Drying rates of tropical grasses

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Abstract

The drying rates of andropogon (*Andropogon gayanus*), signal (*Brachiaria decumbens*), guinea (*Panicum maximum*), molasses (*Melinis minutiflora*) and jaragua (*Hyparrhenia rufa*) grasses were estimated under chamber and field conditions. The grasses were clipped at the ages of 8 and 12 weeks and allowed to dry. Moisture determinations were made on samples taken at the start and the end of drying, and the weight loss of the drying grasses were recorded at hourly intervals on the first day and at longer intervals during the second day. Water loss coefficients were calculated for each grass from regression equations. Morphological characteristics of the grasses such as: leaf weight ratio, leaf: stem ratio, specific leaf area, stem length and diameter were recorded and correlated with water loss coefficients. Higher drying rates were found for jaragua and guinea which had the highest leaf weight ratio and the shortest stems.

Resumen

*Las tasas de secado de las gramíneas andropogon (*Andropogon gayanus*) señal (*Brachiaria decumbens*) guinea (*Panicum maximum*) y gordura (*Melinis minutiflora*) fueron estimadas bajo condiciones de cabinete y de campo. Las gramíneas fueron cortadas a las 8 y 12 semanas de edad y posteriormente se les dejo secar. Se hicieron determinaciones de la humedad con muestras tomadas al principio y al final del secado. Durante el secado de las gramíneas se registró su pérdida de peso cada hora en el primer día y a intervalos más largos en el segundo día. Mediante el uso de ecuaciones de regresión se calcularon los coeficientes de pérdida de agua para cada gramínea. Se registraron las características morfológicas de las gramíneas, tales como: la relación de peso foliar, relación hoja tallo, área específica de hoja, longitud y diámetro del tallo, las cuales fueron correlacionadas con los coeficientes de pérdida de agua. Las gramíneas jaragua y guinea tuvieron las mayores tasas de secado, la mayor relación de peso foliar y los tallos más cortos.*

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Introduction

Haymaking from pasture surpluses plays an important role in herd feeding as well as in pasture management programs. However, during haymaking dry matter losses occur, the extent of which is proportional to the length of time the forage lies on the swath. Therefore, fast and uniform drying is an important trait of a forage to be used for haymaking.

In the same environment, the field drying period for a crop varies from species to species (Person and Sorenson 1970; Morris 1972; Jones and Prickett 1981; Owen and Wilman 1983) according to its initial moisture content, as well as plant morphology (Jones 1979; Jones and Prickett 1981; Owen and Wilman 1983). Forage moisture content decreases with age (Gomide *et al.* 1969; Jones 1979; Savoie *et al.* 1984) and varies among species (Gomide *et al.* 1969; Owen and Wilman 1983).

Though an intact living plant may transpire daily as much water as the total water retained in its tissue, the water loss from a cut plant is much lower due to resistance offered by the epidermis and cuticle (Harris and Shanmugalingan 1982). Cut plant tissue loses moisture three times slower than an equal surface of blotting paper (Leschem *et al.* 1972).

Studies on temperate forage species have demonstrated that leaves not only have a faster drying rate than stems (Leschem *et al.* 1972; Jones and Prickett 1981) but also aid in water loss from stems (Jones 1979). Drying rate is negatively related to stem length (Jones 1979; Owen and Wilman 1983) and positively related to leaf: stem ratio (Jones 1979; Owen and Wilman 1983) area: weight ration and stem exposure (Morris 1972).

Similar data on tropical forages are scarce. In this study 5 tropical grasses were compared for differences in morphological characteristics and drying rates.

Material and methods

This experiment, carried out at Vicosa Federal University, considered 5 grass species: molasses (*Melinis minutiflora*), signal (*Brachiaria decumbens*), guinea (*Panicum maximum*), jaragua (*Hyparrhenia rufa*) and andropogon (*Andropogon gayanus bisquamulatus*). The grasses were sown in plots 2 m × 2 m in size, with 4 replicates, and sampled at the ages of 8 and 12 weeks, after emergence, in the vegetative stage. Samples of each grass were taken over 4 days, one field replicate per day, and allowed to dry either on the field or in a controlled chamber.

Field drying procedure

Eight-week old and 12-week old samples were harvested in early January and early February, respectively, and left to dry in the field, on a 1 m × 1 m nylon screen placed on a *Paspalum notatum* sward.

