Tropical Grasslands (2000) Volume 34, 162–168

Pastures on cropping soils: which tropical pasture legume to use?

B.C. PENGELLY[1] AND M.J. CONWAY[2]
[1] *CSIRO Sustainable Ecosystems, Brisbane*
[2] *QDPI, Emerald, Queensland, Australia*

Abstract

Changes in the economics of cereal and beef production in the northern Australian cropping zone, together with a realisation that soil fertility decline is a major constraint in the production of prime hard wheat, has led to increased interest from producers in short- and long-term ley legume pasture systems. Several legumes, including lablab, leucaena, butterfly pea, caatinga stylo and desmanthus, are now commercially available for use in this tropical and subtropical zone. Each has advantages and drawbacks in particular farming systems. This paper outlines the best uses of these legumes within the northern cropping zone and suggests areas of research and development that must take place to improve the available suite of legume cultivars and to enhance their adoption.

Introduction

Tropical pasture legumes are used on the heavy textured cropping soils for 2 reasons — they provide high quality forage for animal production and they are used to improve soil nitrogen status and overcome soil fertility decline, a major constraint to profitable cereal cropping in the northern grain belt. However, they are almost always used in conjunction with animal production. Legumes are seldom used as green manure crops in the mixed farming systems of the region.

The development of tropical legumes for heavy textured cropping soils has lagged behind cultivar development for non-cropping, light textured soils. While Seca stylo (*Stylosanthes scabra*), Siratro and Aztec (*Macroptilium atropurpureum*) and many other legumes were released to industry and widely adopted on light textured soils prior to 1980, only the annual tropical legumes lablab (*Lablab purpureus*) and cowpea (*Vigna unguiculata*) were available and widely adopted on heavy textured soils at that time. Lablab, in particular, has been widely used in the northern cropping zone following the release of cv. Rongai by NSW Agriculture in 1967. The earlier flowering cv. Highworth was released by the Queensland Department of Primary Industries in 1973. In addition to these tropical legumes, the most common summer-growing legume on cropping soils in northern Australia has been lucerne (*Medicago sativa*). It is widely used in southern Queensland and northern NSW but is poorly adapted to most central Queensland soils and fails to persist in sufficient plant densities for more than 2 years. The exception in central Queensland is the small area of fertile, deep soils with good internal drainage.

Well-adapted tropical perennial legumes for clay soils and agronomic practices required for their successful adoption did not become available until the 1990s. The reasons for this include:

- the perception that cropping soils were capable of producing high yielding, quality grain crops without incorporating a legume phase in the farming system;
- beef markets did not place great emphasis on tenderness so rapid growth rates and young turnoff ages were not essential; and
- researchers had largely failed to find legumes and appropriate agronomy to overcome some of the difficulties in using legumes on clay soils such as soil water extraction, waterlogging, alkalinity, salinity and seedling establishment (Keating and Mott 1987).

Since 1990, there has been a rapid increase in both the number of legumes available and their

Correspondence: B.C. Pengelly, CSIRO Sustainable Ecosystems, Long Pocket Laboratories, 120 Meiers Road, Indooroopilly, Qld 4068, Australia. e-mail: bruce.pengelly@tag.csiro.au

adoption. The legumes include annuals, perennial herbs and shrubs, and leucaena *(Leucaena leucocephala)*. All have a place in the zone's farming systems. This paper outlines the current use of these legumes in the cropping zone of north-eastern Australia, and their advantages and disadvantages, and highlights the need for the development of new cultivars with management guidelines to encourage their adoption.

Soils and Climate

The northern grain belt of Australia lies between northern New South Wales and the Central Highlands of Queensland, a latitudinal range of 30°S to 22°S. Annual rainfall within this region varies (500–750mm) with the percentage falling in the summer months ranging from >70% in the north to about 55% in the south.

Mean maximum temperatures throughout the region in December–January are 32–35°C, and mean minimums for July–August, the coolest months, range from 4–7°C. Frosts occur throughout. At Clermont and Emerald, in the north of the zone, the first frosts can be expected in mid-June while the first frosts occur a month earlier in the Dawson Callide, on the Darling Downs and in the Maranoa (Foley 1945; Hammer and Rosenthal 1978). Hence, the number of frost-free days varies considerably from about 250 in Moree, Roma and Surat to >300 days on the Central Highlands.

