The use of temperate species in the Australian subtropics

K.F. LOWE
Queensland Primary Industries and Fisheries, Department of Employment, Economic Development and Innovation, Mutdapilly Research Station, M.S. 825, Peak Crossing, Queensland, Australia
kevin.lowe@dpi.qld.gov.au

Abstract
Temperate species and tropical crop silage are the basis for forage production for the dairy industry in the Australian subtropics. Irrigation is the key resource needed for production, with little survival of temperate species under rain-grown conditions except for lucerne. Annual ryegrass (*Lolium multiflorum*), fertilised with either inorganic nitrogen or grown with clovers, is the main cool season forage for the dairy industry. It is sown into fully prepared seedbeds, oversown into tropical grasses, especially kikuyu (*Pennisetum clandestinum*) or sown after mulching. There has been a continual improvement in the performance of annual and hybrid ryegrass cultivars over the last 25 years. In small plot, cutting experiments, yields of annual ryegrass typically range from 15 to 21 t DM/ha, with equivalent on-farm yields of 7 to 14 t DM/ha of utilised material. Rust (*Puccinia coronata*) remains the major concern although resistance is more stable than in oats. There have also been major improvements in the performance of perennial ryegrass (*L. perenne*) cultivars although their persistence under grazing is insufficient to make them a reliable forage source for the subtropics. On the other hand, tall fescue (*Festuca arundinacea*) and prairie grass (*Bromus willdenowii*) cultivars perform well under cutting and grazing, although farmer resistance to the use of tall fescue is strong. White clover (*Trifolium repens*) is a reliable and persistent performer although disease usually reduces its performance in the third year after sowing. Persian (Shaftal) annual clover (*T. resupinatum*) gives good winter production but the performance of berseem clover (*T. alexandrinum*) is less reliable and the sub clovers (*T. subterraneum*) are generally not suited to clay soils of neutral to alkaline pH. Lucerne (*Medicago sativa*), either as a pure stand or in mixtures, is a high producing legume under both irrigation and natural rainfall. Understanding the importance of leaf and crown diseases, and the development of resistant cultivars, have been the reasons for its reliability. Insects on temperate species are not as serious a problem in the subtropics as in New Zealand (NZ). Fungal and viral diseases, on the other hand, cause many problems and forage performance would benefit from more research into resistance.

Keywords: temperate grasses, clovers, lucerne, kikuyu, subtropics, irrigation

Introduction
With the exception of lucerne, temperate species are not productive in the subtropics unless fully irrigated because the rainfall pattern is summer-dominant and winter rainfall is unreliable (Fig. 1). However, the reliance on irrigation is reduced in the New South Wales (NSW) subtropical areas where winter rainfall is higher and more reliable. As a result, all data presented in this paper are based on full irrigation; in other words the stands receive around 50 mm of irrigation per fortnight (4-6 ML/ha for annuals (April – November) and 8 ML/ha for perennials (all year)). Most dairy farms have a proportion of the area capable of irrigation; water comes mainly from underground sources.

Most temperate pasture species are used for dairy production although there are large areas of rain-grown lucerne used for beef production, especially west of the Great Dividing Range. The subtropical dairy forage system is based on temperate pastures in the cooler season and tropical grasses in the warmer season to meet milk processor requirements for year-round milk production. Temperate pastures provide high quality forage during the cool season when native and tropical species, which perform only a supplementary role, are dormant. Mean maximum temperatures in winter are around 22ºC in July with 10-20 frosts a year so most temperate grasses continue to grow throughout winter.

Climate and soils
The subtropical region extends from Rockhampton (Queensland) in the north to Taree (NSW) in the south (between latitudes 17 and 32ºS). While generally extending from the coast to the Great Dividing Range, it does extend further west to the Darling Downs, and the Burnett and Biloela regions. The subtropical region can be best described as having a sub-coastal, subtropical climate with mean daily maximum summer temperatures of 30-35°C and winter temperatures of 20-25°C (Fig. 1). However, temperature extremes do occur, exceeding 40ºC in summer and as low as -7ºC in winter. Foliage of introduced and native C_4 grasses becomes completely frosted in winter. Most temperate species are grown on heavy clay alluvial soils of moderate to high fertility. Deficiencies of potassium and sulphur are

Figure 1 Comparison of climatic conditions at Gatton and Mutdapilly in southeast Queensland, and Whangarei in Northland, NZ. ▲ - Average Monthly Maximum daily temperatures (ºC), △ - Average Monthly Minimum daily temperatures (ºC), hatched bars indicate Monthly rainfall (mm).

