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GROWTH CURVE AND NUTRITIVE VALUE OF FORAGE SORGHUM IN THE TROPICS

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A field trial located in the region of the "cerrados" of Brazil was carried out to study the growth curve and nutritive value of forage sorghum under tropical conditions. Three currently recommended sorghum cultivars (Sart, BR601 and Santa Eliza) were studied in two consecutive years. The first cut was made when the crop reached 80-90 cm high; subsequental cuttings were made at intervals of 14 days, well into the dry season. Peak yields were obtained at 120-150 days of age, and varied from 17-20 ton DM.ha^{-1}. Stems represented 50% or more of the crop while the contribution of leaves varied between 10 and 25%. The majority of leaves dried out as the crop matured and represented only 15-20% of total yield at silage harvest. The contribution of panicles at ensiling time varied between 10 and 25%. The average ratio of grain:rachis was 2:1 in BR601. Crude protein (CP) in whole plant was similar in all varieties decreasing exponentially from about 14% at 40-50 days of age and stabilizing in 3-5%. At ensiling time (115-130 days) protein in the stalks represented only 2-3% of DM, while that of leaves was three times higher. Panicles contained a constant proportion of CP, at about 10%. The digestibility of the crop decreased linearly with time at a rate of 0.13%/day for cv.Sart and BR601, while that of Santa Eliza remained constant throughout the experimental period (mean of 52.48% $\pm$ 0.50). It concluded that sorghum has high potential growth and relatively high nutritive value under tropical conditions, although its protein content can be a limiting factor.

Key words: Growth curve, nutritive value, forage sorghum, tropics

Sorghum herbage yields vary within very on limits, from 9 tc 20 t DM/ha in the wet-dry tropics of Brazil (Anon., 1981), depending on the variety, soil moisture regime, fertilizers used, the stage of growth at which the plants are harvested and some other less important factors. Although good yields can be expected in farm practice, forage quality is low (Paiva et al 1978).

In the wet and dry tropics an important alternative is the use of deferred forages and other crops (Vera et al 1981; Pizarro, 1980) and since comparable results for forage sorghum were not available, the present study was carried out in order to estimate the growth curve of sorghum, yield components, nutritive value and digestibility.

Materials and Methods

Three currently recommended sorghum cultivars (*Sorghum bicolor* (L.) Moench.) (Sart, Santa Eliza and BR601) were studied in two consecutive years, in the same soil and with similar management. Planting date was in the first week of November of each year, at a rate of 18-20 seeds per meter, in lines spaced at 70 cm, which resulted in a final population of 222300 plants.ha^{-1}. The soil was a red-yellow latosol, characteristic of the "Cerrados" of Brazil (EPAMIG, Faz. Exp. "Santa Rita", 19°28'S and 44°15'W), and was fertilized with 200 kg.ha^{-1} of 4-14-8; in the second year, an additional 40 kg N were applied 50 days after sowing. A complete description of the area and local climate is given by Liseu (1981).

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For determination of the growth curve, the first cut was made when the crop reached 80-90 cm high; subsequent cuttings were made at intervals of 14 days, well into the dry season. Dry matter yields were determined in five randomly chosen sites within the crop (2 ha); ten linear meters were cut in each place, weighed, chopped and sampled for dry matter (DM) determination at 105°C. In each site, six plants were harvested for separation of plant parts (green and dry leaf blades, stems plus sheaths, and panicles respectively); their contribution was expressed on a DM basis. Samples were analysed for crude protein (CP), soluble carbohydrates (CHO) by the Munson and Walker (1906) method for cv. Sart and Santa Eliza and by the techniques of Clegg (1956) and MacRae et al (1974) modified by Vera (1979) for cv. BR601 and in vitro dry matter digestibility (IVDMD) by the Tilley and Terry method (1963).

