Tropical pasture establishment.
9. Establishing new pastures in difficult tropical environments — do we expect too much?

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Abstract

Sowing pastures in marginal environments is essentially shifting the pasture composition rapidly from one state to another. State and transition ecological theory says such large changes generally occur only when a combination of extreme events coincide. A combination of light soil disturbance, small amounts of new seed plus establishment rains (a common scenario for tropical pasture sowing) is hardly an extreme event for an existing perennial pasture. Hence, the transition needs reinforcement with astute grazing management to achieve this desired leap.

Pasture improvement schemes can be very costly. Therefore, the effort must be concentrated on a limited area to ensure the desired new pasture is achieved. Often large areas are attempted and desirable management can not be achieved, resulting in serious timber regrowth for decades and high cost/benefit ratios. If the pasture is well adapted, it will compete strongly against rivals via its soil seed supplies and control of nutrient balance. If adequate rains do not fall, the cost ecologically and economically to the pastoral enterprise must be absorbed and the exercise repeated later in the hope of a better establishment season.

Often the cost is over-emphasised to disguise a poorly conceived pasture improvement project. If a sown pasture is required, the economics are of equivalent importance to choice of species and post-emergence management.

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Introduction

Conventional wisdom implies that, when land is not suited to field crops, farmers either graze native pastures or sow improved pastures. If sown pastures prove difficult to grow, 'wonder' plants or novel pasture establishment methods are sought. However, such perceived needs are often due to unrealistic expectations of the land, either environmentally or economically. Tropical pasture production is driven primarily by soil moisture and nitrogen as models such as GRASP (McKeon *et al.* 1990) clearly show.

The need to establish a new pasture is basically due to one or more of 3 factors:

(a) desirable natural/native species have been lost;
(b) superior grazing plants have been found for the existing land; or
(c) extra inputs, e.g. water, fertiliser and clearing will be economic if more productive plants are established.

The exercise becomes 'marginal' if the only plants available commercially are poorly adapted, the economics of establishing the new pasture are unrealistic or the proposed enterprise is unsuited to that area. Achieving economically acceptable costs of pasture establishment is more difficult in 'marginal' tropical areas than in temperate regions with a similar degree of climatic uncertainty and low soil fertility. Foremost amongst these difficulties are low base saturation soils, high exchangeable aluminium levels in the soils and extremely rapid onset of severe moisture stress in a poor growing season.

We discuss the practical implications of sowing well adapted plants so that climatic uncertainty and the existing vegetation do not overwhelm the new seedlings.

Definition of pasture establishment

We consider that, where pasture sowing is marginally economic, persistence is essential. Thus successful establishment in such environments is defined as 'achieving a population of sown species which persists and regenerates sufficiently to withstand moderate grazing and normal climatic stresses.' In the absence of these criteria, the sown pasture equates with a forage crop which must either be re-sown or abandoned to weeds afterwards.

Defining marginal environments

Climatic factors

Moisture or the lack of it is the main climatic factor influencing plant growth in the tropics. Temperature, light, slope and aspect, which are frequently mentioned in the northern hemisphere, are irrelevant, as Growth Indices of Fitzpatrick and Nix (1970) show. Timing and quantity of rainfall are critical. For example, buffel grass seedlings grown in regularly watered pots of acidic red soil respond dramatically to small amounts of phosphate fertiliser (Christie 1975; Silcock and Smith 1982). However, under natural semi-arid rainfall at Charleville, only once in 2 years did phosphate-coating of buffel grass seed produce a benefit in 27 surface field sowings on such soils (R.G. Silcock and F.T. Smith, unpublished data). We consider the phosphate was immobilised in the uppermost surface soil layer which was very dry most of the time and unexploited by seedling roots.

Daily rainfall data were examined from 3 Australian environments where tropical pasture establishment conditions are regularly 'marginal' — Longreach (Mean Annual Rainfall 429 mm from an average 30 rain days per year); Camooweal (390 mm from 34 days); and Charleville (495 mm from 38 days). Buffel grass (*Cenchrus ciliaris*) grows well and spreads naturally in all 3 towns. All receive their rain mostly as isolated single or 2-day events usually of less than 25 mm (Bureau of Meteorology data). We consider summer (October–April) rainfall events for these centres have the effectiveness shown in Table 1 and events totalling less than 35 mm will rarely produce significant summer germination.