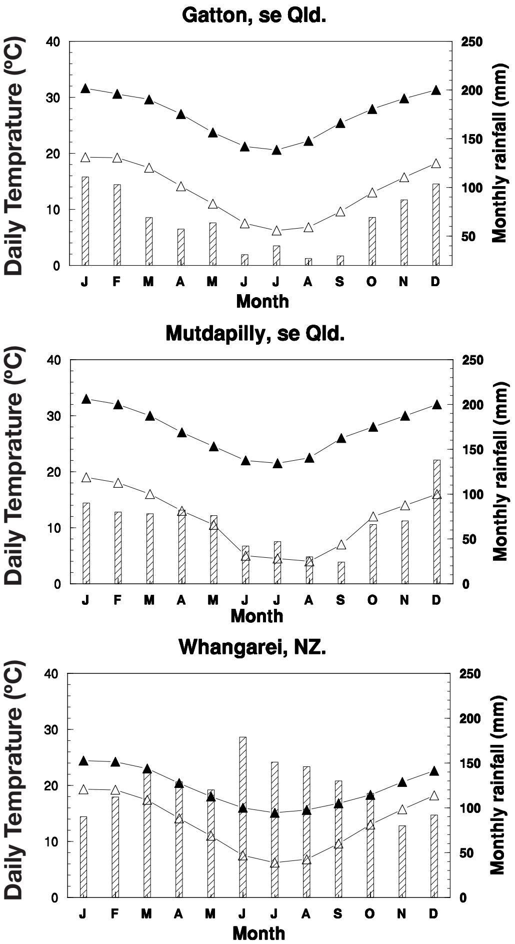
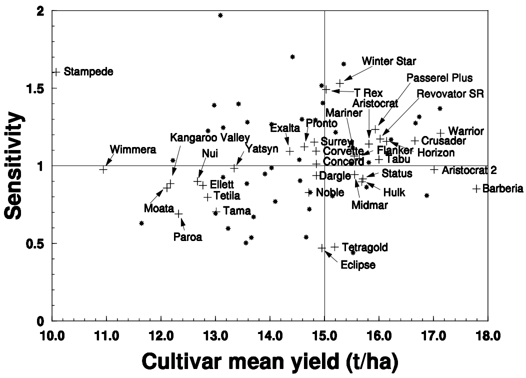


Figure 2 The relationship between cultivar adaptation (regression coefficient = sensitivity) and cultivar mean total yield for 31 cultivars (+) and 54 experimental lines (*) sown annually for 22 years at two sites (Mutdapilly and Gatton Research Stations) in Queensland (adapted from Lowe *et al.* 2007).



more likely than phosphorus. Tropical species are mostly grown on duplex soils of low fertility with phosphorus, potassium and molybdenum the likely deficiencies.

Forage systems

Dairy systems rely on both tropical and temperate pastures and cows are usually fed up to 50% of their diet as supplements (grain, molasses, hay or silage). On the other hand, beef systems rely mainly on native or naturalised C_4 grass systems. Stocking rates are adjusted for subsistence grazing of mature or frosted pasture in winter, resulting in some liveweight loss at this time.

The main introduced grasses for summer are Rhodes grass (*Chloris gayana*), green panic (*Panicum maximum*) and setaria (*Setaria sphacelata)*, with kikuyu only on fertile upland or river flats; these are generally grown in pure swards, with low to moderate inputs of nitrogenous fertilisers. Small pockets in high rainfall areas are sown to the tropical legumes - leucaena (*Leucaena leucocehpala*), Amarillo pinto peanut (*Arachis pintoi*), Shaw creeping vigna (*Vigna parkeri*) and Wynn cassia (*Chamaecrista rotundifolia*) in combination with introduced C_4 grasses. Summer crops such as maize (*Zea mays*) and forage or grain sorghum (*Sorghum bicolor*) are used for silage or grain with legume crops such as lablab (*Lablab purpureum*) or soybeans (*Glycine max*) used for autumn production. In winter, dairy forage systems are based on annual ryegrasses, clovers, herbs or lucerne. If irrigation is unavailable crops of oats (*Avena sativa*) and barley (*Hordeum vulgare*) are used. Lucerne is used throughout the year, both for grazing and hay or silage.