Soils of the region range in origin, and include those developed from basalt *in situ* such as the black earths, those developed from weathered clays such as the brigalow soils and those developed from coarse sediments including brown, red and yellow texture contrast soils (Dawson 1972; Mullins 1981; Gunn 1984). The soils used for cropping are predominantly black, grey or brown clays that are structurally stable. Although they vary considerably in their profile characteristics and soil chemistry, these soils generally have inherently high fertility which has enabled production of prime hard wheat with >13% protein. However, continuous cropping for up to 100 years has resulted in a decline in soil fertility. Today, large areas of the zone's prime cropping soils are seriously depleted in their nitrogen status and will produce prime hard wheat only in dry years. The importance of the problem is recognised by farmers and researchers alike and has been identified as one of the most important issues facing grain growers in the region (Dalal *et al.* 1991).

Those regions with the best soils and highest rainfall (such as the eastern Darling Downs) are used predominantly for cropping. However, a large proportion of properties with cropping enterprises in central Queensland, the Maranoa and the western Darling Downs of Queensland also have significant beef production enterprises. It is the owners and managers of these properties who are best placed to incorporate tropical forage legumes into their farming systems.

Legumes — what are they?

There are 3 families of legumes: Fabaceae, Mimosaceae and Caesalpiniaceae. All families have provided pasture legumes to industry but most of the commercially used legumes in the tropics and elsewhere are from the family Fabaceae. These include such well known legumes as lucerne, stylos, Siratro, lablab and butterfly pea (*Clitoria ternatea*). Most members of the acacia family, Mimosaceae, are trees and shrubs and have limited value as forages although leucaena and desmanthus (*Desmanthus leptophyllus*, *D. pubescens* and *D. virgatus*), are well known members of this family. The members of Caesalpiniaceae are also mostly trees and shrubs. This family is considered the most primitive of the legume families and the majority of members do not nodulate. One of the few tribes with members that do nodulate is *Chamaecristae* and the only commercially released pasture legume derived from this family, *Chamaecrista rotundifolia* cv. Wynn (Wynn cassia), is from this tribe.

The most important feature of legumes used in agriculture is their ability to acquire atmospheric nitrogen for growth through symbiotic association with nitrogen-fixing root nodule bacteria (rhizobia). Fixed nitrogen is immediately available through translocation to the host plant and, as the legume decomposes, nitrogen also becomes available in the soil for uptake and growth by legumes and other plant species. In pulse crops such as chickpeas, mungbeans and soybeans, most of the nitrogen fixed from the atmosphere is removed from the paddock with the grain. However, in forage legumes, most nitrogen stays in the paddock despite losses as animal product and as nitrogen back to the atmosphere from urine. However, in some circumstances, nitrogen fixation may not take place despite the presence of a legume and a suitable rhizobia strain. This is especially so when soil nitrogen is available in sufficient quantities to meet the demand of the legume plant. In these circumstances, the legume is most likely to obtain most of its nitrogen requirements directly from the soil pool resulting in a further decrease in total soil nitrogen.

Rapid change in legume cultivars available

In the past 10 years, there have been large increases in forage legume use in the northern cropping zone. Large areas of leucaena have been sown in central Queensland and in the past 3 years, there has been a rapid increase in the area of butterfly pea sown. It is estimated that a total of 50 000 ha of leucaena is now in production in Queensland and most of that is in central Queensland. The total area sown to butterfly pea in central Queensland is estimated at 12–20 000 ha. During the past 10 years, cultivars of butterfly pea (cv. Milgarra), caatinga stylo (*S. seabrana* cvv. Primar and Unica), desmanthus (cv. Jaribu) and the perennial lablab (cv. Endurance) have all become available to industry. All these cultivars have been developed for use on clay soils. However, with the exception of Endurance, none was developed to meet the demand of short-term or long-term ley pastures. Desmanthus, caatinga stylo and butterfly pea were all developed for permanent pastures on clay soils in northern Australia.

The rapid change in the use of legumes in the cropping lands of Queensland has been due to a number of factors. Firstly, cereal prices have remained relatively low over the past 5 years (Figure 1). Grain production costs have risen during this period and margins are lower. Lower grain prices in conjunction with stronger beef prices over the same period (Figure 1) have made the beef industry more attractive to producers who have the land, knowledge and infrastructure for both cropping and beef production. The last 10 years has also seen an increased export and domestic market demand for steers that have been finished at an earlier age. This demand for higher quality beef has resulted in an increase in feedlot production in the northern cropping zone during this period. However, feedlot margins are small and profitability is very sensitive to small fluctuations in both feed and beef market prices. Hence, the finishing of steers on high quality, legume-based pastures has become more attractive. Improved pastures are most commonly used to produce finished animals for market. Jobling (1999), for instance, found that 56% of forage legume-based pastures sown on to cropping land in the Taroom district of central Queensland were used to finish steers while a further 22% were used to grow weaners.

