

Sown pasture grasses and legumes for marginal cropping lands in southern inland Queensland

DAVID LLOYD, BRIAN JOHNSON AND
SUE O'BRIEN

*Department of Primary Industries and Fisheries,
Toowoomba, Queensland, Australia*

Abstract

A rich suite of pasture legumes and grasses have been released for the Queensland grain belt, particularly from forage evaluation programs carried out during the past 50 years (Gramshaw and Walker 1988; <http://www.pi.csiro.au/ahpc/>). Thus, there is an extensive and comprehensive knowledge of the adaptation of those species and adaptation is being extended widely — for example, to farmer groups in 'LeyGrain' workshops developed and delivered by the authors, and as written information (e.g. Lloyd *et al.* 2006; 2007a; 2007b) and on the website www.dpi.qld.gov.au. However, our knowledge is broad and, as we come to understand natural systems, their limitations and the extent of variation within those systems, it is equally clear that our knowledge of pasture plant adaptation is not as well defined as it needs to be. It is an interesting conflict — the more we understand, the more we begin to realise our lack of understanding. The appropriate species for sowing in different situations are discussed.

Defining the zone

This paper selectively targets the southern portion (Figure 1) of the Grain and Pastoral (GAP) Zone in Queensland (E.J. Weston, personal communication).

The area of about 16M ha is subtropical. Rainfall is low and variable with approximately 65–70% falling in the summer months and 30–35% in the winter. The adaptation of pasture

species has been associated (Weston and Harbison 1980; Weston *et al.* 1981) with the chemical and physical attributes of a number of distinct soil types within Great Soil Groups described in the Atlas of Australian Soils (developed by CSIRO scientists and collated by K.C. Northcote during the 1960s).

The soil associations can be identified by key vegetation species occurring on those soils as follows (Figure 1):

- large tracts of heavy clay soils that, before cropping, carried either native grasslands or brigalow (*Acacia harpophylla*) forest;
- clay-loam and loam soils associated with brigalow-belah (*Casuarina cristata*) and belah, units that are often associated closely with brigalow forest and woodland vegetation;
- loamy dark and red duplex and earth soils that carry a woodland vegetation, including poplar box (*Eucalyptus populnea*), other eucalypts, false sandalwood (*Eremophila mitchellii*), wilga (*Geijera parviflora*) and kurrajong (*Brachychiton populneus*) sometimes occurring in large tracts or intermingled with brigalow and belah soils;
- sandy and loamy yellow duplex soils and uniform sands and loams that occur in a band to the west of the Condamine River, carrying bull oak (*Casuarina luehmannii*), cypress pine (*Callitris glaucophylla*) and eucalypt vegetation, and Granite Belt and Traprock sands and loams, that carry a predominantly eucalypt vegetation; and
- loamy and sandy, deep, red gradational or uniform soils carrying cypress pine, iron bark (*Eucalyptus crebra*) and mulga (*Acacia aneura*), that occur largely in the west of the zone.

The heavy clay soils in the zone, that are structurally stable, have high water holding capacity, are generally fertile and are well suited for cropping, could be excluded from this discussion. However, nitrogen fertility has been run down by cropping and there are now good reasons to sow them to ley or longer-term pasture. The basalt-derived clays in the

east of the zone are less 'marginal' than the heavy soils in the west, based on rainfall alone. However, crop failure has occurred on these Eastern Uplands and Condamine Plains soils (Figure 1), and

significant areas of the Eastern Uplands have been sown to pasture.

The sandy and loamy soils of the Granite-Traprock and Cypress pine-bull oak areas (Figure 1)