A comparison of in vitro and in vivo digestibility for the standing crop was made with cv. Sart. The latter was a continuous digestibility trial with six wethers, beginning at 50 days of age, and until 180 days old. The same cultivar was ensiled at 103 days (28.5% DM), in a 24 ton subterranean silo and its in vivo digestibility determined with six wethers after 9.5 months of storage. Also, to estimate the drop in quality due to ensiling, cv. Santa Eliza was ensiled at 176 days of age (30.48% DM) in a 24 ton subterranean silo and its in vivo digestibility estimated as for cv. Sart after 17 months of storage.

Results

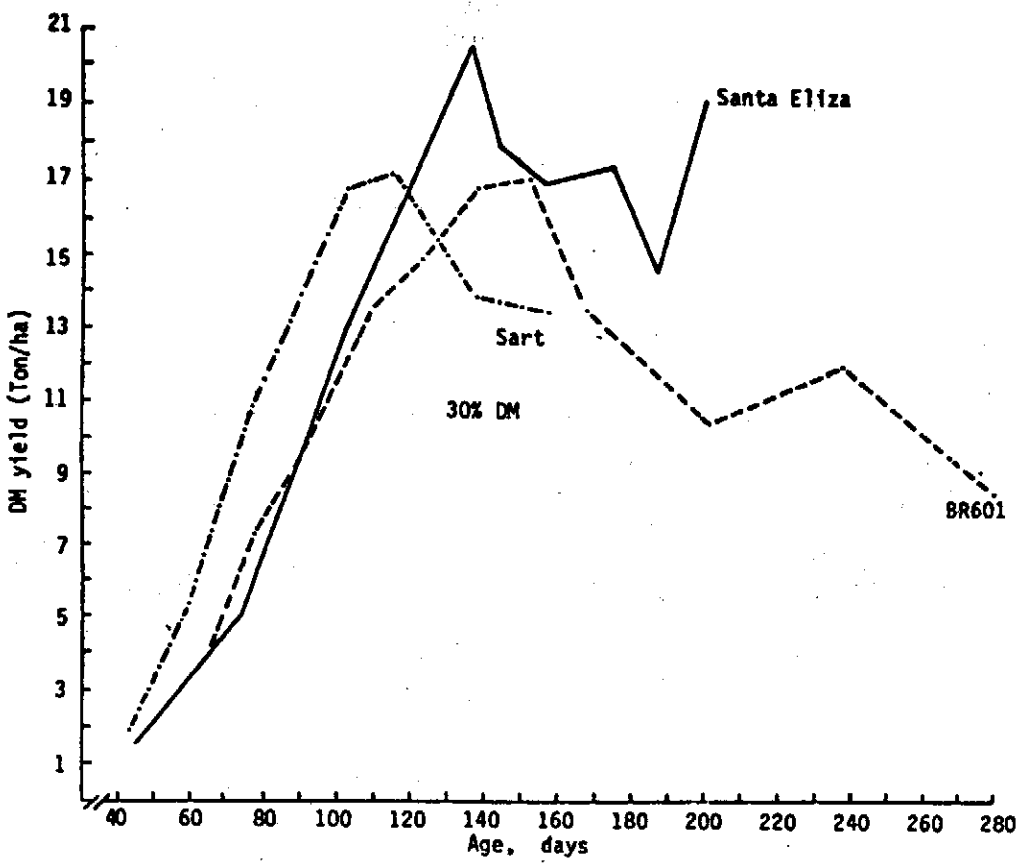
DM yields are presented in Figure 1. Peak yields were obtained at 120-150 days of age, and varied from 17-20 ton DM/ha. These were followed by a linear decrease of 0.33%/day in cv. BR601, 0.45%/day in cv. Santa Eliza, and 0.53%/day in cv. Sart. Peak yields (Figure 1) did not coincide with 30% DM (Figure 3c) in the whole plant, a criterion generally adopted for ensiling.

Stems represented 50% or more of the crop (Figure 2a), while the contribution of leaves varied between 10 and 25 % throughout most of the growing period. The majority of leaves dried out as the crop matured (Table 1) and represented only 15-20% of total yield at silage harvest (Figure 2b). The contribution of panicles at ensiling time varied between 10 and 25%, depending on the variety, and thereafter there was a steady decline in yield of heads (Figure 2c). The average ratio of grain: rachis was 2:1 in cv. BR601.

