Managing summer-active tall fescue (*Lolium arundinaceum* syn. *Festuca arundinacea* Schreb.) based swards in southern Australia

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**Ethics approval**

The conduct of the survey documented in this thesis was approved by the Ethics in Human Research Committee at Charles Sturt University (CSU EHRC protocol number 2007/245).

The use of sheep in this project was approved by the Department of Primary Industries Animal Ethics Committee (DPI AEC code number 2006-04).
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Abstract

This project broadly hypothesised that summer-active tall fescue (*Lolium arundinaceum* syn. *Festuca arundinacea* Schreb.) could be established on heavy textured soils in the high rainfall (> 600 mm/year) zone of southern Australia and swards based on the species managed to provide a year-round source of pasture. Due to the broad nature of this hypothesis, it was divided into six sub-hypotheses, which were tested by conducting a survey and a series of field experiments, under grazing by sheep, in the south west Victoria region of southern Australia.

The results of the survey supported this hypothesis, with only 14% of the surveyed properties containing summer-active tall fescue, which usually comprised a small area of the property or a trial paddock. The primary reasons for the low adoption rate were the slow establishment of the species and its poor nutritive value during spring. There were, however, many successfully established and managed swards in the survey, which were associated with heavy waterlogged soils.

The slow establishment of summer-active tall fescue was addressed by conducting a field experiment under dryland conditions near Hamilton in south west Victoria (Chapter 4). It was hypothesised that summer-active tall fescue can be successfully established in south west Victoria by direct drilling high rates of seed at depth during spring. The experimental results supported this hypothesis, with optimal seedling density being achieved by direct drilling 24 kg seed/ha at a depth of 10 – 20 mm. Seedling densities in excess of 700 seedlings/m² were achieved in this experiment, despite spring rainfall being approximately 50% below average.
Another field experiment was conducted near Hamilton to test the effect of sheep grazing management on a summer-active tall fescue based sward that had been sown in 2004. This experiment tested three separate hypotheses, related to the effect of grazing on the sward’s tiller population dynamics (Chapter 5), productivity (Chapter 6) and nutritive value (Chapter 7). During much of the year, grazing when the summer-active tall fescue was at the three leaf stage produced a stable but vigorous tiller population, while also optimising pasture accumulation rate, pasture consumption and carbohydrate energy reserve levels. During the reproductive stage in spring, however, sward nutritive value was improved by set stocking or grazing when the summer-active tall fescue was at the two leaf stage.

Grazing summer-active tall fescue at the three leaf stage during winter was also impracticable because new leaf initiation appeared to be inhibited by low temperatures, which resulted in poor distribution of feed availability. More frequent grazing regimes, however, made the sward susceptible to weed invasion. A third field experiment was, therefore, conducted on an established sward of summer-active tall fescue to test the hypothesis that applying nitrogen (N) after autumn rains increases sward productivity and nutritive value during winter. This hypothesis was supported, with the application of 25 kg N/ha after autumn rains generating up to an additional 32 kgDM/kgN, relative to the unfertilised swards.

The broad hypothesis for this project has been supported, with summer-active tall fescue swards being successfully established on heavy textured soils in south west Victoria and supporting year-round grazing by sheep.
Table of Contents

Certificate of Authorship ............................................................................................................. i
Ethics approval ........................................................................................................................ ii
Acknowledgments ...................................................................................................................... iii
Abstract ....................................................................................................................................... iv
Table of Contents ....................................................................................................................... vi
List of tables ................................................................................................................................ ix
List of figures .............................................................................................................................. xi
List of photos ............................................................................................................................. xiii
List of publications .................................................................................................................... xiv

Chapter 1. Introduction .............................................................................................................. 1

Chapter 2. A review of the ecology and management of summer-active tall fescue based swards in southern Australia ............................................................... 4
  2.1 Introduction ......................................................................................................................... 4
  2.2 The suitability of perennial ryegrass and summer-active tall fescue to the environment in southern Australia ................................................................. 6
    2.2.1 Climate summary ......................................................................................................... 6
    2.2.2 Plant responses to moisture deficit stress ................................................................. 8
    2.2.3 Plant responses to heat stress ................................................................................ 11
    2.2.4 Plant responses to waterlogging and salinity ............................................................ 13
  2.3 Endophytes ....................................................................................................................... 15
  2.4 Establishment .................................................................................................................... 16
  2.5 Grazing management ......................................................................................................... 20
    2.5.1 Effect of leaf area and carbohydrate reserves on pasture growth ......................... 20
    2.5.2 Effect of season and growth stage on herbage nutritive characteristics ............... 26
  2.6 Nitrogen fertiliser management ......................................................................................... 28
  2.7 Conclusion ......................................................................................................................... 32

Chapter 3. A survey of summer-active tall fescue use and management in south west Victoria ............................................................................................................. 35
  3.1 Introduction ......................................................................................................................... 35
  3.2 Materials and method ........................................................................................................ 36
    3.2.1 Survey methodology ................................................................................................. 36
    3.2.2 Questionnaire design ............................................................................................. 38
    3.2.3 Error and bias .......................................................................................................... 39
    3.2.4 Statistical analysis .................................................................................................... 40
  3.3 Results ................................................................................................................................ 41
    3.3.1 Current use and perception towards summer-active tall fescue ......................... 41
    3.3.2 Cultivar selection and livestock enterprise ............................................................ 43
    3.3.3 Sward establishment ............................................................................................... 44
    3.3.4 Sward persistence and productivity ...................................................................... 46
    3.3.5 Effect of edaphic conditions on sward persistence and productivity ............... 47
    3.3.6 Effect of grazing management on sward persistence and productivity .......... 49
    3.3.7 Sward renovation .................................................................................................... 51
    3.3.8 Future use of summer-active tall fescue............................................................... 51
  3.4 Discussion .......................................................................................................................... 52
  3.5 Conclusion ........................................................................................................................ 58
Chapter 4. Establishing summer-active tall fescue in southern Australia..............60
4.1 Introduction .............................................................................................................60
4.2 Materials and method .............................................................................................61
  4.2.1 Site description ...................................................................................................61
  4.2.2 Site establishment and management .................................................................65
  4.2.3 Experimental design ..........................................................................................69
  4.2.4 Pasture measurements ......................................................................................69
  4.2.5 Statistical analysis ............................................................................................70
4.3 Results ....................................................................................................................70
  4.3.1 Emergence .........................................................................................................72
  4.3.2 Maximum seedling density ................................................................................72
  4.3.3 Proportion of sown seed that emerged .............................................................73
  4.3.4 Seedling survival ...............................................................................................74
  4.3.5 Final seedling density .......................................................................................75
4.4 Discussion ...............................................................................................................76
4.5 Conclusion ..............................................................................................................82

Chapter 5. Effect of grazing management on the tiller population dynamics of summer-active tall fescue .............................................................................................84
5.1 Introduction ............................................................................................................84
5.2 Materials and method .............................................................................................85
  5.2.1 Site description ...................................................................................................85
  5.2.2 Site establishment and management .................................................................86
  5.2.3 Experimental design ..........................................................................................87
  5.2.4 Pasture measurements ......................................................................................91
  5.2.5 Statistical analysis ............................................................................................93
5.3 Results ....................................................................................................................93
5.4 Discussion ...............................................................................................................99
5.5 Conclusion ..............................................................................................................103

Chapter 6. Effect of grazing management on the dry matter production and carbohydrate reserves of summer-active tall fescue based swards .............................................104
6.1 Introduction ............................................................................................................104
6.2 Materials and method ...........................................................................................105
  6.2.1 Site description ..................................................................................................105
  6.2.2 Pasture measurements ......................................................................................105
  6.2.3 Statistical analysis ............................................................................................107
6.3 Results ....................................................................................................................108
6.4 Discussion ..............................................................................................................111
6.5 Conclusion ..............................................................................................................119
List of tables

Table 3-1 Reasons for not using summer-active tall fescue (telephone survey) ............ 41
Table 3-2 Reasons for using summer-active tall fescue (mail survey) ......................... 42
Table 3-3 Proportion of farm area sown to summer-active tall fescue (mail survey) ....... 42
Table 3-4 Cultivars of summer-active tall fescue used and the associated livestock enterprises utilising the swards (mail survey) .......................................................... 43
Table 3-5 Establishment practices and success levels for summer-active tall fescue swards (mail survey) ......................................................................................... 45
Table 3-6 Persistence and annual productivity of summer-active tall fescue swards (mail survey) ........................................................................................................... 46
Table 3-7 Soil fertility of summer-active tall fescue swards and annual fertiliser applications to the swards (mail survey) ........................................................................ 48
Table 3-8 Grazing management of summer-active tall fescue swards (mail survey) ....... 50
Table 4-1 Soil profile characteristics from soil pit near research site ......................... 64
Table 4-2 Characteristics of the soil horizons shown in Table 4.1 ............................ 65
Table 5-1 Studies which have used non-destructive sampling to monitor tiller population dynamics of perennial ryegrass ................................................................. 92
Table 5-2 The slope, intercept and coefficient of determination of the linear regression fitted to the tiller size and density relationship shown in Figure 5-4 ......................... 96
Table 6-1 Apparent annual pasture consumption under set stocking or rotational grazing at the two, three or four leaf stage ................................................................. 110
Table 6-2 The pre-grazing WSC content of the pseudostem component of summer-active tall fescue tillers ................................................................. 111
Table 7-1 The effect of grazing treatment on the pre-grazing NDF, CP, IV DMD and WSC content of the green portion of the sward ....................................................... 127
Table 8-1 The effect of N rate on pasture accumulation rate during autumn and winter 2007 and 2008 .............................................................................................. 146
Table 8-2 The effect of N rate on pasture consumption and N response efficiency during autumn and winter 2007 and 2008 ............................................................ 146
Table 8-3 The effect of N rate on green herbage content during autumn and winter 2007 and 2008 .............................................................................................. 147
Table 8-4 The effect of N rate on summer-active tall fescue tiller density in winter 2007 and 2008 .......................................................................................................................... 147

Table 8-5 The effect of N rate on botanical composition in June 2007 and 2008 ....... 148
List of figures

Figure 2-1 Median annual rainfall across Australia..............................................................7

Figure 2-2 Median December – February rainfall across Australia.................................7

Figure 2-3 Median maximum February temperatures across Australia............................8

Figure 2-4 The regrowth curve of pastures following grazing, showing the phases of pasture growth.................................................................................................................21

Figure 2-5 The effect of different levels of leaf area, resulting from different levels of grazing intensity, on (A) pasture regrowth, senescence and intake by grazing animals and (B) the proportion of pasture that is utilised by grazing animals rather than being lost to death .....................................................................................................................24

Figure 4-1 Weekly distribution of rain during the experimental period. .........................62

Figure 4-2 Monthly rainfall prior to and during the experimental period of the establishment trial ........................................................................................................................................62

Figure 4-3 Mean weekly maximum and minimum air temperatures and soil temperatures measured at a depth of 10 cm during the experimental period......................63

Figure 4-4 Seedling density of summer-active tall fescue sown at 8 kg/ha, 16 kg/ha, 24 kg/ha or 32 kg/ha at sowing depths of 5 mm, 10 mm, 20 mm or 35 mm .......................71

Figure 4-5 Maximum seedling density from sowing depths of 5 mm, 10 mm, 20 mm and 35 mm at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha .......................73

Figure 4-6 The proportion of sown seed that emerged from sowing depths of 5 mm, 10 mm, 20 mm and 35 mm at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha...74

Figure 4-7 Seedling survival from sowing depths of 5 mm, 10 mm, 20 mm and 35 mm at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha ..........................................75

Figure 4-8 Final seedling density measured on 6 April 2009 from sowing depths of 5 mm, 10 mm, 20 mm and 35 mm at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha.................................................................................................................................76

Figure 5-1 Mean monthly maximum and minimum temperatures and rainfall during the experimental period..........................................................................................86

Figure 5-2 The main effect of sampling date on summer-active tall fescue tiller density, showing treatment means under set stocking and rotational grazing at the two, three or four leaf stage............................................................94

Figure 5-3 Summer-active tall fescue tiller size under set stocking and rotational grazing at the two, three or four leaf stage..............................................................................95
Figure 5-4 The relationship between summer-active tall fescue tiller size and density, averaged across grazing treatments, in October 2007, December 2007, February 2008 and April 2008, with linear regression fitted for each sampling date ........................................96

Figure 5-5 Net monthly (a) appearance and (b) death of summer-active tall fescue tillers under set stocking and rotational grazing at the two, three or four leaf stage ......97

Figure 5-6 The appearance and survival of tillers in summer-active tall fescue clumps in response to grazing treatment ..................................................................................................................98

Figure 6-1 The accumulation rate of summer-active tall fescue swards under set stocking or rotational grazing at the two, three or four leaf stage.................................109

Figure 6-2 Pasture consumption under set stocking or rotational grazing at the two, three or four leaf stage.....................................................................................................................110

Figure 7-1 The (a) summer-active tall fescue, (b) clover and (c) annual grass weed content of swards under set stocking or rotational grazing at the two, three or four leaf stage.......................................................................................................................................................126

Figure 8-1 Mean monthly maximum and minimum temperatures and rainfall over autumn and winter 2007 and 2008 ..................................................................................................................137
List of photos

Photo 4-1 Direct drilling summer-active tall fescue on 22 October 2008 at the experimental site near Hamilton. ............................................................68

Photo 4-2 The experimental site on 16 January 2009, following 93 mm of rain during 12 – 14 December 2008. .................................................................68

Photo 5-1 The experimental site on 21 July 2007, showing short periods of waterlogging during winter. Water receded within one week. ............................90

Photo 5-2 Experimental site on 31 January 2007, following 123 mm of rain during January. .................................................................90

Photo 8-1 Experimental site on 25 July 2008.........................................................138

Photo 8-2 Experimental site on 15 May 2007.........................................................138
List of publications


Chapter 1. Introduction

Tall fescue (*Lolium arundinaceum* syn. *Festuca arundinacea* Schreb.) is a deep rooted perennial grass with a diverse array of cultivars ranging from turf-type varieties to cultivars suitable for grazing. Cultivars used in grazing systems range in seasonal growth along a continuum from highly winter-active to highly summer-active, with each type suited to different environments and used for different purposes (Lamp *et al.* 2001).

Winter-active cultivars generally grow rapidly during autumn, winter and spring and become dormant during summer (Anderson *et al.* 1999; Jahufer *et al.* 2002; Reed *et al.* 2004a). Summer dormant grasses, particularly cultivars of perennial ryegrass (*Lolium perenne* L.) and phalaris (*Phalaris aquatica* L.), are commonly used in the high rainfall zone of southern Australia, where annual rainfall exceeds 600 mm/year, because the reduced green leaf area over summer prevents heat injury and reduces the moisture requirements of the plant during a time when moisture is often limiting. Dormant pastures, however, do not utilise soil moisture or summer rain to produce green feed over summer (Norton *et al.* 2006), which is a time of the year when pasture shortfalls often occur, resulting in decreased livestock production or increased supplementary feeding.

Summer-active cultivars of tall fescue do not become dormant over summer, but continue to grow by using soil moisture and responding quickly to summer rain (Norton *et al.* 2006). These cultivars are also heat tolerant, continuing growth at temperatures
exceeding 30°C (Greenwood et al. 2006). This project, therefore, focuses on summer-active cultivars of tall fescue and does not include winter-active cultivars.

Due to its lack of summer dormancy mechanisms, summer-active tall fescue has a high water requirement during summer, relative to summer dormant grasses, to support growth and survival. It must be sown on heavy textured soils that retain moisture from waterlogging in wet seasons, with the plant able to draw on this stored soil moisture during summer. Furthermore, summer-active tall fescue is suited to high rainfall zones (> 600 mm/year), preferably with some summer rain. This project, therefore, focuses on the high rainfall (> 600 mm/year) zone of southern Australia and on areas within this zone that have heavy textured soils which are prone to waterlogging during wet seasons. The high rainfall zone of southern Australia includes the coastal regions of Victoria, the south coast of New South Wales and the southern coastal region of Western Australia. It is acknowledged that these areas have a relatively benign environment and that there are vast areas of southern Australia where annual rainfall is below 600 mm; these areas are not the focus of this project because moisture availability is likely to be insufficient to support high-performance summer-active tall fescue pastures.

A literature review of the establishment and management of summer-active tall fescue revealed a lack of information on the species in such environments (see Chapter 2). This literature review led to the hypothesis that summer-active tall fescue can be established on heavy textured soils in the high rainfall (> 600 mm/year) zone of southern Australia and managed to provide a year-round source of pasture. This hypothesis provided the rationale for a survey and a series of field experiments, each with their own specific hypotheses. The survey (Chapter 3) studied the current attitude towards, use and
management of summer-active tall fescue in the district surrounding Hamilton in the south west Victoria region of southern Australia. From the survey, it was realised that the slow establishment of summer-active tall fescue is a major barrier to its adoption. A field experiment was, therefore, conducted into strategies for improving the establishment of summer-active tall fescue (Chapter 4). A second field experiment investigated the effects of grazing management on the tiller populations, growth and consumption, nutritive value and botanical composition of swards of summer-active tall fescue that had been established in 2004 (Chapters 5, 6 and 7).

In the high rainfall zone of southern Australia, feed shortfalls often occur during winter when pasture growth is limited by low temperatures and feed demand is high due to autumn/winter calving or lambing times. A final field experiment, therefore, investigated the possibility of increasing the winter productivity of summer-active tall fescue by applying nitrogen (N) fertiliser after autumn rains; thus providing a year-round supply of pasture from a summer-active species (Chapter 8). The field experiments in this project were conducted at the Department of Primary Industries research farm at Hamilton in Victoria between 2006 and 2009. The final chapter provides a general discussion and conclusion for the project and presents future research directions.
Chapter 2. A review of the ecology and management of summer-active tall fescue based swards in southern Australia

2.1 Introduction

Many pastures in the high rainfall (> 600 mm/year) zone of southern Australia are based on perennial ryegrass (Quigley et al. 1992) due to its ease of establishment (Hamilton-Manns et al. 1995), its high nutritive value (Walsh and Birrell 1987; Smith et al. 2004) and its ability to tolerate grazing (Waller et al. 1999; Graham et al. 2000). Perennial ryegrass, however, often experiences poor persistence in southern Australia due to the hot and dry summers (Reed 1974; McWilliam 1978; Anderson et al. 1999), which result in the plant density and dry matter (DM) production of swards declining. A survey by Quigley et al. (1992) found that many pastures in south west Victoria contain less than 20% perennial ryegrass. This lack of persistence is often in spite of dormancy mechanisms which slow or cease plant growth during a time when leaf tissue is susceptible to heat injury and the plant’s moisture requirements cannot be met.

Where perennial ryegrass fails to persist, opportunities arise for less desirable species, such as silver grass (Vulpia spp.), barley grass (Hordeum leporinum) and brome grass (Bromus spp.) to invade swards (Snaydon and Howe 1986; Quigley et al. 1992; Panetta et al. 1993). The displacement of perennial grasses from the sward reduces DM production and the nutritive value of the sward (Walsh and Birrell 1987; Frame 1991). The cost of pasture degradation is incurred by livestock enterprises as lost livestock production and/or increased supplementary feeding costs (Cayley et al. 1974).
A need exists in southern Australia to use alternative species to perennial ryegrass, which are more adapted to surviving and remaining productive during hot and dry conditions. Summer-active tall fescue is one such species. This is a perennial C3 grass that is closely related to perennial ryegrass (Darbyshire 1993; Charmet et al. 1997; Wheeler et al. 2002) but is characterised by being more heat tolerant (Lowe and Bowdler 1995; Jiang and Huang 2001; Greenwood et al. 2006), deeper rooted (Garwood and Sinclair 1979; Wilman et al. 1998; Mundy et al. 2006) and more responsive to summer rain (Lawson et al. 2007; Nie et al. 2008). These traits may enable it to survive and remain productive during the hot and dry summers that occur in southern Australia, provided that it is sown in regions that have high annual rainfall (> 600 mm/year), preferably with some summer rain, and on heavy textured soils that retain moisture during wet seasons for use over summer. Such soils are common in the high rainfall zone of southern Australia (Newell 1962).

This review examines the literature relevant to the suitability of summer-active tall fescue as an alternative pasture species to perennial ryegrass on heavy textured soils in the high rainfall (> 600 mm/year) zone of southern Australia. As mentioned in Chapter 1, this includes the coastal regions of Victoria, the south coast of New South Wales and the southern coastal region of Western Australia. This review documents the response of summer-active tall fescue to different management practices relating to establishment, grazing and N fertilisation in these environments. Winter-active cultivars of tall fescue are not considered in this literature review because they are not suited to the target environment and their summer dormancy mechanisms prevent summer growth (Reed et al. 2004a), which may contribute to summer feed shortages that currently occur in southern Australia.
2.2 The suitability of perennial ryegrass and summer-active tall fescue to the environment in southern Australia

2.2.1 Climate summary

As was mentioned previously, this literature review focuses on the high rainfall zone of southern Australia, where annual rainfall exceeds 600 mm/year. These areas are shown in Figure 2-1. Rain in southern Australia is winter and spring dominant and there is a hot and dry period over summer and early autumn during which time sporadic rainfall events can comprise up to 20% of annual rainfall (Figure 2-2). February is, on average, the hottest month of the year, with mean maximum temperatures ranging from 21 – 27°C in coastal regions and becoming higher with distance inland (Figure 2-3). Even coastal regions experience days over summer that exceed 30°C. For instance, Warrnambool (on the south coast of Victoria 38.38°S 142.48°E) experiences an average of 17, Orbost (on the east coast of Victoria 37.69°S 148.46°E) 26 and Albany (on the south coast of Western Australia 34.94°S 117.80°E) 15 days above 30°C per year (Bureau of Meteorology 2009). Temperatures on a dry soil surface can be even higher than air temperatures, reaching up to 47°C on a 30°C day (Julander 1945). A detailed description of the climate in southern Australia is available from the Bureau of Meteorology (2009).
Figure 2-1 Median annual rainfall across Australia, accessed from the Bureau of Meteorology website www.bom.gov.au on 2 December 2009. Copyright of this graphic resides with the Commonwealth of Australia (Bureau of Meteorology 2009).

Figure 2-2 Median December – February rainfall across Australia, accessed from the Bureau of Meteorology website www.bom.gov.au on 2 December 2009. Copyright of this graphic resides with the Commonwealth of Australia (Bureau of Meteorology 2009).
2.2.2 Plant responses to moisture deficit stress

The perennial ryegrass cultivars used in southern Australia often display summer dormancy. The degree of dormancy will depend on the cultivar, as evidenced in the work by Lawson et al. (2007) at Hamilton in Victoria, but generally these mechanisms reduce the amount of green leaf area supported by the plant through the slowing or cessation of growth. This slowing of plant growth reduces leaf susceptibility to heat injury and the amount of moisture required by the plant during dry conditions, which typically occur during summer and early autumn in southern Australia. In many areas of southern Australia, however, up to 20% of annual rain can fall between January and March (Bureau of Meteorology 2009) and dormant plants are unable to produce green
feed in response to this rain (Lawson et al. 2007). This lack of production contributes to feed shortages over summer and increases the requirement for supplementary feeding.

Summer-active tall fescue, on the other hand, is able to produce green feed quickly after summer rain (Lawson et al. 2007; Nie et al. 2008). This ability was demonstrated by Lawson et al. (2007) at Hamilton in Victoria, where summer-active tall fescue (cv. Quantum) produced green paddock feed for 4 – 6 weeks following 123 mm of rain in January 2007, while perennial ryegrass (cv. Banquet) was only mildly responsive to this rain and the Avalon and Fitzroy cultivars of perennial ryegrass did not respond at all due to their summer dormancy mechanisms.

In the absence of rain, summer-active tall fescue is able to survive and remain productive for longer periods than either perennial or Italian ryegrass (*Lolium multiflorum* Lam.) because it has a deeper and more extensive root system (Wilman et al. 1998). In the research by Wilman et al. (1998), transparent covers were used to impose severe moisture deficit stress by restricting rain to field plots. The summer-active tall fescue (cv. Aberystwyth S.170) had a greater number and weight of roots than the other grass species in the 50 – 100 cm soil layer and reported the greatest loss of moisture from the top 100 cm of soil. The species was able to support greater herbage yields and survive longer than the other grasses because it had a greater effective depth of moisture use. Garwood and Sinclair (1979) and Mundy et al. (2006) also found that, under a range of soil water holding capacities, summer-active tall fescue (cvv. Advance and Aberystwyth S.170) had a deeper root system than perennial ryegrass (cvv. Yatsyn and S.23) and was able to extract moisture from greater than 100 cm in the soil profile
and up to 170 cm in some instances. The perennial ryegrass could only extract moisture from a maximum depth of 80 cm.

Anderson *et al.* (1999) reported poor persistence of summer-active tall fescue on light soils in south west Victoria. Poor persistence was presumably due to the severity of moisture stress resulting from the low water holding capacity of the soil and the hot and dry summer conditions. Summer-active tall fescue must, therefore, be sown on heavy textured soils that can retain moisture from the preceding wet winter/spring period and which can be used to support summer growth. Persistent swards in south west Victoria have been achieved on heavy textured soils (Lawson *et al.* 2007).

During severe moisture stress, summer-active tall fescue increases its ability to access soil moisture, while also reducing the amount of leaf area supported by the plant, by increasing its root:shoot ratio (Assuero *et al.* 2002). The species will also display physiological responses to conserve moisture. These responses include closing stomata, which reduces moisture loss via transpiration, and tight leaf rolling, which reduces the surface area of the leaf exposed to evaporation (Johns 1978). These physiological responses occur because the increasing dryness of the air surrounding the leaf causes leaf water potential to decline, which results in changes to the turgor of epidermal cells, such as the guard cells. Open stomata are required, however, for the inward diffusion of CO₂ for photosynthesis. During severe moisture deficit stress, photosynthesis is inhibited causing plant growth rates to decline and/or cease. Furthermore, evaporation of transpired water on the surface of leaves is an important cooling mechanism in plants and once transpiration is reduced to conserve moisture, the plants ability to cool itself is
impaired and the plant may eventually succumb to heat stress (Salisbury and Ross 1978).

2.2.3 Plant responses to heat stress

The optimum temperature for the growth of perennial C3 grasses is between 17 – 21°C (Mitchell 1956; Baker and Jung 1968; Silsberry 1969). Summer temperatures in southern Australia often exceed 30°C, the level at which perennial ryegrass ceases growth (Mitchell 1956; Silsberry 1969). Summer-active tall fescue can tolerate higher temperatures than perennial ryegrass, sustaining growth and plant density at temperatures exceeding 30°C, provided sufficient moisture is available (Lowe and Bowdler 1995; Greenwood et al. 2006).

There is no research that fully explains why summer-active cultivars of tall fescue are more heat tolerant than perennial ryegrass. Research conducted on turf-type cultivars of tall fescue and perennial ryegrass has, however, demonstrated the fundamental principles of plant physiology that result in the collapse of cellular thermostability of tall fescue (Jiang and Huang 2001; Langjun et al. 2006; Xu et al. 2006). During periods of heat stress, higher rates of photorespiration and photoreduction by chloroplasts, mitochondria and peroxisomes cause increased production of reactive oxygen species, such as superoxide, hydrogen peroxide and hydroxyl free radicals (Xu et al. 2006). The accumulation of toxic levels of these oxygen compounds within cells causes oxidative damage to lipids, proteins and nucleic acids and injures the cell membrane, resulting in cell death. Turf-type perennial ryegrass is more susceptible to the accumulation of these toxic oxygen compounds than turf-type tall fescue (Xu et al. 2006).
Plant cells contain enzymatic and non-enzymatic antioxidant systems that protect the cell against oxidative damage by reactive oxygen species (Liu and Huang 2000; Xu et al. 2006). The effectiveness of these antioxidant systems differs between species, resulting in the cellular structure of some species being more thermostable than others. Turf-type tall fescue produces higher levels of the antioxidants ascorbate and glutathione than turf-type perennial ryegrass, which are key metabolites for the removal of toxic oxygen compounds from cells (Xu et al. 2006). Turf-type tall fescue is also able to increase its levels of the enzymes ascorbate peroxidase and superoxide dismutase during heat stress (Langjun et al. 2006). These enzymes protect the cell against oxidative damage because the superoxide dismutase converts superoxide radicals to hydrogen peroxide, which is in turn converted to H₂O and O₂ by the ascorbate peroxidase.

The rate of gross canopy photosynthesis is also controlled by temperature dependent enzymes. In perennial ryegrass, gross canopy photosynthesis increases as temperature rises between 10°C and 25°C, provided that photosynthesis is not limited by a large saturation deficit of water vapour, which often accompanies high temperatures (Woledge and Parsons 1986), or by other factors such as low light intensity, low availability of CO₂ or a slow rate of carbohydrate translocation (Salisbury and Ross 1978). Research has demonstrated that turf-type tall fescue is able to support a higher rate of photosynthesis than turf-type perennial ryegrass at temperatures between 30°C and 35°C (Jiang and Huang 2001; Langjun et al. 2006). It remains unclear if the physiological responses to heat stress displayed by turf-type cultivars of tall fescue exist in grazed summer-active cultivars, with the additional stress of grazing and the
reduction it causes to leaf area possibly reducing the plant’s ability to tolerate heat stress.

2.2.4 Plant responses to waterlogging and salinity

A common characteristic of heavy textured soils in the high rainfall (> 600 mm/year) zone of southern Australia is periodic inundation or waterlogging during wet seasons, typically over winter and spring (Newell 1962; Division of National Mapping 1980). This phenomenon is caused by a combination of high winter and spring rainfall, low evapotranspiration rates during the cooler months, low permeability of subsurface soil horizons and the retention of moisture in clay soils.

Waterlogged soils often have a low O$_2$ content because O$_2$ is relatively insoluble in water compared to CO$_2$ and the rate of diffusion of O$_2$ in water filled soil pores is relatively slow, especially if the pores are discontinuous or blocked. Plants require O$_2$ to generate energy in the form of adenosine triphosphate (ATP) by the process of aerobic respiration (Salisbury and Ross 1978). This energy is then used by the plant for growth and metabolism, with pasture growth rate being positively correlated with soil O$_2$ levels (Rogers and Davies 1973).

