Legumes in native pasture — asset or liability? A case history with stylo

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Abstract

The inclusion of *Stylosanthes* species into 1 M ha of mostly native pastures has had a significant impact on the beef industry in northern Australia. Higher production levels in response to both nutrition of breeding and growing cattle allow producers flexibility in targeting appropriate markets. However, there is recent evidence that legume dominance and its associated impacts on the resource base may have a negative impact on the long-term viability of these production systems. Accelerated soil acidification and nutrient depletion, increased soil erosion and vegetation changes contribute to the potential degradation of this resource through legume dominance in a pasture. Each issue is discussed and solutions based on soil acidity risk mapping and pasture management are presented. The adoption of these strategies will reduce the potential negative impact on the soil resource and sustain productivity.

Introduction

Based on the data of Gramshaw and Walker (1988) and estimated plantings over the last decade, there are at least 8 M ha of sown pasture in Queensland. Approximately 2 M ha contain sown legumes of which half is established to *Stylosanthes* oversown into native pasture.

Since their release 25 years ago, *S. scabra* and *S. hamata* have been planted widely and now assume a highly significant role in the production of beef throughout northern Australia. Because of this widespread use, we will use stylo in this paper to demonstrate the positive values of sown pasture legumes grown on land devoted to cattle production and some negative values that have arisen because of its success. Further, we will outline some research into soil acidification by tropical legumes, the significance of maintaining a strong grass component and the promotion of management options to ensure long-term sustainability.

Stylo as an asset in native pasture

The inclusion of the *Stylosanthes* has proved to be an ideal low-cost method of improving the quality of native pasture and legume-based cropping systems in Asia, Africa, South America and northern Australia (Miller *et al.* 1988; 1991). This is due to the adaptability of the species to inherently infertile soils and climatic conditions ranging from the humid wet to the semi-arid tropics. Moreover, they have the potential to be more widely grown in the subtropics and tropics than any other genus currently being evaluated. Under the moderate to low rainfall regimes of northern Australia and south-east Asia, cultivars of *S. hamata* and *S. scabra* have been successfully established in agropastoral and seed-production systems, as well as being intercropped in plantations of rubber and coconuts and in some annual cropping systems. Indeed, such has been the success of stylos that they form an integral component of beef, poultry and pig industries in Australia and south-east Asia and in the reclamation of 'wastelands' in India (Michalk *et al.* 1993; Pinstrup-Andersen and Pandya-Lorch 1994; Jayan 1995; Liu Goudoa *et al.* 1997).

Coates *et al.* (1997) highlighted the value of stylo to the grazing industries of northern Australia in detail. Cheffins (1996) compiled comprehensive production-system information on native grass-augmented pasture throughout Queensland. Based on the data of Miller *et al* (1997) and

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current beef prices, this translates into a contribution of around $20–25M annually to the beef industry. The value of stylo in native pasture has been enhanced animal performance and in some cases, higher carrying capacities. It costs $30–35/ha to establish stylo into native pasture. This compares with the establishment cost of a buffel pasture ($50-60/ha), sown grass-legume in coastal areas ($120–150/ha) and leucaena-grass ($120–150/ha). Therefore, the features that have made stylo so successful have been the easy, low-cost establishment, adaptation to a wide range of soils and rainfall and a nutritive value much higher than native grass for much of the year.

Coates *et al.* (1997) and Miller *et al.* (1997) reviewed the performance of cattle grazing native pasture-stylo. In general, the higher nutritive value of stylo relative to native grass for most of the year results in faster growth rates, higher turnoff weights, improved breeder and weaner performance and reduced drought risk. In growing cattle, the inclusion of legumes results in a better overall liveweight performance for most of the year and reduced (or even eliminated) liveweight loss in the dry season compared with native pasture. The yearly advantage over native grass ranges from 30–60 kg/animal (Coates *et al.* 1997) depending on soil type, length of growing season and stocking rate. In central Queensland, with conservative stocking and adequate mineral supplements when needed, it is possible to produce a 600 kg liveweight animal at 42 months of age from a stylo-native grass pasture. The system is ideal also for producing young stores for the live cattle trade. The relative productivity of a range of forage systems in Queensland is shown in Table 1.

