QUALITY OF PASTURE AND FORAGE CROPS FOR DAIRY PRODUCTION IN THE TROPICAL REGIONS OF AUSTRALIA

1. REVIEW OF THE LITERATURE

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INTRODUCTION

There are 40 tropical grass cultivars and 23 tropical legume cultivars currently available in Australia (Hutton 1970a) and with considerable emphasis on plant introduction and plant breeding the choice of species or cultivar available for planting in the tropics is likely to increase. The value of these pastures to a dairy farmer depends on their capacity to produce milk, which is a function of both the quantity and quality of herbage grown. This paper reviews the nutritive quality of tropical pasture species and cultivars.

The value of any feed depends upon the quantity eaten and the ability of the food to supply the animal with energy, protein, minerals and vitamins. At the same time the herbage should only have low or insignificant quantities of compounds which are detrimental to animal health. This aspect has been reviewed by Garner (1963) and Hutton (1970b).

The nutritive quality of a feed can be measured in grazing experiments when the quantity is not limiting and lactation potential of the cows has not been reached (Ivins, Dilnot, and Davison 1958). Simple grazing trials of this type provide the most reliable method of studying the nutritive value of herbage. Pastures are grazed selectively and excreta are returned to the sward. The results from such trials are likely to be correct in the practical sense and so are directly applicable to the industry. However the nutritive value of grazed herbage is more difficult to measure than when animals are fed in pens (McDonald 1968) and because of expense only a few important problems can be investigated. Where a large number of cultivars and management treatments need to be studied it is often necessary to resort to indirect methods using both laboratory and animal house techniques (Minson 1971a). Laboratory methods are necessary when only small quantities of herbage are available and large numbers of samples are to be screened, animal house studies allow the relative intake and digestibility of a limited number of feeds to be measured, and grazing experiments are most valuable for the final selection of superior plant species.

In this review emphasis is given to evaluating the quality of perennial tropical pasture species under grazing and to factors influencing pasture quality as determined by laboratory and animal house studies. No mention will be made to the effect of pasture quality upon fertility since this aspect has been reviewed by Lamond (1970).

MILK PRODUCTION PER COW FROM TROPICAL PASTURES

There are few records of milk production under lenient grazing pressure from unsupplemented tropical pastures where milk production is not limited by pasture availability. In many comparisons of tropical pasture species the aim has been to study differences between species or varieties in terms of production per unit area and the results from such trials are influenced not only by the quality of feed but also by differences in herbage yield. Data from trials conducted in Australia, where

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production per cow has been measured at low grazing pressure, are shown in Table 1. Relevant data from other countries is given in Table 2. Milk production in these trials is confounded with different management systems (paddocking, forage conservation, etc.), breeds of varying size, duration of trial and site effects. Thus any comparison of pasture species is of necessity of a generalised nature.

Digitaria decumbens, Panicum maximum and *Pennisetum clandestinum* are consistently three of the better grass species when production per cow is evaluated but production from these species can vary considerably depending upon the stage at which herbage is fed (Appleman and Dirven 1959). With the exception of short-term trials such as those of Smith (1961) and Minson and Kondos (1969) and the exceptionally high production from Kairi in north Queensland (Winks *et al.* 1970) where mean yields over 300 days reached 4,200 kg/head, the results of these trials show that 8-9 kg/cow/day is the maximum that can be achieved from tropical pasture species over relatively long periods. This level of production is much lower than that which can be obtained from temperate pastures grazed at a similar stage of growth.

Hamilton *et al.* (1970) obtained similar milk production per cow from two grass species, *Setaria sphacelata* cv. Kazungula and *Chloris gayana* (Pioneer Rhodes grass) over 2 seasons under a system of grazing management aimed at high production per animal. However differences in pasture quality exist. Stobbs (1970a) showed *Digitaria decumbens* to give approximately 10 percent higher milk production than *Chloris gayana* and cows grazing *Setaria sphacelata* produced only slightly higher milk production than cows on the *Chloris gayana* pasture. This superiority of *Digitaria decumbens* has also been shown at Wollongbar in New South Wales (Jeffery, unpublished date).

