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The Limit Set to Tropical Dairy Production by Nutritional Factors

W. J. A. PAYNE and W. I. LAING, Agricultural Station, Singatoga, Department of Agriculture, Fiji.

IN most humid tropical countries the cattle are stunted, growth is slow sexual maturity is delayed, and milk production is low by temperate zone standards. Hutchinson (1941) quotes an annual production of 110 gallons per cow in New Guinea, while Wright (1945) has estimated that in Ceylon the average annual yield is forty to sixty gallons per cow. Similar productivity figures can be found in the literature for most tropical countries.

This low productivity can be attributed to a complex of factors including the lack of improved indigenous breeds, the low heat tolerance of improved exotic European breeds, faulty nutrition, bad management, and lack of control of disease and parasites.

At Singatoka in Fiji the Department of Agriculture can claim that it has partially solved some of these problems, as the average production of the grade Friesian herd in 1950 was 520 gallons of milk per lactation. The stock, however, still mature slowly, the average weight of Friesian calves being sixty-five pounds at birth and 192 pounds at six months of age compared with weights of eighty-nine and 349 pounds respectively with Friesians in the United States, Eckles (1939).

In this paper we only intend to discuss the limit set to tropical dairy production by nutritional factors, and we wish to emphasise that this is only one facet of a complex of factors limiting productivity in the tropics.

A tropical environment may affect the nutrition of dairy cattle in two ways. First, there is the direct effect on the animal's appetite, nutritional needs, and on the functioning of its alimentary tract. Secondly, there are the indirect effects: the climate may so modify the soil type that the fertility becomes inherently low, or it may have a more direct effect on the nutritive composition of forages by retarding or speeding up growth and the attainment of maturity.

The direct effects of a tropical environment on the nutrition of dairy stock.

There is evidence that the total feed intake of both European and Zebu dairy cattle is depressed by high atmospheric temperatures. Bonsma (1940) states that in South Africa high ambient temperatures raise the body temperature and depress the appetite, while Ragsadale, Worstell, Thompson, and Brody (1949) report that when the temperature is raised above 80 degrees F. in a special chamber the feed consumption, milk production, and body weight are lowered. This depression of food intake is due to a complex of factors, and although there may be a direct effect on the appetite it is probable that the reaction is more subtle.

As the ambient temperature rises the maintenance requirements of the animal fall, furthermore at some stage the animal finds it impossible to eliminate all the excess heat formed during growth or milk production which are therefore reduced, thus lowering still further food requirements. A heat tolerant animal is an animal that by one process or another can eliminate large amounts of excess heat and allow productive processes to proceed even at high ambient temperatures, and as there is a wide variation in heat tolerance in tropical dairy stock there will be a wide variation in intake.

Intake could be maintained at a relatively high level by the utilisation of the most suitable type of dairy stock, that is heat tolerant stock, and by the amelioration of tropical conditions. Payne, Laing and Raivoka (1951) have shown that in Fiji dairy stock graze mainly at night so that they should be placed on the best pastures at that time, and in shady areas during the day. Seath and Miller (1948) have shown that sprinkling with water and the use of a fan also ameliorates tropical conditions. Thus it is probable that appetite is stimulated by the utilisation of some or all of these management practices.

We have computed from data in the literature that the dry matter intake per day per 100 pounds liveweight of experimental dairy cattle stall fed ''ad lib'' various types of tropical forage was 1.45 pounds in New Guinea, Hutchinson (1941), 1.60 pounds in Trinidad, Harrison (1942), 1.50 pounds in Hawaii, Henke (1943), and 1.30 pounds in Trinidad, Duckworth (1949). These roughage intakes are decidedly low and it is probable that where animals have access to concentrates their total intake is much higher. We have computed that in Hawaii where the animals had access to concentrates, Henke (1943), the total dry matter intake was 3.0 pounds per day per 100 pounds liveweight and in the co-operative experiment now being conducted by the New Zealand Department of Agriculture and the Department of Agriculture for Fiji, the intake of a ration composed of barley meal, coconut meal, and lucerne hay in January, 1951, at both Ruakura and Singatoka was approximately 2.0 pounds of dry matter per 100 pounds liveweight. The mean dry bulb temperatures were 82.5 degrees F. at Singatoka and 65.9 degrees F. at Ruakura. Thus when the ration has a comparatively high nutritive value the intake does not appear to be unduly depressed by a temperature above 80 degrees F. and it is quite possible that if dairy stock were fed forages similar in nutritive value to those fed in the temperate zone, the intake would be higher. Some support for this argument is derived from the fact that at Singatoka where pastures are grazed at a much less mature stage than is normal in the tropics the average milk production is comparatively high and an approximate estimate of intake of 2.2 to 2.8 pounds of dry matter per day per 100 pounds liveweight has been made.

