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Northern dairy feedbase 2001.
3. Winter pastures and crops

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Abstract

Pastures based on temperate species are essential so that the subtropical dairy industry can maintain an even flow of milk to factories throughout the year, and are critical in balancing lower quality roughages and cereal grains.

Available soil moisture is the greatest limitation to growing temperate pasture species in the tropics and subtropics although other factors like excess heat, low pH and waterlogging also limit production.

With effective irrigation and the ample solar radiation, very high DM yields can be obtained (>25 000 kg/ha DM) although persistence of perennial temperates is a problem.

Basic studies are being undertaken to understand the response of temperate species to the subtropical environment as a means of defining a more appropriate management system and acquiring more suitable plant material.

A broad program of breeding-selecting of grasses, forage crops and legumes is in place which should result in plant material more suited to the subtropics than the more temperate dairying areas. This needs to be ongoing. Appropriate selection criteria are still being defined but for perennials summer activity and resistance to heat are important and resistance to 'rust' is generally critical.

The emphasis has swung more towards clover–ryegrass from 'high N–ryegrass' pasture as appropriate pasture management techniques are developed for this type of pasture. The impetus for this move is the cost (of N fertiliser) and problems with acidification of soil.

Introduction

This review provides a precis of the agronomy of growing temperate pastures and crops in the subtropical/tropical dairying regions of Australia. The differences between this region and temperate regions as an environment for their growth are considered and the limitations to exploiting their apparent potential growth are highlighted.

Temperate pastures are the most common, and least expensive, forage source used to fill the winter–spring feed gap in subtropical dairying areas. In autumn, they may also supplement the declining forage quality of summer grass pastures. A recent Queensland Dairy Farm Survey (Anon. 1988) found that dairy farmers in SE Queensland grow 12 ha of ryegrass/farm or 0.25 ha/cow. Only 32% of farms irrigate more than 0.132 ha/cow with a further 17% irrigating 0.04–0.132 ha/cow, primarily to grow temperate pasture species. The situation in northern NSW is similar except that nearly 60% of dairy farmers irrigate pasture.

The pasture availability graph (Figure 1) shows the following points of interest:

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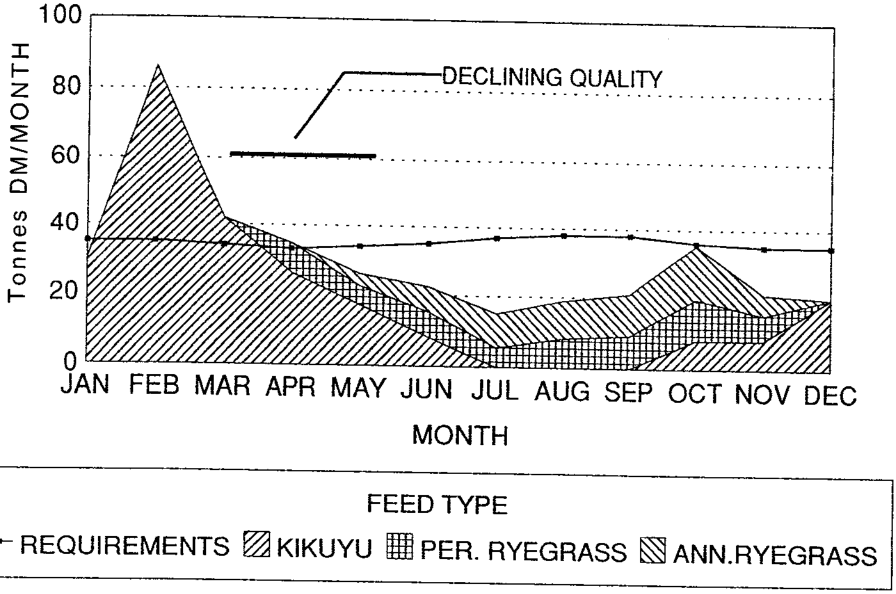


Figure 1. Pasture availability and feed requirements (t DM/month) on a typical dairy farm in northern NSW comprising 14 ha of ryegrass (6 ha perennial and 8 ha annual) and 50 ha summer-growing grass (usually kikuyu). Requirements are for 77 milkers and 45 replacements.

- The temperate species provide insufficient feed to fill the winter-spring feed gap on the typical farm.
- The deficit is usually made up by concentrates and/or loss of cow condition.
- There is no real surplus of temperate pastures for conservation on the typical farm.

The subtropics as an environment for winter-growing pastures and crops

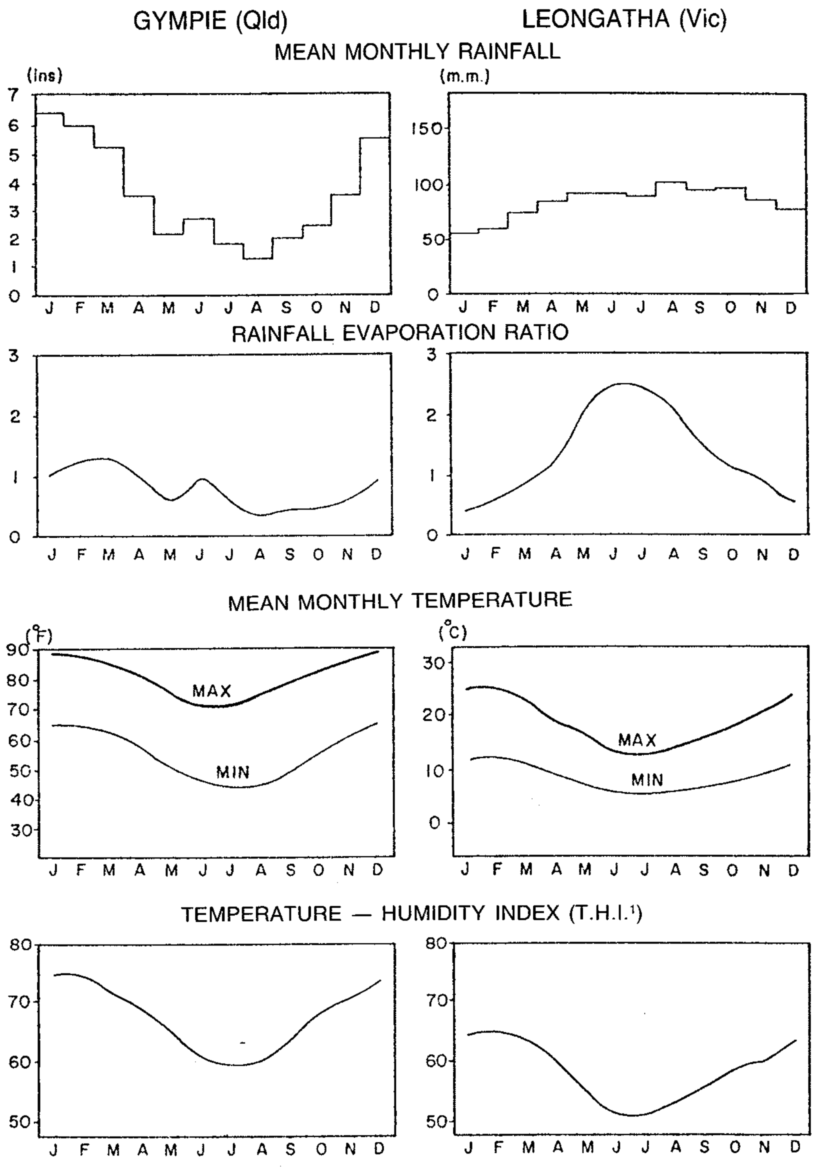
The subtropical region of eastern Australia extends from about Taree (32 °S) to Rockhampton (23 °S), and includes the tableland areas of Eungella and Atherton further north. The region is characterised by summer rainfall and cool to mild winters with some frosts.