In south east Queensland, a 5-year project was conducted in which five forage systems were evaluated, representing the most common systems used in subtropical dairying (Table 1). The project used physical information and computer models to show that all of the common farming systems in the region are capable of much higher milk production from forage than current practices. This was achieved mainly by increasing the focus on better management of C_4 species, efficient water management, planned forage conservation, improved grazing management and complementary feeding with concentrates (Andrews *et al.* 2006).

The role of annual species

Before 1970, cool season pastures in south-east Queensland were based on the hybrid ryegrass (*Lolium hybridum* cv. 'Grasslands Manawa') and white clover

Table 1 Description of the five subtropical dairying farming systems used at Mutdapilly, south east Queensland (adapted from Andrews *et al*. 2006).

Description	Calving pattern	Stocking rate (cows/ha)[1]	Milk production targets (Litres/cow)	Off farm feed[2] (tonne DM/cow)	Main winter forage	Main summer forage
Rain-grown pasture	100% spring	1.9	7040	3 t Concentrate 1 t hay/silage	Oats	Rhodes grass
Limited irrigation[3] pasture	50% spring, 50% autumn	2.8	6560	3 t Concentrate 1 t hay/silage	Annual ryegrass/N	Rhodes grass
Limited irrigation[3] crop	30% spring, 70% autumn	1.4	7300	3 t Concentrate	Annual ryegrass/N, oats, lucerne	Forage sorghum, lab lab, lucerne
High irrigation[4] pasture and crop	30% spring, 70% autumn	2.8	7100	3 t Concentrate	Annual and perennial ryegrass, prairie grass, tall fescue	Lucerne, forage sorghum
Feedlot	All year round	4.3	9650	3 t Concentrate	Maize, lucerne and barley silage	

[1]540-560 kg average cow weights; [2] Purchased rather than produced within the farmlet;
[3] < 20% of farm can be irrigated, [4] >85% of farm irrigated

Table 2 Comparison between annual ryegrass /N and annual clover/ryegrass in the subtropics, both supplemented with 4 kg grain/cow/day (adapted from Moss *et al.* 1987).

Variable	**5 cows/ha**		**10 cows/ha**	
	Ryegrass/N	Clover/ryegrass	Ryegrass/N	Clover/ryegrass
		Milk yield		
Per cow performance (kg)	3407	3434	3031	2921
Per ha performance (kg)	17035	17170	30310	29210
		Fat yield		
Per cow performance (kg)	124	130	110	108
Per ha performance (kg)	620	650	1100	1080
		Protein yield		
Per cow performance (kg)	103	102	91	87
Per ha performance (kg)	515	510	910	870

(cv 'Ladino' or 'Louisiana') (Lowe 1973). These produced around 12 t DM/ha/yr (Kleinschmidt 1964) but rarely persisted for more than two summers (Kleinschmidt 1964; Schroder 1961) and were rapidly dominated by C_4 grasses.

Hybrid ryegrasses were quickly replaced by annual (Italian) ryegrasses as the dairy industry's production levels increased with the change from cream to milk supply systems in the 1970s. 'High-N-rye' was the catch phrase used for the annual ryegrass system which used high seeding rates of ryegrass (20-40 kg/ha) combined with high levels of inorganic nitrogen (300-400 kg N/ha) (O'Grady & Cassidy 1976).

Table 3 Performance of nitrogen-fertilised grasses over 3 years at Mutdapilly, all supplemented with 4 kg grain/cow/day (adapted from Lowe **et al.** 1999b).

Pasture	300-day milk yield (kg/cow)	Milk fat (%)	Protein (%)
'Concord' annual ryegrass	4765	3.89	3.08
'Yatsyn 1' PRG[1]	5232	3.79	3.11
'Matua' prairie grass	5080	3.96	3.10
'AU Triumph' tall fescue	4810	3.72	3.02

[1]PRG = perennial ryegrass

Table 4 The performance of tall fescue cultivars in a perennial grass comparison, sown at Gatton in April 2008.