With regard to the intake of specific food constituents Robinson and Lee (1947) have concluded that the calorific value of the diet has a significant and at times a practically important effect upon the reaction of animals to hot conditions, but that the proportion of protein contained in the diet is of no significance. Nevertheless Mitchell and Edman (1949) in a review of nutrition in a hot climate say that in the case of humans there is some suggestion that protein requirements may be slightly raised, due to an increase in the endogenous catabolism of body proteins which is revealed by an increased output of creatinine, and a loss of nitrogen in sweating. It is therefore of some interest that Brody (1949) reports that the creatinine level in the blood of dairy cows rises steeply with rising ambient temperature. Mitchell and Edman (1949) also report that there are indications that the human requirements of thiamine and ascorbic acid may rise in the tropics, as do the requirements of salt, calcium, and iron. As the B vitamins and ascorbic acid are synthetised within the body of adult ruminants, dairy cows are not likely to be affected by the amount of these vitamins in the diet even if their requirements increase. It is possible, however, that there is an increase in the requirements for certain minerals in the tropics. It is also possible that the tropics have a direct effect on the alimentary tract of the dairy animal. Duckworth (1949) has suggested that digestion may proceed less rapidly, and it may be that the rumen micro fauna and flora are affected by high body temperatures. No-one, however, has yet investigated these aspects of the problem.

There are few reports on the effect of ambient temperature on the water consumption of dairy stock. Reagan and Mead (1939) have stated that there is a decrease in water consumption when the ambient temperature rises above 80 degrees F., whereas Thompson, Worstell and Brody (1949) have reported that although there are large individual variations in water consumption there is a general tendency for it to rise with rising ambient temperature. In the co-operative twin experiment we have noted that although there is a wide variation in water consumption between animals, throughout the experiment consumption has been higher in Fiji. In January when the mean dry bulb temperatures at Singatoka and Ruakura were 82.5 degrees F. and 65.0 degrees F. respectively the mean values for water consumption per animal were 9.5 and 4.6 gallons per day. Thompson et al (1949) have stressed the fact that with dairy cattle kept in a high atmospheric temperature an increase in water consumption is paralleled by an increase in urine excretion. We consider from the available evidence that increased water consumption coupled with increased urine excretion is one of the more important methods of temperature control utilised by dairy cows in the tropics.

The indirect effects of a tropical environment on the nutrition of dairy stock.

The effect of a tropical environment on the quantity and quality of the feed that dairy cattle consume may limit productivity to a greater degree than any direct effect of the environment on the animal.

The seasonal distribution of rainfall appears to be a major limiting factor to forage production in the tropics. By temperate standards the total rainfall is usually high, frequently exceeding 100 inches per annum, and this high rainfall has produced the typical leached acid lateritic soils more suited to forestry than forage production. In areas where the rainfall is lower, the distribution is uneven, and in settled areas the continual burning of the grazings coupled with torrential downpours, have ensured that only the coastal fringes and the river valleys have any residual fertility. At Singatoka in Fiji, the Station is more fortunately sited as the rainfall distribution is quite good, and this fact should be borne in mind when assessing the comparative value of the data from the Singatoka station.

FIGURE I

HERBAGE YIELDS AT SINGATOKA AND PALMERSTON NORTH, N.Z.