During waterlogging, when soil O$_2$ becomes deficient, plants can produce energy by anaerobic alcohol fermentation, which produces carbon in the form of ethanol, lactic acid and alanine. Energy production by anaerobic respiration is inefficient, compared to aerobic respiration (Grable 1966). This inefficiency of energy production can cause an energy shortfall to occur during waterlogging and the plant uses its limited energy
supplies to maintain essential metabolic functions, often at the expense of herbage growth. Rogers and Davies (1973) found that summer-active tall fescue and perennial ryegrass supported similar levels of growth at soil oxygen levels of between 9 – 15% under field conditions.

The damaging effect of hypoxia on herbage production is often associated with salinity caused by the mobilisation of salts in the soil profile during waterlogging. Summer-active tall fescue is generally more tolerant than perennial ryegrass of salinity caused by excesses of NaCl, CaCl₂ and MgCl₂ (Kobayashi et al. 2004). To tolerate salinity, plants must be able to retain or acquire moisture, protect the integrity of their cell walls and maintain ion homeostasis. The general mechanisms of salinity tolerance in plants have been reviewed by Parida and Das (2005) and Volkmar et al. (1998). No research has been conducted to determine the mechanisms of salt tolerance in summer-active tall fescue.

Recent improvements in molecular biology have resulted in transgenic turf-type cultivars of tall fescue with improved salt tolerance (Tian et al. 2006). This was achieved by transferring into tall fescue the Na⁺/H⁺ membrane protein AtNHX, which is an integral membrane protein involved in secondary active transport controlling cellular Na⁺ homeostasis and pH. This technology has not yet been applied to summer-active cultivars suitable for grazing systems.
2.3 Endophytes

Endophytes refer to fungi that live in a mutually symbiotic relationship with grasses. They derive their nutrition and a means of reproduction from the grass, without causing disease to the grass. Endophytes often improve the growth and persistence of summer-active tall fescue (Kallenbach et al. 2003; Burns et al. 2006; Hopkins and Alison 2006) and make the grass more drought tolerant (Elmi and West 1995). Many endophytes, however, produce alkaloids that are toxic to livestock. The ingestion of these alkaloids can result in heat stress and ill thrift over summer and reduce liveweight gains and pregnancy rates (Hemken et al. 1979; Gay et al. 1988).

Easton et al. (1994) reported that summer-active tall fescue cultivars bred outside of the United States of America (USA) have been selected for freedom from toxic endophytes. Summer-active tall fescue swards sown with certified seed in Australia and New Zealand, therefore, do not cause toxicosis in livestock. Many cultivars of summer-active tall fescue are now available in Australia that contain non-toxic endophyte. Research in the USA has shown that these endophytes benefit the persistence and productivity of the plant without producing alkaloids that are toxic to livestock (Kallenbach et al. 2003; Burns et al. 2006; Hopkins and Alison 2006). The benefits of novel endophytes are yet to be shown in Australia.

In southern Australia, perennial ryegrass pastures often contain Neotyphodium lolii, which is an endophyte fungus that produces toxic levels of the alkaloid Lolitrem B (Reed et al. 2004b). The ingestion of this alkaloid can cause staggers in livestock. Ryegrass staggers is an inherent and widespread problem for livestock producers in
southern Australia, especially over summer and early autumn (Reed et al. 2004b) because it lowers animal productivity and can cause livestock deaths (Cunningham et al. 1993). Summer-active tall fescue may be a viable alternative to perennial ryegrass in southern Australia because it does not cause staggers or toxicosis in livestock.

2.4 Establishment

One of the major constraints to the adoption of summer-active tall fescue is its slow establishment compared to perennial ryegrass (Harkess 1970; Brock 1973), particularly at low temperatures (Hill et al. 1985; Hamilton-Manns et al. 1995). In the field, rapid seedling establishment is important to ensure seedlings are not displaced from the sward by weeds or other sown pasture species and to prevent seedling losses to desiccation or pest attack.

Research on summer-active tall fescue (cv. Demeter) has shown that the rate of establishment and the percentage of sown seeds that finally emerge generally increases, while the number of days to first emergence generally decreases, in response to increasing temperature up to a constant temperature of 12°C or an alternating temperature of 18/13°C (Hill et al. 1985; Charles et al. 1991a). Higher temperatures resulted in no further improvements in establishment. Furthermore, Charles et al. (1991a) found that an alternating day/night temperature of 12/6°C resulted in the same rate of establishment, the same total number of sown seeds emerging and the same number of days to first emergence as a constant temperature of 12°C.
The practical implications of temperature at sowing were demonstrated by Charles et al. (1991b) on the Northern Tablelands of New South Wales. In the research by Charles et al. (1991b), spring sowing of summer-active tall fescue (cv. Demeter) resulted in a higher number of established seedlings than autumn sowing because, in the tested environment, autumn sown plots were prone to damping-off and frost damage because minimum temperatures were below 8°C. The higher seedling density achieved following the spring sowing was attributed to gradual increases in minimum temperatures after sowing. Charles et al. (1991b) reported, however, that high evaporation losses and possible moisture stress may inhibit the establishment of swards sown in late spring.

Moisture availability can be improved under dry conditions by increasing the sowing depth, which reduces exposure to predation and the evaporative forces that occur near the soil surface. Increasing sowing depth can, however, delay emergence (Charles et al. 1991a), especially if crusting or soil bulk density create a mechanical impediment (Brock 1973). Delayed emergence gives weeds an opportunity to invade and can result in seed deaths if the seed cannot emerge before its energy reserves become depleted. The optimum sowing depth for summer-active tall fescue was studied by Brock (1973), who found that the seedling density of summer-active tall fescue (cv. Demeter) was maximised by sowing at a depth of 12.5 mm, as compared to sowing on the soil surface or at a sowing depth of 25 mm or 37.5 mm. The number of days to first emergence increases with increasing sowing depth, particularly at low temperatures (Charles et al. 1991a).
To achieve a dense sward of summer-active tall fescue, it is important to give the species an opportunity to develop in the absence of competition from weed species (Dowling and Robinson 1976; Bellotti and Blair 1989b; Charles et al. 1992). Competition from weeds is reduced by preventing weed seed set in the year prior to sowing and by killing weeds immediately before sowing. On the Northern Tablelands of New South Wales, the effect of different pre-sowing weed control methods was tested on autumn sown summer-active tall fescue (cv. Demeter) (Charles et al. 1992). It was found that pre-sowing herbicide treatment improved seedling density by 63%, while heavy pre-sowing grazing improved seedling density by 46%, relative to no weed control. The herbicide treatment involved spraying with Sprayseed® (135 g/L paraquat dichloride and 115 g/L diquat dibromide) at a rate of 3L/ha five days before sowing. A similar trend was observed during the spring sowing.

Pre-sowing herbicide treatment has also improved the establishment of summer-active tall fescue (cv. Demeter) oversown into a Dichelachne, Bromus, Agropyron, Danthonia and Trifolium repens pasture on the Northern Tablelands of New South Wales by reducing competition with the already established species for space, light, water and nutrients (Dowling and Robinson 1976). The seedling density of the oversown summer-active tall fescue was positively related to sowing rate, where rates of 5.5 kg/ha, 11 kg/ha, 22 kg/ha and 44 kg/ha were tested. Summer-active tall fescue has been successfully established at sowing rates of 20 kg/ha under dryland conditions at Hamilton (cv. Demeter) (Reed et al. 2004a) and 20 kg/ha under irrigation in northern Victoria (cv. Advance) (Lawson et al. 2009).
The optimum method of sowing summer-active tall fescue will depend on local paddock conditions. In situations where the paddock is arable and trafficable, sowing into a cultivated seedbed or direct drilling with a tyne drill or triple disc drill have proven to be effective sowing methods (Charles et al. 1991b; Charles et al. 1992). These authors demonstrated, on the Northern Tablelands of New South Wales, that there was no difference in summer-active tall fescue (cv. Demeter) final seedling density between these sowing methods. It is likely, however, that direct drilling will offer advantages in other environments, relative to cultivating the seedbed, by minimising soil disturbance. Direct drilling can also be cheaper in terms of labour requirements and cultivating expenses, though this may be off-set by the higher cost of chemical weed control required. This will reduce evaporative moisture loss, reduce structural and erosive damage to the soil and reduce weed seed germination (Schroder 2006). On steep or rough ground, aerial sowing may be the only option, though establishment rates using this method are generally low (Bellotti and Blair 1989b; Charles et al. 1991b; Charles et al. 1992), with < 5% of aerially sown seed establishing in the research by Charles et al. (1991b).

It was apparent from the cited literature that the effect of seedbed preparation and sowing technique on the establishment of summer-active tall fescue has been extensively researched. Much of this research has been conducted in the summer-dominant rainfall zone of northern New South Wales (Dowling and Robinson 1976; Bellotti and Blair 1989b; Charles et al. 1992) or in a controlled environment (Hill et al. 1985; Charles et al. 1991a). Research is now needed into strategies which livestock producers in the winter-dominant rainfall zone of southern Australia can easily adopt that will improve the establishment of summer-active tall fescue. Specific issues which
could be addressed are sowing rate and sowing depth. Furthermore, most research has used the Demeter or AU Triumph cultivars of summer-active tall fescue (Dowling and Robinson 1976; Bellotti and Blair 1989a; Charles et al. 1991b; a; Charles et al. 1992), from which modern cultivars have been bred for improved establishment vigour.

2.5 Grazing management

2.5.1 Effect of leaf area and carbohydrate reserves on pasture growth

Following defoliation, the regrowth of pasture goes through several phases that are related to light interception, with the pattern of regrowth generally being sigmoid shaped (Brougham 1955; 1956) (Figure 2-4). Although the regrowth curve of pastures was developed following research on ryegrass, it is characteristic of all grasses. In phase one of the regrowth curve, immediately following grazing, pasture growth rates are low because the plant’s ability to photosynthesise is inhibited by low leaf area and poor light interception. When residual leaf area is low, summer-active tall fescue relies on carbohydrate reserves to re-establish leaf area in the absence of current photosynthate (Booysen and Nelson 1975). In the second phase, leaf area is restored and pasture growth rates are maximised. Research on perennial ryegrass has indicated that the optimum stage at which to graze the sward is in the last half of this period (Parsons and Penning 1988). In the third phase, a build-up of leaf material results in all available light being intercepted. A ceiling yield is reached and pasture growth rates begin to decline. Research on perennial ryegrass has indicated that this decline is caused by an increase in the rate of leaf senescence (Bircham and Hodgson 1983; Parsons and Penning 1988).
To ensure the long term persistence and productivity of summer-active tall fescue, the plant must have sufficient carbohydrate reserves to support regrowth immediately after grazing, when low leaf area inhibits the plant’s ability to photosynthesise (Booysen and Nelson 1975; Volenec 1986). Grazing intervals (the time between two successive grazing events) must be sufficiently long to enable the plant to re-establish leaf area and photosynthetic capacity, with the products of photosynthesis excess to the plant’s immediate requirements for growth being stored as carbohydrate reserves (Danckwerts and Gordon 1987). This ensures the plant has sufficient carbohydrate reserves to regrow after the photosynthetic canopy is removed by the next grazing event. The grazing interval required to do this will depend on the prevailing climatic and edaphic conditions.
To date, most studies into the optimum defoliation interval for summer-active tall fescue have been based on a set number of days between defoliations (Schiller and Lazenby 1975; Bell 1985; Kerrisk and Thomson 1990) or on defoliating at predetermined sward heights (Burns et al. 2002). Such intervals fail to account for changes in plant growth rate and physiology that occur throughout the year in response to seasonal growing conditions.

To account for seasonal changes in growth and physiology, Donaghy et al. (2008) undertook greenhouse experiments to develop a plant based indicator for defoliating summer-active tall fescue. These authors based defoliation intervals on leaf stage. Extensive research had previously been conducted on perennial ryegrass, prairie grass (Bromus spp.) and cocksfoot (Dactylis glomerata L.) to develop a leaf stage indicator of when the swards should be grazed to optimise productivity and persistence (Fulkerson et al. 1993; Fulkerson and Slack 1994; 1995; Slack et al. 2000; Fulkerson and Donaghy 2001; Donaghy and Fulkerson 2002; Turner et al. 2006). The research by Donaghy et al. (2008) aimed to develop a similar principle for summer-active tall fescue. In this study, pots of summer-active tall fescue (cv. Advance) were defoliated at either the first, second, third, fourth or fifth leaf stage. A leaf stage was defined as the full emergence of one new leaf. This research found that the rate of sward regrowth, DM production and carbohydrate energy reserves increased with the production of each successive leaf.

The research by Donaghy et al. (2008) requires verification under grazed field conditions and on established swards of summer-active tall fescue. Their research was conducted on newly established pots of summer-active tall fescue that were mechanically defoliated. In light of the slow establishment of summer-active tall fescue
(Hamilton-Manns et al. 1995), it is likely that the newly established swards would respond differently to defoliation than older swards that have a more developed root system. Furthermore, mechanical defoliation does not account for the effect of grazing animals on the sward. Grazing animals affect sward productivity due to trampling (Edmond 1966; Richards et al. 1976; Curll and Wilkins 1983), soil compaction (Witschi and Michalk 1979; Willatt and Pullar 1983; Proffitt et al. 1993; Greenwood et al. 1997) and nutrient return (Curll and Wilkins 1983; Greenwood et al. 1997). Also, mechanical defoliation does not account for the proportion of the sward that is not available to grazing animals (Harris 1983). Much of the research into the grazing management of summer-active tall fescue has been mechanically defoliated rather than grazed (Schiller and Lazenby 1975; Bell 1985; Kerrisk and Thomson 1990; Burns et al. 2002; Sinclair et al. 2006; Donaghy et al. 2008). Future research into the grazing management of summer-active tall fescue must be conducted under grazed rather than mechanically defoliated conditions.

The rate of pasture regrowth during phase one of the pasture regrowth curve is also affected by the amount of residual leaf area retained by the plant after grazing (Booysen and Nelson 1975). Research on perennial ryegrass has demonstrated that if a sward is grazed to a low residual grazing mass, a large amount of leaf area is utilised by grazing animals, but light interception by the plant is reduced, which will in turn reduce photosynthesis and respiration causing the rate of pasture regrowth to decline (Parsons et al. 1983a; Parsons et al. 1983b; King et al. 1984) (Figure 2-5). Conversely, grazing to retain a high residual herbage mass results in a smaller proportion of the leaf area being utilised by grazing animals and a greater proportion of leaf material being lost to death, but the plant retains a greater leaf area to intercept light which will result in faster
Grazing management thus involves compromising pasture growth, driven by leaf area, with the consumption of that leaf area by grazing animals.

**Figure 2-5** The effect of different levels of leaf area, resulting from different levels of grazing intensity, on (A) pasture regrowth, senescence and intake by grazing animals and (B) the proportion of pasture that is utilised by grazing animals rather than being lost to death (after Parsons *et al.* 1983a).
Plants respond to being grazed by exhibiting survival mechanisms which enable them to either tolerate or avoid being grazed (Briske 1986). One method for tolerating grazing involves increasing residual leaf area by increasing tiller density. This increases the plant’s ability to regrow quickly after grazing. The extent to which this survival mechanism is displayed by pastures depends on grazing intensity. There is an inverse relationship between the number of tillers and the size of tillers that can be sustained per unit area of soil (Sugiyama 1995; West et al. 1997; Enquist et al. 1998). In perennial ryegrass, continuous or intense grazing generally results in a large number of small tillers, while rotational grazing favours the production of a fewer number of larger tillers (Bircham and Hodgson 1983; Grant et al. 1983; Chapman and Clark 1984). It is for this reason that, when continuous and rotational grazing regimes are compared under perennial ryegrass, there may be no difference in herbage yield (Chapman and Clark 1984).

Research by Tavakoli et al. (1993) suggests a similar response in summer-active tall fescue, but demonstrates that there is a limit to the plasticity of the relationship. The research by Tavakoli et al. (1993) was conducted at Massey University in New Zealand. The swards were continuously grazed to a height of 3 – 4 cm, 5 – 6 cm or 9 – 10 cm. It was found that grazing to a height of 5 – 6 cm resulted in a higher tiller density than grazing to a height of 9 – 10 cm, suggesting that the more intense grazing regime stimulated tillering. Grazing the sward to a height of 3 – 4 cm, however, reduced tiller density, leaf elongation rate and tiller size relative to the 5 – 6 cm grazing height, which suggests that the plasticity relationship between tiller density and tiller size is disturbed under severe grazing stress.
2.5.2 Effect of season and growth stage on herbage nutritive characteristics

Summer-active tall fescue is a viable alternative to perennial ryegrass in many areas of southern Australia because of their similar nutritive characteristics (Greenwood et al. 2006; Lawson and Kelly 2007). Lawson and Kelly (2007) renovated an irrigated 15-year-old paspalum (*Paspalum dilatatum* Poir) based dairy pasture near Kyabram (36.34°S 145.06°E) in northern Victoria with either perennial ryegrass (cvv. Vedette, Banks and Yatsyn 1) or tall fescue (cv. Advance). *In vitro* dry matter digestibility (*IVDMD*) and crude protein (CP) rarely differed between the species, with these nutritive characteristics being highest in late winter/early spring (*IVDMD* approximated 80 – 84% of DM and CP 17 – 22% of DM) and lowest during summer (*IVDMD* approximated 69 – 72% of DM and CP 13 – 16% of DM). Pasture consumption from the tall fescue sward in the second, third and fourth years after sowing was on average 2.5 t DM/ha.year higher than the perennial ryegrass sward, due mainly to its higher summer and autumn productivity.

Summer-active tall fescue is also a viable alternative to perennial ryegrass under dryland dairy conditions in south west Victoria (Tharmaraj et al. 2008), where conditions are colder and wetter during winter and spring than the irrigation districts studied by Lawson and Kelly (2007) and Greenwood et al. (2006), but where summer moisture deficit can occur. Tharmaraj et al. (2008) found that the nutritive characteristics of the summer-active tall fescue (cv. Advance) based sward varied seasonally, with *IVDMD* and CP being higher in winter (*IVDMD* approximated 75% of DM and CP 23% of DM) than in summer, autumn or spring, during which time they remained unchanged (*IVDMD* approximated 71% of DM and CP 11 – 19% of DM).
Swards based on summer-active tall fescue had higher levels of herbage accumulation during summer than swards based on perennial ryegrass, but this was at the expense of lower winter growth.

The finding by Tharmaraj et al. (2008), that the IVDMD of summer-active tall fescue remains unchanged during summer, autumn and spring, was surprising because it is expected that the production of reproductive stems in spring would result in lower digestibility (Austenson 1963). It is likely that the grazing management used by Tharmaraj et al. (2008) prevented the production of large reproductive stems. Grazing complied with the guidelines developed by Milne (2001) and was based primarily on height, with post-grazing residual heights of 3 – 4 cm. During spring the swards were grazed every 12 – 14 days to a stubble height of 2 – 3 cm. Burns et al. (2002) found that canopy height and defoliation frequency determine the nutritive characteristics of summer-active tall fescue, with herbage at a height of 31 cm generally lower in digestibility and CP than herbage at a height of 15 cm, 11 cm, 10 cm or 8 cm. Pre-grazing canopy height could, therefore, be an effective criterion for summer-active tall fescue grazing management. Pasture height across a paddock is rarely even, however, due to selective grazing and trampling by livestock.

As was discussed earlier, leaf stage is also an effective criterion for grazing summer-active tall fescue. The nutritive value of summer-active tall fescue generally declines with the production of each successive leaf (Sinclair et al. 2006; Donaghy et al. 2008). Donaghy et al. (2008) reported that the respective CP and metabolisable energy (ME) content of summer-active tall fescue (cv. Advance) declined from 27% of DM and 11.3 MJ/kgDM at the one leaf stage to 16% of DM and 9.2 MJ/kgDM at the five leaf stage.
Effective grazing management involves compromising nutritive value, which is highest at an early stage of development, with high pasture consumption and the replenishment of carbohydrate reserves, which require more lenient grazing. Further research is needed to develop grazing strategies for summer-active tall fescue which effectively achieve this compromise.

### 2.6 Nitrogen fertiliser management

There has been no published research into the effect of nitrogen (N) fertiliser on summer-active tall fescue in the winter-dominant rainfall zone of southern Australia. The effect of applying N in autumn to stockpiled (autumn-saved) summer-active tall fescue has, however, been widely researched in the USA (Taylor and Templeton 1976; Archer and Decker 1977; Rayburn et al. 1979; Collins and Balasko 1981a; Gerrish et al. 1994). Stockpiling involves deferring pastures from grazing in autumn to provide an accumulated source of pasture for grazing in winter. In general, applying N to summer-active tall fescue resulted in linear or curvilinear increases in herbage production. Growth responses ranged from 6 – 25 kg DM/kg N. Growth responses depended on the duration of stockpiling and the prevailing environmental conditions. The concept of autumn stockpiling has limited applicability in southern Australia because the practise is rarely used and the yield and nutritive value of stockpiled herbage depends on the duration of stockpiling. Stockpiling pasture is also difficult to practise in southern Australia because feed shortages often occur during autumn, unless there are early autumn rains and an early start to the growing season.
The positive effect of applied N on the yield of summer-active tall fescue was demonstrated on the central coast of New South Wales (Wolfe and Crofts 1969). In this summer rainfall environment, summer-active tall fescue (cv. Demeter) was treated with 14 kg N/ha (control), 42 kg N/ha or 70 kg N/ha as calcium-ammonium-nitrate every 1.5 months throughout the year. The species was particularly efficient in converting the N into DM in early autumn, relative to other grasses, in response to summer rainfall. The site received approximately 280 mm of rain between January and March 1965. The 42 kg N/ha treatment resulted in cocksfoot (cv. Currie), summer-active tall fescue (cv. Demeter) and perennial ryegrass (cv. Kangaroo Valley) generating 7.0 kg DM/kg N, 9.4 kg DM/kg N and 3.3 kg DM/kg N, respectively, during March and April, relative to the control.

Clover is the ideal companion for summer-active tall fescue swards because it has a high nutritive value compared to grass (Stockdale 1999) and it improves soil N fertility by fixing atmospheric N\textsubscript{2} into a plant available form via its symbiotic relationship with Rhizobia bacteria within nodules in its root system (Whitehead 1995; McKenzie \textit{et al.} 2003c). The application of N to summer-active tall fescue swards that contain a clover component is detrimental to clover persistence and productivity (Templeton and Taylor 1966; Frame 1973; Lazenby and Lovett 1975). This is likely due to the stimulated summer-active tall fescue shading out the clover. Nitrogen fertiliser also suppresses N\textsubscript{2} fixation by clover by reducing nitrogenase activity and nodule formation (Minchin \textit{et al.} 1986; McKenzie \textit{et al.} 2003c). Responses to N fertiliser must, therefore, account for the loss of clover DM from the sward and the net change in soil N content.
It was found by Mazzanti et al. (1994) under irrigation at Lusignan in France that the application of N to grazed summer-active tall fescue (cvv. Clarine and Barcel) generated herbage growth primarily by increasing tiller density. Leaf elongation and leaf production per tiller were lesser contributors to herbage growth. This relationship held true under a leaf area index of two or three, and up to a tested N rate of 360 kg N/ha.year, applied every 45 days as ammonium nitrate. Tiller density was occasionally lower at a leaf area index of three, compared to a leaf area index of two, but only at the highest N rate. Simon and Lemaire (1987) found that N application only has a positive effect on tiller formation in summer-active tall fescue (cv. Clarine) until a leaf area index of three is reached, at which stage all available light was eliminated at the level of the tiller buds causing a slowing of new tiller formation.

Logic suggests that the growth of summer-active tall fescue stimulated by N application increases the plant’s requirements for other nutrients, with the plant’s response to applied N being greatest when other nutrients are not deficient. Whitehead (1995) reviewed research demonstrating that if soil pH or low soil phosphorus (P), potassium (K) or sulphur (S) limits pasture growth (demonstrated primarily on perennial ryegrass swards), then sward responses to applied N would be limited. There is no sense, however, in applying P, K or S if these nutrients are not limiting because this will not generate further yield increases in summer-active tall fescue (Moyer et al. 1995; Sweeney et al. 1996).

The response of summer-active tall fescue to applied N is also dependent on moisture availability (Meriaux 1980; Stout et al. 1988; Gerrish et al. 1994). This was demonstrated by Stout et al. (1988) in Pennsylvania, USA, where the response of
summer-active tall fescue (cv. Kentucky-31) to two levels of N fertiliser (90 kg N/ha.year or 180 kg N/ha.year applied in two equal applications in April and June) and three levels of soil water holding capacity (5 cm, 15 cm or 25 cm) was tested. It was found that forage yield was determined by the interactive effects of N and water availability. In situations where moisture was not limiting, N was the primary determinant of yield, accounting for approximately 80% of the variation in yield between the two parameters. When moisture became limiting, such as when precipitation was low or poorly distributed, the potential yields from the applied N were not realised because water availability became the determinant of herbage yield, accounting for approximately 40% of the variation in yield between the two parameters. This finding was confirmed by research in Missouri, USA, where Gerrish et al. (1994) reported no further yield increases from applying greater than 45 kg N/ha to summer-active tall fescue (cv. Kentucky-31) in August due to insufficient moisture being available to support plant growth.

The responsiveness of summer-active tall fescue to N fertiliser must account for the amount of mineral N already present in the soil from previous fertiliser applications and mineralisation of organic matter by soil microbes, particularly under dryland conditions. Nitrate is generally the primary source of plant available N in soil and under dryland conditions large accumulations of soil nitrate may occur over summer and autumn in response to soil wetting and drying following rain (Simpson 1962). The magnitude of this effect is unclear and is affected by moisture availability and grazing frequency. For example, irrigated pastures that have had up to 24 applications of 50 kg N/ha over two years have shown no accumulation of mineral N in the soil presumably due to N uptake.
by pastures and the loss of any N that is not utilised by pastures to the atmosphere via volatilisation (Mundy 1993).

The application of N to summer-active tall fescue increases the plant N content, including nitrate and CP (Taylor and Templeton 1976; Balasko 1977; Fribourg and Loveland 1978; Collins and Balasko 1981b; Stritzke and McMurphy 1982; Collins 1991; Gerrish *et al.* 1994; Singer *et al.* 2003) and generates either a curvilinear or linear increase in digestibility with corresponding decreases in fibre content (Balasko 1977; Collins and Balasko 1981b; Collins 1991; Gerrish *et al.* 1994; Singer *et al.* 2003). Nutritive value responses to applied N are likely to vary throughout the year due to changes in seasonal climatic conditions affecting the growth rate and physiological stage of the plant. It is also likely that the application of N will accelerate the growth of the sward with associated declines in herbage nutritive value as the sward grows and matures. It is important to maintain high nutritive value in summer-active tall fescue swards because the livestock preference for and palatability of the sward is positively related to carbohydrate fractions and negatively related to fibre fractions (Tava *et al.* 1995; Mayland *et al.* 2000). Specific grazing management guidelines for optimising the utilisation of summer-active tall fescue herbage under different fertiliser regimes have not been researched to date.

2.7 Conclusion

In the high rainfall zone of southern Australia, perennial ryegrass is the most commonly used improved pasture species. Perennial ryegrass, however, often lacks persistence and has low levels of production during summer and early autumn in southern Australia due
to the hot and dry summers that are typical of the region. This literature review has suggested that the productivity of pasture systems in southern Australia could be improved by using summer-active tall fescue as an alternative to perennial ryegrass on heavy textured soils that are prone to waterlogging during wet seasons.

There is, however, a lack of information on how summer-active tall fescue should be managed in the high rainfall zone of southern Australia to ensure its successful establishment and persistence. This review and the investigations documented in this thesis were developed to address this lack of information, with the project testing the general hypothesis that summer-active tall fescue can be established on heavy textured soils in the high rainfall (> 600 mm/year) zone of southern Australia and swards based on the species managed to provide a year-round source of pasture. As was mentioned in Chapter 1, this general hypothesis provided the rationale for a survey and a series of field experiments, which each tested a specific component of the general hypothesis.

The lack of published research on summer-active tall fescue in southern Australia was overcome by surveying the experiences of local livestock producers in the southwest Victoria region (see Chapter 3). The survey and the literature review were steps towards understanding the potential for using summer-active tall fescue in the Hamilton environment, identifying the barriers to adoption of the species locally and designing experiments to address the issues.

A major barrier to the adoption of summer-active tall fescue is its slow establishment rate. The literature review discussed the importance of weed control, sowing method, sowing depth and sowing rate when establishing summer-active tall fescue, but the
effectiveness of these techniques had not been tested in the temperate winter rainfall zone of southern Australia. A field experiment (see Chapter 4) was conducted to test the hypothesis that direct drilling high rates of summer-active tall fescue at depth during spring would result in successful sward establishment under dryland conditions in southern Australia.

The literature review documented research into leaf stage based grazing management guidelines for summer-active tall fescue. Leaf stage based grazing intervals have proven successful on other pasture grass species, but had not been fully developed for summer-active tall fescue, with preliminary trials being restricted to newly established pots of summer-active tall fescue in greenhouse conditions. The experiment documented in Chapters 5, 6 and 7 tested hypotheses relating to the effect of leaf stage based grazing intervals on the tiller population, growth and consumption, nutritive value and botanical composition of established swards of summer-active tall fescue under grazed field conditions.

The general hypothesis for this project focused on providing a year-round source of pasture from a summer-active tall fescue based sward. It was realised from the literature review that low temperatures are likely to limit the productivity of summer-active tall fescue during winter in southern Australia. The experiment documented in Chapter 8 tested the hypothesis that applying N fertiliser to summer-active tall fescue after autumn rains would increase winter productivity, thus ensuring a year-round source of pasture from a summer-active species.
Chapter 3. A survey of summer-active tall fescue use and management in south west Victoria

3.1 Introduction

It was identified in Chapter 2 that pasture systems in the high rainfall (> 600 mm/year) zone of southern Australia often lack persistence and don’t realise their productive potential because they are based on pasture species that fail to survive or continue growth during the hot and dry period that typically occurs during summer and early autumn (Reed 1974; McWilliam 1978; Anderson et al. 1999). There is, however, a large degree of environmental variation within southern Australia’s high rainfall zone, with many areas having heavy textured soils which are able to retain moisture from waterlogging in wet seasons (Newell 1962). Summer-active tall fescue could potentially make use of this stored soil moisture to provide a persistent year-round source of pasture in southern Australia. No research had been conducted, however, into the performance of the species on heavy soils in southern Australia. Furthermore, there are some underlying problems with summer-active tall fescue that need to be overcome for it to be effectively used in pasture systems. It is slow to establish relative to other species (Brock 1973; Hamilton-Manns et al. 1995) and it has prolific growth over spring, which can result in rapid nutritive value declines and loss of palatability (Lowe et al. 1999).