The voluntary intake of tropical legumes is usually much higher than that of tropical grass of similar digestibility when fed to sheep indoors (Milford and Minson 1966a) and higher production per cow would be expected. Hamilton *et al.* (1970) demonstrated that in contrast to tropical grasses *Dolichos lab lab* was able to maintain a relatively high level of milk production. However Stobbs (1971) obtained significantly less milk from cows grazing pure stands of either *Phaseolus atropurpureus* or *Desmodium intortum* than from nitrogen fertilised *Digitaria decumbens* pasture. Cows on the legume swards averaged 7.7 kg/cow/day compared with an average of 9.0 kg/cow/day on the grass swards.

The effect of pasture maturity upon milk production is recognised by every dairy farmer and as far as practicable he attempts to feed young material. By selective grazing cows can compensate to some extent for lower quality feed but a stage is quickly reached when herbage quality affects production. Milk production from cows grazing *Chloris gayana* was the same with three and five week regrowths, but with *Setaria sphacelata* milk production was higher from the three week regrowths (Hamilton 1968). Shortening the grazing cycle for cows grazing *Pennisetum purpureum, Panicum maximum* and *Brachiaria mutica* to approximately ten-day intervals improved production per cow and production per unit area in the Philippines (Payne *et al.* 1967). Similar improvements in liveweight-gain have been recorded by grazing more frequently on *Digitaria decumbens* (Creek and Nestel 1966) and *Hyparrhenia rufa/Centrosema pubescens* and *Hyparrhenia rufa/Stylosanthes guyanensis* (Stobbs 1969).

Low production was obtained from continuously grazed *Cynodon dactylon* receiving only small amounts of fertiliser in the south of U.S.A. (King 1964). However, under high nitrogen regimes (400 kg/ha) utilising young material and supplementing with concentrates good production per cow (21.3 kg/cow/day) was obtained (King 1964; Brannon, King, and Cook 1966).

TABLE 1

Milk production per cow on tropical grass and legume pastures in Australia

Species	Mean Yield (Kg/cow/day)	Breed	Management	Site	Reference
Pennisetum clandestinum/ Glycine wightii	12.2	Guernsey and Jersey	Continuously grazed for 10 months	Wollongbar N.S.W.	Holder (1967)
Pennisetum clandestinum	9.8	Guernsey and Jersey	Continuously grazed on N-fertilised pasture	Wollongbar N.S.W.	Holder (1967)
Pennisetum clandestinum/ Glycine wightii	8.2	Grade Jersey monozygotic twins	Indoor feeding for 9 wks.	Wollongbar N.S.W.	Dale and Holder (1968)
Pennisetum clandestinum	16.5	Friesian	Short-term trial grazing 3-4 wk. regrowths fertilised with N	Gatton Queensland	Minson and Kondos (1969)
Pennisetum clandestinum/ subterranean clover	7.8*	Guernsey	Full lactation for 2 years —some conservation	Denmark Res. Stn. W. Australia	Anon (1969)
Setaria sphacelata and *Chloris gayana*	7.0	Jersey	3 and 5 wk. regrowths for periods of 8 wks. *ad lib.* grazing	Samford Queensland	Hamilton *et al.* (1970)
Dolichos lab lab	10.5	Jersey	*Ad lib.* grazing	Samford Queensland	Hamilton *et al.* (1970)
Panicum maximum/ Glycine wightii	10.3–14.0	Friesian	Mean yield for 300 day lactation of 15 cows. Some conservation	Kairi Queensland	Winks et al (1970)
Setaria sphacelata/ Desmodium sp.	9.0	Jersey	Full lactation — some concentrate	Woodford Queensland	Chambers (1970)
Phaseolus atropurpureus and *Desmodium intortum*	7.7	Jersey	Short-term trial under lenient grazing. Cows in various stages of lactation	Samford Queensland	Stobbs (1971)
Digitaria decumbens	9.0	Jersey			Stobbs (1971)

* calculated

TABLE 2

Milk production per cow on tropical grass and legume pastures in countries other than Australia