CP in the whole plant (Figure 3b) was similar in all varieties, decreasing exponentially from about 14% at 40-50 days of age and stabilizing in 3-5%. A similar tendency was shown by CP in stems.(Figure 4a). At ensiling time (115-130 days) protein in the stalks represented only 2-3% of DM, while that of leaves was three times higher (Figure 4b). Panicles contained a constant proportion of CP, at about 10% (Figure 4c).

The digestibility of the crop decreased linearly with time (Figure 3a), at a rate of 0.13%/day for cv. Sart and BR601, while that of Santa Eliza remained constant throughout the experimental period (mean of 52.48% ± 0.50).

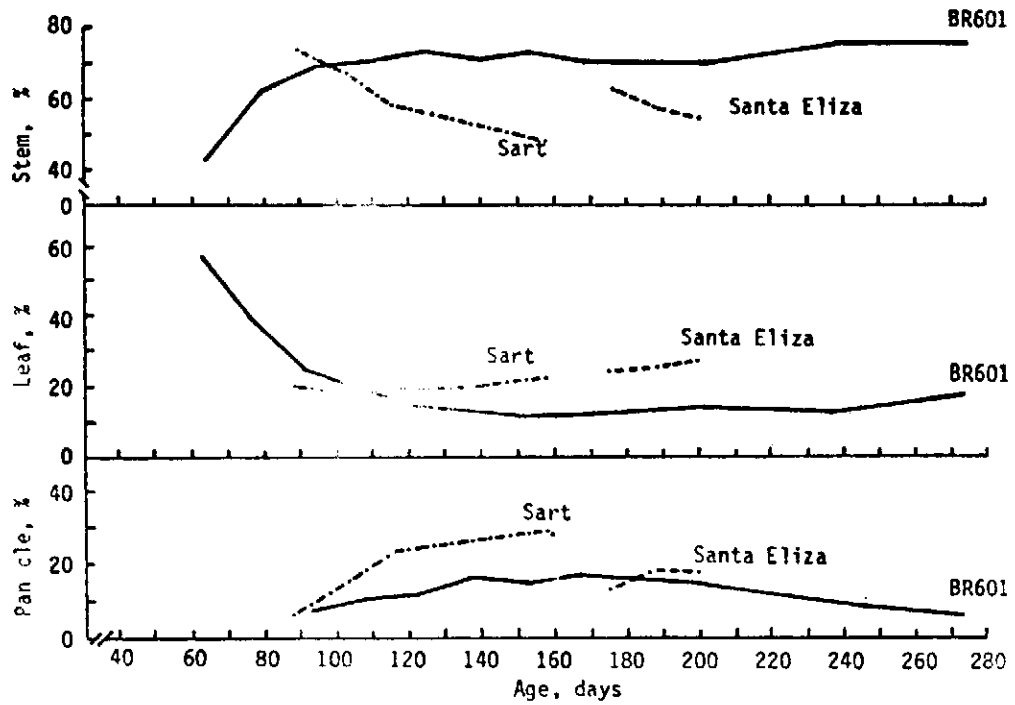
Figure 1:
Sorghum yield



Differences in composition between green and dry leaves were only studied in cv. BR601 (Table 1 and 2). The results showed that although green leaves were high in N and IVDMD, their contribution to DM yield decreased very rapidly with age, followed by a slower increase in dry leaves. CP of the latter remained constant up to the end of the experiment.

At all ages studied, the IVDMD of stems was very similar to that of green leaves (Table 2, cv. BR601), and higher than that of green + dry leaves. As shown in Table 2, the digestibility of grain is much higher than that of rachis. At similar ages, the content of soluble CHO was similar in cv. Sart and BR601 and much higher than that of Santa Eliza (Table 3).

Figure 2:
Yield components



To check the in vitro results, a comparison with in vivo digestibility was made with cv. Sart. Agreement between both techniques was good (Figure 5) except in the latter part of the season, which coincides with physiological maturity of the grain.

Table 1:
Percentage and crude protein content of green and dry leaves in cv. BR601.