'Significant' germination is defined as >1 seedling/dm^2 while 'noticeable' germination would occur when >1 seedling/m^2 emerged after rain. Each summer, the 3 centres average 2–3 rainfall events which could promote significant germination (Table 2). Germinating rain is not the problem — establishment rain is; and that is much harder to deduce from climatic data because species differ in their follow-up rainfall needs (Wilson and Briske 1979) and because antecedent soil moisture must be accounted for.

Goodman (1988), cited by Mao (1992), outlined the rainfall needed at Walgett, NSW (30 °S) for germination and establishment of curly mitchell grass (*Astrebla lappacea*) and naturalised medics (*Medicago* spp.). They suggest that successful establishment requires follow-up rainfall events of 25–37 mm within 10–23 days after a germinating rain of 25–50 mm, depending on time of year. We consider these figures are only a guide and that some measure of net evaporative demand would be more appropriate in a modern decision support package — one that took temperature, vapour pressure deficit, wind speed and cloud cover into account.

For good summer germination, humid cloudy conditions are needed for several days after the

Table 1. Effectiveness of Australian summer rainfall events for pasture growth in subhumid to arid tropical zones.

Size of event	Value for seedling establishment	Value for continued pasture growth	Value for restarting growth of perennials
(mm)			
0–2.5	nil	nil	nil
2.5–10	nil	good	nil
10–25	very poor	good	fair
25–75	fair	excellent	good
75–200	good	excellent	excellent
>200[1]	damaging (disease?)	marginal (erosion?)	detrimental (insects?)

[1] Often causes erosion, flooding or pest and disease outbreaks.

Table 2. Number of probable germinating rainfall events[1] during summer at 3 semi-arid places over >90 years, as judged from long-term rainfall data. Size and duration of major event classes are shown, plus total observed events for each site.

	Consecutive days of effective summer rainfall (Oct.-Apr.)					
Total rain received	1	2	3	4	>4	
35-50 mm	43	37	15	0	1	
50-75 mm	19	24	8	4	3	Camooweal
75-100 mm	3	10	10	7	4	238 events
100-150 mm	1	6	10	6	9	(93 years)
>150 mm	0	0	3	5	10	
35-50 mm	32	37	8	0	0	
50-75 mm	15	27	23	3	0	Longreach
75-100 mm	6	5	7	6	5	226 events
100-150 mm	0	9	12	7	1	(97 years)
>150 mm	0	2	7	2	12	
35-50 mm	38	45	14	1	1	
50-75 mm	17	45	22	10	2	Charleville
75-100 mm	2	16	8	7	3	273 events
100-150 mm	1	9	13	5	3	(98 years)
>150 mm	1	1	3	6	0	

[1] A germination event was defined as follows:
(i) ≥35 mm rain received during the rainfall event;
and (ii) ≥15 mm on the first day or ≥10 mm on day 1 plus ≥20 mm on day 2;
and (iii) until 35 mm is received, falls on consecutive days must also total ≥10 mm;
and (iv) >2.5 mm on each subsequent day.
Where events closely follow, second and subsequent events were counted only if:
(a) ≥10 days separated day 1 of 1 or 2 day events from a subsequent event (except if >100 mm in second event, when 5 days gap was allowed);
(b) ≥15 days separated day 1 of a 3 day event from a subsequent event;
(c) ≥20 days separated day 1 of a 4 day event from a subsequent event;
(d) ≥30 days separated day 1 of a ≥5 day event from a subsequent event.
This is because we consider ungerminated viable seed needs to dry back to air dryness for a significant time after imbibing/wetting before it is primed for subsequent germination, hydropedetic seed excepted. The longer a viable seed is imbibed yet fails to germinate, the longer it needs to be held in a dried state again before being primed for subsequent germination.

rain begins, to keep the surface soil moist. Unfortunately in the semi-arid tropics, the clouds tend to precede the rain and clear away quickly afterwards (Silcock 1986). Subsoil moisture at the end of the dry season is also negligible, but is important for seedling survival (Bellotti *et al.* 1991; Blacket and Thompson 1992). In these circumstances, buried seedlings struggle to emerge through dry, often hard-setting loams (Arndt 1965) while those at the surface are exposed to seed-gathering ants, desiccation and problems of taking root (Dowling *et al.* 1971) in the hot sun. Semi-arid temperate regions generally have the opposite type of regime at the start of the growing season, either prolonged cloudy weather (Mediterranean areas) or full soil moisture profiles awaiting a rise in temperature to promote germination (Continental areas). In arid climates, only very rare seasons provide enough rain to allow successful seedling regeneration (Westoby 1980). Even then, the existence of viable seed for some species may depend on seed set by parent plants earlier in the same season, e.g. oldman saltbush (*Atriplex nummularia*).