A survey was conducted to collect information on the use and management of summer-active tall fescue in the south west Victoria region of southern Australia to determine the performance of the species in different environments and under various management practises.
3.2 Materials and method

3.2.1 Survey methodology

Livestock producers in the Corangamite and Glenelg-Hopkins Catchments in south west Victoria were telephone surveyed in late spring 2007 to quantify the number of properties in these catchments that currently have summer-active tall fescue and the reasons for using/not using summer-active tall fescue on the property. The telephone survey questionnaire is shown in Appendix 1. Livestock producers in these Catchments were sampled from the Yellow Pages Telephone Directory listings of graziers and sheep and cattle stud breeders in the Ballarat, Geelong, Warrnambool, Grampians, Hepburn and Great Ocean Road regions. There were 77 participants in the telephone survey.

A mail survey was then conducted of summer-active tall fescue users in the Corangamite and Glenelg-Hopkins Catchments to determine the environments where summer-active tall fescue is currently being used, the current establishment, grazing and fertiliser practices being undertaken and the productivity and persistence of the swards. The information letter and mail survey questionnaire are shown in Appendix 2 and 3, respectively.

Participants in the mail survey were sampled from four mutually exclusive cohorts. The cohorts were combined for data analysis. Cohort one were the summer-active tall fescue users in the telephone survey. Cohort one provided information on 20 swards from 11 properties. Cohort two was from the EverGraze® mailing list. EverGraze® is a project that aims to improve livestock production while achieving environmental outcomes by
using perennial pastures. An information letter was mailed inviting current summer-active tall fescue users to contact the survey administrator if they wanted to participate. Cohort two provided information on 14 swards from 10 properties. A similar letter was sent to the Fescue Users Group, which comprised cohort three. The Fescue Users Group was organised approximately five years ago to provide a mailing list for people interested in tall fescue. The group was no longer functioning at the time of this survey. Cohort three provided information on 13 swards from eight properties. Cohort four were respondents to an article published in the Grasslands Society of Southern Australia newsletter. Cohort four provided information on 16 swards from eight properties. In total, the mail survey provided information on 63 summer-active tall fescue swards from 37 properties.

It was recognised that a property may contain more than one paddock of summer-active tall fescue. Scope was, therefore, allowed in the mail survey for participants to answer each question for the two largest paddocks of summer-active tall fescue on the property. For the two paddocks on the same property to constitute separate samples, each paddock had to be subject to different management or be located in different microclimates. To constitute a sward, the summer-active tall fescue had to comprise at least 50% of sward herbage mass.
3.2.2 Questionnaire design

The questionnaires for the telephone and mail surveys were designed using the techniques of Dillman (1978) and Filion (1978). Questions were constructed to ensure the survey was short but that the important information was obtained.

The telephone survey generally took less than three minutes. Firstly, the purpose and methodology of the research was explained and consent sought to continue with the survey. If consent was given, the participant was asked if they currently use summer-active tall fescue on their property and why/why not. If they did use summer-active tall fescue they were then asked to participate in the mail survey.

The mail survey comprised five sections and 41 questions. Space was also provided for general comments. The first section provided a general profile of the survey participant, including gender, age group, highest level of education, their position on the farm and how long they have been farming. The purpose of this section was to account for factors that influenced decision making on the property and to identify if the survey participant was the primary decision maker on the property. The second section focused on farm details, including location, rainfall and size. This section identified rainfall zones where summer-active tall fescue was used successfully and the proportion of the property invested in summer-active tall fescue. Section three sought details of current summer-active tall fescue use and management. Section four investigated the future intentions of the survey participant to use summer-active tall fescue. The final section provided details on how to return the survey.
Error and bias

It is acknowledged that this survey was affected by sampling, non-response, coverage and measurement error. These have been reviewed by Dillman (1991). This survey indicates the current use and management of summer-active tall fescue in the Corangamite and Glenelg-Hopkins Catchments in south west Victoria, but it is acknowledged that the results only apply to the sampled populations and the tested conditions.

Sampling error occurred because a sample was observed rather than the entire population. It is possible that the observed sample was not representative of the population from which it was drawn because by listing their details in the Yellow Pages Telephone Directory, or by responding to the mail survey, the sample selects people who are more enterprising or have a greater interest in the research. Drawing a sample from the Yellow Pages Telephone Directory has been used in previous pasture surveys (Austen et al. 2002) because it is an inexpensive way of sampling a large area from a central location.

Non-response error occurs when people who are eligible to take part in the research do not participate. Error occurs because the responses from those who participate are likely to differ from the responses of those who did not participate, with active participants generally being interested in the research or having the strongest opinions. Non-response error is reduced by maximising the response rate. Responses were encouraged by minimising the length of the questionnaires (Childers and Ferrell 1979), providing a
reply paid envelope for return of the mail survey and conducting the telephone survey during lunchtime or in the evening when the farm manager was likely to be available.

Measurement error occurs when there is discrepancy between a measurement and the true value of the parameter that is being measured. It is generally caused by questionnaires that are confusing or by interviewer bias, resulting in inaccurate answers. To minimise measurement error, the questionnaires were tested on focus groups. The focus groups, which were randomly selected from the populations of interest, openly discussed the questionnaires, giving their opinions on the order, clarity and length of the questions. This step ensured that the desired information was being obtained and answers were not influenced by the wording or order of the questions. A script was prepared for the telephone interviews. This script was tested on the focus group and was strictly adhered to during the telephone interviews to prevent interviewer bias.

Coverage error occurs when sections of the population who are eligible to participate in the research are unintentionally omitted or duplicated, or if participants are included who are not eligible to participate. Coverage error was reduced by checking that the survey participants were located in the study area and had not been previously interviewed. Questions were structured to confirm that the survey was completed for summer-active tall fescue and not for another incorrectly identified species or cultivar.

3.2.4 Statistical analysis

All statistical analysis used Genstat Version 11 (Payne et al. 2008). A generalised linear model with a multinomial distribution and logit link was used to relate various
categorised factors, such as production and persistence, with other categorised factors, such as soil type and waterlogging.

3.3 Results

3.3.1 Current use and perception towards summer-active tall fescue

There were 77 participants in the telephone survey, of whom 11 currently used summer-active tall fescue on their property. The most common reasons for not using summer-active tall fescue were the association of the Demeter cultivar with low nutritive value over spring, a lack of knowledge about new cultivars and the slow establishment of the species (Table 3-1). Two participants cited two of these reasons for not using the species. No further results are presented from the telephone survey because few participants used summer-active tall fescue and there were no meaningful correlations in the data. All the summer-active tall fescue users in the telephone survey completed a detailed mail survey. All further results in this chapter relate to the findings of the mail survey.

Table 3-1 Reasons for not using summer-active tall fescue (telephone survey)

<table>
<thead>
<tr>
<th>Reason for not using summer-active tall fescue</th>
<th>No. of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Association of Demeter with low nutritive value in spring</td>
<td>19</td>
</tr>
<tr>
<td>Lack of knowledge about new cultivars</td>
<td>17</td>
</tr>
<tr>
<td>Slow establishment</td>
<td>13</td>
</tr>
<tr>
<td>Unwilling to change from current perennial ryegrass system</td>
<td>8</td>
</tr>
<tr>
<td>Operating a low input farm with no recent pasture improvement</td>
<td>6</td>
</tr>
<tr>
<td>Perception the species won’t survive hot and dry summers</td>
<td>4</td>
</tr>
<tr>
<td>Seed is too expensive</td>
<td>1</td>
</tr>
</tbody>
</table>
Summer growth and tolerance of waterlogging were the main reasons given in the mail survey for sowing summer-active tall fescue swards (Table 3-2). Some swards were sown for a combination of reasons. Generally, the properties in the mail survey had less than 5% of their area sown to summer-active tall fescue, with only three properties having more than 15% of their area sown to summer-active tall fescue (Table 3-3).

Table 3-2 Reasons for using summer-active tall fescue (mail survey)

<table>
<thead>
<tr>
<th>Reason for using summer-active tall fescue</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer growth</td>
<td>22</td>
</tr>
<tr>
<td>Tolerance of waterlogging</td>
<td>22</td>
</tr>
<tr>
<td>Rapid spring growth</td>
<td>9</td>
</tr>
<tr>
<td>Advised by agronomist</td>
<td>7</td>
</tr>
<tr>
<td>Tolerance of clay soils</td>
<td>5</td>
</tr>
<tr>
<td>Tolerance of salinity</td>
<td>3</td>
</tr>
<tr>
<td>Persistent in variable climate</td>
<td>2</td>
</tr>
<tr>
<td>Resistance to pests</td>
<td>2</td>
</tr>
<tr>
<td>Maintains ground cover</td>
<td>2</td>
</tr>
<tr>
<td>Provide a high yielding hay crop</td>
<td>2</td>
</tr>
<tr>
<td>Doesn’t cause ryegrass staggers</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3-3 Proportion of farm area sown to summer-active tall fescue (mail survey)

<table>
<thead>
<tr>
<th>Proportion of farm area sown to summer-active tall fescue</th>
<th>No. of properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5</td>
<td>19</td>
</tr>
<tr>
<td>5 – 10</td>
<td>6</td>
</tr>
<tr>
<td>11 – 15</td>
<td>2</td>
</tr>
<tr>
<td>16 – 20</td>
<td>2</td>
</tr>
<tr>
<td>21 – 25</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>7</td>
</tr>
</tbody>
</table>
3.3.2 Cultivar selection and livestock enterprise

The mail survey indicated that Quantum, Advance, Dovey and Demeter were the most commonly used summer-active tall fescue cultivars (Table 3-4), with some swards comprising a mixture of cultivars. The swards were most commonly used for beef production, followed by dairy milking herds and wool (Table 3-4). Some swards were used for more than one enterprise. Soft leaved cultivars, such as Advance, were used most commonly \((P<0.05)\) under dairy production and tough leaved cultivars, such as Quantum, were most commonly \((P<0.05)\) used for wool production.

**Table 3-4** Cultivars of summer-active tall fescue used and the associated livestock enterprises utilising the swards (mail survey)

<table>
<thead>
<tr>
<th>Summer-active tall fescue cultivar</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantum</td>
<td>22</td>
</tr>
<tr>
<td>Advance</td>
<td>20</td>
</tr>
<tr>
<td>Dovey</td>
<td>13</td>
</tr>
<tr>
<td>Demeter</td>
<td>10</td>
</tr>
<tr>
<td>Jesup</td>
<td>5</td>
</tr>
<tr>
<td>Typhoon</td>
<td>3</td>
</tr>
<tr>
<td>Vulcan II</td>
<td>1</td>
</tr>
<tr>
<td>Lunibelle</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
</tr>
</tbody>
</table>

**Livestock enterprise using the sward**

| Beef                              | 28           |
| Dairy milking herd                | 15           |
| Wool                             | 14           |
| Dairy dry stock                   | 8            |
| Prime lambs                      | 5            |
| Deer                             | 2            |
3.3.3 Sward establishment

Mail survey participants were asked to rate the success of establishment, where establishment was defined as the number of emerged summer-active tall fescue seedlings and the amount of herbage produced following establishment. Of the 63 swards surveyed, the establishment of 11 was rated as poor or very poor (Table 3-5). The reasons for this were ineffective weed control (9 swards) and/or competition from other sown species (7 swards).

Fifty of the 63 surveyed swards were sown since 2001 (Table 3-5). Nine of the Demeter users didn’t know when the sward was sown due to its old age. The most commonly used sowing rate for the summer-active tall fescue was 16 – 20 kg/ha (Table 3-5). Summer-active tall fescue was sown as the main species in 36 of the surveyed swards and as a component of a seed blend in 24 swards (Table 3-5). A seed blend was defined as containing at least one other grass or herb species. When seed mixture was related to establishment success by regression analysis, a p value of 0.078 was obtained. Sowing as the main species resulted in successful establishment in 69% of swards and poor establishment in 15% of swards. Sowing in a seed blend resulted in successful establishment in 46% of swards and poor establishment in 31% of swards. The remaining swards reported acceptable establishment. Phalaris and chicory (Cichorium intybus L.) were the most commonly used companion species. Sowing occurred most often in spring or autumn (Table 3-5).
Table 3-5 Establishment practises and success levels for summer-active tall fescue swards (mail survey)

<table>
<thead>
<tr>
<th>Establishment success</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>9</td>
</tr>
<tr>
<td>Good</td>
<td>25</td>
</tr>
<tr>
<td>Acceptable</td>
<td>14</td>
</tr>
<tr>
<td>Poor</td>
<td>9</td>
</tr>
<tr>
<td>Very poor</td>
<td>2</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sowing year</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1980</td>
<td>1</td>
</tr>
<tr>
<td>1980 – 1990</td>
<td>0</td>
</tr>
<tr>
<td>1991 – 2000</td>
<td>6</td>
</tr>
<tr>
<td>2001 – 2003</td>
<td>26</td>
</tr>
<tr>
<td>2004 – 2006</td>
<td>15</td>
</tr>
<tr>
<td>2007</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Summer active tall fescue sowing rate (kg/ha)</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>6</td>
</tr>
<tr>
<td>10 – 15</td>
<td>12</td>
</tr>
<tr>
<td>16 – 20</td>
<td>24</td>
</tr>
<tr>
<td>21 – 25</td>
<td>7</td>
</tr>
<tr>
<td>26 – 30</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sowing mixture</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main species</td>
<td>36</td>
</tr>
<tr>
<td>Seed blend</td>
<td>24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sowing season</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>8</td>
</tr>
<tr>
<td>Autumn</td>
<td>22</td>
</tr>
<tr>
<td>Winter</td>
<td>4</td>
</tr>
<tr>
<td>Spring</td>
<td>36</td>
</tr>
</tbody>
</table>
3.3.4 Sward persistence and productivity

Survey respondents were asked to rate the persistence of the surveyed swards, where persistence was defined as summer-active tall fescue survival and contribution to herbage mass. Persistence was generally good or very good (Table 3-6). Annual productivity was reported for only 25 of a possible 63 swards and ranged from 4 to 18 t DM/ha.year (Table 3-6).

Table 3-6 Persistence and annual productivity of summer-active tall fescue swards

(mail survey)

<table>
<thead>
<tr>
<th>Persistence rating</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>15</td>
</tr>
<tr>
<td>Good</td>
<td>23</td>
</tr>
<tr>
<td>Acceptable</td>
<td>4</td>
</tr>
<tr>
<td>Poor</td>
<td>8</td>
</tr>
<tr>
<td>Very poor</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual production (t DM/ha)</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 – 5.9</td>
<td>2</td>
</tr>
<tr>
<td>6 – 7.9</td>
<td>7</td>
</tr>
<tr>
<td>8 – 9.9</td>
<td>6</td>
</tr>
<tr>
<td>10 – 11.9</td>
<td>5</td>
</tr>
<tr>
<td>12 – 13.9</td>
<td>1</td>
</tr>
<tr>
<td>14 – 15.9</td>
<td>3</td>
</tr>
<tr>
<td>16 – 17.9</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>38</td>
</tr>
</tbody>
</table>
3.3.5  Effect of edaphic conditions on sward persistence and productivity

The summer-active tall fescue swards in the mail survey were sown on heavy clay (14 swards), clay loam (26 swards), loam (14 swards) or sandy loam (7 swards) soils. When soil type was related to sward persistence by regression analysis, a p value of 0.052 occurred. Clay soils were associated with good persistence in 84% of swards and poor persistence in 9% of swards. Sandy soils were associated with good persistence in 55% of swards and poor persistence in 33% of swards. The remaining swards reported acceptable persistence. Annual rainfall had no effect on sward persistence or productivity, with all the surveyed swards being in the 600 – 850 mm/year rainfall zone.

Forty-four of the swards in the mail survey were sown on soils prone to waterlogging and 19 swards were sown on well drained soils. Waterlogging improved ($P<0.001$) sward persistence and annual sward productivity, relative to well drained soils. Eleven of the surveyed swards were sown on soils affected by salinity and 43 of the surveyed swards were not affected by salinity, sodicity, acidity or high aluminium.

Soil fertility and the annual fertiliser rates applied to the swards in the mail survey are shown in Table 3-7. Response rates to questions about soil fertility and fertiliser use were low because soil samples were not taken from many of the surveyed swards and many swards were not regularly fertilised. The effect of soil fertility on sward persistence and productivity remains unclear due to insufficient samples sizes for regression analysis.
Table 3-7 Soil fertility of summer-active tall fescue swards and annual fertiliser applications to the swards (mail survey)

<table>
<thead>
<tr>
<th>Current soil fertility</th>
<th>No. of swards</th>
<th>Annual fertiliser applied</th>
<th>No. of swards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
<td></td>
<td><strong>kg N/ha</strong></td>
<td></td>
</tr>
<tr>
<td>5 – 5.5</td>
<td>10</td>
<td>&lt; 50</td>
<td>9</td>
</tr>
<tr>
<td>5.6 – 6</td>
<td>7</td>
<td>50 – 100</td>
<td>10</td>
</tr>
<tr>
<td>6.1 – 6.5</td>
<td>9</td>
<td>101 – 200</td>
<td>0</td>
</tr>
<tr>
<td>6.6 – 7</td>
<td>2</td>
<td>201 – 300</td>
<td>2</td>
</tr>
<tr>
<td>7.1 – 7.5</td>
<td>2</td>
<td>301 – 400</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>401 – 500</td>
<td>2</td>
</tr>
<tr>
<td><strong>Olsen P (mg/kg)</strong></td>
<td></td>
<td><strong>kg P/ha</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 10</td>
<td>2</td>
<td>6 – 10</td>
<td>6</td>
</tr>
<tr>
<td>10 – 14</td>
<td>7</td>
<td>11 – 15</td>
<td>8</td>
</tr>
<tr>
<td>15 – 19</td>
<td>14</td>
<td>16 – 20</td>
<td>5</td>
</tr>
<tr>
<td>20 – 39</td>
<td>6</td>
<td>21 – 25</td>
<td>15</td>
</tr>
<tr>
<td>40 – 59</td>
<td>1</td>
<td>26 – 30</td>
<td>4</td>
</tr>
<tr>
<td><strong>CPC S (mg/kg)</strong></td>
<td></td>
<td><strong>kg S/ha</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 10</td>
<td>2</td>
<td>&lt; 10</td>
<td>1</td>
</tr>
<tr>
<td>10 – 19</td>
<td>4</td>
<td>10 – 20</td>
<td>14</td>
</tr>
<tr>
<td>20 – 30</td>
<td>3</td>
<td>21 – 30</td>
<td>19</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>2</td>
<td>31 – 40</td>
<td>4</td>
</tr>
<tr>
<td><strong>Skene K (mg/kg)</strong></td>
<td></td>
<td><strong>kg K/ha</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 100</td>
<td>3</td>
<td>&lt; 50</td>
<td>7</td>
</tr>
<tr>
<td>100 – 199</td>
<td>4</td>
<td>50 – 100</td>
<td>2</td>
</tr>
<tr>
<td>200 – 299</td>
<td>17</td>
<td>101 – 150</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 299</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.3.6 Effect of grazing management on sward persistence and productivity

Seasonal grazing intervals, stocking rates and residual grazing heights for the swards in the mail survey are shown in Table 3-8. Five of the surveyed swards had been established in 2007 and had not yet been grazed. The sample size for questions relating to grazing was thus only 58. During spring, the sample size for questions relating to grazing was further reduced because 16 swards were excluded from grazing to be conserved for hay.

Regression analysis showed no effect of grazing interval or stocking rate on the persistence or productivity of the surveyed swards. Residual grazing height in spring was related to sward persistence (P=0.062), with grazing to a residual height of 6 cm resulting in better persistence (good persistence in 71% of swards and poor persistence in 20% of swards) than grazing to below 4 cm (good persistence in 45% of swards and poor persistence in 44% of swards). The remaining swards reported acceptable persistence.
Table 3-8 Grazing management of summer-active tall fescue swards (mail survey)

<table>
<thead>
<tr>
<th>Grazing interval (days)</th>
<th>No. of swards</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destocked</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Set stocked</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>&lt; 10 days</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10 – 20 days</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>21 – 30 days</td>
<td>9</td>
<td>24</td>
<td>12</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>31 – 40 days</td>
<td>13</td>
<td>11</td>
<td>15</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>&gt; 40 days</td>
<td>12</td>
<td>7</td>
<td>9</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stocking rate (DSE/ha)</th>
<th>No. of swards</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mob stocked</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>&lt; 10</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10 – 20</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>21 – 30</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>&gt; 30</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Residual grazing height (cm)</th>
<th>No. of swards</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3 – 5</td>
<td>20</td>
<td>23</td>
<td>21</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>6 – 8</td>
<td>14</td>
<td>13</td>
<td>9</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>9 – 11</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>
3.3.7 Sward renovation

Information about sward renovation was provided for 36 of the swards in the mail survey. Eighteen swards had never been renovated. Sixteen swards had been oversown. The type of renovation used on the remaining two swards was not reported. Oversowing was used to increase the clover content of the sward (10 swards), increase the density of the summer-active tall fescue (4 swards) or to thicken the sward with perennial ryegrass (3 swards).

3.3.8 Future use of summer-active tall fescue

In the telephone survey, 11 of the 66 respondents that did not currently use summer-active tall fescue intended to use the species in the future. Reasons for their decision were the species rapid summer growth where moisture is available (3 participants), rapid spring growth (1 participant), tolerance of grazing in winter (1 participant), tolerance of salinity (1 participant) and recommendations by agronomist (1 participant). The remaining participants did not give a reason.

Of the 37 mail survey participants, 24 intended to continue using summer-active tall fescue, while 5 did not intend to continue use and 6 didn’t know or were still considering. Those that did not intend to use summer-active tall fescue in the future cited poor establishment (3 participants) and low herbage nutritive value in spring (1 participant) as the reasons for their decision. One participant did not give a reason.
3.4 Discussion

Summer-active tall fescue was not commonly used in the Corangamite and Glenelg-Hopkins Catchments in south west Victoria. The primary reason for the low adoption rate was the association of the Demeter cultivar with low nutritive value in spring. Demeter was introduced to Australia in 1931 (Oram 1990) and since then breeding programs have selected cultivars for improved nutritive value (de Santis and Chiaravalle 2001). It is likely that the results of the telephone interviews were biased by participants with negative experiences with Demeter in the past because people with strong negative opinions are often more willing to participate in surveys than other people (Dillman 1991). Conversely, people with good or indifferent experiences from using summer-active tall fescue may have been disinterested in the research and unwilling to participate; thus, the views of these people would have been under-represented. Despite the constraints of the survey methodology, it was clear that future research must focus on demonstrating the attributes of modern cultivars of summer-active tall fescue, as compared to Demeter, and extend this information to farmers.

The most commonly used cultivars of summer-active tall fescue in the mail survey were Advance, Quantum, Dovey and Demeter. The high incidence of Demeter swards in the mail survey reinforces the need for future research and demonstration sites on modern cultivars. Modern cultivars of summer-active tall fescue are classified as being either tough or soft leaved, according to their nutritive value and zones of adaptation. Soft leaved cultivars, such as Advance, are generally higher in nutritive value than tough leaved cultivars, such as Quantum, but require greater moisture availability and higher soil fertility to meet their potential (Callow et al. 2003). Soft leaved cultivars are also
more palatable than tough leaved cultivars due to their higher carbohydrate and lower fibre fractions (Tava et al. 1995; Mayland et al. 2000). In this survey, soft leaved cultivars were most commonly used to meet the relatively high nutrient requirements of dairy enterprises.

During spring, no matter which cultivar is used, summer-active tall fescue must be grazed or cut to keep it in a short and leafy vegetative state or its nutritive value will decline rapidly (Cherney et al. 1993; Wilman et al. 1996; Lowe et al. 1999). This is primarily due to the development of reproductive stems, which tend to be larger and more fibrous than other improved pasture grass species, such as perennial ryegrass (Hume and Brock 1997; Chaves et al. 2006). Reproductive development can also lower the palatability of the leaf and stem components of the sward by causing the translocation of water soluble carbohydrates, which are positively related to palatability, to the seed heads for conversion into starch (Tava et al. 1995; Mayland et al. 2000; Chaves et al. 2006). As was mentioned in the literature review (Chapter 2), the intensity and frequency of grazing required to maintain summer-active tall fescue in a short and leafy vegetative state during spring will vary depending on the prevailing environment. This survey has thus provided justification for conducting research into the leaf stage based grazing intervals which account for seasonal changes in plant growth and physiology.

In this survey, grazing the sward to a height of less than 4 cm during spring was associated with poor summer-active tall fescue persistence. As was mentioned in the literature review (Chapter 2), prolonged intense grazing can slow the growth and eventually result in the death of pasture grasses because the continued removal of leaf
material limits the plant’s ability to photosynthesise and eventually results in the depletion of the plant’s carbohydrate energy reserves. It was clear from this survey that many summer-active tall fescue swards were being overgrazed during spring, possibly in an effort to maintain nutritive value and prevent the production of large reproductive stems. This reinforces the need to develop comprehensive guidelines for grazing the species, especially during spring.

It must be acknowledged, however, that questions relating to pasture height are affected by conjecture, with survey participants likely to have given an approximation of residual pasture height which was not actually measured and which is likely to vary across the paddock and may differ each time the paddock is grazed. The reliability of estimates of annual sward productivity are also questionable because it is unlikely that farmers actually measured herbage mass. Although this survey has provided a valuable indicator of the residual grazing height of the sward and annual sward productivity, the findings of this survey need to be confirmed under replicated and objective experimental conditions.

The other major barrier to the adoption of summer-active tall fescue in this survey was the slow establishment of the species. Poor establishment in this survey was often associated with sowing the summer-active tall fescue in a seed blend with other species. Previous research conducted in the > 550 mm/year rainfall zone of southern New South Wales has demonstrated that, when sowing perennial pastures, diverse pasture mixtures generally result in only the two species sown at the highest rates persisting, with phalaris and subterranean clover (*Trifolium subterraneum* L.) being the most persistent species in the tested study area (Virgona and Hildebrand 2006). The weak competitive
ability of summer-active tall fescue seedlings (Harkess 1970; Brock 1973; Hamilton-Manns et al. 1995), especially at low temperatures (Hill et al. 1985; Charles et al. 1991a), may result in its displacement from the sward by other sown species if it is sown in seed blends, as has been evidenced in this survey. It must be acknowledged, however, that the measure of establishment success used in this survey, which required the survey participant to rate establishment success from very poor to very good, was highly subjective. The subjective nature of this survey and the prevalence of survey participants sowing summer-active tall fescue in seed blends clearly indicates that guidelines for establishing summer-active tall fescue need to be developed by replicated experiments and extended to farmers.

Many of the participants in this survey would not use summer-active tall fescue because they were unwilling to change from perennial ryegrass systems. The high incidence of perennial ryegrass use in this survey supports previous survey work by Quigley et al. (1992) which found that perennial ryegrass was the most commonly used improved pasture grass species in some areas of south west Victoria. It was concluded from the literature review that summer-active tall fescue may be better suited than perennial ryegrass to heavy textured soils in the high rainfall zone of southern Australia due to its deeper root system and better heat tolerance (Garwood and Sinclair 1979; Jiang and Huang 2001). Despite this, even participants in the mail survey who had chosen to sow summer-active tall fescue were reluctant to invest large areas of their property in the species because they were uncertain how it would perform and how it should be managed. Generally, less than 5% of a property was sown to summer-active tall fescue and this often amounted to only a trial paddock.
A critical management practice that arose from this survey was the need to sow summer-active tall fescue on clay soils that are prone to waterlogging during wet seasons. Such soils have a high water holding capacity and retain moisture during wet seasons which the plant can draw on to survive and continue growth during dry seasons via its deep root system (Garwood and Sinclair 1979; Nie et al. 2008). The poorer persistence of the species on light soils presumably occurred because the species does not display summer dormancy and will continue to grow over summer despite the moisture deficit, which will eventually cause plant deaths (Norton et al. 2006). Previous research has shown that waterlogging for short periods over winter does not adversely affect the survival of summer-active tall fescue, providing soil oxygen levels do not fall below 14%, with the species also being more tolerant of the salinity exchanges that are associated with waterlogging than other improved grasses, such as perennial ryegrass (Rogers and Davies 1973; Davies et al. 2004). In fact, general comments from the mail survey indicated that summer-active tall fescue was often selected for saline areas due a reputation of being tolerant of salinity. This survey has suggested that summer-active tall fescue can provide a persistent source of pasture from heavy soils that become waterlogged for short periods and from saline soils.

The choice of summer-active tall fescue as a pasture species was often based on the requirement for a high yielding hay crop. Summer-active tall fescue swards that have been left ungrazed can support two cuts of hay in spring and have recorded annual herbage utilisation of up to 7.4 t DM/ha (Baker et al. 1988). Grazing summer-active tall fescue swards in early spring, prior to cutting for hay, has been shown to reduce hay yields, but to have a positive effect on hay nutritive value because the hay is cut at an earlier stage of maturity (Baker et al. 1988; Prigge et al. 1999). The hay in the research
by Baker et al. (1988) had 10.5% crude protein (CP), 69.7% neutral detergent fibre (NDF) and 55.3% \textit{in vitro} dry matter digestibility (IVDMD) following early spring grazing and 8.5% CP, 71.4% NDF and 52% IVDMD when the sward was not grazed in spring. Horney et al. (1996) demonstrated that DM intake and body weight gains of steers fed summer-active tall fescue hay was increased by cutting the hay in the early vegetative stage to improve hay nutritive value and palatability. In light of 25% of the surveyed swards being used for hay, this is an area that warrants further research to determine guidelines for maximising hay nutritive value, while still achieving high yields.

The results from the survey did not show a correlation between fertiliser use and the persistence and productivity of the surveyed summer-active tall fescue swards. This is most likely due to low sample sizes preventing accurate regression analysis and may also be due to the surveyed paddocks not being fertilised. Despite the lack of research into its effectiveness, 22 of the surveyed swards were treated with N fertiliser and 38 were treated with P fertiliser. Phosphorus fertiliser use was generally above the average P fertiliser use for the region, which is 6 kg P/ha.year (Trompf et al. 1998) and was a similar level to the maximum rates used by the participants in the south west monitor farm survey (Patterson et al. 1998). Clearly, in light of no conclusive research being available on the response of summer-active tall fescue to applied fertiliser in southern Australia, this is an issue that needs to be investigated.
3.5 Conclusion

Summer-active tall fescue is a pasture grass species generally not used in the south west Victoria region of southern Australia. The primary reason for its low adoption rate is the negative association of the out-dated Demeter cultivar with low nutritive value over spring. Other reasons for the species low adoption rate included its slow establishment and the reluctance of livestock producers to change from current perennial ryegrass based pasture systems. A fundamental management practise that arose during this research was the importance of sowing summer-active tall fescue on heavy textured soils that become waterlogged during wet seasons; sowing the species on lighter or well drained soils often resulted in poor persistence.