Drying started at 11 am and lasted until 3 pm, next day. The samples were weighed at hourly intervals until 7 pm on the first day and at 7 am, 11 am and 3 pm on the second day. Two 50 g samples were taken daily from each plot and dried in a forced air oven at 100 °C for 24 hours, at the start and end of the drying period, to estimate initial and final moisture content. From the initial moisture content, the dry matter weight of each field sample was determined. This, together with the weight loss recorded during the drying period, allowed an estimation of the intermediate moisture content of each sample. Field drying curves were drawn relating water loss to drying time. The weather conditions prevailing during drying are shown in Table 1.

Chamber drying procedure

Drying in controlled conditions was carried out in a chamber of 5.4 m length, 3.7 m width and 2.1 m height controlled to maintain air temperature between 29–30 °C, air flux at 65 m^3/h, and relative humidity 55–60%. Grass samples (100 g) were placed in the chamber over a period of 4 days, one field replication per day. These samples were placed as a thin layer on a 1 m × 1 m nylon screen, which rested on a table.

The drying started at 11 am and lasted until 5 pm next day. Each sample was weighed at hourly intervals during the first 8 hours and after 10, 13, 20, 24, 26 and 30 hours of drying. Extra samples were oven dried at the start and end of the drying period to estimate their initial and final moisture contents. Their intermediate moisture content was estimated from the weight losses obtained from weighing during the drying period. Moisture contents, expressed as g water/g dry matter, were fitted to the equation $Y = A.e^{-bt} + C$, of Morris (1972), where Y is the moisture content after t hours of drying, A is the difference between the initial moisture content and final moisture content C. The drying coefficient 'b' represents the rate of water loss per unit of water in the plant tissue.

To evaluate the differential drying rate of lamina and stem, 50 g samples of each grass were taken in triplicate, from each field replicate,

Table 1. Daily climatic data for the period January 5–10 and February 1–6, 1987

	January						February					
	5	6	7	8	9	10	1	2	3	4	5	6
Temperature (°C)												
Maximum	31.4	30.2	30.0	31.2	34.2	31.8	28.6	31.3	33.1	30.0	32.0	32.0
Minimum	16.8	17.4	18.2	16.9	19.0	20.4	19.1	18.8	21.2	20.2	17.6	19.9
Relative humidity (%)												
12 o'clock	77	75	77	76	79	78	76	75	78	73	69	68
6 o'clock pm	50	54	50	55	69	65	60	58	44	70	57	54
12 o'clock pm	87	95	95	85	78	85	91	83	87	95	92	83
Radiation (hours)	8.8	8.8	10.6	12.0	9.9	8.2	7.0	9.7	6.2	3.5	8.4	8.7
Rain (mm)	0	0	1.3	0	0	0	0	0	0	0	0	0
Evaporation — Class A (mm)	4.3	5.4	4.2	6.4	6.0	6.8	5.1	5.7	5.6	5.7	3.5	5.2

Table 2. Morphological traits of the grasses at 8 and 12 weeks age

Traits	Age (weeks)	Grasses Andropogon	Signal	Guinea	Molasses	Jaragua
Stem						
length (cm)	8	18.6^{abcA}	33.7^{aB}	13.8^{bcB}	26.8^{abB}	9.9^{cA}
	12	27.4^{bA}	59.7^{aA}	28.8^{bA}	56.4^{aA}	18.7^{bA}
diameter (mm)[1]	8	2.6-1.9	2.4-1.8	4.5-2.0	2.0-1.9	2.1-1.6
	12	3.8-2.4	1.8-1.6	6.4-2.8	1.9-1.5	3.2-1.9
Leaf blade/tiller	8-12	3.5^{b}	3.5^{b}	3.3^{b}	4.5^{a}	3.2^{b}
length (cm)	8	30.7^{bB}	20.0^{cA}	42.8^{aB}	17.2^{cA}	40.0^{aB}
	12	48.4^{bA}	19.0^{cA}	59.1^{aA}	16.2^{cA}	51.9^{abA}
width (cm)	8	0.9^{bcB}	1.0^{bcA}	1.4^{aA}	1.1^{bA}	0.8^{cA}
	12	1.4^{abA}	1.0^{cA}	1.5^{aA}	1.2^{bA}	0.8^{cA}
area (cm^2/blade)	8	25	19	52	17	30
	12	62	17	81	18	38
area (cm^2/tiller)	8	81	60	141	63	79
	12	242	65	316	91	146
Specific leaf						
area (dm^2/g)	8-12	2.5^{b}	2.8^{ab}	2.3^{b}	3.3^{a}	2.8^{ab}
Leaf weight ratio (g/g)	8	0.64^{bA}	0.48^{cA}	0.72^{aA}	0.61^{bA}	0.76^{aA}
	12	0.58^{bB}	0.35^{dB}	0.72^{aA}	0.44^{cB}	0.76^{aA}