Cultivar	Dry matter yield (kg/ha)			% occurrence at end of Year 1
	Spring	Summer	Total Year 1	
'Demeter'	7520	5170	17907	62.3
'Advance Max P'	8010	4220	17580	57.3
'Quantum II'	7840	3630	17710	74.3
Best experimental line	9340	5200	20690	70.0
LSD (5%)	930	800	1690	NS

These pastures are sown in early April and, depending on the cultivar used, grow until late November. Annual production levels are higher than for the perennial pastures of the 1960s, typically ranging from 15 to 21 t DM/ha for small plot, cutting experiments (Lowe *et al.* 2007) to 7 to14 t DM/ha utilised from farm-based pastures. The lower farm yields relate to less efficient irrigation, the effect of grazing and lower fertiliser inputs. Rust is the major disease of temperate grasses and limits forage utilisation in spring.

There are a range of establishment methods used for annual ryegrass. They are sown into fully prepared seedbeds, into C_4 species suppressed by herbicides, cultivation or grazing using zero-till seeders, or broadcast on to the pasture which is then mulched (mulch strike). C_4 species can continue to grow if conditions remain warm, seriously affecting ryegrass establishment. In a study of commercial sowings in northern NSW, K. Sinclair (pers. comm.) found that broadcasting diploid ryegrass seed resulted in the establishment of 650 seedlings/m^2 with 2150 tillers/m^2 compared with 400 and 1400, respectively, when the seed was direct-drilled. The difference can be explained by C_4 grass competition; there was only 18% of kikuyu in the forage on offer after 4 weeks in the broadcast, compared to 41% in the direct-drilled, areas. Seeding rates are generally increased to compensate for this competition.

One innovative technique in high rainfall areas is to oversow annual ryegrass into Amarillo peanut (*Arachis pintoi* cv. 'Amarillo'), a high quality, summer growing tropical legume. During summer, the peanut is an aggressive competitor and dominates the C_4 grasses but in autumn it is grazed down and causes little competition to the establishing ryegrass. The system reduces the nitrogen requirement of the ryegrass.

Annual clovers are sown with annual ryegrass or alone to reduce the amount of fertiliser nitrogen required and to increase per cow milk production. While Persian (Shaftal) clover, berseem and sub clover (*T. subterraneum*) have all been used, Persian is the most reliable with good winter growth. Typically, 'Haifa' white clover is sown with Persian clover to extend production into summer. In an experiment in central Queensland, milk production from July to November was 13.9 L/cow/day from annual ryegrass/N compared with 14.6 L/cow/day for annual clovers (Chopping *et al.* 1983). Milk production per cow and per hectare (Table 2) proved higher with the legume system at a stocking rate of 5 cows/ha but not at 10 cows/ha in an experiment in south east Queensland (Moss *et al.* 1987).

Improvements in the performance of annual ryegrass

There was a rapid leap in the performance of annual ryegrass in the subtropics around 1975 with the introduction of 'Midmar' Italian ryegrass (marketed in Australia as cv. 'Aristocrat'), bred in South Africa (Goodenough *et al.* 1987). This cultivar was both higher yielding with better rust resistance (Lowe *et al.* 1983) than other commercial cultivars available at that time. The selection of 'Aristocrat 2' further improved rust resistance and yield (Lowe *et al.* 2007). Performance of NZ-bred ryegrasses has steadily increased and the best are now similar yielding to 'Aristocrat 2' (Fig. 2).

When a component of the selection process for annual ryegrasses occurs in a subtropical environment, there is a much greater chance of adaptation. For example, 'Grasslands Warrior' was bred by Dr Syd Easton of AgResearch, with selection for rust *in situ* in Queensland and this success has been repeated for other NZ breeding programmes. Fig. 2 demonstrates the advances made in the performance of new cultivars, with the older cultivars grouped on the left-hand side and the newer ones on the right (i.e. higher yielding). Cultivars falling close to a sensitivity of one will perform well under all environmental conditions while the distance above or below one indicates their reliability in good or poor conditions, respectively.

