Note

QUANTIFYING HERBAGE MASS ON ROTATIONALLY STOCKED PALISADEGRASS PASTURES USING INDIRECT METHODS

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ABSTRACT: Indirect, non-destructive methods for estimating herbage mass on pasture may help growers to better estimate herbage mass and manage the grazing process. The objective of this study was to evaluate two methods for estimating herbage mass on Marandu palisadegrass [*Brachiaria brizantha* (A. Rich.) Stapf] pastures, over two grazing seasons. The relationships between herbage mass and two indirect, non-destructive measurements (sward surface height - SSH and rising plate meter - RP) were analyzed via regression analysis. Mean determination coefficients (r^2) for the regression models were 0.82 and 0.91 for RP and SSH, respectively. Time within season influenced both slope (b) and intercept (a) of the regression models in both methods. The change in model parameters over the course of the seasons suggests the need for frequent model revision and revalidation.
Key words: *Brachiaria brizantha*, sward surface height, herbage allowance, rising plate meter, linear regression

QUANTIFICAÇÃO DA MASSA DE FORRAGEM EM PASTOS DE CAPIM MARANDU SOB LOTAÇÃO ROTATIVA COM O USO DE MÉTODOS INDIRETOS

RESUMO: Métodos indiretos e não-destrutivos para a estimativa da massa de forragem no pasto podem auxiliar o manejador no estabelecimento de estratégias ótimas de pastejo. O objetivo deste trabalho foi avaliar métodos indiretos de estimativa de massa de forragem em pastos de capim Marandu [*Brachiaria brizantha* (A. Rich.) Stapf] sob lotação rotativa durante dois anos. Para descrever as relações entre massa de forragem e dois métodos testados (altura do dossel e disco ascendente) foram empregadas regressões lineares. As equações geradas apresentaram coeficiente de determinação médio (r^2) de 0,82 e 0,91 para o disco e altura, respectivamente. A época do ano exerceu influência sobre o coeficiente angular (b) e o intercepto (a) das regressões de ambos os métodos. Essa alteração dos componentes das curvas ao longo do tempo indica a necessidade de freqüente revalidação dos modelos.
Palavras-chave: *Brachiaria brizantha*, altura de dossel, oferta de forragem, disco ascendente, regressão linear

INTRODUCTION

Palisadegrass [*Brachiaria brizantha* (A. Rich.) Stapf] is one of the most cultivated tropical grasses in cattle production systems of Brazil. Its high dry matter (DM) yield (~ 28 Mg ha^{-1} yr^{-1}) together with spittlebug (*Deois* sp. and *Notozulia entreriana*) resistance has contributed to a marked increase in productivity of these systems over the last 30 years (Santos et al., 2003; Macedo, 2004; Vilela et al., 2004).

Herbage mass is defined as the total herbaceous plant biomass above the soil level per unit land area (FGTC, 1992), and is essential for proper interpretation of research data in response to experimental treatments. In addition, herbage mass values are key to farmer decision-making in grazing management (Mannetje, 2000). Because animal performance is closely associated with herbage mass (Burns et al., 1989; Wales et al., 1999), it is to the best interest of the grassland manager to be able to make accurate herbage mass measurements, so that the foraging operation can be managed efficiently and planned according to feed supply and demand (Gonzalez et al., 1990).

Values of herbage mass can be generated either by direct (destructive) herbage sampling or by indirect methods, when herbage mass is well correlated with some other vegetation characteristic. Indirect methods reduce sampling time and costs and increase precision (Bransby et al., 1977). Among the many options sward surface height (SSH) and rising plate meter (RP) readings (Gonzalez et al., 1990; Da Silva & Cunha, 2003) have been most frequently used as indirect methods of herbage mass estimation.

Indirect methods require calibration, a procedure that establishes functional relationships between the indirect measurement and the actual herbage mass value harvested. Failures in calibration compromise accuracy and limit the indirect estimations. The objective of this study was to evaluate the effectiveness of SSH and RP readings as indirect methods for estimating herbage mass in rotationally stocked Marandu palisadegrass pastures.

MATERIAL AND METHODS

The trial was carried out in Pirassununga, Brazil (21°59' S, 47°26' W, 634 m altitude) from Aug 2002 through April 2004 on established Marandu palisadegrass pastures. A calibration dataset from a study investigating the effect of herbage allowance treatments on pasture and animal performance under rotational stocking (35-d grazing cycle; 28-d rest, 7-d grazing) was used, as detailed by Braga et al. (2006). Daily allowance levels were 5%, 10%, 15% and 20% of liveweight with experimental units arranged in a randomized complete block design with four replications. Each experimental unit was divided into five paddocks (3,150 m^2 per paddock). The indirect sampling methods were chosen to take advantage of contrasts in sward structure generated by herbage allowance treatments and by phenological shifts due to the effect of the growing season, assuming this would make for stronger calibration of the indirect measurements.