This survey has provided valuable information into farmer attitudes towards and current use of summer-active tall fescue in the south west Victoria region of southern Australia, but there were numerous sources of bias in this survey that must be acknowledged. These relate to sampling, non-response, measurement and coverage error, which are inherent in all surveys. There were also questions in this survey that were subjective and involved rating the performance of swards, in terms of establishment success and persistence. It is often difficult to avoid such bias in surveys, while still achieving a high response rate. Despite these limitations, this survey has provided focus for future research by identifying important issues. In particular, replicated field experiments are required to verify the effect of establishment procedures and grazing and fertiliser management on the persistence and productivity of the species.
This survey has also demonstrated that there is a widespread lack of knowledge about summer-active tall fescue among livestock producers in southern Australia, with many survey participants basing their opinion of the species on the out-dated Demeter cultivar. There is clearly a need to test the performance of modern cultivars of summer-active tall fescue, as compared to Demeter, and to extend this information to livestock producers.
Chapter 4. Establishing summer-active tall fescue in southern Australia

4.1 Introduction

The survey documented in Chapter 3 identified that the slow establishment of summer-active tall fescue is a major barrier to the adoption of the species. Research has shown that summer-active tall fescue seedlings take approximately twice as long to emerge than perennial rye grass seedlings (Brock 1973; Hamilton-Manns et al. 1995), with emergence being further inhibited at temperatures below 12°C (Charles et al. 1991a). Slow establishment gives weeds an opportunity to invade (Charles et al. 1991b). The cost of poor establishment is incurred by livestock producers as lost sward and livestock production and the cost of re-sowing the sward.

The establishment of summer-active tall fescue is likely to be improved in southern Australia by sowing in spring when temperatures are increasing, rather than sowing in autumn (Charles et al. 1991b; a). Spring sowing can, however, result in moisture deficit stress, particularly if sowing occurs late in the season or if the season is dry. One way of overcoming this problem is by direct drilling, which reduces soil moisture losses through evaporation by minimising soil cultivation. Protection against desiccation and predation generally increases with increasing sowing depth, but if sowing is too deep emergence may be delayed or seeds may die before they penetrate the soil surface (Brock 1973). A field experiment was conducted to test the hypothesis that summer-active tall fescue can be successfully established in the south west Victoria region of southern Australia by direct drilling high rates of seed at depth during spring.
4.2 Materials and method

4.2.1 Site description

The experiment was conducted at the Department of Primary Industries research farm at Hamilton, in south west Victoria, Australia (37°50’S, 142°04’E; altitude 200 m). Climatic data collected from the on-farm weather station indicates a temperate climate with long term (1963 – 2009) average annual rainfall of 685 mm. Rainfall is winter and spring dominant with summer and early autumn typically being hot and dry, though large sporadic rainfall events may occur during this time.

Rainfall in the six weeks after sowing, which occurred on 22 October 2008, was below average (Figure 4-1), with only 61 mm of rainfall during October and November 2008, compared to the long term average of 117 mm for this period (Figure 4-2). Since 1963, there have only been nine years when October and November rainfall has been less than 70 mm. The only rainfall events in the six weeks after sowing were 14 mm of rain between 1 – 3 November 2008 and 22 mm of rain between 21 – 23 November 2008 (Figure 4-1). Between December 2008 and February 2009 the site received 132 mm of rain, which is higher than the long term average of 107 mm for this period. This rain was poorly distributed, however, with 93 mm on 12 – 14 December 2008 and only 3 mm during January 2009 and 2 mm during February 2009. Large summer rainfall events had also occurred in the two years prior to the experiment, with 95 mm of rain falling between 18 – 20 January 2007 and 98 mm of rain falling between 3 – 4 November 2007.
Figure 4-1 Weekly distribution of rain during the experimental period.

Figure 4-2 Monthly rainfall prior to and during the experimental period (black bars). Long term averages are indicated by the white bars.
February is, on average, the hottest month at the site, with long term (1965 – 2009) average maximum and minimum daily temperatures of 26°C and 11°C. The air and soil temperatures during the experiment, as compared to the long term average for the site, are shown in Figure 4-3. Soil temperature was measured at a depth of 10 cm. On 28, 29 and 30 January 2009 and 7 February 2009 the maximum day time temperature reached between 42 – 44°C. This is approximately 18°C above the long term average. During these hot conditions, soil temperatures reached 26°C, which is approximately 6°C above average. Soil temperatures remained at between 26 – 22°C for five weeks during the experiment.

**Figure 4-3** Mean weekly maximum (■) and minimum (○) air temperatures and soil temperatures measured at a depth of 10 cm (▲) during the experimental period. Long term weekly averages are indicated by the lines.
The soil profile to a depth of below 1 m was determined from a soil pit near the site. This soil pit indicated that the geology of valley soils at the site was a tertiary/quaternary basalt. The soil mapping unit was a monivae clay loam. Soil profile characteristics from the pit are shown in Tables 4.1 and 4.2.

Table 4-1 Soil profile characteristics from soil pit near research site

<table>
<thead>
<tr>
<th>Surface Soil</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 – 15 cm</td>
<td>Dark brown (10YR3/3); very fine sandy clay loam; weak coarse blocky structure; very firm consistence (dry); pH 5.3; clear change to:</td>
</tr>
<tr>
<td></td>
<td>A2 15 – 40 cm</td>
<td>Brown (10YR5/3); conspicuously bleached (10YR7/1 dry); light fine sandy clay loam; massive structure; very firm consistence (dry); pH 5.9; abrupt change to:</td>
</tr>
<tr>
<td>Subsurface Soil</td>
<td>B1 40 – 50 cm</td>
<td>Brown (10YR5/3); light medium clay; weakly structured; very strong consistence (dry); pH 6.6; clear change to:</td>
</tr>
<tr>
<td></td>
<td>B21 50 – 65 cm</td>
<td>Brown (10YR5/3) with brownish yellow (10YR6/6 and 6/8) mottles; medium clay; very strong consistence (dry); many (30%) ferruginous nodules (2-4 mm); pH 6.6; gradual change to:</td>
</tr>
<tr>
<td></td>
<td>B22 65 – 100 cm</td>
<td>Yellowish brown (10YR5/4) with brownish yellow (10YR6/6 and 6/8) mottles; medium heavy clay; moderate coarse blocky, parting to lenticular structure; very strong consistence (moist); many (20-40%) ferruginous nodules (2-6 mm); some manganese stains; pH 6.7:</td>
</tr>
<tr>
<td></td>
<td>B23 100 cm</td>
<td>Light brownish grey (10YR6/2) with many (40%) brownish yellow (10YR6/8) and dark red (2.5YR4/8) mottles; weak coarse prismatic, parting to moderate lenticular structure; rigid consistence (moist); contains few (5%) ferruginous nodules (2-6 mm); pH 6.7.</td>
</tr>
</tbody>
</table>
Table 4-2 Characteristics of the soil horizons shown in Table 4.1

<table>
<thead>
<tr>
<th>Horizon</th>
<th>pH (CaCl$_2$)</th>
<th>EC 1:5</th>
<th>Field capacity pF2.5</th>
<th>Clay content (&lt;0.002)</th>
<th>Exchangeable Na$^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>4.8</td>
<td>0.10</td>
<td>38</td>
<td>18</td>
<td>0.18</td>
</tr>
<tr>
<td>A2</td>
<td>5.2</td>
<td>&lt;0.05</td>
<td>24</td>
<td>11</td>
<td>0.08</td>
</tr>
<tr>
<td>B1</td>
<td>5.7</td>
<td>0.06</td>
<td>27</td>
<td>34</td>
<td>0.45</td>
</tr>
<tr>
<td>B21</td>
<td>6.0</td>
<td>0.13</td>
<td>35</td>
<td>50</td>
<td>1.30</td>
</tr>
<tr>
<td>B23</td>
<td>6.0</td>
<td>0.12</td>
<td></td>
<td></td>
<td>1.70</td>
</tr>
</tbody>
</table>

4.2.2 Site establishment and management

The site was direct drilled on 22 October 2008 with a tyne spacing of 15 cm. This sowing date ensured that establishment was not inhibited by low soil temperatures (< 12°C) (Hill et al. 1985; Charles et al. 1991a) and that the paddock was dry enough to be driven on. After sowing, the site was rolled with rubber tyre rollers. No fertiliser was applied at sowing.

Seed weight was estimated to be 2.65 grams per 1000 seeds by a seed counter. Germination rate was tested by placing 100 seeds on filter paper in each of two glass petri dishes with 5 ml of distilled water. They were incubated at constant temperature of 20°C in diffuse domestic light. Germination was defined as having taken place when the shoot was 1 mm in length. Germination rate was 98% in both petri dishes.

Clover was not sown in this experiment because subterranean clover, which is typically used in the Hamilton district, is an annual and must be sown in autumn to allow it to set seed. In the Hamilton district, clover is usually oversown into spring sown swards the following autumn. It is important to maintain a clover component in grass swards in southern Australia because it has a high nutritive value compared to grass (Stockdale 1999) and it improves soil N fertility by fixing atmospheric N$_2$ into a plant available
form via its symbiotic relationship with *Rhizobia* bacteria within nodules in its root system (Whitehead 1995).

The site had previously been sown to plantain (*Plantago lanceolata* L.) and perennial ryegrass. Competition from these species, as well as other weeds, was reduced by preventing seed set in the year ahead of sowing. This was done by cutting the paddock for hay in spring 2007 and then rotationally grazing the paddock with sheep until August 2008.

In August 2008 the site was sprayed with 2 L/ha of Roundup PowerMAX® (540 g/L glyphosate, ~10% w/v surfactant with water comprising the balance) and 100 ml/ha of FASTAC DUO® (100 g/L alpha-cypermethrin, 741.9 g/L liquid hydrocarbons and 0 – 5% w/v surfactant) to remove existing herbage and control pests, such as cockchafers (*Aphodius pseudotasmaniae*) and red legged earth mites (*Halotydeus destructor*). Eight days after spraying, the paddock was mob stocked by sheep for 12 days to reduce post-grazing herbage mass to approximately 800 kg DM/ha. The paddock was harrowed in September 2008 to aerate the soil surface and stimulate the germination of weed seeds. This weed herbage and any remaining pests were again sprayed with the same products in October 2008 one week prior to sowing. Herbage mass at the time of sowing was < 100 kg DM/ha. The plots were also sprayed in January 2009 with 1.2 L/ha of MCPA 500 (2-methyl-4-chlorophenoxyacetic acid at a concentration of 50%, with the remainder comprising inert ingredients) for control of wild radish (*Raphanus raphanistrum*) that had invaded areas of the site following summer rain.
The experimental site was relatively uniform in terms of soil type and slope and was not affected by drains or trees. Soil samples (0 – 10 cm) taken in October 2007 indicated that the soil was a grey brown clay loam (Northcote 1979; McDonald 1998) with pH_{water} of 5.6, P (Olsen) of 24 mg/kg, K (Skene) of 340 mg/kg, S (CPC) of 8 mg/kg and electrical conductivity of 0.19 dS/m. In April 2008, 18 kg P/ha, 22 kg S/ha and 41 kg Ca/ha was applied as single superphosphate.

Prior to the experiment, the site had been rotationally grazed by sheep, but during the experiment it was not grazed because seedlings were not firmly rooted. The ability of seedlings to be grazed, without being up-rooted, was tested by randomly sampling 40 seedlings, 10 from each level of sowing depth, at weekly intervals by gripping the seedling 1 cm above ground level and pulling it gently. If the seedling was up-rooted, then it was considered not ready to be grazed, but if the leaves broke rather than the seedling being up-rooted then it was considered able to be grazed. For the plots to be grazed, 30 of the 40 sampled seedlings had to be firmly rooted, but this never occurred due to the dryness of the soil. Seedlings in fixed quadrats were not sampled so as not to interfere with the repeated measure of seedling density.
Photo 4-1 Direct drilling summer-active tall fescue on 22 October 2008 at the experimental site near Hamilton.

Photo 4-2 The experimental site on 16 January 2009, following 93 mm of rain during 12 – 14 December 2008.
4.2.3 Experimental design

Endophyte-free summer-active tall fescue (*Lolium arundinaceum* syn. *Festuca arundinacea* Schreb. cv. Quantum) was direct drilled in a factorial combination of four sowing depths (5 mm, 10 mm, 20 mm or 35 mm) and four sowing rates (8 kg/ha, 16 kg/ha, 24 kg/ha or 32 kg/ha) applied to 1.5 m by 6 m plots laid out in a randomised complete block design with eight replications. These levels of sowing rate incorporated the sowing rates used by participants in the survey of summer-active tall fescue use and management in south west Victoria (refer Chapter 3) and also tested high and low variations of these sowing rates. The sowing depths compared surface sowing, which would enable rapid emergence if moisture was sufficient, with incremental increases in depth that would gradually increase access to soil moisture, but which would delay emergence and increase seed dependence on endosperm reserves.

4.2.4 Pasture measurements

After sowing, plots were monitored daily for emergence. Seedling emergence was recorded when the shoot became visible. Once emergence had occurred, summer-active tall fescue seedling density (seedlings/m²) was recorded from five fixed 30 cm by 15 cm quadrats per plot. Seedling density was initially estimated on a daily basis, but once seedling numbers became less variable at the end of December 2008 seedling density was estimated monthly until April 2009. Measurements ceased in April 2009 because seedlings could no longer be identified as individuals.
4.2.5 Statistical analysis

The effect of sowing depth and sowing rate on summer-active tall fescue seedling density was analysed by Genstat Version 11 using repeated measures analysis of variance (Payne et al. 2008). The effect of sowing depth and sowing rate on maximum seedling density, the proportion of sown seed that emerged, seedling survival and final seedling density was analysed by two-way analysis of variance. Prior to analysis, residuals were checked for normality and the implications of transforming the data were investigated. The presented data are not transformed.

4.3 Results

Seedling density was affected by a three-way interaction between sowing depth, sowing rate and sampling date ($P<0.05$) (Figure 4-4).
Figure 4-4 Seedling density (seedlings/m²) of summer-active tall fescue sown at 8 kg/ha (■), 16 kg/ha (○), 24 kg/ha (▲) or 32 kg/ha (×) at sowing depths of 5 mm, 10 mm, 20 mm or 35 mm. The vertical error bars indicate the sowing depth by sowing rate by sampling date interaction l.s.d (P=0.05), with the left bar indicating the l.s.d for comparing treatments with different levels of sowing depth, sowing rate or sampling date and the right bar indicating the l.s.d for comparing treatments with the same levels of sowing depth, sowing rate or sampling date.
4.3.1 Emergence

Seedling emergence from plots sown at a depth of 5 mm had occurred on 10 November 2008 at the 24 kg/ha or 32 kg/ha sowing rates and on 24 November 2008 at the 16 kg/ha sowing rate (Figure 4-4). No seedlings emerged from plots sown at a depth of 5 mm and a sowing rate of 8 kg/ha. Emergence from the 10 mm, 20 mm and 35 mm sowing depths occurred on 24 November 2008 at all levels of sowing rate, prior to which seedling density had not been higher than 0 seedlings/m² at $P=0.05$.

4.3.2 Maximum seedling density

Seedling density was statistically highest for all treatments between 24 November 2008 and 5 January 2009. Maximum seedling density, as occurred on 24 November 2008, is shown in Figure 4-4. At the 5 mm, 20 mm and 35 mm sowing depths, maximum seedling density increased ($P<0.05$) with increasing sowing rate up to 32 kg/ha (Figure 4-5). At the 10 mm sowing depth maximum seedling density increased ($P<0.05$) with increasing sowing rate up to 24 kg/ha, but there was no difference in maximum seedling density between the 24 kg/ha and 32 kg/ha sowing rates. Maximum seedling density was lowest ($P<0.05$) at the 5 mm sowing depth and highest ($P<0.05$) at the 10 mm and 20 mm sowing depths, at each level of sowing rate, with the 10 mm and 20 mm sowing depths not differing from each other (Figure 4-5).
Figure 4-5 Maximum seedling density (seedlings/m²) from sowing depths of 5 mm (■), 10 mm (○), 20 mm (▲) and 35 mm (×) at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha. The vertical error bar indicates the sowing depth by sowing rate interaction (P=0.05).

4.3.3 Proportion of sown seed that emerged

The proportion of sown seed that emerged was highest (P<0.05) at sowing depths of 10 mm and 20 mm, which did not differ from each other, and lowest (P<0.05) from the 5 mm sowing depth, at each level of sowing rate (Figure 4-6). At the 10 mm and 20 mm sowing depths, the proportion of sown seed that emerged did not differ between the 8 kg/ha, 16 kg/ha and 24 kg/ha sowing rates, which were higher (P<0.05) than the 32 kg/ha sowing rate. At the 5 mm and 35 mm sowing depths, there was no effect of sowing rate on the proportion of sown seed that emerged.
Figure 4-6 The proportion of sown seed that emerged from sowing depths of 5 mm (■), 10 mm (○), 20 mm (▲) and 35 mm (×) at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha. The vertical error bar indicates the sowing depth by sowing rate interaction ($P=0.05$).

4.3.4 Seedling survival

Sowing at a depth of 5 mm resulted in lower ($P<0.05$) seedling survival (the difference between maximum seedling density and final seedling density) than the 10 mm, 20 mm and 35 mm sowing depths, at each level of sowing rate (Figure 4-7). At a sowing rate of 8 kg/ha, there was no difference in seedling survival between the 10 mm, 20 mm and 35 mm sowing depths. At sowing rates of 16 kg/ha, 24 kg/ha and 32 kg/ha, sowing at a depth of 35 mm generally resulted in higher seedling survival than sowing at a depth of 10 mm or 20 mm. At the 10 mm, 20 mm and 35 mm sowing depths, seedling survival was higher ($P<0.05$) at the 32 kg/ha sowing rate than it was at the 8 kg/ha sowing rate.
Figure 4-7 Seedling survival (final seedling density as a proportion of maximum seedling density) from sowing depths of 5 mm (■), 10 mm (○), 20 mm (▲) and 35 mm (×) at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha. The vertical error bar indicates the sowing depth by sowing rate interaction (P=0.05).

4.3.5 Final seedling density

There was no difference in final seedling density (measured on 6 April 2009) between the 10 mm, 20 mm and 35 mm sowing depths at each level of sowing rate. Final seedling density increased (P<0.05) linearly with increasing sowing rate (Figure 4-8).
Figure 4-8 Final seedling density (seedlings/m²) measured on 6 April 2009 from sowing depths of 5 mm (■), 10 mm (○), 20 mm (▲) and 35 mm (×) at sowing rates of 8 kg/ha, 16 kg/ha, 24 kg/ha and 32 kg/ha. The vertical error bar indicates the sowing depth by sowing rate interaction (P=0.05).

4.4 Discussion

Rainfall during October and November 2008 was only 61 mm, which is approximately half of the long term average rainfall for this period at the site. Rainfall is the primary determinant of seedling germination, emergence and growth in south west Victoria, with irrigation rarely being used. It is an attribute of this experiment that it was conducted under dryland field conditions; this accounts for the biotic and abiotic stresses incurred by establishing seedlings, such as moisture availability, temperature, insect and fungal attack, weed competition and variations in soil texture (Parsons and Chapman 2000). Previous research has often failed to account for the effect of these
factors on establishing summer-active tall fescue seedlings because it was conducted under controlled environmental conditions and watered to field capacity (Hill et al. 1985; Charles et al. 1991a). It must be acknowledged, however, that the results of this experiment only apply to the tested conditions, and since rainfall during the initial two months of the experiment was unseasonably low, it is unlikely that the results will apply in other years at the site. The results do, however, indicate that summer-active tall fescue can be successfully established in south west Victoria, even during dry seasons, provided that correct management practises are followed. This finding may help overcome the perception in the district that the species is difficult to establish (refer Chapter 3) and increase the rate of adoption of the species. In light of the drier than average spring conditions in this research, further research is needed to determine how summer-active tall fescue establishes under a range of environmental conditions to develop guidelines which livestock producers can apply to their individual properties.

There was a week of unprecedented hot weather over late January/early February 2009, with maximum day time temperatures often exceeding 40°C. It is likely that the growth and survival of the summer-active tall fescue seedlings in this experiment was reduced by the hot weather during January and February, with the optimum temperature for the growth of perennial C3 grasses being between 17 – 21°C (Mitchell 1956; Baker and Jung 1968; Silsbury 1969). Seedling density at all levels of sowing depth had remained unchanged from 24 November 2008 until 5 January 2009; however, between 5 January 2009 and 2 March 2009, during which time hot temperatures prevailed, seedling density progressively declined, indicating that seedling deaths had occurred. Visual observations made during the experiment indicated that the leaves of the seedlings showed signs of heat damage, such as brown burn marks and wilting.
It is likely that the negative effect of hot temperatures on seedling survival was confounded by moisture deficit stress during this time, with only 5 mm of rain falling during January and February 2009. Long term climate data indicated that such hot conditions are uncommon in south west Victoria, though their incidence may increase under climate change scenarios. The hot and dry conditions during the trial also prevented the plots from being grazed in the six months after sowing because the seedlings were not firmly rooted. This would have major practical limitations for livestock producers and may lead them to consider other, faster establishing, pasture species, as was evidenced in the results of the survey (Chapter 3). Although it was not the objective of this study, it has arisen that further research into the autumn sowing of summer-active tall fescue is warranted in order to avoid the hot and dry conditions that can occur over summer and achieve a sward that can be grazed soon after sowing.

Autumn sown swards, however, are exposed to low temperatures during winter. Previous research has shown that the establishment of summer-active tall fescue is impaired at temperatures below 12°C (Hill et al. 1985; Charles et al. 1991a). Long term climate data indicates that soil temperatures at the site are generally less than 12°C between May and September, hence why this experiment was sown in October. Furthermore, autumn sown swards must compete with winter growing annual weeds, such as winter grass (Poa spp.) and capeweed (Arctotheca calendula). Research on the Northern Tablelands of New South Wales has shown that spring sowing results in higher summer-active tall fescue seedling densities than autumn sowing, with this being attributed to avoiding low winter temperatures. A further option is to sow earlier in spring. Sowing would occur when soil temperatures are below 12°C, but temperatures would be gradually rising and seedlings may have sufficient time to develop a root
system before dry conditions take effect during summer. A limitation of this approach, however, is that paddocks in early spring are often too wet to drive on in south west Victoria.

The plots sown at a depth of 5 mm and a sowing rate of 24 kg/ha or 32 kg/ha emerged on 10 November 2008, following 14 mm of rain on 1 – 3 November 2008. Emergence from the deeper sowing depths did not occur until 24 November 2008, following 22 mm of rain on 21 – 23 November 2008. Previous research has shown that, in situations where moisture is not limiting, sowing summer-active tall fescue on the soil surface minimises the number of days until first emergence, relative to sowing at depths of 15 mm, 30 mm or 45 mm (Charles et al. 1991a). Our research has partially supported this finding under dryland field conditions, with a sowing depth of 5 mm accelerating emergence by two weeks, relative to sowing at depths of 10 mm, 20 mm or 35 mm, during a drier than average season.

Practises that accelerate summer-active tall fescue emergence are likely to minimise the opportunity for weed invasion. Although sowing at a depth of 5 mm was not an effective establishment technique under the dry conditions in our research, it is possible that shallow sowing during a spring when rainfall is average, where irrigation is available or during autumn may benefit summer-active tall fescue establishment. Long term weather data indicates that, since 1963, there have been 20 years when October and November rainfall exceeded 117 mm, which represents a 43% chance of achieving higher than average rain during this time at the site.
Maximum seedling density was higher at the 10 mm and 20 mm sowing depths than it was at the 35 mm sowing depth, but the higher rate of seedling survival between December 2008 and April 2009 at the 35 mm sowing depth resulted in there being no difference in final seedling density between the 10 mm, 20 mm and 35 mm sowing depths, at each level of sowing rate. Under field conditions at Palmerston North in New Zealand, Brock (1973) reported that mechanical impedance by soil inhibited summer-active tall fescue emergence from sowing depths of 25 mm and 37.5 mm, with maximum emergence occurring at a depth of 12.5 mm. The extent to which soil bulk density affected seedling emergence in our study remains unclear, though given the dry soil conditions it is unlikely that a mechanical barrier to emergence existed. It is more likely that the endosperm reserves of many of the seeds sown at the 35 mm sowing depth had become depleted before the seedling had penetrated the soil surface and developed a root and shoot system capable of providing its nutrient requirements.

Seedlings that did emerge from the 35 mm sowing depth had a greater chance of survival than those sown shallower, presumably, because deeper sowing places the seed in proximity of soil moisture and protects the seed against the evaporative forces that occur near the soil surface. As there was no difference in final seedling density between the 10 mm, 20 mm and 35 mm sowing depths under the relatively dry conditions of this study and in light of the higher maximum seedling density of the 10 mm and 20 mm sowing depths, sowing summer-active tall fescue at a depth of 35 mm appeared to be unjustified in this study.

At the 10 mm, 20 mm and 35 mm sowing depths, final seedling density and the rate of seedling survival increased linearly with increasing sowing rate. Previous research
conducted at Glen Innes in New South Wales has also demonstrated a positive relationship between sowing rate and summer-active tall fescue (cv. Demeter) seedling density where the summer-active tall fescue was oversown into existing swards at sowing rates of 5.5 kg/ha, 11 kg/ha, 22 kg/ha and 44 kg/ha (Dowling and Robinson 1976). It is likely that maximising seedling density will have on-going benefits for sward persistence and productivity by ensuring the sward maintains density even if some seedling deaths occur. In this respect, sowing summer-active tall fescue at a sowing rate of 32 kg/ha is justified and an effective establishment technique.

Sowing rates must, however, also reflect realistic practises and be cost-effective. At the 10 mm sowing depth, increasing the sowing rate from 24 kg/ha to 32 kg/ha did not improve maximum seedling density. It is likely that competition between seedlings for resources, particularly moisture, limited the number of seedlings that could be supported. Previous research has successfully established summer-active tall fescue at sowing rates of 20 kg/ha of Demeter under dryland conditions at Hamilton in south west Victoria (Reed et al. 2004a) and 20 kg/ha of Advance under irrigation in northern Victoria (Lawson et al. 2009). The research by Reed et al. (2004a) achieved a plant density of 160 plants/m² under dryland conditions at Hamilton, which is lower than some of the plant densities achieved in this research. This again indicates that summer-active tall fescue can be successfully established in south west Victoria, even during dry seasons. Textbooks have recommended sowing summer-active tall fescue at rates of 18 – 25 kg/ha (Milne 2001) and 15 – 20 kg/ha (Fribourg and Milne 2009) in the 600 – 800 mm rainfall zones of Australia. In this experiment, sowing summer-active tall fescue at a rate of 24 kg/ha and at a depth of 10 – 20 mm appeared to be optimum.
4.5 Conclusion

This experiment has supported the hypothesis that summer-active tall fescue can be successfully established in the south west Victoria region of southern Australia, even when spring rainfall is below average. A sowing depth of 10 mm or 20 mm and a sowing rate of at least 24 kg/ha were optimal for summer-active tall fescue under the tested environmental conditions. Sowing at a depth of 35 mm appeared to be unjustified because it did not improve final seedling density and appeared to inhibit seedling emergence, relative to sowing depths of 10 mm and 20 mm. This was despite the higher rate of seedling survival under the 35 mm sowing depth treatment. Sowing at a depth of 5 mm also appeared to be unjustified in this experiment because few seedlings sown at this depth survived summer. The 5 mm sowing depth did, however, accelerate seedling emergence by approximately two weeks relative to the deeper sowing depths. Sowing at rates higher than 24 kg/ha at the 10 mm and 20 mm sowing depths did not improve seedling density during much of this experiment.

As was mentioned in the discussion section, it is an attribute of this experiment that it was conducted under dryland field conditions because this accounts for the biotic and abiotic stresses that establishing seedlings are exposed to under realistic farm practises in southern Australia. The results of this study are, however, highly dependent on the prevailing environment and since rainfall during the initial six weeks of the experiment was below average and there was a period of unprecedented hot weather in late January/early February 2009, it is unlikely that the results of this experiment will apply in other years at the site. There is a need, therefore, to conduct more extensive research under a range of environmental conditions to develop establishment guidelines for
summer-active tall fescue that livestock producers can apply to their individual situations. Autumn sowing or sowing in early spring are practices that warrant further study.

Furthermore, agronomists and farmers often seek analysis of the long term benefits/costs of pasture establishment in terms of the patterns of annual and seasonal yield, long term botanical composition and the incidence of weeds in the years following establishment. This analysis was not possible within the time frame of this project. The following chapters in this thesis do, however, provide this data for swards of summer-active tall fescue that were established in 2004. This information, together with the results of this establishment trial, is invaluable for assessing the return on investment for newly established pastures.

Importantly, the survey documented in Chapter 3 identified that livestock producers in south west Victoria are reluctant to use summer-active tall fescue on their property because of a perception the species is slow to establish. This research has shown that summer-active tall fescue can be successfully established in south west Victoria, even in dry years, and this finding may overcome negative perceptions of the species.
Chapter 5. Effect of grazing management on the tiller population dynamics of summer-active tall fescue

5.1 Introduction

The growth, survival and density of a grass sward are determined by the productivity and persistence of the individual tillers which comprise the sward (Mitchell and Glenday 1958; Korte et al. 1982; McKenzie 1994). Tillers are shoots which arise from the base of the grass plant at or below ground level and usually encompass a leaf blade and pseudostem (stem plus leaf sheath). Grazing has a profound effect on the growth and survival of grass tillers by reducing their photosynthetic capacity and the subsequent availability of the substrates required for metabolism and growth (Booysen and Nelson 1975; Parsons et al. 1983a; Volene 1986). Grazing also causes disturbance to the sward, which can have a stimulatory effect on tiller formation (Tavakoli et al. 1993).