Climatic constraints

Rainfall. Total rainfall varies from 700-2500 mm depending on location, distance from the coast, and elevation. Rainfall in summer ranges from 100-150 mm per month and in winter from 25-50 mm per month. Murtagh (1982) showed that the coefficient of variation of rainfall was greatest in June and July. This is in marked contrast to the rainfall pattern in temperate areas (Figure 2). RAINMAN (Clarkson and Owens 1991) shows that for Ipswich (southern, subcoastal Queensland), there was only a 48% chance of receiving 100 mm of rain in the 3 winter months (June-August) whilst in the 3 summer months (December-February) the chance of receiving the same rainfall was 99%.

The rainfall:evaporation ratio (Figure 2) indicates the effectiveness of rainfall received. In Gippsland, a typical temperate dairying district, moisture limits growth only from December-February. By comparison, at Gympie in the subtropics, there is only a period between January-March where moisture restriction on plant growth is unlikely. This problem is appropriately summarised by Mawson and White (1971) who wrote '*In the subtropics, pasture growth periods producing quality pasture are less predictable and of shorter duration because of higher evaporation, and higher rainfall intensity and variability*'.

Temperature. The major differences between temperate areas and the subtropics is the higher average monthly temperature in the subtropics and the greater diurnal and annual range. The optimum temperature for growth of temperate



¹T.H.I. = 0.55 (Mean Temp) + 0.2 (Dew Pt) + 17.5 (in °F) (Johnson 1965)

Source: Climatic Averages, Australia (Bureau of Meteorology 1956)

Figure 2. Seasonal trends in climatic elements for Gympie (Qld) and Leongatha (Vic.) (Mawson and White 1971).

species lies between 20-25 °C (McWilliam 1978) and as temperatures in the subtropics lie within this optimum range for much of the cool season, growth of temperate species is more likely to be optimised in winter-spring than in temperate areas.

Humidity. Humidity is higher in the subtropics, which affects both plant and pathogen growth. Figure 2 shows the seasonal fluctuations of the Temperature-Humidity Index between coastal south-east Queensland and Gippsland. The index is higher throughout the year in the subtropics but more so from November–February when major problems occur with the persistence of perennial temperate species, particularly the grasses.

Frost. Frosts occur from May–October with frequency and severity increasing with both distance from the coast and elevation. Coastal areas average 20, and elevated areas 50, frosting days per annum. Although frosts can result in foliar damage to some lucerne (*Medicago sativa*) cultivars and oats (*Oryza sativa*) and can damage the autumn and early spring growth of tropical grasses, generally there is little damage to temperate species.

Edaphic limitations

Soils. Soils range from extremely arable clays to infertile duplex soils, with a large range of fertility levels. Availability of irrigation is probably the most critical factor which dictates the soils used for the production of winter forage; the alluvial clays and clay loams along rivers are generally chosen. However many farms are now irrigating from farm dams, which widens the choices of soil to be used. Red volcanic soils on tableland areas are also used for temperate pasture and crop production, with or without irrigation. Infertile, duplex soils are usually used only for raingrown pastures with a white clover (*Trifolium repens*) component and generally only in the southern section of the subtropical zone where a higher winter rainfall component is received.

There are two major restrictions to growth of temperate species on irrigated soils. Firstly, pH is generally neutral to slightly acid on these soils but the practice of applying large amounts of nitrogen fertiliser has reduced pH (Reason *et al.* 1989). On the heavy alluvial clays, this reduction is still small and pasture growth is unlikely to be affected (Cowan 1991). On the red volcanic soils, pH has been reduced to levels which affect growth (R.G. Walker, personal communication). There is a need to evaluate and monitor the effect of continued application of high rates of nitrogen on soil pH, nutrient availability and its effect on the environment. Secondly, soil compaction from cattle grazing on wet soil has a major effect on pasture growth. Lowe *et al.* (1992) have shown that damage can result in a reduction of temperate pasture yields and that this reduction can last well into the next growing season, especially if direct drilling is practised for the establishment of annual pastures.

Soil fertility *per se* is not a restriction for irrigated pastures as the high returns from such pastures justify the application of the necessary fertiliser inputs. On the other hand, the raingrown situation needs attention. The interaction of nutrition, particularly phosphorus, and cultivar adaptation needs to be investigated if white clover is to fulfil its potential in the subtropics (Jones 1987).

Topographical limitations. The distribution of naturalised white clover is restricted to the moist coastal strip, and the higher-altitude, wetter areas of the Darling Downs. It is also found in better watered and more mesic valley areas of the subcoastal districts and in isolated tableland districts (Jones 1987). Elevated areas are cooler and less prone to moisture stress than the subcoastal lowland areas and this is borne out by the performance of these species on the New England plateau region. There is some evidence, from a survey of sowings of clover associated with tropical species in the late 1960s, that persistence of white clover was better on the southern, rather than northern slopes (Lowe *et al.* 1986).

Selection and breeding

Experience with temperate species has shown that there are contrasting requirements for production and persistence in the subtropics compared with temperate environments. Higher temperatures (and higher radiation levels) during the cool season result in higher growth rates than those recorded in temperate environments but during summer also result in greater stress, increased disease pressure, depressed growth rates, greatly increased mortality rates and competition from C_4 summer-growing grasses.

The following criteria need to be addressed if cultivars are to be adapted to the subtropics:

Primary breeding goals

Rust resistance. Rust is the most damaging disease on perennial and annual ryegrasses (*Lolium* spp.) and winter cereals, particularly oats, and plays a lesser role with other temperate grasses and legumes. Performance of annual ryegrasses has been highly and positively correlated with resistance to rust in coastal south-east Queensland (Lowe *et al.* 1993). It is therefore essential that ryegrasses selected for subtropical environments are highly resistant to rust.

Current research indicates that annual ryegrasses generally have a higher degree of rust resistance than perennial ryegrasses although the variation found in both is large. This suggests that considerable progress is possible from the current gene pool. The resistance of oat varieties is generally controlled by a single gene. This makes breeding and selection difficult as resistance can quickly break down with a change in the races present in the rust population. Rust resistance in ryegrass is more complex and appears to last longer. For example, the resistance in Midmar and Aristocrat ryegrasses has remained largely intact for close to twenty years.

