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EFFECT OF FERTILIZATION ON THE YIELD AND NUTRITIVE VALUE OF TROPICAL FORAGES ON AN ULTISOL IN COLOMBIA

L E Tergas and G A Urrea

Tropical Pastures Programme, CIAT, Apartado Aéreo 6713, Cali, Colombia

In a split-plot randomised block experiment carried out at CIAT-Quilichao, a study was made of the seasonal production of dry matter and the nutritive value of elephant (*Pennisetum purpureum*), imperial (*Axonopus scoparius*) and guatemala (*Tripsacum laxum*) grasses as well as sugar cane (*Saccharum officinarum*) during the second year following their establishment. The mean total dry matter yield of all species rose significantly ($P < .001$) with fertilizer application. Differences due to species and to season were also highly significant ($P < .001$), but an interaction ($P < .001$) was found between the variables studied such that although elephant grass produced the highest annual mean total yield, the production of imperial and guatemala grasses were higher during the longer of the wet seasons of the year. The mean crude protein (P) and phosphorous (P) contents and the *in vitro* dry matter digestibility (IVDMD) of the forage of imperial grass were significantly higher ($P < .05$) at the three levels of fertilization than those of the other species, especially as compared with sugar cane which was lowest of all. Nutritive value also increased with fertilizer level ($P < .001$), although differences were found in the different species and at different times of year, giving significant interactions ($P < .01$) due to fertilizer-species for P content and IVDMD and due to species-season for CP, P and IVDMD.

Key words: Ultisol, elephant grass (*Pennisetum purpureum*), sugar cane (*Saccharum officinarum*), imperial grass (*Axonopus scoparius*), guatemala grass (*Tripsacum laxum*), crude protein, phosphorous, *in vitro* digestibility.

Forage production from grass species used for cutting is of great importance in the development of the cattle industry in tropical Latin America as a complement to grazing. The use of cutting species contributes to an increase in stocking rate in intensive systems of production and also helps to reduce the scarcity of forage and/or to supplement the relatively low nutritive value of the forage available in prolonged dry seasons of the year.

Elephant grass (*Pennisetum purpureum*) is the most important of the species used for cutting in the tropics (Goncalez and Mendonca, 1982). Native to Africa, it has been introduced to practically all tropical and subtropical parts of the world where it used principally for cutting and on a minor scale for grazing at altitudes from sea level up to 2000 m (Bogdan, 1977). Sugar cane (*Saccarum officinarum*) is considered to be an excellent forage plant (Bregger and Kidder, 1971) with a production potential equivalent to a stocking rate of 20 animals/hectare/year, but with limitations with regard to voluntary consumption (Leng and Preston, 1976). *Axonopus scoparius*, imperial grass, is very tolerant of poor, acid soils (Lotero et al 1969), but is not well adapted to tropical regions below 600 m above sea level with

mean temperatures above 25°C (Argüelles and Alarcon, 1977). Guatemala grass, *Tripsacum laxum*, is another forage plant grown in the tropics which has been highly considered because of its vigour, abundant leaf formation and ability to maintain its nutritive value in an advanced stage of growth (Bogdan, 1977).

The objectives of the present study were to determine seasonal dry matter production and the nutritive value of the forage produce during the second year after establishment by the above-mentioned species, grown on a poor, acid soil with three levels of fertilization.

Materials and Methods

The experiments were carried out at the Quilichao Experiment Station of CIAT, at latitude 30°06' N and longitude 76°31'W. The station stands 45 km south of Cali, near Santander de Quilichao, Cauca, at an altitude of 990 m above sea level. The soil is an Ultisol (Palehumult ortoxic), with a pH of 4.1-4.6 (water), 2-4 ppm of soluble phosphorous (P) (Bray II) and 3.7-4.0 me interchangeable aluminum (Al) per 100 mg soil. Mean annual rainfall during the last 7 years, including those in which the experiments were conducted, has amounted to 1690 mm, with two well-defined rainy seasons from March to May and from September to December, respectively, followed by relatively dry periods of approximately 90 days' duration during the rest of the year.