Species	Mean Yield Kg/cow/day	Breed	Management	Country	Reference
Digitaria decumbens	7.0–9.0	Friesian crosses	Rotationally grazed over 3 short periods without supplementation	Surinam	Appelman & Dirven (1959)
Hyparrhenia veld	13.6–15.0	Friesian	Short term trial	Zambia	Smith (1961)
Cynodon dactylon	10.1	Mixed breeds—mainly Friesian	Hay fed over 28 weeks plus concentrates	U.S.A.	Brooks *et al.* (1962)
	11.8		Pelleted hay fed over 28 weeks plus concentrates	U.S.A.	Brooks *et al.* (1962)
Setaria sphacelata	6.4	Monozygotic twins of mixed breeds	2 stocking rates over 8 months	Kenya	Kidner (1963)
Pennisetum purpureum/ Brachiaria mutica/ Panicum maximum	6.5	Friesian x Sindhi	Full lactation of rotationally grazed cows	Philippines	Payne *et al.* (1967)
Melinis multiflora/ Hyparrhenia rufa/ Panicum maximum	6.5	Various	Official and private herds 1950-61. Full lactation with some concentrates	Brazil	Joviano and Costa (1968)
Digitaria decumbens	6.7	Jersey, Criollo and crosses	Complete lactation from 21-day regrowth. Concentrates provided at 1Kg/4Kg milk	Costa Rica	Blydenstein *et al.* (1969a)
Panicum maximum	6.9	Jersey, Criollo and crosses	Complete lactation from 28-day regrowth. Concentrates provided at 1Kg/4Kg milk	Costa Rica	Blydenstein *et al.* (1969b)
Panicum maximum Digitaria decumbens Pennisetum purpureum	11.4	Friesian	8 month lactation from well fertilized pasture without concentrates. Few animals	Puerto Rico	Costas and Vicente-Chandler (1969)

MILK QUALITY ON TROPICAL PASTURES

The sub-optimum plane of nutrition which is often experienced when cows graze solely on tropical pasture not only results in low milk production but also changes in milk composition (Tucker 1969). High producing dairy cows in their first month or two of lactation are a special case of undernutrition as they are usually in negative energy balance even when offered liberal amounts of an adequate diet (Stull *et al.* 1966). When on poorer quality tropical feeds the cow is forced to draw more heavily upon body reserves and this affects milk composition.

When milk yield is depressed due to a low intake of digestible energy the percentage of butter fat (B.F.) increases and the percentage of solids-not-fat (S.N.F.) decreases (Burt 1957; Rook and Line 1961). This results in a low casein:fat ratio when cows graze poor quality feed. A decrease in the yield and S.N.F. content of milk and an increase in fat content was recorded when cows were moved from *Digitaria decumbens* pasture or *Digitaria decumbens* pasture supplemented with concentrates to pure stands of either *Phaseolus atropurpureus* or *Desmodium intortum* (Stobbs 1971). The protein content, particularly casein, was lower when cows grazed the legume treatments and casein:fat ratios of 0.47:1 were measured compared with 0.73:1 from cows grazing tropical grass pasture and receiving concentrate supplements (Stobbs 1971; Stobbs and Fraser 1971). Dale and Holder (1968) noted that the S.N.F. content of milk from monozygotic twin cows on a lucerne-concentrate diet was higher than that from contemporaries on *Pennisetum clandestinum/Glycine wightii* and Hamilton (1968) showed a higher percentage protein in the milk from cows grazing young regrowth of *Setaria sphacelata* compared with mature *Chloris gayana.* Similarly an increase in the intake of *Cynodon dactylon* was achieved by feeding ground and pelleted rations resulting in milk with a higher S.N.F. content (Brooks *et al.* 1962).

Associated with the higher fat percentage when cows graze poor quality feed are changes in the composition of the fat. Milk fat is made up of fatty acids of varying chain lengths; the proportion of each of these acids being affected by the quantity and quality of feed consumed. Numerous studies have shown that short-chain fatty acids are synthesised within the mammary tissue (Linzell 1968; Jones, E. A. 1969) whereas long-chain fatty acids are mainly derived from body fats (Lascelles *et al.* 1964). On restricted or poor quality diets cows catabolise depot fat reserves and produce milk with a lower proportion of short-chain fatty acids and a higher proportion of long-chain fatty acids. Parodi (1971) showed that under tropical conditions in Australia a sub-optimum plane of nutrition in winter resulted in milk with a high oleic acid content. Similarly preliminary grazing and pen-feeding studies with tropical pasture species (Stobbs and Brett, unpublished data) suggests that changes in milk constituents and the proportion of fatty acids in milk reflect the intake of digestible energy and it is hoped that such measurements can be used in the selection of superior species.