[1] Mean values for larger and smaller estimations, respectively.
Capital letters compare means between ages, A>B, P<0.05.
Lower case letters compare means in the same line, a>b>c, P<0.05.

separated into fractions of leaf blade and stem (tiller remaining) and oven dried after 0, 7 and 30 hours of exposure to the chamber conditions. The moisture content of each fraction was expressed on a wet basis.

Morphological traits

Grass samples were taken from each plot for determination of stem length and diameter, leaf blade length, width, area and number per tiller as well as specific leaf area and leaf weight ratio. Leaf weight ratio was estimated on a dry matter basis from 100 g freshly clipped samples. All other traits were estimated from 10 tillers sampled from each plot. Leaf blade length and width were measured on all expanded leaves of a tiller, after lamina separation. Stem diameter, measured on the medium third of the tiller remaining, was expressed as the average of the extreme values found for each tiller. Stem length was measured from the base of the tiller to the ligule of the last expanded leaf.

Results and discussion

Morphological characteristics

The 5 grass species differed ($P < 0.05$) in many of the traits considered (Table 2). Pseudostem was observed in jaragua and andropogon up to 12 weeks of age as well as in guinea at 8 weeks. Molasses and signal exhibited true stems, totally or partially covered by leaf sheath, with circular sections and average diameter of 2 mm. Species differences regarding stem diameter became more pronounced at 12 weeks, andropogon and guinea having thickest stems.

The number of expanded leaves per tiller averaged 3.1 and 4.1 at 8 and 12 weeks of age; similarly, an increase in leaf length and area due to plant age was observed in all grasses except molasses and signal whose leaf laminas were 2 to 3 times shorter than the other grasses. Highest figures for leaf area per tiller or per blade were observed in guinea and andropogon, while lowest figures occurred with molasses and signal. Tiller leaf area differed markedly among species, particularly at 12 weeks. The species also differed ($P < 0.05$) in leaf weight ratio, the ratios for molasses and signal not only being the smallest but decreasing as the plants aged.

Drying in controlled chamber

Initial moisture and moisture content after 7 and 30 hours in the drying chamber, of the whole tiller, leaves and stems (tiller remaining), are shown in Table 3. These figures show differences in initial moisture among tillers only at the age of 12 weeks.

Table 3. Moisture level of whole tillers, leaf blades and stems of 8 and 12 week old grasses; initial and after 7 and 30 hours of drying in chamber

Ages (weeks)	Plant part	Grasses				
		Andropogon	Signal	Guinea	Molasses	Jaragua
Initial moisture (%)						
8	T[1]	79.0^{a}	80.1^{a}	81.2^{a}	82.4^{a}	80.8^{a}
	L[1]	72.2^{aB}	75.8^{aA}	74.4^{aB}	76.0^{aB}	75.7^{aB}
	S[1]	80.4^{bcA}	77.6^{cA}	84.9^{aA}	81.0^{abcA}	83.1^{abA}
12	T	77.2^{ab}	74.5^{b}	79.4^{a}	76.6^{ab}	77.7^{ab}
	L	67.6^{bB}	74.0^{aA}	72.9^{aB}	69.4^{bB}	73.2^{aB}
	S	77.4^{cA}	72.2^{dA}	84.4^{aA}	79.0^{bcA}	81.3^{abA}
Residual moisture after 7 hours (%)						
8	L	44.3^{cB}	57.1^{aB}	46.9^{bcB}	53.8^{abB}	40.0^{cB}
	S	66.4^{aA}	68.5^{aA}	67.5^{aA}	67.9^{aA}	62.0^{aA}
12	L	46.8^{abB}	51.8^{aB}	47.1^{abB}	44.5^{bB}	41.3^{bB}
	S	68.6^{aA}	60.6^{bA}	66.1^{abB}	67.1^{aA}	60.4^{bA}
Residual moisture after 30 hours (%)						
8	T	22.4^{b}	28.7^{a}	22.4^{b}	24.7^{ab}	13.7^{c}
	L	12.6	16.0	14.6	15.3	12.7
	S	27.1	34.9	36.6	26.8	17.1
12	T	27.7^{a}	27.3^{a}	25.4^{a}	28.5^{a}	17.3^{b}
	L	10.5	11.4	10.6	10.8	10.4
	S	27.6	19.1	26.0	30.2	13.3