As was discussed in the literature review (Chapter 2), a useful criterion on which to base grazing management is the concept of leaf stage, which indicates the physiological age of a tiller based on the number of fully expanded leaves it contains. Such an indicator provides a practicable way of managing grazing to ensure the tiller’s long-term requirements for growth and survival are met, rather than focussing grazing regimes solely on meeting livestock nutritional requirements (Fulkerson and Donaghy 2001). Preliminary research into grazing intervals for summer-active tall fescue, which are based upon leaf stage, has been undertaken under controlled environmental conditions.
and mechanical defoliation (Sinclair et al. 2006; Donaghy et al. 2008). Such research has not been conducted under grazed field conditions.

A grazed field experiment was, therefore, conducted to compare the tiller populations of summer-active tall fescue swards under set stocking and different leaf stage based grazing regimes. It was hypothesised that grazing a summer-active tall fescue based sward in southern Australia at the four leaf stage would maximise tiller growth and survival and that more frequent grazing would improve tiller density.

5.2 Materials and method

5.2.1 Site description

The experiment was conducted at the Department of Primary Industries research farm at Hamilton, in south west Victoria, Australia (37°50’S, 142°04’E; altitude 200 m) in close proximity to the site of the establishment trial documented in Chapter 4. As was mentioned in Chapter 4, the site has a temperate climate with long term (1963 – 2009) average annual rainfall of 685 mm, as indicated by the on farm weather station. Rainfall is winter and spring dominant with summer and early autumn typically being hot and dry, though large sporadic rainfall events during this time may occur. The long term (1965 – 2009) average maximum and minimum daily temperatures in the warmest month (February) are 26°C and 11°C and in the coolest month (July) are 12°C and 4°C. Monthly rainfall and temperatures are shown in Figure 5-1.
Figure 5-1 Mean monthly maximum (■) and minimum (○) temperatures and rainfall (black bars) during the experimental period. Long term averages are indicated by the lines and white bars.

5.2.2 Site establishment and management

Summer-active tall fescue (cv. Quantum) was direct drilled at 19 kg/ha and at a depth of approximately 20 mm in November 2004 with 7.5 kg N/ha, 16 kg P/ha, 1 kg S/ha and 1 kg Ca/ha, applied as mono-ammonium phosphate (MAP). Prior to sowing, in October 2004, the site was sprayed twice with 2 L/ha of Roundup PowerMAX® (540 g/L glyphosate, ~10% w/v surfactant with water comprising the balance) and 100 ml/ha of FASTAC DUO® (100 g/L alpha-cypermethrin, 741.9 g/L liquid hydrocarbons and 0 – 5% w/v surfactant) to remove existing herbage and to control pests such as cockchafers (Aphodius pseudotasmaniae) and red legged earth mites (Halotydeus destructor). The
sward was oversown in May 2005 with subterranean clover cv. Leura at 8 kg/ha and cv. Gosse at 3 kg/ha and white clover (*Trifolium repens*) cv. Mink at 1.5 kg/ha.

The site was fertilised with 18 kg P/ha, 1 kg S/ha and 13 kg Ca/ha, applied as triple super phosphate in February 2005, May 2006 and March 2007. Soil samples (0 – 10 cm) taken in September 2006 indicated that the soil was a darkish yellowish greyish brown very fine sandy clay loam (Northcote 1979; McDonald 1998) with pH\(_{\text{water}}\) of 5.6, P (Olsen) of 18 mg/kg, K (Skene) of 420 mg/kg, S (CPC) of 18 mg/kg and electrical conductivity of 0.17 dS/m. A complete soils description to a depth of below 1 m, as assessed from a soil pit near the site, was provided in Chapter 4, section 4.2.1.

The site was sprayed in September 2005 with 750 ml/ha of Tigrex\(^\circledR\) (250 g/L MCPA ethyl hexyl ester, 25 g/L diflufenican, 325 g/L hydrocarbon solvent, 150 g/L N-methyl-2-pyrrolidone and 105 g/L non-ionic emulsifiers) to control broadleaf weeds, particularly capeweed. Sward botanical composition in September 2006, prior to the grazing treatments being imposed, was 85% summer-active tall fescue and 5% subterranean clover, with no difference between grazing treatments.

5.2.3 Experimental design

Four grazing treatments were imposed on field plots of endophyte-free summer-active tall fescue (*Lolium arundinaceum* syn. *Festuca arundinacea* Schreb. cv. Quantum) in a completely randomised design with three replications. The grazing treatments were set stocking or rotational grazing at the two, three or four leaf stage. The grazing treatments were imposed from September 2006 until October 2008. During this time, the set
stocked swards were continuously grazed by sheep to maintain a constant herbage mass of 800 – 1200 kg DM/ha. The rotationally grazed swards were mob-stocked by sheep when they had reached their designated leaf stage and were grazed to a residual herbage mass of 800 – 1200 kg DM/ha within a 2 – 10 day period. Throughout this thesis, sheep stocking rates are not reported because it was the purpose of the trial to measure the agronomic characteristics of the pasture sward, not to measure animal performance or carrying capacity. Sheep were used in this study to act as lawnmowers and utilise the pasture, but they were not experimental units. Stocking rates were adjusted throughout the year to ensure the desired residual herbage mass of 800 – 1200 kg DM/ha was achieved within a 2 – 10 day period.

Herbage mass was estimated from 10 fixed points per plot using a calibrated falling plate meter (Bransby et al. 1977). Herbage mass was measured from the rotationally grazed plots in the first week of each month, as well as pre- and post-grazing. Herbage mass from the set stocked plots was estimated monthly. It is acknowledged that grazing over a 2 – 10 day period allowed tiller regrowth and subsequent replenishment of carbohydrate reserves during the grazing period. It is also possible that sheep may have been re-grazing leaves during this period, thus affecting the ability of individual leaves to replenish their carbohydrate reserves. Carbohydrate content is positively related to the rate of pasture regrowth (Volenc 1986). It is unlikely that this affected relative treatment performance because all plots had the same potential for carbohydrate replenishment during the grazing period, with consistent grazing management being used for all treatments.
A communal grazing design was used to impose the grazing treatments (Michalk and McFarlane 1978; Lodge and Gorden 2000). The experiment consisted of 12 fenced plots that were 15 m by 10 m in size and separated by 3 m laneways. Two sides of each plot could be closed to exclude sheep from the plot or opened to allow sheep to graze the plot. The plots were grazed by Merino and Coopworth ewes that were maintained in condition score > 2.5. High stocking rates were used to prevent preferential grazing and to ensure a uniform residual herbage mass across the plots. Stocking rates varied throughout the year to reflect pasture growth rates. The use of high stocking rates and daily monitoring of the site prevented camping by the sheep in particular plots to ensure uniform nutrient return across the site.

The leaf stage of each plot was assessed independently by randomly sampling 12 tillers per plot and averaging the number of fully expanded leaves above the remnant of the last grazed leaf. Plots in the same treatment were always at the same leaf stage and were thus grazed at the same time.

A tiller was defined as being a shoot arising from an axillary bud within a leaf sheath and which grew vertically. Tillers arose from either the crown of the plant or from above ground nodes. These were defined as aerial tillers, though their presence was rare. Tillers were regarded as individuals if there was a visible shoot, whether or not the leaf was encompassing. For a tiller to be classified as alive there was green or white material within the pseudostem, though this was often surrounded by dead material. Dead tillers were brown and withered in appearance. Rhizomes and stolons, although rare, were differentiated from tillers due to their horizontal growth and rooting at the nodes.
Photo 5-1 The experimental site on 21 July 2007, showing short periods of waterlogging during winter. Water receded within one week.

Photo 5-2 Experimental site on 31 January 2007, following 123 mm of rain during January.
5.2.4 Pasture measurements

Summer-active tall fescue tiller density (tillers/m$^2$) was measured every two months between September 2006 and October 2008 using the procedure described by Cayley and Bird (1996). This involved counting the number of live summer-active tall fescue tillers in 10 randomly sampled 8 cm diameter soil cores per plot.

Tiller size (mg/tiller) was measured to coincide with tiller density measurements in October 2007, December 2007, February 2008 and April 2008. Twenty live whole summer-active tall fescue tillers were randomly harvested per plot at the intersection of the stem and root material. These tillers were dried at 100°C for 24 hours before being weighed. Sampling occurred prior to the rotationally grazed plots being grazed. The set stocked areas were also sampled at these times despite having less leaf material.

The effect of grazing treatment on summer-active tall fescue tiller appearance rate (tillers/m$^2$.month), death rate (tillers/m$^2$.month) and survival (the number of tillers which were alive at the beginning of the month that were still alive at the end of the month) was measured by conducting a marked tiller study between October 2006 and October 2008. All live tillers within five fixed 10 cm diameter circular quadrats per plot were marked with coloured plastic-coated wire and their subsequent life histories monitored at monthly intervals for two years.

Quadrats were located randomly along the plot transects. If the random nature of quadrat placement resulted in no summer-active tall fescue being present in the quadrat, it was relocated so it was on the nearest clump of summer-active tall fescue along the
transect. This approach was adopted to ensure sufficient numbers of tillers were present in each quadrat to allow data analysis.

At the first sampling, in October 2006, all live tillers in each quadrat were tagged with the same colour plastic-coated wire. During each subsequent monthly tiller marking, new tillers which had appeared since the previous marking were tagged with a unique colour of wire and recorded, while tillers that had died since the previous marking were untagged and recorded. Thus a matrix of tiller survival over two years was created. This non-destructive approach to tiller marking has been adopted by previous researchers on perennial ryegrass (Table 5-1). Five quadrats were used in this experiment to ensure that tiller marking was completed within five days, to minimise the effect of sampling date on tiller numbers.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Circular quadrat diameter</th>
<th>Number of quadrats per grazing treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>McKenzie (1994)</td>
<td>10.0 cm</td>
<td>16</td>
</tr>
<tr>
<td>Hernandez-Garay et al. (1993)</td>
<td>6.5 cm</td>
<td>6</td>
</tr>
<tr>
<td>Hongwen et al. (1990)</td>
<td>6.5 cm</td>
<td>9</td>
</tr>
<tr>
<td>Korte et al. (1987)</td>
<td>10.2 cm</td>
<td>16</td>
</tr>
<tr>
<td>L’Huillier (1987)</td>
<td>10.0 cm</td>
<td>32</td>
</tr>
<tr>
<td>Korte et al. (1984)</td>
<td>10.2 cm</td>
<td>16</td>
</tr>
<tr>
<td>Korte et al. (1982)</td>
<td>10.2 cm</td>
<td>20</td>
</tr>
</tbody>
</table>

Basal frequency, which is an estimate of plant persistence, was not measured in this project because the intensive marked tiller study indicated the survival/persistence at the level of the individual tiller.
5.2.5 Statistical analysis

The effect of grazing treatment on summer-active tall fescue tiller populations was analysed by repeated measures ANOVA using Genstat Version 11 (Payne et al. 2008). If no interaction between grazing treatment and sampling date was detected, antedependence ANOVA was used to test if the parameter being measured was dependent on its value at previous sampling dates. If no dependence was detected the level of antedependence was set at zero and one-way ANOVA was used to compare treatment means within each sampling date. Prior to analysis, residuals were checked for normality and the implications of transforming the data were studied. The presented data are not transformed because none of the transformation techniques (square root, log_{10}) revealed statistically significant effects that weren’t already apparent in the untransformed data. The coefficients of linear regression for grazing treatment and sampling date effects on the relationship between tiller size and density were compared using the pairwise test. The data were log_{10} transformed for this analysis.

5.3 Results

Between September 2006 and August 2007 there was no effect of grazing treatment on summer-active tall fescue tiller density (Figure 5-2). By October 2007 all treatments had lower ($P<0.05$) tiller densities than at the start of the study. Set stocking resulted in higher ($P<0.05$) tiller densities than all other treatments after January 2008.
Figure 5-2 The main effect of sampling date on summer-active tall fescue tiller density (tillers/m$^2$) (black line), showing treatment means under set stocking (○) and rotational grazing at the two (■), three (×) or four (▲) leaf stage. The error bars indicate the l.s.d.’s ($P=0.05$) for comparing treatment means within each sampling date. Sampling dates without error bars showed no effect of grazing treatment. The l.s.d ($P=0.05$) for the main effect of sampling date was 726 tillers/m$^2$. Tiller density was measured from randomly sampled soil cores.

Set stocking generally had the smallest ($P<0.05$) tiller size which showed no significant variation over time (Figure 5-3). During October and December 2007, grazing at the four leaf stage resulted in larger ($P<0.05$) tillers than the other treatments. Tillers grazed at the two or three leaf stage were intermediate of the other treatments, but their respective sizes showed no consistent relationship.
Figure 5-3 Summer-active tall fescue tiller size (mg/tiller) under set stocking (○) and rotational grazing at the two (■), three (×) or four (▲) leaf stage. The error bars indicate the grazing treatment by sampling date interaction l.s.d ($P=0.05$), with the left bar indicating the between treatment l.s.d and the right bar indicating the within treatment l.s.d. Tiller size was measured from randomly sampled tillers.

Grazing treatment had no effect on the relationship between summer-active tall fescue tiller size and density. At each sampling date, there was an inverse relationship between tiller size and density (Figure 5-4). The slope of the linear regression did not differ between sampling dates, but the intercept of the regression lines was different ($P<0.05$) (Table 5-2).
Figure 5-4 The relationship between summer-active tall fescue tiller size and density, averaged across grazing treatments, in October 2007 (□), December 2007 (●), February 2008 (×) and April 2008 (△), with linear regression fitted for each sampling date. Regression coefficients are shown in Table 5-2.

Table 5-2 The slope, intercept and coefficient of determination of the linear regression fitted to the log_{10} transformed tiller size and density relationship for each sampling period, averaged across grazing treatments, as shown in Figure 5-4. Means within the slope and intercept columns with the same letter do not differ ($P>0.05$)

<table>
<thead>
<tr>
<th>Sampling date</th>
<th>Slope</th>
<th>Intercept</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2007</td>
<td>-3.29a</td>
<td>13.26a</td>
<td>0.54</td>
</tr>
<tr>
<td>December 2007</td>
<td>-3.37a</td>
<td>13.28b</td>
<td>0.58</td>
</tr>
<tr>
<td>February 2008</td>
<td>-2.59a</td>
<td>10.54c</td>
<td>0.70</td>
</tr>
<tr>
<td>April 2008</td>
<td>-2.87a</td>
<td>11.31b</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Seasonal trends in tiller appearance and death are shown in Figures 5-5 and 5-6. Throughout the experiment, tiller appearance rates were highest ($P<0.05$) in late autumn and spring and lowest ($P<0.05$) during winter and most of summer. There was
also a sharp increase \((P<0.05)\) in tiller appearance during January 2007, relative to tiller appearance rates in the previous month. Tiller death rates were higher \((P<0.05)\) in February 2007 than they had been in the preceding month. During the second year of the study, set stocking generally resulted in higher rates of tiller appearance and death than grazing at the three or four leaf stage.

![Graphs](image)

**Figure 5-5** Net monthly (a) appearance and (b) death of summer-active tall fescue tillers (tillers/m²) under set stocking (○) and rotational grazing at the two (■), three (×) or four (▲) leaf stage. The error bars indicate the grazing treatment by sampling date interaction l.s.d \((P=0.05)\), with the left bar indicating the between treatment l.s.d and the right bar indicating the within treatment l.s.d. Data was collected from clumps of summer-active tall fescue in fixed quadrats.
Figure 5-6 The appearance and survival of tillers in summer-active tall fescue clumps in response to grazing treatment. Data was collected from clumps of summer-active tall fescue in fixed quadrats.
5.4 Discussion

The set stocked swards developed a dense population of small tillers, with tiller density generally declining and tiller size increasing as grazing became less frequent. Grazing imposes an active selective force on a grass sward (Brougham et al. 1960; Vaylay and van Santen 1999). One way that grasses cope with this stress is by adjusting their tiller populations to avoid or tolerate being grazed (Briske 1986). Supporting a large number of small tillers maximises the leaf area below the defoliation height that is accessible to livestock. Such swards can regrow quickly after grazing due to the high proportion of photosynthetic material that is left ungrazed (Parsons et al. 1983a). This mechanism for surviving intense grazing stress has previously been observed in perennial ryegrass (Brock et al. 1996). The extent to which this survival mechanism is displayed in summer-active tall fescue depends on the level of grazing stress being imposed, as was evidenced in this experiment. It is also likely that the greater accumulation of herbage under infrequent grazing necessitates the development of large tillers to access solar radiation (Lemaire 2001). Changes in tiller populations are not instantaneous, but are a gradual anatomical change. It took a year for the summer-active tall fescue tiller populations to respond to grazing treatment, as was evidenced by the lack of treatment effect and large l.s.d’s in the tiller density data-set. Summer-active tall fescue swards are, therefore, capable of adapting to their respective levels of grazing stress through changes in tiller populations, but this is a gradual process which can take years to become apparent.

Tiller appearance rate was generally highest under set stocking and tended to decline as grazing became less frequent. The stimulatory effect of frequent or intense defoliation
either by grazing or cutting on tiller appearance has been demonstrated in previous research conducted on perennial ryegrass (Grant et al. 1981; Korte et al. 1982; Lowe and Bowdler 1988; McKenzie 1994). Increases in tiller appearance rate are associated with increased leaf production because tiller buds form in the axils of leaves (Jewiss 1972). Grazing regimes that support the production of new leaves, such as occurred under set stocking, will stimulate tillering by providing sites for new tiller formation. Increasing light or temperature, or both, also stimulates tiller appearance (Robson 1974; Simon and Lemaire 1987). Tiller appearance rates were thus highest during spring and summer, particularly under grazing regimes that prevented herbage build up and allowed light penetration into the sward canopy. The sward was generally in a vegetative state during summer and high rates of tiller appearance occurred immediately after summer rainfall events, such as occurred in January 2007. Tiller death rates in the months following these rainfall events were often high due to a lack of follow-up rain and the sward being unable to sustain such high tiller numbers during times of moisture deficit stress.

The rate of tiller death also tended to be highest under set stocking, which, coupled with this treatment’s high tiller appearance rate, resulted in net tiller turnover being more rapid under set stocking than in the other grazing treatments. This result was unexpected, with higher tiller death rates being expected under the more leniently grazed treatments because long grazing rotations favour the production of reproductive and aerial tillers which die after flowering in spring, causing tiller death rates to rise (L'Huillier 1987; McKenzie 1994). Furthermore, it was expected that greater shading would occur in the leniently grazed swards causing tiller death in the lower strata of the sward canopy (Ong et al. 1978; Simon and Lemaire 1987). It is likely that the high rates
of tiller death under set stocking occurred because the ability of the sward to photosynthesise was impaired by the constant consumption of its leaf material; this would eventually result in the depletion of carbohydrate energy reserves which are required for tiller growth and survival (Volenec 1986; Donaghy et al. 2008). Poor survival of summer-active tall fescue tillers under long term set stocking by sheep has been reported in previous research (Tavakoli et al. 1993). Long term set stocking or grazing at the two leaf stage is unlikely to be an effective grazing method for summer-active tall fescue because it results in high rates of tiller death. It is apparent from Figure 5.2 that the absolute tiller density of the set stocked plots was declining, which indicates that new tiller appearance was not sufficient to maintain sward density in light of the high rate of tiller death. This was true for all of the grazing treatments, but appeared to be more marked for the set stocked plots, which had the most unstable tiller population. When considered in addition to other measures taken during the trial, such as low pasture accumulation rates (Chapter 6, Figure 6.1) and poor botanical composition (Chapter 7, Figure 7.1), set stocking appeared to be the most detrimental grazing method for the summer-active tall fescue.

Tiller death rates were particularly high during spring and summer during both years of the research, particularly under set stocking. High tiller death rates were most likely due to moisture deficit and heat stress, which have been attributed as the cause of poor sward persistence in previous locally conducted research (Reed 1974; McWilliam 1978; Anderson et al. 1999). Thom (1991) reported that defoliation during summer increases the rate of vegetative tiller death in perennial ryegrass pastures in New Zealand. A similar effect was reported in this research on summer-active tall fescue, with set stocking and short grazing rotations during summer being particularly detrimental to
tiller survival. Thus, over the stressful summer and early autumn period, longer grazing regimes, such as those based on the three leaf stage, may benefit tiller survival and improve sward density.

The tiller densities of the summer-active tall fescue in this research were markedly lower than the tiller densities observed from comparable perennial ryegrass swards in the district. For instance, Waller (2001) reported that, in a year of average rainfall, perennial ryegrass swards that were continuously stocked by sheep supported spring tiller densities in excess of 7500 tillers/m$^2$ in the Hamilton region of south west Victoria. This is approximately double the spring tiller density of the summer-active tall fescue at the commencement of this experiment. The low summer-active tall fescue tiller density may have been due, at least in part, to the below average rainfall in the two years after the sward was established, with only 541 mm and 492 mm of rain falling in 2005 and 2006. It also supports previous research which has found summer-active tall fescue generally has fewer but larger tillers with greater longevity than perennial ryegrass to compensate for its lower leaf and tiller appearance rate (Hume and Brock 1997; Kemp et al. 2001).

Estimates of tiller density from the fixed quadrats were 4 – 6 times higher than the tiller density estimated by random sampling. This was most likely due to the placement of the fixed quadrats on clumps of summer-active tall fescue. Previous research on perennial ryegrass has also reported that tiller density in fixed quadrats is higher than that of the surrounding sward (Hernandez-Garay et al. 1993; Bahrani et al. 2003) due to the presence of drill rows and the stimulation of tillering within the quadrat by sward disturbance during quadrat placement and tiller counting. Future studies into the tiller
density of summer-active tall fescue, or other grasses, must be estimated from completely random sampling.

5.5 Conclusion

This research has shown that summer-active tall fescue is able to adjust its tiller populations in response to grazing pressure. Set stocked swards had a dense population of small tillers, with tiller density decreasing and tiller size increasing as grazing became less frequent. This supports the hypothesis of this experiment. Set stocking also resulted in a high rate of tiller appearance and death. On the other hand, swards grazed at the four leaf stage had lower tiller turnover with fewer and larger tillers which were better able to survive adverse environmental conditions.

Although this research has provided valuable information into the effect of grazing on the tiller populations of summer-active tall fescue, a major constraint of the research was the two year time frame. The lack of treatment effects on some of the measured parameters in the first year of the experiment indicates that it takes at least a year for summer-active tall fescue tiller populations to adapt to grazing. Research into grazing regimes for the species must be of longer duration than was possible in this research.

The next two chapters in this thesis provide further results from this experiment, focusing on pasture growth rates, consumption by sheep, carbohydrate content, nutritive value and botanical composition. These results need to be considered in addition to the tiller population study to determine optimum grazing regimes for summer-active tall fescue.
Chapter 6. Effect of grazing management on the dry matter production and carbohydrate reserves of summer-active tall fescue based swards

6.1 Introduction

Livestock production in southern Australia relies on pasture as the main source of energy and nutrients (Doyle et al. 2000). Maximising pasture production is, therefore, a major goal for livestock producers in order to minimise supplementary feeding costs and ensure enterprise sustainability. Pasture growth and accumulation is determined by the amount of leaf material the plant has available for photosynthesis and by the amount of carbohydrate the plant has stored in its tiller bases as energy reserves, with both of these factors being affected by grazing management (Booysen and Nelson 1975; Volenec 1986). As was mentioned in the literature review (Chapter 2), effective grazing management involves compromising the plant’s need to retain leaf area for photosynthesis with the livestock’s need to consume the swards leaf material for nutrition (Brougham 1955; 1956; Parsons et al. 1983a; Parsons et al. 1983b; King et al. 1984; Parsons and Chapman 2000).

The previous chapter (Chapter 5) studied the effect of leaf stage based grazing regimes on the growth and survival of individual tillers within a sward of summer-active tall fescue. Chapter 6 expands on this research to determine whole sward productivity and determine sheep preferences for grazing summer-active tall fescue. It was hypothesised that grazing a summer-active tall fescue based sward in southern Australia at the three leaf stage would maximise the accumulation rate of the sward, the amount of pasture
consumed by sheep and the water soluble carbohydrate (WSC) content of the summer-active tall fescue tillers.

6.2 Materials and method

6.2.1 Site description

The experiment was conducted on field plots of endophyte-free summer-active tall fescue (Lolium arundinaceum syn. Festuca arundinacea Schreb. cv. Quantum) at the Department of Primary Industries research farm at Hamilton, in south west Victoria, Australia (37°50’S, 142°04’E; altitude 200 m). The climate, experimental design and treatments, and site establishment and management are described in Chapter 5.

6.2.2 Pasture measurements

Pasture accumulation rate (kg DM/ha.day) and consumption (kg DM/ha) were estimated using a calibrated falling plate meter (Bransby et al. 1977). In the rotationally grazed plots, pasture accumulation rate and consumption were estimated from 10 fixed points per plot. Herbage mass was measured from the rotationally grazed plots in the first week of each month, as well as pre- and post-grazing. If grazing intervals were longer than one month, pasture accumulation rate was estimated as the difference in herbage mass in successive months. If grazing rotations were shorter than one month, pasture accumulation rate was estimated as the difference between post-grazing herbage mass and the subsequent pre-grazing herbage mass. Pasture consumption was estimated as the difference between pre-grazing herbage mass and the subsequent post-grazing herbage mass. The amount of pasture accumulated during the grazing period, based on
average accumulation rates in the month before and after grazing, was included as consumption. Pasture accumulation rate in the set stocked plots was estimated as the difference in DM at monthly intervals, estimated from 10 points located under cages that excluded grazing. Pasture consumption in the set stocked plots was estimated as the amount of DM that had accumulated under the cages, minus the herbage mass of the grazed areas. The cages were moved at monthly intervals.

It must be acknowledged that, in this thesis, estimates of pasture accumulation and consumption were made from the whole sward, not just the summer-active tall fescue component. These estimates must, therefore, be considered in conjunction with the analysis of botanical composition because during certain times of the year, pasture species other than the summer-active tall fescue contributed a large proportion of herbage mass in the sward. Botanical composition for this experiment is provided in Chapter 7, Figure 7.1. It must also be acknowledged that measuring pasture accumulation rate and consumption from under cages that excluded grazing for one month in the set stocked plots may have confounded the results of the trial because the pasture under the cages may have had sufficient rest time from grazing to accumulate WSC which would have a positive effect on growth. The impact of this was minimised by moving the pasture cages to a new location every month.

The water extraction – Anthrone method of the Great Britain Ministry of Agriculture, Fisheries and Food (1973) was used to determine the WSC content of the plots grazed at the three leaf stage relative to set stocked plots on 1 October 2007 and 22 September 2008. Forty randomly sampled soil cores per plot were extracted to a depth of 10 cm. Sampling occurred immediately prior to the three leaf stage plots being grazed, with
sampling always occurring between midday and 1 pm to account for diurnal variations in WSC content (Lechtenburg et al. 1972). The pseudostem portion of the summer-active tall fescue was separated from the cores, as this is the primary site of WSC storage in grasses (Danckwerts and Gordon 1987). Pseudostem included stem and leaf sheath material and was measured to below ground level at the intersection with the root material. The samples were then dried at 60°C for 48 hours and then the green portion of the pseudostem was analysed for WSC to indicate energy reserves of the plant that are available for growth and metabolism. Tiller bases were often located 3 – 4 cm below ground level. Herbage samples cut to ground level were also analysed for WSC content to indicate sward nutritive value. These will be discussed in Chapter 7. It would have been useful to measure the level of WSC in the tiller bases of all the grazing treatments with many sampling dates. However, the collection of WSC samples from below-ground plant parts is a time consuming and expensive process. Therefore, two treatments that were likely to have statistically significant differences in WSC content were sampled. Sampling occurred in two successive years at approximately the same time (stage of the season) in both years to show how WSC had changed over time for the two treatments of interest.

### 6.2.3 Statistical analysis

The effect of grazing treatment on pasture accumulation rates, consumption and WSC content was analysed by repeated measures ANOVA using Genstat Version 11 (Payne et al. 2008). If no interaction between grazing treatment and sampling date was detected, antedependence ANOVA was used to test if the parameter being measured was dependent on its value at previous sampling dates. If no dependence was detected
the level of antedependence was set at 0 and one-way ANOVA was used to compare treatment means within each sampling date. Prior to analysis, residuals were checked for normality and the implications of transforming the data were studied. The presented data are not transformed.

6.3 Results

Grazing treatment had no effect on pasture accumulation rates during the initial 10 months of the experiment (Figure 6-1). In August, September and December 2007 and over spring 2008, grazing when the summer-active tall fescue was at the three leaf stage resulted in higher \((P<0.05)\) pasture accumulation rates than set stocking and grazing at the two leaf stage. Grazing at the three leaf stage also resulted in higher \((P<0.05)\) pasture accumulation rates than set stocking in May 2008.
Grazing when the summer-active tall fescue was at the three leaf stage resulted in the highest \( (P<0.05) \) annual herbage consumption during 2007 and 2008, relative to the other grazing treatments (Table 6-1). In 2007, there was no difference in herbage consumption between set stocking or grazing at the two or four leaf stage, but in 2008 these treatments differed \( (P<0.05) \) from each other with herbage consumption under the four leaf treatment being higher \( (P<0.05) \) than set stocking or grazing at the two leaf stage. Seasonal trends in pasture consumption are shown in Figure 6-2.
Table 6-1 Apparent annual pasture consumption (kg DM/ha) under set stocking or rotational grazing at the two, three or four leaf stage, with l.s.d’s \((P=0.05)\) for comparing means within years

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set stocked</td>
<td>11 288</td>
<td>8 474</td>
</tr>
<tr>
<td>Two leaf stage</td>
<td>10 272</td>
<td>7 193</td>
</tr>
<tr>
<td>Three leaf stage</td>
<td>14 165</td>
<td>12 245</td>
</tr>
<tr>
<td>Four leaf stage</td>
<td>11 268</td>
<td>11 537</td>
</tr>
<tr>
<td>L.s.d ((P=0.05))</td>
<td>2 621</td>
<td>623</td>
</tr>
</tbody>
</table>

Figure 6-2 Pasture consumption (kg DM/ha) under set stocking (green) or rotational grazing at the two (blue), three (yellow) or four (red) leaf stage. The error bars indicate the grazing treatment by sampling date interaction l.s.d \((P=0.05)\), with the left bar indicating the between treatment l.s.d and the right bar indicating the within treatment l.s.d.
In October 2007 and September 2008 there was no difference in the WSC content stored in the pseudostem material of set stocked summer-active tall fescue tillers compared to tillers grazed at the three leaf stage (Table 6-2).