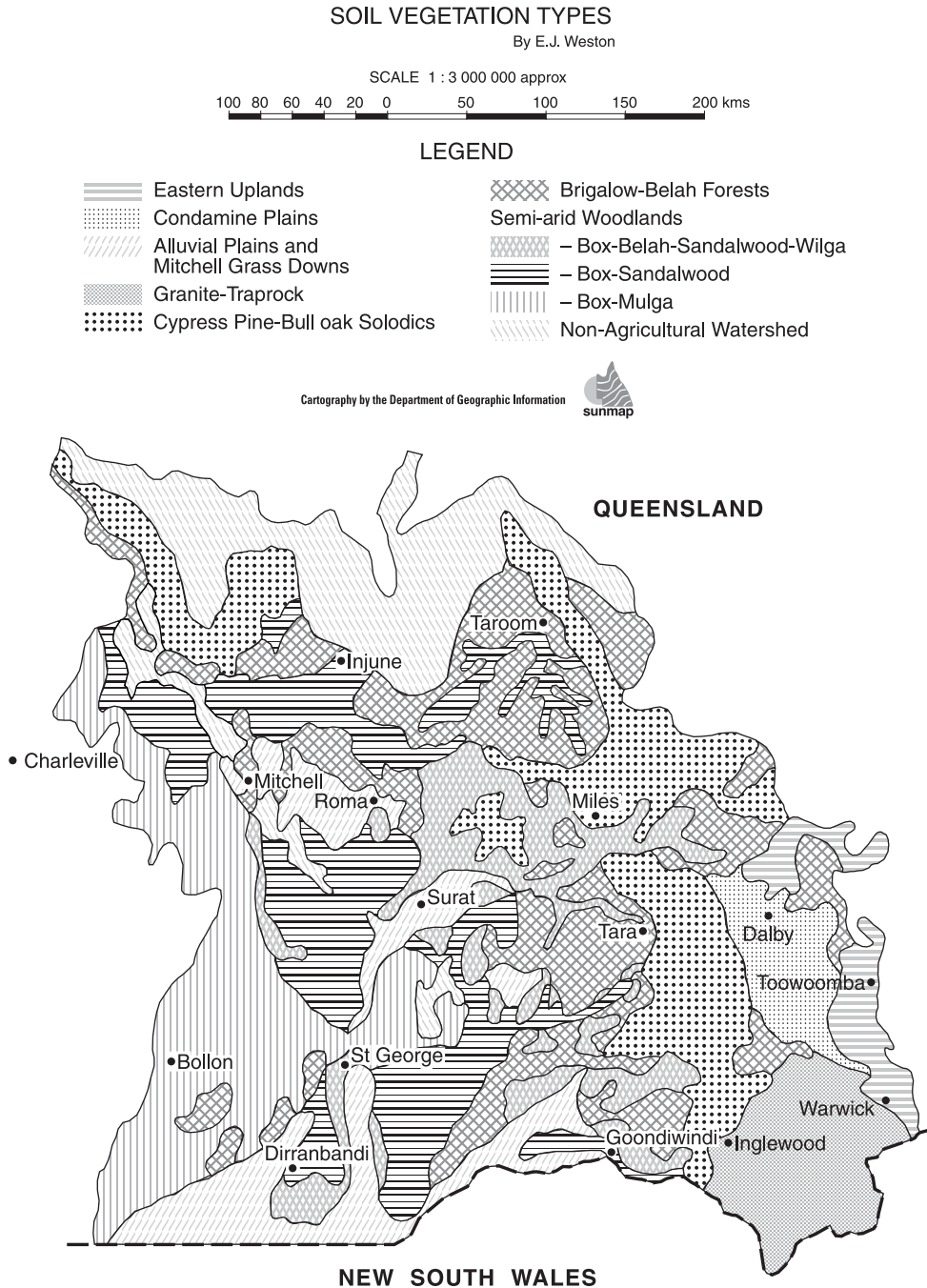


Figure 1. Soil/vegetation associations in the GAP zone of southern inland Queensland.

have a very limited cropping capability, yet there are areas of arable soils that are suited to sown pasture.

Thus, all of the broad soil/vegetation groups in the zone (Figure 1) are included in this discussion.

Every broad soil type is variable (Table 1), especially with regard to the pH, texture, sodicity and solodicity of surface soils and subsoils, profile salinity, profile chloride concentrations and profile depth, which influence species adaptation. Soil phosphorus levels are often low and, where deficient, the application of phosphorus fertiliser is important for the growth and persistence of legumes. In evaluation programs, the variability in surface soil attributes has been better defined than subsoil chemical attributes, particularly sodicity and salinity.

Pasture species adaptation

The broad adaptation of pasture grass and legume cultivars in the GAP Zone in Queensland has been defined by their evaluation during the past 50 years and the on-going collation of information (e.g. Weston *et al.* 1984; Cook *et al.* 2005; Lloyd *et al.* 2006; 2007a; 2007b).

Grasses, with few exceptions, have wide adaptation across soils and climates, except for limitations placed on the establishment of some by the physical nature of the surface of heavy clay soils. A small number of species are also constrained to the south-eastern and eastern areas of the zone, which are cooler and receive more rain in both summer and winter, by the aridity of the remainder of the zone. Soils vary in their chemical attributes (Table 1) and the release of the majority of cultivars from evaluation programs

across the zone reflects their ability to perform across those widely varying conditions. Some evidence, presented later, suggests a possible relationship between grass species adaptation and soil pH. Further research is needed to provide a better understanding of the adaptation of pasture plant cultivars to soils, associated with constraints within their subsoils.

Legume adaptation is constrained by surface soil pH, P and the Ca/K:Na/Mg ratio and, to an extent soil depth, while applying the same subsoil caveat as with grasses. The heavy clay soils are neutral to alkaline and are mainly calcareous. The loamy and sandy soils are more variable. This has consequences for the adaptation of the legume cultivars available for the zone.