Negative impacts

Until recently, little attention was given to potential long-term impacts of these systems on the soil resource base. A scientific review of the extent of the problem associated with the use of introduced legumes (McIvor *et al.* 1996) identified soil acidification and nutrient depletion, erosion and vegetation changes as potential mechanisms of degradation.

Accelerated acidification and nutrient depletion

Increased use of stylos with accompanying management practices, such as intensive seed/fodder production (with the associated export of plant material), has resulted in accelerated soil acidification and nutrient depletion (Figure 1). More recently, legume-based production systems of north-east Thailand and southern China have shown significant accelerated acidification with rates of acid addition similar to those observed in northern Australia (Noble *et al.* 1999; Guodoa *et al.* 1999). It is of note that, under these semi-arid tropical conditions, significant acidification to > 90 cm occurred (Figure 1). This makes remediation by conventional means extremely costly and impractical (Noble *et al.* 1997, 1999; Moody and Aitken 1997).

Soils that have exhibited the greatest degree of acidification are light-textured and are characterised by their poor fertility, low pH buffering capacity and low productivity. Notwithstanding these limitations, these soils are assuming increasing agricultural and economic importance. Indeed the introduction of stylos specifically

Table 1. Average commercial steer performance from a range of pasture systems.

Forage system	Av. stocking rate	Liveweight gain/year		Av. age at 600 kg LWt
	(ha/steer)	(kg/head)		(months)
Native pasture — NQ	10	80–100	8–10	> 55
Native pasture — CQ	4	100–140	25–35	> 50
Native pasture-stylo — NQ	5	130–165	26–33	45
Native pasture-stylo — CQ	3.5	140–170	40–48	42
Buffel grass — new	2	170–190	85–95	40
Buffel grass — run-down	3	140–150	47–50	45
Leucaena — buffel grass	1.5	250–280	167–187	30

targeted these areas so as to improve their productivity. Estimated net acid addition rates range from zero in the case of extensive pasture production systems on well-buffered soils to 10.6 kmol H^+/ha/yr under intensively managed seed/fodder production systems. The dominant factors influencing acidification under these legume-based systems are product removal, proton accumulation due to the nitrification process and nitrate leaching, and excess cation uptake from depth