The use of moisture-attracting coatings around seeds has not been successful in Australia (Campbell 1985; Blumenthal and Hilder 1989) or overseas (Hull *et al.* 1963; Scott 1975) under most field conditions. In tropical areas, seedlings germinating with such moisture-enhancing coatings could still die rapidly after storms because there is no subsoil moisture to tap into. Moisture-attracting coatings are theoretically useful on surface-sown seed in very windy environments but again, sustained high wind speeds after rain are not common in tropical regions.

Landscape factors

Several landscape factors influence pasture establishment in the tropics. Soil physical factors favouring establishment include a soft, crumbly and uneven soil surface. Sandy soils generally make good seedbeds while heavy clay soils often cause reseeding problems (Leslie 1965). Thus degraded duplex soils which have lost their loamy A horizon have compounded physical problems which make pasture regeneration difficult.

Soil nutrient levels may significantly affect establishment in high rainfall zones where protracted leaching has occurred. Legumes are often more sensitive to nutritional imbalances and deficiencies than grasses (Andrew and Fergus 1976). In some instances they also have specific rhizobial requirements that are controlled by either soil pH or pH-related factors such as available calcium (Coventry and Evans 1989).

Phosphate deficiency is very common in seedlings because it is a relatively immobile element, especially at extremes of pH. This can be expensive to correct over large areas but techniques such as band placement of fertiliser and seed pelleting may offer economical solutions. Some species are more demanding of phosphate as seedlings than others. *Cenchrus ciliaris* is very demanding while *Eragrostis curvula* is not (Silcock 1980).

Nitrogen deficiency in very young grass seedlings in rangeland is uncommon, but it can severely limit growth rate once plants are well tillered. It is relatively expensive to correct and rarely recommended. Other nutrient deficiencies occur on particular soil types. Potassium deficiency can be critical for small-seeded species on leached sands, e.g. in Cape York and on pumice soils. Sulphur deficiency has restricted establishment of stylos on some euchrozems in northern Australia (Gilbert and Shaw 1979). Imbalances and toxicities occur commonly, e.g. aluminium toxicity on very acid soils. While some species grow poorly on particular soil types, e.g. saltbushes usually require neutral to alkaline soils, some species are very adaptable (*Cenchrus ciliaris* and *Themeda triandra*) and have very wide edaphic tolerance.

Unmanageable grazing pressure

The role of grasshoppers in damaging newly sown tropical pastures is probably under-rated (Bellotti *et al.* 1991). They are most active in summer which is the tropical pasture sowing season and some species can be quite selective feeders. For example, *Oedaleus australis* eats grasses only, the wingless *Monistria* eats no grass and only certain dicotyledons, and the Australian plague locust eats all kinds but prefers slightly wilted forage. In south-west Queensland, rhodes grass (*Chloris gayana*) seedlings seem particularly attractive to several grasshopper species, to the extent that small plots fail to establish after emergence while *Urochloa mosambicensis* and buffel grass do. Time and intensified property management will probably show up numerous other pests and diseases of marginal pastures which have to date escaped notice; e.g. *Pheidole* ants are recorded as eating the emerging coleoptile of buffel grass seedlings in mulga country at Charleville (R.G. Silcock, unpublished data). Stylos have not persisted in unprotected sowings in southern inland Queensland despite establishing satisfactorily, although they have persisted for 2 decades in a netted nursery at Charleville (F.T. Smith, personal communication). Rabbits actively seek and destroy stylo plants in dry times and their role in the failure of commercial sowings warrants investigation. If a critical mass of stylo became established, the effect of rabbits could possibly be nullified. Kangaroos have a strong preference for patches of green *Urochloa mosambicensis* and avoid green buffel grass, when green feed is plentiful. In this way, they make establishment of *Urochloa* even more difficult in marginal environments.

Biological requisites for marginal environments

Plant type

In general, the most suitable pasture plants in tropical Australia, are perennials unless moisture comes in well defined pulses. Adapted annuals such as summer grass (*Digitaria sanguinalis*), button grass (*Dactyloctenium radulans*) and *Desmodium* spp. seed rapidly and produce very little leaf. Material breaks down in the dry season leaving little soil protection.

