. The mayor plot was the clone studied and the minor plot was the cutoff frequency (60,90 and 120 days), each treatment had three replicates. Soil preparation in each plot was conventional by equipment for fallow, crawl and furrow. Plant sowing was carried out in a plot of 4x9 m, each plot had four skip-rows of 0.80 m and skip-plant of 0.30 m.

Evaluation and information analyzing:

Data were collected from central rows per each plot. Two observation types were considered in evaluation, which were establishment time and evaluation of production. Morphological variables were evaluated each 15 days and were considered: plant height (PH) from soil to the highest part of the plant without spread and not considering the inflorescences, plant circumference average (PCA) of four plants, leaf length (LL) in green leaves from ligule base to leaf tip, width leaf (WL), shoots number average (SNA) per three plants, buds number average (BNA) per ten stems and dry matter production (DMP). At the beginning of the forage production period, a cutoff homogenization was carried out at 15 cm of length, once the forage of each plot harvested and green forage (fresh weight) was weighed, three samples were processed in laboratory of Campo Experimental Chetumal in INIFAP. The samples were dried in a Forced Air Oven at 66°C per three days. Afterward, samples were weighted again to obtain the dry matter production. Furthermore, crude protein percentage (CPP) was measured from dry matter. Dry matter was milled with a Thomas Wiley® Mini Cutting Mills with sieve of 3 mm, packed, tagged and sent to bromatology laboratory of Universidad Autonoma de Yucatan for analyzing. Variance analysis and Tukey test ($P < 0.05$) was carried out with Statistical Analysis System (SAS) Software.

Results:-

Statistical differences ($p \leq 0.05$) were detected for PH in cutoff frequencies and clones, like so the interaction in treatments. The highest PH observed at 120 days of cutoff was 2.8 m, in the case of 60 and 90 days of cutoff, the highest values were 1.84 and 1.96 cm respectively. In interaction treatment, the CT-169 clone showed the highest height with 2.8 cm at the 120 days of cutoff and the lowest was CT-115 with 1.71 m at the 60 days. In LL, significative differences ($P \leq 0.05$) were detected both cutoff frequencies and clones, the averages obtained for 60, 90 y 120 days of cutoff were 91.3, 95.6 y 99.2 cm respectively. In interaction, the OM-22 clone presented the most LL (114.1 cm) at 120 days, in the case of CT-115, CT-169 and purple king grass clones, reached the highest values of 95.3, 92.0 and 95.6 cm respectively (Table 1).

Table 1:- Plant heights and lengths of Cuban clone plants in three cutoff frequencies.

| Cuban clone | Cutoff frequencies (days) | | | | | | |
|-------------------|---------------------------|--------------------|-------------------|--|--------------------|--------------------|--------------------|
| | Plant height (m) | | | | Leaf length(cm) | | |
| | 60 | 90 | 120 | | 60 | 90 | 120 |
| CT-115 | 1.71 ^c | 1.85 ^{cd} | 2.7 ^{ab} | | 89.9 ^b | 91.2 ^b | 95.3 ^b |
| CT-169 | 1.84 ^a | 1.96 ^a | 2.8 ^a | | 87.4 ^c | 90.0 ^c | 92.0 ^c |
| OM-22 | 1.73 ^{bc} | 1.84 ^c | 2.5 ^{ab} | | 100.1 ^a | 109.3 ^a | 114.1 ^a |
| Purple king grass | 1.79 ^{bc} | 1.91 ^b | 2.2 ^{cb} | | 87.9 ^b | 92.0 ^b | 95.6 ^b |

Similar letters correspond to treatments statistically equal according to Tukey test ($P \leq 0.05$).

In plant circumference average (PCA), significative differences for cutoff ($p \leq 0.05$) were observed. The highest value was obtained at the 60 days with 160.83 ± 12.2 cm, followed by 120 days with 124.96 ± 15.08 cm and 90 days with 112.70 ± 0.91 cm for all clones. In width leaf (WL), no significant statistical differences were detected. Presented values were 3.48, 3.44 and 3.27 cm for 120, 90 and 60 days of cutoff respectively, even though in CT-115, CT-169, purple king grass and OM-22 clones were obtained 2.8, 3.5, 3.7 and 4.2 cm of WL respectively. In shoot number average (SNA), no differences significative were detected ($P \geq 0.05$) in cutoff frequencies. Values obtained for this variable were 28.43 ± 5.00 , 24.45 ± 3.53 and 22.27 ± 1.98 shoots average for 60, 120 and 90 days of cutoff. Nevertheless, for CT-115, OM-22, Purple king grass and CT-169 clones were obtained 19, 21.5, 24.7 and 32.5 SNA respectively. In buds number average (BNA), results showed significative statistical differences ($P \leq 0.05$) both cutoff frequencies and clones, as well as, interaction variables. In cutoff frequencies, 8.13 ± 0.32 , 7.40 ± 1.27 and 5.46 ± 1.33 BNA were detected for 120, 90 and 60 days of cutoff respectively. In clones, average values were 9.9, 8.7, 7.5 and 6.6 for CT-169, purple king grass, OM-22 and CT-115, respectively and finally in interaction treatments, the most value detected was 21.0 BNA for CT-169 clone at the 120 days of cutoff (Table 2).