The forage species elephant grass (*P. purpureum*), sugar cane (*S. officinarum*), imperial grass (*A. scoparius*) and Guatemala grass (*T. laxum*) were established in 1978 with three levels of fertilization: a control, a medium level with annual applications during two years of 150 kg of dolomitic limestone, 100 kg nitrogen (N) and 44 kg of phosphorous (P) per hectare, and a high level consisting of 2000 kg dolomitic limestone, 200 kg N, 88 kg P, 42 kg of potassium (K), as well as 20 kg of sulphur (S), 5 kg of boron (B), and 1 kg of copper (Cu) per hectare, with the same frequency of application. The N applications were divided into two fractions each year. Urea, ammonium sulphate, triple superphosphate, potassium chloride, elemental sulphur, borax and copper sulphate were used as sources of each of the elements, respectively. At the end of one year, the forage was cut to equalise the stands and after the second application of fertilizer, production was measured by cutting, using intervals of 6 weeks in the rainy season and 8 weeks in the dry season of the year. The yield of dry matter was determined by taking a random sample of a square meter of the green forage cut at 15 cm above ground level. Two sub-samples were then taken and dried in a forced air oven at a temperature of 60°C for 24 hours in order to determine the humidity. The sub-samples were ground in a Willey mill with a 1 mm sieve and submitted to laboratory analysis for crude protein (CP, N x 6.25), phosphorous (P) and *in vitro* digestibility of the dry matter (IVDMD), and the results calculated on a dry matter basis.

Statistical analysis. A split plot design in randomised blocks was used where the principal plots corresponded with fertilizer levels and the subplots with grass species, using two repetitions. The analysis of variance of the results, in terms of dry matter yield, CP content and IVDMD, was carried out independently for dry and rainy seasons of the year 1979. Duncan's multiple range test was used to compare means in cases where significance at the $P < .05$ level was detected.

Results and Discussion

The mean total production of dry matter of the species studied was affected significantly both by fertilizer level ($P < .001$) as shown in Table 1, as well as by species (Table 2). Higher yields were obtained from the heavier fertilizer application and from elephant grass. Season also had a highly significant ($P < .001$) effect. Higher yields were obtained during the rainy season, especially the second one which was longer than the first. Furthermore, the second dry season was less severe than the first. A total of 139 mm of rain fell in August which is usually considered to be a dry month with a mean precipitation of less than 60 mm. Highly significant interactions ($P < .001$) were obtained between the variables fertilizer level, forage species and season of the year.

The increases in dry matter yield due to fertilizer levels were in the order of 32.0% in the case of the intermediate level and 67.0% in the case of the high level, as compared with the control. These effects were more marked in the rainy season (mean 39.0 and 74.8%) than in the dry period (21.9 and 54.0%, Table 1). This explains the importance of the fertilizer-season interaction and its possible effects on the efficiency of fertilizer use and the costs of tropical forage production. It may be advisable to use small or moderate applications in a strategic fashion for forage production and to apply the fertilizer only when soil humidity is sufficient to permit a response in plant growth.

The mean total dry matter production of elephant grass was significantly ($P < .05$) greater than the yield of the other grasses studied, at all levels of fertilizaer application (Table 2). However, the average yields of imperial and guatemala grasses were higher during the second, more prolonged, wet season. In contrast, the production of the sugar cane was very poor in all the seasons studied, and showed a very limited response to the levels of fertilizer used, except perhaps at the highest level. This illustrates the

Table 1:
Effect of fertilizer levels on seasonal dry matter[1] production. Means of various forage species[2] during the second year of evaluation by cutting at CIAT-Quilichao, 1979.

Fertilizer level[3]	Dry season (60 days)	Wet season (90 days)	Dry season (90 days)	Wet season (125 days)	Total (365 days)
	t/ha				
I	5.17	8.89	6.81	9.75	30.62 c[4]
II	6.19	12.10	8.45	13.83	40.57 b
III	7.72	15.28	10.81	17.33	51.14 a
Mean	< 36 d[4]	12.09 b	8.69 c	13.64 a	40.78

1/ 60°C for 24 hours
2/ *P. purpureum, S. officinarum, T. laxum, A. scoparius*
3/ I: Control
II: 150, 100, 44 kg/ha of Lime, N and P, respectively
III: 2000 200, 88, 41 kg/ha of Lime, N, P and K, respectively, plus S, B and Cu.
4/ Values in the same line or column accompanied by different letters are significantly different ($P < .05$)

Table 2:
Effects of fertilizer level on the seasonal dry matter[1] yield of various forage species during the second year of evaluation by cutting at CIAT-Quilichao, 1979.