Grasses

Rhodes grass (*Chloris gayana*) was the first introduced summer-growing grass and has been used commercially since the early 1900s. It is a ubiquitous species, adapted to a wide range of soil types. Cultivars now sown are mainly cvv. Katambora and Finecut. Rhodes grass is an outstanding coloniser and an excellent pioneer species, but is difficult to establish on heavy clay soils and is less drought-tolerant than most other grass cultivars released for the zone. It is tolerant of moderately saline soils.

Subsequently, pasture sowings were focused on the arable clay and clay-loam soils of the Brigalow Belt that carried brigalow and associated vegetation prior to clearing more than 50 years ago. The outstanding examples of widespread sowing and adaptation to this area of grasses, which were originally sown into the ash of fires that followed clearing, were:

Table 1. Range in surface soil (0–10 cm) attributes in soils sampled within broad soil/vegetation groups (E.J. Weston and D.L. Lloyd, unpublished data).

Soil/vegetation group	pH (water)	EC (ms/cm)	Cl ⁻ (ppm)	Na ⁺ (meq/100g)	Ca ⁺⁺ (meq/100g)	Ca:Na ratio	P(bicarb) (ppm)
Heavy clay Ug ¹	6.3–8.9	0.09–0.59	10–928	0.32–3.00	14–33	5–76.9	8–68
Belah Db	6.6–8.5	0.110–0.151	20–117	0.38–0.42	7.8–18	20–42.9	7–29
Woodland Dd	7.3	0.518	887	2.50	19	7.6	69
Woodland Dr Gn	4.7–6.5	0.01–0.079	10–53	0.05–0.36	0.5–32	3.4–340	2–29
Cypress/bull oak, Granite-traprock Dy	4.9–6.6	0.013–1.030	6–1769	0.32–3.00	0.7–9.6	1.4–35.5	2–15
Red earths Gn	5.0–6.1	0.065–0.124	21–39	0.18–0.22	2.7–12	15–54.5	3–19
Uniform Uf	6.6–8.0	0.080–0.161	20–33	0.20–0.31	8.3–26	26.8–130	12–33

¹ Classification as given by Northcote (1971).

Buffel grass (*Cenchrus ciliaris*). The introduction of buffel grass germplasm and its extensive evaluation in the early 1950s have provided the most widely adapted summer-growing grass species in the zone and the cornerstone of the Queensland beef industry. Buffel grass is adapted to about 7 M ha of friable clays to loams in the hotter and drier western portion of the zone (Figure 1). The tall cvv., e.g. Biloela, Nunbank and Boorora, were successful on fertile friable brigalow soils but not on soils of lower P fertility. The shorter cvv. American and Gayndah are widely successful on all soils, but particularly on loamy soils with a lower soil P status, to which the taller cvv. are not well adapted (Muller 2001).

Buffel grass is not well adapted to heavy clay soils or to sandy-loams of lower fertility, or to the climate and soils in the east of the zone. It sets large quantities of seed, is an excellent coloniser and is exceptionally resilient to the environment. Despite suffering rundown or decline (Graham 2001), it persists. The current challenge is to economically manage buffel grass decline through the use of legumes.

Green panic (*Panicum maximum*). The introduction of *Panicum maximum* germplasm led to the release of cvv. Petrie green panic and Gatton panic. Green panic was sown into large areas of fertile, friable brigalow clay-loam soils. Initially, the pastures were very productive but, as soil fertility has declined, green panic has not persisted as well as buffel grass except under trees and on roadsides. Gatton panic has largely replaced green panic in current sowings, and is demonstrating a wider adaptation to loam and clay-loam soils.

In the mid-late 1950s, the first signs of soil fertility decline in the heavy clay soils following long periods of continuous cropping heralded the need to consider, apart from the use of nitrogen fertiliser, pasture rotation. Thus, pasture species suited to soils with very high clay contents, particularly where buffel grass was not well adapted, were needed and the following ensued:

- Bambatsi panic (*Panicum coloratum*) was released for its adaptation to heavy clay soils that can become waterlogged in wet summer conditions, yet become dry in the winter (Lloyd 1981). This cultivar is also adapted to moderate levels of soil salinity and this extends its role onto heavy brigalow soils that sometimes contain high concentrations of salt. The establishment of Bambatsi is more reliable than that

of all other grasses except purple pigeon grass (*Setaria incrassata*). Bambatsi is now widely sown on all clay soils but is best adapted to those with the highest clay content.