In oats, rust is a complex of many races and the proportions of these change with time. The races are identifiable and the reaction of varieties to each is known. However there is no comparable information for ryegrass. This basic information is essential if rust in ryegrass is to be controlled.

There is considerable variation in rust susceptibility within cultivars of *Festuca arundinacea* and most cultivars of *Dactylis glomerata* are badly affected. However rust has not been recorded on *Phalaris aquatica* cultivars in the subtropics. Rust can seriously affect the performance of *Trifolium resupinatum* (Persian or shaftal clover). Newer selections are more seriously affected than the older cultivar, Maral, so disease screening must be considered in any selection program.

Improved summer growth. Early research on the persistence of perennial temperate pastures in the subtropics indicated that poor summer growth was a major limitation to their use on farms. Firstly, it allowed the ingress of summer-growing grasses which then provided severe competition. Farmers were also reluctant to apply the frequent irrigation required to maintain persistence because the pastures were contributing little to milk production at that time. In turn, this allowed such factors as heat stress and rust to further weaken the grass stand allowing more weed grass invasion. The greater summer growth of fescue cultivars such as Demeter and Alta improved the summer performance of permanent temperate pastures (Lowe and Bowdler 1984) but their poor quality, especially when mature, restricted their use. Increased summer and autumn production from perennial ryegrasses is a means of extending the usefulness of these pastures, both in terms of better summer grazing, better suppression of weed ingress and a justification for better summer irrigation management.

Secondly, selecting fescue cultivars with better forage quality attributes and better animal acceptability is an alternative option. White clover also suffers from summer grass competition; a more aggressive white clover would increase its contribution to yield earlier in the life of the stand and increase its competitiveness during summer.

Production. The ability to produce high yield, particularly in winter–spring, still remains of paramount importance in selecting cultivars for the subtropics and persistence and disease resistance must be combined with high yield potential.

Dryland vs irrigation. While the majority of temperate dairy pastures in the subtropics are grown under either supplementary or full irrigation, considerable areas are grown under rainfed conditions, particularly in the southern extremities of the zone. These situations require additional selection criteria; *e.g.* seeding ability, root and stolon survival and stolon density.

Therefore the **primary breeding goals** for cultivars for the subtropics are:

(a) rust resistance (annual ryegrass, perennial ryegrass, fescue, persian clover),
(b) winter–spring yield (annual ryegrass, perennial ryegrass, white clover), and
(c) summer survival and growth (perennial ryegrass, white clover).

Secondary breeding goals

Heat tolerance. Although extremes of temperature can occur in both temperate and subtropical environments, average daily maximum temperatures are much higher in subtropical areas. Therefore, it is essential that all temperate species selected for use in the subtropics be tolerant of heat stress. The growth and tiller development of temperate grasses are reduced at higher temperatures (Wilson and Ford 1971) and when this is combined with water stress, growth virtually ceases (McWilliam 1978). Temperate legumes appear to have a higher temperature requirement than temperate grasses in general (Mitchell and Lacanus 1962) and particularly during establishment (R.J. Moss, personal communication; G.D. Chopping, personal communication).

Nitrogen requirements. There is a link between the nitrogen status of the temperate grass component, particularly over the summer period, and persistence. Research by Cameron *et al.* (1969) showed the value of strategic applications of nitrogen in maintaining a *Bromus unioloides* (prairie grass) pasture component without reducing the clover component. Low nitrogen status has been linked to lower persistence of perennial ryegrass in northern NSW (Fulkerson *et al.* 1993). Rust damage as a consequence of N deficiency can be severe and may be one mediating factor of N on plant survival. Low nitrogen status over the first summer appears to be due to a lag time in nitrogen being transferred from the clover component to the grass until late in the summer or autumn (K. Lowe, unpublished data). While nitrogen status may not affect the susceptibility to infection of the grass, it appears to influence the damage which results from the infection. Thus, selection needs to be conducted under both low and high nitrogen levels. Selecting cultivars of white clover that are quicker in releasing nitrogen to the grass, or that produce greater quantities of symbiotic nitrogen under subtropical conditions, should be a priority.

Rooting depth. A major limitation of perennial ryegrass in northern NSW is 'sod pulling' where grazing animals pull out the entire plant during grazing. This has been related to shallow rooting on heavy clay soils. However, it has also been reported on volcanic red soils on the southern Queensland tableland areas. The phenomenon is particularly associated with the cultivar, Ellett. Research has demonstrated that this can be exacerbated by nitrogen fertiliser (Fulkerson *et al.* 1993). Further work is necessary to pinpoint the cause of this problem, particularly whether it is associated with irrigation management or insect damage or whether it is cultivar specific and whether cultivar selection may be useful.

Humidity. High humidity is a feature of subtropical environments so any species which is used in the subtropics needs to be able to tolerate high humidity. High humidity and temperature favour the rapid development of pathogens; in the case of temperate grasses and winter cereals, rust is the most damaging. Little research has been done to separate the effects of high humidity and high temperature on the growth of temperate species as they do not coincide in temperate environments.

In general, infection of ryegrass plants with the endophyte, *Acremonium holii*, improves its vigour by deterring attacks by various pathogens (Argentine stem weevil, Prestige *et al.* 1992) but also by an allopathic effect on other components of the pasture including weeds (Valentine 1992; Foot *et al.* 1992) and perhaps summer grass (W. Fulkerson, unpublished data). There is also a report from Dalby in Queensland where the use of Concord ryegrass in a paddock has subsequently suppressed the establishment of a widely distributed grass weed (D. Gladman, personal communication). Allopathic inhibition of summer-growing grass could play a major role in improving ryegrass persistence in the subtropics if this effect could be established.

The **secondary breeding goals** differ in their importance, depending on the pasture species being considered. The role that some play in the subtropics has yet to be firmly established. In some, such as rooting depth and heat tolerance, research programs in temperate areas may adequately satisfy subtropical needs. Others, such as humidity and endophyte, may require basic research to firmly establish the role they play in species performance in the subtropics.

Establishment

In this section the establishment and initial maintenance of temperate pasture will be considered. Some types are in common use, while others are in various stages of evaluation.

Annual pastures

These pastures are either annual or biennial ryegrass (cvv. Concord, Aristocrat, Tetilla etc) or annual clovers (*Trifolium subterraneum, Trifolium resupinatum* and *Trifolium alexandrium*) to provide early feed. They are usually resown directly on to a summer grass base pasture each year at relatively high seeding rates (25–40 kg/ha) to provide early feed.

To have pastures ready to graze in May, they need to be sown in late March–early April. If a conventional seedbed is required, preparation needs to start in early March. This is often difficult due to wet and waterlogged conditions and the reluctance of farmers to lose potential growth from summer-growing grass pasture.

Zero or minimum-till technology. The use of zero or minimum-till technology to establish winter pastures and forage crops overcomes some of the problems outlined above. Additional benefits offered by zero or minimum-till technology include (Anon. 1984):

- Less fuel and labour.
- Summer grass pasture can grow longer into winter.
- Weed problems are minimised in the undisturbed soil (e.g. fireweed).
- Firmer paddocks underfoot permit earlier grazing or machinery movements in wet weather.
- Delays in conventional seedbed preparation are overcome.
- Reduced risk of soil erosion.