**Table 6-2** The pre-grazing WSC content (% DM) of the pseudostem component of summer-active tall fescue tillers, sampled to below ground level, with l.s.d’s for comparing means within sampling dates

<table>
<thead>
<tr>
<th></th>
<th>October 2007</th>
<th>September 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set stocked</td>
<td>17.4</td>
<td>14.0</td>
</tr>
<tr>
<td>Three leaf stage</td>
<td>18.2</td>
<td>12.5</td>
</tr>
<tr>
<td>L.s.d</td>
<td>5.71</td>
<td>8.63</td>
</tr>
</tbody>
</table>

### 6.4 Discussion

After the initial 10 months of this experiment, grazing when the summer-active tall fescue was at the three leaf stage resulted in markedly higher pasture accumulation rates than the set stocked swards. As was mentioned in the literature review (Chapter 2), pasture grass swards derive the energy and substrates required for growth from two sources; firstly, from photosynthesis and secondly from WSC stored in the tiller bases (Booysen and Nelson 1975; King *et al.* 1984; Volenec 1986). If energy availability from either of these sources is inhibited over a long period of time the growth of the sward is likely to decline, as appeared to happen to the set stocked swards in this research.

During spring in the two years of this study there was no difference in the amount of WSC stored in the tiller bases of set stocked summer-active tall fescue tillers compared to tillers grazed at the three leaf stage. It appears, therefore, that energy availability from WSC is not attributable as the cause of the lower pasture accumulation rate of the set
stocked swards during spring. This result was surprising because previous research has shown that if summer-active tall fescue or perennial ryegrass are repeatedly defoliated at the one leaf stage as opposed to the three leaf stage, the WSC level of the sward and the rate of pasture re-growth declines (Fulkerson and Donaghy 2001; Donaghy et al. 2008). It was expected that the high proportion of leaf area consumed under set stocking in this research, combined with the lack of rest time to rebuild leaf area would make the sward reliant on WSC energy reserves to support growth in the absence of current photosynthate (Brougham 1955; 1956; Parsons et al. 1983a). It seems that this is not the case, with the summer-active tall fescue in this research able to tolerate set stocking to a herbage mass of 1200 kg DM/ha over a two year period without WSC levels becoming depleted. It must be acknowledged, however, that WSC was only measured in spring. There may have been treatment effects on WSC at other times of the year.

It is likely that the WSC level of the set stocked swards was not depleted in spring, despite the intense grazing pressure, because the swards were able to adapt their tiller populations to maintain sufficient leaf area and photosynthetic capacity to replenish their WSC reserves. The previous chapter (Chapter 5) found that the set stocked swards maintained leaf area by supporting a large number of small tillers at a height that was not accessible to livestock, while plots grazed at the three leaf stage had a fewer number of large tillers. Tavakoli et al. (1993) observed similar tillering responses in summer-active tall fescue under continuous grazing by sheep in New Zealand, while Matthew et al. (1996) has studied the plasticity of the tiller size/tiller density relationship in perennial ryegrass. There is a limit, however, to the ability of summer-active tall fescue to adjust its tiller populations in response to grazing pressure. It is likely that, despite increased tillering and leaf area, photosynthesis under the set stocked swards was
insufficient to support pasture accumulation to rates as high as swards grazed at the three leaf stage. It must be acknowledged, however, that photosynthesis was not actually measured in this research, with all links made between tiller density, leaf area, photosynthetic rate and pasture accumulation rate being based on previous research.

Furthermore, it is a limitation of this research that WSC from the tiller bases was only estimated once a year. It is possible that WSC levels may have varied seasonally and grazing treatment effects may have become apparent at other times of the year. Pasture accumulation and respiration rates are the major uses of WSC in pasture grasses (Booysen and Nelson 1975; Volenec 1986), with their rate depending on seasonal conditions and the method of sampling used, with WSC levels often declining during the drying process. Water soluble carbohydrate levels also depend on cloud cover and the potential of the sward to intercept solar radiation for photosynthesis (Kingsbury 1965; Vartha and Bailey 1980). It is possible that WSC levels in spring were lower than at other times of the year because adequate moisture and mild temperatures would have increased WSC use for accumulation and respiration, with intermittent cloud cover and variable spring weather conditions also limiting the potential of the sward to intercept solar radiation during this time. Clearly, there are many factors which determine the WSC content of grass tillers, especially under grazed field conditions. In this trial, there was a high degree of variability between plots in the same treatment, as evidenced by the high l.s.d’s shown in Table 6.2. The research by Donaghy et al. (2008) is especially pertinent, therefore, because it was conducted under glasshouse conditions where many of the rogue variables that affect WSC levels under field conditions can be controlled.
In spring, tillers grazed at the three leaf stage had large reproductive stems bearing seed heads, while the set stocked tillers were prevented from developing reproductive stems by continuous grazing. Previous research has shown that the development of seed heads in perennial ryegrass (Waite and Boyd 1953) and Italian ryegrass (Griffith 1992) reduces the level of WSC stored in tiller bases during spring because the WSC is translocated to the seed head where it is stored as starch. This may also have occurred in the summer-active tall fescue, thus lowering the rate of WSC accumulation in the three leaf stage tillers during spring, relative to the set stocked tillers. The exact contribution of starch to WSC during spring cannot be determined in our study because the near infrared spectroscopy technique used does not discern between starch and other constituents of WSC.

There are various other environmental factors which may also have impaired the accumulation rate of the set stocked swards in this research which are not directly related to energy availability for growth. For instance, the set stocked swards generally experienced slower accumulation rates than the other grazing treatments during winter. It is possible that the short sward height and low herbage mass made the swards susceptible to frost and waterlogging damage. The high grazing pressure may also have caused trampling damage in the soft wet ground (Edmond 1966; Richards et al. 1976; Curll and Wilkins 1983), though this would have been partially offset by the higher rate of nutrient return associated with the constant grazing (Curll and Wilkins 1983; Greenwood et al. 1997). It is known that the root growth of summer-active tall fescue increases with the production of each successive leaf (Donaghy et al. 2008). It is, therefore, likely that the root system of the set stocked swards was less developed than the other grazing treatments which would have limited moisture availability and the
potential for growth of the set stocked swards during summer. Root dynamics were not actually measured in this research, so this cannot be definitely related to pasture accumulation rate.

In this research, the summer-active tall fescue was able to support at least four live leaves per tiller at a time, but the production of the fourth leaf was associated with a decline in pasture accumulation rates. This was most likely caused by shading in the lower strata of the sward as herbage accumulated, causing leaf senescence and inhibiting the production of new tillers (Hunt 1965; Simon and Lemaire 1987). Similar effects have been observed in perennial ryegrass, where accumulation rate is also maximised at the three leaf stage before a ceiling yield is reached and leaf senescence causes accumulation and sward nutritive value to decline (Fulkerson and Slack 1994; 1995; Fulkerson and Donaghy 2001). Similarities in the accumulation of the two species are not surprising in light of their close genetic relationship (Darbyshire 1993; Charmet et al. 1997; Wheeler et al. 2002). The accumulation of dead material in the lower strata of the sward is also likely to lower the nutritive value of the sward, with dead material being lower in nutritive value to green material (Stockdale 1999). This will be discussed in Chapter 7. It is concluded that basing grazing rotations for summer-active tall fescue swards on the four leaf stage is not justified, with effective grazing management ensuring the consumption of herbage before this stage.

Grazing the summer-active tall fescue at the three leaf stage resulted in the highest level of pasture consumption during October and November 2007, with 9 247 kg DM/ha being consumed under this treatment during this time. It must be noted that the three leaf stage treatment was generally not grazed during August and September 2007.
because it had not reached its specified leaf stage (sheep entered the plots on 22 September 2007, but were still on the plots in October, so this was counted as October consumption). The October/November 2007 pasture consumption, therefore, included a large amount of carry-over herbage accumulated during August/September 2007. The high level of pasture consumption in October/November 2007 under the three leaf treatment was also due to a rapid pasture accumulation rate, particularly compared to set stocking or grazing at the two leaf stage. Although grazing at the three leaf stage resulted in less frequent grazing events than set stocking, this was offset by the greater DM produced under the three leaf treatment and, thus, there was no shortage of feed under the three leaf treatment. Grazing at the three leaf stage also resulted in more frequent grazing than occurred under the four leaf stage treatment. During mid- to late spring, grazing summer-active tall fescue at the three leaf stage is, therefore, an effective strategy for maximising the consumption of herbage.

The nutritive value of summer-active tall fescue tends to decline, however, with the production of each successive leaf (Donaghy et al. 2008) and with the production of reproductive stems (Hume and Brock 1997; Chaves et al. 2006). In our research, there appeared to be no palatability problems with grazing the summer-active tall fescue at the three leaf stage, with little residual herbage being left ungrazed. Furthermore, the higher level of pasture consumption under the three leaf treatment will partially compensate for the lower concentration of nutrients in the herbage. These factors will be discussed in more detail in Chapter 7, but it appeared from the analysis of pasture accumulation rate and consumption that grazing at the three leaf stage was an effective grazing strategy during mid to late spring.
Grazing the summer-active tall fescue at the three or four leaf stage also resulted in the highest pasture consumption over summer and during early autumn in 2007/08, as compared to set stocking or grazing at the two leaf stage. In southern Australia, feed shortfalls often occur over summer and early autumn due to the prevalence of pasture species that become dormant during the hot and dry conditions (Reed 1974; McWilliam 1978; Anderson et al. 1999; Lawson et al. 2007). This research has demonstrated that summer-active tall fescue does not display such dormancy mechanisms and is able to produce green feed in response to the sporadic rainfall events that often occur during this time. Grazing at the three or four leaf stage resulted in the most efficient conversion of this rainfall into pasture, with 4 221 kg DM/ha and 3 679 kg DM/ha being consumed between December 2007 and March 2008 under the three and four leaf stage treatments in response to 130 mm of rain that fell during this time. This research has shown that there is a prolonged period between mid-spring and early autumn when grazing summer-active tall fescue at the three leaf stage results in the most efficient growth and utilisation of pasture. It now remains to test such a concept under different environmental conditions to determine if grazing guidelines based on the three leaf stage can be widely applied.

At other times of the year, however, particularly during late autumn, winter and early spring, grazing at the three leaf stage did not support a high level of pasture consumption. During this time, there were prolonged periods when this treatment remained ungrazed because it had not reached its designated leaf stage. A similar effect occurred with the four leaf stage swards during this time. Temperature is a primary determinant of leaf appearance interval in pasture grasses (Templeton et al. 1961; Silsbury 1970; Robson 1974) and during the relatively cold winter conditions, the
summer-active tall fescue appeared to allocate resources towards the growth of existing leaves instead of the initiation of new leaves. This is evidenced by the high pasture accumulation rates during this time, with few leaf appearance intervals. Given the relatively slow leaf appearance rate of summer-active tall fescue compared to other grasses (Kemp et al. 2001; Cullen 2002), such further inhibition of new leaf formation results in grazing rotations based on the three or four leaf stage being impracticable during cold conditions, with more frequent grazing needed to ensure feed availability for livestock.

Future research may need to use a different basis for grazing management of summer-active tall fescue during winter, such as pre- and post-grazing herbage mass. Other possibilities include combining the treatments tested in this research, such as grazing at the three leaf stage throughout the year, but shortening rotations or set stocking during winter and early spring. The implications of such a strategy in terms of nutritive value and botanical composition are discussed in Chapter 7. A further option includes stimulating the growth of the swards during winter by using a growth promoter. This strategy is discussed in Chapter 8.

The slow leaf appearance rate of summer-active tall fescue, relative to perennial ryegrass, is probably due to differences in the prioritisation of WSC reserves for growth following defoliation. Summer-active tall fescue gives leaf and root accumulation equal priority for the allocation of WSC reserves after defoliation (Donaghy et al. 2008), whereas perennial ryegrass gives root accumulation the lowest priority for WSC allocation after defoliation, in favour of re-establishing its leaf area, replenishing its WSC reserves and initiating new tillers (Donaghy and Fulkerson 1998). The
prioritisation of WSC towards root accumulation may be beneficial to the long term persistence and productivity of summer-active tall fescue, especially during hot and dry conditions, by improving the species ability to extract moisture from the soil profile, but it makes grazing rotations based on the three and four leaf stage impractically long during cold seasons.

6.5 Conclusion

This research has shown that summer-active tall fescue can be managed in southern Australia to provide a year-round source of pasture, which supports the original hypothesis for this project (refer Chapter 1). It took the summer-active tall fescue sward 10 months to adjust to the grazing regimes imposed during this experiment. Once this adjustment was made, grazing summer-active tall fescue at the three leaf stage generally maximised pasture accumulation rates and consumption, relative to the other grazing treatments, which is in support of the hypothesis for this experiment. Dry matter consumption from grazing at the three or four leaf stage was, however, often poorly distributed and resulted in feed shortfalls, particularly over late-autumn, winter and early spring. During these times, set stocking or grazing at the two leaf stage improved feed availability. The specific mechanisms that determined pasture growth rate in this research remain unclear, with WSC levels stored in the tiller bases being unaffected by grazing treatment. There were, however, confounding issues which affected WSC levels in this study, including differences in the residual leaf area of the treatments driven by tiller size/tiller density plasticity (refer Chapter 5) and seasonal variation in pasture accumulation rates, respiration and photosynthesis.
This research has clearly shown that grazing summer-active tall fescue at the three leaf stage from mid-spring until early winter, as would be done on a perennial ryegrass sward, is optimal in terms of maximising pasture accumulation rate, pasture consumption and enabling the sward sufficient rest time between grazing to rebuild WSC levels. During winter, however, shorter grazing rotations or set stocking may provide more frequent grazing, with leaf appearance intervals under the three and four leaf treatment during this time being impractically long. Future research is warranted into possible alternative guidelines for grazing during cold conditions, such as herbage mass, or into strategies for stimulating growth during this time (refer Chapter 8). Grazing regimes must be flexible to reflect changing seasonal conditions and to meet the feed requirements of livestock. It is likely that a combination of the treatments tested in this research would benefit overall enterprise production and sustainability, with future research required to test such grazing regimes. The next chapter (Chapter 7) will consider sward nutritive value and botanical composition, in addition to the measures of sward productivity documented in this chapter, to determine the overall feeding value of summer-active tall fescue swards and the impact this has on grazing guidelines.
Chapter 7. Effect of grazing management on the nutritive value and botanical composition of summer-active tall fescue based swards

7.1 Introduction

The previous two chapters (Chapters 5 and 6) documented the effect of grazing management on the productivity of a summer-active tall fescue based sward at the individual tiller level, in terms of tillering rates and survival, and at the whole sward level, in terms of pasture accumulation and consumption. As sward productivity increases, however, the nutritive value of the sward tends to decrease due to the deposition of structural cellular material which has low digestibility (Cherney et al. 1993; Wilman et al. 1996). Effective grazing management, therefore, involves compromising sward productivity and sward nutritive value.

Maintaining the nutritive value of summer-active tall fescue based swards can be especially challenging during spring because the species produces reproductive stems which can be larger and thicker than those of perennial ryegrass (Hume and Brock 1997). These reproductive stems are low in digestibility, which means the nutritive value of summer-active tall fescue can decline more rapidly during spring than perennial ryegrass (Lowe et al. 1999; Greenwood et al. 2006). The survey of livestock producers (Chapter 3) found that low nutritive value of summer-active tall fescue during spring is perceived as a major barrier to the adoption of the species.

Sward nutritive value is also dependent on the botanical composition of the sward. Clover, for instance, is generally higher in nutritive value than grasses (Stockdale 1999),
while annual weeds, such as capeweed or annual grasses, can lower sward nutritive value, especially if they become reproductive (McIvor and Smith 1973; Doyle et al. 1989). Effective grazing management, therefore, ensures the presence of high nutritive value pasture species in the sward and prevents weed invasion.

This chapter studies the effect of leaf stage based grazing regimes on the nutritive value and botanical composition of a summer-active tall fescue based sward by continuing the experiment documented in Chapters 5 and 6. It was hypothesised that grazing a summer-active tall fescue based sward in southern Australia at the four leaf stage would maximise the summer-active tall fescue and clover content of the sward, but that more frequent grazing would improve the nutritive value of the sward.

7.2 Materials and method

7.2.1 Site description

The experiment was conducted on field plots of endophyte-free summer-active tall fescue (*Lolium arundinaceum* syn. *Festuca arundinacea* Schreb. cv. Quantum) at the Department of Primary Industries research farm at Hamilton, in south west Victoria, Australia (37°50’S, 142°04’E; altitude 200 m). The climate, experimental design and treatments, and site establishment and management are described in Chapter 5.
7.2.2 Pasture measurements

The dry-weight-rank method of t’Mannetje and Haydock (1963) was used to determine botanical composition (% DM) of the plots every two months between September 2006 and October 2008. This involved visually ranking the 1st, 2nd and 3rd species in 20 circular 0.1 m² quadrats per plot according to their contribution to herbage mass. In the event that there were less than 3 species present in the quadrat, the cumulative ranking technique of Jones and Hargreaves (1979) was adopted, where more than one rank can be recorded for a given species.

The rotationally grazed plots were estimated for crude protein (CP), *in vitro* dry matter digestibility (*IVDMD*), neutral detergent fibre (NDF) and water soluble carbohydrate (WSC) pre-grazing on 15 January 2007, 16 July 2007, 30 October 2007, 7 December 2007, 26 March 2008, 14 May 2008, 28 July 2008, 22 September 2008 and 23 October 2008. Sampling always occurred between midday and 1 pm to account for diurnal variations in WSC content (Lechtenburg *et al.* 1972). In Table 7-1, missing values occurred when treatments were not ready to be grazed to coincide with sampling or, in the case of WSC, could not be sampled between midday and 1 pm due to labour constraints. Nutritive value from the set stocked plots was estimated to coincide with the rotationally grazed plots.

Nutritive value was estimated from 30 random herbage samples per plot cut at ground level. For each plot, the samples were bulked, mixed thoroughly and the green portion of a subsample dried at 60°C for 48 hours. The CP, *IVDMD*, NDF and WSC content of this sample was estimated by near infrared spectroscopy (NIR). Near infrared spectra
were collected using a FOSS-NIRSystems 6500 scanning monochromator in conjunction with Infrasoft International Software. Near infrared spectra calibrations had previously been derived from large sample populations using the procedures of Shenk and Westerhaus (1991). Only the green portion of the sward was analysed because in pasture swards that contain a large proportion of green herbage, sheep generally self-select a diet consisting of highly digestible green herbage, rather than eating dead material (Hamilton et al. 1973). Referencing methods used for NIR calibrations were as follows; CP using the Kjedahl method, NDF by the method of van Soest and Wine (1967), IVDMD using a pepsin-cellulase technique (Clarke et al. 1982) and WSC by the method of Yemm and Willis (1954), with analytical values adjusted using a linear regression based on similar samples of known value. Any spectral outliers from the calibrations were analysed by wet chemistry techniques as described above.

7.2.3 Statistical analysis

The effect of grazing treatment on botanical composition and whole sward nutritive value was analysed by repeated measures ANOVA using Genstat Version 11 (Payne et al. 2008). If no interaction between grazing treatment and sampling date was detected, antedependence ANOVA was used to test if the parameter being measured was dependent on its value at previous sampling dates. If no dependence was detected the level of antedependence was set at 0 and one-way ANOVA was used to compare treatment means within each sampling date. Prior to analysis, residuals were checked for normality and the implications of transforming the data were studied. The presented data are not transformed.
7.3 Results

At the commencement of the experiment all swards had the same botanical composition (Figure 7-1). In December 2006, the set stocked swards had the highest ($P<0.05$) summer-active tall fescue content. This effect had ceased by February 2007 and in the latter months of 2007 and over much of 2008 the set stocked swards had the lowest ($P<0.05$) summer-active tall fescue content, which tended to increase ($P<0.05$) as grazing became less frequent. There was little consistent effect of grazing treatment from September 2006 to March 2008 on the clover content of the swards (Figure 7-1). From April 2008 to October 2008 the clover content in the set stocked treatments was higher ($P<0.05$) than in the swards grazed at the three or four leaf stage at three out of the four sampling dates, the other treatment was usually intermediate. Over winter 2007 and 2008, the set stocked swards had the highest ($P<0.05$) annual grass weed content. The contribution of other species, such as broadleaf weeds, to the swards was not higher than 2% of herbage mass throughout the experiment.

In July 2007, the set stocked swards had a lower ($P<0.05$) IVDMD and CP content and higher ($P<0.05$) NDF content than swards grazed at the three leaf stage (Table 7-1). In winter 2008, there was no effect of grazing treatment on CP or IVDMD, but set stocked swards had a lower ($P<0.05$) NDF content than swards grazed at the three leaf stage. At all other times of the year, set stocking resulted in the highest ($P<0.05$) CP content. During October 2008, IVDMD was highest ($P<0.05$) and NDF lowest ($P<0.05$) under set stocking with nutritive value declining consistently as grazing became less frequent. Between December 2007 and October 2008 grazing at the three leaf stage consistently resulted in higher ($P<0.05$) WSC content than set stocking.
Figure 7-1 The (a) summer-active tall fescue, (b) clover and (c) annual grass weed content of swards (% DM) under set stocking (○) or rotational grazing at the two (■), three (×) or four (▲) leaf stage. The error bars indicate the grazing treatment by sampling date interaction l.s.d ($P=0.05$), with the left bar indicating the between treatment l.s.d and the right bar indicating the within treatment l.s.d.
<table>
<thead>
<tr>
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<th>Three leaf stage</th>
<th>Four leaf stage</th>
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In vitro dry matter digestibility (% DM)

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Crude protein (% DM)

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Water Soluble Carbohydrate (% DM)

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7.4 Discussion

In October 2008, set stocking or grazing at the two leaf stage minimised NDF and maximised IVDMD and CP relative to the other grazing treatments. During mid-spring, summer-active tall fescue develops reproductive stems, which are generally larger and more fibrous than occur in other improved pasture grass species, such as perennial ryegrass (Hume and Brock 1997; Chaves et al. 2006). Milne (2001) reported that the nutritive value and palatability of summer-active tall fescue declines rapidly when reproductive stems develop, but the development of these stems can be avoided by maintaining high grazing pressure, as has been evidenced in this project. Milne (2001) recommended that grazing pressure be sufficient to ensure the height of summer-active tall fescue does not exceed 7 cm during the reproductive phase. There are, however, limitations to the use of pasture height as a guide for grazing pastures because it is possible for swards of the same height to differ in herbage mass due to differences in tiller density (Chapman and Clark 1984), which in turn affects the photosynthetic capacity of the sward and its potential for re-growth (Parsons et al. 1983b). Our research supports the finding that intense grazing pressure during mid-spring is required to maintain nutritive value, with set stocking to a herbage mass of approximately 1200 kg DM/ha or rotational grazing at the two leaf stage being optimal.

The nutritive value of swards grazed at the four leaf stage, in terms of NDF, IVDMD and CP, was particularly low in October 2008, relative to the other grazing treatments. Visual observations made during the study reported that livestock were reluctant to eat the reproductive stems in swards grazed at the four leaf stage. The palatability and animal preference for summer-active tall fescue is negatively correlated with fibre
content (Tava et al. 1995; Mayland et al. 2000). Thus, it is likely that the high NDF content of swards grazed at the four leaf stage limited sward palatability during spring. Milne (2001) reported that, once the height of a summer-active tall fescue sward exceeds 15 cm, its palatability declines more rapidly than occurs in perennial ryegrass. Summer-active tall fescue, therefore, requires more frequent or intense grazing than perennial ryegrass during the reproductive phase, with grazing rotations based on the four leaf stage being unsuitable due to nutritive value declines and lack of palatability.

Between December 2007 and October 2008, set stocking consistently resulted in the lowest WSC content, which tended to increase with lengthening grazing interval. As was demonstrated by Danckwerts and Gordon (1987), the pseudostem is the primary site of WSC storage in summer-active tall fescue, rather than the leaf material, with tiller bases often being 3 – 4 cm below ground level. Samples cut to ground level, therefore, do not indicate WSC storage levels in the tiller bases and are more an indicator of sward nutritive value and palatability, with palatability generally being positively correlated with WSC content (Tava et al. 1995; Mayland et al. 2000). Visual observations made during this project have not supported this, however, with no palatability issues being apparent in the set stocked plots.

In early to mid-summer in both years of the study, set stocked swards had higher or equal nutritive value than swards grazed at the three leaf stage, in terms of NDF, IVDMD and CP. During summer, summer-active tall fescue is in a vegetative stage and management to prevent reproductive stem development is not required. It appeared, however, that the nutritive value of the summer-active tall fescue continued to benefit from intense grazing pressure during summer. This was presumably because set
stocking maintained the sward at an earlier stage of maturity than swards at the three leaf stage. As summer-active tall fescue matures, changes occur in its cellular structure and the relative proportions of leaf, stem and inflorescent material (Elizalde et al. 1999; Stockdale 1999; Parsons and Chapman 2000; Chaves et al. 2006). The stem and inflorescent components of summer-active tall fescue have lower IVDMD and CP than the leaf material (Chaves et al. 2006). As the species matures, the contribution of leaf material to total sward herbage mass declines, while the contribution of stem material increases, thus causing sward nutritive value to decline (Austenson 1963). These declines become more marked as maturity progresses due to cell wall lignification and an increase in the concentration of the structural polysaccharides that comprise the cell wall, such as hemicellulose and cellulose, which are mainly indigestible when they form part of NDF and link with lignin. The increase in cell wall coincides with a decrease in cell contents, which are the soluble and digestible component of the cell (Elizalde et al. 1999; Parsons and Chapman 2000; Donaghy et al. 2008). It is for this reason that set stocking summer-active tall fescue during summer can improve the nutritive value of the sward, without being detrimental to botanical composition.

Set stocking during winter and early spring was detrimental to sward nutritive value and botanical composition, presumably, due to invasion by winter-growing annual grass weeds, such as *Vulpia* spp. and *Hordeum leporinum*. These species generally have low nutritive value and palatability (Doyle et al. 1989; Code 1996) and are difficult to control because livestock preferentially graze other species, like the summer-active tall fescue and clover components of the sward, which enhances seed production by the annual grasses and increases the potential for seedling recruitment (Jones and Whalley 1993). Thus, swards with a high content of annual grass weeds become vulnerable to
invasion in successive years (Smith 1965), as was evidenced in this research. The preferential grazing of the summer-active tall fescue and clover components of the sward places additional stress on these species, which further increases the competitive ability of the annual grass weeds (Gurung et al. 1994; Ciavarella et al. 2000; Dumont et al. 2000). It is well documented that grazing disturbance favours the replacement of tall perennial species with shorter annual species (Milchunas and Lauenroth 1989; Sternberg et al. 2000; Hayes and Holl 2003). Summer-active tall fescue, therefore, requires rotational grazing during winter and early spring to overcome potential annual grass weed invasion.

Grazing at the three or four leaf stage effectively prevented annual grass weed invasion and increased the contribution of summer-active tall fescue to the sward during winter and early spring. Long grazing rotations allowed the summer-active tall fescue to build-up herbage mass, effectively shading out annual grasses like Poa spp. and Vulpia spp. which are vulnerable to light competition due to their short stature and fine needle-like leaves (Rosch et al. 1997; Ballare and Casal 2000). Previous research has shown that swards rested from grazing accumulate litter over autumn which impedes the emergence of Vulpia spp. seedlings by providing a physical barrier to emergence (McGowan 1970; Burke and Grime 1996; Dowling et al. 1998; Dalling and Hubbell 2002). The litter of some perennial grasses, such as phalaris, also has allelopathic effects on annual grasses (Tozer 2004). Resting swards from grazing is, however, likely to reduce pasture consumption and utilisation, as was evidenced in Chapter 6. Further research is warranted into the effects of resting summer-active tall fescue swards during autumn to accumulate litter as a potential weed control method.
Grazing treatment generally had no effect on clover content during this experiment. There was, however, a brief period in April 2008 when the set stocked swards had markedly higher clover content than the other grazing treatments. This presumably resulted in the CP content of the set stocked swards being high at this time because clover is generally higher in CP and IVDMD and lower in NDF than perennial grasses (Stockdale 1999). It is likely that set stocking the clover during its flowering period increased seed set by stimulating branching (Steiner and Grabe 1986). The relatively low herbage mass of the set stocked swards over summer and autumn would have encouraged the softening and emergence of clover seed. The low herbage mass would also have favoured clover growth by increasing light availability and reducing competition from the summer-active tall fescue; such effects have been reported from phalaris swards in a similar environment (Tozer 2004). Summer-active tall fescue swards have the potential to support high clover yields due to their clump forming nature. Effective grazing management must, therefore, aim to maximise the productivity and persistence of clover, as well as the summer-active tall fescue component of the sward.

7.5 Conclusion

This research has clearly demonstrated that with effective grazing management high nutritive value summer-active tall fescue swards can be achieved in southern Australia. There are, however, often times of the year when nutritive value needs to be compromised to achieve high rates of herbage production and maintain botanical composition.
During the reproductive phase in spring, sward nutritive value was highest under set stocking or at the two leaf stage and declined with the production of the third and fourth leaf, which is in support of the hypothesis for this experiment. The palatability of summer-active tall fescue at the four leaf stage appeared to be low during spring. It would appear, therefore, that set stocking or grazing at the two leaf stage were optimal during spring for summer-active tall fescue. When considered in addition to the results of Chapter 6, however, it is apparent that higher pasture consumption occurred under the three leaf stage treatment, with no palatability issues being reported from grazing at the three leaf stage. A further benefit of grazing at the three leaf stage is that it enables the sward to replenish its carbohydrate reserves. Although Chapter 6 failed to show any difference in WSC content between set stocking and grazing at the three leaf stage, in Chapter 7 differences in the WSC content of the above ground herbage did become apparent.

