Sustaining productive pastures in the tropics 6. Nitrogen fertilized grass pastures

J.K. TEITZEL,[1] M.A. GILBERT,[2] AND R.T. COWAN[3]
Queensland Department of Primary Industries, [1]South Johnstone, [2]Indooroopilly and [3]Ipswich; Queensland, Australia

Abstract

Nitrogen fertilized pastures are being used more in high rainfall areas as part of both beef and dairy production systems. Because of their productivity at critical times of the year, they have useful roles in reducing stress on other pasture types and boosting production from groups of cattle to match specific market requirements. On properties where cool-dry season management is critical, higher and less seasonal production can be attained by applying N fertilizer to a seasonally responsive grass on the deeper soils. On predominantly poorly drained properties N application to grasses resistant to trampling on high country, allows stock reductions on low areas during the wet season. The application of 200-300 kg/ha N annually gave near optimum milk and beef production per hectare in areas with annual rainfall greater than 800-1000 mm. Disadvantages of N fertilized pastures are high capital outlays in fertilizer and stock. However, under present economic conditions N fertilizer has a role in increasing productivity and sustainability of tropical and sub-tropical property management systems. Use on special purpose pastures can lead to substantial gains in farm profitability.

Resumen

Las pasturas fertilizadas con nitrógeno son más utilizadas en las áreas de alta precipitación como parte de los sistemas de producción tanto de bovinos de carne como de leche. Debido a su productividad durante los períodos críticos del año, las pasturas fertilizadas han jugado un papel útil en la reducción de la tensión impuesta sobre otro tipo de pasturas y en la estimulación de la producción de grupos de ganado para cubrir los requerimientos del mercado. Se podría lograr una producción elevada y menos estacional mediante la aplicación del fertilizante N a las gramíneas con capacidad de respuesta en suelos profundos de las propiedades en las que el manejo en la estación fría y seca es critico. La aplicación de N a las gramíneas resistentes al pisoteo en campos elevados permite la reducción del ganado en las áreas bajas durante la estación húmeda en las propiedades con predominancia de suelos pobremente drenados. La aplicación de 200 a 300 kg/ha N al año causó una producción de leche y carne por hectárea cercana a la óptima en las áreas con una precipitación anual mayor que 800-1000 mm. Las desventajas de las pasturas fertilizadas son las altas inversiones de capital en fertilizantes y en ganado. Sin embargo, bajo la condiciones económicas actuales la fertilización con N tiene un papel creciente en la productividad y en el sostenimiento de los sistemas de manejo de las propiedades tropicales y sub-tropicales. El uso de pasturas con un propósito especial puede conducir a una ganancia substancial en la rentabilidad de la granja.

Correspondence: Dr J.K. Teitzel, QDPI, South Johnstone, Qld 4859, Australia.

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Introduction

Low soil nitrogen (N) is one of the most important limitations to pasture growth in the tropics and sub-tropics. The first major Australian review of the topic (Henzell, 1962) outlines widespread pasture growth responses to fertilizer N. Since that time there has been an even greater number of papers reporting plant growth responses, and there are now reports of long term grazing studies where increased beef and dairy production have been recorded. These studies have shown that N fertilized grass pastures (grass-N pastures) attain animal production levels higher than those expected from tropical grass-legume pastures and are more robust in their response to various forms of management. This paper reviews recent studies of the productivity of grass-N pastures, outlines some of their weaknesses and discusses their role in increasing the profitability and efficiency of beef and dairy enterprises based on tropical and sub-tropical pastures.

Pasture response to nitrogen

During the summer months (October to April) when temperatures favour rapid growth, pasture yield is closely related to summer rainfall and N supply (Figure 1). Low temperatures limit growth during autumn, winter and spring (Murtagh 1975; Miller and van der List 1977) particularly in the tropical highlands and sub-tropics. However, differing sensitivity to low temperatures may be exploited in grass-N pastures because species such as Narok setaria, Nandi setaria, kikuyu and rhodes grasses are less sensitive than others to low temperatures (Ivory and Whiteman 1978; Pearson *et al.* 1985).