The role of perennial grasses in the subtropics

Few farmers now use perennial temperate grasses except for special situations (e.g. upland tropical area of the Atherton Tableland, sown every year). The newer cultivars of perennial ryegrass show substantial improvement in yield with up to 45% of the original population surviving for up to 3 years under cutting. However, this performance has not been duplicated under grazing. On the other hand, tall fescue cultivars have shown acceptable persistence for 3 years with the survival of most cultivars around 90% (on a basal area basis) in cutting experiments (Lowe *et al.* 2008) and around 70% under grazing (Lowe *et al.* 1999a).

Establishment of tall fescue in the subtropics is less of an issue than it is in the cooler environment of New Zealand. Indications from early research suggest that if tall fescue and perennial ryegrass were sown together, the tall fescue could suppress the invasion of C_4 grasses by expanding into areas previously occupied by ryegrass, particularly if cultivars with high seedling vigour (such as 'Dovey' or 'Quantum') are used (Lowe *et al.* 2009).

One problem with tall fescue is that, like New Zealand, Australian farmers believe that it is poorly utilised by dairy cows. There have been a many studies of this quality/management issue in the subtropics and they generally agree with experience in NZ. Callow *et al.* (2003) suggested a management regime where tall fescue-based pasture was defoliated every 2 weeks in summer and 4 weeks in winter, with autumn and spring intermediate to these. Using this schedule, forage quality of mixed tall fescue/perennial ryegrass/white clover pastures remained high throughout the year while pasture yield dropped by only 9% compared with pastures defoliated on a fixed 4-weekly schedule. The majority of this loss came from the white clover, rather than the grass component.

'Grasslands Matua' prairie grass is another option for the subtropics. Its persistence is inferior to tall fescue but survival is high because of its ability to seed and re-establish annually (Fulkerson *et al.* 2000). In a grazing study in northern NSW, Fulkerson *et al.* (2000) found that prairie grass gave superior DM yields and persistence over 3 years compared with perennial ryegrass and tall fescue, particularly on acid red soils. In milk production studies in south east Queensland, perennial ryegrass (cv. 'Yatsyn 1') was the most efficient temperate grass for milk production over 3 years, provided plant losses incurred each summer were replaced by oversowing (Lowe *et al.* 1999a). It produced more milk per kg of dry matter on offer than 'Concord' annual ryegrass, 'Grasslands Matua' prairie grass or 'AU Triumph' tall fescue (Table 3). However, milk production from prairie grass was not significantly different in all 3 years and, once efficient tall fescue management was achieved by Year 3, so had its performance. Over the 3 years, the milk production from all three perennial grasses was superior to that from 'Concord' annual ryegrass. Tall fescue was the only grass capable of being grazed year-round and to improve plant density over 3 years.

Improvements in the performance of perennial grasses

There has been an improvement in the performance of perennial ryegrasses in the subtropics, similar to that demonstrated in annual ryegrasses (Lowe *et al.* 2008). This improvement may be even more substantial when it is considered that most of the older cultivars (such as 'Grasslands Nui', 'Grasslands Ruanui' and 'Grasslands Ariki') were not compared with the newer cultivars in the analysis. Previous research has shown that they produced lower yields and had poorer persistence than 'Kangaroo Valley' perennial ryegrass (Lowe & Bowdler 1984), which only performed moderately in this analysis.

The most recent releases such as 'Tolosa', 'Horizon' and 'Fitzroy' have shown increased yields under cutting compared with 'Yatsyn 1', 'Banks', 'Ellett' and 'Embassy'. Rust resistance also appears to have improved. There is some evidence from more recent experiments in Queensland (Table 4) that newer tall fescue cultivars, bred in Europe, may bring about yield improvement compared with the current cultivars. There is also evidence that the performance of perennial ryegrasses improves moving south into the cooler subtropical areas of northern and central NSW (Fulkerson *et al.* 1993; T. Launders pers. comm.).

The presence of endophyte has improved the DM yield and persistence of both perennial ryegrass (Lowe *et al.* 2008) and tall fescue (D.E. Hume & K.F. Lowe unpublished data) under subtropical conditions. For perennial ryegrass, yield was improved by 18 and 11% and persistence by 210 and 190% for the standard and AR1 endophyte, respectively. Yields were higher in all seasons and differences in DM yield increased with pasture age. However, these improvements were not sufficient to make perennial ryegrass suitable for long-term pastures. The results were of a similar magnitude for tall fescue. In both species, improvements were achieved despite the lack of an important insect pest.