Features of such technology are direct drilling, surface sowing into uncultivated or lightly tilled ground, and herbicides to suppress existing grasses (Moore 1987).

If direct drilling is used early in the season, summer grasses need to be checked with herbicide. If sowing later in the season, hard grazing, slashing or mulching can be sufficient check for summer grasses to allow establishment of temperate species. Where herbicide is not used to suppress the perennial summer grass, temperate species cannot be sown successfully into uncultivated ground until May.

Temperate pasture species sown into uncultivated seedbeds often display slow early growth compared with similar plants in prepared seedbeds. Improved seed-soil contact and mineralisation of nitrogen and sulphur during cultivation are regarded as the factors responsible for the improved growth in cultivated seedbeds (Moore 1987).

Lack of suitable direct-drill sowing machinery at an affordable price forces farmers to rely on contractors, and sowings cannot always be made at the optimum time and conditions.

Perennial pastures

Minimum tillage has not generally been used to establish perennial ryegrass pastures, since herbicide (e.g. glyphosate) gives insufficient long-term control of competitive summer grasses, particularly couch. Perennial ryegrasses sown into a well prepared seedbed usually persist for up to 3 years.

High ryegrass/High N. Commonly 30-40 kg/ha perennial ryegrass (cvv. Yatsyn, Ellett or Kangaroo Valley types) plus white clover is sown into a fully prepared seedbed. At this seeding rate, clover makes little or no contribution in the first year and therefore urea needs to be applied at 100-120 kg/ha/month.

Low ryegrass/Nil N. At sowing rates of 15-20 kg/ha perennial ryegrass plus white clover, the sward has a good balance of grass and clover and only needs strategic application of urea during the winter and spring of its establishment year.

Perennial legume/Tropical grass-based pasture. Establishment and maintenance of winter growing legumes like *Trifolium repens* and *Lotus pedunculatus* into a kikuyu-based pasture as a perennial source of winter feed is being evaluated at Wollongbar. This pasture can be established reliably by surface sowing approximately one month before onset of frost. The system relies on appropriate fertiliser input (P, K and Mo and perhaps S), irrigation (see below) and management. Appropriate management after establishment seems to be to stop kikuyu shading clover either by heavy follow-up grazing or mulching in autumn.

Characteristics of the various pasture types are outlined in Table 1.

Assumptions for Table 1

- Maintenance costs include irrigation @ $120/ha (conventional travelling irrigator).
- Perennial ryegrass persists for 3 years and winter legumes persist for at least 4 years.
- Urea applied at 120 kg/ha to all types of pasture at sowing and on a monthly basis for type 1 and 4 and strategically for type 5.
- Bloat control is costed at $10/cow for types 2, 5 and 6 (@ 4 cows/ha).
- Cost of mulching for type 6 is $40/ha.
- Types 1-3 and 6 oversown into summer-growing grass pasture.

Table 1. Types of temperate pasture, major characteristics, establishment items and costs of establishment and maintenance.

		Establishment items							
		Seed (kg/ha)		Fertiliser (kg/ha)				Costs ($/ha)	
Pasture type	Comments	Clover	Ryegrass-oats	Super phosphate	Urea	Muriate of potash	Land prep. ($/ha/yr)	Estab.	Maint.
Annual									
1. High ryegrass-high N	Early feed Highest total DM	—	35	100	100	—	30	200	439
2. High density clover	Higher quality Nil N fertiliser Spring growth peak Bloat control needed	20	—	100	100	50	30	195	160
3. Oats	Early feed Lower quality	—	70	100	100	—	30	120	—
Perennial									
4. High ryegrass-high N	Early feed High total DM	4	35	100	120	50	30	235	476
5. Ryegrass-clover	High quality Reduced N fertiliser Reduced soil acidification Lower maint. costs Bloat control needed	4	15	250	100	100	30	135	326
6. Winter legume	Nil N fertiliser Reduced estab. costs Lower maint. costs Higher quality Bloat control needed	4	—	250	100	100	30	31	274

Establishment costs

Table 1 gives typical costs for establishing temperate pastures in the subtropics.

Recommendations on establishing pasture are well accepted and successful and further research effort in this area appears unwarranted at this stage.

Management required to maintain productive pastures

An appropriate management system for temperate pasture species in the subtropics–tropics must address the problems of severe competition from C_4 summer-growing grasses and climatic extremes of dry spring and hot, humid and wet summer–autumn. The management practices developed for temperate pastures reflect attempts to overcome these problems and limitations.

Grazing management

Grazing management for perennials has emphasised growth and utilisation and also persistence. In general, the 'harder' the grazing the more feed is utilised, but there is a limit which probably depends on season and perhaps cultivar or variety and needs to be defined more closely. Most dairy farmers in the subtropics grow insufficient temperate pastures and often overgrazing is the problem.

Duration of grazing is critical as continuous grazing by stock beyond 48 hours will severely deplete reserves and depress subsequent regrowth in an environment where pasture growth seldom falls below 30 kg DM/ha/d. Recent studies indicate that regrazing after 3 days reduces regrowth by more than 20% (W. Fulkerson, unpublished data). Extending the duration of grazing a ryegrass–clover pasture from 1 or 3 days to 6 days reduces growth by 40% in spring in Tasmania (Michell and Franks 1992).

Interval between grazings is optimised by defoliating before onset of senescence and this can be seen in the field in ryegrass by referring to leaf number. This interval may be too long if the sward lodges (shading), rust sets in or stock are unable to utilise the extra pasture growth effectively. With clovers, onset of senescence of the lower leaves is also an indicator of when to defoliate (Fulkerson *et al.* 1993) but more basic work needs to be done in this environment on the ecology of ryegrass–clover associations.

Irrigation

Figure 3 shows the required irrigation schedule (days) for ryegrass and kikuyu grown on the NSW north coast, based on mean evapotranspiration figures, a root zone of 30 cm for ryegrass and 60 cm for kikuyu and soil holding 25 and 50 mm available water, respectively (C. Rolfe, personal communication).

This illustrates the inadequacy of present systems of irrigation which apply water by travelling irrigators every 14–21 days and thus severely restrict growth through moisture deficit. Even in mid-winter, 14-day watering intervals barely suffice and in spring 5–6-day intervals are necessary.

Long lateral systems of irrigation are being refined for this environment. These can irrigate down to 4-day intervals at about half the energy cost of travelling irrigators.

Clover is more sensitive to low temperatures and if clover-dominant pastures are restricted by lack of moisture in spring, their growth, relative to potential, will be more markedly affected than ryegrass. This is one reason for the more variable production of clover on a within-season and between-season basis, claimed by farmers, and one reason why they resist using more clover.

Fertiliser

In general, appropriate fertiliser requirements for optimum growth of temperate pastures are known and should be based on providing adequate levels of nutrients as indicated by soil analysis.