Table 2:- Plant circumference, width leave, shoots number and buds number averages in three cutoff frequencies of clones evaluated of *Pennisetum purpureum*.

| Cutoff frequencies (Days) | Plant circumference average (cm) | Width Leave average (cm) | Shoots number average | Buds number average |
|---------------------------|----------------------------------|--------------------------|-----------------------|---------------------|
|---------------------------|----------------------------------|--------------------------|-----------------------|---------------------|

| | | | | |
|-----|---------------------------|------------------------|-------------------------|-------------------------|
| 60 | 160.83±12.2 ^a | 3.27±0.15 ^a | 28.43±5.00 ^a | 5.46±1.33 ^c |
| 90 | 112.70±0.91 ^c | 3.44±0.15 ^a | 22.27±1.98 ^a | 7.40±1.27 ^{ab} |
| 120 | 124.96±15.08 ^b | 3.48±0.20 ^a | 24.45±3.53 ^a | 8.13±0.32 ^a |

Similar letters correspond to treatments statistically equal according to Tukey test ($P \leq 0.05$)

The results for dry matter production (DMP) indicated significant differences ($p \leq 0.05$) in treatments. The average of DMP obtained was 70.5 ton DM/ha at 120 days followed by 44.3 at 90 days and 31.3 at 60 days of cutoff. In interaction treatments the average was 78 ton DM/ha for OM-22 clone at 120 days (Table 3).

Table 3:- Forage yield (ton DM/ha) and quality of Cuban clones in three cutoff frequencies.

| Cuban clone | Cutoff frequencies (days) | | | | | |
|-------------------|---------------------------|-------------------|-----------------|-------------------|-----------------|-------------------|
| | 60 | | 90 | | 120 | |
| | DMP (ton/ha) | CPC (%) | DMP (ton/ha) | CPC (%) | DMP (ton/ha) | CPC (%) |
| CT-115 | 31 ^a | 12.3 ^a | 37 ^b | 11.4 ^a | 67 ^c | 10.8 ^a |
| CT-169 | 31 ^a | 12.8 ^a | 47 ^a | 11.7 ^a | 72 ^b | 10.7 ^a |
| OM-22 | 32 ^a | 11.7 ^b | 47 ^a | 11.0 ^a | 78 ^a | 8.9 ^b |
| Purple King grass | 31 ^a | 12.7 ^a | 46 ^a | 11.8 ^a | 65 ^c | 11.0 ^a |
| Average | 31.3 | 12.4 | 44.3 | 11.5 | 70.5 | 10.4 |

Similar letters correspond to treatments statistically equal according to Tukey test ($P \leq 0.05$). DMP: dry matter production, CPC: crude protein content.

Crude protein content (CPC) is influenced by cutoff frequency ($P \leq 0.05$). The CPC decreased in four clones when the regrowth was old (Figure 1). Furthermore, differences in CPC between clones were observed. The OM-22 clone showed the lowest values in cutoff frequency of 60 and 120 days evaluated, but it was different ($P \geq 0.05$) in 90 days of cutoff frequency (Figure 1c)

