Sustaining productive pastures in the tropics 4. Augmenting native pasture with legumes

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Abstract

Native pastures in the Australian tropics and subtropics are augmented with legumes to increase cattle diet quality and quantity. Approximately 50,000 ha are oversown each year and are potentially productive and sustainable. Key features of legume adaptation and animal productivity are discussed, along with a plea for greater emphasis in legume evaluation on the mineral concentrations of plants at contrasting levels of soil fertility. The potential of augmented pastures to add nitrogen to pastoral systems is contrasted with other, extractive practices designed to improve livestock diet, but their limitations as sustainable resources are also outlined. Simplicity of management is suggested as a key requirement in the success of augmented pastures and it is argued that wide adaptation to climate, soil and management are vital ingredients in that simplicity.

Resumen

Con el fin de incrementar la calidad y cantidad de la dieta del ganado bovino, las pasturas nativas de Australia son combinadas con leguminosas. Cada año se sobre-siembran aproximadamente 50,000 ha las cuales son potencialmente productivas y sostenibles. Se discute, juntamente con algunos rasgos claves para la adaptación de leguminosas y la productividad animal, la petición de un mayor énfasis en la evaluación de la concentración mineral de las leguminosas en suelos con niveles contrastantes de fertilidad. Se contrasta el potencial de la adición de nitrógeno a las pasturas combinadas en los sistemas de pastoreo con otras prácticas extractivas diseñadas para mejorar la dieta del ganado, se hace hincapié en sus limitaciones como recursos sostenible. Se sugiere como un requisito clave para el éxito de las pasturas combinadas la simplicidad del manejo, y se argumenta que una amplia adaptación al clima, al suelo, y al manejo son ingredientes vitales en dicha simplicidad.

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Introduction

Livestock grazing native pastures in the tropics and sub-tropics can select a nutritious diet in summer and autumn but often struggle for a maintenance diet in winter and spring. Early plant maturity, drought and frost combine to produce fibrous forage with low concentrations of protein and energy, and low soil fertility often results in low concentrations of minerals. Oversowing, the concept of adding legumes to the grass-dominant native pasture forage base, has the twin objectives of presenting some forage with higher nutritive value to grazing livestock and of increasing nitrogen turnover in ecosystems chronically short of nitrogen. The concept is founded on legumes being largely independent of soil mineral nitrogen supply by virtue of the legume-rhizobium symbiosis. The concept is successfully implemented commercially, with perhaps 50,000 ha of native pasture being augmented annually. The basis of this success is wide adaptation of a few legume genotypes and the resulting improved productivity from grazing livestock. This paper discusses factors in adaptation of tropical legumes, constraints and opportunities in increasing animal production from oversown pastures and aspects of sustainability in grazing these pastures.

Adaptation of legumes

Adaptation of legumes to an augmenting situation implies easy establishment, persistence, spread and regeneration despite low soil fertility, regular drought, variable grazing pressure, frost and fire.

Persistence

Persistence is vital. Though often described as low input systems, costs of establishment of augmented pasture are considerable and ought not to recur within 10-20 years. Initial and recurring costs for other practices to increase animal productivity in the tropics are shown in Table 1. Despite annual costs similar to those of dry season supplements, initial cost of oversowing per head of cattle is two orders of magnitude greater.

Legumes persist in pasture through perenniality, vegetative reproduction and seedling recruitment. Perenniality has limited value since even apparently strong perennials have a shorter lifespan than we would wish for a pasture. For example, Gardener (1984) found Seca stylo *(Stylosanthes scabra* cv. Seca) plants as old as 8 years but 50% of Seca stylo plants in an eight year old pasture were less than 3 years old. Nevertheless, in marginal rainfall environments, perennials are better able to cope with growing season droughts. Vegetative reproduction is unlikely to be significant in the semi-arid and sub-humid environments where oversown legumes are mostly used.

Seedling recruitment remains the mechanism by which legumes must persist in the long term. This means that legumes must reliably set seed and that some seed must be hard. Fast germination is desirable in semi-arid environments (McKeon and Mott 1984). The mechanisms that lead to successful seedling recruitment are the same ones that favour initial establishment and later spread.

