Relationship between quality indicators and age indicators in *Pennisetum purpureum* cv. Cuba CT-169 in Cauto Valley, Cuba

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In a random block design with four replications, quality indicators related to the climate and age of *Pennisetum purpureum* cv. Cuba CT-169 were determined in both seasonal periods. The experiment was carried out in a fluvisol soil, under non-irrigation conditions and without fertilization. A multivariate analysis of main components was made, considering the climatic factors and the quality indicators. The preponderance value, equal or higher than 0.75 was considered as the selection factor. Linear multiple equations and the values of the coefficient of determination were above 0.88. The highest R2 were obtained for DMD and OMD (equation II = a + b*CF +d* Age, $P < 0.001$). *Pennisetum purpureum* cv. Cuba CT-169 can be characterized by rainfall, temperature (minimum, mean, maximum) and relative humidity, also through CP, CF, ADF, L, CW, DMD, OMD, ME, FNE, CC and cellulose. Linear multiple regression equations were established between DMD, OMD, ME and FNE considering: a) CP, CC and age; b) CF, CW and age; c) CP, L and age, with high R2 and low standard errors of estimation and square mean of the error. Further studies on regrowth physiology in other varieties and types of soil are recommended. More studies mainly on the performance of the chemical composition indicators are suggested to collect more information about the climatic conditions of Cauto Valley so as to validate results in other regions of the country.

Key words: *Pennisetum purpureum*, *multivariate, multiple regressions*

Mathematical expressions and, particularly, those applied to biology could be an important tool for understanding the dynamics of a phenomenon. According to Delgadillo *et al*. (2006), Biomathematics is determinant in the study of biology. This is revealed by the increasing number of available publications on this theme.

In agriculture, multiple regressions have been used when there is the basic assumption that a dependent variable is related to one or more independent variables whose measurements are made in the same unit of response (González 1970).

The dynamics of pasture growth in Cuba, specifically in Cauto Valley, has been studied through the application of cubic and quadratic mathematical expressions (Ramírez *et al*. 2010 and Fernández *et al*. 2001). However, the information relating the quality and age indicators under these climatic conditions is scarce.

The objective of this paper was to determine mathematical expressions relating the quality and age indicators with special emphasis on the digestibility and energy of *Pennisetum purpureum* cv. Cuba CT-169 in Cauto Valley.

Materials and Methods

Research area. The study was developed in "La Almendra" farm, devoted to seed production and located in Granma province at 12 km from Bayamo city in the southeastern region of Cuba. *Pennisetum purpureum* cv. Cuba CT-169 with four years of establishment was used. The study was carried out during the poor rainy (January to April) and rainy (July to October) periods of 2005.

During the poor rainy period, rainfall was of 130 mm, with a mean temperature of 24.3ºC, average minimum temperature of 18.9ºC and maximum of 30.6ºC, with an average relative humidity of 71%. In the rainy season rainfall was of 759 mm, with 27.2C of mean temperature, 23.5ºC minimum, 33ºC maximum and 81% of relative humidity. The soil corresponded to the fluvisol type (Hernández *et al*. 1999), with pH 6.2. P_2O_5, K_2O and total N contents were: 2.5, 38.5 and 34 mg/100 g of soil, respectively, with 3.2% of organic matter (Dirección de Suelos y fertilizantes de Granma 2005).

Treatment and experimental design. A random block design with four replications was utilized. Treatments were the regrowth ages (30, 45, 60, 75, 90 and 105 d).

Experimental procedure. In each period (January and July for the poor rainy and rainy seasons, respectively), at the beginning of the assessment a uniformity cut was made at 20 cm from the soil in each plot of 25 m2 corresponding to each one of the regrowth ages. Plant population in the plots was 95% of *Pennisetum purpureum* cv. Cuba CT-169, 3% of grasses of Dichathium genus and 2% of species of Ciperaceas family. During the experimental period there was no irrigation or fertilization.

Sampling was carried out through a total cut of each plot, except 50 cm at each side of the plot as border effect in each treatment and a representative sample was randomly taken of the CT-169. Each sample was dried in an oven of air circulation at 65ºC for 72 h.