Waterlogging and pasture drainage

In recent studies (W. Fulkerson and K. Slack, unpublished data) prolonged waterlogging (4–5 weeks) reduced pasture growth by only 18% but regrowth after grazing was reduced by 73% indicating the importance of keeping stock off

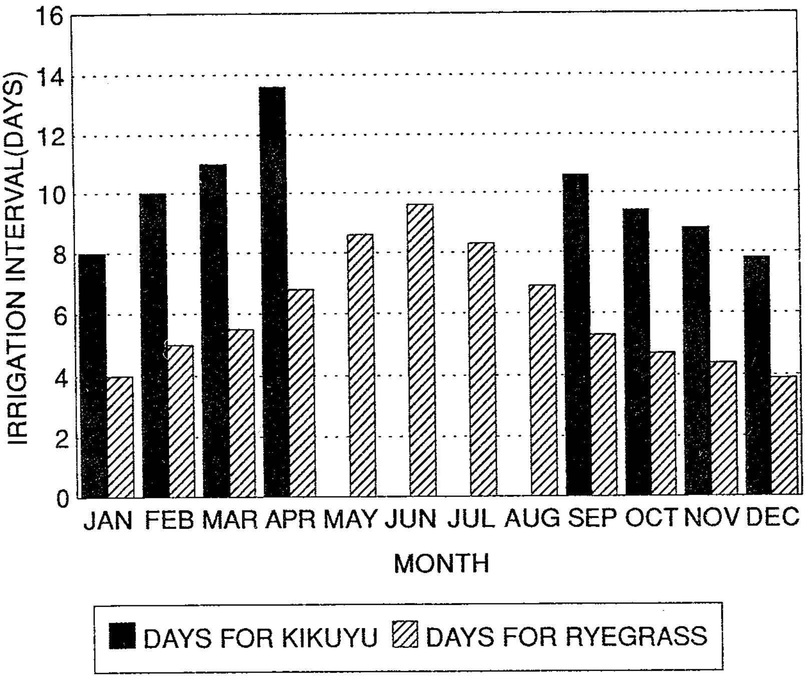


Figure 3. Appropriate irrigation interval (days) for ryegrass and kikuyu on the clay floodplains of northern NSW.

waterlogged pasture. The only way to cope with this is to have fodder reserves and an appropriate facility for feeding (feed pad).

Management for perennation

Although total yield is high, perennial ryegrass often lasts only 2 years, needs to be oversown in the third (usually with annual ryegrass) and re-established in the fourth. As a consequence, nearly all Queensland, and over 80% of nothern NSW dairy farmers use annual ryegrass pasture. The need to resow ryegrass each year or perennials every 3 years results in a severe autumn feed gap, as these pastures re-establish and summer grass pastures decline in quality and quantity.

After establishment of a perennial ryegrass pasture, plant numbers typically decline during the establishment year to a stable population in the first spring but then fall again over the summer with invasion by summer-growing grasses (see Figure 4).

Several factors influence plant survival over the critical first summer:

- Increasing defoliation interval over winter-spring from 2 to 4 weeks has been shown to increase ryegrass survival by 20% and reduce summer grass infestation to 39% (Fulkerson *et al.* 1993) and this is considered to be due partly to development of a better root system and perhaps a higher build up of plant reserves (Weinman 1961). The mechanism of action of grazing management on ryegrass-clover survival needs to be resolved.
- Application of N increases plant survival under cutting (Fulkerson *et al.* 1993), but N restricts root development to the soil surface and therefore, under grazing, sod pulling by stock may nullify any beneficial effect of N. Sod pulling

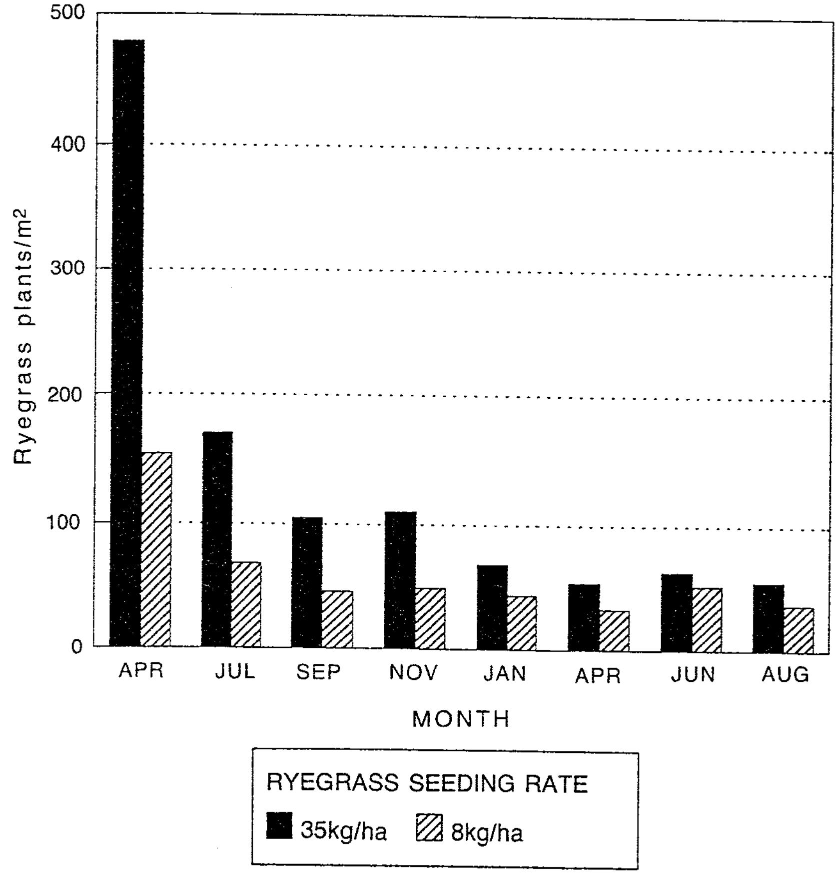


Figure 4. Change in plant density/m^2 from sowing (April) to the spring of the second year for ryegrass at seeding rates of 35 and 8 kg/ha.

has been seen to severely reduce plant population with a loss of 30% of plants at each grazing not being uncommon (see also Thom *et al.* 1986). This impact of N on plant survival needs to be evaluated under grazing situations.

- Appropriate grazing and irrigation management for the subtropics in summer for persistence (and production) is largely unknown, although Thom *et al.* (1986) reported an effect of grazing interval in summer on ryegrass persistence in competition with *Paspalum dilatatum*. It is not even clear whether summer grass invasion is a consequence of loss of ryegrass plants or is the cause of it, or both. Field observations do indicate that a 'closed' canopy of temperates over summer reduces summer grass invasion. Such a practice may prevent summer grasses establishing in a shaded understorey and would reduce soil temperature.
- The ryegrass cultivars commonly used (Ellett, Yatsyn) produce few reproductive tillers in the subtropical environment (presumably due to inadequate vernalisation during the relatively warm winters) and the few seeds set would have little chance of survival under present management. Therefore, obtaining new ryegrass plants through natural seeding seems unlikely.
- The impact of rust and low soil pH (Fulkerson *et al.* 1993) are factors that could also mitigate against persistence and which need to be evaluated.