Establishment

Speed and success of establishment of oversown pasture is largely a function of weather, time of sowing, vigour of native pasture, and expectations. Without soil disturbance, 2 to 8 years may elapse before oversown legumes become fully productive. This delay can be reduced by fertilizer on low fertility soils, by minimal cultivation (in strips for example), and by pulling timber followed by hot fire. Vigorous grass pasture inhibits establishment of oversown legumes, so that oversowing is less successful on fertile soils than on the open pastures supported by infertile soils. In the former environments, grass competition needs to be minimized by late burning, heavy grazing, strip cultivation or herbicide application.

Spread

Natural spread is important in oversown pastures as a means of increasing the area in which legume occurs with no further cost. Spread from original sowing occurs mainly through cattle once seeding has occurred. Early spread is favoured by encouraging maximum seed set in autumn, and then grazing before seed falls, particularly in the second year. Up to 40% of tropical legume seeds ingested by cattle are excreted in a viable condi-

Table 1. Comparative costs of pastures and supplement for a 5 month period of grazing or supplementation

	Stocking rate	Initial cost	Initial cost	Cost for 5 months
	(head/ha)	($/ha)	($/head)	($/head)
Augmented pasture (Fire, legume seed, 0-10 kg/ha P)	0.4	60	150	3.75[1]
Conventional sown pasture (Cleared, cultivated, legume and grass seed, 10-20 kg/ha P)	1.0	400	400	10.00[1]
Dry season M8U (Molasses + 8% urea)	—	—	2	20.00
Dry season urea + CSM (28% cottonseed meal)	—	—	2	9.50

[1] Assuming indefinite life, no maintenance costs and annual cost of 6% of initial cost.

tion (Simao Neto *et al.* 1987). On infertile soils, we have observed that the margins of dung pats seem to be a favourable microenvironment for seedling establishment.

Importance of soil fertility

These agronomic attributes of successful legumes must be capable of expression under a variety of stresses. Sub-optimal soil fertility is likely to be common, since beef producers only use fertilizer in exceptional circumstances. Plant introduction and evaluation programs have found legumes that are reasonably tolerant of at least low soil phosphorus. For example, Verano (*Stylosanthes hamata* cv. Verano) and Seca stylo grown on soils with low phosphorus sorption capacity produce near maximum yields at extractable soil phosphorus levels of 12 ppm and 8 ppm, respectively, and produce 50% of maximum yield at half these levels (Probert and Williams 1985; Gilbert and Shaw 1987). Seca can persist at even lower levels (Coates *et al.* 1990).

However, although probably originating from low phosphorus soils, these legumes were often evaluated under near-optimal soil phosphorus levels. This could have resulted in selection of accessions with higher phosphorus requirements than rejected accessions. There is no doubt that differences in phosphorus requirement exist among tropical legumes, even within a genus (Jones 1974; McIvor 1984; Probert and Williams 1986). Evaluation needs to take account of such potential variation by growing legumes under at least two contrasting nutrient supply situations, one of them a low fertility situation likely to be encountered in practice.

Fire effects

Fire is inevitable in oversown pasture. If severe enough, all existing plants will be killed (Gardener 1980) and the legume will need to regenerate from seed. This requires a reserve of seed in the soil, implying that, for successful regeneration, regular, if not annual, seed set needs to occur. As many perennial legumes set little seed in their first year, fire in the first dry season can be catastrophic.

Grazing effects

For the tropical legumes adapted to oversowing, Seca, Verano, fine-stem stylo (*Stylosanthes guianensis*), and Wynn cassia (*Cassia rotundifolia* cv. Wynn), the effect of increasing grazing pressure is almost always to favour the legume at the expense of the grass in the pasture (Bowen and Rickert 1979; Winter *et al.* 1989; Cook 1988). This is due to the preference of cattle for grass over legume in the growing season (Gardener 1984), favouring the legume in terms of survival of adult plants, setting of seed and successful establishment of seedlings. This behaviour contrasts with that of other tropical legumes like siratro (*Macroptilium atropurpureum* cv. Siratro) where heavy grazing results in short-lived plants and low seed yields (Jones and Bunch 1987).

Animal productivity from augmented pastures

Animal response to augmentation is dependent on legume yield and quality. The relative importance of yield and quality changes from south to north (Table 2). In the south, native pastures on relatively fertile soils support high levels of animal performance at relatively high stocking rates. Towards the north, on less fertile soils, animal performance is lower, despite much lower stocking rates and high pasture availability. Augmentation aims, therefore, to increase diet quality in the north and both yield and quality in the south.