Fertilizer level[2]	Species	Dry season	Wet season	Dry season	Wet season	Total
		60 days	90 days	90 days	125 days	365 days
		t/ha				
I	P. purpureum	8.55	13.68	10.05	9.94	42.22
	S. officinarum	2.60	3.40	2.61	3.14	11.75
	A. scoparius	4.43	9.39	7.04	12.04	32.91
	T. laxum	5.09	9.09	7.53	13.88	35.60
II	P. purpureum	11.06	19.01	13.08	13.80	56.95
	S. officinarum	3.25	4.07	3.15	3.67	14.14
	A. scoparius	4.93	12.20	8.84	18.50	44.48
	T. laxum	5.53	13.10	8.73	19.36	46.72
III	P. purpureum	14.70	24.21	16.31	17.63	72.85
	S. officinarum	4.93	4.95	4.67	6.43	20.98
	S. scoparius	5.29	15.54	11.10	21.81	53.74
	T. laxum	5.95	16.44	11.16	23.45	57.00

1/ 60°C for 24 hours.
2/ I: Control
II: 150, 100, 44 kg/ha of Lime, N and P, respectively.
III: 2000, 200, 88, 41 kg/ha of Lime, N, P and K, respectively, plus S, B and Cu

heavy mineral requirements of the crop, in terms of lime and phosphorous (Bonnet et al 1958).

Dry matter yields of elephant grass above 85 t/ha are the highest forage yields reported under tropical conditions, exceeding even those of sugar cane (Cooper, 1970). Under comparable conditions, dry matter yields of elephant grass have exceeded those of similar grasses such as guatemala and its production during the dry season of the year has also been higher (Pedreira, 1976). Elephant grass responds very well to fertilization with NPK provided that soil humidity is not a limiting factor, according to evidence published from Colombia (Lotero et al 1968), Costa Rica (Guerrero et al 1970), Puerto Rico (Vicente-Chandler et al 1967), Tobago (Walmsley et al 1978) and Thailand (Hoshino et al 1979). On acid soils, moderate applications of lime have shown a positive effect on elephant grass forage production, varying in accordance with the drop in interchangeable Al (Sánchez et al 1979; Salinas and Delgadillo, 1980). Under comparable conditions, yields of imperial grass have reached only 70% in total and 45% in the dry season, as compared with elephant grass (Funes et al 1971).

Tables 3 and 4 show that highly significant effects ($P < .001$) due to fertilizer level, forage species and season were recorded on the CP and P contents, as well as on the IVDMD in each of the seasons of the year. At the same time, highly significant fertilizer grass species interactions were found for P content and IVDMD ($P < .01$) only, while interactions significant a the $P < .05$ level were obtained for species-season for the three variables measuring nutritive value which were studied. In general, the nutritive value of imperial grass was higher ($P < .05$) than that of elephant grass which, in turn, was superior ($P < .05$) to guatemala grass. Sugar cane, on the other hand, was consistently lowest of all ($P < .05$) in terms of the parameters studied.

The nutritive value of tropical forages is normally low, especially when they are harvested at a mature stage. A CP content as low as 6.9% has

Table 3.
Effects of fertilizer level on the crude protein (CP) and phosphorous (P) contents of various forages[1] during the second year of evaluation by cutting at CIAT-Quilichao, 1979.

Fertilizer level[2]	Species	Dry season 60 days		Wet season 90 days		Dry season 90 days		Wet season 125 days	
		CP	P	CP	P	CP	P	CP	P
		%							
I	P. purpureum	10.4	0.13	12.1	0.13	10.7	0.12	12.9	0.13
	S. officinarum	6.9	0.08	7.2	0.12	6.3	0.08	8.7	0.10
	A. Scoparius	10.1	0.13	12.9	0.14	11.6	0.13	12.8	0.14
	T. laxum	9.8	0.12	11.8	0.14	10.9	0.12	11.9	0.12
II	P. purpureum	12.2	0.15	12.6	0.16	12.2	0.13	13.7	0.13
	S. officinarum	8.4	0.12	7.8	0.13	7.0	0.11	9.9	0.12
	A. scoparius	11.3	0.14	13.4	0.15	12.9	0.15	14.4	0.15
	T. laxum	10.4	0.13	12.5	0.15	12.3	0.13	12.9	0.13
III	P. purpureum	12.3	0.16	13.0	0.16	12.7	0.14	14.3	0.16
	S. officinarum	8.5	0.13	8.3	0.15	7.4	0.12	10.5	0.14
	A. scoparius	12.1	0.16	14.0	0.17	14.1	0.15	15.3	0.16
	T. laxum	11.7	0.14	13.3	0.15	12.6	0.14	14.9	0.15