Plant survival in relation to management practices has received little attention to date but even in the temperate dairying areas, persistence problems are causing concern.

Pasture yields

The yield produced by winter-growing forages is dependent on a number of factors including location, forage type, cultivar, establishment method and management (particularly irrigation).

Location

The potential production of annual temperate pastures varies considerably at various locations in the subtropics and tropics (Table 2). Seasonal variation in temperature and length of the growing season are the main reasons for the differences. For example, the low values at Ayr reflect competition at the beginning and end of the growing season from existing summer grass pasture into which the temperate species were sown. The lower potential on the Darling Downs is related to the colder night temperatures.

Comparative performance of species

Within the species groupings, cultivar differences are important; evaluation processes have highlighted the differences in pasture and milk yield which can be expected from cultivars adapted to the subtropics (Lowe *et al.* 1983; 1985). This is particularly highlighted by differences in yield of perennial ryegrasses in south-east Queensland. There is a progressive increase in annual yield from 15 t/ha from a rust-susceptible, winter-active and poorly adapted cultivar such as Victorian perennial, through 20 t/ha for Kangaroo Valley to 25 t/ha for an adapted, rust-tolerant and more summer-active experimental line (K. Lowe, unpublished data). The search for better adapted cultivars will be an ongoing one

Table 2. Total annual growth (t DM/ha) of irrigated, high-seeding-rate Concord annual ryegrass and Persian clover pastures in the subtropics and tropics.

Location	Grass	Legume	Reference
Central coastal NSW	15	12	T. Launders (unpub. data)
Northern coastal NSW[1]	16	14	W. Fulkerson (unpub. data)
South-east coastal Queensland[3]	25	15	K. Lowe and T. Bowdler (unpub. data)
Subtropical highlands (Darling Downs)	15	12	R. Chattaway (pers. comm.)
Tropical lowlands (Ayr)[2]	7	9	Goodchild *et al.* (1982)
Tropical highlands (Atherton Tableland)	11	10	R. Walker (pers. comm.)

1 Data for northern coastal NSW are for Yatsyn perennial ryegrass and Haifa white clover.
2 Data for Ayr are for Tama ryegrass and Clare subterranean clover.
3 Located on research station.

because adaptation can be lost as a result of genetic drift or the breaking down of disease resistance.

Annual nitrogen-fertilised ryegrasses under adequate irrigation have the potential to give the highest yields in the subtropics (Table 3). Annual grass–legume mixtures from high density sowings of annual legumes are lower yielding but produce more milk due to better quality (Moss *et al.* 1987).

Table 3. Total annual yield (t DM/ha) of winter forage crops from experiments conducted in south-east Queensland (K. Lowe and T. Bowdler, unpublished data).

	Irrigated	Raingrown
Aristocrat ryegrass (400 kg N/ha)	29	—
Persian clover (pure stand)	15	—
Yatsyn-Persian clover (100 kg N/ha)	17	
Yatsyn perennial ryegrass (400 kg N/ha)	19	—
AU Triumph fescue (400 kg N/ha)	25	
Yatsyn-white clover (100 kg N/ha)	18	—
Trifecta lucerne	23	15
Culgoa oats (300 kg N/ha)	16	9

Nitrogen-fertilised perennial temperate grasses are lower yielding in the first 6 months (April-September) but are capable of yields equivalent to the annuals over a full 12-month period. When grown with white clover, the grass yield is considerably lower but total yield is similar (Table 4) because of the contribution of white clover. Selection for more adapted cultivars, improved nitrogen transfer from the clover component and improved management strategies may improve overall performance of perennial pastures. For example, recent cut-plot trials by Fulkerson *et al.* (1993) indicate that ryegrass–clover pastures can produce up to 85% of high ryegrass–high N pastures (12 900 vs 15 500 kg DM/ha) with appropriate irrigation, fertiliser and grazing management. Furthermore, grazing studies have shown a 12% yield advantage in favour of clover–ryegrass pasture over ryegrass–N pastures (W. Fulkerson, unpublished data) for the May–November period under appropriate irrigation and grazing management.

Table 4. DM yields in the establishment year of pastures sown to 35 or 8 kg perennial ryegrass and 4 kg Haifa white clover/ha (Fulkerson *et al.* 1993).

Pasture type	Seeding rate for ryegrass (kg/ha)	Yields (kg DM/ha)	
		Sowing to Aug	Sep to Nov
Ryegrass dominant	35	5 600	9 800
Clover dominant	8	2 700	11 200

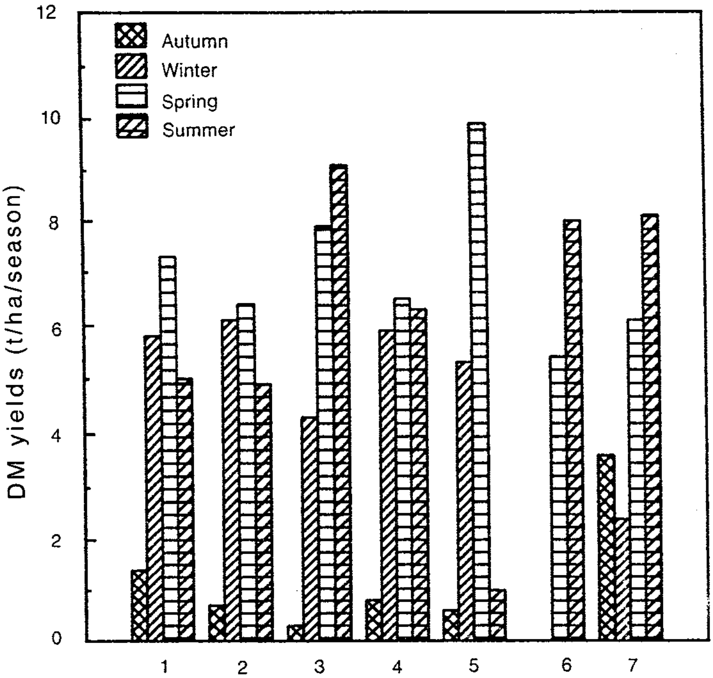
Recently, attempts have been made to establish and maintain winter-growing perennial legumes (*Trifolium repens* cv. Haifa; *Lotus pedunculatus* cvv. Maku and Sharnae) into a kikuyu sward. Production in the establishment year to the end of November 1992 was 11 200 kg DM/ha (Fulkerson and Slack 1993).

Except in the southern extremity of the region, forage oats is the only reliable form of winter feed under rainfed conditions. The new varieties, Amby and Culgoa, are grazing tolerant and have a long growing season and therefore will improve the reliability of this feed source. Culgoa is resistant to current rust strains but Amby has already shown susceptibility to a new strain.