The principal end products of digestion providing energy for a dairy cow are the steam volatile fatty acids, the three most important being acetic, propionic and butyric. These characteristically alter in their relative proportions with changes in dietary composition, particularly with varying amounts of concentrates and roughages and affect the quantity and quality of milk produced (Cowan, Oliver, and Elliott 1970). The efficiency of use of energy for lactation depends upon the relative proportions of these acids (Blaxter 1962). There is a tendency for tropical herbages to yield higher proportions of acetic acid than temperate feeds (Topps, Reid and Elliott 1965) which is consistent with a higher roughage intake (Cowan, Oliver and Elliott 1970). However there is very little variation in the relative proportions of volatile fatty acids produced in the rumen of cows grazing different tropical pastures (Lambourne and Antwi, private communication).

Mineral composition of milk is not generally influenced by the mineral content of the diet (Groenewald 1935; Stobbs and Fraser 1971) although mineral composition of milk varies considerably throughout the lactation (A.R.C., 1965). Mineral deficiencies in herbage can however result in reduced milk production (Bisschop 1964).

FACTORS INFLUENCING THE FEEDING VALUE OF TROPICAL PASTURES

The grazing trials which have been conducted to date have provided only limited information about the factors controlling the quality of tropical pastures. However indoor feeding experiments with sheep (Milford and Minson 1966a; Milford and Minson 1966b; Minson 1971a; Minson 1971b) have helped considerably in the understanding of nutritive quality and in general the level of animal production from pastures has been shown to be directly related to feeding value (Milford and Minson 1966c). Provided that tropical plants contain sufficient mineral and protein to meet the requirements of the ruminant animal, production is related to the quantity of feed eaten and the digestibility of the feed (Elliott, Fokkema, and French 1961; Holmes, Franklin, and Lambourne 1966).

Digestibility

High yielding cows require large quantities of readily available dietary energy to sustain milk production (Dirven 1965; Hardison 1966). Net energy of a feed is the most desirable way of expressing the energy value of a feed but, with few exceptions (Graham 1967), this has not been possible with tropical herbage because of the elaborate equipment required. The evaluation of feeds using starch equivalent, Scandinavian food units or total digestible nutrients do however give some measure of the relative energy values of feeds. Fortunately there is a high correlation between dry matter digestibility of tropical herbage and these energy values (Milford 1967). It is therefore difficult to overestimate the importance of digestibility when considering the quality of tropical pastures. Firstly none of the indigestible fraction of the food is available to the animal for maintaining the normal body functions or for milk production. Secondly with ruminants the level of voluntary food intake generally increases with increasing digestibility of the food.

French (1957) in a review on the nutritive value of tropical grasses noted that the data showed them to be high in fibre and low in crude protein. More recently the chemical composition of tropical pasture species and the effect of crude fibre and lignification on organic matter digestibilities has been summarized by a number of workers (Miller and Rains 1963; Grieve and Osbourn 1965; Hardison 1966; Butterworth 1967; Minson 1971a, 1971c). The dry matter digestibility of tropical grasses is generally low. Minson and McLeod (1970) found tropical grass herbage to be on average 12.8 percentage units lower than temperate grass herbage. These workers found a high negative correlation ($r = -0.76$) between dry matter digestibility and ambient temperature in both tropical and temperate grasses and concluded that the difference between tropical and temperate grasses was mainly due to the conditions under which each is usually grown, the former in warm to hot and the latter in cool climates. Legumes did not behave in the same way since respective digestibilities of temperate *Trifolium repens* and tropical *Phaseolus atropurpureus* were similar in both summer and winter.

The *in vitro* technique for estimating digestibility of tropical herbage (McLeod and Minson 1969) makes it possible to screen large numbers of plant samples. A wide range of variation in digestibility exists not only between species but also within species; Minson (1971a) showed a range of 7-22 digestibility units within various selections of seven species of tropical pasture. This would indicate that considerable improvement for this character is possible (Hutton 1971), and such improvement has been achieved by Burton, Hart, and Lowery (1967) who selected coast cross 1 with 12.3 percent more digestible dry matter than the main parent coastal. When selecting for improved feeding value *Digitaria* species appear to have a high potential based either on *in vitro* digestibility (Strickland 1970) or compared with other species (Gomide *et al.* 1969). Conversely the scope for selection for higher digestibility is less with *Chloris gayana,* (Milford and Minson 1968). The digestibility of *Setaria* species compares favourably with other grasses and some introductions of *Setaria splendida* have higher digestibilities than either Nandi or Kazungula cultivars of *Setaria sphacelata* (Hacker and Jones 1969).