Increased beef production

A number of experiments have shown increased beef production from grass-N pastures over grass-legume alternatives. Examples include data, shown in Table 1, from rain-grown tropical pastures in three widely separated centres on the east coast of Australia and an irrigated experiment in Western Australia. These show remarkably similar levels of beef production. Greatest differences in rain grown pastures could be anticipated between Lismore and Innisfail which are about 1500 km and 11° of latitude apart, with higher productivity expected in the warmer and wetter environment of Innisfail. However, it appears that factors such as the reduction in radiant energy due to cloud cover and water-logging of soils during the Innisfail wet season, constrain beef production at least as much as the cooler and drier conditions at Lismore. With soil mineral deficiencies corrected, productivity on the Beerwah site, representative of infertile soils in the sub-tropics, was similar to the other sites. In the above experiments, increased production was achieved by increasing stocking rates, and not through production per head (average c. 0.5 kg/hd/day).

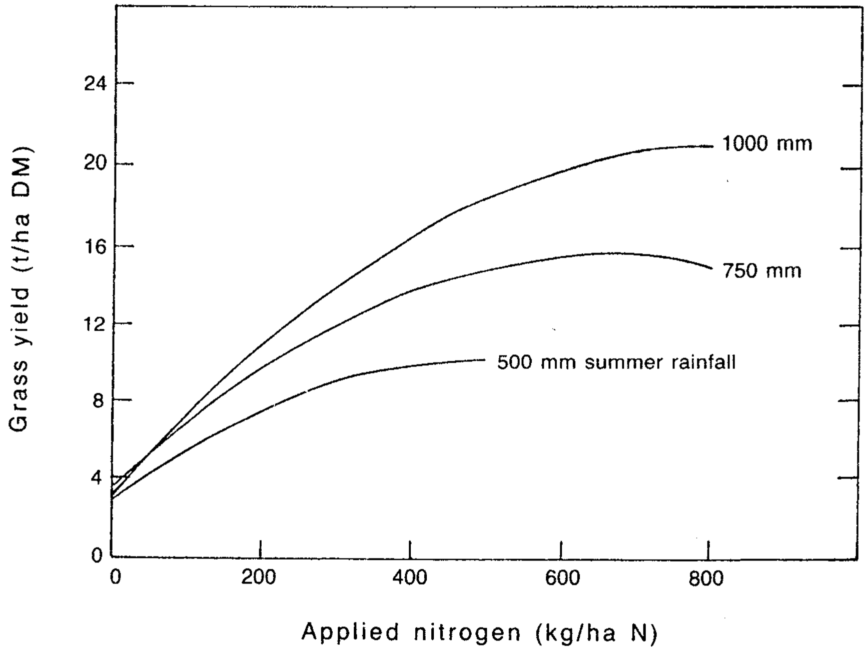

Figure 1. Relations between nitrogen supply, summer rainfall (1 October-30 April) and annual pasture grass yield in the sub-tropics and tropics of Queensland (Gilbert *et al.* unpublished data). Data collected from 31 sites.

Table 1. Effects of nitrogen fertilizer on beef production from a range of tropical pastures

Location	Annual Rainfall	Pasture Type	N Rate	Liveweight Gain	Reference[1]
	(mm)		(kg/ha/yr)	(kg/ha/yr)	
Lismore	1250	Kikuyu/W.Clo.	0	513	a.
,,		Kikuyu	134	713	a.
,,		,,	336	1167	a.
,,		,,	672	1247	a.
Beerwah	1650	Pangola/var leg.	0	507	b.
,,		Pangola	168	699	b.
,,		,,	448	1106	b.
Innisfail	3600	Guinea/Centro	0	490	c.
,,		Makueni/belalto	0	550	c.
,,		Signal	180	940	c.
,,		,,	196	1017	d.
,,		,,	336	1149	d.
,,		,,	532	1107	d.
Ord River	Irrigated	Pangola	100	560	e.
,,	,,	,,	200	920	e.
,,	,,	,,	300	1170	e.
,,	,,	,,	350	1230	e.

[1] a. Mears and Humphreys (1974); b. Bryan and Evans (1971); c. Teitzel, Wilson and Mellor (1991); d. Harding and Grof (1978); e. Jones (1990).