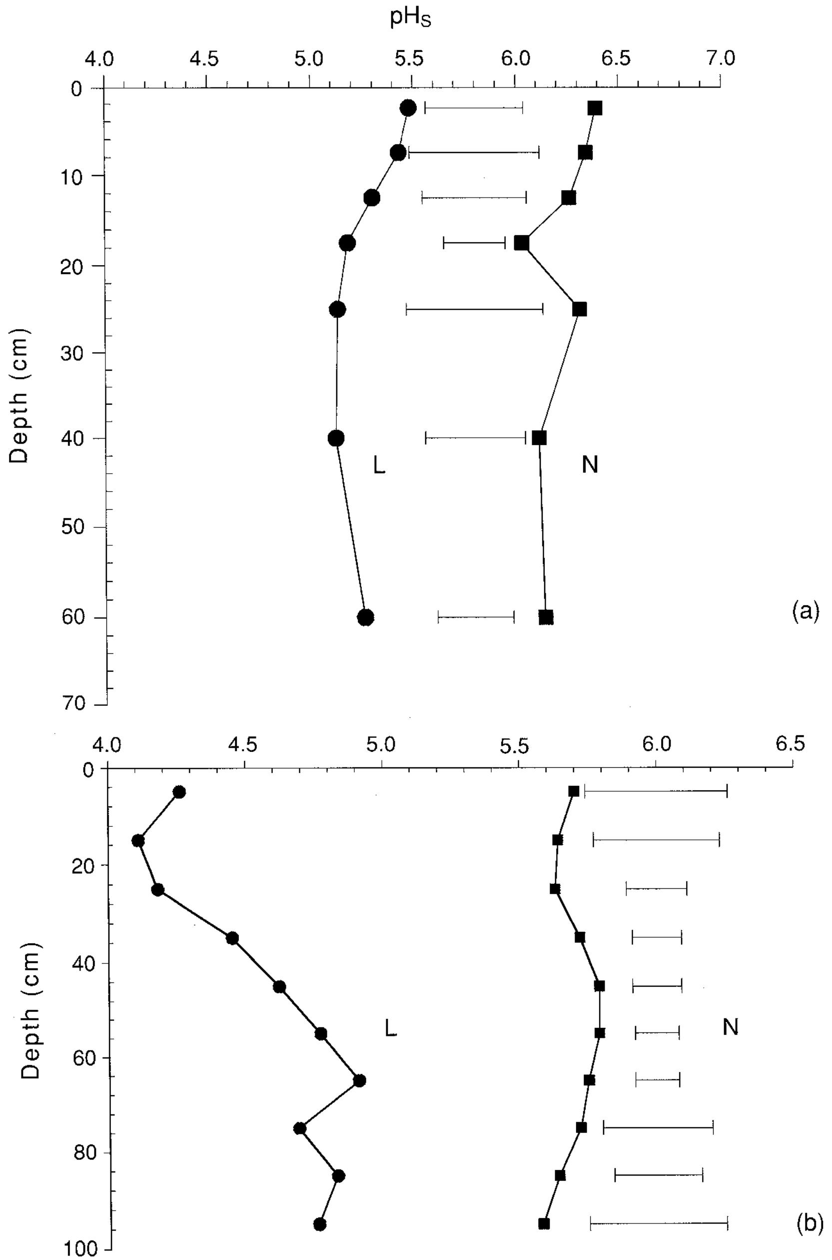

Figure 1. Soil pH_s (pH_s = pH of a soil:0.01M $CaCl_2$ 1:5 suspension) profiles for sites in surveys undertaken in (a) northern Australia and (b) north-east Thailand of (L) *Stylosanthes* seed production system and (N) a reference site. Horizontal bars represent the LSD (P<0.05) for that specific depth interval.

with its associated effect on base nutrient status of the exchange complex.

In the most extreme cases (intensively managed systems producing stylo hay and seed), considerable quantities of Ca, Mg and K are lost from the exchange complex of soils in plant material removed from the field. For example, a dry matter yield of 3t/ha/yr would result in a net loss of 46, 7 and 42 kg/ha/yr, respectively, of Ca, Mg and K.

A reduction in plant productivity will arise due to acidity *per se*, as is clearly demonstrated in studies evaluating the tolerance of selected grass and stylo species (Noble and Nelson 1999) (Figure 2). With increasing degrees of acidity, significant declines in dry matter production were noted.

Other considerations

The importance of maintaining vegetative cover to reduce water runoff and soil erosion has long been recognised as a goal of sound grazing management (Sallaway and Waters 1994; McIvor *et al.* 1995; Scanlan *et al.* 1996). In a study investigating the effect of different percentage cover in pastures dominated by *Bothriochloa pertusa* (a stoloniferous, naturalised grass) and *Heteropogon contortus* (a native, tussock, perennial grass) on runoff, pastures dominated by the former species had lower runoff and lower rates of soil movement than pastures dominated by *H. contortus* at the same level of cover (Scanlan *et al.* 1996). One could infer from these observations that pastures dominated by stylos but lacking the presence of a stoloniferous grass species would be more vulnerable to soil loss. Furthermore, the introduction of a legume often encourages the use of increased stocking rates such that soil surface water runoff and soil loss are increased (Hook 1998).