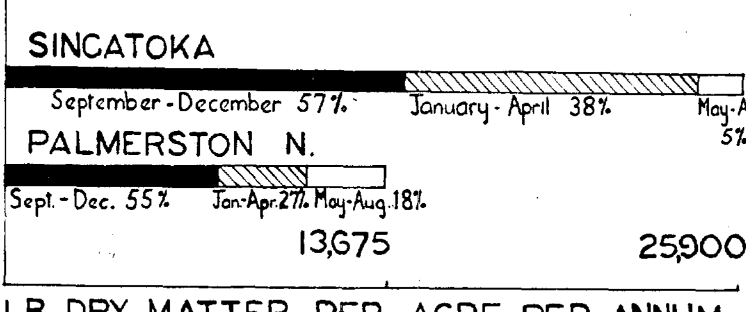
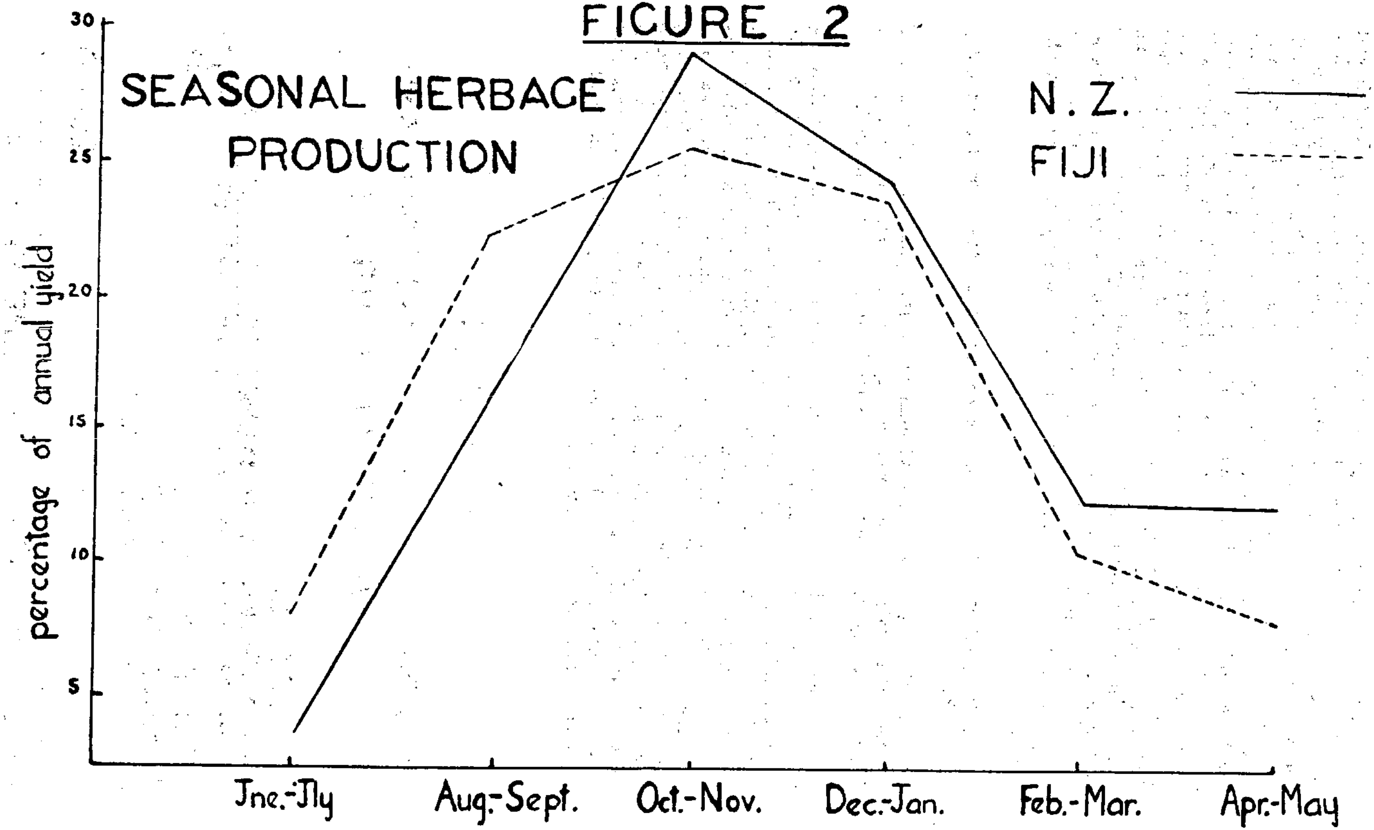


FIGURE 2


SEASONAL HERBAGE
PRODUCTION
N.Z.
FIJI
30
25
20
15
10
5
percentage of annual yield
Jne.-Jly
Aug.-Sept.
Oct.-Nov.
Dec.-Jan.
Feb.-Mar.
Apr.-May

Gross Yield.