There is, however, a need for caution in extrapolation. Substantially lower levels of production were measured in other experiments: eg Whiteman *et al.* (1985), Jones and Jones (1989) and Jones and Evans (1989). Reasons for lower levels of production are unclear. Jones and Evans (1989) were unable to establish a relationship between liveweight gain in different years and rainfall, length of growing season and date of first severe frost. Whiteman *et al.* (1985) and Mellor *et al.* (1973) measured differences in the productivity of different grass cultivars under grazing, so careful species selection could be a factor. Another consideration is that other soil minerals could be more limiting than N. This has been the case with phosphorus and sulphur on a few commercial *Brachiaria decumbens* pastures in the humid tropics (J.K. Teitzel, unpublished data).

To achieve production levels similar to those in Table 1, it may be important to restrict N fertilizer to seasonally responsive grasses growing on land classes with the required drainage and moisture characteristics and with other soil mineral deficiencies corrected. We are therefore concerned about the likely effectiveness of any opportunistic use of N fertilizers. Greater efficiencies are likely from planned use on special purpose pastures.

Increased dairy production

Annual milk production from grass-N pastures ranges from 6000 to 9000 l milk/ha under dryland conditions (Table 2) at stocking rates of 2 cows/ha in dry areas (800mm AAR) to 2.6 cows/ha in high rainfall areas (1200mm AAR). The milk production response to N is linear between 150 and 600 kg/ha N in new pastures, but becomes curvilinear after 3 years with near optimum production from annual applications of 200 kg N/ha (R.T. Cowan, unpublished data).

Acidification

Soil acidification is a major concern with the long term use of N fertilizer. Table 3 shows soil acidification under a range of grazed pastures. Generally, acidification rate increased with increasing N fertilizer rate and initial soil pH. Ammonium sulphate was particularly acidifying. However, some 90% of the 15700 tonnes of N fertilizer applied annually to pastures in Queensland is sold as urea.

Acidification caused by nitrate leaching may be minimized by using deep-rooted perennial pastures (Ridley and Coventry 1990). In the

Table 2. Effects of stocking rate and nitrogen fertilizer level on milk production from tropical grasses. Figures adjusted to zero supplement input

Pasture AAR[1]	N Rate	Stocking Rate	Milk production		Reference[2]
	(kg/ha/yr)	(cows/ha)	(kg/cow/yr)	(kg/ha/yr)	
Kikuyu					
1140 mm	300	2.5	2216	5540	a.
		3.3	2031	6702	a.
		4.9	1901	9315	a.
Gatton panic					
1285 mm	200	2.5	2580	6450	b.
		3.0	2450	7350	b.
	400	2.5	2980	7450	b.
		3.0	2850	8550	b.
	300	2.6	3300	8580	c.
Rhodes grass					
800 mm	0	2.0	1123	2246	d.
	300	2.0	2254	4508	d.

[1]AAR : Average Annual Rainfall
[2]a. Colman and Kaiser (1974); b. Davison *et al.* (1985); c. Davison *et al.* (1989); d. Cowan *et al.* (1987)

Table 3. Effect of different forms and rates of N fertilizers on soil acidification rates in grazed tropical pastures

Fertilizer	N rate	Duration	Initial pH (H_2O)	Annual pH changes	Reference
	(kg/ha)	(years)			
urea	180	13	5.4	−0.018	J.K. Teitzel (unpublished data)
	180	15	5.4	−0.021	
	180	15	5.5	−0.013	
	300	12	4.8	−0.034	
	150	3	7.5	−0.000	R.T. Cowan (unpublished data)
	300	3	7.5	−0.067	
	450	3	7.4	−0.167	
	600	3	7.7	−0.333	
Ammonium nitrate	200	5	6.3	−0.120	T.M. Davison (unpublished data)
	300	7	5.3	−0.029	
	400	5	6.3	−0.160	
	125	10	4.9[1]	−0.003	Cited by Helyar and Porter (1989)
Ammonium sulphate	336	na	4.9[1]	−0.158	
	100	3	6.3	−0.130	Evans *et al.* (1978)
	300	3	6.0	−0.200	

[1] pH in $CaCl_2$.
na not available.

seasonally dry tropics of north Queensland, soil nitrate accumulates in winter and spring, reaches a peak at the onset of the wet season (Crack 1972), and without the presence of perennial grasses could leach and cause acidification. Data from Dakota, USA, showed no nitrate leaching from brome grass pastures fertilized with 110 kg N/ha annually, but substantial leaching under corn (Power *et al.* 1972).