The two indirect methods tested were sward surface height (SSH) and rising plate meter (RP - Ashgrove Pastoral Products, Hamilton, New Zealand), with the plate measuring 35.5 cm in diameter and weighing 480.2 g, running on a 2-m graded rod. The RP was calibrated monthly, pre- and postgraze, in paddocks within experimental units, on selected sampling dates (Table 1). On those occasions, at least five 1-by-1 m sites within or across paddocks were chosen so as to represent the range of lowest to highest herbage mass across all herbage allowance treatments. At each site, first four SSH readings (relaxed canopy) followed by four RP readings were taken. The herbage was then clipped (from the 1-m^2 sites) at soil level and oven-dried at 60°C to constant weight. Herbage mass

Table 1 - Model parameters of the linear regressions from rising plate meter (RP) method in the herbage mass estimation of Marandu palisadegrass pastures.

Date	sample	$n^{(1)}$	$a^{(2)}$	$b^{(3)}$	$r^{2(4)}$	CV(5)	Root MSE(6)	y-range
			kg DM ha^{-1}			%	-------- kg DM ha^{-1}	--------
Aug 2002	pre	10	238.8	114.8	0.97	11.0	666	1443-12747
Nov 2002	pre	17	421.8	89.3	0.54	39.9	1310	566-6221
Jan 2003	pre	16	1926.7	64.9	0.74	17.7	1077	3410-9625
Feb 2003	pre	16	2903.1	70.1	0.86	9.2	742	5203-10557
Mar 2003	pre	7	1458.6	87.1	0.67	33.3	2196	2474-11691
May 2003	pre	8	2070.7	98.0	0.61	22.6	1707	3429-10081
Sep 2003	pre	5	-1603.2	135.9	0.96	13.9	712	1362-8076
Nov 2003	pre	19	2144.5	52.9	0.60	26.5	1380	1739-10089
Jan 2004	pre	30	1048.7	70.3	0.91	13.2	748	1960-10446
Feb 2004	pre	10	2768.6	56.2	0.95	9.1	627	3310-10773
Mar 2004	pre	35	1477.3	81.4	0.85	16.0	1246	2584-18175
Jun 2004	pre	10	1926.3	108.7	0.82	19.7	1231	2530-10668
Jan 2004	post	20	1221.8	66.3	0.86	18.8	918	1353-10359
Feb 2004	post	5	1552.9	97.3	0.96	13.6	744	1927-10830
Apr 2004	post	10	576.4	108.1	0.96	12.9	674	1065-10466

(1) = number of observations; (2) = intercept; (3) = slope; (4) = coefficient of determination; (5) = coefficient of variation (%); (6) = root mean square error.

data were regressed on mean SSH height and RP height at each sampling site. SSH calibrations took place only in the second year of the trial (Table 2) and not all experimental units were represented on each evaluation.

Data were analyzed using PROC GLM of SAS (SAS Institute, 1999) using covariance analysis of the main effects to look for differences in model slope and intercept to detect differences between months. This analysis combines concepts of analysis of variance and regression analysis. If slopes do not differ, the hypothesis of non-difference of intercepts is tested. If the difference is not significant for slope and intercepts, a single model can be fitted to the data. Regression models that differ in intercepts reflect an interaction between groups and independent variables. This set is then analyzed as an interaction and generates the statistics to estimate different regressions of y on x for different values or specified classes. In this application, the Type-I sum of squares provides the most useful information (Tonini et al., 2004; Freund & Little, 1985). Regression models were generated using PROC REG (SAS Institute, 1999) and contrasted in determination coefficient (r^2), root mean square error (Root MSE) and coefficient of variation (CV).

RESULTS AND DISCUSSION

Both slope (b) and intercept (a) of the all RP regression models differed across months ($p < 0.05$; Table 1), so models are shown separately. Only five models resulted in r^2 lower than 0.80, and adjusted-r^2 values were higher than 0.60 for all models. Highest data dispersion (residual values of the best-fit line) was recorded in the Nov./2002 (CV = 39.9%) and March/2003 (CV = 33.3%) samplings, but the coefficient of variation remained lower than 20% at all other sampling times. Slightly higher CV values (22.7%) were recorded from grazed bermudagrass [*Cynodon dactylon* (L.) Pers.] pastures, where herbage mass ranged from 225 to 7,850 kg DM ha^{-1} (Gonzalez et al., 1990).

In the present study, intercept values increased early in the season (Table 1), but not beyond early March for the RP method. This increase was also reported by Da Silva & Cunha (2003) in continuously stocked bermudagrass pastures. Those authors concluded that such an increase was associated with increasing proportions of dead leaves and stems at the lower portions of the canopy. For example, stem proportion in pregraze forage increased from 40% in Jan./2003 to 46% in Feb./2003, and fell back to 40% in March/2003 (data not shown). The proportion of dead material, however, increased linearly until March/2003 (30% Jan., 33% Feb. and 38% March). This resulted in a higher intercept for the RP model in Feb./2003 (Table 1), although it is difficult to distinguish the effect of each plant part component on the models. In addition, the increase in intercept was associated with the decrease in slope. Because of its physical properties (mainly lower resistance to bending and compression) dead plant material may have contributed more to high intercept than stem. When the stem proportion is high, bulk density is generally lower, resulting in decreased slope values. Herbage mass estimated by indirect methods is known to be influenced by sward structure and thus calibrations should take into account that factor (Gonzalez et al., 1990). Consequently, it is unlikely that any one calibration model will provide good estimates of herbage mass from RP readings.