In addition to these market issues, a series of years with lower than average annual rainfall has resulted in producers moving to beef production which is considered a lower-risk production strategy because it is less sensitive to the timing of rainfall events.

Which legume for which circumstance?

Which legume should be used in particular circumstances? Soil and climatic variation in the region have a major impact on plant adaptation and plant selection. In addition, the availability of legumes for short-term leys, for long-term leys of 2–5 years and for permanent pasture provides genuine options that enable particular legumes to be sown in their appropriate niches.

The current legume cultivars are being used in a variety of ways to meet the individual requirements of producers. Annual legumes such as lablab are sown either with or without a short-term grass species such as forage sorghum. Such pastures are expected to be productive for only one season. At the other extreme, legumes such as leucaena and caatinga stylo are sown in permanent pasture systems. Long-term ley pastures, aimed at providing grazing for perhaps 2–5 years, fulfil an intermediate role between annual and permanent pastures.

Leucaena

Leucaena-based pastures frequently provide liveweight gains of >1 kg/hd/d (>250 kg/hd/yr). The rapid expansion of leucaena in central Queensland has occurred through the development of good agronomic practices that have overcome the major problems of emergence and weed control at the seedling stage (Larsen *et al.* 1998). Where soils and climate are appropriate, such as on the deeper brigalow soils of central Queensland, leucaena is superior to all other alternatives for animal production per unit area. However, it has not been as successful on the shallower downs soils of the Central Highlands, possibly due to their low available soil water capacity. Leucaena use is largely restricted to central Queensland and the more tropical parts of the cropping regions of Queensland. It has not been successfully used in regions with shorter frost-free periods such as the western Darling Downs and Maranoa areas.

Leucaena has other limitations and drawbacks. At about $210/ha, it is costly to establish and does not reach full production for at least 2 years. It cannot be considered as a plant for short or long ley farming because of costs of returning the land to cropping. Despite these limitations, leucaena is one of the most successful pasture development stories in the cropping regions of Queensland during the past 10 years.

Caatinga stylo

The two cultivars of caatinga stylo, cv. Primar and cv. Unica, were released in 1996 on the basis of their performance on heavy textured soils (Edye *et al.* 1998). While the best known of the stylos, Seca and Verano (*S. hamata*), are well adapted to light textured soils, caatinga stylos are adapted to heavy textured soils and are used in permanent pasture systems in the cropping zone. Based on seed sales, an estimated 6000 ha of caatinga stylo has been established to date. Caatinga stylo is a perennial that is tolerant of drought and has the capacity to regenerate very rapidly from seed. It is tolerant of grazing and is probably more tolerant of soils with lower phosphorus status than some of the other legume options in the region. Unfortunately, unlike most stylos including Seca and Verano, caatinga stylo requires a specific rhizobia for effective nodulation. This particular strain of rhizobia is available in commercial peat preparations but the short life of the rhizobia on the seed when sown into dry soils with a high surface temperature in spring or summer, the normal sowing time, can lead to poor nodulation and nitrogen fixation. However, research to develop an inoculant technology that promotes survival of these and other rhizobia on seed at high temperature under dry-sowing conditions is well advanced (McInnes and Date 1999). Another drawback of caatinga stylo is that it has small seeds and establishment on soils that develop surface crusts can be problematic. Where caatinga stylo is sown, the use of herbicides to control competition from weeds and mature grasses greatly enhances survival during establishment, as seedlings of this species seem to be more sensitive to competition than those of other stylos, particularly Seca.