- The identification of and reasons for difficulties in the establishment of grasses on heavy clay soils (Leslie 1965) resulted, indirectly, in the later release of purple pigeon grass cv. Inverell. It is best adapted to heavy, fertile clay soils and is the easiest grass to establish on those soils.
- In the evaluation program that released Bambatsi panic, germplasm of *Dichanthium aristatum* was found to be well adapted to heavy clay soils. The germplasm showed weediness traits and produced higher stem and lower leaf proportions than cv. Bambatsi. Subsequently, the identification of leafier germplasm led to the release of blue grass cv. Floren. It is a rapid coloniser and is a successful competitor with the floodplain weed, lippia (*Phyla canescens*).

Since the late 1960s, a large area of loamy duplex and gradational loamy and sandy woodland soils, with limited cropping capability, has been cleared for arable or pastoral use. These soils have been severely degraded by more than 30 years of cropping in exploitative systems that have mimicked those applied to the heavy soils. Thus, pasture species evaluation extended to those soils, with a particular focus on the genera *Bothriochloa*, *Dichanthium*, *Digitaria* and, in the south-east, *Paspalum*.

Cultivars of these species have been released and their adaptation has been studied on a wide range of soils (W.J. Scattini and B. Johnson, unpublished data; Table 2; R.G. Silcock, personal communication). This has provided insights that identify some general trends in adaptation (Table 3), while demonstrating that there is some difficulty in identifying the limits of their adaptation across these highly variable soils. Critical soil chemical attributes were not determined in these studies.

These species include:

- Bothriochloa insculpta* cvv. Hatch and Bisset (creeping blue grass)
- Bothriochloa pertusa* cv. Medway (Indian blue grass)
- Bothriochloa bladhi* cv. Swann (forest blue grass)
- Digitaria eriantha* ssp. *eriantha* cv. Premier (digit grass)

Digitaria milanijana cv. Strickland (tall finger grass)

Paspalum nicorae cv. Blue Dawn (Brunswick grass)

Paspalum notatum cv. Competidor (Bahia grass)

The data presented in Table 2 are of persistence after 7 years. Other species may have been equally or more productive in the short term. Additionally, neither rhodes grass cv. Callide nor buffel grass cv. Biloela performed well. We now understand that these are not the best-adapted cultivar of each species for the GAP Zone. Silcock (*ibid*) has shown that buffel grass cv. Gayndah has performed well on 3 marginal cropping soils and we know that cv. American performs equally well on similar soils. However, the better adapted

rhodes grass cvv. Katambora and Finecut colonise well but do not persist as well as other species.

The following are broad summaries of the adaptation of grasses listed in Tables 2 and 3:

- Creeping blue grass is very well adapted to alkaline, dark, duplex loams and uniform clay loams and friable clays of moderate fertility. Cultivar Hatch may be better adapted to soils with higher clay contents than cv. Bisset, and both may be able to exploit lower soil N conditions than some other species. However, the species does not seem to be as well adapted to acid, yellow duplex soils as Premier digit grass. Indian blue grass seems better adapted to acid or alkaline trend soils that are hard-setting.
- Premier digit grass is very widely adapted. It will grow well on soils from light, friable

Table 2. Summary of the adaptation of grasses to key soil/vegetation units in the Maranoa, Western Downs and Eastern Downs — assessed as persistence and ground cover in the seventh year after sowing in 1983 (W.J. Scattini and B. Johnson, unpublished data).

Location	Soil	Soil attributes	Pasture adaptation ¹
Maranoa	Brown Mitchell grass cracking clay	Friable, deep, uniform, alkaline	<i>Good:</i> Premier > Qld blue <i>Average:</i> Bambatsi, Inverell, Callide <i>Poor:</i> Hatch
	Brown cracking clay on fringe of brigalow-belah and Mitchell grass clay	Friable, deep, alkaline	<i>Good:</i> Hatch, Inverell, Bisset > Premier <i>Average:</i> Bambatsi, Biloela <i>Poor:</i> Petrie, Callide
	Red, duplex poplar box/sandalwood loam	Hard-setting, shallow, acid surface, alkaline trend	<i>Good:</i> Medway <i>Average:</i> Bisset, Premier <i>Poor:</i> Callide, Biloela, Hatch, Inverell
Western Downs	Grey, brigalow-belah, cracking clay without melonholes	Friable, deep, uniform, alkaline	<i>Good:</i> Premier > Callide, Hatch, Medway, Bisset, Inverell <i>Average:</i> Petrie, Biloela <i>Poor:</i> No commercial cv. tested
	Grey brigalow cracking clay with melonholes	Heavy, deep, uniform, alkaline	<i>Good:</i> Bisset, Inverell <i>Average:</i> Callide, Bambatsi <i>Poor:</i> Biloela, Petrie
Eastern and South-eastern Downs	Heavy, upland, cracking clay black earth	Heavy, colluvial, uniform, alkaline	<i>Good:</i> Bisset > Hatch, Bambatsi, Qld blue, Premier <i>Average:</i> Callide, Inverell <i>Poor:</i> Petrie
	Yellow duplex loam carrying open eucalypt forest	Hard-setting, gravelly, alkaline trend	<i>Good:</i> Medway, Bisset, Competidor <i>Average:</i> Bambatsi, Qld blue <i>Poor:</i> Callide, Hatch, Inverell
	Solodic yellow duplex sandy-loam carrying bull oak/cypress pine/eucalypt	Friable, shallow, acid	<i>Good:</i> Premier, Competidor <i>Poor:</i> Bisset, Hatch, Biloela, Callide, Bambatsi, Petrie
	Traprock yellow duplex loam	Hard-setting, shallow, gravelly, acid	<i>Good:</i> Premier, Competidor <i>Average:</i> Medway <i>Poor:</i> Hatch, Bambatsi, Callide
	Granite Belt yellow duplex sand	Friable, moderately deep, acid	<i>Good:</i> Blue Dawn, Competidor <i>Average:</i> Paspalum, Premier <i>Poor:</i> Callide, Biloela, Hatch, Bisset, Bambatsi, Inverell