There is a wide variation in gross yield both between species and within the same species from country to country. The arresting fact is that in some tropical countries certain species yield an enormous weight of green feed annually. In assessing the value of this data it must be remembered that the yields are not usually average yields in the field but are obtained from experimental plots. At Singatoka the yields given are from quite small plots on fertile alluvial soils but no fertilisers have been used. Not only are the yields of pasture grasses high at certain stations, but so also are the yields of fodder grasses and legumes.

This strikingly high yield of some tropical forages in certain localities is also shown in Figure 1, where the annual dry matter yield at Singatoka, Fiji, is compared with the yield at Palmerston North, New Zealand. The Singatoka data are based on the mean annual plot yields of thirty-one different grasses, several of which are low yielders, while the Palmerston North figures are those quoted by Hamilton (1944) for high quality pastures.

Seasonal Variation in Grass Yield.

It might be thought that in the wet tropics, where growth is continuous, there would be little fluctuation in yield from season to season. Unfortunately this is not the case, and at Singatoka under partially improved pasture conditions the seasonal variations are greater, even on a percentage basis, than in New Zealand (Figure 1). Low production in the May-August period must be a major factor limiting productivity, and can only be overcome by the conservation of part of the September-December "flush" by introducing such practices as topdressing or spray-irrigation or by using species whose growth cycle is out of step with the majority.

There is a remarkably close parallel in cyclic growth conditions between New Zealand and Fiji, although the basic reasons for this may be different in the two environments. This is well demonstrated in Figure 2, the Fiji figures being based on all the Singatoka experimental yield data, the bimonthly sub-totals being expressed as a percentage of the annual total, while the New Zealand figures are derived from North Island data quoted by McMeekan, Campbell, Cooper, Stevens, and Ward (1943).

Dry Matter Content.

The majority of tropical grasses mature quickly so that management becomes somewhat more difficult than in the temperate zone. Nevertheless dry matter content, stage of maturity, and total yield are quite well correlated as with temperate zone grasses. Table 2 gives some details available in the literature on the dry matter content of some tropical forages and it will be noted that the dry matter content of some species that are properly managed is around twenty-five per cent, that is practically identical with the dry matter content of temperate pasture.

Crude Fibre Content.

The crude fibre content of tropical forages appears to be consistently higher than that of temperate pastures (Table 3) and this trend is especially marked in tropical legumes, although, "Creeping Indigo" (Indigofera endecaphylla), and "Vaivai" (Leucena glauca) are apparently exceptional. Crude fibre content usually increases as the plant matures. Schofield (1945) has shown that there is a marked increase in the crude fibre content of "Guinea" (Panicum maximum) from 29.9 to 42.3 per cent with less frequent cutting.

Crude Protein Content.

It has been generally assumed that the low crude protein content of tropical forages is a major limiting factor to dairy production in the tropics. A critical review of the literature, however, reveals the fact that there are enormous variations in the yields quoted (Table 4) and that the stage of maturity of the forage is of major importance. Parham (1948) gives 5.6 per cent as the crude protein content of ''Para'' (Brachiaria mutica) whereas Cartmill (1944) gives the figure of 13.4 per cent for young ''Para'' that has been harvested monthly. Hutchinson (1941) quotes values for ''Elephant Grass'' (Pennisetum purpureum) ranging from 10.9 per cent crude protein when it is one foot high to 1.3 per cent when it is sixteen feet high. At Singatoka a mature ''Guinea-Calopo'' mixture yielded 8.2 per cent crude protein while an immature stand of ''Kavirondo Sorghum-Calopo'' yielded 13.4 per cent.

As the majority of tropical forages mature very rapidly it is probable that the crude protein content is only high for a short period in the growth cycle, but during that period the crude protein content is as high in some tropical forages as it is in temperate pastures at the normal cutting or grazing times.