Pasture quality

Relationships between pasture quality and animal performance on oversown pastures are uncertain.

Table 2. Pasture availability and animal performance on native pasture communities in northern Australia

	Latitude	Stocking rate	Pasture DM	Liveweight gain
	(°S)	(ha/head)	(t/head)	(kg/head/yr)
Queensland blue grass	21-26	4	12	150
Brigalow pastures	20-26	4	10	160
Southern spear pastures	21-26	6	18	120
Northern spear grass	16-21	10	25	100
Monsoon tall grass	11-16	20	40	80
Fire grass	12-16	40	60	70

However, contrasted with the maximum annual liveweight gain of about 170 kg on stylo pastures without winter rain, gains of up to 220 kg have been recorded on leucaena. We interpret this as a response to higher quality, in terms of digestibility, protein and green leaf availability. Seca stylo goes some way toward the leucaena model of a deep-rooted perennial carrying green leaf into the dry season. Dry season cattle performance on Seca stylo has generally been superior to that on the annual Verano in north-eastern Queensland, although annual liveweight gain has been similar.

On infertile soils, mineral content has proved to be more important than digestibility or protein content. Large responses to supplementation of cattle on oversown pastures with sulphur and sodium (Hunter *et al.* 1979), phosphorus and sodium (Winter 1988) and phosphorus (Winter *et al.* 1990) have been recorded. The implications of sub-optimal phosphorus supply are likely to be widespread and strategies to counter it have been developed. These are summarised in Miller *et al.* (1990) and involve considerations of soil phosphorus, fertilizer history, cattle history and reproductive status in giving options for fertilizer and supplement use. In brief, supplements can replace fertilizer in promoting high levels of animal performance. The potential for selecting legumes with higher mineral concentrations needs to be explored in evaluation programs. As Jones (1974) pointed out, high phosphorus uptake is desirable, but the expression of this as high dry matter yield may not be in the best interests of animal production in low input systems if the result is low concentration of phosphorus in forage. A possible penalty of lower yield is a less competitive legume, although the importance of growth rate compared to seed set and seedling recruitment is unclear.

Pasture quantity

The notion of augmenting yield of native pasture with tropical legumes in the sub-tropics is a less promising one than of augmenting quality in the northern tropics. Less reliable summer rainfall and lower autumn temperatures in the sub-tropics will limit growth of tropical legumes. Hence temperate legumes such as medics and serradella have potential in the sub-tropics.

The question of quantity of legume required for animal production is unresolved. Gillard *et al.* (1980) proposed that cattle could obtain 'sufficient' legume in their wet season diet when legume yield exceeded 600 kg/ha but Norman and Stewart (1967) and Miller (unpublished data) have found that animal performance varied directly with legume availability.

The role of grass

The role of grass in productivity of augmented systems is not very clear except at extremes. Animal performance is clearly depressed in the absence of adequate grass, particularly where phosphorus is limiting (Winter *et al.* 1989). At least in situations of reasonable soil fertility, any grass seems to be adequate, with high productivity reported from stylo with red natal grass (*Rhynchelytrum repens*) (Bowen and Rickert 1979), annual *Digitaria* spp. and *Brachiaria* spp. and spear grass (*Heteropogon contortus*) (Winks *et al.* 1974).

Sustainability of augmented pastures

Tropical agriculture in Australia has been based on a mining philosophy. Soil fertility resources have been exploited in an extractive way. Beef production has been no exception although the mining has been slow. Grass pastures established after brigalow and scrub clearing, forage cropping, supplementary feeding and tree killing are all designed to extract more from existing resources.

Augmentation of native pasture with legumes is one of the few practices that, philosophically at least, aims to add to the resources — by transferring atmospheric nitrogen to the soil-pasture-animal system. Unintended effects on other resources disqualify the practice from having a perfect environmental score but the distinction remains. The contribution of oversown legumes to soil nitrogen is problematical. Estimates of soil nitrogen accretion by *Stylosanthes* spp. in the dry tropics by Vallis and Gardener (1984) average 17 kg/ha/yr, an amount of the same order as annually turns over in tropical native pastures (Mott *et al.* 1985) and that could substantially increase pasture system productivity. However, some of these estimates were from more intensively developed pastures and could easily overstate the potential.