a>b>c>d, ($P<0.05$) lower case letters compare means in the same line; capital letters compare means between leaf and stem (A>B)
[1] Tiller (T); Leaf (L) and Stem (S).

Initial moisture differences between leaves and stems ($P < 0.05$) are generally observed, stem values being greater. The increase in the difference in moisture between leaves and stems after 7 or 30 hours of drying is in line with data reported by Leschem *et al.* (1972), Harris *et al.* (1974) and Jones and Prickett (1981), demonstrating faster drying rates for leaves than stems. The residual moisture in the whole tiller after 30 hours of drying also differed among species, lowest values being found for jaragua and highest ones for signal and molasses.

Figures 1 and 2 represent the drying curves of each grass clipped at the ages of 8 and 12 weeks, respectively. In general, the moisture loss was very fast during the first 9 hours, and proceeded at a much slower rate later on. Jaragua, followed by guinea, lost moisture the fastest, while signal had the slowest drying rate, mainly at the age of 8 weeks. The parameters of the curves for Figures 1 and 2, drawn from the equation $Y = A.\ e^{-bt} + C$ fitted to experimental data, are presented in Table 4. It can be observed that signal has the lowest values of 'b', the moisture loss coefficient, while jaragua has the highest values.

For 8 week old samples, if a 20% residual moisture (wet basis), equivalent to 0.25 g moisture/g dry matter, is considered the optimal moisture level for baling, the drying time needed for each grass would be 38.0, 30.4, 29.7, 28.8 and 18.3 hours for signal, andropogon, molasses, guinea and jaragua, respectively, as calculated from equation $y = A.\ e^{-bt} + C$, using the parameters in Table 4, or derived from Figure 1. The drying rates of the grasses correlated directly with leaf weight ratio and inversely with stem length (Table 5). These findings are in line with reports by Morris (1972), Jones (1979) and Owen and Wilman (1983).

Field drying

Experimental data recorded for the drying rates of the five grasses under field conditions are presented in Figures 3 and 4. Intensive moisture loss can be observed during the first 3 hours. Eight-weeks old samples of jaragua and andropogon reached moisture level equal to or below 0.25 g/g DM, by the end of the first day. None of the species, except jaragua, reached a moisture level of 0.5 g/g DM by the end of the first day (1900 hrs), when harvested at the age of 12 weeks. An increase in moisture level was observed in all grasses on the morning of the second day as a result of wetting by dew, favoured by night weather conditions of high air humidities and low temperatures (Table 1). Still, this wetting effect

Table 4. Equation[1] parameters for moisture content (g/g dry matter) as a function of drying time and standard errors (in brackets)

Grasses	Age (weeks)	Parameters A	b	C
Andropogon	8	3.624 (0.065)	.1385 (0.0066)	.196 (0.053)
	12	3.053 (0.024)	.1226 (0.0027)	.312 (0.020)
Signal	8	3.852 (0.052)	.1041 (0.0039)	.176 (0.051)
	12	2.666 (0.025)	.0957 (0.0029)	.223 (0.026)
Guinea	8	4.116 (0.057)	.1568 (0.0050)	.205 (0.039)
	12	3.480 (0.028)	.1604 (0.0029)	.322 (0.018)
Molasses	8	4.602 (0.061)	.1244 (0.0048)	.136 (0.057)
	12	3.000 (0.022)	.1173 (0.0020)	.286 (0.019)
Jaragua	8	4.228 (0.067)	.1735 (0.0071)	.073 (0.048)
	12	3.361 (0.022)	.1651 (0.0026)	.165 (0.014)