Establishment of legume sown into native pastures is usually slow because of low seeding rates and minimum disturbance (mostly aerially sown) prior to oversowing. However, the legume

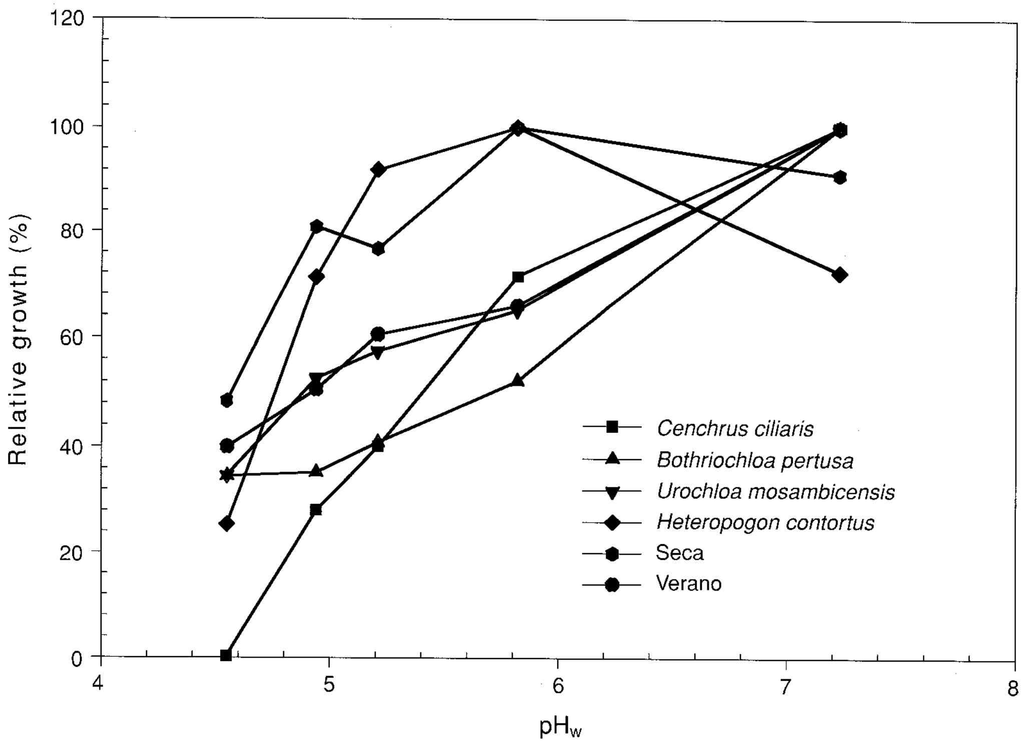

Figure 2. Relative growth response of selected introduced grass and *Stylosanthes* species to increasing soil acidification. (pH_w = pH of a soil:water 1:5 suspension).

increases with time and in many cases can eventually dominate the pasture. The introduction of exotic pasture species has attracted considerable criticism from environmentalists because of its impacts on biodiversity. However, there is little detailed information on what changes have occurred.

As a result of the identification of potential problems associated with the introduction of legume-based pasture systems, the beef industry commenced a research, development and extension program in 1997 to counter these problems. This was a commendable, proactive, whole-of-industry effort, given the fact that the current problems in Queensland are insignificant compared with problems caused by fertilised, temperate pastures in southern Australia.

Management of negative impacts

Soil acidity risk mapping as a tool to manage soil acidification

The rate at which a soil acidifies in a stylo-based pasture system is a function of the percentage legume in the pasture. Acidification rates in stylo-dominant pasture are higher than in those with a substantial proportion of grass (Noble *et al.* 1997). Numerous factors influence species dominance in a sward. In the case of stylos, we suggest that it is a function of grazing pressure, rainfall, pH buffering capacity, soil P content, and the productivity of the pasture.

