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Length and width to estimate dry mass of *Panicum maximum* cv. Tanzânia leaves

L.G. BARIONI[1], P.M. SANTOS[1], A. COLDEBELLA[1] and M. CORSI[2]

[1]*Ph D student. Departamento de Produção Animal, Universidade de São Paulo, Piracicaba, SP, Brasil, 13418-900, lgbarion@carpa.ciagri.usp.br.* [2]*Departamento de Produção Animal, Universidade de São Paulo, Piracicaba, SP, Brasil, 13418-900*

ABSTRACT

An analysis of the relationship of leaf length (LL) and leaf width (LW) with leaf dry weight (LDW) in *Panicum maximum* was carried out with the objective of improving estimations of tissue flow in that plant. Data was collected in a mob grazing experiment with 28 days grazing interval sampled the day before grazing in 9 grazing cycles. Regression analysis revealed highly significant effect ($P < 0.001$) of both LL and LW on LDW. A lack of fit test gave strong evidence of non-linear relationship of LDW with LL ($p < 0.05$), fitting the model $LDW=\beta_0 LL^{\beta_1}$, while LW presented a linear relation with LDW. LL was a better predictor of LDW than LW. LL solely or in combination with LW produced equations with high R^2 (0.61 – 0.90 and 0.80 – 0.92, respectively). The power relationship between leaf length and leaf dry weight imply that longer leaves are heavier per unit of length and, therefore the use of a constant to describe dry weight may be misleading when treatments affect leaf size in *Panicum maximum* pastures.

KEYWORDS: Leaf, model, weight, regression, *Panicum maximum*

INTRODUCTION

Leaf area index and leaf mass have often been pointed out as important state variables in pastoral systems, affecting on both plant photosynthetic potential (Hay and Walker, 1989) and herbage intake by the grazing animals (Poppi et al, 1981; Flores et al., 1993; Forbes and Colleman, 1993) and are therefore valuable indicators of pasture status. Also methodologies for quantifying tissue flow rely on measurement of leaf elongation and length of senescent part of the tissue. Calculations usually assume constant dry weight per unit of length (usually mm) in order to estimate tissue mass flow rates (Grant et al., 1983). This paper aims to analyze the relationship between size measurements (length and width) and the dry weight of *Panicum maximum* cv. Tanzânia leaves in order to improve estimations of leaf mass and tissue flow in those plants.

MATERIAL AND METHODS

Data was collected from a mob grazing experiment carried out in Piracicaba, SP, Brazil, 22°42'30" S, 47°38'30" W, from October 1995 to October 1996 (Santos, 1997). The experiment was conceived in a factorial design with three grazing intervals (28, 38 and 48 days) and two cultivars Tanzania and Mombaça with 7 replications. All treatments received 400 kg of nitrogen as urea in 5 applications during the experimental period and were grazed to a residual dry mass averaging 1900 kg.ha^{-1}. Only data collected for Tanzania under 28 days grazing interval were analyzed. Ten representative tillers were taken from each plot the day before grazing, totaling 70 tillers per evaluation date. Leaf length (LL) was measured from ligulae to the leaf tip in the fully grown leaves and from the ligulae of the last expanded leaf to the leaf tip in the growing leaves. Leaf width (LW) was measured at the widest place of the leaf. Leaves were detached from stem and weighted fresh. Leaf dry weight (LDW) was calculated by multiplying fresh weight by the average whole sample dry matter (65°C until constant weight).

A total of 1098 observations in 9 dates of measurement (09/02/9 6, 13/03/96, 11/04/96, 14/05/96, 08/06/96, 30/06/96, 31/07/96, 29/08/96, 25/09/96) were included in the analysis. Data was categorized into 6 independent groups (three seasons: summer, autumn and winter; and two leaf types: elongating and fully grown leaves). A test of lack of fit was applied to a simple linear model to verify non-linear trends (Drapper, 1981).

RESULTS AND DISCUSSION

Length and width were highly significant ($P< 0.001$) both in simple and multiple regression analysis models (Table 1). Lack of fit was significant in the simple linear model ($LDW = \beta_0 + \beta_1$ LL; $p < 0.05$) in all datasets except for expanded leaves in summer, indicating a non-linear relationship between those variables. An exploratory analysis showed a power relation described by the equation $LDW=\beta_0 LL^{\beta_1}$ was adequate whenever lack of fit was detected (Figure 1; Table 1).

LL was a better predictor than LW, with the first producing equations with higher R^2 and lower RSD (Table 1). In the multiple linear regression model ($\log LDW=\beta_0+\beta_1 \log LL+\beta_2 LW$) both measurements were significant and presented R^2 varying between 0.80 and 0.92 and RSD between 0.026 and 0.106). The relationships were found to be stable both throughout the year and between leaf types (completely expanded and emerging). Using just one equation for all data had R^2 close to the highest found in the respective model (Table 1).