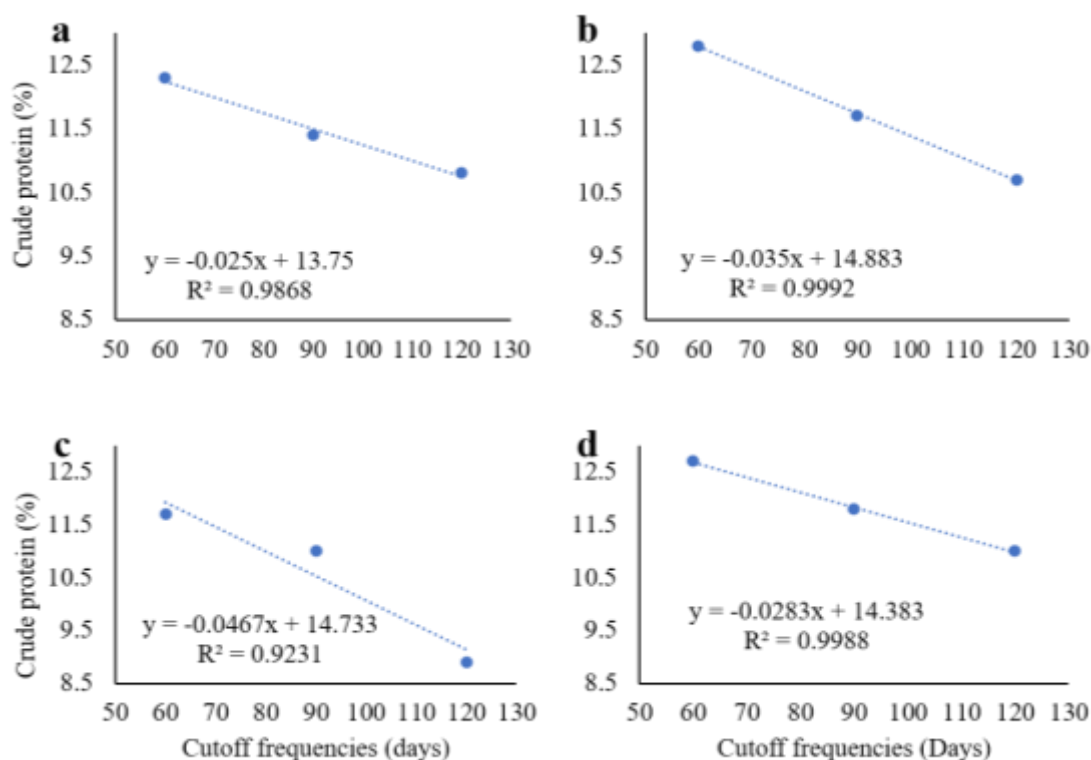


Figure 1:- Effect of forage cutoff frequency in crude protein percentage of *Pennisetum purpureum*. a) CT-115 clone, b) CT-169 clone, c) OM-22 clone and d) Purple king grass clone.

The CPC for 90 days of cutoff frequencies was similar in all clones which showed values from 11.0 to 11.8 % of protein crude (Figure 1). With regard to treatments of 120 days of cutoff frequency, it was not observed significant differences ($P \geq 0.05$) in CT-115, CT-169 and purple king grass clones about crude protein percentage, but in OM-22 clone, significant difference ($P \leq 0.05$) was observed due to showed the lowest value (8.9 %) as can be observed in Figure 1c.

Discussion:-

The PH observed (176.5 and 189 cm) at 60 and 90 days was higher than the studies reported in *P. purpureum* by Díaz (2007). He mentioned that average heights observed in his studies were 37 and 93 cm at 60 and 90 days respectively. Whereas for CT-115 clone, our results are similar to those reported by Martínez *et al.* (1996) who mentioned that this clone showed the lowest height at the same cutoff frequencies in comparison to the other clones that he studied, nonetheless averages observed in the three cutoff frequencies evaluated for each clone are agree with Zepeda *et al.* (2018), who reported that plant height tends to increase at older ages but different behavior between clones. This coincides with observed by Martínez *et al.* (2010), who found that CT-169 presented a tall size and rapid growth, and by Caballero (2013), who obtained a higher height in CT-169 accession, without significant differences with the king grass and CT-115. Da Cunha *et al.* (2011) mentioned that this behavior is attributed to the biochemical, physiological individuality, high genetic variability and distinctive morphological characteristics of each plant, which determine its productivity and quality. This behavior was also observed by Leonard *et al.* (2014) and García *et al.* (2014) when they evaluated *Cenchrus* genus plants to determine growth and yield and they concluded that these two variables were related with regrowth age.

The PCA in our results were less than reported by Díaz (2007) in *Pennisetum* varieties studied. He mentioned that PCA were 200 cm, in contrast our results showed 160, 112 and 134 cm at 60, 90 y 120 days of cutoff respectively. However, in another study carried out in Yucatan peninsula by Chuc (2004), values of 45.12, 46.40 y 56.37 cm at 30, 60 y 90 days of cutoff respectively were showed, it means that our results were higher than he reported. On the other hand, values obtained in OM-22 clone did not adjust in a mathematical model due to values that were high at 60 days of cutoff and then low at 90 days and then high again at 120 days, this behavior were similar to the reported by Zepeda *et al.* (2018), who mentioned that PCA in OM-22 clone decreased between 45 and 90 days of cutoff and then increased again.