Most farmers will not achieve the yields shown in Table 3 under commercial conditions because of lower inputs and less exacting management. It is estimated that farmers' yields are 50–70% of the above values. While the yields in Table 3 have generally been obtained under optimum conditions from small plot research, it still suggests that there is potential for improvement by a well targeted extension program.

Although total production is important for temperate species, seasonal distribution must be considered (Figure 5). Spring yield was highly correlated with overall yield of annual ryegrasses in the subtropics and therefore should be used as a criterion, along with rust resistance, for selecting potential cultivars (Lowe *et al.* 1993).

Summer production may be an important criterion for perennial temperate grasses as it justifies the better water management required to maintain plant survival and overall persistence (Lowe and Bowdler 1984). For this reason, the fescues appear a good possibility for perennial pastures, provided that animal acceptance–forage quality problems have been overcome with the more recently available cultivars. This aspect is currently being investigated at Mutdapilly Research Station with a grazing comparison of Yatsyn ryegrass, AU Triumph fescue and Matua prairie grass. Highly winter-active lucerne cultivars are suited to dairying in the subtropics as they are capable of growth rates of 10–40 kg/ha/d in winter, while maintaining rates of 60–80 kg/ha/d for the rest of the year.



1. Concord annual ryegrass (sown early April)
2. Yatsyn 1 perennial ryegrass (sown early April)
3. A U Triumph fescue (sown early April)
4. Experimental summer-active perennial ryegrass (sown early April)
5. Persian clover–annual ryegrass mixture (sown early April)
6. Trifecta lucerne (sown mid-June) (first year production)
7. Trifecta lucerne (second year production)

Figure 5. The seasonal production of irrigated pasture at Gatton, south-east Queensland.

The lower seedling vigour and higher temperature optima of clovers reflect the different seasonal distribution of growth of 'ryegrass-dominant', compared with 'clover-dominant' pastures (see Table 4).

The 'ryegrass-dominant' pasture provides early feed while the 'clover-dominant' pasture achieves a higher spring peak.

Response to nitrogen

Yields of annual ryegrass increase linearly with applied N up to 100 kg/ha/cut (K. Lowe, B. Robinson and R. Walker, unpublished data). Currently, research is proceeding to further elucidate these responses and to determine the effects on clover present in mixtures. Recovery levels of nitrogen by the ryegrass crop need to be determined to estimate the efficiency of utilisation to counter adverse publicity and environmental concerns.

Lowe *et al.* (1980) found that oats responded linearly to applied N up to 67 kg N/ha/cut under irrigation and 34 kg N/ha/cut under raingrown conditions. About 35–60% of the nitrogen applied was recovered, the recovery being influenced more by seasonal conditions than the total amount of water applied to the crop.

There have been few studies to determine the requirements of the intensive, N-fertilised ryegrass and ryegrass–clover systems for nutrients other than N, particularly phosphorus and potassium although the requirements of white clover have been determined (Rayment and Bruce 1979;

Bowdler and Piggott 1990). Extension officers have preferred to recommend luxury rates to satisfy potential usage as indicated by plant and soil analyses and growth potential (Rayment 1983; Rayment and Bruce 1984). In the future, economics and environmental considerations will dictate that only sufficient fertiliser to meet crop needs should be applied and this will require more detailed research. Sulphur requirements on the heavy soils have been adequately investigated (Dickson and Asher 1974; Bowdler and Piggott 1990; G.M. Hawley, personal communication).

Forage quality of temperate pastures in the subtropics

Milk production from dairy cows grazing subtropical pastures is low compared with temperate pastures (Stobbs 1971a). The primary nutritional factor limiting milk production is low energy intake associated with low digestibility (Jeffery and Holder 1971; Stobbs 1971b). Temperate grass and legume species are integrated with basal summer grass pasture to provide an overall improvement in feed quality and to offset the winter-spring feed gap.

Recommended dietary allowances

The following generalised nutritional ideotype is widely accepted: structural carbohydrates low and readily fractured; soluble carbohydrates high and in balance with amino acids; protein with low rumen degradability; lipids up to 15 per cent of DM to provide high efficiency of utilisation; and condensed tannins approximately 6 per cent of DM to bind plant proteins and provide a bypass effect (Black 1985). For a 600 kg Friesian cow at pasture consuming 16.6 kg DM/d and producing 18.8 kg milk/d, dietary allowances are 0.75 dry matter digestibility (DMD), 21.6 g N/kg DM, 4 g Ca/kg DM, 3.2 g P/kg DM, 5 g K/kg DM and 1.9 g Mg/kg DM (Feeding Standards for Australian Livestock 1990). These values provide a reasonable benchmark to assess the quality of alternative feeds although there are slight differences with ARC (1980; 1984) and NRC (1985) standards.

The nutrient status of basal pasture and alternative temperate species

Examination of about 5 000 records (J. Ayres, unpublished data) from the NSW subtropics provides data (Table 5) to assess the quality of basal pasture and to compare alternative temperate pasture species and forage crops.

Basal summer grass pasture (kikuyu, paspalum, carpet grass). At no time during winter-spring does this pasture meet energy requirements. The digestibility of kikuyu and paspalum is between 0.58–0.68, and for carpet grass is between 0.46–0.55 during June–September with a maximum value of 0.64 in October. The nitrogen concentration of kikuyu is between 23–30 g N/kg DM and exceeds requirements. However, carpet grass (5–17 g N/kg DM) is consistently nitrogen-deficient and paspalum provides sufficient nitrogen only in late spring. The phosphorus and calcium concentrations of kikuyu (2.5–3.5 g P/kg DM; 3.5–4.6 g Ca/kg DM) are marginal. For

Table 5. The apparent deficiency status of basal subtropical pasture (N-fertilised kikuyu) and alternative temperature species in winter–spring.

	Jun	Jul	Aug	Sep	Oct	Nov
Kikuyu	E[1] Ca 7[2] 28	E Ca 6 17	E Ca 15 8	E Ca P 9 9 13	E Ca 4 36	E Ca 9 28
Forage Oats	n/a[3]		P 6	P 7	N Ca P 2 3 2	n/a
Forage Lupins	E P 3 9	E P — 18	E P 1 22	E P 7 19	E N P — 4 4	n/a
Ryegrass		Ca 4	Ca P 1 6	Ca P 2 6	E P 95 4	E P 123 6
White Clover		Ca P 1 1	P 5	E P 7 10	P 7	

[1] Denotes limiting nutrient (E: energy, N: nitrogen, Ca: calcium, P: phosphorus).
[2] Denotes number of data records. [3] Not available for grazing.

paspalum and carpet grass, the phosphorus status is grossly deficient. Without supplementation these pastures are not capable of providing for more than 10 l milk/cow/d (Jeffery and Holder 1971).