Crude protein (CP) and crude fibre (CF) according to AOAC (1995) were determined. Acid detergent fibre (ADF), neutral detergent fibre (NDF), cellular wall (CW), cellulose (Cel), hemicellulose (Hem), cell content (CC) and lignin (L) according to van Soest and Wine (1967). For this, 200 g of each sample with 4 replications per treatment were used. *In situ* digestibility after 72 h of incubation was measured by the method of the nylon rumen bag (Orskov *et al*. 1980) using two bovines of the Cuban Criollo breed, of 400 kg live weight, rumen was cannulated and treated against ectoparasites and endoparasites before the beginning of the trial. Throughout the experimental period, animals were stabulated, with a previous adaptation period to the feed of two weeks. Samples of each regrowth age were six fold incubated in each animal.

Statistical analysis. For the normal data distribution Kolmogorov's-Smirnov's test cited by Massey (1951), was used and for the homogeneity of variances, Bartlett's test (1917). An analysis of main components was carried out (Visuata 1998), taking into account the climatic factors and the quality indicators. It was considered that the relationship between the variables evaluated, necessary condition to accomplish the analysis of main components, showed correlation values higher than 0.50, with positive and negative correlations. It was considered that the value was not lower than 50% from the total of relationships.

As selection factor the preponderance value equal or higher than 0.80 was established. This allowed to select the variables that were used in the linear multiple equations, to establish the relationships between DMD, OMD, ME, FNE and CP, CF, cellular content (CC), cell wall (CW), lignin (L) and age. To select the expressions of best adjustment the following parameters were considered: high coefficient of determination (R^2), high significance, significant contribution of the terms and low coefficients of non-determination ($1-R^2$), standard errors of the terms, standard errors of estimation and mean square of the error.

Results and Discussion

An analysis of main components was carried out to establish the indicators (table 1) and value their contribution to *Pennisetum purpureum* cv. Cuba CT-169 performance. Two components were determined with individual values higher than the unit, accounting for 89.84% of their performance (table 2).

In the first component are shown with positive sign the digestibility, CP, CC and OM, and with negative sign, CF, ADF, L, Cel and CW. CF and L reflected high preponderance values, which coincides with the results of Díaz *et al*. (2002). These authors indicated that in forages the fibrous structural components account for greater percentage of variability. This agrees with what is reported in the literature regarding that the CF determines a minimum of digestible fractions with a wide range of variability. However, the CW offers a more accurate criterion concerning their main constituents (hemicelluloses, cellulose and lignin). The ADF agrees even more with the presence of cellulose and lignin (van Soest 1987).

Temperature and relative humidity showed a high preponderance value in the second component (table 2) which is unusual. An explanation for this pattern of response could be related to the DM production capacity and the marked effect exerted by the temperatures in this process. In this sense, Herrera (2006) found high R^2 involving temperatures with the yield of Pennisetum varieties obtained by tissue cultures. At the same time, this author reported that certain relative humidity value decreases water losses by transpiration among these varieties.

Verdecia *et al*. (2012) in *Panicum maximum* cv. Mombaza reported high relationships between the quality indicators, temperatures and rainfall in Cauto Valley. This differs from that obtained in this study, where the relationship with rainfall was not the best, maybe due to the type of plant studied.

Amarante and Domicio (2002), evaluating three cultivars of *Panicum maximum* Jacq. through the chemical composition and *in vitro* dry matter digestibility, indicated that in tropical grass evaluation, the quality indicators are fundamental for the selection.

From the metabolic point of view, the inverse relationship of the coefficients characterizing the protein contents and the fibrous fraction could describe the classical antagonism between the formation of foliar protein and the majority compounds of the cell wall (cellulose, hemicelluloses and lignin). This aspect has been described in the foliage of other species during the biomass aging process (Pineda 2004), and that brings response to the performance reflected in this study.

After realizing a multivariate analysis and considering its results, multiple equations were established to relate DMD, OMD, ME and FNE (dependent variables) to the CP, CC, CF, CW and L (independent variables). For this, three variants were considered: I) soluble compounds CP and CC; II) structural compounds CF and CW and III) a soluble compound (CP or CC) and one structural (L). In all cases, regrowth age was utilized. These considerations were based on the criterion of offering options according to the possibilities of analyses in laboratories and in previous studies carried out, where the usefulness of employing more than one indicator of this type of relationship (Herrera 1981 and Herrera and Hernández 1986).