There is some variation in the digestibility of stem and leaf fractions of tropical grasses (Hacker 1971) and tropical legumes (Jones, R. J. 1969). The relative digestibility of the leaf fraction of a temperate grass species such as *Phleum pratense* is considerably higher than the sheath or stem whereas two *Setaria* introductions were shown by Hacker (1971) to have leaf of relatively low digestibility. Leafiness is therefore not always a good indicator of digestibility. Recently *in vivo* digestibility studies on six Panicum varieties showed no relationship between digestibility and leafiness (Minson 1971b).

It is generally recognised that the digestibility of tropical pasture plants falls as they mature. The main constitutions of crude fibre when young are cellulose and hemicellulose which are highly digestible but with age there is a progressive increase in structural carbohydrate, especially lignin which is virtually indigestible. Thus it is necessary to utilise immature herbage in order to obtain a high energy intake. The rate of decrease in digestibility is generally about 0.1 digestibility units per day, which is very much lower than the 0.5 units reported for temperate grasses (Minson, Raymond, and Harris 1960). Minson (1971a) considers that this difference may be real because tropical species have initially a lower digestibility than temperate species and may also be due to the excessively long periods for which data on tropical species are often collected. The rate of decrease in digestibility in younger tropical herbage has been shown to be as high as for temperate species (Minson 1971a). Milford and Minson (1966a) showed that the decline in digestibility with age was more rapid in tropical grasses compared with tropical legumes which retained relatively high digestibilties at maturity and even after frosting (Milford 1967). *Dolichos lab lab* and *Vigna sinensis* are examples of annual legumes which maintain a high digestibility with age (Milford and Minson 1968) and *Phaseolus atropurpureus* (Jones, R. J. 1969) of a perennial legume. Similarly with increasing maturity *Digitaria decumbens* has a relatively high digestibility compared with *Chloris gayana* (Milford and Minson 1966a).

Intake

The quantity of dry matter voluntarily eaten by an animal is the most important factor controlling the productive value of a feed (Milford 1960b). The intake of a dairy animal is controlled to a considerable extent, although not exclusively (Blaxter, Wainman, and Wilson 1961; Montgomery and Baumgardt 1965), by distention of the digestive tract, particularly the reticulo-rumen (Campling and Batch 1961). The more rapidly the breakdown and digestion of feed proceeds in the reticulo-rumen the faster can be the rate of passage of digesta onwards to the rest of the alimentary canal. It is therefore understandable that tropical herbages which are relatively low in digestibility (and high in fibre content) have a low voluntary intake. Although feed digestibility directly affects voluntary intake in temperate species (Blaxter 1961) the relationship is not so good for tropical species (Milford and Minson 1966a; Milford 1967; Minson 1971a) partly due to the different times required to break down different tropical feeds. However a general trend for the voluntary intake to decrease with decreasing digestibility of dry matter has been shown to exist, within species, for *Chloris gayana* (Milford and Minson 1968), *Panicum species,* (Minson 1971b) and for all legumes tested (Minson 1971c). There is some indication that voluntary intake does not increase so markedly with increased digestibility above 67 percent (Conrad, Pratt, and Hibbs 1963; Corbett 1969) but tropical feeds rarely achieve this level of digestibility.

To date there are no reliable methods for estimating voluntary intake of feeds either under grazing (Milford 1961) or in the laboratory (Minson 1971a) and most comparisons of the intake of tropical pasture species are derived from indoor feeding trials with cattle or sheep. Values for tropical grasses have been reviewed by Miller and Rains (1963); Hardison (1966) and Minson (1971a), for tropical legumes by Minson (1971c) and for hays by Marshall, Bredon, and Juko (1961). For a valid comparison of voluntary intake herbage from pasture swards cut from one site at a similar stage of growth needs to be fed to a considerable number (8-10) of animals to overcome the large variation in intake exhibited amongst animals. Unfortunately these conditions have not always been observed and many of the determinations on tropical herbage are of limited value for comparison with other data.