Clovers and lucerne

White clover is the most successful legume species in the subtropics, occurring naturally in wetter areas such as creeks and gullies. In rain-grown situations its growth is very seasonal. It relies mostly on the soil seed bank for annual regeneration, high seed production being an essential attribute for successful cultivars. While a number of overseas-bred cultivars produce high DM yields and, in some cases, have a higher stolon density, they have failed to replace 'Haifa' because of low seed yields. In many cases, this is exacerbated by insufficient irrigation in the summer, meaning stands deteriorate or die out. Disease, most likely stolon rots, do substantial damage and stands rarely last more than 2 years.

Lucerne is mostly sown in pure irrigated stands as a perennial forage producer of hay and silage or for grazing. While lucerne needs good drainage, it is sown on soils ranging from deep sands to moderately heavy clays. Disease is a major concern in the humid warm conditions, with resistance to crown rot (*Colletotrichum trifolii*) and root rot (*Phytophthora medicaginis*) essential for good yield and persistence, while leaf diseases (such as stemphylium leaf spot (*Stemphylium vesicarium*) and pepper spot (*Leptosphaelulina trifolii*)) can reduce hay quality (Irwin *et al.* 2001).

There was substantial improvement in the performance of lucerne after lucerne aphids arrived in Australia in 1977 with the release of locally-adapted cultivars in the early 1980s. Since then, there has been little further genetic gain (Irwin *et al.* 2001). Experiments conducted between 1978 and 1990 suggested that the mean yield of the experimental material increased by an average of 38% over 'Hunter River', the original Australian cultivar (Lowe *et al.* 2000). The use of winter active cultivars and the improvements in insect and disease resistance is the basis of this advancement (Lowe *et al.* 2009). The use of the ingression of *M. sativa* subsp. *falcata* genes and heterosis in single crop hybrids have not broken this hiatus in yield improvement but new research is suggesting that highly active *M. sativa* material from the Middle East or crosses with *M. arborea* from the Mediterranean region may be the answer to improved yields *per se* (Lowe *et al.* 2009).

The role of C_4 grasses

Kikuyu and 'Callide' Rhodes are the most important C_4 grasses for dairying in the subtropics, with a wider range of species utilised in the beef industry. Kikuyu has probably the widest distribution of all C_4 grasses in Australia, ranging from the south west corner of Western Australia, through South Australia and Victoria to the Atherton Tableland in north Queensland mainly in coastal and sub-coastal areas under better soil fertility. While kikuyu tolerates oversowing with temperate species during the cool season, Rhodes grass will not, despite both grasses spreading from runners. Kikuyu will quickly recover from the renovation and competition imposed by oversowing but Rhodes looses density and vigour, taking months to recover. Kikuyu needs to be well managed to achieve adequate milk production (Reeves 1996; Reeves *et al.* 1996) and to ensure good establishment of annual ryegrasses or clovers during the cool season. Currently, there is a project in Queensland using the biotechnological method called "Tilling" (Targeting induced local lesions in genomics) and molecular markers to select higher digestibility, lower lignin cultivars. Increased variability in the natural populations of 'Whittet' kikuyu have been achieved by treating with mutagenic chemicals.

Conclusions

Temperate species have improved dairy farming in the subtropics, increasing the reliability of cool season production. The winter and spring performance of annual ryegrass in the subtropics is equal or better than in cooler temperate climates. Temperate legumes produce more milk/kg DM and require less fertiliser inputs but are less suited to high stocking rates than grass/N systems. Perennial ryegrass struggles to achieve adequate production and survival and, to date neither new germplasm nor endophytes have provided the quantum leap in performance that is needed. Tall fescue cultivars and 'Grasslands Matua' prairie grass are more adapted than perennial ryegrass but tall fescue needs good management to be well utilised by dairy cattle. Irrigation is required for most temperate species; the alternatives are to grow cereal crops on stored soil moisture or use conserved fodder and silage, all with lower feed quality. Under the current milk supply system, mostly to the fresh milk market, the cost of growing temperate species can be justified economically. However, the main inputs, water and nitrogen, are increasingly under threat in their actual and environmental costs.

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