A similar effect occurred during summer and early autumn, where set stocking or grazing at the two leaf stage improved sward nutritive value, but grazing at the three leaf stage resulted in higher pasture consumption and provided an opportunity for WSC replenishment. Clearly, a compromise needs to be made between productivity and nutritive value. Modelling the effects of different grazing regimes on livestock production would be useful for developing grazing strategies for individual properties. Such modelling was not possible in this project because the parameter sets for summer-active tall fescue within most available modelling packages have not been developed or validated, with the undertaking of such work being outside of the objectives of this project and not relative to the hypothesis being tested.
Chapters 6 and 7 have clearly shown that winter is a challenging time for summer-active tall fescue, with weed invasion being a problem and leaf appearance rates appearing to be inhibited by low temperatures. The botanical composition data partially support the hypothesis tested by this experiment, that grazing at the three or four leaf stage maximises the summer-active tall fescue content of swards. Grazing at the three leaf stage did not, however, provide frequent enough grazing, but set stocking or grazing at the two leaf stage made the swards susceptible to annual weed invasion. Chapter 8 will, therefore, investigate how N fertiliser can be used as a growth stimulant for summer-active tall fescue during winter.
Chapter 8. Using nitrogen to improve the winter growth of summer-active tall fescue based swards

8.1 Introduction

Summer-active tall fescue has a demonstrated ability to survive and remain productive during summer and early autumn in many areas of southern Australia due to its heat tolerance and efficient use of water (Garwood and Sinclair 1979; Jiang and Huang 2001; Greenwood et al. 2006; Lawson et al. 2007). Winter production from summer-active tall fescue, however, is often limited by low temperatures (Mitchell 1956; Reed et al. 2004a). Low temperatures reduce pasture accumulation by inhibiting the enzyme functions that drive cellular growth and by reducing the activity of the soil microbes responsible for the mineralisation of N in the soil into a plant available form (Salisbury and Ross 1978; Puri and Ashman 1998). This lack of winter production may contribute to a winter feed shortage during a time when demand for pasture is high due to calving and lambing. It would benefit livestock producers if the productivity of summer-active tall fescue could be improved over winter.

Applying N fertiliser to perennial ryegrass based pastures in mid to late autumn increases the DM production of the sward during winter (McKenzie et al. 1999b; McKenzie et al. 2003a). Response rates of up to 15.8 kg DM/kg N have been reported following the application of 45 kg N/ha in mid-April to swards near Warrnambool in south west Victoria (McKenzie et al. 1999b). Applying N fertiliser to perennial ryegrass based swards has also increased the CP content of the sward (McKenzie et al. 1999a; McKenzie et al. 2003b), with increases of up to 0.067% CP/kg N being reported.
following the application of 45 kg N/ha in late autumn (McKenzie et al. 1999a). Increases in metabolisable energy (ME) and decreases in NDF and WSC content also occur following N application (McKenzie et al. 1999a; McKenzie et al. 2003b). The specific effects of N fertiliser on ME remains open to conjecture, with studies reporting that sward digestibility can increase or remain unchanged by N fertiliser (van Vuuren et al. 1991). The potential to use N fertiliser as a tool to increase the productivity and nutritive value of summer-active tall fescue swards during winter remains to be tested. A grazed field experiment was, therefore, conducted to test the hypothesis that applying N to a summer-active tall fescue based sward after autumn rains in southern Australia would increase the productivity and nutritive value of the sward during winter.

8.2 Materials and method

8.2.1 Site description

The experiment was conducted at the Department of Primary Industries research farm at Hamilton, in south west Victoria, Australia (37°50’S, 142°04’E; altitude 200 m). Climatic data collected from the on farm weather station indicates a temperate climate with long term (1963 – 2008) average annual rainfall of 685 mm. Rainfall is winter and spring dominant with summer and early autumn typically being hot and dry, though large sporadic rainfall events during this time may occur. During this experiment, winter (June, July and August) rainfall in both 2007 (214 mm) and 2008 (225 mm) was close to the long term average (233 mm) (Figure 8-1). While the long term (1965 – 2008) data indicates that July is usually the coolest month, with average maximum and minimum daily temperatures of 12°C and 4°C, June was the coldest month in 2007.
(maximum and minimum daily temperatures of 11°C and 3°C, respectively) and August was the coldest month in 2008 (maximum and minimum daily temperatures of 11°C and 3°C, respectively) (Figure 8-1). In 2007 and 2008 there were 28 and 26 respective days between June and August when the minimum temperature fell below 2°C.

![Figure 8-1 Mean monthly maximum (■) and minimum (○) temperatures and rainfall (black bars) over autumn and winter 2007 and 2008. Long term averages are indicated by the lines and white bars.](image-url)
Photo 8-1 Experimental site on 25 July 2008.

8.2.2 Site establishment and management

Summer-active tall fescue (cv. Quantum) was direct drilled at a sowing rate of 19 kg/ha and a sowing depth of approximately 20 mm in November 2004 with 7.5 kg N/ha, 16 kg P/ha, 1 kg S/ha and 1 kg Ca/ha, applied as mono-ammonium phosphate (MAP). Prior to sowing, in October 2004, the site was sprayed twice with 2 L/ha of Roundup PowerMAX® (540 g/L glyphosate, ~10% w/v surfactant with water comprising the balance) and 100 ml/ha of FASTAC DUO® (100 g/L alpha-cypermethrin, 741.9 g/L liquid hydrocarbons and 0 – 5% w/v surfactant) to remove existing herbage and to control pests such as black headed cockchafers (*Aphodius pseudotasmaniae*) and red legged earth mites (*Halotydeus destructor*). The sward was oversown in May 2005 with subterranean clover (*Trifolium subterraneum*) cv. Leura at 8 kg/ha and cv. Gosse at 3 kg/ha and white clover (*Trifolium repens*) cv. Mink at 1.5 kg/ha.

The site was also fertilised with 18 kg P/ha, 1 kg S/ha and 13 kg Ca/ha, applied as triple super phosphate in February 2005, March 2006 and March 2007. Lime (calcium carbonate) was applied at 1.6 t/ha in February 2005. Soil samples (0 – 10 cm) taken in September 2006 indicated that the soil was a darkish grey brown clay loam (Northcote 1979) with pH\(_{\text{water}}\) of 5.2, P (Olsen) of 22 mg/kg, K (Skene) of 230 mg/kg, S (CPC) of 15 mg/kg and electrical conductivity of 0.13 dS/m. The average nitrate content of the soil was 90 mg/kg. A complete soils description to a depth of below 1 m, as assessed from a soil pit near the site, was provided in Chapter 4, section 4.2.1.

The site was sprayed in September 2005 with 750 ml/ha of Tigrex® (250 g/L MCPA ethyl hexyl ester, 25 g/L diflufenican, 325 g/L hydrocarbon solvent, 150 g/L N-methyl-
2-pyrrolidone and 105 g/L non-ionic emulsifiers) to control broadleaf weeds, particularly capeweed (*Arctotheca calendula*). Capeweed control was again undertaken in July 2007 by spray-grazing the site with 1 L/ha of Nugrex® (250 g/L MCPA ethyl hexyl ester, 25 g/L diflufenican, 362 g/L N-Methyl-2-pyrrolidone and 10 – 30% nonoxynol). Sward botanical composition on 25 April 2007, prior to N application, was 97% summer-active tall fescue and 2% subterranean clover, with no difference between treatments.

All plots were grazed by sheep when the 50 kg N/ha treatment was, on average, at the three leaf stage; defined as three fully expanded leaves per tiller above the remnant of the last leaf to be grazed. Leaf stage was estimated from 10 random tillers per plot. Grazing occurred at the three leaf stage because previous research has shown that this maximises the rate of sward regrowth and sward persistence by ensuring sufficient time between successive grazing events for the plant to replenish its energy reserves and also ensure the consumption of herbage with high nutritive value (Donaghy *et al.* 2008; Fulkerson and Donaghy 2001; Sinclair *et al.* 2006).

Grazing involved mob-stocking the entire site at 50 – 150 DSE/ha, typically with dry Merino and Coopworth ewes. This was sufficient to reduce all the plots to a residual herbage mass of approximately 1200 kg DM/ha within a 2 – 10 day period and ensured that the residual herbage mass across the site was uniform, with no large clumps of ungrazed herbage.

The site was grazed three times between May and August 2007 and twice between May and August 2008, with the same grazing management being used throughout the
remainder of the year. It is acknowledged that grazing over a 2 – 10 day period allowed
tiller regrowth and subsequent replenishment of carbohydrate reserves during the
grazing period. Carbohydrate content is positively related to rate of pasture growth
(Volenec 1986). It is unlikely, however, that carbohydrate replenishment affected
relative treatment accumulation rates because all plots had the same potential for
carbohydrate replenishment during the grazing period due to the consistent grazing
management applied to all treatments.

8.2.3 Experimental design

Five N treatments were imposed to 10 m by 10 m field plots of endophyte-free summer-active
tall fescue (Lolium arundinaceum syn. Festuca arundinacea Schreb. cv. Quantum) in a randomised complete block design with three replications. The
treatments were once-off autumn applications of 0, 25, 50, 100 or 200 kg N/ha applied
as urea (46% N) on 27 April 2007 and 7 April 2008. In April 2007, fertiliser was
applied when rain was expected, with 45 mm falling over 27, 28 and 29 April 2007. In
April 2008, the fertiliser was applied after 24 mm fell between 29 March 2008 and 3
April 2008. Follow-up rain occurred throughout May in both years of the experiment
(Figure 8-1). The N treatments were selected on the basis that applying 25 – 75 kg N/ha
is optimum for perennial ryegrass production in Victoria, above which declining N use
efficiency diminishes profitability (McKenzie et al. 1999b; McKenzie et al. 2003a). The
other treatments tested high and low variations of these rates, as compared to an
unfertilised sward. A once-off application of N in autumn was used, instead of multiple
applications over autumn/winter, because the research by McKenzie et al. (1999b)
found that N applied in autumn had residual effects for up to 10 weeks. It is likely that
low temperatures, rather than N availability, would be the primary limitation on summer-active tall fescue growth in winter, thus making multiple applications of N into winter unwarranted.

8.2.4 Pasture measurements

Pasture accumulation rate (kg DM/ha.day) and consumption (kg DM/ha) were estimated from herbage mass using a calibrated falling plate meter (Bransby et al. 1977). Herbage mass was measured from 10 fixed points per plot in the first week of each month, as well as pre- and post-grazing. If grazing intervals were longer than one month, pasture accumulation rate was estimated as the difference in herbage mass in successive months. If grazing rotations were shorter than one month, pasture accumulation rate was estimated as the difference in herbage mass between post-grazing and the subsequent pre-grazing. Pasture consumption was estimated as the difference in herbage mass between pre-grazing and the subsequent post-grazing. The amount of pasture accumulated during the grazing period, based on average accumulation rates in the month before and after grazing, was included as consumption. Nitrogen response efficiency (kg DM/kg N) was calculated from the amount of extra pasture consumed during each grazing, relative to the unfertilised plots.

It must be acknowledged that, in this thesis, estimates of pasture accumulation and consumption were made from the whole sward, not just the summer-active tall fescue component. These estimates must, therefore, be considered in conjunction with the analysis of botanical composition because during certain times of the year, pasture species other than the summer-active tall fescue contributed a large proportion of
herbage mass in the sward. Botanical composition for this experiment is provided in Table 8.5.

The green herbage content (% DM) of the sward was determined in April, June and July 2007 and 2008 by cutting 30 random herbage samples per plot to ground level. For each plot, the samples were bulked and mixed thoroughly and a sub-sample was divided into green and dead herbage, dried at 100°C for 24 hours and then weighed.

Summer-active tall fescue tiller density (tillers/m²) was measured in June and August 2007 and 2008 using the procedure described by Cayley and Bird (1996). This involved counting the number of live summer-active tall fescue tillers in 10 randomly sampled 8 cm diameter soil cores per plot. A tiller was defined as a shoot arising from the base of the plant at or below ground level.

The dry-weight-rank method of t’Mannetje and Haydock (1963) was used to determine botanical composition (% DM) in June 2007 and 2008. This involved visually ranking the 1st, 2nd and 3rd species in 20 circular 0.1 m² quadrats per plot according to their contribution to herbage mass. In the event that there were less than 3 species present in the quadrat, the cumulative ranking technique of Jones and Hargreaves (1979) was adopted, where more than one rank can be recorded for a given species.

Summer-active tall fescue plant frequency (% of cells) was estimated on 10 July 2008 using the procedure described by Cayley and Bird (1996). A 1 m by 1 m quadrat divided into 10 cm by 10 cm cells was used. The presence of summer-active tall fescue
in each cell was recorded if the base of at least one plant was present in the cell. Error
was reduced by sampling when all plots had similar herbage mass.

Herbage nutritive value was estimated prior to the first grazing after N fertilisation in
2007 and 2008. Thirty random herbage samples per plot were cut to ground level. For
each plot, the samples were bulked, mixed thoroughly and the green portion of a sub-
sample dried at 60°C for 48 hours. The CP, IV/DMD, NDF and WSC content of this
sample was estimated by near infrared spectroscopy. Near infrared spectra were
collected using a FOSS-NIRSystems 6500 scanning monochromator in conjunction
with Infrasoft International Software. Near infrared spectra calibrations had previously
been derived from large sample populations using the procedures of Shenk and
Westerhaus (1991). Only the green portion of the sward was analysed because in
pasture swards that contain a large proportion of green herbage, sheep generally self-
select a diet consisting of highly digestible green herbage, rather than eating dead
material (Hamilton et al. 1973). Referencing methods used for NIR calibrations were as
follows; CP using the Kjedahl method, NDF by the method of van Soest and Wine
(1967), IV/DMD using a pepsin-cellulase technique (Clarke et al. 1982) and WSC using
the anthrone method (Yemm and Willis 1954), with analytical values adjusted using a
linear regression based on similar samples of known IV/DMD. Any spectral outliers
from the calibrations were analysed by wet chemistry techniques as described above.

8.2.5 Statistical analysis

The effect of N treatment on the measured parameters was analysed by repeated
measures ANOVA using Genstat Version 11 (Payne et al. 2008). If no interaction
between N treatment and sampling date was detected, antedependence ANOVA was used to test if the parameter being measured was dependent on its value at previous sampling dates. If no dependence was detected the level of antedependence was set at 0 and one-way ANOVA was used to compare treatment means within each sampling date. Prior to analysis, residuals were checked for normality and the implications of transforming the data were studied. Presented data are not transformed.

8.3 Results

During both years of the experiment, applying 25 kg N/ha increased (P<0.05) pasture accumulation rate and pasture consumption for at least 10 weeks following N application, after which time there was no effect of N application (Tables 8.1 and 8.2). There were no further increases in pasture accumulation rate or consumption from applying more than 25 kg N/ha in either year, relative to the 25 kg N/ha treatment. In some instances applying more than 25 kg N/ha reduced (P<0.05) pasture accumulation rate and consumption relative to 25 kg N/ha. Nitrogen response efficiency was generally greatest when 25 kg N/ha was applied, with N response efficiency generally declining as the N rate increased, becoming negligible at 100 and 200 kg N/ha (Table 8-2).
Table 8-1 The effect of N rate on pasture accumulation rate (kg DM/ha.day) during autumn and winter 2007 and 2008 with l.s.d’s for comparing means within accumulation periods ($P=0.05$)

<table>
<thead>
<tr>
<th>N rate (kg N/ha)</th>
<th>Accumulation periods 2007</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>L.s.d ($P=0.05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27 Mar – 14 May</td>
<td>15</td>
<td>23</td>
<td>15</td>
<td>15</td>
<td>13</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>22 May – 9 Jul</td>
<td>27</td>
<td>41</td>
<td>40</td>
<td>37</td>
<td>36</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

Table 8-2 The effect of N rate on pasture consumption (kg DM/ha) and N response efficiency (kg DM/kg N) during autumn and winter 2007 and 2008. Pasture consumption l.s.d’s for comparing means within grazing periods ($P=0.05$) are also shown

<table>
<thead>
<tr>
<th>Grazing periods 2007</th>
<th>Grazing periods 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>N rate (kg N/ha)</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1185</td>
</tr>
<tr>
<td>25</td>
<td>1652</td>
</tr>
<tr>
<td>50</td>
<td>1278</td>
</tr>
<tr>
<td>100</td>
<td>1260</td>
</tr>
<tr>
<td>200</td>
<td>1208</td>
</tr>
<tr>
<td>L.s.d ($P=0.05$)</td>
<td>273</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>19</td>
<td>32</td>
<td>3</td>
<td>27</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
<td>15</td>
<td>6</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Nitrogen rate had no effect on the green herbage content of the swards in winter 2007.

In winter 2008, applying 25 kg N/ha increased ($P<0.05$) green herbage content, relative to the unfertilised plots, but applying 100 or 200 kg N/ha did not improve the green herbage content of the sward, relative to unfertilised plots (Table 8-3).

**Table 8-3** The effect of N rate on green herbage content (% DM) during autumn and winter 2007 and 2008 with l.s.d’s for comparing means within sampling dates ($P=0.05$)

<table>
<thead>
<tr>
<th>N rate (kg N/ha)</th>
<th>Sampling date 2007</th>
<th>Sampling date 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11 Apr</td>
<td>19 Jun</td>
</tr>
<tr>
<td>0</td>
<td>70</td>
<td>88</td>
</tr>
<tr>
<td>25</td>
<td>71</td>
<td>91</td>
</tr>
<tr>
<td>50</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>100</td>
<td>72</td>
<td>88</td>
</tr>
<tr>
<td>200</td>
<td>84</td>
<td>87</td>
</tr>
<tr>
<td>L.s.d ($P=0.05$)</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

There was no effect of N treatment on tiller density in June or August 2007. In June and August 2008, all the N fertilised plots had higher ($P<0.05$) tiller densities than the unfertilised plots (Table 8-4). Rates above 25 kg N/ha resulted in no further increase in tiller density and in some instances reduced ($P<0.05$) tiller density when compared to 25 kg N/ha.

**Table 8-4** The effect of N rate on summer-active tall fescue tiller density (tillers/m²) in winter 2007 and 2008 with l.s.d’s for comparing means within sampling dates ($P=0.05$)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1035</td>
<td>1771</td>
<td>1453</td>
<td>1592</td>
</tr>
<tr>
<td>25</td>
<td>1135</td>
<td>2017</td>
<td>2256</td>
<td>2495</td>
</tr>
<tr>
<td>50</td>
<td>1579</td>
<td>1957</td>
<td>2269</td>
<td>2329</td>
</tr>
<tr>
<td>100</td>
<td>1294</td>
<td>1951</td>
<td>1878</td>
<td>2024</td>
</tr>
<tr>
<td>200</td>
<td>1181</td>
<td>2117</td>
<td>1858</td>
<td>1884</td>
</tr>
<tr>
<td>L.s.d ($P=0.05$)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>199</td>
<td>137</td>
</tr>
</tbody>
</table>
Nitrogen application rate had no effect on botanical composition in June 2007 (Table 8-5). In June 2008, the summer-active tall fescue content decreased ($P<0.05$) and the capeweed content increased ($P<0.05$) as the N rate increased (Table 8-5). In June 2008 the clover content, decreased ($P<0.05$) once the N rate exceeded 25 kg N/ha.

**Table 8-5** The effect of N rate on botanical composition (% DM) in June 2007 and 2008 with l.s.d’s for comparing means within species for each sampling date ($P=0.05$)

<table>
<thead>
<tr>
<th>N rate (kg N/ha)</th>
<th>Tall fescue</th>
<th>Clover</th>
<th>Cape weed</th>
<th>Tall fescue</th>
<th>Clover</th>
<th>Cape weed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>47</td>
<td>2</td>
<td>39</td>
<td>81</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>48</td>
<td>2</td>
<td>36</td>
<td>73</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>50</td>
<td>49</td>
<td>2</td>
<td>38</td>
<td>74</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>100</td>
<td>39</td>
<td>1</td>
<td>51</td>
<td>64</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>200</td>
<td>46</td>
<td>1</td>
<td>43</td>
<td>61</td>
<td>4</td>
<td>34</td>
</tr>
<tr>
<td>L.s.d ($P=0.05$)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Applying N increased ($P<0.05$) summer-active tall fescue plant frequency in winter 2008 relative to the unfertilised plots (66 vs 61% of cells) with no difference between the 25, 50, 100 or 200 kg N/ha application rates.

Nitrogen application had no effect in either May 2007 or May 2008 on the CP (24 and 25%DM in 2007 and 2008, respectively), NDF (50 and 42%DM), IVDMD (75 and 83%DM) or WSC (16 and 11%DM) contents of the whole sward prior to grazing.

### 8.4 Discussion

Applying 25 kg N/ha after autumn rains improved the accumulation rate of the sward for at least 10 weeks following N application. Similar effects have been observed in perennial ryegrass swards in the district, with once-off applications of between 15 and...
60 kg N/ha accelerating growth for up to 10 weeks over autumn and winter (McKenzie et al. 1999b).

Using low rates of N fertiliser to grow additional pasture over winter may provide a cheaper source of feed than supplementary feeding with cereal grains to meet livestock nutritional requirements (McKenzie et al. 2003a). For instance, over the two years of this experiment, the application of 25 kg N/ha after autumn rains resulted in the consumption of an additional 1 099 kg DM/ha over winter, relative to the unfertilised plots. Based on the May 2008 cost of urea ($750/t, GST excluded, including freight and spreading, Landmark Ltd) the additional herbage would have cost approximately 4 c/kg DM, compared to cereal grain supplements which cost between 22 – 32 c/kg DM, though their cost can vary widely depending on grain type and season.

It must be acknowledged, however, that this economic analysis is simplistic and a more detailed analysis, considering a range of grain and forage prices, the availability of conserved forage and incorporating current soil N status, is required to determine the feasibility of N application for individual enterprises. Furthermore, there is a lag time between applying N fertiliser and observing pasture accumulation increases; cereal grain supplements, on the other hand, provide an immediate and convenient source of feed. With effective feed budgeting, applying N fertiliser to summer-active tall fescue may provide a relatively cheap way of feeding livestock over winter, while also providing the benefits of summer accumulation and persistence for which the species is renowned.
There were no further increases in herbage accumulation rate from applying more than 25 kg N/ha. This result was surprising because research on perennial ryegrass based pastures in similar environments has shown that applying N fertiliser at rates of up to 75 kg N/ha in autumn and up to 100 kg N/ha in spring increases DM yields and accelerates the time by which a predetermined DM yield is reached (McCollough 1976; Eckard and Franks 1998; Jacobs et al. 1998; McKenzie et al. 1999b; Wilkins et al. 2000; Elliott and Abbott 2003; McKenzie et al. 2003a). There are several possible explanations for the summer-active tall fescue failing to respond to the higher N rates. First of all, responses to applied N must account for the amount of mineral N already present in the soil from previous fertiliser applications, mineralisation of organic matter by soil microbes and urine return following high stocking rates. Soil tests taken in this research indicate that the plant available N content of the experimental site was already high before the N treatments were imposed. It is also likely that nitrate accumulated in the soil over autumn in response to soil wetting and drying following rain (Simpson 1962). The degree to which residual soil N levels masked N treatment effects in this experiment remains unclear and would depend on moisture availability and plant uptake of the available N for growth (Mundy 1993).

The growth of the summer-active tall fescue and its subsequent ability to utilise the applied N is likely to have been impaired by low soil temperatures. The effect of low temperatures on the growth of established swards of summer-active tall fescue has not been studied, but the growth of seedlings have been shown to be inhibited at temperatures below 12°C (Hill et al. 1985; Charles et al. 1991a; b). The minimum soil temperature required for the growth of perennial ryegrass is 5°C (Kemp and Guobin 1992). Soil temperatures were never this low in our study, with minimum soil
temperatures only reaching 7.9 and 8.1°C in June 2007 and August 2008, respectively, which were the coldest months. Herbage accumulation rates indicate that the swards were still actively growing, despite the low temperatures, at rates of between 13 – 41 kg DM/ha.day in 2007 and 10 – 28 kg DM/ha.day in 2008. Low temperatures would have affected all treatments and is unlikely to have affected relative treatment effects, though the magnitude of N responses is likely to have been reduced. The ranges of temperatures which summer-active tall fescue can tolerate need to be determined in future research because this is an intrinsic stress on the plant and to avoid plant deaths, management practises must strengthen the plant or prevent additional stress during suboptimal times of the year.

The high capeweed content of the swards during both years of the experiment is also likely to have contributed to the lack of response to N rates above 25 kg N/ha, with capeweed content tending to increase with increasing N rate. Capeweed appears bulky, but once dried it contributes little to DM production, especially when in the vegetative stage, because it has a lower DM content than grasses and clover, being only 6.4 – 7.2% DM compared to 14.3 – 18.5% DM (McIvor and Smith 1973). The prostrate growth habit of capeweed enables it to smother and shade other species out of the sward. Furthermore, capeweed is an aggressive scavenger of soil N and can reduce N availability to other pasture species by accumulating N in its herbage (Unkovich et al. 1998). This reduces the growth potential and competitiveness of other pasture species. Accumulation of toxic levels of nitrate in capeweed herbage can also cause nitrate poisoning in livestock under certain conditions (Fairnie 1969), although the sheep in this experiment showed no symptoms. It must be acknowledged, however, that the N content of individual pasture species in this trial was not measured; only the CP content
of the whole sward was measured. It is not possible, therefore, to quantify the N uptake by the capeweed, clover and tall fescue components of the sward. The capeweed content in the research by McKenzie et al. (1999b) and McKenzie et al. (2003a) was negligible, which may have increased the responsiveness of the perennial ryegrass swards to higher N rates. When N fertilisers are used to generate growth from summer-active tall fescue swards over winter, effective capeweed control must be undertaken.

A benefit, however, of applying N fertiliser in autumn and winter is that losses of ammonia to the atmosphere via volatilisation are minimised. Nitrogen in the form of urea is susceptible to volatilisation, especially in summer, due to high temperatures and evaporation (Vallis et al. 1982; Prasertsak et al. 2001; Eckard et al. 2003). Eckard et al. (2003) reported N losses of approximately 4 kg N/ha over summer due to ammonia volatilisation at air temperatures between 15°C and 20°C in a similar environment to the current study, with N losses to volatilisation increasing as air temperature increased. It is likely, therefore, that some ammonia volatilisation occurred in the current study, especially during May when maximum temperatures often approached 20°C.

A further benefit of applying N in late autumn to promote winter growth is that moisture availability is unlikely to limit N responses due to the winter dominant rainfall patterns in southern Australia. In this experiment, winter rainfall was generally representative of the long term average. It is known that the application of N fertiliser to increase DM production also increases plant water use (van Herwaarden et al. 1998) and that where moisture becomes limiting, DM production will decline (Hebblethwaite 1977). Late autumn N applications are, therefore, less likely to be affected by the moisture deficits that can occur over spring and summer.
Nitrogen response efficiency was always highest at 25 kg N/ha and tended to decline as N rate increased, to become negligible at 100 and 200 kg N/ha. This supports findings by Lowe et al. (2005), McKenzie et al. (2003a) and Eckard and Franks (1998), who reported that N response efficiency declines with increasing rate of N application on perennial ryegrass based pastures, although the swards in their research were more responsive to N rates above 25 kg N/ha. Koutroubas et al. (2000) attributed this relationship to the tendency of plants to utilise nutrients that are the most limiting with greater efficiency than nutrients that are less limiting as a means of gaining a competitive advantage. It is likely, however, that the low N use efficiency of the high N treatments in our research were caused by the factors discussed earlier relating to residual N levels in the soil and site invasion by capeweed.

During this research, the summer-active tall fescue never comprised more than 80% of sward DM during winter, with a large proportion of other species always being present in the sward. This is because summer-active tall fescue is a clump-forming grass, which gives other pasture species an opportunity to fill the sites around the clumps. Ideally, these sites would be entirely occupied by clover, which has a high nutritive value compared to grass (Stockdale 1999) and improves soil N fertility by fixing atmospheric N into a plant available form via its symbiotic relationship with *Rhizobia* bacteria within nodules in its root system (Whitehead 1995; McKenzie et al. 2003c). The ability of clover to compete with weeds to fill these sites over winter is inhibited, however, because its growth ceases at temperatures below 10°C (Kemp and Guobin 1992), as evidenced by the low clover and high capeweed content in this research.
Effective grazing management of summer-active tall fescue swards must minimise gaps in the sward and ensure that these gaps are filled by a desirable species. In this respect, capeweed is not an adverse species, in small quantities, because it is relatively digestible and palatable when it is vegetative, compared to other weed species found in the district, such as Poa spp. or Erodium spp., and it is also more easy to control (McIvor and Smith 1973). Our research has shown that the species which fill the gaps in summer-active tall fescue swards are integral to whole sward production and nutritive value due to the clump forming nature of summer-active tall fescue. Further research is, therefore, needed into the gap dynamics of summer-active tall fescue. An opportunity may exist, for example, to fill these sites with other improved grass or herb species, although such mixtures are yet to be tested.

In the second year of this research, the unfertilised plots had up to three times more clover over winter than plots receiving 200 kg N/ha. This may have masked N treatment effects because swards with a high clover content would have benefited more from N$_2$ fixation. Previous research into the effect of N fertiliser on the productivity of swards comprising perennial ryegrass and white clover (Trifolium repens) has acknowledged that N$_2$ fixation by the clover can alter N levels in the soil (McKenzie et al. 2003c). The extent to which clover affected soil N content in this research is unclear, but it is likely that rates of N$_2$ fixation were insufficient to support high rates of pasture accumulation because the contribution of clover to sward herbage mass was low in all the plots. It is likely that a higher clover content could have been retained in all the swards if grazing had been more frequent to remove the herbage stimulated by the N application before shading occurred in the lower strata of the sward (Simon and Lemaire 1987; McKenzie
It is important that the additional pasture grown following N application is consumed in order to maximise the economic benefit of applying N fertiliser.

Nitrogen application had no effect on the CP, IVDMD, NDF or WSC content of the swards in this research. In terms of CP, this result is surprising because previous research has shown a consistent positive relationship between N rate and summer-active tall fescue CP content (Taylor and Templeton 1976; Balasko 1977; Fribourg and Loveland 1978; Collins and Balasko 1981b; Stritzke and McMurphy 1982; Collins 1991; Gerrish et al. 1994; Singer et al. 2003). The reason for the lack of effect remains unclear. It must be noted, however, that the CP content of all the plots in this experiment was a similar level to that reported from perennial ryegrass based swards in similar environments that had been treated with the same or similar N rates (McKenzie et al. 1999a; Jacobs et al. 2002; McKenzie et al. 2003b). For example, McKenzie et al. (1999a) reported that the application of 45 kg N/ha in mid-May to perennial ryegrass based pastures near Simpson in south west Victoria resulted in a CP content of approximately 24% DM when harvested at the three leaf stage. This amounted to a N use efficiency of 0.098% CP/kg N, relative to the unfertilised swards. It is likely that, in this study, the factors mentioned earlier as potentially masking N treatment effects, including the high residual N levels in the soil, the capeweed invasion of the site and growth impairment by low temperatures, may have negated differences between N treatments in the summer-active tall fescue swards.