There are however considerable real variations in voluntary intake between and within tropical pasture species (Minson 1971a). These vary from 4 percent for *Chloris gayana* (Milford and Minson 1968) to 63 percent for *Cenchrus ciliaris* (Milford 1960a). Some of these differences are associated with differences in digestibility but others are completely unrelated as those recorded for *Panicum* varieties (Minson 1971b). Intake of tropical legumes is generally higher than tropical grasses of similar digestibility (Milford and Minson 1968) although not as high as for temperate legumes such as *Medicago sativa* (Hamilton *et al.* 1970). Fertilization generally has little effect on the intake of tropical grass (Paladines and De Alba 1963) unless the mineral composition is below a critical value (Minson 1967).

It is possible that the ability of the ruminant grazing tropical forage to obtain a sufficiently high dry matter intake to achieve high productivity may also be impaired by the high water content of, or the free water on the ingested fodder. Experimental evidence for this hypothesis would suggest that this is unlikely to be a major cause of low productivity although objective trials have not been conducted with tropical herbage. Campling and Balch (1961) showed that the direct introduction of large volumes of water into the rumen, unless retained in a rubber bladder that physically reduced rumen volume did not reduce intake by the animal.

Although grinding generally tends to reduce digestibility, voluntary intake is improved due to a faster rate of passage through the rumen (Minson 1963). Dry and dusty feeds are not eaten with relish but pelleting of such feeds improves their intake. Grinding and pelleting of *Cynodon dactylon* resulted in a higher herbage intake and higher milk production compared with hay (Brooks *et al.* 1962). Intake and production from silage made from tropical herbage is generally less than the original herbage or hay (McWilliams and Duckworth 1949). However, additional concentrates allowed a reasonable intake of *Cynodon dactylon* silage to be consumed and consequently good animal production to be obtained (King 1964).

Intake of dry matter can be adversely affected by the quantity of feed on offer (Willoughby 1959) although the extent of this effect differs for different plants. The structure of a plant is equally important (Allden and Whittaker 1970). Stobbs (1970b) found that dairy cows grazing pure swards of *Phaseolus atropurpureus* and *Desmodium intortum* had difficulty in satisfying their nutritional requirements most probably due to difficulty in harvesting palatable material from these trailing legumes. Hutton (1971) has suggested changing the geometry of legume cultivars by breeding to increase their contribution to animal production.

Protein

The nitrogen content in the forage produced by tropical pastures, particularly unimproved grassland, is generally low by temperate standards (French 1957; Bredon and Horrell 1961; Butterworth 1967). Apart from a short period at the commencement of the growing season, probably associated with rapid mineralisation of soil nitrogen, the nitrogen concentration falls rapidly with growth and reaches a low level before flowering; this continues into maturity as nitrogen is translocated from the tops to storage tissues in stems and roots, (Henzell 1971). Consequently the nitrogen concentration in the dry season forage may fall below 0.5 percent of the dry weight and even with very selective grazing the concentration in the diet may fall below 1.1 percent (7 percent crude protein) the level at which nitrogen begins to limit intake of feed by sheep (Milford and Minson 1968).

The application of nitrogen to the sward, the inclusion of legumes or the feeding of nitrogen supplements are obvious ways of overcoming any deficiency which may exist. Nitrogen declines more rapidly with age in tropical grasses than in tropical legumes (Milford and Haydock 1965) and could explain why tropical legumes are particularly valuable for animal production in the dry season (Stobbs and Joblin 1966; Stobbs 1966). Among the grasses studies by Milford and Minson (1966a) the decline in nitrogen content was least in *Pennisetum clandestinum* and greatest in *Cenchrus ciliaris* and *Digitaria decumbens*. Thus the feeding value of such species as *Digitaria decumbens* near maturity can be limited by a deficiency of crude protein. Late applications of nitrogen have been successfully used to raise the nitrogen content and intake of *Cynodon dactylon* (Blue, Gammon, and Lundy 1961) and *Digitaria decumbens* (Kretchmer 1965; Minson 1967). Blydenstein *et al.* (1969a) showed that 12.5 percent of the nitrogen applied to a *Digitaria decumbens* sward was recovered in milk which made the practice of nitrogen fertilisation attractive in Costa Rica. Swamp grasses such as *Entolasia imbricata* (Bogdan 1963; Stobbs 1968) and some grasses on wet sites in Surinam (Dirven 1969) have a relatively high nitrogen content at all stages of growth.