	Age, days										
	63	78	93	108	123	138	153	168	202	238	274
Green leaves:											
Contribution to yield, %	57	38	24	19	11	7	1	1	3	-	-
Crude protein content, %	17.4	14.0	12.3	12.2	11.2	9.8	-	-	-	-	-
Dry leaves:											
Contribution to yield, %	-	-	-	-	4	5	11	11	12	14	17
Crude protein content, %	-	-	-	-	-	4.6	5.5	5.2	4.2	4.1	5.9

Table 2:

Percentage IVDMD in sorghum plant components.

	IVDMD, %									
	Age, days									
	176	187	200							
Santa Eliza:										
Leaf	44.59	44.79	40.96							
Stems + sheaths	53.84	51.60	54.86							
Panicles	53.25	61.97	60.60							
	Age, days									
	89	103	115	137	145	158				
Sart:										
Leaf	54.02	49.05	42.61	43.05	40.44	32.60				
Stems + sheaths	62.35	61.22	55.68	60.30	60.90	55.06				
Panicles	64.30	71.38	70.72	72.23	77.62	72.98				
	Age, days									
	63	78	93	108	123	138	153	168	202	238
BR601:										
Leaf, green	67.23	64.83	66.95	66.38	63.39	63.51	59.46	56.05	56.69	60.36
Leaf, dry	-	-	-	-	44.78	49.13	50.27	43.13	33.44	31.01
Stems + sheaths	67.98	60,29	59.40	64.72	64.63	64.32	60.93	53.14	41.25	38.63
Rachis	-	-	-	-	-	-	33.89	39.36	34.34	29.65
Panicles	-	-	54.53	63.36	71.99	70.92	60.94	58.85	37.26	35.45
Grain	-	-	-	-	-	-	72.64	77.13	77.30	-

The in vivo DM digestibility of sorghum cv. Sart ensiled at 103 days of age was 55.28%, which compares with an in vivo digestibility of 56.9% for the standing crop at the same age. On other hand, the standing crop of cv. Santa Eliza at 176 days of age had an in vitro digestibility of 51.51%, while the ensiled crop had, after 17 months of storage, an in vivo digestibility of 47.10%.