Norman (1961), Torssell (1976), Andrew and Mott (1983) and McKeon *et al.* (1985) studied the mechanisms regulating germination of *Stylosanthes* and some grasses in an attempt to explain why they invade and persist well. Their results indicate that large seed banks are crucial for withstanding false seasonal breaks after early summer storms. The grasses seem better adapted to this, possibly because of their smaller seed size and the possession of a seed envelope to restrict water uptake by the caryopsis for some hours after rain begins. In western Queensland, a range of 20 sown grasses survived false seasonal breaks from small (12 mm) storms to establish good stands while most tropical legumes (seed 100% scarified) sown at the same time, including *Stylosanthes scabra*, failed to establish any plants (R. Strickland, R. Greenfield and R.G. Silcock, unpublished data). Tropical legumes are normally sown as scarified seed but this practice may be inappropriate for marginal environments because all scarified seeds will absorb moisture rapidly after rain. Partially scarified seed may be a better option. An adapted native grass established better than exotic grasses such as buffel where rains following sowing were poor but good rains eventually fell (Silcock and Smith 1990; Bellotti *et al.* 1991). Watt (1978) identified a useful characteristic (hydropedesis) (Figure 1) in Queensland bluegrass (*Dichanthium sericeum*) seed which allows germination to be suspended just prior to radicle emergence after small falls of rain without loss of viability or embryo dehydration, provided follow-up rains occur within a few weeks. This phenomenon seems to assist the grass to establish reliably on heavy cracking clays which are notorious for tropical pasture establishment failures if a shallow sowing depth is essential (Leslie 1965).

Species adaptation

Few pasture cultivars currently available are well adapted to marginal Australian tropical environments. Documented failures in these environments include: Edye *et al.* (1964) on desert country in central Queensland; Hall *et al.* (1987) on north-west Queensland mitchell grass downs; Mallett (1955) in the Port Hedland area; Norman (1961) in the Katherine area; Winkworth (1958) in central Australia; and McKeague and Wincen (1988) in Cape York. Satisfactory results were obtained only with adapted species.

The *Stylosanthes* and *Cenchrus* genera have been outstanding but neither is regarded as having high seedling vigour. They are adapted because they can tolerate drought, and grow and persist under grazing on relatively infertile soils. Both genera display a high degree of woody or

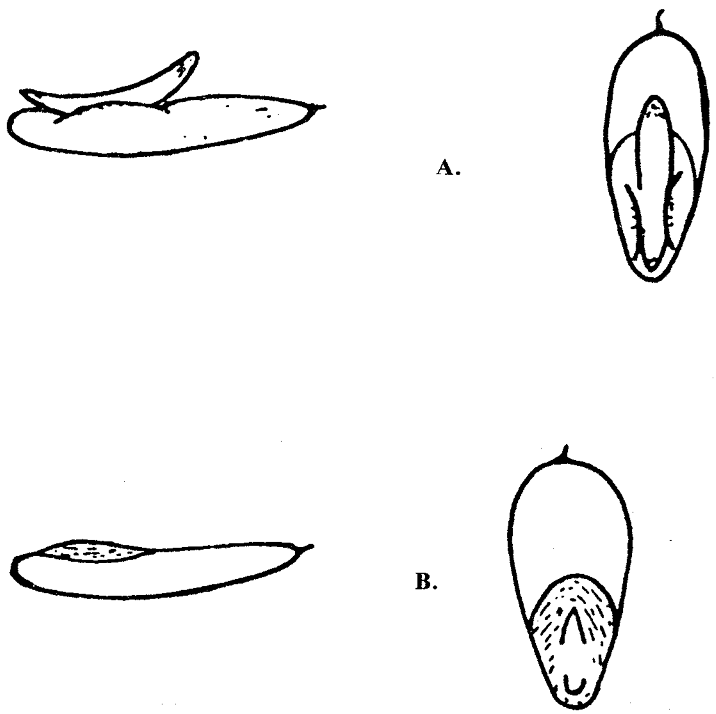

Figure 1. Germinating grass caryopses in a hydropedetic state (A) compared to dormant seeds imbibed for the same time (B). Note the swollen, elongated embryo sitting above the grain and the radicle not yet burst through the coleorhiza of the hydropedetic seeds.

fibrous tissue which is characteristic of perennial herbaceous plants found in these environments. They also seed freely and have significant levels of seed dormancy, although not nearly as much as native species like *Rhynchosia minima* and *Dactyloctenium radulans* (Silcock *et al.* 1990). Unfortunately, native species with strongly dormant seed tend to be more sporadic in their presence than pastoralists desire.