The results showed the power parameter of the nonlinear equations between LL and LDW to vary between 1.33 and 1.91. A power relation of 2 would be expected between LL and LDW if they presented allometric growth (admitting constant specific leaf area). This result highlights the predominance of elongation in leaf area development. Figure 1 shows separately the relationship between LDW and LL and LW in winter. It can be noticed that while leaf length varied at the proportion of 10 times, leaf width changed less that half that amount. The same trend was found in all periods. Regarding the assumption of specific leaf weight , previous work of Wilson (1976) has found this index to increase with leaf size. The magnitude of those changes seems, however, to be smaller than the variation of the length/width ratio. The results suggest that the use of a constant to describe weight per unit of leaf length (LDW/LL) would not be adequate for estimating mass of those leaves, since longer leaves are heavier per unit of length. Use of an average would not generate error if the samples have exactly the same range and distribu-

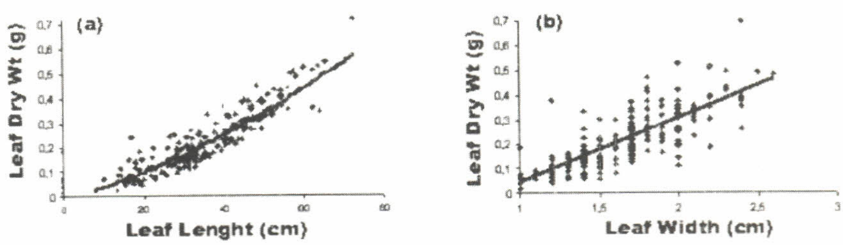

Figure 1 - Individual observations and regression line for (a) the power relation between leaf length and leaf mass and (b) the linear relation between leaf width and leaf dry weight.

Table1 - Regression analysis statistics for prediction of leaf dry weight from leaf length and width

Model	Season	Leaf Type	Parameters β_0	β_1	β_2	Statistics Adj R2	RSD	Observations
$LDW = \beta_0 LL^{\beta_1}$	Summer	FG[1]	0.0027	1,328	-	0,61	0.149	207
		E[2]	0.0002	1,870	-	0,85	0.094	149
	Autumn	FG	0.0006	1,638	-	0,85	0.061	275
		E	0.0002	1,649	-	0,79	0.049	136
	Winter	FG	0.0013	1,417	-	0,82	0.050	207
		E	0.0002	1,914	-	0,90	0.030	124
	All		0.0002	1.649	-	0.85	0.087	1098
$LDW = \beta_0 + \beta_1 LW$	Summer	FG	-0,260	0,337	-	0,52	0,164	207
		E	-0,304	0,327	-	0,34	0,196	149
	Autumn	FG	-0,243	0,254	-	0,70	0,090	275
		E	-0,183	0,200	-	0,62	0,065	136
	Winter	FG	-0,216	0,261	-	0,61	0,074	207
		E	-0,121	0,185	-	0,61	0,059	124
		All	-0.340	0.329		0.63	0.137	1098
$\log LDW = \beta_0 + \beta_1 LW + \beta_2 \log LL$	Summer	FG	-5,886	0,981	0,504	0,80	0.106	207
		E	-7,721	1,467	0,409	0,92	0.068	124
	Autumn	FG	-6,845	1,199	0,487	0,91	0.047	275
		E	-6,895	1,162	0,516	0,87	0.038	136
	Winter	FG	-6,395	1,058	0,604	0,89	0.039	207
		E	-7,310	1,415	0,330	0,92	0.026	124
	All		-6.876	1.224	0.475	0.91	0.067	1098

LDW = leaf dry weight (g), LL = leaf length (cm) and LW is leaf width (cm).[1]E = Elongating leaves, [2]FG = Fully expanded leaves tion of LL, though errors may be potentially large otherwise, particularly when treatments have effect on leaf size. The assumption of constant LDW/LL may also be misleading when modeling leaf growth during pasture regrowth, where obviously leaves are shorter at the beginning of the period. The statistics for regression equations indicate that those relations may be successfully used to estimate individual leaf mass and consequently leaf tissue dynamics in *Panicum maximum* cv. Tanzânia pastures and should be preferred in detriment to constant LDW/LL ratio.

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The analysis of results from paired paddock comparisons

D.R. KEMP[1], P.M. DOWLING[2], D.L. MICHALK[2] and G.D. MILLAR[2]

CRC for Weed Management Systems, Pasture Development Group

[1]University of Sydney, Faculty of Rural Management, david.kemp@orange.usyd.edu.au

[2]NSW Agriculture, Orange Agricultural Institute; Orange NSW 2800 Australia.