Stocking rates

With well adapted legumes, augmented pastures give good production at stocking rates of about 0.4 steers/ha with live trees (Winks *et al.* 1974) and up to 0.8 steers/ha with trees killed (Shaw and 't Mannetje 1970). These stocking rates are similar to those that confer stability. Table 3 lists stocking rates promoting stability and instability of native perennial grasses. Only data from oversowings involving no cultivation are given. With live trees, pastures were stable at stocking rates up to about 0.5 steers/ha. Where trees had been killed, stocking rates up to about 0.7 steers/ha were tolerated, except in the Northern Territory. This picture is complicated by variations in soil fertility or fertilizer history.

In practice, it will be difficult to convince producers to stock conservatively, since animal production in the short term is quite insensitive to large fluctuations in pasture composition (Winks *et al.* 1974; Shaw and 't Mannetje 1970). Drought and other management imperatives make some overgrazing of these pastures inevitable and there are plenty of examples of unstable pastures, oversown and not.

The main consequence of reduction of perennial native grass is a reduction in basal area and foliage cover, particularly at the end of the dry season, facilitating weed invasion and soil erosion. What is required for these situations are management guidelines either to rehabilitate perennial grasses or to introduce grazing tolerant grasses where the native perennials are beyond rehabilitation. Limited information suggests lower stocking rates, particularly during the wet season, will facilitate recovery of perennial grasses (Shaw and 't Mannetje 1970; Gardener 1984). Strategic spelling may be sufficient to maintain native grasses. Unfortunately, such guidelines run counter to those favouring high legume content (e.g. Gardener 1984). There are indications that at least some species of exotic grass can be established without cultivation (J.G. McIvor, personal communication), and that the process can be hastened by intermittent heavy grazing (R.J. Jones, personal communication).

Fire

An unintended consequence of legume augmentation is a possible increase in woody regrowth resulting from an absence of regular fire. Legume augmentation on infertile soils shares this distinction with continuous heavy use of urea supplementation (Landsberg 1989) but the more competitive sward and heavier grazing of the oversown pasture may compensate. The most economical solution may well be to sacrifice some production from oversown pastures in the interests of occasional fire. Indeed, there are those who think this may be necessary to control the legume itself (W.H. Burrows, personal communication). There is no doubt some legumes can recover from occasional fire either as adult plants after a cool fire (Gardener 1980) or from seed after a hot fire (Miller and Webb 1989).

Diseases and pests

Apart from poor adaptation, sustainability of the legume fraction of augmented pastures is most threatened by diseases (e.g. anthracnose) and pests, particularly where the technology is reliant on a few widely adapted genotypes (e.g. Seca stylo). To maximize genetic diversity, mixtures of genotypes of shrubby stylo (*Stylosanthes scabra*) are being tested and released, and most commercial plantings are of more than one species. Pursuit of registration of new cultivars under Plant Variety Rights legislation by research organisations could inhibit the development of variable cultivars, to the detriment of adaptability.

Table 3. Stocking rates (steer/ha) and the stability of native grasses in augmented pastures

Pasture	Perennial grasses stable	Perennial grasses unstable
Trees live		
Gillard (1979) Spear + *S. humilis*	0.4	—
Miller *et al.* (1982) Kangaroo + *S. guianensis*	0.1	0.8
Winter (1988) Mixed + *S. hamata*	0.5	0.7
Winter *et al.* (1989) Mixed + *Stylosanthes* spp.	—	0.45
Miller *et al.* (unpubl.) Mixed + *S. scabra*	0.25	—
Trees killed		
Shaw and 't Mannetje (1970) Spear + *S. humilis*	0.75	1.2
Ritson *et al.* (1971) Spear + *S. humilis*	0.4 (cows)	0.8 (cows)
Gillard (1979) Spear + *S. humilis*	0.4	—
Winter *et al.* (1989) Mixed + *Stylosanthes* spp.	—	0.45

Management for sustained productivity

Augmented pasture systems have been developed with simple management in mind. Complex management systems will not be implemented and we suggest that superlative adaptation of legumes, as exemplified by Seca stylo, will overcome many management deficiencies. Research and development with augmented pastures should therefore concentrate on wide adaptation to both environment and management. This will only be possible by a good deal of on-farm research.

For sustained animal production, management ought to aim for reasonable proportions of both legume and perennial grass in the pasture, meeting at least minimum soil fertility requirements for legume establishment and persistence, and supplementing animals with any shortfall in minerals.

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