One factor that may influence the crude protein content of forages in the humid tropics is the lack of available nitrogen in the soil. Jagoe (1949) working in Malaya has shown that the crude protein content of ''Carpet grass'' (Axonopus compressus) was raised from 9.7 to 10.9 per cent by using shade trees and to 14.3 per cent by using leguminous shade trees.

Mineral Content.

Very little information is available on the calcium and phosphate content of tropical forages, and what there is shows a marked variation between species and in the same species at different stages of growth. (Table 5). It would appear, however, that frequency of cutting affects the phosphate content and therefore the calcium-phosphate balance. Schofield (1946) has shown that the majority of tropical grasses when cut monthly had a phosphate content approximating to temperate standards, but when cut at three monthly intervals this was the case in only four out of nineteen. Nothing definite is known of the trace element content of tropical forages, although it is claimed by some authorities that deficiences in trace elements may be limiting productivity in many parts of the tropical world.

Digestibility Coefficients.

The available information on the digestibility coefficients of tropical forages reveals nothing new (Table 6). but it is of some interest to note that the crude protein digestibility coefficients of some tropical forages compare quite favourably with similar figures given for temperate pastures.

Conclusions.

The productivity of tropical pastures is not a limiting factor, and from the available evidence on grass yields it is reasonable to suppose that the number of stock carried per acre could be as high as, if not higher than in the temperate zone. However there is a considerable seasonal variation in yield even in the humid tropics and this would be a major factor limiting productivity unless conservation was practised. Hay could be made in the dry tropics, but would probably not be economic in the humid tropics, not only because of the difficulties of curing, but also because it is liable to mould in the stack. Artificial drying would be an efficient method of conservation but fuel is usually expensive and few farmers in the tropics have the necessary capital with which to purchase the equipment. Silage can be made and it is probably the most practicable method of fodder conservation. There is also the possibility of utilising forage species, whose growth cycle is out of step with the majority of species, as field reserves for the season of general low productivity.

There is evidence that the total food intake of dairy cattle decreases with rising ambient temperature, so that the quality of the feed becomes of paramount importance for high dairy productivity. The majority of tropical forage plants mature quickly and as with temperate zone herbage the crude fibre content increases and the crude protein content decreases as the plants mature. Although it is generally understood that tropical forages have a low protein content and a high crude fibre content it is reasonable to assume from the available evidence that at certain stages of growth some tropical forages will have at least the same feeding value as temperate pastures. Tropical forages, however, will only have a high nutritive value for a relatively short period in the growth cycle and this complicates management problems. Pastures must be utilised at an early stage of growth which means a very close control of grazing. We advocate not only rotational grazing but also some form of close folding such as "fore and aft" grazing with an electric fence. The problem then is to find tropical grass and legume species that will thrive under this system of management, and our experience at Singatoka has convinced us that many of the common species of pasture plants used in Fiji thrive under this new system.

Little is known of the mineral and vitamin content of tropical forages and still less of the animal's need of these nutritive factors. They do not, however, at the present time appear to be major limiting factors.

The availability of unlimited supplies of fresh cool water is undoubtedly necessary for high productivity as there is evidence that a high water consumption is one of the more important methods of temperature control utilised by dairy cattle in the tropics. Piped water supplies are almost unknown in rural areas and there is good reason to believe that the availability of cool fresh water is one of the factors limiting productivity. We may summarise by saying that the indirect effects of a tropical environment on the dairy animal are more easily ameliorated than the direct effects. With effective grassland husbandry it is likely that tropical pastures and fodder crops will be as productive, if not more so, than those in the temperate zone, and properly managed they will also be as nutritious. There may still be, however, physiological limitations to the productivity of dairy animals that pose more difficult problems.

In conclusion we wish to say that we are indebted to the Director of Agriculture, Fiji, for the facilities provided for any work outlined in this study and for permission to present this work.

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TABLE 1.