One strategy to address this issue is the identification of soils that are predisposed to accelerated soil acidification. A Soil Acidity Risk Map has been developed for Dalrymple Shire that estimates the time it would take for the soil pH to drop from its current value to a base pH of 5.0 (Figure 3). The approach used clearly shows that a significant percentage of the Shire has soils that are predisposed to accelerated soil acidification. Light-textured, sandy soils with a very low internal capacity to buffer acid additions dominate the southern region of the Shire. In contrast, the basalt-derived soils that occur in the northern region of the Shire and isolated pockets of vertisols have considerably higher internal buffering capacities and hence would take longer to acidify.

Pasture management to reduce stylo dominance and soil degradation

Managing pasture composition to prevent stylo dominance is probably the most important option to avoid increasing soil acidification. No value for maximum stylo contribution in the pasture is available but Partridge *et al.* (1996) suggest that the balance be maintained at 50:50 stylo:grass. As a result, grazing management aimed at preventing stylo dominance is probably more effectively applied before dominance occurs than waiting until stylo exceeds, say, 75% of the total yield. For example, Cooksley (1999) reported that pasture composition in a heavily stylo-dominant pasture (>90% stylo in pasture) was resistant to change regardless of management options, including grazing management and fire, implemented to alter pasture composition.

Summer resting. Coates *et al.* (1997) reviewed studies of the diet selected by cattle grazing stylo-native grass pasture. The evidence indicated that, during summer, cattle select a diet dominated by grasses rather than stylo. This selective grazing of native grass in summer physiologically weakens the grasses favouring stylo dominance. Consequently, one management option is to remove or reduce grazing during summer to increase the competitive ability of the grasses.

In a study examining the management of pasture composition at "Strathmuir", Marlborough (D.M. Orr *et al.*, unpublished data), the proportion of stylo fell from 55% in autumn 1997 to 35% in autumn 1999. This occurred when cattle had been excluded over the summer (November–March inclusive) between 1996–97 and 1998–99 summers (Figure 4).

Fire. Fire provides scope for manipulating the stylo:grass balance. While individual stylo plants are resistant to fire since they can re-shoot from below-ground buds (Gardener 1980), a single hot fire was successful in reducing the proportions of Seca at a site in central Queensland (C.H. Middleton, unpublished data).

Survival of Seca plants following fire varies widely with estimates of individual plant survival between 10% in central Queensland (D. M. Orr, unpublished data) and 33% at Lansdown, north Queensland (Gardener 1980). In the former study, interpretation of individual legume and grass plant distribution in permanent quadrats suggested that Seca plants killed by the fire were in close proximity to individual perennial grass tussocks whereas those that survived were distant from perennial grass tussocks. Fire seemed to be more effective in killing Seca where perennial grasses were available to 'carry' the fire. This suggests that fire may be more beneficial in managing Seca populations when there is still a relatively high proportion of grass in the pasture.

In addition, fire increases the potential for seedling regeneration in the summer following the fire. For example, Miller and Webb (1989) reported seedling regeneration of both Seca and Verano was more than sufficient to replace those adult plants that were killed as a result of burning in the previous dry season. Thus, the size of the soil seedbank may be useful in determining how soon a fire can be used to manage pasture composition.