1/ 60°C for 24 hours
2/ I: Control
II: 150, 100, 44 kg/ha of Lime, N and P, respectively
III: 2000, 200, 88, 41 kg/ha of Lime, N, P and K, respectively, plus S, B and Cu

been reported for elephant grass and, in the same study, values of 3.9-5.5 % were found for imperial grass (Blasco and Bohorquez, 1968). In another study, the mean yearly CP content of elephant grass was 7.9%, compared with 6.7 % for imperial grass (Pedreira, 1976). An increase in CP content may be obtained from N fertilization, as shown in Puerto Rico with levels of up to 1600 kg kg N/ha (Vicente-Chandler et al 1967), but even so values in excess of 12-14% were not obtained. Butterworth (1967) recorded levels of 11.3% CP for elephant grass, 7.4% for sugar cane, 6.2% for imperial grass and 7.8 % for guatemala grass. The CP levels obtained in the present study agree with those cited, except in the case of imperial grass which contained consistently higher levels than those of the other species (Table 3).

Both elephant and imperial grasses have been considered to have very low P levels, in the range 0.05-0.13% (Blasco and Bohorquez, 1968) although Comide and Zometa (1978) reported mean levels of 0.18% P in elephant and 0.15% for imperial and guatemala grasses. The present results also show low P levels even though relatively high levels of P were applied as fertilizer (Table 3).

The IVDMD of the species studied has generally been found to vary between 51.5 and 61.5% (Butterworth 1967). In the present case, the IVDMD levels were very low in the control plots, but rose significantly to levels comparable with those reported in the literature when fertilizer was applied (Table 4), even though it is concluded that nutritive value is not significantly altered by fertilizer application, with the possible exception of rises in the CP content.

Conclusions

Of the species studied, elephant grass consistently produced higher yields of dry matter both during the rainy and the dry seasons of the year, and responded well to moderate levels of fertilizer application. Imperial and guatemala grasses produced well during the wet season, but relatively poorly in the dry season which is when forage is most urgently needed. Sugar cane yields were notoriously low throughout the year, suggesting that the fertilizer requirements of this species on poor, acid soils are very high.

The nutritive value of imperial grass was better than that of the other species under each fertilizer treatment and in both seasons of the year. However, its CP levels were in the range 10-15% and the mean levels of P (0.13%) and IVDMD (48.0%) were quite similar between species, except for sugar cane which showed much lower values.

Finally, it is important to point out a possible effect of fertilizer application on the IVDMD of all the forages studied. This may be because cations such as calcium and potassium encourage new shoots and the production highly digestible new green tissue besides, at the same time, preventing structural changes in the plant (Rolando, 1981).

Table 4.
Effects of fertilizer levels on dry matter[1] digestibility of various forages during the second year of evaluation by cutting at CIAT-Quilichao, 1979

Fetilizer level[2]	Species	Dry season 60 days	Wet season 90 days	Dry season 90 days	Wet season 125 days
		%			
I	*P. purpureum*	41.4	42.9	41.4	42.2
	S. officinarum	33.4	37.2	37.0	37.5
	A. scoparius	45.5	44.4	41.7	47.0
	T. laxum	38.3	44.4	34.8	38.0
II	*P. purpureum*	48.4	51.6	46.3	47.3
	S. officinarum	38.7	40.9	38.8	40.3
	A. scoparius	57.4	60.5	53.9	55.5
	T. laxum	48.2	53.0	41.5	47.0
III	*P. purpureum*	58.4	60.9	55.5	55.3
	S. officinarum	47.2	49.7	47.8	49.9
	A. scoparius	65.6	67.3	61.3	62.7
	T. laxum	51.2	53.5	50.8	51.6

1/ 60°C for 24 hours
2/ I: Control
II: 150, 100, 44 kg/ha of Lime, N and P, respectively
III: 2000, 200, 88, 41 kg/ha of Lime, N, P and K, respectively, plus S, B and Cu

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