[1] $Y = A.e^{-bt} + C$

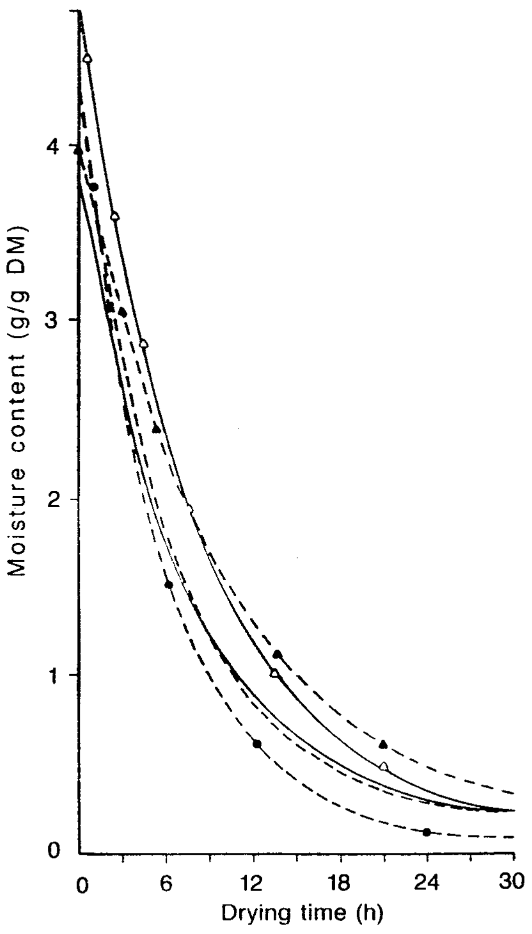

Figure 1. Drying curves of 8-week old grasses in a controlled chamber — Andropogon; ●---● Jaragua; --- Guinea; △—△ Molasses; ▲---▲ Signal.

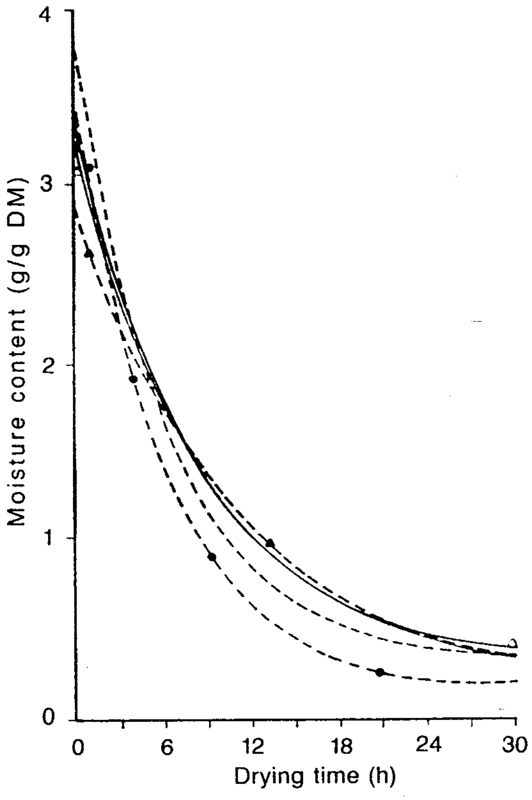

Figure 2. Drying curves of 12-week old grasses in a controlled chamber — Andropogon; ●---● . Jaragua; --- Guinea; △—△ Molasses; ▲---▲ Signal.