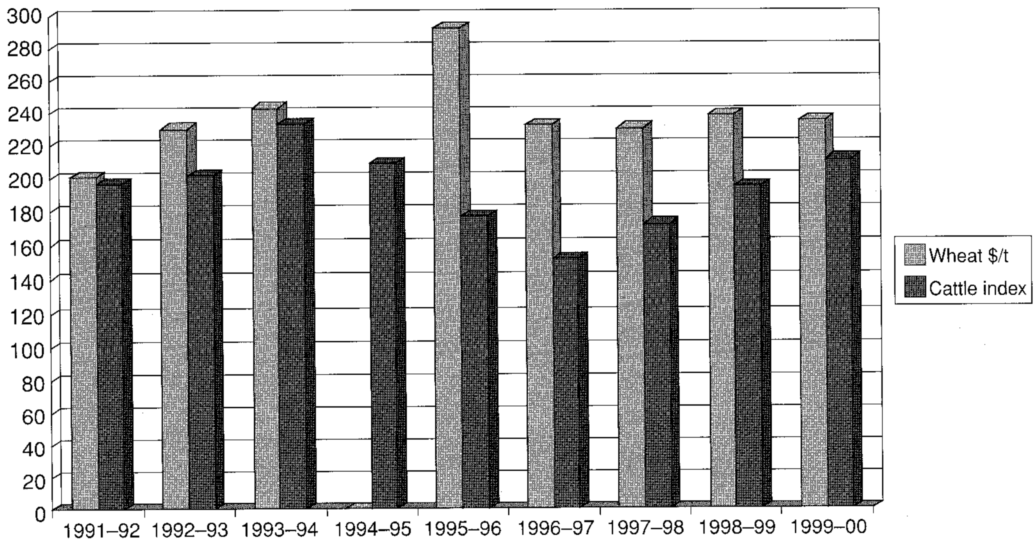

Figure 1. Pool prices for prime hard wheat and Qld cattle price index for the period 1991 to 2000. No wheat prices are available for 1994–95. (R. Jones, AWB, Emerald, personal communication; Rolfe and Donaghy 2000).

In summary, caatinga stylo has the ability to establish and persist in permanent pastures and successfully recruit seedlings on clay soils. It has been successfully established into buffel grass pastures and into native *Bothriochloa-Dichanthium* grasslands.

We are not able to define its geographical limitations. It has been successfully grown from Roma to the Central Highlands but its potential value in the southern extremes of the cropping zone is not known.

Butterfly pea

Butterfly pea is a perennial shrub. In 1992, Milgarra was released for use on clay soils in north Queensland (Anon 1992) but over the past 5 years it has emerged as a very well adapted legume on the cropping soils of central Queensland. It is estimated that 12–20 000 ha have been sown on a wide range of soils in central Queensland. It is being used predominantly as a long-term ley legume with expectations that it will remain in production for perhaps 5 years. Grazing management that ensures it occasionally sets seed may enable butterfly pea to persist as a permanent pasture species.

Rapid adoption by farmers over the past 3 years has been due in part to more attractive beef markets compared with those for wheat, but the development of sound agronomic practices, especially those associated with establishment and weed control, have also played a major role. Liveweight gains of 0.7–1.3 kg/hd/d have been achieved on butterfly pea pastures.

Current knowledge suggests that butterfly pea is best adapted to the regions north of Wandoan and Taroom, although some recent commercial sowings have been carried out in subtropical regions. The recognition of the value of this legume by producers in central Queensland confirms that a new butterfly pea cultivar for subtropical regions is a priority research target.

Desmanthus

Desmanthus cultivars *D. virgatus* cv. Marc, *D. leptophyllus* cv. Bayamo and *D. pubescens* cv. Uman were released as a mixture, known as Jaribu Desmanthus in 1991 (Cook *et al.* 1993). To date an estimated 3000 ha have been established in permanent pasture systems in the zone. These cultivars differ in flowering time and habit and it was proposed that their release as a composite would enable the best-adapted component or cultivar in a particular environment to eventually dominate while still maintaining smaller components of the other cultivars to take advantage of between-season variation. Marc is early flowering and low-growing and has proved the most persistent of the 3 cultivars in permanent pasture systems. Bayamo is more erect and flowers later than Marc, while Uman is also erect but very late-flowering. In most commercial sowings of Jaribu, Marc proved to be the most prolific seed producer, recruited the highest number of seedlings but produced low levels of dry matter. Bayamo has usually had the best dry matter production, produced moderate amounts of seed but had low seedling recruitment. Uman has produced only moderate dry matter production together with low seed production and seedling recruitment. Once established, the original plants of Bayamo and Uman have persisted strongly but, because of its greater seedling recruitment, Marc frequently becomes the dominant cultivar after 3–4 years. Because of its low dry matter production, the contribution Marc makes to both animal diet and soil nitrogen is limited. Given that desmanthus is a small-seeded legume with the associated problems of seedling establishment, and also requires specific rhizobia (Date 1991), the small gains in diet and soil nitrogen derived from Marc are often seen as small reward for the effort of establishing desmanthus-based pastures. Hence, use of this legume in cropping zone soils has been limited.