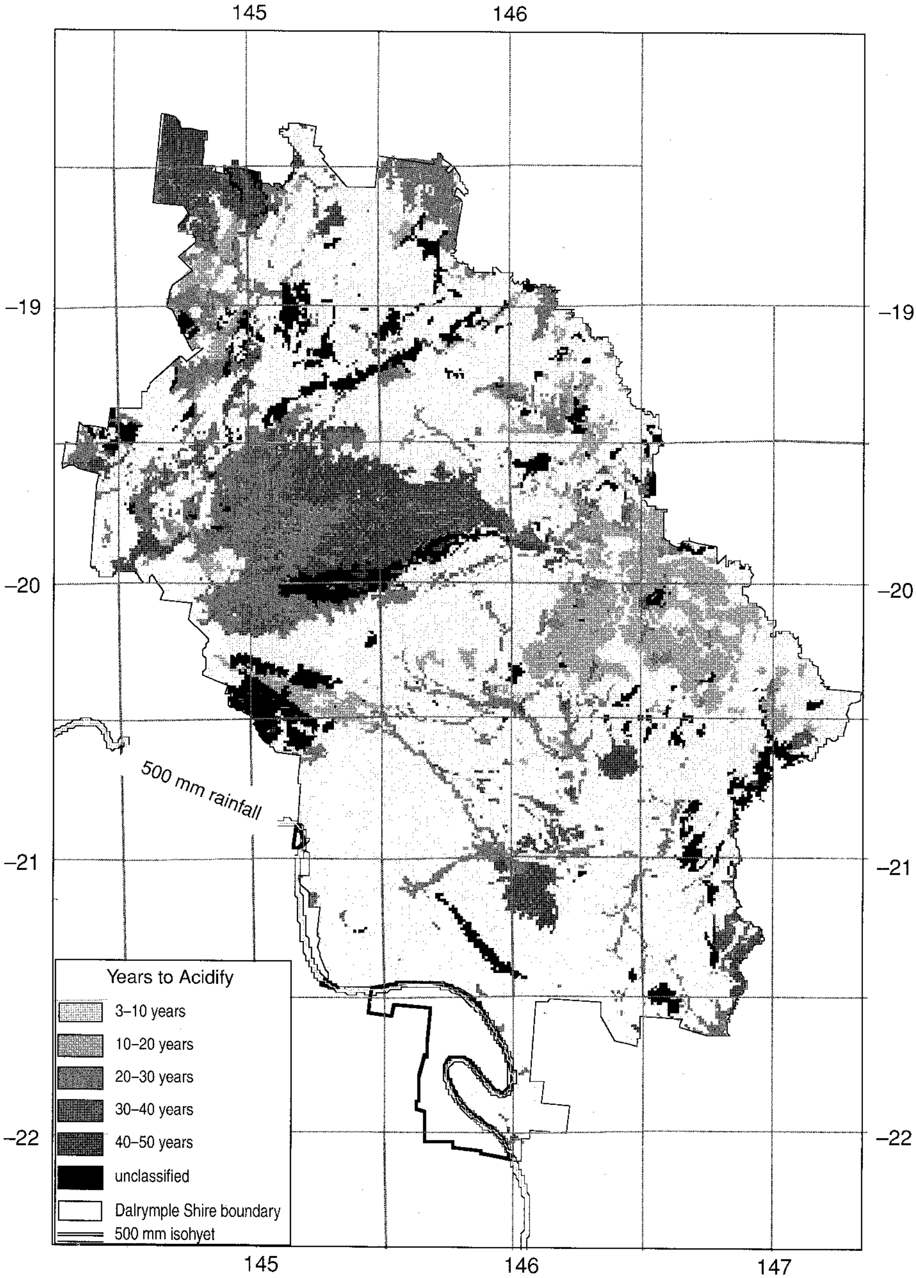

Figure 3. Acidification risk map for Dalrymple Shire based on the time required for the soil pH to decline to 5.0.

Sowing a grazing-tolerant grass when establishing stylos. Since stylos are generally more grazing-tolerant than native grasses, a vigorous, productive, perennial sown grass grown in association with stylo will benefit the system. It will take up the 'fixed' nitrogen that contributes to the acidification process and provide ground cover, especially if stoloniferous, to limit soil loss. Furthermore, a resilient grass will make it easier to manage stylo dominance and maintain or increase animal production.