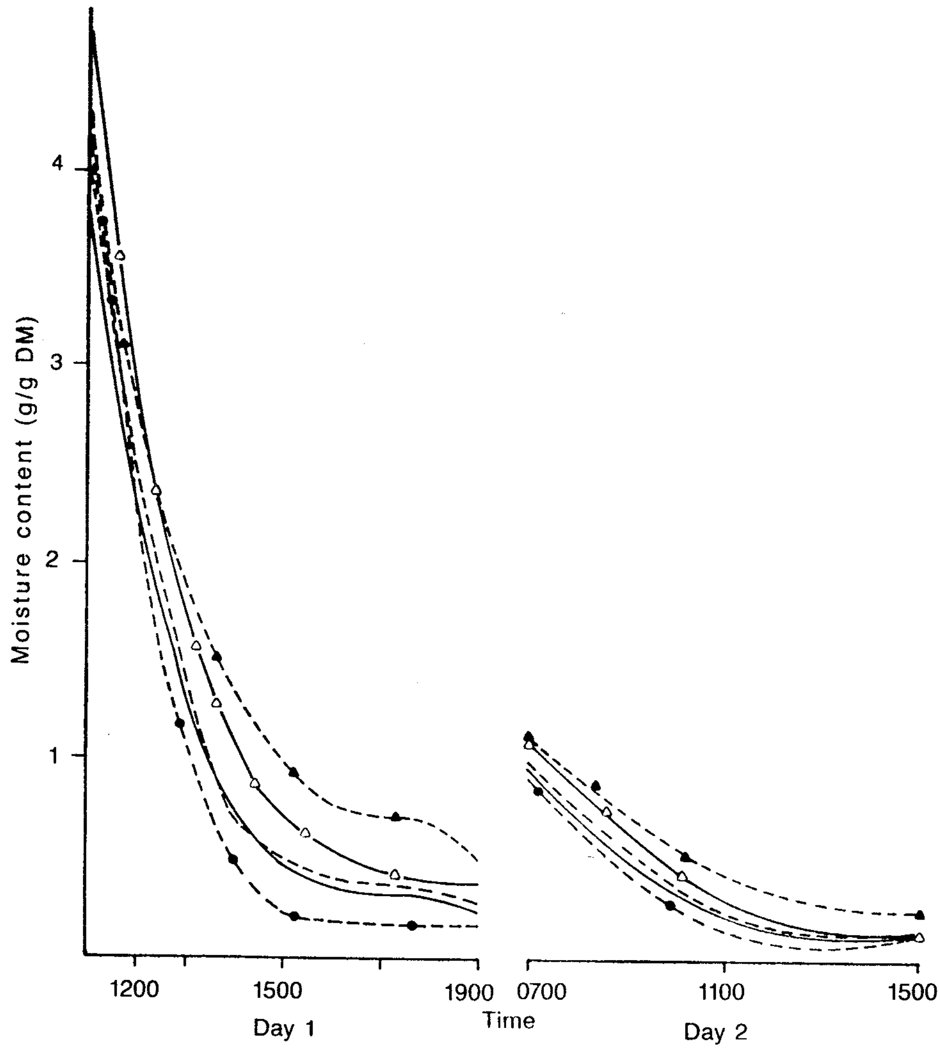

Figure 3. Field drying curves for 8-week old grasses — Andropogon; ●---● Jaragua; --- Guinea; △—△ Molasses; ▲---▲ Signal.

disappeared after the first hours of morning drying, so that moisture level of about 0.25 g/g DM was reached by mid-day in all 8 weeks samples except for signal; however, for 12-week old samples jaragua reached the later moisture level well before the other species. In agreement with the drying rates under chamber conditions, these field data point to jaragua as the fastest drying species and molasses and signal as the ones that dry more slowly.

These observed differential drying rates may clearly be attributed to morphological traits since the species did not show substantial difference in initial moisture. Residual moisture content after 2 days of drying correlated closely with stem length and leaf weight ratio, with 'r' values of 0.82 and −0.72, respectively.

Even though it would be dangerous to extrapolate to large scale field drying, the rates of drying reported in this study, which dealt with small sized samples, are in good agreement with reports from Pizarro (1980) regarding jaragua reaching 25% residual moisture (wet basis) in only six hours, as well as with the findings of Gomide and Cruz (1986) about the shorter length of time needed for jaragua to reach baling conditions when compared with guinea. Again, the smaller moisture loss coefficient observed for molasses