Rhizomatous and strongly stoloniferous species are not available commercially for marginal tropical parts of Australia. In natural pastures, they also seem to be confined to more fertile soils, e.g. *Glycine falcata*. This is unfortunate because, as grazing pressure is raised, such 'protective' habits are advantageous. Australian plants adapted to heavy grazing tend to have tussocks with a very deep crown, e.g. *Chrysopogon fallax* and *Ruellia australis*, but this does not help them to spread rapidly. Locating plants with strongly stoloniferous habit, e.g. *Digitaria milanjiana* and *Bothriochloa insculpta*, might circumvent the difficulties of establishing tropical pastures from seed in difficult environments.

Regenerative mechanisms

Species which regenerate and propagate readily from seed tend to be short-lived, e.g. *Rhynchelytrum repens* and *Urochloa panicoides*. Similarly, free seeding plants tend to have either low total dry matter yields or a low proportion of edible leaf, e.g. *Aristida* spp. and *Psoralea eriantha*. Low fertility soils may also restrict the amount of flowering and the earliness to first flowering of seedlings. Hence, the pasture idiotypes we need for marginal environments are not well suited for easy, cheap establishment. In addition, plants adapted to harsh conditions are often woody and slow growing — just the opposite of what pastoralism requires. Thus the likelihood of having a desirable perennial pasture plant to sow from seed in marginal or degraded areas is very low.

However, we should try to capitalise on adaptive seed mechanisms which enhance establishment and the long-term presence of existing populations, e.g. embryo dormancy, sturdy seed coats, hydropedesis and seed burial enhancement mechanisms. These seed characteristics are often deliberately nullified in the preparation of commercial seed and are rarely used to advantage. Seed dormancy of purple pigeon grass (*Setaria incrassata*) has been exploited by undersowing it with a wheat crop in early winter (Scattini and Johnson 1988), so it can germinate in spring after the wheat harvest. Sowing a mix of scarified and unscarified legume seed might overcome unreliable breaks of season, e.g. in stylos. In practice, lightly scarified tropical pasture legume seed often has a significant proportion of seed which will not imbibe water immediately. Conversely, many grasses completely lose embryonic dormancy with time; e.g. 12 months for buffel, so that almost no viable seed sown from a good quality commercial source remains after the first germinating rains. Where special dormancy-breaking or seed-conditioning treatments are used, e.g. sweating in *Panicum maximum*, an even physiological state might not exist so that false seasonal breaks after sowing might not produce a complete failure.

More subtle dormancy mechanisms, involving depth of sowing and time of germinating rains are rarely a practical issue with tropical pasture sowings. However, mean temperature, temperature fluctuations, light quality and soil nitrate levels are powerful ways of controlling germination (Williams 1983). The depth of the seed below the soil or litter surface and the amount of shading could be managed to exploit such mechanisms if they existed in a particularly valuable adapted species. With Bambatsi panic (*P. coloratum* var. *makarikariense*), graziers now take extra care with sowing depth and subsoil moisture conservation to maximise the likelihood of a successful establishment. Sowing failures with Bambatsi are now uncommon whereas failures were once common in southern Queensland.

Practical ways to enhance establishment in marginal environments

Infusion/Interseeding

Heady (1975) claimed that, if 10% of the species present in a rangeland pasture were desirable, good management was probably a more economic way to enhance animal productivity than resowing the pasture. This philosophy is sound for extensive situations in marginal environments, as such a transition requires the chance combination of episodic events after sowing. Oversowing *Stylosanthes* into existing pastures has been successful, especially where phosphate is applied to preferentially stimulate the stylo (Miller and Stockwell 1991). However grasses are not introduced easily to already grass-dominant pastures (Cook and Dolby 1981). Adapted exotic grasses can be introduced successfully on some better soils, e.g. buffel and Indian bluegrass (*Bothriochloa pertusa*), where the native pastures have been sufficiently debilitated by grazing. Other bluegrasses with low nitrogen demands, e.g. Angleton grass (*Dichanthium aristatum*) and Sheda grass (*D. annulatum*), have spread into existing pastures in higher rainfall zones (Bisset and Sillar 1984) but not in drier areas.