¹ Bambatsi = Bambatsi panic (*Panicum coloratum*); Biloela = buffel grass (*Cenchrus ciliaris*); Bisset, Hatch = creeping blue grass (*Bothriochloa insculpta*); Blue Dawn = Brunswick grass (*Paspalum nicorae*); Callide = rhodes grass (*Chloris gayana*); Competidor = Bahia grass (*Paspalum notatum*); Inverell = purple pigeon grass (*Setaria incrassata*); Medway = Indian blue grass (*Bothriochloa pertusa*); Paspalum = paspalum (*Paspalum dilatatum*); Petrie = green panic (*Panicum maximum*); Premier = digit grass (*Digitaria eriantha* ssp. *eriantha*); Qld blue = Queensland blue grass (*Dichanthium sericeum*).

Table 3. Broad adaptive relationships of grasses in the evaluation studies of W.J. Scattini and B. Johnson (unpublished data) and R.G. Silcock (unpublished data).

Cultivar	Wide climatic adaptation	South-east only	Heavy clays	Friable clays	Loams	Sands	Alkaline soils	Acid soils
Premier	✓			✓	✓	✓	✓	✓
Bisset	✓			✓	✓		✓	
Medway	✓				✓		Alkaline trend	✓
Inverell	✓		✓	✓				
Swann	?	✓			✓			✓
Competidor		✓			✓	✓		✓
Blue Dawn		✓				✓		✓

brigalow and Mitchell grass downs clays to the poorest traprock soils. It is outstanding on granite sands, shallow sandy loams and red duplex soils and earths. Strickland tall finger grass, a different species of the same genus, appears promising but needs development and promotion.

- Swann forest blue grass is the best-adapted grass to the hard-setting, acid, traprock loams in the south-east of the zone. Its adaptation in drier areas is, as yet, unclear.
- The release of Brunswick grass cv. Blue Dawn has provided a summer-growing grass for farmers on the Granite Belt. It is particularly competitive and shows an ability to resist invasion by African lovegrass (*Eragrostis curvula*). Bahia grass cv. Competidor may also be used in this area. Both are restricted by aridity in the west of the zone.

The adaptation of these promising grasses has not been precisely defined, despite their release more than 20 years ago. This has been due to a combination of limited R&D, their slow adoption that was largely associated with lower beef prices until the early 2000s, the occurrence of dry conditions and drought since 1991, and high seed prices. There was a low demand for seed until 2004, when demand rose strongly owing to the improved market price for beef. Seed production is opportunistic and its cost is high during dry conditions.

Legumes

Legumes are essential to fix nitrogen on soils of low inherent or induced fertility and for the provision of high quality forage. A range of both summer- and winter-growing legumes that are adapted to the zone, have been released through State and National programs for pasture legume development between the 1950s and 2005.

Both ley and long-term legumes have been developed in these programs. Ley legumes are needed to fit short pasture phases in cropping systems; long-term legumes are needed for permanent pastures that may be regarded as long-term phases on arable soils. Thus, the legume cultivars released have differing attributes to enable them to fit the complexity of subtropical farming systems — they include long-term perennials, self-regenerating annuals (a desirable attribute for both short- and long-term phases), short-term perennials, and annuals that must be resown each year.

Temperate legumes. No long-term temperate perennials are used commercially in the zone.

The temperate annual legumes that require sowing each year include the annual vetches (*Vicia sativa* and *V. benghalense*) cvv. Common, Popany, Languedoc and Blancheffleur. They are not widely used.