Oats (common oats, Saia oats). The only digestibility data for common oats is a value of 0.75 in September with Saia oats having a digestibility of 0.81 in August (Lowe and Bowdler 1988). Nitrogen concentration in common and Saia oats is 19–51 g N/kg DM with progressive decline to a marginal deficiency in October. Calcium concentration is 2.5–11.6 g Ca/kg DM declining to deficiency status in October. Phosphorus level is 1.9–3.1 g P/kg DM with values substantially below requirements in August–October. The values for potassium and magnesium are in excess of requirements except for a marginal magnesium level in October.

Legume forage crops (lupins, vetch). The digestibility of lupin forage is 0.60–0.68 during winter–early spring and declines to low levels in October. Nitrogen concentration is 19–35 g N/kg DM with a marginal deficiency level in October. Phosphorus is deficient at all times (1.3–2.5 g P/kg DM). Other minerals are non-limiting (6.3–8.0 g Ca/kg DM; 11–18 g K/kg DM; 2.5–3.2 g Mg/kg DM). Data for vetch are meagre with the exception of nitrogen (28–35 g N/kg DM); the calcium and phosphorus concentrations in vetch generally exceed those in lupins.

Oats or lupins do not fully offset the nutritional limitations of basal pasture. Both crops are available for only short periods of grazing (oats: July–October; lupins: June–September); lupins are persistently limiting in available energy and phosphorus, and both crops decline rapidly in quality following flowering.

Ryegrass (perennial ryegrass, annual ryegrass). The digestibility of perennial ryegrass during winter–early spring is 0.75–0.79 but declines to 0.72 in October and 0.69 in November. Nitrogen concentration is 25–45 g N/kg DM. Values for calcium are low (2.1–3.9 g Ca/kg DM) in winter and for phosphorus (1.9–2.3 g P/kg DM) in spring. Potassium and magnesium values exceed requirements (20–40 g K/kg DM; 2.5–4.5 g Mg/kg DM). The digestibility and nitrogen content of Italian ryegrass are similar to those in perennial ryegrass; the phosphorus content of annual ryegrass is generally lower but its calcium content exceeds the deficiency level of perennial ryegrass in September.

Clover (white clover, Kenya clover). Dry matter digestibility of white clover is 0.75–0.79 during winter. Nitrogen concentration is between 27–37 g N/kg DM from August–November. Calcium, potassium and magnesium values are very high (9–14 g Ca/kg DM; 16–38 g K/kg DM; 2.5–2.7 g Mg/kg DM). However, phosphorus values are below requirements (1.5–2.8 g P/kg DM) other than in November (3.0 g P/kg DM). The nutritional value of Kenya clover in winter–spring is similar to that of white clover with comparable phosphorus and nitrogen values, and the same depression in quality in September. The digestibility of white clover, however, is consistently higher than that of Kenya clover.

Neither ryegrass nor white clover in monoculture fully offsets the deficiency status of basal summer grass pasture. Ryegrass overcomes the deficiency of available energy until onset of maturity in October. However, the calcium and phosphorus status of ryegrass is limiting. White clover overcomes the deficiency of available energy; however, the phosphorus status of white clover is apparently limiting. Ryegrass and white clover in combination more comprehensively offset the deficiency status of basal pasture with the exception of calcium in July and phosphorus in September.

Impact of management on forage quality

The quality of temperate pastures can be substantially modified by various management practices.

- There is a negative relationship between defoliation interval and N concentration in forage (Antuna *et al.* 1992; Fulkerson *et al.* 1993). However, with adequate available soil N and if defoliation interval does not lead to senescence of the older leaves, N concentration seldom falls below a protein equivalent of 16% in vegetative swards.

  In temperate dairying areas, delaying defoliation over the anthesis–stem elongation period leads to a rapid decline in both DMD (3% units/week) and protein (0.4% unit/week) concentration (Tyson *et al.* 1988) of annual and biennial ryegrass and early varieties of perennials. However, in the subtropics, the commonly used perennial ryegrass varieties, Yatsyn and Ellett, have very few reproductive tillers and the sward is easily kept in a vegetative state. This contrasts with the situation in temperate areas where spring defoliation management is geared to prevention of seed development.

- The selective behaviour of dairy cows means that increasing severity of grazing leads to a concomitant decline in quality of herbage intake as the animals progress from the leaves to the lower stems and perhaps senescent material.

The gradation in 'quality' of forage at different heights in the sward is as follows (W. Fulkerson, unpublished data):

Stubble height	N	Water soluble carbohydrate
(cm)	(%)	(%)
>12	3.23	6.32
5-12	2.04	16.8
2-5	1.81	18.0
0-2	2.11	17.5

- There is a positive linear relationship between the proportion of clover and the protein content of a ryegrass-clover sward.

  Protein (%) sward = 18 + 0.12 clover (%).

  Clover content can be altered by several management factors:
- *Seed rate.* The mean clover content of a pasture sown with 8 kg ryegrass seed/ha was 53% and at 35 kg/ha was 8% (both sown with 4 kg Haifa white clover/ha) (Fulkerson *et al.* 1993).
- *N fertiliser.* The mean clover content of a pasture sown with 8 kg ryegrass (plus 4 kg white clover) was 26% with N fertiliser applied (100 kg urea/ha/month) and 53% without N fertiliser.
- *Defoliation.* Hard and frequent defoliation tends to favour clover over ryegrass. However, studies by Fulkerson *et al.* (1993) found that long petiole varieties of white clover (e.g. Haifa) could compete with ryegrass with their proportion remaining the same even at very long defoliation intervals (up to 46 days and 4 500 kg of pasture on offer).

Summary

In reviewing the role of temperate pasture species and crops in the subtropical-tropical dairying areas, the following points need to be considered when establishing research needs in this area.

- The need to recognise the importance of temperate pastures in filling the winter-spring feed gap with high quality forage.
- Ample solar radiation and high temperatures in winter-spring provide the potential for substantially higher yields than in temperate areas.
- High humidity and temperature, excessive precipitation in summer-autumn, and lack of rain in spring are climatic aspects which impact unfavourably on plant growth and survival. Competition from C_4 grasses under these climatic conditions is a major reason for the lack of persistence of temperate pasture species.
- The pre-eminence of the grass-legume mixed sward (for best quality, cost/benefit and environmental care) compared to high fertiliser monoculture systems.
- The current temperate cultivars grown in the tropics-subtropics have been selected in temperate dairying areas. It would be more appropriate to select suitable plant material and develop appropriate management to cope with this contrasting environment. To achieve this requires a better understanding of the plant's response to this environment through plant physiology and ecological studies.
- Emphasis on plant selection should be on:
  (a) higher total production — in view of the relatively high production costs, particularly for annuals, and
  (b) perennation (primarily ryegrass and white clover) and this may include selecting for summer activity, rust and other pathogen tolerance, better root development, and alternative grasses, provided forage quality is adequate.
- Emphasis on plant selection and management should be on:
  (a) legumes which co-exist with ryegrass, thus reducing the need for fertiliser N and, as a consequence, reduce costs and environmental problems, and
  (b) the appropriate management and plant material will differ substantially for rain-grown and irrigation situations.

- The capacity to manage integrated pastures by incorporating fodder conservation, drainage, and effective irrigation into the whole farm context must be developed.

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