The extra difficulty in over-sowing grasses in drier areas probably hinges on the disguised role of mature stemmy grasses such as *Aristida* under regular heavy grazing. They build up and compete strongly for moisture and nutrients, acting more like inedible woody weeds than fodder. While they exist in significant numbers, there is no biological niche for alternative grasses to occupy. In the tropics we are unable to use the sod-seeding technology that is used to interseed annual species, e.g. oats or ryegrass for winter grazing in temperate regions. Winter temperatures in southern Australia restrict perennial pasture growth but there is still plenty of moisture for the annuals. In the tropics, deep rooted shrubs, e.g. leucaena and shrubby stylo, can fill that forage role but with a much lower production rate in winter because there is little moisture. Subtropical annuals can not fill this role because lack of moisture limits their establishment, just as it does in summer in Mediterranean climates.

Many perennial tropical legumes seem well adapted to establishing in competition with grasses (Cook and Dolby 1981) and this should be exploited where possible. However, the seed should be buried for best results (Lazenby and Schiller 1969) and the 'Crocodile Seeder' was designed for this purpose (Partridge 1992a). Unlike many awned Andropogonoid grasses, e.g. *Bothriochloa*, tropical legume seeds are generally not self-burying nor do they, once wetted, adhere tightly to the surface of bare, hard-setting soils as many non-leguminous dicotyledons, e.g. *Goodeniaceae* can. They require loose surfaces such as are found in deep litter under trees or local soil deposition sites. Alternatively, the seed could be sown encased in some soil-attracting structure, e.g. burr or pellet, which enhances soil-seed contact without promoting false germination or making the post-germination situation too xeric (Jones and Muirhead 1966).

Full cultivation usually ensures good establishment even in poor establishment years (McIvor and Gardener 1981) but that is too expensive for extensive pastoral areas in Australia. Having big areas of land fully cultivated in semi-arid areas is also potentially very damaging to the soil if extremes of climate, e.g. floods and droughts, occur. On balance, we consider most people should sow predominantly primed seed into a properly prepared seedbed on a smaller area. If the species is well adapted, total failures due to poor establishment rains are relatively few, provided competition from existing vegetation or vigorous annual weeds is minimal. Hence sowing new cultivars into existing pastures in tilled or herbicide-controlled strips is often suggested as a cost-effective compromise, e.g. via the band-seeder. In marginal environments, like the Maranoa region of Queensland, results to date have not been encouraging (Partridge 1992b). This may be a function of lack of adequate control of adjacent perennial vegetation or inadequate control of stock or kangaroos. Big tussocky grasses have root systems that spread a long distance laterally (30 cm at 20 cm depth) and so compete very strongly with seedlings where only a narrow band of herbicide is applied.

Artificially concentrating runoff in pits, furrows or shallow ponds is a useful way of increasing the effectiveness of marginal establishment rains (Noble *et al.* 1984). Correct placement of seed along the pits, so that emerging seedlings are not flooded (Malcolm and Allen 1981), can be a problem but it is a potentially valuable technique. Only small areas can be treated at a time because of the cost. As with band-seeding, sensible post-establishment management is vital so that the new plants set seed and begin to spread naturally. Pitting is effective for sowing most grasses, legumes and shrubs but the machinery is difficult to use on rough, timbered or rocky country.

If offset disks are used to generate broad tilled strips, the chances for sown grasses to establish are much better. This method has been used successfully for buffel grass under open eucalypt woodland in sandy red earths west of St George (J. Beardmore, personal communication) and for native grasses around Charleville on similar soils (Johnston and Evenson 1992). However, if strips become too narrow, e.g. rotary hoe width <1 m, stock can use them as grazing paths and severely overgraze the new plants to the exclusion of adjacent old wiregrasses. A staggered layout using a niche seeder could reduce the problem. On very open scalded country, strip overgrazing is not usually as great a problem because the grazier can clearly see when the new pasture is being overgrazed. Burning the whole area before sowing would also help to minimise strip grazing in the first year and also reduce selective insect defoliation of small seedlings. However ants might collect sown seed more actively after a burn.

Feeding legume seed to animals for dispersal in the dung is quite feasible for some species, e.g. *Stylosanthes*, (Dillon and Smith 1988) but the value of the dung pat for subsequent germination is not proven. Whether burial by dung beetles enhances or detracts from establishment of incorporated seed is not known and such ideas do not appear relevant to sheep enterprises. This method appears unsuitable for some grasses, e.g. buffel grass, as all embryos are killed in the digestive tract. Small seeded panicoid grasses may possibly be spread this way but, so far, no commercially valuable grasses of this type are recommended for marginal environments.