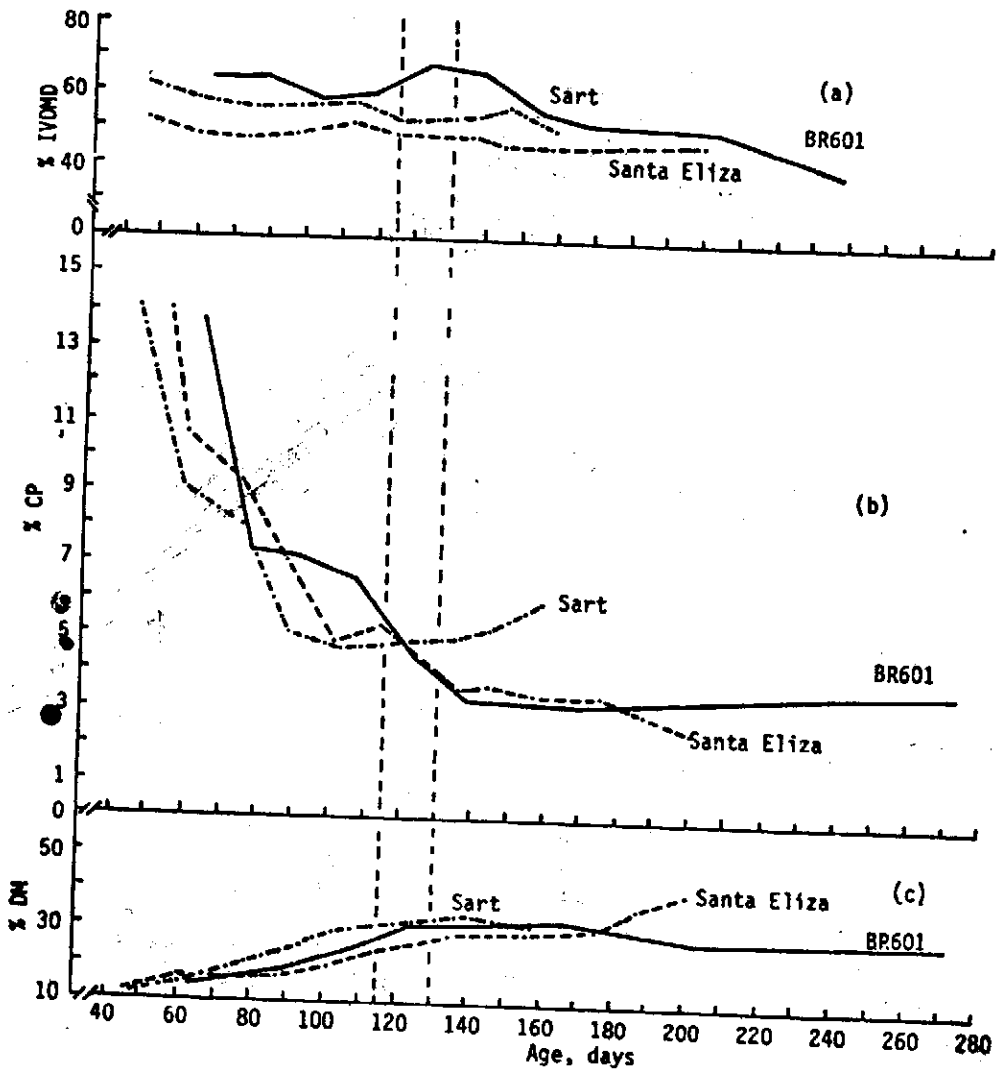
Discussion

Sorghum DM yields were generally very high, and comparable to that of other crops used for conservation. Pizarro and Vera (1980) reported a range of yields for tropical maize of 10-18 tons DM.ha^{-1} depending on the year considered. Regional trials have indicated a slightly higher yield of sorghum than of maize (Anon., 1981). The other major crop for ensilage in tropical regions is elephant grass which showed a DM yield of 12-15 tons DM.ha^{-1} over an equivalent growth period (Andrade and Gomide, 1972).

In the wet and dry tropics an important economic alternative use of sorghum and maize is the deferred use of the crop for the dry season. Previous experiments with maize have shown that losses in quality of the deferred standing crop are minimal during the dry season (Pizarro, 1980).

Since comparable results were not available, the study of the growth curve of sorghum was continued up to 280 days of age. This showed that there was a steady loss in yield (Figure 1), no apparent loss of CP (Figure 3b) and a slight decrease in grain content (Figure 2c). The latter was due mainly to bird attack. The occasional regrowth resulting from scattered showers occurring during the dry season did not result in an improved N content of IVDMD, despite the maintenance of a low DM content (Figure 3c) and slight increase in leaf percent (Figure 2b) in all cultivars. Still another alternative use is grazing the sorghum stover after grain harvesting. In this case, the major plant part left in the field is the stems (Figure 2a) whose quality in terms of CP (Figure 4a) and IVDMD (Table 2) is fairly stable.

Figure 3:
Chemical composition



The possible existence of differences in quality between stems of different cultivars (Table 2 and Hanna et al 1977) is an important consideration and deserves further research, since they make a major contribution to yield (Figure 2a).

Contrary to what happens with maize (Pizarro and Vera, 1980) or elephant grass (Andrade and Gomide, 1972), sorghum can be ensiled over extended periods of time since its DM content remains stable at around 30% for many weeks (Figure 3c). Nevertheless this will be generally accomplished at the expense of nutritive value (Figure 3a and b). The quality of the crop at 30% DM is similar or slightly higher than that of tropical maize (Pizarro and Vera, 1980). The variability in IVDMD between cultivars at ensiling time was about 15 units, several times higher than that observed between varieties of maize (Vera and Pizarro, 1981). The daily rate of decrease in IVDMD varied significantly between cultivars, except in cv. Santa Eliza in which digestibility remained constant, an observation also reported by Fernandes (1978) for a range of ages from 112 to 217 days. This constancy in digestibility is consistent with that observed in terms of soluble carbohydrates (Table 3), which are also lower in cv. Santa Eliza relative to the two other sorghums under study. Still another possible explanation for the differences in IVDMD between cultivars is the observed disparity in the nutritive value of panicles (Table 2). It is clear that panicle quality is related to the ratio of grain: rachis, as the former has a much larger IVDMD (Table 2) and CP content (12% vs 7%) than that of rachis. As the season progressed, loss of grain by bird attack reduced panicle digestibility, which approached that of the rachis.