Previous research on summer-active tall fescue has shown that the application of N fertiliser is an effective way of generating either a curvilinear or linear increase in digestibility with corresponding decreases in fibre and WSC content (Balasko 1977;
Collins and Balasko 1981b; Collins 1991; Gerrish et al. 1994; Singer et al. 2003). Our research has not supported this finding, though the factors that potentially masked N treatment effects, as mentioned earlier, must be acknowledged. The lack of effect was particularly surprising in 2008, when the unfertilised plots and the plots receiving 25 kg N/ha had a relatively high clover content, compared to the other treatments, because clover has a higher CP and IVDMD content and lower NDF content than grasses (Stockdale 1999).

Research on perennial ryegrass based swards has reported variable effects of N fertiliser on the NDF content of the sward; some research has reported no effect of N fertiliser on NDF content (Blaser 1964; Valk et al. 1996), while other research has found that increasing the N fertiliser application rate decreases the NDF content (Wilman and Wright 1978; Moller et al. 1996; McKenzie et al. 1999a; Duru et al. 2000). In the field experiment conducted by McKenzie et al. (1999a) the application of 45 kg N/ha in mid-May to perennial ryegrass based pastures resulted in a NDF content of approximately 46% DM when harvested at the three leaf stage. This N treatment resulted in declines in NDF content of 0.04% NDF/kg N, relative to the unfertilised swards. It has been suggested that the effect of N fertiliser on NDF is dependent on the growth stage of the pasture, with N only having an effect on NDF in the early stages of growth (Valk et al. 1996; Wilman et al. 1977). It is, therefore, possible that if grazing had been more frequent in this study, NDF may have been more responsive to applied N rate.

It is an attribute of this research that it was grazed and thus accounted for the dynamic effect of livestock on sward performance. Grazing animals affect sward productivity due to trampling (Edmond 1966; Richards et al. 1976; Curll and Wilkins 1983), soil
compaction (Witschi and Michalk 1979; Willatt and Pullar 1983; Proffitt et al. 1993; Greenwood et al. 1997) and nutrient return (Curll and Wilkins 1983; Greenwood et al. 1997). The mob-stocking grazing management used in this study may have altered treatment effects because it is likely that not all of the treatments were at the same herbage mass when grazing occurred. Plots that received 25 or 50 kg N/ha had a higher herbage mass at grazing because these plots had the fastest herbage accumulation rate. It is necessary to acknowledge this effect, as has been done in previous N trial research (McKenzie et al. 1999a), though this effect did not appear to affect the nutritive value of the treatments in our study.

8.5 Conclusion

This experiment has supported the hypothesis that applying N fertiliser to summer-active tall fescue swards after autumn rains increases the productivity of the sward during winter. This was evidenced by the higher rates of herbage accumulation, herbage consumption, green herbage content and tiller density of the swards treated with 25 kg N/ha, relative to the unfertilised swards. Such production increases will benefit livestock production over the critical calving and lambing period that often occurs during winter by improving pasture availability and reducing the cost incurred for supplementary feeding over this period. Applying higher rates of N fertiliser than 25 kg N/ha resulted in no further increases in DM production or tiller density, making rates above 25 kg N/ha unjustified. Applying N fertiliser did not improve the nutritive value of the summer-active tall fescue swards over winter, though nutritive value at this time was similar to values reported from perennial ryegrass swards in similar environments treated with the same N rates. This aspect of the hypothesis is, therefore, not supported.
There were several factors which are likely to have masked N treatment effects in this research and which possibly prevented the swards from responding to N rates above 25 kg N/ha. These factors included the already high level of plant available N in the soil, the high capeweed content of the swards, which tended to increase with increasing N rate, and nutrient return and urine patches caused by the high stocking rates. Future research is, therefore, needed to test the response to higher N rates under conditions where these factors are not likely to interfere with N treatment effects. The gap dynamics of summer-active tall fescue swards needs to be studied and effective weed control measures developed to prevent weed invasion of high N swards. Studies into gap dynamics may consider the potential to increase the clover content of summer-active tall fescue swards or to integrate other improved grass or herb species into the sward to occupy the gaps. Also, grazing guidelines need to be developed to ensure that the additional herbage generated by N fertiliser is efficiently utilised by livestock, without damaging the persistence of the sward.
Chapter 9. General discussion, conclusions and future research directions

9.1 Introduction

At the commencement of this project, it was broadly hypothesised that summer-active tall fescue based swards could be established on heavy textured soils in the high rainfall (> 600 mm/year) zone of southern Australia and managed to provide a year-round source of pasture (refer Chapter 1). The purpose of Chapter 9 is to integrate the findings of this project and determine whether or not this information supports the hypothesis.

9.2 Adaptability to southern Australia’s environment

A review of literature (Chapter 2) found that a need exists in the high rainfall (> 600 mm/year) zone of southern Australia to use alternative pasture species to perennial ryegrass, which is currently the most dominant improved perennial pasture species in the region (Quigley et al. 1992). This need has arisen because perennial ryegrass often lacks persistence and fails to remain productive during the hot and dry period that occurs during summer and early autumn in southern Australia (Reed 1974; McWilliam 1978; Anderson et al. 1999). Livestock producers incur the cost of poor pasture persistence and low productivity as increased supplementary feeding, lower livestock production and the need to re-establish pastures that have failed to persist.

The literature review found that summer-active tall fescue was likely to be better adapted to heavy textured low lying soils in the summer-dry environment of southern Australia than perennial ryegrass because it is more heat tolerant (Lowe and Bowdler
1995; Jiang and Huang 2001; Greenwood et al. 2006), deeper rooted (Garwood and Sinclair 1979; Mundy et al. 2006) and more responsive to summer rain (Lawson et al. 2007; Nie et al. 2008). Summer-active tall fescue must, however, be sown on heavy textured soils that have a high water holding capacity to provide a source of stored soil moisture which the species can draw on for use during summer, with the species often failing to persist on light soils (Anderson et al. 1999). The findings of the literature review, therefore, supported the broad hypothesis of this project, suggesting that summer-active tall fescue was likely to provide a more persistent and productive source of pasture than perennial ryegrass from heavy textured soils within the high rainfall zone of southern Australia.

9.3 Current use and perception of summer-active tall fescue

Most of the research into summer-active tall fescue had been conducted in North America and New Zealand and there was a lack of information on the performance of the species in southern Australia. The survey on the current use and management of summer-active tall fescue in south west Victoria (Chapter 3) found that the species was rarely used due to its slow establishment and low nutritive value during spring. The survey did, however, identify swards of summer-active tall fescue which had been successfully established and managed to support grazing. Sward persistence and productivity were positively associated with sowing summer-active tall fescue on heavy textured soils that became waterlogged during wet seasons; sowing the species on lighter or well drained soils often resulted in poor persistence and low productivity. The survey results, therefore, supported the broad hypothesis of the project.
It must be acknowledged, however, that there were numerous sources of bias in the survey. These related to sampling, non-response, measurement and coverage error, which are inherent in all surveys (Dillman 1991). There were also questions in the survey that were subjective and involved rating the performance of swards, in terms of establishment success and persistence. It is difficult to avoid such bias in surveys, while still achieving a high response rate.

Despite the limitations of the survey, when used in conjunction with the results from replicated field experiments, it provides a comprehensive view of summer-active tall fescue use and management in southern Australia’s high rainfall zone. The survey also provided focus for research in this project and led to a field experiment being conducted into strategies for improving the establishment of summer-active tall fescue (Chapter 4).

The survey has also demonstrated that there is a widespread lack of knowledge about summer-active tall fescue among livestock producers in south west Victoria. In terms of extension of information, there were two primary issues that warrant future work. Firstly, livestock producers need to be made aware of the difference between the old Demeter cultivar of summer-active tall fescue relative to the modern cultivars that have become available, with many survey participants being reluctant to use summer-active tall fescue on their property due to negative experiences with Demeter in the past. Demeter was introduced into Australia in 1931 (Oram 1990) and since then new cultivars have been bred or introduced which have superior nutritive value. Due to the widespread knowledge of Demeter among livestock producers, it would be useful to use this cultivar as a control in future research to which new cultivars could be compared. The second area of extension must focus on comparing the benefits of summer-active
tall fescue relative to perennial ryegrass because many survey participants were reluctant to change from their current perennial ryegrass based pasture systems to try an alternative species.

### 9.4 Establishing summer-active tall fescue

Summer-active tall fescue is slow to establish, relative to other pasture grass species (Brock 1973; Charles *et al.* 1991a; Hamilton-Manns *et al.* 1995), with this being a major barrier to the adoption of the species in southern Australia (refer Chapter 3). The literature review (Chapter 2) found that the establishment of summer-active tall fescue is likely to be improved in Australia by sowing during spring when soil temperatures are at least 12°C and are rising (Hill *et al.* 1985; Charles *et al.* 1991a) and by removing competition from weeds and other sown grass or herb species (Dowling and Robinson 1976; Bellotti and Blair 1989b; Charles *et al.* 1992). Prior to this project, no research had been undertaken into the establishment of summer-active tall fescue in the winter dominant rainfall zone of southern Australia.

This project found, under dryland conditions near Hamilton, that the seedling density of summer-active tall fescue was optimised by direct drilling 24 kg/ha of seed at a depth of 10 – 20 mm. Productive swards of summer-active tall fescue were achieved six months after sowing in spite of below average spring rainfall during the experiment. This demonstrates that summer-active tall fescue can be successfully established in southern Australia, despite its slow establishment rate, even during dry seasons. Deeper sowing was unjustified, even during the drier than average season, because it appeared to inhibit seedling emergence.
The results of establishment trials are, however, highly dependent on the prevailing environment. To develop comprehensive guidelines for establishing summer-active tall fescue which livestock producers can apply to their individual properties, it is necessary to undertake further field experiments under a range of environmental conditions. Future research may include strategies for autumn sowing or sowing in early spring to reduce the risk of moisture deficit that occurs from mid- to late spring sowing.

9.5 Grazing and fertiliser management of summer-active tall fescue based swards

To develop a comprehensive understanding of the effect of grazing management on a pasture grass sward, studies must include the fundamental unit of the sward; the tiller. The growth, survival and density of these tillers determine the productivity and persistence of the sward (Mitchell and Glenday 1958; Korte et al. 1982; McKenzie 1994). Grazing summer-active tall fescue at the three leaf stage generally optimises tiller survival in the summer-dry environment of southern Australia, while also producing a stable tiller population that does not fluctuate dramatically in response to changes in environmental conditions (refer Chapter 5). Set stocking or grazing at the two leaf stage increase the rate of tiller appearance through sward disturbance, but these tillers often have a short life span and high rate of tiller death. On the other hand, if grazing rotations are too long, such as grazing at the four leaf stage, tiller populations will become excessively low and there may be large declines in the crude protein content and digestibility of the pasture on offer.
To ensure the survival and rapid regrowth of tillers after grazing, there must be sufficient time between successive grazing events for the plant to re-build its photosynthetic canopy and replenish its energy reserves (Booysen and Nelson 1975; Volenec 1986). This can be achieved by allowing the plant to grow at least three new leaves before it is grazed again (refer Chapters 6 and 7).

It is often necessary, however, to compromise achieving high yields of summer-active tall fescue and enabling the plant to rebuild its carbohydrate energy reserves with utilising that herbage at an early stage of maturity when its nutritive value is high. The nutritive value of summer-active tall fescue declines with the production of each successive leaf, with this effect being most marked in spring when large reproductive stems develop (refer Chapter 7). Set stocking or grazing at the two leaf stage during spring generally improves the nutritive value and palatability of the sward during this time and in some instances results in a high clover content (refer Chapter 7).

Furthermore, grazing regimes based on the three leaf stage are not practicable during winter because low temperatures appear to inhibit new leaf appearance (refer Chapter 8), resulting in excessively long grazing rotations and poor distribution of feed availability. Set stocking or grazing at the two leaf stage during winter is not ideal either because swards become susceptible to annual grass weed invasion (refer Chapter 7). Low winter production may contribute to a feed shortage during a time when demand for pasture is high in southern Australia due to calving and lambing. This winter feed shortage can be overcome, however, by applying N fertiliser after rains in autumn (refer Chapter 8). Applying more than 25 kg N/ha is often not justified as there was little, if
any, further increase in pasture accumulation and there were often large declines in
clover and increases in capeweed contents (refer Chapter 8).

This project has proposed that the optimum management regime for an established
sward of summer-active tall fescue involves grazing at the three leaf stage throughout
the year, except during spring when the sward requires set stocking to 1200 kg DM/ha
to maintain nutritive value during its reproductive phase, with 25 kg N/ha being applied
following autumn rains to stimulate winter growth. While this management regime
worked well under the tested conditions at Hamilton, it is not known if such a regime
would work under other environmental conditions. Further research needs to be
conducted to test the response of summer-active tall fescue to management practises
under a range of conditions, including different livestock enterprises, such as cattle, and
different rainfall zones and soil types. It is also likely that the species would benefit
from irrigation during summer and is a viable species for the irrigation districts which
were not included in this project. It is a constraint of this project that it only had a two
year timeframe, which was not long enough to determine a treatment effect on sward
persistence in the tested environment. Future research into the persistence of pasture
swards in high rainfall zones needs be conducted over a longer duration, though the
exact length of time needed will vary, with many pasture swards persisting for over 10
years.

Future research must view a sward of summer-active tall fescue as being a dynamic
combination of pasture species growing together. This is because summer-active tall
fescue is a clump-forming grass, which provides other species with an opportunity to
fill the gaps surrounding the fescue clumps, especially capeweed in high N soils (refer
Ideally, the gaps would be occupied by clover or possibly another improved grass or herb species. Due to the slow establishment of summer-active tall fescue, future research is warranted into the oversowing of companion species, as sowing them with the summer-active tall fescue would possibly result in its displacement from the sward.

Livestock production was not measured in this project, which focused solely on the agronomic characteristics of summer-active tall fescue. Liveweight gains, reproductive performance, wool production and milk production from sheep and/or cattle systems from summer-active tall fescue need to be determined in the future because these are the drivers of farm income and profitability. To date, it is not possible to accurately simulate livestock production and farm income from summer-active tall fescue swards because the parameter sets which define the species within models, such as GrassGro®, have not been validated. Future research is needed to compare modelled predictions with real data and, if they differ, conduct experiments to re-define the parameters.

In conclusion, this project has supported the hypothesis that summer-active tall fescue can be established on heavy textured soils in the high rainfall (> 600 mm/year) zone of southern Australia and managed to provide a year-round source of pasture.
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Appendix 1. Telephone survey questionnaire

*Tick the most appropriate answer box or write the answer in the space provided.*

**PART A – FARMERS DETAILS**

**Question 1.** What is your gender?
- □ Male
- □ Female

**Question 2.** What is your age?
- □ Younger than 24
- □ 25 - 34
- □ 35 - 44
- □ 45 - 54
- □ 55 - 64
- □ 65 - 74
- □ Older than 74

**Question 3.** What is your highest level of education?
- □ Year 10
- □ Year 11
- □ Year 12
- □ Certificate 1 – 1V
- □ Diploma or advanced diploma
- □ Bachelor or higher degree
- □ Other; please specify:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
Question 4. What is your position on the farm?
   □ Owner
   □ Lease or rent property
   □ Sharefarmer
   □ Manager
   □ Employee
   □ Other; please specify:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Question 5. How long have you been farming?
   □ Less than 5 years
   □ 5 to 10 years
   □ 11 to 20 years
   □ More than 20 years

PART B – FARM DETAILS

Question 6. What are the main enterprises on your property?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Question 7. What size is the property?
______________________________________________________________________

Question 8. What is your average annual rainfall?
______________________________________________________________________

Question 9. What are the main pasture species used on the property?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Question 10. Do you currently use summer-active tall fescue on your property?
   □ Yes; go to question 14.
   □ No; go to question 11.
Question 11. Why don’t you use summer-active tall fescue on your property?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Question 12. Do you intend to use summer-active tall fescue in the future?
Yes / No

Question 13. Why do / don’t you intend to use summer-active tall fescue in the future?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

End of survey

Question 14. What cultivar/s of summer-active tall fescue are you currently using?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

If the cultivar/s is/are unknown:

Do you get any growth out of the tall fescue over summer? Yes / No

Question 15. Why do you currently use summer-active tall fescue on your property?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Question 16. How many hectares of summer-active tall fescue do you currently have on the property?
Or if cultivar is unknown:
How many hectares of the summer-growing tall fescue do you currently have on the property?

______________________________________________________________________
______________________________________________________________________
| Question 17. | Do you intend to continue using summer-active tall fescue in the future?  
   □ Yes  
   □ No |
|---|---|
| Question 18. | Why do / don’t you intend to use summer-active tall fescue in the future?  
   |  
   |  
   |  
   |  |
| Question 19. | Would you mind if I mailed you a more detailed survey which would contain questions about how you manage the summer-active tall fescue on your property? Yes / No |
| Question 20. | What is your postal address so I can mail you the survey?  
   |  
   |  
   |  |

190
Appendix 2. Information letter included with mail survey

Printed on Charles Sturt University letterhead with faculty contact details and current date.

TO THE FARM MANAGER

I am undertaking a PhD project - *Managing summer-active tall fescue (Lolium arundinaceum syn. Festuca arundinacea) in south western Victoria* - under the supervision of the Department of Primary Industries and Charles Sturt University. A component of this project is a survey of summer-active tall fescue users in south western Victoria.

The purpose of this survey is to collect information pertaining to the grazing and fertiliser management of summer-active tall fescue and the effect management has on the productivity and persistence of the pasture. This information, together with the results of field trials that are being conducted at DPI Hamilton, will be used to develop comprehensive guidelines for the use of summer-active tall fescue in south western Victoria.

Summer-active tall fescue has been identified as a pasture species of interest due to its tolerance of heavy, waterlogged soils and potential for summer growth. Research suggests that growing this pasture species on heavy soils that have a high water holding capacity, or in areas that experience summer rainfall, could provide a source of feed over summer. However, little is known about how this pasture species can be effectively managed, prompting my current research.

To assist with my research I am seeking feedback from people who have used summer-active tall fescue on their properties. Enclosed with this letter is a questionnaire which can be filled in and returned in the reply paid envelope to me, Margaret Raeside, at:

*Margaret Raeside*

*Department of Primary Industries*

*Private Bag 105*

*Hamilton Vic 3300*

Participation in this survey is voluntary. By filling in and returning this survey you are indicating your consent to take part in this survey. All information that is gathered in this survey will be kept confidential. Results will only be made available on a collected basis, where the characteristics of numerous farms will be presented.

If you would like further information about this survey, or any other aspect of my research into summer-active tall fescue, please feel free to contact me, or my supervisor Dr Michael Friend, at the contact details given below.

<table>
<thead>
<tr>
<th>Margaret Raeside</th>
<th>Dr Michael Friend</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="mailto:Margaret.Raeside@dpi.vic.gov.au">Margaret.Raeside@dpi.vic.gov.au</a></td>
<td><a href="mailto:mfriend@csu.edu.au">mfriend@csu.edu.au</a></td>
</tr>
<tr>
<td>(03) 5573 0752</td>
<td>(02) 6933 2285</td>
</tr>
</tbody>
</table>
NOTE:

Charles Sturt University’s Ethics in Human Research Committee has approved this project. If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Ethics in Human Research Committee
Academic Secretariat
Charles Sturt University
Private Mail Bag 29
Bathurst New South Wales 2795

Tel: (02) 6338 4628
Fax: (02) 6338 4194

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Your assistance with my research to develop management guidelines for summer-active tall fescue is greatly appreciated. All participants will be sent a summary of the results at the completion of this project.

Yours sincerely

Margaret Raeside
Appendix 3. Mail survey questionnaire

Please tick the most appropriate answer box or write the answer in the space provided. Space has also been provided at the end of each section for any comments you would like to add.

PART A – FARMERS DETAILS

Question 1. What is your gender?
☐ Male
☐ Female

Question 2. What is your age?
☐ Younger than 24
☐ 25 - 34
☐ 35 - 44
☐ 45 - 54
☐ 55 - 64
☐ 65 - 74
☐ Older than 74

Question 3. What is your highest level of education?
☐ Year 10
☐ Year 11
☐ Year 12
☐ Certificate 1 – 1V
☐ Diploma or advanced diploma
☐ Bachelor or higher degree
☐ Other; please specify:

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Question 4. What is your position on the farm?

- Owner
- Lease or rent property
- Sharefarmer
- Manager
- Employee
- Other; please specify:

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Question 5. How long have you been farming?

- Less than 5 years
- 5 to 10 years
- 11 to 20 years
- More than 20 years

PART B – FARM DETAILS

Question 6. Where is the farm located? (ie. 5 km south of town X)

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Question 7. What is the average annual rainfall for the area in mm?

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Question 8. What is the size of the farm in hectares?

____________________________________________________________________
____________________________________________________________________
Question 9. What are the main pasture species used on the property?

You may tick more than one

- Perennial ryegrass
- Italian ryegrass
- Annual ryegrass
- Tall fescue
- Phalaris
- Cocksfoot
- Subterranean clover
- White clover
- Annual medics
- Lucerne
- Don’t know
- Other; please specify:

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Question 10. Do you currently use summer-active tall fescue on the farm?

□ Yes
□ No
□ Don’t know

Summer-active tall fescue varieties include, but are not limited to:

Demeter Jesup Kentucky-31
Quantum Lunibelle Grasslands Roa
Goar Advance Alta
AU Triumph Dovey
Vulcan II Typhoon

If you answered ‘no’ please specify the reasons why you do not use summer-active tall fescue:

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

If you answered ‘yes’ to Question 10 please proceed to PART C – DETAILS OF SUMMER-ACTIVE TALL FESCUE USE. 
If you answered ‘no’ to Question 10 please proceed to PART D – THE FUTURE OF SUMMER-ACTIVE TALL FESCUE.

PART C – DETAILS OF SUMMER-ACTIVE TALL FESCUE USE
**Question 11.**  In total, how many hectares of summer-active tall fescue do you currently have on the property?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

*As a property may contain several paddocks of summer-active tall fescue, please answer the following questions for the two largest paddocks of summer-active tall fescue on the property. If there is only one paddock of summer-active tall fescue on the property, please leave the unneeded answer space blank.*

**Question 12.**  What cultivar/s of summer-active tall fescue do you currently use?

*You may tick more than one*

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demeter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AU Triumph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulcan II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jesup</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunibelle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dovey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typhoon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kentucky-31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasslands Roa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other; please specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 13.**  If you planted the summer-active tall fescue, why did you choose summer-active tall fescue as a pasture species?

______________________________________________________________________
______________________________________________________________________

*Questions 14 to 17 relate to the soil type and fertility under summer-active tall fescue on your property.*
Question 14.  Which best describes the soil type currently under summer-active tall fescue on your property?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy clay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay loam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy loam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other; please specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question 15.  Which best describes the drainage of the soil under summer-active tall fescue on your property?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone to waterlogging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well drained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other; please specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question 16.  Are you aware of the area under summer-active tall fescue being affected by any of the following?  
You may tick more than one answer.

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkalinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High aluminium content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None of the above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other; please specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Question 17.** Which best describes the fertility of the soil currently under summer-active tall fescue on your property?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly fertile</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Moderately fertile</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Unfertile</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Don’t know</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Other; please specify:</td>
<td>___________________</td>
<td>___________________</td>
</tr>
</tbody>
</table>

If soil tests have been taken, please fill in the table below:

<table>
<thead>
<tr>
<th>P (Olson)</th>
<th>K (Skene)</th>
<th>S (CPC)</th>
<th>pH</th>
</tr>
</thead>
</table>

Comments on the effect of soil type and fertility on the summer-active tall fescue:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

**Questions 18 to 30 relate to the establishment and renovation of the summer-active tall fescue on your property.**

**Question 18.** What year was the summer-active tall fescue sown?

*If you don’t know, write ‘don’t know’ in the space provided*

Paddock 1: _______________________________________

Paddock 2: _______________________________________

**Question 19.** At what rate was the summer-active tall fescue sown in kg /ha?

*If you don’t know, write ‘don’t know’ in the space provided.*

Paddock 1: _______________________________________

Paddock 2: _______________________________________
Question 20. What season was the summer-active tall fescue sown?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Autumn</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Winter</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Spring</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Don’t know</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

Question 21. Was the summer-active tall fescue sown as the main pasture species, or was it sown in a blend?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main species</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Sown in a blend</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Don’t know</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

If the summer-active tall fescue was sown in a blend, please specify the other pasture species sown:

Paddock 1:  ____________________________________________________
            ____________________________________________________
            ____________________________________________________

Paddock 2:  ____________________________________________________
            ____________________________________________________
            ____________________________________________________

Question 22. How would you rate the establishment of the summer-active tall fescue?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Good</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Acceptable</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Poor</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Very poor</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Don’t know</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Other; please specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Question 23. If establishment of the summer-active tall fescue was poor or very poor, what do you believe to be the cause of the poor establishment?

Paddock 1: ___________________________________________________________

______________________________________________________________

Paddock 2: ___________________________________________________________

______________________________________________________________

Question 24. How would you rate the persistence of the summer-active tall fescue?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Good</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Acceptable</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Poor</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Very poor</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Don’t know</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Other; please specify:</td>
<td>____________</td>
<td>____________</td>
</tr>
</tbody>
</table>

Question 25. If persistence of the summer-active tall fescue was poor or very poor, what do you believe to be the cause of the poor persistence?

Paddock 1: ___________________________________________________________

______________________________________________________________

Paddock 2: ___________________________________________________________

______________________________________________________________
Question 26. How often does pasture renovation on the summer-active tall fescue occur?

Never □ □
Yearly □ □
Every two years □ □
Every five years □ □
Don’t know □ □
Other; please specify: ________________ ________________

Question 27. If the summer-active tall fescue was renovated, what type of pasture renovation was carried out?

No renovation □ □
Oversowing □ □
Sod seeding □ □
Don’t know □ □
Other; please specify: ________________ ________________

Question 28. If pasture renovation occurred on the summer-active tall fescue, what were the reasons that prompted pasture renovation?

Paddock 1: ____________________________________________
____________________________________________________
____________________________________________________

Paddock 2: ____________________________________________
____________________________________________________
____________________________________________________
Question 29. What would be your assessment of the current condition of the summer-active tall fescue paddocks?

Paddock 1
% of weeds: 
% of tall fescue: 
% of legume (ie. clover): 
Other; please specify:

Paddock 2
% of weeds: 
% of tall fescue: 
% of legume (ie. clover): 
Other; please specify:

Question 30. What would be your assessment of the current annual productivity of the summer-active tall fescue paddocks, in tonnes DM/ha.year?

Paddock 1: 
Paddock 2: 

Comments on the establishment and renovation of the summer-active tall fescue:

Questions 31 to 35 relate to grazing management of the summer-active tall fescue on your property.
**Question 31.** What are the livestock enterprises that graze the summer-active tall fescue?  
_You may tick more than one answer._

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prime lambs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1\textsuperscript{st} cross (merino x meat sire)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2\textsuperscript{nd} cross</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Wool</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wethers</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Wethers and self replacing merino flock</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Self replacing merino flock</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Beef</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breeders</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Fattening/finishing</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Dairy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry stock including heifers or bulls</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Milking herd</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Don’t know</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other; please specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 32.** Is the summer-active tall fescue rotationally grazed or set stocked?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotationally grazed</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Set stocked</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Don’t know</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
**Question 33.** For each livestock enterprise, please indicate the general seasonal grazing frequency for the summer-active tall fescue (days or weeks between grazings).

<table>
<thead>
<tr>
<th>Livestock enterprise:</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Autumn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Spring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 34.** For each livestock enterprise, please indicate how low the summer-active tall fescue is generally grazed during each season (height or mass to which the pasture is grazed).

<table>
<thead>
<tr>
<th>Livestock enterprise:</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Autumn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Spring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Livestock enterprise:</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Autumn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Spring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Question 35.** Please indicate the general stocking rate (animals /ha) of the summer-active tall fescue pasture for each season for the relevant livestock enterprise. Please leave the unneeded space blank.

<table>
<thead>
<tr>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaned lambs</td>
<td>Dry ewes or wethers</td>
<td>Pregnant ewes, bearing singles</td>
<td>Pregnant ewes, bearing twins</td>
</tr>
<tr>
<td>Ewes, single lamb at foot</td>
<td>Ewes, twin lambs at foot</td>
<td>Weaned calves</td>
<td>Pregnant heifers</td>
</tr>
<tr>
<td>Dry cows empty, or steers</td>
<td>Dry cows, pregnant</td>
<td>Dairy cows, early lactation or cows with 0 – 3 month old calf at foot</td>
<td>Dairy cows, late lactation or cows with 4 – 10 month old calf at foot</td>
</tr>
<tr>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 36 relates to fertiliser management of the summer-active tall fescue on your property.**

**Question 36.** In the tables below, please indicate the fertiliser schedule used over a typical year on the summer-active tall fescue, include what months fertiliser is applied, and the type and amount of fertiliser applied during each application. If no fertiliser is generally applied, write ‘nil’ and proceed to the next question.

<table>
<thead>
<tr>
<th>Paddock 1</th>
<th>Month</th>
<th>Type of fertiliser</th>
<th>Amount of fertiliser</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Paddock 2</th>
<th>Month</th>
<th>Type of fertiliser</th>
<th>Amount of fertiliser</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
Questions 37 and 38 relate to the conservation and irrigation of the summer-active tall fescue on your property.

Question 37. Do you ever cut the summer-active tall fescue for hay or silage?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question 38. Is the summer-active tall fescue irrigated?

<table>
<thead>
<tr>
<th></th>
<th>Paddock 1</th>
<th>Paddock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments on the effect of conservation and/or irrigation on the summer-active tall fescue:

________________________________________________________

PART D – THE FUTURE OF SUMMER-ACTIVE TALL FESCUE

Question 39. Do you plan to plant more summer-active tall fescue in the future?

□ Yes
□ No
□ Maybe
□ Don’t know

If you answered ‘no’ please specify the reasons why you do not intend to plant more summer-active tall fescue in the future:

________________________________________________________

________________________________________________________
Question 40. Do you currently use the internet?
☐ Yes
☐ No
☐ Don’t know

Question 41. What information or services would help improve your knowledge or management of summer-active tall fescue?
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

PART E – SURVEY COMPLETION

Thankyou for taking part in this survey. Please return the completed survey in the reply paid envelope to:

Margaret Raeside
Department of Primary Industries
Private Bag 105
Hamilton Vic 3300