Promotion of best management practice

In recognition of the potential future problems associated with stylo dominance, a series of 7 Stylo Management Guideline Leaflets (DPI Notes, Agdex 131/21) were prepared in collaboration with industry in 1998. The features highlighted were:

- Stylo dominance — a need for management.
- Stylo dominance — areas at risk.
- Grazing management to prevent stylo dominance.
- Using fire to manage stylo dominance.
- A rôle for sown grasses.
- Managing seed and hay crops.
- The role for fertiliser.

These have been widely distributed since 1998 through various media outlets (press, radio, TV, video, industry newsletters and electronic media) and via group interactive methods (Landcare, Future Profit, field days, meetings, workshops and conferences). In addition, an easy-to-read colour brochure was prepared and mailed to all graziers in areas north of 26° and east of the 500 mm annual rainfall isohyet.

More than 7000 beef producers have been made aware of the need for responsible pasture management. The success of the program will be measured in 2000–2001 to determine its effectiveness in delivering the message and the adoption of good management.

Conclusions

The establishment of legume-based pasture systems in the tropics has had, and will continue to have, a profound effect on the profitability of

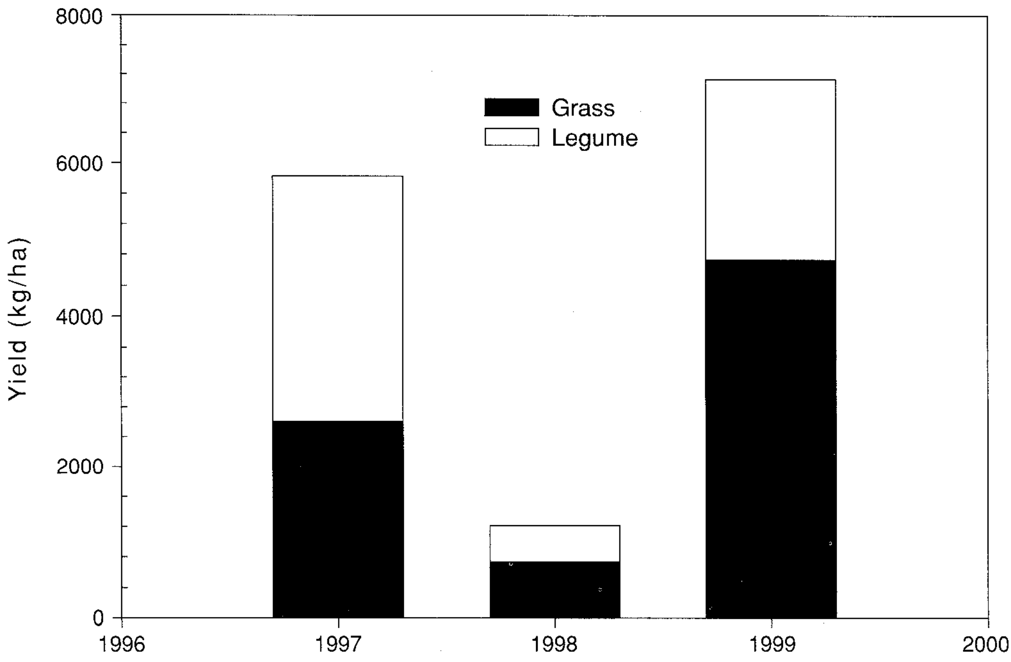

Figure 4. Changes in total yield and the proportions of grasses and legume (Seca and Verano stylo) between autumn 1997 and 1999 following removal of grazing over summer (D.M. Orr *et al.*, unpublished data).

livestock industries. While accelerated resource degradation associated with stylo-based pasture systems is a potential threat to long-term sustainability, the adoption of prudent management strategies would significantly minimise this risk. In addition, a field-based tool kit to assess soil predisposition to accelerated acidification has been developed and is currently being tested. Management strategies that promote the maintenance of balanced grass-legume composition will slow down the rate of acidification and soil loss by capturing greater amounts of nitrogen and protecting soil.

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