Well adapted, self-regenerating annuals possess hard-seed attributes that enable them to develop seed reserves and survive a number of consecutive seasons when no seed is set. In the subtropics, these legumes are able to set large quantities of seed about 1 year in 10, but no seed in about 3 years in 10. There are 3 major groups that are divided according to adaptation to soil pH and the relative calcium status of the soils:

- Annual medics (*Medicago* spp.), which are adapted to calcareous neutral-alkaline soils with a Ca/K:Na/Mg ratio >6. They are well adapted to the soils characterised in Table 1, except the Cypress pine/bull oak solodics and the Granite-traprock soils (with attributes described in Table 2). The annual medics, particularly burr medic, can cause bloat. Powdery mildew has, during the past decade, limited the performance of all species except snail medic.

Species used in the zone include:

- barrel medic (*M. truncatula*). The cultivars Paraggio, Caliph and Jester are most widely used in perennial pastures, and have been developed with resistance to lucerne aphids. Cultivar Paraggio is the most resistant to powdery mildew.
- snail medic (*M. scutellata*). The cultivars Sava and Silver are best suited to short-term crop/pasture rotations.
- new spineless burr medic (*M. polymorpha*). The cultivars Cavalier and Scimitar are relatively untried in the subtropics owing to the occurrence of drought since their release.
- the early-flowering hybrid disc medic (*M. tornata* x *M. littoralis*) cv. Toreador. This has similarly remained untried, and an early-flowering button medic (*M. orbicularis*) cv. Bindaroo is in the cultivar release pipeline.
- Subclover (*Trifolium subterraneum* ssp. *subterraneum*) and serradella (*Ornithopus* spp.), which are adapted to acid to neutral soils with a Ca/K:Na/Mg ratio < 6. Their adaptation is restricted to the sandy and loamy Cypress pine/bull oak solodics and the Granite-traprock soils (Table 1, Figure 1):
 - Subclover is adapted equally well to the sandy and loamy soils of the Granite Belt and Traprock where new hard-seeded cultivars including York, Urana, Izmir and Coolamon develop hard-seed reserves that ensure their perenniality in long-term sown and native grass pastures. The adaptation of subclovers is restricted by rainfall to the south-east of the zone.
 - Serradella is adapted to sandy, friable soils west of the Condamine River and on the Granite Belt. Yellow serradella (*Ornithopus compressus*) cvv. Yelbini, Santorini and Charano are hard-seeded and persistent components of long-term pastures on these soils. Slender serradella (*O. pinnatus*) cv. Jebala would have a role on sandy, shallow soils if seed were available. French serradella (*O. sativus*) cvv. Cadiz, Erica and Margarita do not develop a large hard-seed reserve and are not suitable for permanent pastures in the subtropics.
- Woolly pod vetch (*Vicia villosa*) cv. Namoi, which is widely adapted to soils and climates in the zone. It is not as widely sown as the medics and subclovers/serradellas since its

seed production is generally less reliable, as it requires more specific management during flowering and seed set.

There are 2 short-term temperate perennial legumes that are used in short-term phases in crop/pasture rotations:

- Lucerne (*Medicago sativa*) is a widely adapted short-term perennial legume that is best adapted to deep, alkaline soils, most of which are heavy clays. However, it can be grown on deep soils of loamy and sandy texture. Lucerne is tolerant of saline soils and therefore performs well across a variety of subsoils from calcareous to sodic and slightly saline. It is widely used as it is easy to establish and produces palatable forage of high nutritional value that promotes high liveweight gains. However, it can cause bloat in beef cattle and management for bloat is recommended. Lucerne is also an excellent crop for conservation as hay or silage. Lucerne stands, both as pure swards or grass-legume pastures, decline after 3–4 years. It does not recruit readily through self-seeding and is prone to disease in both very wet and very dry conditions. Being deep-rooting, it dries soil to depth. Thus, the replenishment of soil water following a lucerne phase is slow. The new cv. Pegasis is the first lucerne cultivar to have been evaluated and released for dryland subtropical environments since the early 1980s. Cultivar UQL-1 has multiple resistances to anthracnose that is a useful attribute in wet summers.
- Sulla (*Hedysarum coronarium*) is a short-term perennial legume that appears to be best adapted to calcareous soils, although the full extent of its adaptation is unclear. It is very productive and does not cause bloat. Two cultivars, the semi-erect cv. Wilpena and the prostrate cv. Moonbi, have recently been released. In the subtropics, sulla is susceptible to root-rotting diseases caused by *Rhizoctonia solani* AG 2–2 (Ryley *et al.* 2004) on brigalow soils, and by *Sclerotium rolfsii* on black earths. These diseases threaten the perenniality of swards and persistence, even in the short term, will be dependent on a substantial seed set. The hard-seed dynamics (Bell *et al.* 2003) suggest that this legume is unlikely to develop a large seed reserve and it may be more effectively used in systems as a winter annual.