ABSTRACT

Paired-paddock comparisons are a common way of evaluating new grassland practices at a scale more relevant to farmers. They are also being used to replace or augment designed experiments and can be the only source of information available on a practice. However, it is often uncertain if the differences between paddocks are significant. Importantly, a current trend among funding organisations is to support paddock comparisons. The need for valid procedures to compare unreplicated treatments is increasingly urgent. It is suggested that a range of tools be used to infer statistical significance from using typical error values from related studies or subsampling, through to multivariate techniques to follow trends. Local 'rules of thumb' could be developed and data evaluated with calibrated models. A final judgement on treatment effects would need to be based upon the use of several criteria to achieve a 'balance of probabilities'. Consideration of these problems suggests that paired-paddocks should only be used to evaluate contrasting treatments where large effects are expected and not small variations within a practice.

KEYWORDS: Paired-paddocks, evaluation, multivariate, inference

INTRODUCTION

Grassland research tends to follow a common sequence. Initially ideas are explored in small plots, the more successful are then scaled up to paddocks and then ideally tested in a grazing system. Paddock-scale grazing experiments are usually done once the range of treatments is narrowed down and when the technology involved is sufficiently different to common practice that it needs to be fully evaluated. The expense of running paddock-scale grazing experiments often limits their use.

Paired-paddock comparisons have been widely used in grassland studies for many years. They are often used to: demonstrate at a local farm scale the better treatments coming from research programs *e.g.* as a simple contrast with some standard common practice; bypass designed experiments and test ideas coming from smaller scale studies; extend the range of treatments and information in parallel studies to a core experiment; and evaluate on-farm innovations developed by farmers. In each case there is a problem in evaluating the significance of the results obtained *i.e.* are the differences real? This paper aims to outline some of the issues involved and consider some methods that could help to form an opinion as to the scientific merits of any paddock differences obtained.

CRITERIA FOR EVALUATION

Grasslands are ecosystems that are typically assessed using a range of criteria *e.g.* saleable animal products, water balance, nutrient leakage and the retention of desirable species.

To enable a reasonable comparison it is assumed that paired paddocks have been established using best practice *i.e.* a random allocation of treatments and there are as many factors in common as possible so that the paddock comparison better reflects the treatments. Before applying treatments, some initial measurements of the system should always be taken to see if the paired paddocks are similar, else the results will be suspect.

Saleable animal products enable an economic evaluation to be done on treatments. However, a simple evaluation of animal products often contains the assumption that the stocking rate and grazing pressure were optimal for that system. It is doubtful if that is commonly the case. A better analysis could be done if other data were available on the likely response curve to stocking rates for that system so that the position of the paired-paddocks on the response curve could be estimated. The data obtained could also be tested against established, calibrated models (Donnelly *et al*., 1997) provided sufficient measurements are taken to run the model effectively.

To decide if the stocking rates were optimal, additional local criteria could be used. These criteria would include the levels and quality of herbage mass available throughout the year – to test if the grassland was being over- or under-grazed. Tools such as the 'Pasture Management Envelope' (Spain *et al*., 19; Kemp *et al.* 1991) can be developed from local and research information to decide upon appropriate boundary values within which grasslands are being effectively managed and as a way of testing if stocking rates were appropriate.

The use of animal data requires that each paddock of the comparison is a closed system. If the animals are off the paddocks for any significant periods then animal performance information can only be effectively used for the periods they are in the paddocks.

Total grassland production provides another measure of the performance of each paddock. Ideally, this needs to be the net primary growth of the grassland determined with the use of exclusion cages. Standing herbage mass is of less value as that is the balance between herbage growth and animal consumption which then complicates any evaluation.

Grassland composition often determines the animal, sustainability and biodiversity performance of the system and provides a valuable way of assessing the impact of treatments. Problems can arise though if only one component is monitored without due consideration of how the whole grassland ecosystem is responding to treatments. A significant change in one component may not always be reflected in significant changes in other components and this results in the possibility of a type II statistical error.

Other criteria such as components of the water balance, nutrient status and pathways will depend upon the aims of a paired-paddock comparison. In this and the other cases considered above, they need to be measured with sufficient accuracy to reflect the status and trends in each paddock under study. Often parameters are not measured with the intensity and rigour required to get a reasonable estimate of the mean.

STATISTICAL INFERENCES

Commonly, paired-paddock comparisons involve two treatments and no replication. The main information available from which inferences can be drawn is the difference between the paddocks. The level of error that could be used to test the significance of any difference usually needs to be inferred from other sources.

Subsample errors can be estimated for criteria such as herbage mass or variation in a soil nutrient *etc*., from the samples taken within each paddock to give an indication of the general variation likely for that parameter. Other estimates could