ANNUAL GREEN MATTER YIELD OF CERTAIN TROPICAL FORAGES (in tons per acre)

Species	Fiji		Australia	Phillipines	Columbia	Guam	Malaya	India	Hawaii
	Singatoka		N.Q.						
	(1950)	(1948) Parham	Schofield (1944)	Jacobson (1914)	Anon (1932)	Briggs (1921)	Anon (1938)	Lander (1943)	Henke (1943)
Panicum maximum	121.3		27.5				13.0 to 16.0	4.0 to 100.0	54.4
Pennisetum polystachyum	110.1								
Panicum maximum var. colaratum	79.8		24.1						
Brachiaria decumbens			53.1						
Brachiaria mutica	57.4		20.8			35.0			53.2
Urochloa bolbodes			26.7						
Hyparrhenia aucta			31.9						
Melinis minutiflora	28.9	8.0	26.5	5.0	16.0		9.3		
Ischaemum aristatum	20.9	32.0							
Digitaria milanjiana	50.3	20.0	21.7						
Chloris gayana	61.9	15.0	21.7					5.0	
Paspalum dilatatum	35.3		17.8						

TABLE 2.

DRY MATTER PERCENTAGE OF CERTAIN TROPICAL FORAGES

Species	Fiji	Australia N.Q.				New Guinea	Hawaii
	Wright (1922)	Schofield (1944)			Cartmill (1944)	Hutchinson (1941)	Shorey (1906)
		Cut Monthly	Cut Bimonthly	Cut Trimonthly			
Brachiaria mutica		22.8	31.3	30.3	22.8	24.6	25.4
Panicum maximum		26.9	30.1	33.5	29.0	21.5	35.5
Melinis minutiflora		23.5	27.3	32.1	27.4		
Paspalam paniculatum					25.7		
Pennisetum polystachyum	11.0						
Cynodon dactylon						38.5	54.5
Paspalum dilatatum		27.9	30.3	30.7			26.4
Paslelum conjungatum					23.1	22.0	
Centrosema pubescens						21.0	
Desmodium heterophyllum						28.0	
Stylosanthes guianensis						26.0	
Indigofora endecaphylla						26.3	
Leucaena glauca						36.0	
Pennisetum purpureum						17.9	
Tripsacum laxum						21.9	
Various (New Guinea pasture)						27.0	

TABLE 3.

CRUDE FIBRE PERCENTAGE OF CERTAIN TROPICAL FORAGES.

Species	Fiji		Australia N.Q.			Hawaii		Puerto Rico	New Guinea
	Parham (1948)	Wright (1922)	Cartmill (1944)	Schofield (1945)	Wilsie & Takahashi (1934)	Shorey (1906)	Krauss (1932)	Telford & Childers (1947)	Hutchinson (1941)
Brachiaria mutica	38.9		30.4			35.9		33.5	
Panicum maximum			34.8	28.9	33.1	28.2		41.7	
Digitaria milanjiana	38.2			31.2					
Pennisetum polystachyum		31.3							
Melinis minutiflora	42.6		31.9	30.0				37.6	
Cynodon dactylon						22.9			29.5
Pennisetum purpureum					33.8			32.8	37.9—50.4
Paspalum conjugatum			32.3						28.1
Various (New Guinea pastures)									34.3
Pueraria phaseoloides	42.1							28.6	
Calopogonium muconoides	37.8								
Centrosema pubescens	43.4								38.1
Indigofera endecaphylla								27.2	
Desmodium heterophyllum									37.1
Stylosanthes guianensis	49.3								28.1
Leucaena glauca (leaves)							14.9		

TABLE 4.

CRUDE PROTEIN PERCENTAGE OF CERTAIN TROPICAL FORAGES

Species or Pasture	Fiji			Hawaii	
	Singatoka (1950)	Parham (1948)	Wright (1922)	Henke (1943)	Shorey (1906)
Brachiaria mutica		5.6		6.4	9.1
Panicum maximum	10.9				
Digitaria milanjiana		4.9			
Pennisetum polystachyum			9.9		
Melinis minutiflora		3.7			
Cynodon dactylon					6.9
Pennisetum purpureum				4.9	
Paspalum conjugatum					
Axonopus compressus					
Pueraria phaseoloides		15.7			
Calopogonium muconoides		14.6			
Stylosanthes guianensis		7.9			
Centrosema pubescens		17.4			
Indigofera endecaphylla					
Desmodium heterophyllum					
Desmodium tortuosum					
Cajanus indicus (tops)				18.9	
Leucaena glauca (leaves)				22.7	
N.G. pasture (selected)					
N.G. pasture (unselected)					
Temperate zone, mixed species, early bloom)					
Mature pasture	8.2				
Immature pasture	13.4				

TABLE 4—Continued.