Table 3:

Percentage soluble carbohydrates in sorghum.

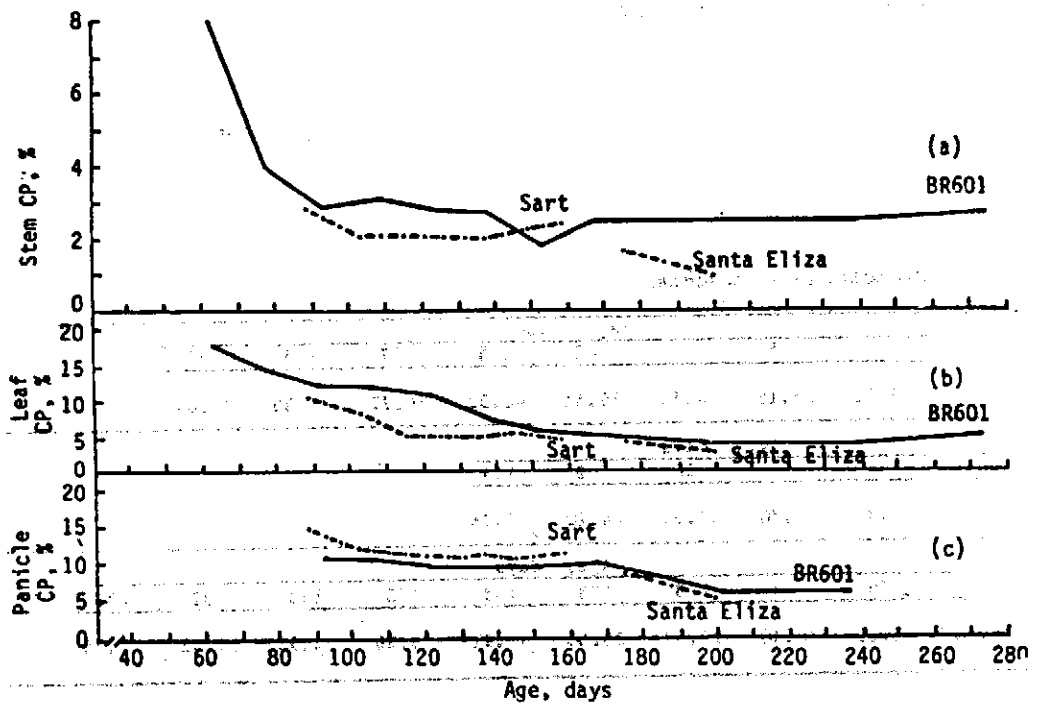
	Age, days									
	45	59	75	89	103	115	137	145	158	
Sart	20.65	27.72	26.15	34.53	39.51	40.52	36.77	35.06	34.07	
	Age, days									
	45	59	74	88	102	114				
Santa Eliza	18.72	27.88	25.70	23.63	24.10	25.76				
	Age, days									
	63	78	93	108	123	138	153	168	202	238
BR601	14.64	23.11	30.30	29.67	39.64	40.91	29.86	24.56	11.52	7.79

Such variability between cultivars was not observed in terms of CP (Figure 3b). Nitrogen content of the crop was slightly lower than that of tropical maize at a similar DM content (Miller and Blair-Rains, 1963; Thomas, 1979; Pizarro and Vera, 1980) and higher than in elephant-grass (Andrade and Gomide, 1972; Silveira et al 1976).