It appears that nitrate leaching under grazed tropical pastures will be minimal. Nitrogen is usually applied as urea, at less than 300 kg/ha N annually, during the growing season when the demand for N by the grass is high. In these circumstances it is likely that most of the available nitrate is taken up by the plant, rather than being leached through the soil profile. However, careful monitoring of the situation should continue.

Economics

At a stocking rate of 2 cows/ha, increasing the annual N application from 0 to 300 kg/ha N as urea increased annual milk production by 4000 l/ha (Cowan *et al.* 1987). The combined cost of the urea and the maintenance P and K is in the order of $340/ha, compared with an increased income of about $1000/ha, demonstrating an obvious economic benefit to dairy farms.

A current bio-economic study of the cattle fattening industry in the humid tropics of Queensland (Teitzel 1991) indicated that (under prevailing cattle prices) optimum economic benefits would be derived if all well drained land classes were planted to grass-N pastures. Sensitivity analyses indicated that cattle prices had to drop below 80 cents/kg liveweight for grass legume pasture systems to become more profitable than grass-N systems on well drained lands. When beef prices were set at $1.15/kg liveweight, the model indicated that operating profits from grass-N systems were around $200/ha/yr higher than grass-legume alternatives.

An analysis of financial operating margins for three alternative pasture systems is presented in Table 4. The starting point is a cattle operating margin of $224.40. This is obtained by purchasing 200 kg store steers for $220 per head, selling them at 450 kg (local butchers) for $495 and subtracting costs associated with purchasing, health, deaths and disposal. An enterprise operating margin is calculated by subtracting the pasture running costs. This indicates a substantial margin in favour of the grass-N system over lower input alternatives. The financial analysis is extended to examine capital outlays and the effect of borrowing (at 18.5% interest) all operating monies outlayed in cattle and pastures. Again, the higher productivity of the grass-N system more than compensates for the higher costs involved.

Sensitivity analyses indicated that profitability is most sensitive to stocking rates, purchase and disposal prices and cattle growth rates. In comparison, the effects of running costs (fertilizer etc.) were minor. In many other tropical areas, economic analyses of grass-N systems should be even more favourable because beef prices are higher and fertilizer prices lower.

Flexible and sustainable pasture systems

Beef producers in the tropics and sub tropics have difficulty maintaining their sown pastures and sustaining production. Without adequate inputs of nitrogen, either from legumes or fertilizer, initial levels of production from sown tropical grass pastures will not be sustained (eg Robbins *et al.* 1987). Improved grass-legume pastures are notoriously sensitive to grazing mismanagement (eg Whiteman 1980) and to trace element deficiencies

Table 4. Appraisal of three pasture options when fattening weaners for local butchers trade at Innisfail, Queensland

Parameter	Pasture Options		
	Common Commercial	Fertilized Grass-Legume	Grass-N
Cattle Margin/head (see text)	$224.40	224.40	224.40
No. head/ha	1.5	2.5	5.0
Fattening period (days)	625	500	500
No. head fat/yr/ha	0.87	1.83	3.65
Cattle Margin/yr/ha	$195.23	410.65	819.06
Pasture Costs/yr/ha	$36.00	66.00	194.00
Operating margin/yr/ha	$159.23	334.65	625.06
Total Financial Outlay			
in cattle/yr/ha	$378.90	631.50	1263.00
in pastures/yr/ha	$36.00	66.00	194.00
farm value/ha	$2500.00	2500.00	2500.00
Return on Total Outlay %	5.46	10.78	15.80
Interest (18.5% money operating cattle & pastures)	$76.76	129.04	269.55
Operating margin/yr/ha (after interest on operating moneys)	$82.47	215.61	355.51

[1] Includes costs for weed control, landtaxes, miscellaneous and all fertilizers.

which are difficult to detect without the use of specialized procedures (eg Andrew and Fergus 1976). In contrast, grasses fertilized with N support high stocking rates (Bryan and Evans 1971), are relatively easy to establish and are more competitive against weeds than legume based pastures (Teitzel *et al.* 1971).