Tropical legumes. The adaptation of tropical legumes that are used in southern inland Queensland

is delineated by soil attributes (texture, pH) and latitude. The tropical legumes do not cause bloat. They can be identified within 4 categories viz. annuals, self-regenerating annuals, short-term perennials and perennials.

- Lablab (*Lablab purpureus*) cv. Highworth and cowpea (*Vigna sinensis*) cvv. Caloona and Ebony, are high-producing annuals adapted to alkaline, arable clay and clay-loam soils. Lablab is very productive and has been widely used as a forage ley legume in rotation with crops in subtropical farming systems. The perennial lablab cv. Endurance has had limited success owing to its lower productivity than the annual cultivars and its poor persistence.
- Wynn cassia (*Chamaecrista rotundifolia*) cv. Wynn is adapted to acid, sandy and loamy surfaced soils that are low in calcium. In semi-arid areas, it acts as a self-regenerating annual. While it is relatively unpalatable when green, it is well utilised after setting seed and haying off.
- Burgundy bean (*Macroptilium bracteatum*) cvv. Juanita and Cadarga are newly released, productive, palatable, short-term perennial legumes for use in leys rather than in long-term grass-legume stands, where they offer considerable promise. Burgundy bean is sold and sown as a mixture of the 2 cultivars for use on clay and clay-loam soils. It can set large quantities of seed if grazed leniently or spelled during flowering. Regeneration from seed can be an important adjunct to the perennialisation of individual plants, particularly during dry seasons.
- The perennial legumes adapted to the zone include desmanthus and caatinga stylo. They provide options for clay and clay-loam, and clay-loam and loamy soils, respectively:
 - Desmanthus (*Desmanthus virgatus*) cv. Marc is a short, shrubby legume that is adapted to deep, alkaline, clay and clay-loam soils. Desmanthus was originally released as cv. Jaribu, a mixture of 3 cultivars from different species but including cv. Marc, which was the survivor and dominant component because it flowers early and is able to set large quantities of hard seed. In contrast, cvv. Bayamo and Uman were later-flowering, set little seed and did not survive in the sward. Initially, sporadic establishment and hard seed restricted colonisation by desmanthus in mixed pastures but, over time, the cv. Marc component has thickened and the legume is competing

strongly with buffel grass. Desmanthus has been re-released as cv. Marc and a superior strain of *Rhizobium* is now available.

- Caatinga stylo (*Stylosanthes seabrana*) cvv. Primar and Unica are herbaceous legumes developed for clay-loam and loamy soils in the zone. Sold as a mixture of the 2 cultivars, caatinga stylo appears to be adapted to soils with a range of pH from slightly acid to slightly alkaline. It produces large quantities of hard seed, which enables it to develop a large seed reserve.

There are 2 perennial legumes whose adaptation has been considered to be restricted to central Queensland by the short summer growing season and the occurrence of frost in the south of the zone. These are leucaena (*Leucaena leucocephala*) cvv. Tarramba and Cunningham, and butterfly pea (*Clitoria ternatea*) cv. Milgarra. Leucaena is now being strongly promoted in the GAP Zone. It shows some promise for deep, friable, clay soils in the zone but is unlikely to find a place on the less fertile, generally shallower loamy soils. It may be favoured by generally warmer seasons that have been encountered in the south during the past 20 years. However, drier summers than those experienced in central Queensland are likely to limit the performance of leucaena and a series of severe frosts will set back its development severely. Butterfly pea has also been promoted but it is better suited to more 'tropical' environments. It is severely affected by frost and is slow to re-grow in the spring. It produces less biomass than better-adapted legumes, particularly in its second year.

Adaptation to saline soils

Dryland salinity is limited in the zone, although many soils within areas designated of salinity hazard are sodic at the soil surface and/or saline within the profile.

Tolerance of salinity is generally categorised by threshold levels at which there is no depression in yield (Gordon 1998):

- high (EC_{se}>6.0 dS/m) e.g. barley = 8.0, cotton = 7.7, sorghum = 6.8, wheat = 6.0
- medium (EC_{se} = 2.0–6.0 dS/m)
- low (EC_{se} = 0–2.0 dS/m)

In 3 laboratory experiments, Russell (1976) determined the soil salinity at zero and half plant yield with a number of tropical and temperate

grasses and legumes (Table 4). Some of these may be useful for pastures in recharge areas in salinity hazard zones.

Thus, rhodes grass and Bambatsi panic are the grasses best-adapted to areas of moderate salinity. Bambatsi has been used to reclaim saline black earths on the south-eastern Darling Downs and is tolerant of waterlogging. Rhodes grass is better adapted to soils of lighter texture, but is less drought- and waterlogging-tolerant than Bambatsi. Logan (1958) also recorded good growth of Bambatsi panic and rhodes grass at moderate to high levels of soil salinity.