For LL, our data were similar to that obtained by Ledea Rodríguez *et al.* (2018), who studied new varieties of *Cenchrus purpureus* at 60, 80, 100 and 120 days of cutoff frequencies. They indicated uniform behavior in all varieties in time function, but different behavior per each variety. Also, our results are similar to those of Martínez *et al.* (2009) who mention that the CT-169 clone is characterized by robust stems and long internodes, with longer and wider leaves than purple king grass. By contrast, Pastrana and Rivas (2015) reported that when cutting the CT-169 from 42 to 84 days, they found average values of 104.9 cm in LL, this means that our results differ with that they obtained.

The data obtained for WL in this study were different from those obtained by Pastrana and Rivas (2015) because they report values of 4.67 to 5.56 cm and 3.87 to 4.52 cm of width leaf for OM-22 and CT-169 at cutoff frequencies of 42 to 84 days respectively. Nevertheless, the widest leaf value observed in the OM-22 clone agrees with that mentioned by Martínez *et al.* (2009) who mention that this clone is an excellent forage plant with exuberant growth of very wide and glabrous leaves. In other studies, values of 3.7 cm of WL have been reported in clone CT-115 established in northern Mexico (Nava *et al.*, 2013) and in the Yucatan peninsula (Chávez, 2003), nonetheless the growth values of the purple king grass and Cuba OM-22 clones demonstrated to have elements that are superior to other *Pennisetum*, since both clones are characterized by having longer and wider leaves.

Regarding SNA and BNA, García *et al.* (2014) found that SNA was lower when evaluating the same cultivars in times of higher and lower rainfall, they mention that their results could be due to the density of plants in the stage of establishment. However, Chuc (2004) described similar values to ours in clone CT-115. It is important to consider that severe intensity of defoliation could cause alterations in the morphology and structure of the pastures and, therefore, a decrease in the use of environmental resources for forage production.

In BNA, Espinoza (2009) reported 8 buds for each plant at different cutoff frequencies in studies with *Pennisetum*, this means that our results are similar to what they reported. Chuc (2004) reported values of up to 14 buds at 90 days. These studies could indicate that the behavior of the species could be influenced by the type of soil. In general,

clones do not perform well in soils with partial stagnation and soils poor in organic matter and with high rockiness, such as lithosols in the Yucatan peninsula, where many strains die or develop poorly, while in heavy soils (vertisol) develop well and with good productions (Herrera and Ramos, 1990).

The DMP for the three cutoff frequencies (60, 90 and 120 days) were higher than the data obtained by Ledea Rodríguez *et al.* (2017) who studied the dry matter production of two *Pennisetum purpureum* cultivars (CT-115 and CT-500) and found values of 40 and 30 ton DM/ha respectively with the same cutoff frequencies, moreover, they reported better production with increasing age of the regrowth. In another study carried out in Yucatan, Ramos *et al.* (2013) reported yields of 25 ton DM/ha with every 60 days of cutoff frequencies at a height of 10 cm from the ground, being less than those obtained in this study.

The cutting frequency influences both production and quality of forage. When grasses are cutoff frequently, they show high quality, good protein and mineral content and high digestibility, even though the production of dry matter is less. Barrón *et al.* (2009), mention that when cutting interval increases, dry matter production increases but quality decreases. This characteristic may be because as the age of the regrowth increases, the synthesis of structural carbohydrates (lignin, cellulose and hemicellulose) increases, the soluble forms decrease, and the quality is affected. The increase in yield is determined with the age of the plant due to an increase in the metabolic capacity of the grasses in the process of mobilization and synthesis of organic substances for the formation and operation of their structures (Ramírez *et al.*, 2008). The differences in production observed between clones, reflects that the percentage of dry matter depends on the variety and the growth time, since as the age of the shoots increases, a greater amount of dry matter accumulates both in leaves and in stems.

The decrease in the metabolic activity of the grasses can decrease the percentage of protein as the plant ages due to the reduced synthesis of protein compounds. Protein synthesis decreases with regrowth age, due to different processes such as senescence and decreased absorption of nutrients by the roots. Some authors (Barrón *et al.*, 2009; Ramírez *et al.*, 2008; Ramos *et al.*, 2013) consider that increasing the age at cut, increase the synthesis of structural carbohydrates (lignin, cellulose and hemicellulose) and decrease the metabolites and affect quality.

Conclusions:-

The cutoff frequency is a factor that influences the plant yield due to the yield increases with age and it reaches its highest value after 120 days. These values could be considered acceptable for the genus *Pennisetum*. The highest yield was observed at 120 days of cutoff frequency in clone OM-22. The three cutoff frequencies presented different contents of crude protein (CP), which decreased with age, a normal characteristic in tropical pastures. It was observed that the greater the cutting interval, the height of the plant, buds, number of shoots, length and width of the leaf increased. The observed values for components and total yield varied compared to other studies, which could be determined by soil type and climatic conditions.

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