Grazing management

Grazing management is very important to successful pasture establishment in difficult environments. It can preferentially favour the desirable species in a mixture, provided these species are capable of natural spread on that soil. Unfortunately, many species used commercially are only marginally suited to many soils and they will not thicken up after the initial establishment phase on well disturbed ground, e.g. Bambatsi and green panic. Foregoing grazing of a small area of new pasture imposes little cost on a well executed establishment program. Most perennial pasture plants are relatively invigorated by moderate defoliation late in their establishment year and by periodic heavy defoliation every 2–3 years thereafter. In practice, dry seasons ensure this happens intermittently but it should be deliberate grazing policy to do this to keep sown pastures healthy. If grazing animals are unavailable to do the heavy defoliation, fire can be used. It is hard to envisage a pasture cultivar suited to marginal tropical environments which is not fire tolerant.

Another role for grazing cattle is to trample weakly stoloniferous grasses, such as creeping bluegrass (*B. insculpta)*, into moist soil so that they root better at the nodes. In the Roma district, trampling has greatly enhanced the eventual spread of *B. insculpta* from original plots by ensuring better winter survival of new crowns. This could apply equally well to stoloniferous *Digitaria* spp. which may be compatible with shrubby stylo in northern Australia.

Native species

Where conventional pastures are difficult to establish, alternatives include the development of unusual plants, special sowing techniques and husbanding of unusual animals that can utilise the existing forage effectively. Unusual animals rarely receive serious consideration, e.g. antelope and giraffes certainly would not be widely applicable because fencing costs would be extremely high. Sowing techniques have already been discussed. Special plants from overseas have received considerable attention without great success in difficult environments but native plants have received only cursory attention. Current evidence suggests that selection within our native pasture species could produce easily established species with similar grazing potential to the failed exotics (Johnston *et al.* 1990; Silcock 1991; Bellotti *et al.* 1991).

Within 5 years we should have a short list of native grazing plants for detailed agronomic evaluation for marginal subtropical areas. Evaluation for tropical areas is far less advanced but needs to be done. At present the candidates include: *Astrebla lappacea, A. pectinata, Dichanthium sericeum, Thyridolepis mitchelliana, Monachather paradoxa, Bothriochloa ewartiana* and *Rhynchosia minima. Brachiaria praetervisa* may have a special role for mine rehabilitation on red soils along rivers in northern Queensland (Silcock 1991). Advances in harvesting fluffy seeds satisfactorily by brush harvesters is helping to speed up progress (Beisel 1983). Cultivar selection for desirable agronomic traits from within a species may still be needed to satisfy seed industry needs. An alternative is to harvest seed from natural populations comprised of a mix of species for sowing elsewhere on the same property. A mixed pasture will be more robust and biologically stable than a monospecific pasture. Availability of contract brush harvesters at reasonable cost is a constraint to this strategy at present as is suitable irrigated land away from the coast where diseases like ergot seriously impair seed production of many dryland pasture plants.

At least with native species, there is little risk of releasing a new weed, a potential concern with exotic species once they become widespread, e.g. *Eragrostis curvula, Stylosanthes scabra* and leucaena.

Conclusions

When sowing a new pasture, some compromise must be made between risk of failure and cost of seed even though land preparation is usually the major cost. Native seed often has dormancy mechanisms limiting the extent of germination after small falls of rain, e.g. Queensland bluegrass (Watt 1978). Hence a relatively sparse establishment would be achieved from fresh seed under good conditions compared to that from 'treated' seed which was primed to germinate, e.g. by dehulling or scarification. However, 'primed' seed may all be lost if poor conditions follow germination and is more expensive. In addition, priming generally reduces the storage life of seed (Hong and Ellis 1992) and merchants are unwilling to store seed for lengthy periods.

The questions to be considered are: (a) Is resowing 2 or 3 times affordable? or (b) Should mixed dormancy seed be sown at high rates? or (c) Should mixed dormancy seed be sown at 'normal' rates followed by astute stock management for some years afterwards until the pasture establishes?

These previous points, as well as plant type or cultivar, must be considered in attempting to improve the grazing potential of marginal environments. Otherwise far too much may be expected of many of the plants suited to long-term pastures in unfavourable sown pasture zones.

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