To take advantage of these characteristics Teitzel *et al.* (1971) recommended that about 25 per cent of each cattle fattening property should be planted to grass-N pastures to relieve pressure on the less robust grass-legume pastures during periods when they were poorly productive or particularly susceptible to mismanagement. Grazing studies over 11 years (Teitzel *et al.* 1991) measured sustainable beef production of 650 kg liveweight gain/ha/yr from an integrated system, compared to 550 kg/ha/yr from a corresponding all grass-legume system. Weed yields in the grass-legume pastures of the integrated systems were about half those in the corresponding pastures of the all grass-legume systems.

A numerical evaluation of the above situation (Teitzel 1991) revealed that the most important factors affecting the optimum proportion of grass-N pasture were the array and classes of lands on a property, cattle prices and management objective. Instead of restricting grass-N pastures to 25 percent of the property, the model indicated that when beef prices were above 80 cents/kg liveweight, all well drained land classes should be planted to grass-N pastures. The model also calculated the optimum number and class of cattle to be purchased and sold each month and determined the grazing programs for each animal group and land class/pasture type combination.

Commercially, the selection of the grass cultivar for the grass-N pasture also varies with the composition of the land classes on a property. In the humid tropics, when much of the property is poorly drained, well drained land classes should be planted to *Brachiaria humidicola*, which is highly productive and resistant to trampling damage during the warm wet season. Such pastures can be heavily stocked in the wet season, allowing a reduction in grazing pressure on the poorly drained land classes. This contrasts with the situation on predominantly well drained properties where feed shortages are greatest during the cool-dry season. In this case, because of its superior winter growth, *Brachiaria decumbens* is favoured on deep soil with good moisture holding capacity.

Temperate pasture species are often the primary feed source on irrigated dairy farms, and tropical grasses are used to maintain production from December to May. On unirrigated farms, tropical grasses are the primary feed source throughout the year. High pasture yield is sought because yield is linearly related to milk production (adjusted for supplement intake) up to about 3000 l/cow/lactation (Davison *et al.* 1985); and grass yield is positively related to N and moisture supply (M.A. Gilbert, unpublished data).

Grass-N pasture systems could play similar special purpose roles in more extensive cattle enterprises. For instance, by relieving grazing pressure during spring and early summer, they could help sustain the productivity of native pastures by allowing desirable perennial plants to set seed. Other special purposes include the provision of quality forage for nutritionally vulnerable animal classes such as weaners and first calf heifers. All these options need to be assessed experimentally.

Future and Conclusions

In view of the promising results and analyses reviewed in this paper, there would seem to be potential benefits in studying the productivity, profitability and sustainability of a range of whole property management systems involving the use of intensive grass-N pastures for special purposes. Integration of such pastures on a whole farm basis, could be expected to increase productivity, give greater management flexibility and increase the sustainability of less robust pastures in regions receiving annual rainfalls greater than 800 mm in southern areas and 1000 mm in the more seasonal northern tropics.

It is rare for cattle grazing grass-N pastures to have annual growth rates in excess of 0.5 kg/hd/day. Financial models (Teitzel 1991) indicate that an increase in daily weight gain from 0.5 to 0.6 kg/head would increase profits from fattening enterprises on such pastures by about $70/ha/year and reduce time to turnoff by 3 to 5 months, depending on market specifications. Promising legume cultivars and other means of increasing cattle growth rates, need to be tested to further develop legume complemented grass-N systems.

A sudden reduction in beef prices would probably result in a cessation of fertilizer inputs. It seems reasonable that there would be some residual effect of previously applied N, and the value of this should be investigated. Legume complemented grass-N systems would have advantages in this situation.

We need more accurate methods for field diagnosis and monitoring of N and other elements, particularly, P, K and S. Interpretation of these data should take into account factors such as stocking rate and costs of additional fertilizer to determine economic as well as biological optima.

Despite these knowledge gaps, grass-N pastures are economically attractive under certain conditions and have a valuable role in increasing the flexibility and sustainability of tropical and subtropical pasture management systems.

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