In temperate sorghum and maize, leaf blades make an important contribution to DM yield (Schmid et al 1976; Fribourg et al 1976; Thomson and Rogers, 1968; Perry and Compton, 1977; Bunting, 1976) but not so under tropical conditions (Table 1). Nevertheless, differences in CP (Table 1) and IVDMD (Table 2) between green and dry leaves are large. A similar tendency has been found for leaves of tropical maize (Pizarro, Marques and Vera, unpublished).

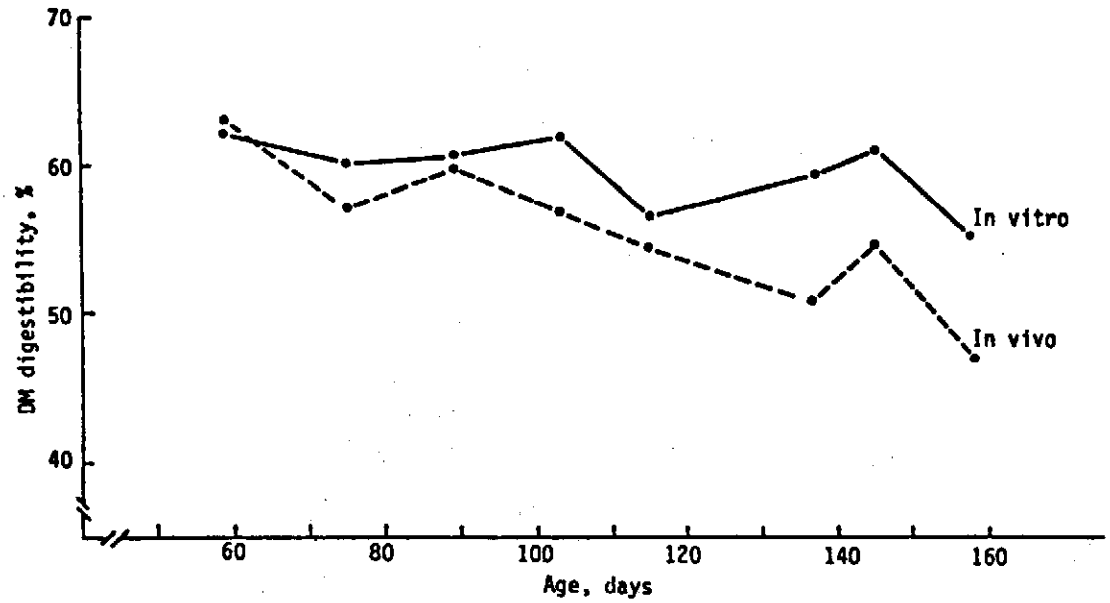
A significant difference between in vitro and in vivo digestibility of the mature plant of cv. Sart was observed (Figure 5). In these three stages of growth, DM percent of grain was 80% or higher indicating physiological maturity. It is possible that the fine grinding of the sample unduly increased IVDMD (Tilley and Terry, 1963) since it has been shown that processing of the sorghum grain significantly increases in vivo digestibility (Armstrong, 1972).

Figure 4:
Crude protein



The fall in digestibility (2.86% after 285 days' storage) was very small for cv. Sart and higher (8.56% after 503 days) for Santa Eliza.. Results from a comparative trial with maize silage under similar conditions showed a decrease of 6% in maize silage, compared with the standing crop (Pizarro and Vera, 1980).

Figure 5:
In vitro versus in vivo DM digestibility of sorghum (cv Sart) as a function of age



References

Andrade, I F & Comide, J A 1972 Curva de crescimento e valor nutritivo do Capim elefante (*Pennisetum purpureum*, Schumach) A-146 Taiwan. Revista da Sociedade Brasileira de Zootecnia. 1:41-58.

Anonymous. 1981 Ensaio nacional de sorgo forrageiro em Minas Gerais. Relatório Milho e Sorgo da EPAMIG, 77/79.

Armstrong, D G 1972 Developments in cereal processing ruminants. In: Cereal Processing and Digestion, pp. 9-37. U.S. Feed Grains Council, London.

Bunting, E S 1976 Effects of grain formation on dry matter distribution and forage quality in maize. Experimental Agriculture. 12:417-428.