Despite weaknesses in the components of Jaribu, the genus *Desmanthus* is one of the very few which has been consistently observed to persist under heavy grazing on clay soils in its native environment (the Americas). For this reason, it is still perceived as having potential on the cropping soils of Queensland and northern NSW. However, use of the composite of Jaribu is not appropriate. If desmanthus is to be used in permanent pasture systems, then Marc, or a similar cultivar with higher dry matter production, might be the only alternative. For short-term pastures of < 4 years, the higher yielding cultivars Bayamo and Uman (or new cultivars currently being developed from high yielding species including *D. leptophyllus)* should have a role. Late-flowering cultivars would not produce large seed yields and hence be more suitable in ley systems. This is in contrast to the requirements for use in permanent pasture systems where high seed yields support seedling regeneration and persistence. Certainly in short-term pastures, where high yields of quality forage are necessary to warrant the costs of establishment, Marc does not appear to have a role.

The 3 species of desmanthus used in Jaribu can be productive and persistent in both permanent and ley pastures in the region. However, before large-scale use of these legumes takes place, there is an urgent need to identify suitable cultivars to develop appropriate guidelines for both their establishment and grazing management.

Lablab

Lablab has been amongst the most widely used legumes for ley pastures in the region with in excess of 40 000 ha sown annually. It is an annual, has large seeds, is easily established and is drought-tolerant (Hendricksen and Minson 1985). It is high-yielding (frequently >4 tonnes/ha) and can provide liveweight gains of 0.6–1.0 kg/hd/d with medium to high stocking rates.

Where farmers require a summer-growing annual, lablab is the most obvious choice and large areas are sown in the region each year. A major limitation for some producers is that it is an annual. However, a new perennial cultivar, cv. Endurance, has recently been developed from crossing Rongai with a wild, perennial form of the species from east Africa. This cultivar is slightly less productive than the 2 annual cultivars but it can persist under grazing for at least 2 years. The availability of Endurance means that lablab can now be considered a viable option where farmers require a summer-growing legume for at least a 2-year ley pasture phase within their cropping system.

Future needs for research and development

While leucaena, lablab and butterfly pea have been widely adopted, at least in some regions, major constraints to legume use still remain and new cultivars to fill particular environments are being sought. Some, such as leucaena and butterfly pea, are not adapted to the cooler, southern areas of the zone. Researchers need to assess whether more cold-tolerant cultivars of these or other species can be developed to fill the range of farming system niches. One new option being assessed is burgundy bean (*M. bracteatum*). This plant is being evaluated under grazing at sites between central Queensland and northern NSW and results so far indicate that it might be successfully used as a legume in 2–3 year phase pastures throughout the zone. A new, more drought-tolerant and persistent cultivar of perennial lablab is also being assessed. Studies are also underway in an attempt to identify a more cold-tolerant butterfly pea cultivar for use in southern Queensland and northern NSW.

Despite the availability of a range of legume cultivars, some of the important management constraints associated with their use need to be overcome before widespread adoption can occur.

Firstly, adoption of legumes that require specific rhizobia such as caatinga stylo and desmanthus will be slow, unless better survival of rhizobia in the soil can be achieved. McInnes and Date (1999) have demonstrated that substantial improvements in rhizobia survival on seed sown into dry soil might be achieved through the use of new technology. The rapid advancement of their findings to commercial use is essential to enable these legumes to be fully utilised.

Secondly, researchers need to develop methods of sowing legumes whilst minimising the available soil nitrogen at establishment. Conventional tillage usually results in soil nitrogen being made available to both the legumes and other plants, including weeds. This not only limits the amount of nitrogen fixation taking place but also results in competition from weeds. Tillage and sowing techniques that minimise soil nitrogen availability at establishment need to be developed to assist in reducing weed competition at this most susceptible phase of pasture development.

Thirdly, guidelines for using grasses in association with legumes should be developed. In particular, information on the most appropriate choice of grass and methods of establishment and grazing management to maintain the legume-grass balance need to be produced to minimise pasture establishment failures and encourage adoption. This issue is particularly important because, although grasses compete with legumes and reduce legume yield and overall forage quality, their inclusion can result in the suppression of weeds, decreased soil erosion, and an increase in soil organic matter.