In the first studies made to predict DMS from the chemical constituents of the pastures, structural carbohydrates, CP and regrowth age (Herrera 1981) were mainly used. Later, Valenciaga *et al*. (2006) and Valenciaga (2007) established in *Pennisetum purpureum* cv. Cuba CT-115 the relationship between digestibility, age, silica and lignin monomers in Cuba CT-115 with high R^2 and low estimation errors, similar to those

Table 1. Correlation between the studied indicators of *Pennisetum purpureum* cv. Cuba CT -169

Indicators	Min. T	Max.T .	Mean.T	RH	CP	CF	NDF	L	CW	DMD	OMD	ME	FNE	CC	Hemm.	Cel	OM	MO
Rainfall	1.00	0.68	0.65	0.66	0.67	-0.63	0.72	0.60	0.61	0.50	-0.61	-0.64	-0.74	-0.77	-0.50	0.07	0.57	-0.67
Min. T T. mín.	0.68	1.00	0.98	0.99	0.95	-0.12	0.26	-0.02	0.17	-0.11	-0.05	-0.09	-0.34	-0.40	0.11	-0.24	-0.07	-0.33
Max.T.	0.65	0.98	1.00	0.94	0.89	-0.21	0.31	-0.01	0.22	-0.06	-0.13	-0.15	-0.39	-0.46	0.06	-0.14	-0.07	-0.38
Mean.T.med.	0.66	0.99	0.99	1.00	0.93	-0.16	0.28	-0.02	0.19	-0.09	-0.08	-0.12	-0.36	-0.42	0.09	-0.20	-0.08	-0.35
RH	0.67	0.095	0.89	0.93	1.00	0.02	0.14	-0.10	0.02	-0.21	0.08	0.03	-0.18	-0.24	0.21	-0.34	-0.13	-0.21
CP	-0.63	-0.12	-0.21	-0.16	0.01	1.00	-0.98	-0.85	-0.92	-0.61	0.93	0.94	0.80	0.72	0.60	-0.20	-0.78	0.30
CF	0.72	0.26	0.31	0.28	0.14	-0.98	1.00	0.80	0.89	0.64	-0.89	-0.89	-0.80	-0.74	-0.60	0.13	0.73	-0.37
NDF	0.60	-0.02	-0.001	-0.02	-0.10	-0.85	0.80	1.00	0.69	0.92	-0.96	-0.94	-0.48	-0.39	-0.90	0.59	0.99	-0.26
L	0.61	0.17	0.22	0.19	0.02	-0.92	0.89	0.69	1.00	0.53	-0.83	-0.86	-0.82	-0.77	-0.50	0.08	0.59	-0.21
CW	0.50	-0.11	-0.06	-0.09	-0.21	-0.64	0.58	0.92	0.48	1.00	-0.86	-0.82	-0.14	-0.05	-1.00	0.85	0.94	-0.02
DMD	-0.61	-0.05	-0.13	-0.08	0.08	0.93	-0.89	-0.96	-0.83	-0.91	1.00	0.99	0.61	0.52	0.90	-0.50	-0.93	0.20
OMD	-0.64	-0.09	-0.15	-0.12	0.03	0.94	-0.89	-0.94	-0.86	-0.86	0.99	1.00	0.65	0.57	0.80	-0.45	-0.89	0.18
ME	-0.74	-0.34	-0.39	-0.36	-0.18	0.80	-0.80	-0.48	-0.82	-0.14	0.61	0.65	1.00	0.99	0.10	0.36	-0.39	0.54
FNE	-0.77	-0.40	-0.45	-0.42	-0.24	0.72	-0.74	-0.39	-0.77	-0.05	0.52	0.57	0.99	1.00	0.0	0.44	-0.30	0.56
CC	-0.50	0.11	0.06	0.09	0.21	0.64	-0.58	-0.92	-0.48	-1.0	0.86	0.82	0.14	0.05	1.00	-0.85	-0.94	0.02
Hem.	0.07	-0.24	-0.14	-0.20	-0.34	-0.20	0.13	0.59	0.08	0.93	-0.50	-0.45	0.36	0.44	-0.90	1.00	0.64	0.32
Cel	0.57	-0.07	-0.07	-0.08	-0.13	-0.78	0.73	0.99	0.59	0.91	-0.93	-0.89	-0.39	-0.30	-0.90	0.64	1.00	-0.26
OM	-0.67	-0.33	-0.33	-0.35	-0.21	0.30	-0.37	-0.26	-0.21	-0.06	0.20	0.18	0.54	0.56	0.02	0.32	-0.26	1.00