Models for estimating herbage mass from SSH were affected ($p < 0.05$) by month both in slope and intercept (Table 2), suggesting that month-specific models give better herbage mass predictions than whole-season models. Intercept values tended to in-

Table 2 - Model parameters of the linear regressions from sward surface height method in the herbage mass estimation of Marandu palisadegrass pastures.

Date	sample	$n^{(1)}$	$a^{(2)}$	$b^{(3)}$	$r^{2(4)}$	CV(5)	Root MSE(6)	y-range
			kg DM ha^{-1}			%	-------- kg DM ha^{-1}	--------
Nov 2003	pre	10	-1003.0	154.4	0.93	12.7	665	2337-10089
Jan 2004	pre	20	507.4	105.1	0.93	11.4	640	2316-10446
Feb 2004	pre	20	1098.6	99.4	0.90	13.2	839	1960-10773
Mar 2004	pre	18	622.5	132.2	0.90	14.2	949	2584-13081
Jun 2004	pre	10	787.2	195.5	0.87	16.7	1052	2530-10668
Jan 2004	post	20	924.5	115.6	0.87	18.0	878	1353-10359
Feb 2004	post	5	1492.5	160.9	0.96	13.7	751	1927-10830
Apr 2004	post	10	444.8	180.1	0.94	17.2	900	1065-10466

(1) = number of observations; (2) = intercept; (3) = slope; (4) = coefficient of determination; (5) = coefficient of variation (%); (6) = root mean square error.

crease early in the growing season, likely due to increasing proportions of dead plant material at the base of the canopy, which contributed to increases in herbage mass but not in SSH, as reported by Da Silva & Cunha (2003). The SSH models generated in the present study have r^2 above 0.85 and CV below 20%. These values are consistent with those of Gonzalez et al. (1990), who reported $r^2 = 0.86$ and CV = 21.7% for prediction models for bermudagrass SSH. SSH has been regarded as a better herbage mass predictor than RP and capacitance meters in annual ryegrass (*Lolium multiflorum* Lam.) (Cauduro et al., 2006), even with r^2 lower than 0.70 due to excessive amounts of dead plant material at the base of the sward. Overall, research suggests that for temperate grasses both SSH and RP readings have good applicability giving both good herbage mass estimates, as r^2 often exceeds 0.90 and the CV are seldom above 10% (Bransby et al., 1977; Santillan et al., 1979; Griggs & Stringer, 1988).

Under the conditions of the present study both methods resulted in good fit of the models, similar to those reported for low-growing leafy swards, typical of vegetative temperate grasses, suggesting that both are reliable predictors of herbage mass in grazed Marandu palisadegrass pastures. Based on root-MSE and CV values, SSH (root-MSE = 834 kg DM ha^{-1}) seems to be better than RP (root-MSE = 1065 kg DM ha^{-1}). The higher RP dispersion is thought to be due to the wide range of herbage mass values sampled destructively (for calibration purposes), but also to the high proportion of stems and to plant lodging, especially at the high herbage allowance treatments (15 and 20%). CV values, however, were relatively low, and similar to those reported by Da Silva & Cunha (2003) and Gonzalez et al. (1990). CV ranged from 11 to 18% for the SSH method, probably influenced by the lower range in herbage mass values used in the calibration, compared to those used for RP calibration (Table 2).

Gonzalez et al. (1990) found that herbage mass values above 7000 kg DM ha^{-1} increased data variability because of the high proportion of stems in the sward, which in fact weakened the linear relationship of SSH and RP. If defoliation management keeps the sward within limits where stem elongation and lodging are minimized, then the use of indirect methods for estimating herbage mass can be reliable to the point where destructive sampling can be restricted to calibration purposes only. Under these circumstances, the association between variables is high and data dispersion tends to be low.

The RP was a quicker, more agile method than SSH, although its initial cost is higher. In addition, plate readings are more objective than sward height readings, which may include observer effects as well as difficulty in identifying the exact plane that corresponds to the surface of the sward.

There was an effect of time of the year (season) on model parameters, likely a result of the impact of environment on sward structure. This means that calibration must be done frequently and at all times of the year or of the grazing season, regardless of the indirect method of choice. Both methods studied were able to give good estimates of herbage mass, pre- and postgraze, with enough accuracy to allow for their use not only in grazing management practice but also in grazing research. Sward height measurements may need improved methodology so that actual values are easier to establish, and the effect of the observer can be minimized. If highly accurate and highly precise herbage mass estimates are needed in experimentation, the use of direct methods - more time-consuming - may be advantageous due to their generally lower root-MSE values, if the sample size is adequate.

ACKNOWLEDGMENTS

To FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo), ESALQ (Escola Superior de Agricultura “Luiz de Queiroz”/USP) and FZEA (Faculdade de Zootecnia e Engenharia de Alimentos/USP) for the provision of a graduate scholarship and research funds for this project.

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Received September 25, 2007
Accepted May 26, 2008