Recent history has shown that adoption of legumes is severely constrained by the lack of guidelines for establishment and management. The successful adoption of both leucaena and butterfly pea in central Queensland seems to suggest that it is only when innovative farmers become involved in developing these management guidelines that successful adoption will take place. This input from innovative farmers in developing management guidelines will be necessary before either desmanthus or caatinga stylo, or any other new plants, can take their place as successful legumes in the northern cropping zone.

References

ANON (1992) New herbage plant cultivars. *Clitoria ternatea* L. Butterfly pea cv. Milgarra. *Tropical Grasslands,* **26,** 70–74.

COOK, B.G., GRAHAM, T.W.G., CLEM, R.L., HALL, T.J. and QUIRK, M.P. (1993) Evaluation and development of *Desmanthus virgatus* on medium to heavy textured soils in Queensland, Australia. *Proceedings of the XVII International Grassland Congress, Rockhampton, 1993.* **III**, 2148–2149.

DALAL, R.C., STRONG, W.M., WESTON, E.J. and GAFFNEY, J. (1991) Soil fertility restoration of cropping lands in subtropical Queensland. *Tropical Grasslands*, **25,** 173–180.

DATE, R.A. (1991) Nitrogen fixation in *Desmanthus:* strain specificity of *Rhizobium* and responses to inoculation in acidic and alkaline soil. *Tropical Grasslands*, **25,** 47–55.

DAWSON, N.M. (1972) Land Inventory and Technical Guide; Miles Area, Queensland. Part 1. Land classification and land use. *Division of Land Utilization Technical Bulletin No. 5. QDPI, Brisbane, Australia.*

EDYE, L.A., HALL, T.J., CLEM, R.L., GRAHAM, T.W.G., MESSER, W.B. and REBGETZ, R.H. (1998) Sward evaluation of eleven "Stylosanthes seabrana" accessions and *S. scabra* cv. Seca at five subtropical sites. *Tropical Grasslands*, **32,** 243–251.

FOLEY, F.C. (1945) Frosts of the Australian Region. *Bureau of Meteorology Bulletin No. 32.*

GUNN, R.H. (1984) Soil Landscapes of the Brigalow Belt of Queensland. In: Bailey, A. (ed.) *The Brigalow Belt of Australia.* pp. 7–21. (Royal Society of Queensland: Brisbane, Australia).

HAMMER, G.L. and ROSENTHAL, K.M. (1978) Frost and minimum temperature probabilities (data for Charleville, Dalby, Emerald, Goondiwindi and Roma). *Queensland Agricultural Journal*, **104**, 177–201.

HENDRICKSEN, R.E. and MINSON, D.J. (1985) *Lablab purpureus* — A review. *Herbage Abstracts*, **55,** 215–227.

JOBLING, T. (1999) Producers' Requirements for Tropical and Subtropical Ley Legume Species. A Survey of the Taroom-Wandoan Region. *University of Queensland Agricultural Science Report, Brisbane.*

KEATING, B.A. and MOTT, J.J. (1987) Growth and regeneration of summer-growing pasture legumes on heavy clay soil in south-eastern Queensland. *Australian Journal of Experimental Agriculture*, **27**, 633–641.

LARSEN, P.H., MIDDLETON, C.H., BOLAM, M.J. and CHAMBERLAIN, J. (1998) *Leucaena* in Large Scale Grazing Systems: Challenges for Development. In: Shelton, H.M., Gutteridge, R.C., Mullen, B.F. and Bray, R.A. (eds) Leucaena — *Adaptation, Quality and Farming Systems.* pp. 324–330. (ACIAR: Canberra).

MCINNES, A. and DATE, R.A. (1999) Improving survival of rhizobia on *Stylosanthes* and *Desmanthus* seed at high temperature. In: Slattery, J. and Curran, E. (eds) *Proceedings of the Twelfth Australian Nitrogen Fixation Conference.* pp. 3–4. *The Australian Society for Nitrogen Fixation.*

MULLINS, J.D. (1981) Appraisal of the physical resources and cropping systems of the grain growing environmental zones of Queensland. *Division of Land Utilization Report No. 81/2. QDPI, Brisbane, Australia.*

ROLFE, J. and DONAGHY, P. (2000) Welfare Benefits: the changing face of the Queensland beef industry. *Contributed paper to the 44th Annual Conference of the Australian Agricultural and Resource Economics Society, Sydney, January 2000.* (in press).