Clegg, K M 1956 The application of the anthrone reagent to estimation of starch in cereals. Journal of the Science of Food and Agriculture. 7:40-44.

Fernandes, W 1978 Produtividade do sorgo Santa Eliza (*Sorghum vulgare*, Pers.) em seis idades e valor nutritivo das silagens. MS Thesis, Viçosa University, Minas Gerais, Brazil. 64 pp.

Fribourg, H A; Duck, B N & Culvahouse, E M 1976 Forage sorghum yield components and their *in vivo* digestibility. Agronomy Journal. 68:361-365.

Hanna, W W; Monson, W G & Burton, G W 1977 Morphological and anatomical factors affecting forage quality. Georgia Agricultural Research. 18:17-21.

Liseu, L C 1981 Curva de produçao, composiçao química, digestibilidade *in vitro* e taxa de fermentaçao do sorgo. MS Thesis, Escola Superior Agricultura de LAVRAS, Minas Gerais, Brazil. 96 pp.

MacRae, J C; Smith, D & McCready, R M 1974 Starch estimation in leaf tissue. A comparison of results using six methods. Journal of the Science of Food and Agriculture. 25:1465-1469.

Miller, T B & Blair-Rains, A 1963 The nutritive value and agronomic aspects of some fodders in Northern Nigeria. I. Fresh herbage. Journal of the British Grassland Society. 18:158-167.

Munson, L S & Walker, P H 1906 The unification of reducing sugar methods. Journal of the American Chemistry Society. 28:663-686.

Paiva, J A J; Pizarro, E A; Rodríguez, N M & Viana, J de A C 1978 Qualidade da silagem da regiao Metalúrgica de Minas Gerais. Arquivos da Escola de Veterinaria. Universidade Federal de Minas Gerais. 30:81-88.

Perry, L J & Compton, W A 1977 Serial measures of dry matter accumulation and forage quality of leaves, stalks, and ears of three corn hybrids. Agronomy Journal. 69:751-755.

Pizarro, E A 1980 Curva de crescimento de uma cultura de milho. In: Reuniao da Sociedade Brasileira de Zootecnia, 17. Fortaleza. pp. 435-436.

Pizarro, E A & Vera, R R 1980 Efficency of fodder conservation systems; maize silage. In: C Thomas (Editor). Proceeding of a Conference on Forage Conservation in the 80's Brighton. British Grassland Society, Occasional Symposium, 11. pp. 436-441.

Schmid, A R; Goodrich, R D; Jordan, R M; Marten, G C & Meiske, J C 1976 Relationships among agronomic characteristics of corn and sorghum cultivars and silage quality. Agronomy Journal. 68:403-406.

Silveira, A C; Tosi, H & Faria, V P 1976 Determinaçao dos carboidratos do capim-elefante variedade napier por diferentes métodos de análise. Revista da Sociedade Brasileira de Zootecnia. 5:9-18.

Thomas, C 1979 Effect of source of nitrogen supplement and corn and cob meal inclusion on the voluntary intake and performance by steers given maize silage. Tropical Agriculture (Trinidad). 56:327-332.

Thomson, A J & Rogers, H H 1968 Yield and quality components in maize grown for silage. Journal of Agricultural Science (Cambridge). 71:393-403.

Tilley, J M A & Terry, R A 1963 A two-stage technique for the *in vitro* digestion of forage crops. Journal of the British Grassland Society. 18:104-111.

Vera, R R 1979 Solubilidade e distribuçao dos carboidratos nao estructurais do capim "Napier". Arquivos da Escola de Veterinaria. Universidade Federal de Minas Gerais, Belo Horizonte. 31:85-90.

Vera, R R; Pizarro, E A & Martins, M 1981 Yield and quality of tropical legumes during the dry season: *Galactia striata* (Jacq.) Urb. In: XIV International Grassland Congress, Kentucky, U.S.A.

Vera, R R & Pizarro, E A 1981 Modelo matemático da produçao de silagem de milho. Arquivos da Escola de Veterinaria. Universidade Federal de Minas Gerais, Belo Horizonte. 33:553-567.

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