PREDICTING MILK PRODUCTION USING DATA FROM LABORATORY AND ANIMAL HOUSE STUDIES

The estimated composition of tropical grasses and legumes has been used to calculate the level of milk production which might be expected from fresh herbage of varying quality, (Glover and Dougall 1961; Payne 1963; Dirven 1965; Hardison 1966). Dirven (1965) and Hardison (1966) calculated that potential production per cow was much less than from temperate zone pastures and that most tropical pastures, rotationally grazed every 20-30 days, would supply protein for 10 Kg of milk whereas the energy content was only sufficient for a much lower level of production. Despite this low potential production per cow Glover and Dougall (1961) and Payne (1963) suggested that production per acre could approach that obtained on the best temperate grass pastures because of the much higher carrying capacity of tropical pastures. Dirven (1970) calculated that a maximum of 9,000 Kg/ha was possible on tropical pastures compared with a similar level of production on temperate pastures, although higher levels of production have occasionally been achieved under field conditions. This contrasts with the estimated maximum production from beef cattle, with lower nutrient requirements for production than dairy cows, for which Dirven (1970) estimated that 1,650 Kg/ha of liveweight-gain could be obtained from well managed tropical pasture compared with 1,000 Kg/ha liveweight-gain in temperate regions.

The nutritive value and the limitations of tropical pasture for milk production are discussed by Glover and Dougall (1961) who concluded that the potential milk yield of cows was limited when the crude protein content falls below 12 percent and above this level available energy was considered to be the major limiting factor. Similar conclusions were reached by Dirven (1965) and Hardison (1966). Hamilton *et al.* (1970) obtained a greater response to energy supplements than protein supplements with nitrogen fertilised autumn pasture in South-east Queensland. However on non-fertilised tropical pasture Ipsen (1970) obtained a response from feeding a high protein concentrate ration (18% D.C.P.) compared with a lower protein concentrate ration (15% D.C.P.).

Levels of production under grazing vary considerably from those estimated from chemical composition (Holder 1967). This is mainly due to the animal's ability to select a more nutritious diet whilst grazing (Lesperance *et al.* 1960) and to difficulties experienced in measuring voluntary intake under grazing for the purpose of estimating potential production (Milford 1964). Lactation can have a marked effect upon intake (Hutton 1963). Although the relative intake of various feeds can be accurately measured with sheep in pens and the ranking order is similar for cattle (Playne 1970) the actual intake per unit of metabolic weight can be twice as high for cattle as for sheep (Minson 1971c). Laboratory and animal house studies are therefore useful in ranking tropical pasture plants in order of nutritive quality and the results of such investigations are valuable in explaining the factors influencing feeding value. The true value of any pasture can only be assessed under grazing conditions.

CONCLUSIONS

Technical difficulties in studying the grazing animal and the high cost of this work have discouraged research with animals grazing in genuine pasture conditions and in consequence a large part of research to date has been concerned with nutritional diseases rather than production problems. This is particularly the case in the tropics and sub-tropics where there is a lack of knowledge about the quality of tropical pasture species for dairy production. It is therefore not surprising that the enormous potential of tropical species is not being exploited. However animal house studies and an increasing knowledge of the principles of nutrition have allowed a better understanding of the quality of tropical pasture plants to be made.

In general tropical species have a lower digestibility and intake than temperate species which is reflected as a lower production per cow. Insufficient intake of digestible energy is the feed factor primarily responsible for limiting production under practical farming conditions, although lack of protein can also be important under certain conditions. Four methods of increasing intake of digestible energy are (i) selection and breeding better cultivars (ii) grazing forage younger (iii) feeding concentrates (iv) pelleting forage. Each of these methods tends to increase milk production per cow but apart from the first also increases costs. It is therefore encouraging to find a large variation in digestibility, intake and plant structure which exists between and within tropical pasture species. Plant breeders should be encouraged to select for higher nutritive quality because small increases in this character will have a marked effect upon animal productivity and will allow our dairy products to compete more effectively on the world market.

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