CRUDE PROTEIN PERCENTAGE OF CERTAIN TROPICAL FORAGES.

Species or Pasture	Trinidad	Australia		New Guinea	Malaya	Puerto Rico	British Isles
		North Queensland					
	Harrison (1942)	Schofield (1945)	Cartmill (1944)	Hutchinson (1941)	Jagoe (1949)	Telford & Childers (1947)	Schneider (1947)
Brachiaria mutica	8.5		13.4			7.5	
Panicum maximum	9.9	9.9-15.3	10.9			4.3	
Digitaria milanjiana		12.8					
Pennisetum polystachyum							
Melinis minutiflora		11.0	10.6			6.4	
Cynodon dactylon				10.3			
Pennisetum purpureum	8.9			1.3-10.9		6.8	
Paspalum conjugatum				5.8-17.7			
Axonopus compressus					9.7-14.3		
Pueraria phaseoloides						15.4	
Calopogonium muconoides							
Stylosanthes guianensis				12.3			
Centrosema pubescens				20.9			
Indigofera endecaphylla				12.9		19.6	
Desmodium heterophyllum				14.3			
Desmodium tortuosum				17.6			
Cajanus indicus (tops)							
Leucaena glauca (leaves)							
N.G. pasture (selected)				8.5			
N.G. pasture (unselected)				4.7			
Temperate zone, mixed species, early bloom)							13.4
Mature pasture							
Immature pasture							

TABLE 5.

LIME AND PHOSPHATE CONTENT OF CERTAIN TROPICAL GRASSES

Species	Percentage of CaO						Percentage of P 205					
	Australia		Hawaii				Australia		Hawaii			
	Schofield (1946)	Cartmill (1944)	Edwards & Goff (1935)				Schofield (1946)	Cartmill (1944)	Edwards & Goff (1935)			
			Farm 1	Farm 2	Farm 3	Farm 4			Farm 1	Farm 2	Farm 3	Farm 4
Panicum maximum var. typica	1.00	0.72					0.79	0.45				
Panicum maximum (strain 3820)	1.04						0.97					
Panicum maximum var. coloratum	0.94						0.98					
Brachiaria mutica	0.57						0.88					
Hyparrhenia aucta	0.37						0.50					
Melinis minutiflora		0.41					0.60					
Paspalum conjugatum		0.51						0.52				
Paspalum paniculatum		0.47						0.50				
Paspalum dilatatum	0.43		1.19	1.00	0.81	0.83	0.61		0.66	0.55	0.49	0.28

TABLE 6.

DIGESTIBILITY COEFFICIENT OF CERTAIN TROPICAL FORAGES

Species	Month of cut	Remarks	Dry Matter	Organic Matter	Crude Fibre	Crude Protein	Country	Author
Brachiaria mutica		8 weeks	56.5		55.7	67.0	Trinidad	Harrison (1941)
				60.0	59.0	65.0	Hawaii	Work (1937)
Tripsacum laxum	January	16 weeks	59.1		64.1	62.7	Trinidad	Harrison (1942)
	September	6 weeks	52.2		60.2	58.4	Trinidad	Harrison (1942)
	October	8 weeks	48.2		59.3	47.2	Trinidad	Harrison (1942)
Pennisetum purpureum	March	9 weeks	59.0		62.0	64.0	Trinidad	Harrison (1942)
	September	7 weeks	63.4		71.6	60.2	Trinidad	Harrison (1942)
						53.4	Hawaii	Henke (1943)
				67.0	68.0	63.0	U.S.A.	Kidder (1939)
Panicum maximum	January	9 weeks	47.9		54.7	58.0	Trinidad	Harrison (1942)
				57.0	57.0	59.0	India	Lander &
Axonopus compressus	February	Immature	52.8		54.7	50.2		Dharmani (1936)
Leucaena glauca						64.8	Trinidad	Harrison (1942)
Cajanus indicus		Tops only				68.9	Hawaii	Henke (1943)
Phaseolus mungo				73.0	72.0	82.0	Hawaii	Henke (1943)
New Guinea pastures		Immature					Trinidad	Harrison (1942)
		'In vitro'				72.0	New Guinea	Hutchinson (1941)