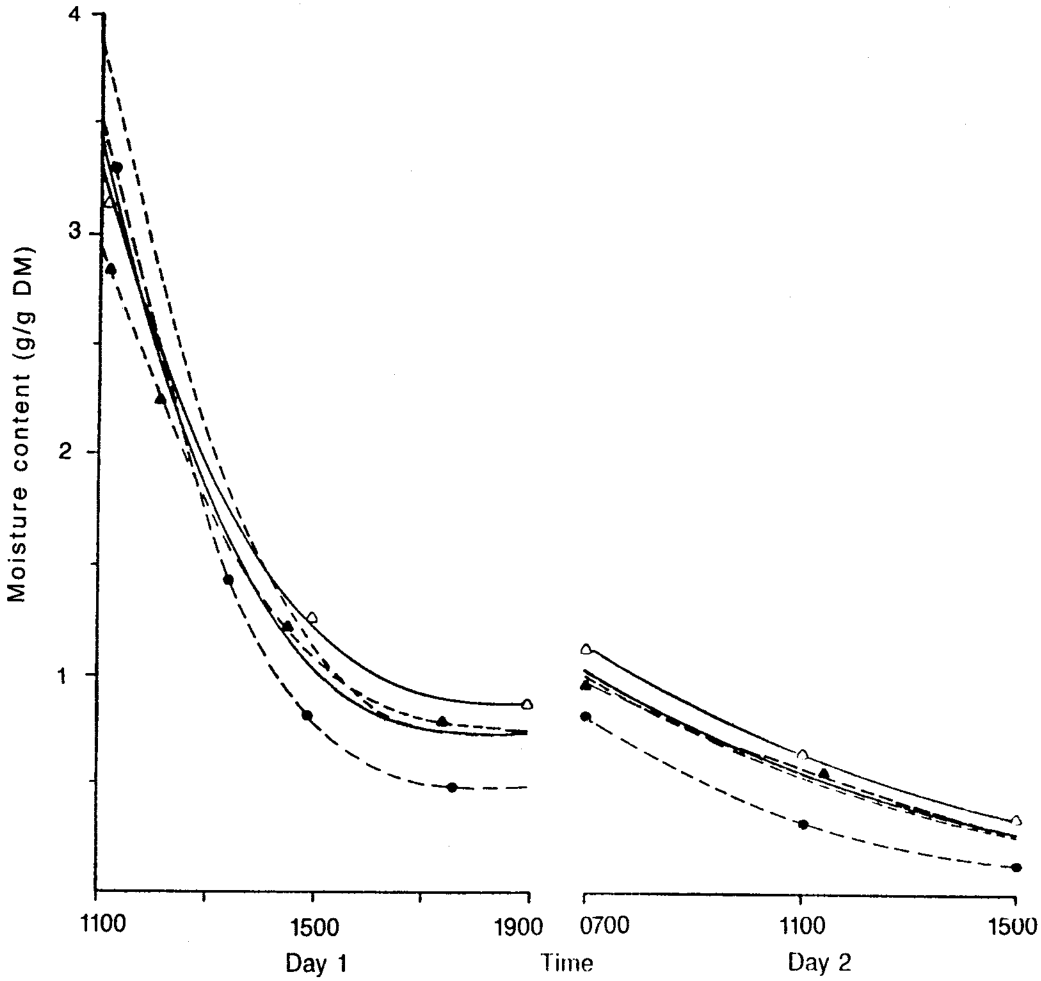

Figure 4. Field drying curves for 12-week old grasses — Andropogon; ●---● Jaragua; --- Guinea; Δ—Δ Molasses; ▲---▲ Signal.

agrees with the difficulties in making hay out of this grass as reported by Vilela *et al.* (1971) and Carvalho (1979). In fact, Vilela *et al.* (1971) reported that molasses had to lie in the field for 56 hours, including 29 hours of exposure to sun light, during a haymaking process which involved daily tedding and windrowing of the grass.

Data presented point to the need to appraise the leafiness of the grasses, by choosing either the correct species or plant age, in order to improve the chances of a successful haymaking. Of the five species studied, jaragua followed by guinea and andropogon would be the most suitable for haymaking.

Table 5. Simple linear regression coefficients between moisture loss coefficients and morphological traits of 8 and 12 week old grasses

	Ages (weeks)		
	8	12	8-12[1]
Leaf weight ratio (g/g)	0.983	0.972	.948
Stem length (cm)	−0.988	−0.839	−.780
Stem diameter (mm)	0.172	0.659	.433
Blade length (cm)	0.889	0.836	0.751
Blade width (cm)	−0.051	0.003	−0.056
Blade area (cm^2/leaf)	0.638	0.507	0.611
Blade area (cm^2/tiller)	0.559	0.604	0.379
Specific leaf area (dm^2/g)	−0.338	−0.425	−0.403

[1] Figures derived from 10 pairs of observations.

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