Table 2. Results of the analysis of main components of *Pennisetum purpureum* vc. Cuba CT-169

Main component	CP1	CP2
Rainfall	-0.75	-0.55
Minimum Temperature	-0.22	-0.97
Maximum Temperature	-0.27	-0.93
Mean Temperature	-0.24	-0.95
Relative humidity	-0.09	-0.96
CP	0.94	-0.08
CF	-0.95	-0.05
ADF	-0.92	0.22
L	-0.95	0.03
CW	-0.92	0.34
DMD	0.97	-0.16
OMD	0.97	-0.13
ME	0.95	0.13
LNE	0.94	0.19
CC	0.92	-0.34
Hem.	-0.51	0.42
Cel	-0.88	0.27
OM	0.87	0.14
Eigen value	11.51	4.65
Variance explained, %	63.98	25.86
Total variance acumulada %	63.98	89.84

Table 3. Linear multiple equations for *Pennisetum purpureum* cv. Cuba CT-169

Variable	a	b	SE±	c	SE±	d	SE±	R^2	$1-R^2$	CMe	SE±
DMD I	43.71	0.35	0.01	0.58	0.06	-0.09	0.01	0.97	0.03	0.70	0.83
DMO I	42.64	0.49	0.18	0.57	0.08	-0.07	0.02	0.96	0.04	1.19	1.09
ME I	20.88	-0.28	0.08	-0.05	0.04	-0.10	0.01	0.91	0.09	0.26	0.51
LNE I	11.70	-0.05	0.05	-0.06	0.02	-0.05	0.01	0.90	0.10	0.09	0.31
DMD II	105.1	0.23	0.12	-0.64	0.07	-0.14	0.01	0.98	0.02	0.74	0.86
OMD II	110.5	0.01	0.17	-0.62	0.09	-0.12	0.02	0.96	0.04	1.37	1.17
ME II	9.19	0.008	0.08	0.07	0.04	-0.07	0.009	0.90	0.10	0.33	0.57
LNE II	4.75	-0.035	0.04	0.07	0.03	-0.04	0.005	0.90	0.10	0.09	0.31
DMD III	65.90	0.67	0.24	-0.67	0.91	-0.13	0.04	0.95	0.05	1.85	1.36
OMD III	65.13	0.90	0.20	-1.67	0.19	-0.07	0.03	0.93	0.07	2.20	1.48
ME III	19.18	-0.25	0.09	-0.56	0.34	-0.08	0.01	0.92	0.08	0.26	0.51
LNE III	9.30	-0.07	0.06	-0.08	0.22	-0.04	0.01	0.88	0.12	0.11	0.33

R^2 all at $P < 0{,}001$

I=a+b*PB+c*CC+d*Age, II=a+b*CF+c*PC+d*Age and III=a+b*CP+c*Lig.+d*Age

obtained in this research.

The above mentioned authors showed the decrease of the digestibility of this species on increasing its regrowth age, since as the maturity stage of the plant advances, there are physiological changes which provoke the diminution of the citoplasmatic cell content (equation I). As a consequence of the thickening of the cell wall, the cellular lumen is reduced and the fibrous components are increased (equation II). These processes were observed more markedly in the rainy period, when the climatic conditions favor plant growth and intensify the development of these processes.

It can be concluded that *Pennisetum purpureum* cv. Cuba CT-169 can be characterized from rainfall, minimum, mean and maximum temperatures and relative humidity. Also, considering CP, CF, ADF, L. CW, DMD, OMD, ME, FNE, CC and cellulose. Linear multiple regression equations were established between DMD, OMD, ME and NFE from: a) CP, CC and age, b) CF, CW and age and c) CP, L and age. This represents options according to the available resources in the laboratories.

Further studies on the regrowth physiology in other varieties and types of soil are recommended. Specially, attention should be given to the performance of those indicators of chemical composition which generate greater information for the climatic conditions of Cauto Valley. It is suggested to extend this study to other grass varieties, and to corroborate results in other regions of the country.

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