Pangola grass (*Digitaria eriantha* ssp. *pentzii*) and *Sorghum almum* are also both moderately tolerant of soil salinity. Other species from these genera, e.g. digit grass, tall finger grass and silk sorghum (a hybrid of *Sorghum halepense*, *S. roxburghii* and *S. arundinaceum*), may also be tolerant, but this has not been tested. There is anecdotal evidence from experiments in the Lockyer Valley, Queensland that the *Digitaria* spp. perform relatively well in saline soils.

Among the adapted pasture legumes, lucerne is moderately tolerant of saline soils but little is known of the salt tolerance of the remainder. Lucerne has been the subject of significant salinity research. From a range of studies, the threshold EC_{se} for production lies between 1.5 and 2.0 dS/m, after which, production decreases by approximately 6.4% per 1 dS/m increase. The variation in thresholds measured in the 2 experiments (Table 4) may have been due to variation in seed source.

Siratro (*Macroptilium atropurpureum*) is nearly as well adapted to saline soils as lucerne

but is rarely used in the GAP Zone. However, both are intolerant of waterlogging and are not suited to the reclamation of saline discharge areas (Logan, *ibid*). Burgundy bean, a close relative of siratro, should be tested for its salt tolerance.

The pasture plants investigated in these early studies appear less tolerant of saline conditions than the most-tolerant crops. Our knowledge of the salt tolerance of the newer pasture cultivars is limited and more comprehensive comparative studies would enable the better targeting of pasture species to soil types.

Sowing mixtures

While it has been a long-recommended practice to sow legumes with grasses to provide fixed nitrogen for the system, there is a current and sometimes contentious trend to develop pastures using mixtures of grasses.

Mixtures of grass species

What is the philosophy behind the current trend to sow mixtures of different grass species and cultivars? Are these mixtures sown to enhance biodiversity or because there is a lack of precise knowledge where each fits into a landscape of climatic and soil variability? Has the significance of grass species and cultivar diversity in any paddock been clearly articulated? There are no clear answers.

The composition of mixtures should be selected for the paddock to be sown and comprise the best-adapted species. If soils within the

Table 4. Pasture plant tolerance of soil salinity (Russell 1976).

Species	Soil salinity (EC _{se}) ¹ at zero plant yield (dS/m)	Soil salinity (EC _{se}) at half plant yield (dS/m)
Experiment 1 — Tropical legumes		
Lucerne	1.88	1.02
Siratro	1.74	0.99
Lablab	0.95	0.55
Experiment 2 — Temperate legumes		
Lucerne	1.61	0.88
Snail medic	1.48	0.82
Barrel medic	1.40	0.78
Experiment 3 — Tropical grasses		
Bambatsi	3.25	1.70
Rhodes grass	2.90	2.32
<i>Sorghum almum</i>	2.78	1.46
Pangola grass	2.77	1.47
Buffel grass	1.61	1.42

¹ Electrical conductivity in saturated extract.

paddock vary widely, an attempt should be made to sow different species or mixtures of species in those parts of the paddock defined by changes in soil type. This is not always possible owing to the close association of different soil types that occur, particularly in the Brigalow Belt.

When sowing mixtures, for every species sown that is not appropriate and fails, there is a void that could have been sown with a more suitable species. This leads to slower pasture development and low early productivity. There is a high cost in sowing mixtures of poorly adapted species.

The sowing rates of the components of mixtures need to be considered carefully. High sowing rates of rapidly growing pioneer species such as rhodes grass lead to dominance of that species. If rhodes grass dominance is the objective, then sow only rhodes grass. There is little reason for sowing other species if their initial plant density is low and their occurrence in the pasture is, at best, sporadic.

Selecting components of mixtures to include species that develop rapidly in spring and others that develop slowly and flower later in the autumn has been proposed to extend the grazing period. This may be useful but it is primarily essential to select the best-adapted species.

The more palatable species in mixtures, e.g. Gatton panic and Premier digit grass, have more grazing pressure applied to them and astute grazing management will need to be applied to maintain them in the pasture. For this reason, it may be preferable to sow different paddocks to different species.

Mixtures of legume species

It is not uncommon to sow mixtures of legumes into grass pastures. However, the most important issue is to sow species that can compete and persist. The sowing of temperate and tropical legumes with summer grasses will, independently, cause sowing and grazing management conflicts. These issues are not the subject of this paper, but they may influence decisions about sowing mixtures.

Sowing medic or subclover mixtures comprising different species and cultivars is regarded as good practice, as this capitalises on the benefits of different flowering times to

seed production in an unreliable spring rainfall environment.

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